BIOMAERL: MAERL BIODIVERSITY; FUNCTIONAL STRUCTURE AND ANTHROPOGENIC IMPACTS

FINAL REPORT
EC STUDY CONTRACT MAS3-CT95-0020

1999

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FINAL REPORT
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1) FINAL MANAGEMENT REPORT

1.1. *Introduction to project objectives*

The 3-year BIOMAERL programme (1996 -1999), funded by the EC under MAST-III, involved collaboration between five laboratories in four countries (UK, France, Spain, Malta; see partner list above). The project sought to redress the dearth of biological knowledge concerning maerl habitats, and provide information upon which informed management decisions could then be made for this habitat in European seas. Thus it set out: a) to examine W European maerl-bed biodiversity; b) to establish the functional roles played by key elements of the biota; c) to assess the impacts of a variety of anthropogenic disturbances on representative grounds; d) to compile an inventory of NE Atlantic and Mediterranean maerl-bed biota, and e) to develop management guidelines and conservation strategies for european maerl beds.

There were five specific objectives:-

1.) To establish sampling sites, optimum sampling protocol and key species (including those most affected by human impacts) for each study area on the basis of which to prosecute objectives 2-5.

2.) To determine the range of structural difference between sites. This involved detailed assessment of site edaphic factors, in particular the structural complexity of the habitat. It included physico-chemical sampling of the overlying water column and of the maerl gravel itself, both in the field (salinity, temperature, Secchi disc transparency, water currents) and subsequently in the laboratory (seston gravimetry, maerl granulometry, calcimetry, porosity, shear strength, pH, Eh and organic content). Species records derived as an adjunct to this objective have also contributed to objective 5.

3.) To determine the dynamics of key species and the impact of natural disturbances. Clearly, sources of natural variation (like habitat heterogeneity, seasonal variation, species interactions) were required to be considered before the impact of Man could be properly adjudged in context.

4.) To identify the main anthropogenic threats to, and impacts on, maerl grounds in each region. These threats included aquaculture, demersal fishing activities and eutrophication.

Objectives 3 & 4 necessitated taking area-quantifiable samples to derive population densities, biomass and size-structure data on selected organisms. Given the disparate circumstances of different partners, the different characteristics of the study sites, and the different sources of anthropogenic disturbance in each region, a range of sampling methodologies has had to be called upon to deliver these objectives. Objective 4 necessitated deliberate disturbance of a small area of unimpacted ground, to elucidate the consequences of an accurately quantifiable imposed stress factor (in this case mechanical disturbance by towed gear). Species records derived during the prosecution of objectives 3 & 4 also contributed to the database in objective 5.

5.) To provide an inventory of the mega/macrobiota (fauna and flora) of maerl systems in the NE Atlantic and Mediterranean Sea, to compare regional (boreal, lusitanian and Mediterranean) differences in biota, and integrate knowledge gained under objectives 1-4 into a coherent management strategy for conservation of European maerl beds.

1.2 General managerial comments

At the outset, as co-ordinator, I should like to pay tribute to the selfless hard work and dedication of all who have participated in BIOMAERL. This programme proceeded without a single cross word between participants and represented a model of enthusiastic European co-operation.

The BIOMAERL project began on 1st February 1996. Ten project meetings have been held, at regular (3-monthly) intervals, throughout the subsequent 3-year period of the contract, with venues rotating equitably between partners. The schedule as laid down in the Technical Annex has been followed as assiduously as circumstances have allowed. It will be seen from what follows that the Tasks we set ourselves have all been accomplished. As is inevitable with any piece of research, certain evolutions, substitutions and additions have occurred.

Partners took an early decision, based on experience gained in pilot surveys (see First 6-monthly Report), to substitute a 1.0mm screen for the 0.5mm screen envisaged at the outset for retention of macrofauna. There is a dichotomy in the literature as to which sieve should be regarded as standard in this respect (0.5mm or

1.0mm). Although Holme & McIntyre (1984) advocated 0.5mm, Baltic marine biologists had standardized on 1.0mm (Dybern *et al.,* 1976; Ankar *et al.,* 1979), following most of the classical work on marine benthos. Thiel (1983) also considered 1mm as being the cut-off point between macro- and meiofauna. At the design stage of this project, no guidance was available from published work on maerl habitats. As the project broke new ground, it soon became obvious that more progress would be made by using a 1mm screen freeing time to sample larger areas with more replicates. Holme & McIntyre (*loc.cit.*) anticipated this stating that "in general, it is suggested that a 0.5mm sieve should be used for macrofaunal separation, but since this may retain too large a volume of material on coarse grounds, a compromise may have to be made" . The adoption of the 1mm sieve as standard meant that more samples could be taken than were originally specified, enhancing the statistical rigour of the data, as was endorsed by the EC (see end of Year 1 Report).

One difficulty encountered was the inevitable weather-dependency of sampling trips. Strenuous efforts have been made by each partner group to make alternative arrangements, although stringent financial limits concerning boat-time meant that commercial alternatives could not be countenanced.

The major financial difficulty has been that encountered by the Maltese group (UM) which received no financial assistance from the EC (since Malta is, as yet, not a member state of the European Union). Their ability to adhere to the agreed programme has been nothing short of miraculous. The tenacity of Prof. Schembri to the programme in the face of one financial setback after another has been truly inspirational.

All partners have had an equal and equivalent role in gathering data. Some of the routine work has been assisted by volunteer student labour under supervision, at no cost to the programme. In this way, involvement of a wide circle of people has been accommodated which facilitated skills transference between partner countries. Specialist tasks have been delegated among participants to the most suitable personnel or research group. On several occasions, reciprocal working visits (of weeks or months duration) between laboratories have taken place by partner personnel, particularly younger scientists. This has helped enormously to cement the programme into an integrated whole. All partners have taken an active role in sample processing, data analysis, report writing and presentation of results in a wide variety of fora (see below).

A welcome added value of BIOMAERL has been that it has built upon an existing data set derived from an earlier EC-funded project (under Fisheries Sector contract PEM/93/08) at UMBSM thereby achieving a unique 4-year database relevant to the topic of scallop dredging on maerl beds in the Clyde Sea area.

Publicity for the work undertaken and results obtained has been achieved by submission of scientific papers to Conferences and international journals, by poster presentations at meetings, by exposure in local newspapers and in television programmes (see below). Appropriate material from this Final Report will be released for general consumption on the web sites of UMBSM [http://www.gla.ac.uk/Acad/Marine].

1.3 Personnel

We congratulate Dr A. Sánchez Mata, who left the project at the end of October 1998 to take up a 2-year marine biology lectureship at the University of Santiago de Compostela. Partners would like to think that her experience gained during the BIOMAERL contributed in no small measure to her selection, and all wish her well in her new career. The list of personnel involved in the project during the whole period of the contract is as follows:

(UMBSM)	*% of person's time*	*Funded or not*
Dr J.Hall-Spencer	100	Yes
Prof. P.G.Moore	10	No
(UBO)		
Mr J.Grall	100	Yes
Prof. M.Glémarec	50	No
Mrs M. Guillou	30	No
(USC)		
Dr A.Sánchez Mata	100 (until 31 Oct.1998)	Yes
Mr E.Abella Rey	50	Yes
Ms M.E.Pita Siebert	50	Yes
Ms Ch.de la Huz Serrano	50	Yes
Prof. J.Mora Bermúdez	10	No
Ms N.Zumalave Rivas	50 (from 1 Nov 1998)	Yes
Mr A. Penedo Padin	50 (from 1 Nov 1998)	Yes
Collaborator (Univ.Vigo; UV)		
Dr M.Lastra	10	No
(UA)		
Prof. A.A.Ramos-Esplá	50	No
Ms A.Seva Patiño	50 (until 28 Feb.1997)	Yes
Ms C.Barberá Cebrián	50	Yes
Mr C.Valle Pérez	50 (from 1 Oct 1996)	Yes
Mr J.L.Patiño Cañaveras	50 (from 1 Oct 1997)	Yes
Ms C.Martinez Gõmez	50 (from 1 Oct 1997-31 Dec 1997)	Yes
Mr C.Bordehore Fontanet	100 (from 1 Jan 1997)	No
Mr J.Mallol Ferrer	50 (from 1 Jan 1998)	Yes
Ms C.Mena Sellés	50 (from 1 May 1998)	Yes
Ms S.Ruiz Rodriguez	50 (from 1 Oct 1998)	Yes
Ms M.Vivas Salvador	50 (from 1 Oct 1998)	Yes
Mr J.Guillén Nieto	30	No
Mr A.Aranda López	30	No
(UM)		
Prof. P.J.Schembri	20	No
Mr E.Lanfranco	10	No
Mr J.A.Borg	10	No
Mr A.Mallia	2 (until Feb. 1997)	No
Ms S.Farrugia	10 (until June 1997)	No
Ms M.Rizzo	100	No
Ms J.R.Mifsud	10	No
Collaborator		
Mr C.Mifsud	10	No

1.4 Report on meetings held

BIOMAERL project meetings have been held as follows:-

Millport	Feb. / Mar. 1996 (split meeting)
Santiago	11-13 May 1996
Malta	12-15 Sept. 1996
Alicante	31 Jan.- 4 Feb. 1997
Brest	30 May-1 June 1997
Millport	20-22 Sept. 1997
Santiago	8-12 Jan. 1998
Malta	29 May-2 June 1998
Alicante	18-22 Sept. 1998
Brest	15-19 Jan. 1999

1.5 Publicity

Scientific publications resulting from BIOMAERL

See under section 2. Detailed Scientific Report (below)

Student dissertations resulting from BIOMAERL

Farrugia, S., 1997. *Lower infralittoral and upper circalittoral macrobenthic communities off the northeastern coast of Malta.* Unpubl.B.Sc. dissertation, Dept of Biology, University of Malta.

Mifsud, J.R., 1997. *Morphological diversity in maerl-forming calcareous algae from off the northeastern coast of the Maltese islands.* Unpubl.B.Sc. dissertation, Dept of Biology, University of Malta.

A further three dissertations are in progress, two of which are B.Sc.(Hons) Final year dissertations, expected to be presented in May 1999, and the third is a Masters dissertation, expected to be presented by the end of the year 2000.

Camilleri, K., *The epibiotic fauna of a maerl ground off the Northeast coast of Malta.* B.Sc. dissertation, Department of Biology, University of Malta.

Cilia, R , *A study of the non-corallinaceous macrophytes of a maerl ground off the Northeast coast of Malta, and their epiphytes.* B.Sc. dissertation, Department of Biology, University of Malta.

Mifsud, J.R., *Habitat architecture of maerl beds from off the North-eastern coast of Malta.* M.Sc. dissertation, Department of Biology, University of Malta

Five M.Sc. student dissertations are in progress in the University of Alicante, due to finish either later in 1999 or 2000, as follows:

Bordehore Fontanet, C., *Taxonomy, biology and ecology of the Ascidiacea associated with the maerl beds in the SE Iberian Peninsula.*

Mallol Ferrandiz, J., *Contributions to the knowledge of the Ophiuroidea (Echinodermata) of the maerl beds in the SE Iberian Peninsula.*

Martínez Pérez, C., *Contribution to the knowledge of the Mollusca of the maerl beds in the SE Iberian Peninsula.*

Patiño Cañavares, J.L., *Contribution to the knowledge of the Amphipoda of the maerl beds in the SE Iberian Peninsula.*

Vivas Salvador, M., *Contribution to the knowledge of the Polychaeta of the maerl beds in the SE Iberian Peninsula.*

Six dissertations are currently in progress at UBO based on BIOMAERL, as follows:

Issa, R., *Variation saisonniere de l'epiflore des bancs de maerl de la rade de Brest-France.* Diplome d'Etudes Aprofondies en Oceanologie Biologique.

Haug, E., *Evolution saisonniere des pigments algaux des contenus stomacaux de trois especes d'oursins de l'ecosystème du maerl en rade de Brest.* Diplome d'Etudes Aprofondies en Oceanologie Biologique.

Conan, S., *Variations spatiales et temporelles de la flore epiphyte des bancs de maerl de la rade de Brest.* Maitrise de Biologie des

Populations, Mention Milieu Marin.

Jarosz, N. *Variabilité spatiale et temporelle du megabenthos dans les bancs de maerl de la rade de Brest.* Maitrise de Biologie des Populations, Mention Milieu Marin.

Joly, G., *Impact d'une zone de dragage sur la macrofaune et la megafaune benthique des bancs de maerl des Glenans.* Maitrise de Biologie des Populations, Mention Milieu Marin.

Le Floc'h, E., *Evaluation de l'impact de la ville de Brest sur le benthos des bancs de maerl de la rade de Brest.* Maitrise de Biologie des Populations, Mention Milieu Marin.

Three M.Sc. dissertations are in progress at USC and UV are expected to be presented in November 1999:

Mulet Abeledo, M., *Seasonal biodiversity in two maerl grounds of Ría de Vigo.* M.Sc. dissertation, Departamento de Biología Animal, Facultad de Biología, Universidad de Santiago.

Pazos Garrido, I., *Tridimensional population dynamics of benthic fauna from a maerl ground.* M.Sc. dissertation, Departamento de Biología Animal, Facultad de Biología, Universidad de Santiago.

Pita Siebert, M.E., *Structural differences and seasonal variations of maerl bottoms.* M.Sc. dissertation, Departamento de Ecología y Biología Animal, Facultad de Ciencias del Mar, Universidad de Vigo.

Communications and posters on BIOMAERL delivered at Conferences

Five presentations (given as posters and oral communications) by members of the USC team, dealing with different aspects of the BIOMAERL programme in Ria de Vigo grounds were presented at the *Xth Iberian Symposium on Benthic Marine Studies*, 23-26 February 1998 in the Algarve (Playa de Carvoeiro, Portugal), as follows:

Sánchez-Mata, A., Abella, F.E. & Mora, J., Biodiversidad especifica de los fondos de maerl (*Lithothamnion corallioides* (P.& H..Crouan) P.& H.Crouan and *Phymatolithon calcareum* (Pallas) Adey & McKibbin de la Ria de Vigo.pp. 168-169.

Mora, J., Sánchez-Mata , A.& Lastra, M., Variación estacional de la fauna bentónica de un fondo de maerl bajo la influencia de un polígono de bateas de mejillón. p.96.

Sánchez-Mata, A.,de la Huz , Ch. & Mora, J., Caracterización fisiogeoquimica de los fondos de maerl de la Ria de Vigo. p.128.

Pita, M.E., Lastra, M., Sánchez-Mata, A. & Mora, J., Efecto de los campos de bateas de mejillón sobre la distribucion vertical de la infauna en los fondos de maerl.p.159.

Sánchez-Mata, A., Grall J. & Hall-Spencer, J., Diferencias estrucurales biogeográficas de los fondos de maerl en aguas del Atlántico Norte entre las latitudes 42° y 56°, p.124.

Other BIOMAERL presentations, this time from the UA team, were also communicated at this meeting:

Aranda López, A. & Solano García, I., Composición florística y estructura de los fondos detríticos del SE Ibérico. p.106.

Barberá, C., Valle, C., Martínez, M.C., Patiño, J.L , Bordehore, C. & Ramos-Esplá, A.A., Contribución al conocimiento de la macrofauna asociada a los fondos de maërl de la Reserva marina de Tabarca (Alicante, SE Península Ibérica). p.131.

Guillén Nieto, J. & Barberá Cebrián, C., Variación de las poblaciones de crustáceos decápodos en las comunidades del detrítico del SE Ibérico afectadas por el impacto de la pesca de arrastre. p.144.

Three presentations (two posters and one oral communication) dealing with different aspects of the BIOMAERL project in Ría de Vigo grounds were presented at the *XIII Bienal Real Sociedad Española de Historia Natural*, that took place from 6-10 July 1998 in Vigo (Galicia, Spain); they were:

Sánchez Mata, A., Abella Rey, F.E. & Mora Bermúdez , J., Evolución estacional de las especies indicadoras del macrozoobentos en fondos de maerl de la Ría de Vigo.

Mora Bermúdez, J., Sánchez Mata, A. & Abella Rey, F.E., Cambios estructurales en la composición de dos fondos de maerl sujetos a diferentes condiciones ambientales. p.48

Mora Bermúdez, J., Pita, M.E. & de la Huz, Ch., Importancia de la naturaleza de las muestras en la obtención de resultados faunísticos en el estudio de los fondos de maerl.

[unfortunately, by oversight of the conference organisers the last two mentioned were omitted from the published abstracts]

A summary of the Maltese contribution to the BIOMAERL project was presented at the 1998 Annual Biology Symposium organised by the Department of Biology of the University of Malta. This Symposium was held on 21 November 1998. The abstract of this presentation was published in the Abstracts Book distributed at the Symposium.

A poster giving an overview of the BIOMAERL programme was exhibited at a Conference on "Aquatic life cycle strategies" held at the University of Plymouth, UK (14-17 April 1997).

A poster on the effects of scallop dredging on Scottish maerl beds was also presented at a Workshop on maerl-related issues held in Galway, Ireland (30 May 1997).

A poster was presented by Dr J.M.Hall-Spencer on Long-term effects of scallop dredging maerl beds, at the ICES Symposium on Marine benthos dynamics: environment and fisheries impacts in Heraklion, Crete (IMBC) on 4-9th October 1998.

Two complementary BIOMAERL project posters have been produced, which have been displayed at the following international meetings:

Third Marine Science & Technology Conference, 23-27 May 1998, Lisbon

ICES Conference, *Marine benthos dynamics: environmental & fisheries impacts*, 5-9 October 1998, Hiraklion, Crete.

Workshop on "*Effects of fishing on non-target species and habitats: biological, conservation and socio-economic issues*" Beaumaris, N.Wales, 7-10th December 1998.

These posters are available as resource material to project partners on request. Meantime they are on permanent display in public places in UMBSM and UBO. Dr J.M.Hall-Spencer (UMBSM) is thanked for his efforts in creating these useful visual aids.

Lectures given on BIOMAERL topics

Prof P.G.Moore delivered an invited lecture "Biodiversity: the crisis you know and the crisis you don't know" as part of the series "Les Conferences de l'Ecole Doctorale des Sciences de la Mer" which dealt with BIOMAERL-related issues.

Dr J.M.Hall-Spencer presented a talk entitled "Human threats to the molluscan fauna of European maerl beds" at the Molluscan Conservation Conference - a strategy for the 21st century, organised by the Conchological Society of Great Britain in November 1996

Dr J.M.Hall-Spencer gave a talk to the UK Marine Nature Conservation Review team, the Joint Nature Conservation Committee and other interested parties concerning suitable methods for monitoring maerl beds during a Workshop held in Millport 6-9 May 1997.

Dr J.M.Hall-Spencer gave a talk entitled "Observations on *Upogebia deltaura* (Leach) (Crustacea: Decapoda) on NE Atlantic maerl beds" to the Scottish Marine Group/ Scottish Association of Marine Science Conference on Aspects of Crustacean Biology held in the University of Glasgow, 26th May 1998.

Ms Miraine Rizzo presented a paper entitled "Does fishing have an impact on Maltese maerl grounds?" to the ICES Symposium on Marine benthos dynamics: environment and fisheries impacts held in Heraklion, Crete (IMBC) on 4-9th October 1998.

Prof. A.A.Ramos Esplá gave a talk entitled "The Marine Reserve of Tabarca (Alicante), past, present and future" for the Faculty of Sciences, University of Alicante (about the importance of protecting and conserving marine biodiversity for the long term, especially seagrass meadows and maerl beds).

Prof. A.A.Ramos Esplá gave a public lecture entitled "¿Está la biodiversidad marina mediterránea amenazada?" in the Culture lecture room of the CAM of Alicante and Cartagena on 16 February 1998 (about the impacts on Mediterranean benthic communities, especially seagrass meadows and maerl beds).

Prof. A.A.Ramos Esplá gave a talk entitled "The marine reserve of Tabarca: the protection of biodiversity and living resources" in the QUARTZ Hall, Brest on 15 January 1999 at the invitation of the Permanent Commission of the National Park of Iroise.

Professor M.Glémarec gave a lecture entitled "Complexité architecturale et biodiversité" at the Navires cotiers et océanographiques de l'Atlantique et de la Manche. Colloque National de Bordeaux, 9-10 June 1997.

Professor J.Mora and Dr A.Sânchez-Mata have incorporated the findings of the BIOMAERL project into the USC doctoral programme on Ecosystems and zoological resources at the Universidade of Santiago de Compostela, giving immediate feedback from research to teaching the next generation of young marine scientists.

Audiovisual exposure of BIOMAERL

The USC cruise of March 1997 was filmed by a TVGA (Television Gallega: Galician Television) team on board. It was televised in April 1997 during the programme *Telexornal*. A videotape of this recording is available. A video, including underwater footage, relating the work of the BIOMAERL project is being assembled by UA. A French television crew was given facilities on board the RV *Cotes d'Aquitaine* in November1997 to take pictures of maerl sampling in the bay of Brest for a television programme on the FRANCE 3 channel in March 1998.

Articles on BIOMAERL in the popular press

Articles in local newspapers publicizing the work of the BIOMAERL project have appeared in Spain (*La Verdad*, 28 June 1998, Alicante) and France (*Le Telegramme*, Brittany; *Ouest France* 16/17 January 1999).

World Wide Web access to BIOMAERL

The BIOMAERL project is referred to under the biodiversity theme in the UBO web site [http://www.univ-brest.fr/IUEM/BIOFLUX], and also on the UMBSM website [http://www.gla.ac.uk/Acad/Marine].

Visiting scientists

A most useful international contact was achieved when Dr Viviane Testa spent two days with the group (during its Millport meeting in September 1997), and presented a talk on her maerl researches (from a sedimentary geological perspective) off Brazil.

Two undergraduate students: Ms. Susanne McCullock (University of Glasgow, Scotland) and Ms. Karen Buttigieg (University of Southampton, England), visited the Department of Biology (University of Malta) during the period July to September 1996 to work on the BIOMAERL project on a voluntary basis. They both helped with the collection and sorting of maerl samples and with the measurement of physicochemical parameters.

Ms Myriam Bouker (Institut National Agronomique de Tunis, Tunisia) visited the Department of Biology (University of Malta) during the period between 22 August - 18 September 1997 to learn practical techniques in marine benthic ecology. She helped with the sorting of maerl samples, identification of maerl fauna and flora from the winter 1997 samples, as well as carried out granulometric analyses of these samples.

During the period July to September 1997, the Maltese Ministry of Education and National Culture funded a full-time student summer worker to work on the BIOMAERL project. Mr Michael Refalo carried out granulometric analyses of maerl sediments and determinations of rhodolith sphericity for samples from the Pilot Survey.

Voluntary student helpers to BIOMAERL programme

It is appropriate, at this juncture, to stress and acknowledge the importance of volunteer undergraduate student labour to the successfulness of this programme. In

particular, it has enabled a much larger workload of samples to be sorted than would otherwise have been the case. We believe that by encouraging such involvement, the various teams have helped to educate and inform a younger generation, true to the spirit of EU prioritization of investment accountability to the citizen. Thus we thank the following (unlisted in the Personnel list, above) for their sterling efforts in support of BIOMAERL: M.Mulet Abeledo, I. Pazos Garrido, L.Munin Munin,
S. Abiven, A. d'Alès de Corbet, V. Augeraud, K. Bialecki, S. Conan, E. Le Floc'h, L. Guérin, N. Guillou, B. Haupmann, L. Houssay, N. Jarosz, M. A. Jean Mougin, G. Joly, B. Jezequel, J. Jourdes, M. Kirshman, E. Lorena, A. Lorrain, E. Madigou, K. Masski, S. Nedellec, X. Paul, M. Poisson, M. Saliou, K. Thoraval., R.Issa, E.Haug, L.Guérin, R.Aliaga Sânchez, M.Entrena Lillo, J.Solano, H.Goudge, Antje Kaffenburger, M. Dolzel, M. Packer, J. Milligan and K. Russell.

Mr T.D.I Stevenson is thanked for computational assistance at UMBSM.

1.6 Report on fieldwork

1.6.1 Clyde Sea area (UMBSM)

Use of research vessels

Sampling was conducted using two UMBSM-owned research vessels. RV *Aplysia* (11m, cruising speed 7 knots), skippered by Mr D. Frazer, was used on equipment trials and sampling within 20km of UMBSM. RV *Aora* (15m, cruising speed 9 knots, 260hp), skippered by Mr M. Parker, was used locally and on overnight trips up to 50km from UMBSM. An inflatable Zodiac (5m, 30hp) was used as a support tender for diving operations. Equipment deployed from the RVs included a Valeport current meter, N.I.O. water sampler, van Veen grab, Secchi disc and ring-dredge.

Dives completed

It was possible to take full advantage of the diving staff and facilities available at UMBSM since the maerl beds studied were shallow (-6 to -15m CD) and relatively sheltered from wave action. Over 200 man-hours were spent underwater collecting samples, using still and video camera equipment and monitoring physical and biological changes within contrasting maerl habitats over a 2-year period. 85 SCUBA dives were completed at Stravanan Bay, Bute and 57 were completed at Creag Gobhainn, Loch Fyne. A further 9 dives were completed offshore from UMBSM, testing equipment. Staff involved with underwater survey work were: Dr R.J.A.Atkinson; Mr H. Brown, Mr K. Cameron, Mr J. Chamberlain, Dr J. Hall-Spencer, Dr D. Hughes, Dr S.Wieczorek and Dr S. Marrs.

Days spent in the field

Flexibility within the UMBSM research vessel programme enabled a total of 50 successful cruises to be made to investigate Clyde Sea maerl grounds as part of the BIOMAERL project. A further 2 days were spent working around the Cumbrae Islands during equipment trials of the *RoxAnn®* hydro-acoustic processor (with Mr D. Neil of Marine Micro, Aberdeen), an ROV (with Mr C. Shand of the Marine Laboratory, Aberdeen), a Valeport current meter and an underwater air-lift. This gave a total of 52 days spent doing fieldwork.

Samples taken (biota)

An early objective of the programme (Sub task 1.3), was to establish the optimum sampling protocol in each region, taking into account the major sources of natural and anthropogenic disturbance to local maerl beds. Sampling at UMBSM was designed to elucidate the main short and long-term effects of storms and scallop dredging to maerl habitats.

The following benthic sampling gear and techniques were tested on local maerl beds; beam trawl, scallop dredge, Naturalist's dredge, ring dredge, bucket dredge, van Veen grab, Day grab, Jonasson & Olausson box corer, Senckenberg box corer, hand-held cores, air-lifting, resin cast cores, resin cast burrows, video from a Remote Operated Vehicle, 1m^2 quadrats and transect swims using SCUBA.

A beam trawl and a gang of three scallop dredges captured larger members of the community and allowed an assessment to be made of the damage caused to non-target species when maerl beds are fished for scallops (Hall-Spencer & Moore, in press b).

However, tows of a few minutes duration affected >300m^2 (Hall-Spencer & Moore, in press a) and were too destructive for use as a regular sampling method on such small maerl deposits. Instead, video and frequent diver observations were utilized to provide information on the distribution, abundance, behaviour and identity of larger inhabitants of local maerl beds under Task 5.

Smaller dredges impacted limited areas (<15m^2) and proved useful since they collected fauna that burrowed too deeply to be collected in grabs or cores. Of the dredges tested, a 75cm wide ring-dredge dug deepest into the maerl (<23cm) and was adopted for regular use. Grab sampling provided a quantitative means of assessing small organisms that were abundant in the surface layer of the maerl. Trials revealed that a 0.1m^2 van Veen grab worked best on local grounds, penetrating maerl to 15cm with >90% of grabs brought up full. Of the coring devices tested, the Jonasson & Olausson box corer had a poor success rate since pebbles, which were common, prevented adequate penetration of the sediment. Hand-held 0.08m^2 circular cores proved to be ideal for sampling small (<1mm) but very abundant members of the near surface maerl fauna (Hall-Spencer, 1998). They were also a useful means of monitoring the abundance of living maerl on experimental plots within each deposit (Hall-Spencer & Moore, in press a). The most difficult group of organisms to sample proved to be the deep-burrowing megafauna which could not be collected using the methods outlined above. However, a combination of air-lifting, Senkenberg box cores and resin-cast burrows provided novel information on these elusive organisms (Hall-Spencer & Atkinson, in press).

By June 1996, preliminary trials had been completed and a 75cm ring dredge, 1m^2 quadrats, 0.08m^2 hand-held cores and a 0.1m^2 van Veen grab were chosen as the most suitable combination of sampling devices to regularly monitor the dynamics of key species on impacted and control grounds over a two year period. To complete Tasks 3 & 4, and in the light of discussion with collaborators at the second BIOMAERL meeting, UMBSM opted for a seasonal sampling programme of three replicate van Veen samples (1mm sieved), three hand-held core samples (1mm sieved), ten sediment-surface quadrats and one ring dredge sample (2mm sieved) per site, giving totals of 48 grabs, 48 cores, 160 quadrats and 16 dredge samples.

As the biological sampling programme progressed it proved possible to achieve the agreed level of sampling and, on many occasions, to include a greater degree of temporal and spatial replication to improve the accuracy of our population estimations. **Overall, in fact, 65 grab samples, 176 core samples, 600 surface quadrats and 30 dredge samples were taken for analysis from May 1996 to May 1998.**

In addition, eight complete resin-cast thalassinid burrows, nine $1m^2$ air-lift samples and four *Limaria hians* nests were collected using SCUBA for subsequent laboratory investigation. This supplemented our knowledge of the ecology of local maerl beds and allowed as exhaustive a list as possible to be drawn up of the macrobiota present on local maerl habitats in completion of Task 5. During SCUBA dives, video footage and 926 *in situ* photographs were taken of storm- and dredging disturbance together with the benthos associated with Scottish maerl beds. This material has been used to illustrate scientific papers, produce posters for presentation at Conferences and Symposia and to disseminate information to the general public at lectures and in the popular press.

Samples taken (Physical parameters)

On 48 occasions water samples were taken of surface and bottom water (1m above sediment surface) to monitor the range and timing of fluctuations in salinity, temperature and turbidity (Secchi disc depth) over the 1996-98 period. The amount of seston suspended in water samples was measured on 21 occasions over one year at each site. A Valeport current meter was deployed on 32 cruises for periods up to 48h which gave a thorough knowledge of the benthic current field in each area encompassing spring, neap and mid-tidal conditions. A gauge designed to measure changes in sediment macro-topography due to wave action was used approximately bimonthly between May 1996 and May 1998 (Hall-Spencer & Atkinson, in press). This allowed an assessment to be made of the magnitude and frequency of natural disturbance due to storms. In addition to the agreed programme, the loan of equipment from Dunstaffnage Marine Laboratory (Oban) allowed us to monitor the effects of a *Skeletonema costatum* phytoplankton bloom on the oxygen saturation and chlorophyll-*a* content of the water column in April 1997. This monitoring of physical parameters contributed to the data needed to explain major latitudinal differences between European maerl habitats (BIOMAERL team, submitted).

TABLE 1.1. List of UMBSM research cruises.

Cruise Ref. No.	Date	Sites sampled	Tasks accomplished	Vessel
UMBSM 1	12.2.96	Impacted	Physicochemical parameters; grab samples; quadrats; in situ photography; site marking	Aplysia
UMBSM 2	27.2.96	Control	Physicochemical parameters; grab samples; site marking	Aora
UMBSM 3	28.2.96	Impacted	Physicochemical parameters; grab samples;	Aora
UMBSM 4	20.3.96	Impacted	Physicochemical parameters; ring dredge, quadrats, cores, in situ photography	Aplysia
UMBSM 5	21.3.96	Impacted	Physicochemical parameters; grab samples, Naturalist's dredge, quadrats, in situ photography	Aplysia
UMBSM 6	6.6.96	Control	Physicochemical parameters; grab samples; ring dredge; quadrats; cores; in situ photography	Aora
UMBSM 7	7.6.96	Impacted	Physicochemical parameters; grab samples; quadrats; in situ photography	Aora
UMBSM 8	18.7.96	Impacted	Physicochemical parameters; grab samples, ring dredge, beam trawl	Aplysia
UMBSM 9	22.7.96	Impacted	Physicochemical parameters; quadrats, in situ photography	Aplysia
UMBSM 10	30.7.96	Control	Physicochemical parameters; grab samples; ring dredge; air-lift; cores; quadrats; in situ photography	Aora

UMBSM 11	31.7.96	Control	Physicochemical parameters; ring dredge, quadrats, air-lift, in situ photography	Aora
UMBSM 12	20.8.96	Impacted	Physicochemical parameters; grab samples, ring dredge, quadrats, air-lift; in situ photography	Aplysia
UMBSM 13	21.8.96	Impacted	Physicochemical parameters; cores, quadrats, air-lift, in situ photography	Aplysia
UMBSM 14	19.9.96	Impacted	Physicochemical parameters; grab samples, ring dredge, quadrats, cores, in situ photography	Aplysia
UMBSM 15	20.9.96	Impacted	Physicochemical parameters; cores, quadrats, air-lift, in situ photography	Aplysia
UMBSM 16	9.10.96	Control	Physicochemical parameters; grab samples, ring dredge, cores, quadrats, in situ photography	Aora
UMBSM 17	6.11.96	Fairlie Channel	Physicochemical parameters; RoxAnn hydro-acoustic processor survey	Aora
UMBSM 18	7.11.96	Impacted & Tan Buoy	Physicochemical parameters; RoxAnn, grab samples	Aora
UMBSM 19	19.11.96	Impacted	Physicochemical parameters; ring dredge, grab samples, quadrats, bait-pump, cores, in situ photography	Aora
UMBSM 20	26.11.96	Impacted	Physicochemical parameters; ring dredge, quadrats, bait-pump, resin casting	Aora
UMBSM 21	5.12.96	Impacted	Physicochemical parameters; ring dredge, resin casting, quadrats	Aora
UMBSM 22	6.12.96	Impacted	Physicochemical parameters; air-lift, resin casting, quadrats	Aora
UMBSM 23	16.12.96	Impacted	Physicochemical parameters; air-lift, resin casting, quadrats	Aora
UMBSM 24	17.12.96	Control	Physicochemical parameters; grab samples, quadrats, in situ photography	Aora
UMBSM 25	18.12.96	Control	Physicochemical parameters; grab samples, ring dredge, cores, quadrats, in situ photography	Aora

UMBSM 26	22.1.97	Impacted	Physicochemical parameters; ring dredge, grab samples, cores, quadrats, in situ photography	Aora
UMBSM 27	26.2.97	Impacted	Physicochemical parameters; ring dredge, grab samples, quadrats, in situ photography	Aora
UMBSM 28	26.3.97	Control	Aborted trip	Aora
UMBSM 29	3.4.97	Impacted	Physicochemical parameters; ring dredge, grab samples, quadrats, in situ photography, chlorophyll measurements	Aora
UMBSM 30	10.4.97	Control	Physicochemical parameters; ring dredge, quadrats, in situ photography	Aora
UMBSM 31	11.4.97	Control, Ardlam. Point	Physicochemical parameters; grab samples, quadrats, in situ photography	Aora
UMBSM 32	23.4.97	Impacted	Physicochemical parameters; ring dredge, grab samples, quadrats, in situ photography	Aplysia
UMBSM 33	21.5.97	Control, Impacted	Physicochemical parameters; grab samples, quadrats, air-lift, in situ photography	Aora
UMBSM 34	22.5.97	Control and W. Channel	Physicochemical parameters; ring dredge, grab samples, quadrats	Aora
UMBSM 35	20.8.97	Control, Impacted	Physicochemical parameters; ring dredge, grab samples, quadrats, in situ photography	Aora
UMBSM 36	21.8.97	Control	Physicochemical parameters; ring dredge, quadrats, in situ photography	Aora
UMBSM 37	1.9.97	Fairlie Channel	Equipment test	Aora
UMBSM 38	2.9.97	Tan Buoy	Physicochemical parameters; grab samples, quadrats	Aora
UMBSM 39	22.9.97	Impacted	Physicochemical parameters; ring dredge, grab samples	Aora
UMBSM 40	24.9.97	Control, Impacted	Physicochemical parameters; ring dredge, gab samples, quadrats, airlift	Aora

UMBSM 41	25.9.97	Control, Impacted	Physicochemical parameters; ring dredge, grab samples, quadrats, in situ photography	Aora
UMBSM 42	23.10.97	Impacted	Physicochemical parameters; ring dredge, quadrats, air-lift	Aora
UMBSM 43	24.10.97	Impacted	Physicochemical parameters; grab samples, quadrats, in situ photography	Aora
UMBSM 44	10.12.97	Impacted	Physicochemical parameters; grab samples, quadrats, in situ photography	Aora
UMBSM 45	19.1.98	Control, Impacted	Physicochemical parameters; ring dredge, grab samples, quadrats, in situ photography	Aora
UMBSM 46	20.1.98	Control	Physicochemical parameters; ring dredge, quadrats	Aora
UMBSM 47	17.3.98	Impacted	Physicochemical parameters; ring dredge, grab samples, quadrats, in situ photography	Aora
UMBSM 48	18.3.98	Impacted	Physicochemical parameters; quadrats, in situ photography	Aora
UMBSM 49	20.4.98	Control	Physicochemical parameters; ring dredge, grab samples, quadrats, in situ photography	Aora
UMBSM 50	21.4.98	Control	Physicochemical parameters; air-lift, quadrats	Aora
UMBSM 51	19.5.98	Impacted	Physicochemical parameters; ring dredge, grab samples, quadrats, in situ photography	Aora
UMBSM 52	17.11.98	Impacted	Physicochemical parameters; air-lift, in situ photography	Aora

Problems encountered

The recurrent problem throughout, as with any work involving co-ordination of ships and diving teams, was the occasional need to cancel planned sampling trips due to poor weather. However, flexibility within the schedule for the UMBSM research vessels allowed extra cruises to be booked to provide the required spread of sampling effort throughout the main two-year fieldwork programme (Tasks 2-5). Sampling effort is summarized in Table1.2 which shows the months in which research cruises were successfully completed to each site. Proximity to UMBSM allowed the site impacted by anthropogenic activities (UKI) to be sampled more frequently. Occasional equipment failures (e.g. dry suits, air-lift hose) were quickly remedied, although the leakage of a Nikonos V underwater camera system was a costly set-back.

TABLE 1.2. Calendar showing period of sampling trials (Task 1) and subsequent two-year sampling programme (Tasks 2-5) at the control (UKC) and impacted (UKI) sites. '●' indicates months in which the benthos and physical parameters were sampled.

Year						1996											1997									1998		
Month	f		a		j	j	a	s	o	n	d	j	f		a		j	j	a	s	o	n	d	j	f		a	
UKC	●				●	●			●	●				●	●	●			●	●				●			●	
UKI	●	●			●	●	●	●		●	●	●	●		●	●			●	●	●		●	●		●		●
Phase	trials				2 year sampling programme																							

1.6.2 Brittany (UBO)

Use of research vessels

Grab and dredge samples were collected using RV *Cotes d'Aquitaine*. Samples collected by divers were achieved using RV *Sainte Anne du Portzic*. Physicochemical parameters were collected weekly using the latter.

Dives completed

A total of 9 dives have been completed during the study. Diving was accomplished by members of the UMR CNRS 6539 'BIOFLUX' team from the RV *Sainte Anne du Portzic*. Samples were taken using an airlift and sea urchins were collected by hand.

Days spent in the field

A total of 91 cruises have been made since the beginning of the project. Each cruise involved sampling at both the impacted and control sites in the bay of Brest, while 7 cruises were made in the Glenan archipelago. This gives a total of 92 days spent in the field.

Samples taken

During the pilot survey cruise, 66 Smith-McIntyre grabs and 44 AQUAREVE dredge samples were taken in March 1996. In addition, water column parameters were sampled by way of 12 CTD profiles and 12 Niskin bottle water samples.

Seasonal sampling consisted then of 7 Smith-McIntyre samples (biological and sediment analysis), 7 AQUAREVE dredge samples together with 3 Reineck box corer samples collected on the impacted and control grounds of each region surveyed (Glenan and bay of Brest). The Glenan site, however, was not sampled during the Autumn 1996 cruise as severe storms prevented access to this site. Additional samples were therefore taken in the bay of Brest. We have also taken extra samples on each cruise to estimate spatial variability of maerl beds in Brittany. **This gives a total of 468 grab samples, 384 AQUAREVE dredge samples and 54 Reineck box corer samples collected during the period between May 1996 and December 1997.**

Additional samples were also taken by SCUBA divers using an air lift to collect macrofauna (0.14 m^2 quadrat). Sea urchins were also collected over a larger area of maerl (78.5 m^2) for studies on the effects of grazing on epiphytic seaweeds. Cores were also taken on these occasions to investigate stratification within the sediment. A total of 54 such macrofaunal samples were taken together with 46 'sea urchin' samples.

Physical parameters of the water column were sampled by way of 173 CTD profiles and 163 water samples at the control and impacted stations of the two regions. In the bay of Brest, these parameters were sampled roughly every week, while at Glenan they were taken only seasonally. The variables assessed were: salinity, temperature, fluorimetry, irradiance and suspended matter.

TABLE 1.3. List of UBO Biological Sampling Cruises

Biologic alCruise Ref. N°.	Date	Sites sampled	Task Accomplished	Vessels used
UB1	03.96	UBBC&I UBGC&I	Smith-McIntyre grabs AQUAREVE	Cotes d'Aquitaine
UB2	05.96	UBBC&I UBGC&I	Smith-McIntyre grabs AQUAREVE Reineck Cores	Cotes d'Aquitaine
UB3	08.96	UBBC&I UBGC&I	Smith-McIntyre grabs AQUAREVE Reineck Cores	Cotes d'Aquitaine
UB4	11.96	UBBC&I	Smith-McIntyre grabs AQUAREVE Reineck Cores	Cotes d'Aquitaine
RDB28	12.96	UBBC&I	Sediment samples taken by divers for macrofauna Sea Urchins collected Sediment cores	Ste Anne du Portzic
UB5	03.97	UBBC&I UBGC&I	Smith-McIntyre grabs AQUAREVE Reineck Cores	Cotes d'Aquitaine
UB6	05.97	UBBC&I UBGC&I	Smith-McIntyre grabs AQUAREVE Reineck Cores	Cotes d'Aquitaine
RDB37	03.97	UBBC&I	Sediment samples taken by divers for macrofauna Sea Urchins collected Sediment cores	Ste Anne du Portzic
RDB41	04.97	UBBC&I	Sediment samples taken by divers for macrofauna Sea Urchins collected	Ste Anne du Portzic
RDB47	05.97	UBBC&I	Sediment samples taken by divers for macrofauna Sea Urchins collected Sediment cores	Ste Anne du Portzic
RDB50	06.97	UBBC&I	Sediment samples taken by divers for macrofauna Sea Urchins collected	Ste Anne du Portzic
UB7	07.97	UBBC&I UBGC&I	Smith-McIntyre grabs AQUAREVE Reineck Cores	Cotes d'Aquitaine
UB8	09.97	UBBC&I UBGC&I	Smith-McIntyre grabs AQUAREVE Reineck Cores	Cotes d'Aquitaine
UB9	11.97	UBBC&I UBGC&I	Smith-McIntyre grabs AQUAREVE Reineck Cores	Cotes d'Aquitaine
RDB69	02.98	UBBC&I	Sediment samples taken by divers for macrofauna Sea Urchins collected	Ste Anne du Portzic
RDB71	03.98	UBBC&I	Sediment samples taken by	Ste Anne du

			divers for macrofauna Sea Urchins collected	Portzic
RDB78	05.98	UBBC&I	Sediment samples taken by divers for macrofauna Sea Urchins collected	Ste Anne du Portzic
RDB82	06.98	UBBC&I	Sediment samples taken by divers for macrofauna Sea Urchins collected	Ste Anne du Portzic

Problems encountered

A severe storm during the 19th and 20th November 1996 prevented a planned trip to Glenan. Autumn data are thus missing for 1996. To compensate for this problem, extra samples were taken in the bay of Brest. A serious fire in the laboratory destroyed some samples for November 1996 (cruise UB4). Samples destroyed were 2 AQUAREVE samples from UBBC, plus 2 grab samples from UBBC and 2 from UBBI.

The biggest problem encountered during the project was sorting time. Student volunteer labour was necessary for sample sorting if all the contracted samples were to be analysed before the end of the project. However, extra samples will be analysed during 1999 and eventual BIOMAERL publications will include the complete data set.

1.6.3 Galicia (USC)

Use of research vessels

Fieldwork on maerl beds of the northern margin of Ría de Vigo was accomplished using the vessel "Vidal Calvar" (25 m, cruising speed 10 knots, 2 crew), skippered by Mr. B. Fernández Fuentes with the aid of 7 research staff (6 from USC and 1 from UV). An inflatable Zodiac (4 m, 25 hp) was used as a support vessel to assess the extent of the maerl banks and for diving operations (colonization of maerl substratum experiments). The equipment employed included a ring dredge (Rallier du Baty), a Van Veen grab, a box corer, a vertical sampler corer, hand vane testers, plankton nets, Secchi disc, WTW water and sediment analysers and Van Dohrn bottles.

The cruises began (in April, 1996) later than had been originally planned, due to delays from the USC administration over financial support.

Dives completed

To set an experiment on maerl colonization in sandy grounds, a total number of 14 dives were completed from October 1998 to January 1999 in the southern area of Ría de Vigo. Staff involved with underwater survey work were: Dr M. Lastra, Dr J. Troncoso, Dr A. Sánchez-Mata, Mr L. Sampedro, Ms Ch. de la Huz, Ms M.E. Pita, Ms S. Pita and Mr G. Macho.

Days spent in the field

A total of 34 successful cruises were accomplished to investigate Ría de Vigo maerl grounds in the "Vidal Calvar" (from April 1996 to April 1998), 17 of which were at Cangas inlet (USC, control site) and other 17 at Limens inlet (USI, impacted site). Another 7 days were spent at the beginning of the project to locate and estimate the total surface and limits of the maerl banks (using a Van Veen grab, a portable GPS and an inflatable Zodiac) and to test the equipment from the "Vidal Calvar". Another 14 days were spent in the inflatable Zodiac for diving colonization experiments in the maerl grounds. This gave a total of 55 days spent doing fieldwork. The 34 cruises for which gear had to be hired to be used on board the "Vidal Calvar" are listed below:

TABLE 1.4. List of USC sampling cruises

Site: Cangas	**Cruise Ref. Number**	**Date**
USC (Control site)	RDV02	25.04.1996
USC (Control site)	RDV04	29.05.1996
USC (Control site)	RDV06	25.06.1996
USC (Control site)	RDV08	30.07.1996
USC (Control site)	RDV10	04.09.1996
USC (Control site)	RDV12	26.09.1996
USC (Control site)	RDV14	22.10.1996
USC (Control site)	RDV16	29.11.1996

USC (Control site)	RDV18	28.12.1996
USC (Control site)	RDV20	28.01.1997
USC (Control site)	RDV22	25.02.1997
USC (Control site)	RDV24	21.03.1997
USC (Control site)	RDV26	25.04.1997
USC (Control site)	RDV28	17.07.1997
USC (Control site)	RDV30	28.10.1997
USC (Control site)	RDV32	23.01.1998
USC (Control site)	RDV34	28.04.1998

TABLE 1.5. List of USI cruises

Site: Limens	**Cruise Ref. Number**	**Date**
USI (Impacted site)	RDV01	24.04.1996
USI (Impacted site)	RDV03	27.05.1996
USI (Impacted site)	RDV05	24.06.1996
USI (Impacted site)	RDV07	29.07.1996
USI (Impacted site)	RDV09	03.09.1996
USI (Impacted site)	RDV11	25.09.1996
USI (Impacted site)	RDV13	21.10.1996
USI (Impacted site)	RDV15	28.11.1996
USI (Impacted site)	RDV17	27.12.1996
USI (Impacted site)	RDV19	27.01.1997
USI (Impacted site)	RDV21	24.02.1997
USI (Impacted site)	RDV23	20.03.1997
USI (Impacted site)	RDV25	24.04.1997
USI (Impacted site)	RDV27	18.07.1997
USI (Impacted site)	RDV29	27.10.1997
USI (Impacted site)	RDV31	22.01.1998
USI (Impacted site)	RDV33	27.04.1998

The sampling sites were visited monthly from April 1996 to April 1997, and seasonally from April 1997 to April 1998 (April, July and October 1997, January and April 1998). Besides these a total of 14 cruises were accomplished between October 1998 and January 1999 for *in situ* maerl colonization experiments, as detailed below:

TABLE 1.6. List of cruises to USC experimental site

Site: Toralla	**Cruise Ref. Number**	**Date**
USE (Experiment site)	RDVE01	18.06.1998
USE (Experiment site)	RDVE02	20.06.1998
USE (Experiment site)	RDVE03	22.06.1998
USE (Experiment site)	RDVE04	26.06.1998
USE (Experiment site)	RDVE05	04.07.1998
USE (Experiment site)	RDVE06	20.07.1998
USE (Experiment site)	RDVE07	18.08.1998
USE (Experiment site)	RDVE08	21.08.1998
USE (Experiment site)	RDVE09	16.09.1998
USE (Experiment site)	RDVE10	27.09.1998
USE (Experiment site)	RDVE11	14.10.1998
USE (Experiment site)	RDVE12	23.10.1998
USE (Experiment site)	RDVE13	19.11.1998
USE (Experiment site)	RDVE14	18.12.1998

Samples taken

The following benthic sampling gear and techniques were tested on Ría de Vigo maerl beds: ring dredges (Rallier du Baty and Naturalist's), Van Veen grabs, Reineck box corer, vertical sampler corer, hand vane testers, plankton nets, Secchi disc, WTW water and sediments analysers, resin-cast cores and Van Dohrn bottles.

The total number of samples taken from the 34 cruises accomplished is 502, detailed as follows: 306 box-corer samples (1170 vertical sampler corer), 136 water samples, 38 Van Veen samples, 14 Rallier du Baty samples and 8 resin-cast cores.

TABLE 1.7. Detailed listing of USC samples

Month	Site USCC (Control)
April 1996	9 box-corer, 3 Van Veen grabs, 4 water samples
May 1996	9 box-corer; 1 Van Veen grabs, 4 water samples
June 1996	9 box-corer; 1 Van Veen grabs, 4 water samples
July 1996	9 box-corer; 1 Van Veen grabs, 4 water samples
August 1996	9 box-corer & vertical box-corer sampler; 1 Van Veen grabs, 4 water samples
September 1996	9 box-corer; 1 Van Veen grabs, 4 water samples
October 1996	9 box-corer & vertical box-corer sampler; 1 Van Veen grabs, 4 water samples; 1 ring dredge sample; 2 resin casting samples
November 1996	9 box-corer & vertical box-corer sampler; 1 Van Veen grabs, 4 water samples; 2 resin casting samples
December 1996	9 box-corer & vertical box-corer sampler; 1 Van Veen grabs, 4 water samples
January 1997	9 box-corer & vertical box-corer sampler; 1 Van Veen grabs, 4 water samples; 1 ring dredge sample
February 1997	9 box-corer & vertical box-corer sampler; 1 Van Veen grabs, 4 water samples
March 1997	9 box-corer & vertical box-corer sampler; 1 Van Veen grabs, 4 water samples
April 1997	9 box-corer & vertical box-corer sampler; 1 Van Veen grabs, 4 water samples; 1 ring dredge sample
July 1997	9 box-corer & vertical box-corer sampler; 1 Van Veen grabs, 4 water samples; 1 ring dredge sample
October 1997	9 box-corer & vertical box-corer sampler; 1 Van Veen grabs, 4 water samples; 1 ring dredge sample
January 1998	9 box-corer & vertical box-corer sampler; 1 Van Veen grabs, 4 water samples; 1 ring dredge sample

April 1998	9 box-corer & vertical box-corer sampler; 1 Van Veen grabs, 4 water samples; 1 ring dredge sample

Month	Site USCI (Impacted)
April 1996	9 box-corer, 3 Van Veen grabs, 4 water samples
May 1996	9 box-corer; 1 Van Veen grabs, 4 water samples
June 1996	9 box-corer; 1 Van Veen grabs, 4 water samples
July 1996	9 box-corer; 1 Van Veen grabs, 4 water samples
August 1996	9 box-corer & vertical box-corer sampler; 1 Van Veen grabs, 4 water samples
September 1996	9 box-corer; 1 Van Veen grabs, 4 water samples
October 1996	9 box-corer & vertical box-corer sampler; 1 Van Veen grabs, 4 water samples; 1 ring dredge sample; 2 Resin casting samples
November 1996	9 box-corer & vertical box-corer sampler; 1 Van Veen grabs, 4 water samples; 2 Resin casting samples
December 1996	9 box-corer & vertical box-corer sampler; 1 Van Veen grabs, 4 water samples
January 1997	9 box-corer & vertical box-corer sampler; 1 Van Veen grabs, 4 water samples; 1 ring dredge sample
February1997	9 box-corer & vertical box-corer sampler; 1 Van Veen grabs, 4 water samples
March 1997	9 box-corer & vertical box-corer sampler; 1 Van Veen grabs, 4 water samples
April 1997	9 box-corer & vertical box-corer sampler; 1 Van Veen grabs, 4 water samples; 1 ring dredge sample
July 1997	9 box-corer & vertical box-corer sampler; 1 Van Veen grabs, 4 water samples; 1 ring dredge sample
October 1997	9 box-corer & vertical box-corer sampler; 1 Van Veen grabs, 4 water samples; 1 ring dredge sample
January 1998	9 box-corer & vertical box-corer sampler; 1 Van Veen grabs, 4 water samples; 1 ring dredge sample
April 1998	9 box-corer & vertical box-corer sampler; 1 Van Veen grabs, 4 water

	samples; 1 ring dredge sample

Problems encountered

No current speed measurements have been accomplished to date. It was hoped that suitable meters might be available on loan from the Oceanographic Institute and from the Centro Superior de Investigaciones Pesqueras in Vigo, but because they are in constant use there, this has not proved possible.

1.6.4 Alicante (UA)

A total of 49 cruises have been accomplished between January 1996- June 1998: 27 cruises to the Tabarca Marine Reserve (control site), 18 cruises to Benidorm island (impacted site), and 4 to Alicante Bay.

Use of research vessels

a) SCUBA diving, UW photographs, hydrological and sedimentological samples, dredge and grab samples : these have been taken using

- Pneumatic boats: *Sirpus* (33 days) of the University of Alicante (4.2m, 25HP outboard engine) was utilized on 4 days on the control site and 3 at the impacted site; *Posidonia* (12 days) of the Institute of Littoral Ecology (4.5m, 30HP outboard); and *Broadcast* (2 days) of the Image Studio of the University of Alicante (4.7m, 60HP outboard). These boats can carry 3 divers with complete SCUBA equipment and sampling gear, and a boatman to support and assist on the surface.

b) Heavier dredge and grab samples : have been taken using

- Oceanographic Vessel : *Odon de Buen* (4 days) of the Instituto Español de Oceanografía (20m, cruising speed 10 knots, 6 crew).
- Commercial vessel : *Kontiki II* (2 days) (18m, cruising speed 10 knots, 4 crew).

Dives completed

A total of 78 dives were carried out during the period April 1996 to August 1998. The diving personnel assisting with this work were: Mr A. Aranda, Ms C. Barberá, Mr C. Bordehore, Dr J.E. Guillén, Mr J. Mallol, Mr J.A. Moya, Mr J.L. Patiño, Prof. A.A. Ramos and Mr C. Valle. Dives of about 20-25 mins duration bottom time (plus 6 minutes of decompression time) were undertaken at 33-41m depth. 44 (2 with hydroplane to search for the maerl beds) dives took place at the unimpacted site (Tabarca) and 33 (1 with hydroplane) dives at the impacted site (Benidorm) to take quadrat/core samples, U/W photographs and video and thermo/salinometer recordings.

Days spent in the field

A total of 49 cruises have been made since the start of the project (Table 8). Each cruise involved sampling by SCUBA diving (quadrats and cores) and/or hydrological parameters (transparency, seston) and remote sampling (dredges and grabs) at the control (33 cruises) or impacted sites (18 cruises) ; also some cruises (4) have been carried out in Alicante Bay. This represents a total of 49 days spent in the field.

Samples taken

During the pilot survey different sampling methods were tested : remote sampling (runner dredge, naturalist's dredge, beam-trawl, van Veen grab) and direct sampling (diver quadrats).

- Observation trips : 3 hydroplane observation trips were done to locate the maerl beds at the control and impacted sites.
- Quantitative study :
    - 33 grab samples were taken.
    - 131 diver quadrats (6 of each station control/impacted). Equipment trials revealed that the coarse nature of the sediment studied here created difficulties with the loss of sampled material (see problems encountered), it was decided to change to direct sampling with diver quadrats, that being very much more efficient. Initially work proceeded with a large quadrat (40

x 40cm = 0.16 m^2), but this was subsequently changed to a smaller one (22.4 x 22.4cm = 0.05 m^2) with material being retained in a mesh bag (1mm mesh).

- UW images : 14 dives with a Nikonos V camera and SP-103 flash at the control (11 dives) and impacted site (3 dives) ; and UW/TV on the runner dredge (1 transect), and UW/Video (1 dive) at the control site.
- Sedimentological study : 24 core (90mm diameter) samples have been taken.
- Qualitative study :
    - 59 dredge samples either with the small runner dredge (0.45 x 0.25m frame) or a larger version (1.00 x 0.30cm frame) have been taken.
    - A small beam trawl (1.00 x 0.40m frame) was tested (6 samples), but the roughness and hardness of maerl bottoms prevented adequate sampling.
- Hydrological parameters : On 18 occasions transparency measures (Secchi disc) and seston samples (51 Niskin bottle) were taken at the control and impacted sites; 26 temperature/salinity profiles have been measured by the Hugrún thermo-salinometer sensor (with SCUBA equipment)

Overall, 131 diver quadrat samples, 59 dredge samples, 6 beam trawl samples, 33 grab samples, 24 core samples were collected between April 1996 and August 1998 (including 16 UW filming opportunities exposing 8 rolls of film).

TABLE 1.8. List of UA sampling cruises.
UAC = control site, UAI = impacted site, UAB = Alicante Bay

Cruise Ref. No.	Date	Sites sampled	Tasks accomplised	Vessel
UAC-1	25.04.96	Control	Hydroplane observations	Sirpus
UAC-2	27.04.96	Control	Hydroplane observations	Sirpus
UAC-3	04.05.96	Control	Scuba maerl sampling	Sirpus
UAI-4	30.05.96	Impacted	Hydroplane observations	Posidonia
UAC-5	27.06.96	Control	Naturalist's dredge and grab samples	Sirpus
UAI-6	29.06.96	Impacted	Naturalist's dredge and grab samples	Posidonia
UAC-7	06.08.96	Control	Physicochemical parameters, diver quadrats	Sirpus
UAC-8	05.09.96	Control	Physicochemical parameters, diver quadrats, cores, in situ UW photography	Sirpus

UAI-9	28.09.96	Impacted	Physicochemical parameters, diver quadrats, cores, in situ UW photography	Posidonia
UAI-10	01.10.96	Impacted	Physicochemical parameters, diver quadrats, grab samples, cores, in situ UW photography	Posidonia
UAC-11	05.10.96	Control	Physicochemical parameters, diver quadrats, run-ner dredge, grab samples,	Sirpus
UAC-12	03.12.96	Control	Physicochemical parameters, diver quadrats, cores, runner dredge, in situ UW photography	Sirpus
UAI-13	11.12.96	Impacted	Physicochemical parameters, diver quadrats, cores, runner dredge, in situ UW photography	Posidonia
UAB-14	19.12.96	Impacted	Physicochemical paramters, runner dredge, beam trawl, grab samples	Kon-Tiki II
UAC-15	05.02.97	Control	Physicochemical parameters, cores, resin, in situ UW photography, mark buoy	Sirpus
UAC-16	06.02.97	Control	Physicochemical parameters, cores, resin, beam trawl, grab samples, in situ UW photography	Sirpus
UAC-17	09.02.97	Control	Diver quadrats, cores	Sirpus
UAC-18	13.02.97	Control	Runner dredge, grab samples	Sirpus
UAC-19	18.02.97	Control	Physicochemical parameters, diver quadrats, cores,	Sirpus
UAC-20	19.02.97	Control	Cores, in situ UW photography	Sirpus
UAC-21	20.02.97	Control	Physicochemical parameters, diver quadrats, cores, grab samples, in situ UW photography	Sirpus
UAI-22	02.04.97	Impacted	Physicochemical parameters, runner dredge	Posidonia
UAI-23	03.04.97	Impacted	Physicochemical parameters, diver quadrats, cores	Posidonia
UAI-24	16.04.97	Impacted	Physicochemical parameters, diver quadrats, cores	Sirpus
UAB-25	04.06.97	Impacted	Beam trawl, grab samples	Odón de Buén
UAC-26	09.06.97	Control	Physicochemical parameters, diver quadrats, cores, in situ UW photography	Sirpus
UAC-27	10.06.97	Control	Physicochemical parameters, runner dredge	Sirpus
UAI-28	11.06.97	Impacted	Physicochemical parameters, runner dredge, in situ UW photography	Posidonia
UAI-29	12.06.97	Impacted	Physicochemical parameters, diver quadrats	Posidonia

UAI-30	26.08.97	Impacted	Physicochemical parameters, runner dredge	Posidonia
UAI-31	27.08.97	Impacted	Physicochemical parameters, diver quadrats, cores	Posidonia
UAC-32	27.08.97	Control	UW television	Broadcast
UAC-33	29.08.97	Control	Physicochemical parameters, diver quadrats, cores, in situ UW photography	Sirpus
UAC-34	01.09.97	Control	Physicochemical parameters, runner dredge, in situ UW photography	Sirpus
UAB-35	28.11.97	Impacted	Runner dredge, grab samples	Odón de Buen
UAI-36	29.11.97	Impacted	Physicochemical parameters, diver quadrats, cores, runner dredge, grab samples	O. de Buen, Sirpus
UAC-37	13.12.97	Control	Physicochemical parameters, diver quadrats, cores, runner dredge, in situ UW photography	O. de Buen, Sirpus
UAB-38	16.01.98	Impacted	Physicochemical parameters, runner dredge, grab samples	Kon-Tiki II
UAC-39	04.03.98	Control	Physicochemical parameters, runner dredge	Sirpus
UAC-40	06.03.98	Control	Physicochemical parameters, diver quadrats, cores, in situ UW photography and video	Sirpus, Broadcast
UAI-41	07.03.98	Impacted	Physicochemical parameters, diver quadrats, cores, runner dredge	Sirpus
UAC-42	22.05.98	Control	Physicochemical parameters, runner dredge	Sirpus
UAC-43	23.05.98	Control	Physicochemical parameters, diver quadrats, cores, in situ UW photography, mark buoy	Sirpus
UAI-44	10.06.98	Impacted	Physicochemical parameters, runner dredge	Sirpus
UAI-45	17.06.98	Impacted	Physicochemical parameters, diver quadrats, cores	Sirpus
UAC-46	25.08.98	Control	Physicochemical parameters, diver quadrats, cores, in situ UW photography	Sirpus
UAC-47	26.08.98	Control	Physicochemical parameters, runner dredge	Sirpus
UAI-48	27.08.98	Impacted	Physicochemical parameters, runner dredge	Sirpus
UAI-49	28.08.98	Impacted	Physicochemical parameters, diver quadrats, cores	Sirpus

TABLE 1.9. Detail of UA sampling cruises. obs. = flora/fauna observations, quad. = diver quadrats, resin = resin cast cores, U/W ph. = underwater photographs, SD = Secchi disc, sest. = seston, T/S = temperature/salinity measurements.

Station	Date	obs.	quad.	resin	core	U/W ph.	dredge	grab	SD	sest.	T/S
UAC-1	25.04.96	+									
UAC-2	27.04.96	+									
UAC-3	04.05.96	+									
UAI-4	30.05.96	+									
UAC-5	27.06.96						1	3			
UAI-6	29.06.96						1	3			
UAC-7	06.08.96	+	4						+	+	+
UAC-8	05.09.96	+	3		+	+			+		+
UAI-9	28.09.96	+	3		+	+			+	+	+
UAI-10	01.10.96	+	4		+	+		3			+
UAC-11	05.10.96	+	6				2	3			+
UAC-12	03.12.96	+	6		+	+	2		+	+	+
UAI-13	11.12.96	+	6		+	+	2		+	+	+
UAB-14	19.12.96						2	3	+		+
UAC-15	05.02.97	+		+	+	+			+	+	
UAC-16	06.02.97	+		+	+		2	3			+
UAC-17	09.02.97	+	6		+						
UAC-18	13.02.97						3	3			
UAC-19	18.02.97	+	6		+						+
UAC-20	19.02.97	+			+	+					
UAC-21	20.02.97	+	6		+	+		3			+
UAI-22	02.04.97						3		+	+	
UAI-23	03.04.97	+	6		+						+
UAI-24	16.04.97	+	6		+						+
UAB-25	04.06.97						3				
UAC-26	09.06.97	+	6		+	+					+
UAC-27	10.06.97						3		+	+	
UAI-28	11.06.97						3		+	+	
UAI-29	12.06.97	+	6								+
UAI-30	26.08.97						3		+	+	
UAI-31	27.08.97	+	6		+						+
UAC-32	27.08.97	+				+					
UAC-33	29.08.97	+	6		+	+					+
UAC-34	01.09.97	+				+	2		+	+	
UAB-35	28.11.97						1	3			
UAI-36	29.11.97	+	6		+		3	3	+	+	+
UAC-37	13.12.97	+	6		+	+	3		+	+	+
UAB-38	16.01.98						2	3	+		+
UAC-39	04.03.98						3		+	+	
UAC-40	06.03.98	+	6		+	+					+
UAI-41	07.03.98	+	6		+		3		+	+	+
UAC-42	22.05.98						3		+	+	
UAC-43	23.05.98	+	3		+	+					+
UAI-44	10.06.98						3		+	+	
UAI-45	17.06.98	+	6		+						+
UAC-46	25.08.98	+	6		+	+					+
UAC-47	26.08.98						3		+	+	
UAI-48	27.08.98						3		+	+	

Problems encountered

It has not been possible to utilize a large vessel capable of deploying heavy remote-sampling gear (e.g. 0.1m^2 van Veen grab) for routine sampling. UA could only hire an oceanographic vessel once a year. Thus the bulk of UA sampling has had to be from small inflatable boats, with some additional samples being achieved by rental of a commercial vessel.

A major practical problem has been to consistently relocate the marker buoy on the permanent transect to take U/W photographs (one was lost in 1996, and another in 1997). The buoy has been deliberately situated below surface (-3m deep) to reduce the possibility to interference by fishermen, but that made it difficult to relocate.

Due to the high diversity and small size of animals in the quadrat samples it takes a very long time to separate a sample fully (2-3 weeks). This problem has been only partially solved with the addition of two persons to the UA team.

1.6.5 Malta (UM)

Use of research vessels

Most biological samples (1996-97) were collected using the Maltese fishing boat F54 "St. Peter", but in January and April 1998 the F11 "Giuseppe L" was used. Physicochemical factors were measured during these biological sampling trips, and additional measurements of water column parameters were made on cruises aboard M.Y. "Nemertes" and fishing boat S9413.

Dives completed

Since the Maltese maerl grounds studied occur at depths between 40 and 80m, routine sampling using SCUBA was considered too dangerous, so remote sampling methods were used. However, two dives have been accomplished, one at the impacted site (46m) and one at the control (53m), during which core samples were collected. As the time available on the bottom was very limited due to the depth, only four core samples from each station could be collected.

Days spent in the field

A total of 29 cruises have been made since the start of the project. Each cruise involved sampling at both the impacted and control sites, except on one occasion when the two sites were sampled separately on two consecutive days, by means of SCUBA diving (11 and 12 September 1997). This gives a total of 29 days spent in the field.

Samples taken

43 grab samples were collected during the pilot survey. Two grab samples and one dredge sample from each of the impacted and control sites were additionally collected prior to the seasonal sampling programme starting (20 June 1996). This gives a total of 47 grab samples and 2 dredge samples collected before the seasonal sampling programme was started.

During each seasonal sampling trip, 6 van Veen grab samples and 1 biological dredge sample were collected from each impacted and control site. The dredge samples were not collected during the April 1998 sampling trip, because the vessel used (the 'Giuseppe L' F11) was not powerful enough to drag the dredge. On the other hand, 4 'extra' grab samples from each site were collected during this sampling trip. This gives a total of 104 grab samples and 14 dredge samples collected during the period between July 1996 and April 1998. On one occasion, 4 core samples were collected from each site by hand using SCUBA diving.

Overall, 151 grab samples, 16 dredge samples and 8 core samples were collected between April 1996 and April 1998.

On 17 occasions, physical parameters of the water column at the control and impacted sites were measured. These parameters were: Secchi depth, temperature and salinity profiles and suspended organic matter.

An additional sampling trip was made for the collection of megabiota, which were not generally collected by means of the grab and dredge used for the seasonal sampling. This was done using a Maltese shrimp trawl [in Maltese *gangmu*] (Dimensions: mouth width 154cm, mouth height 58cm; length of net 250cm and mesh size 2cm). Apart from the megabiota, some large rhodoliths which were caught by the trawl were also collected.

During the same sampling cruise, the impact of bottom-set gill-net fishing [in Maltese *parit*] (Dimensions: height *ca* 2m and length *ca* 400m) on Maltese maerl grounds was assessed. This was done by experimentally deploying bottom-set gill-nets on the impacted and control sites. The nets were left to fish overnight and any megabiota, including fish and large rhodoliths, which were entangled with the nets were collected.

TABLE 1.10. List of UM research cruises

Cruise Ref. N°.	Date	Sites sampled	Task Accomplished	Vessels used
1/96	6.04.96	STT; MCT	van Veen Grab samples (Pilot Survey)	St. Peter
2/96	7.04.96	SPIT; SPBT; QTT	van Veen Grab samples (Pilot Survey)	St. Peter
3/96	8.04.96	GTT; SMTT; MTT; SGTT	van Veen Grab samples (Pilot Survey)	St. Peter
4/96	9.04.96	QPT; WTT; CT	van Veen Grab samples (Pilot Survey)	St. Peter
5/96	20.06.96	Impacted and Control	van Veen grab samples and dredge samples (additional sampling trip)	St. Peter
6/96	23.07.96	Impacted and Control	van Veen grab samples and dredge samples	St. Peter
7/96	7.08.96	Impacted and Control	Physicochemical parameters	M.Y. Nemertes
8/96	15.09.96	Impacted and Control	van Veen grab samples; during the Malta BIOMAERL meeting	St. Peter
9/96	1.10.96	Impacted and Control	Physicochemical parameters	M.Y. Nemertes
10/96	5.11.96	Impacted and	Physicochemical	M.Y. Nemertes

		Control	parameters	
11/96	6.11.96	Impacted and Control	van Veen grab samples and dredge samples; also tested box-corer	St. Peter
1/97	7.01.97	Impacted and Control	Physicochemical parameters; van Veen grab samples and dredge samples	St. Peter
2/97	23.2.97	Impacted and Control	Physicochemical parameters	S9413
3/97	20.4.97	Impacted and Control	van Veen grab samples and dredge samples	St. Peter
4/97	2.05.97	Impacted and Control	Physicochemical parameters	S9413
5/97	10.07.97	Impacted and Control	Physicochemical parameters; van Veen grab samples and dredge samples	St. Peter
6/97	22.08.97	Impacted and Control	Physicochemical parameters	S9413
7/97	11.09.97 12.09.97	Impacted Control	Collection of core samples by SCUBA diving	M.Y. Nemertes
8/97	21.09.97	Impacted and Control	Physicochemical parameters	S9413
9/97	19.10.97	Impacted and Control	Physicochemical parameters; van Veen grab samples and dredge samples	St. Peter
10/97	26.11.97	Impacted and Control	Physicochemical parameters	M.Y. Nemertes
11/97	9/10.12.97	Impacted and Control	Physicochemical parameters; sampling using a Maltese shrimp dredge; fishing with bottom set gill-nets	St. Peter
1/98	14.01.98	Impacted and Control	Physicochemical parameters; van Veen grab samples and dredge samples	Giuseppe I
2/98	14.02.98	Impacted and Control	Physicochemical parameters	M.Y. Nemertes
3/98	30.03.98	Impacted and Control	Physicochemical parameters	M.Y. Nemertes
4/98	7.04.98	Impacted and Control	van Veen grab samples and dredge samples	Giuseppe I
5/98	14.05.98	Impacted and Control	Physicochemical parameters	S9413

6/98	20.06.98	Impacted and Control	Physicochemical parameters	M.Y. Nemertes

Problems encountered

During the course of this project the Maltese group had to overcome a number of problems with respect to the science, logistics and administration of the project.

The main scientific problem was that the Maltese maerl grounds studied occurred below safe diving depth using ordinary SCUBA techniques, and therefore could only be sampled remotely. Attempts to use a box-corer to obtain intact cores failed. For safety and financial reasons, it was only possible to organise one dive each on the two maerl grounds using deep-diving SCUBA techniques. However, during the short time available on the bottom, the physiognomy of the grounds was observed *in situ* and a limited number of cores taken by hand.

The main logistic problem concerned the availability of boats. As there are no research vessels available in Malta, the Maltese group hired a fishing boat for the sampling trips. Being a working fishing boat, this vessel was not always available when required. This created problems especially in winter when adverse weather gave few opportunities for sampling. Towards the end of the sampling programme, the boat originally used was no longer available and UM had to find and use a second boat at very short notice.

But the most serious problem of all concerned funding of the Maltese group. Malta, not being a EU member state, participated in this project on a self-funding basis. Originally, the Maltese government was to make funds available to the University of Malta to enable Maltese participation in this project. However, these funds were subject to the Maltese government concluding negotiations with the EU on a financial protocol. Following the general election in Malta in October 1996, there was a change in government and the new administration had a different policy vis-à-vis Malta-EU relationships, necessitating a review of all existing and pending arrangements. Following a review by the EU of the Fourth EU-Malta financial protocol, the EU no longer allowed funds granted to Malta under this protocol to be used to support

Maltese participation in the EU's Fourth Framework Programme. In effect this meant that no EU funds whatsoever were given to the Maltese BIOMAERL group. This left the UM team with a severe problem, since the group had been operating on funds advanced to it by the University of Malta, which had to be refunded.

This problem was partly alleviated by a research grant from the University of Malta and another one from the Malta Council for Science and Technology, while the (then) Maltese Ministry of Education and National Culture supported the employment of a full-time research assistant. Travelling expenses were met from the yearly allocation for such purpose made available to the academic staff by the University.

Following the most recent change of administration, after the Maltese general election held in September 1998, the Maltese Government has re-activated its application to join the EU. Unfortunately, this event came too late in the project to affect the funding situation of the Maltese group.

1.7 Archiving of quality-checked BIOMAERL data

Data are archived at UMBSM in accordance with procedures laid down in the Technical Annex of the contract.

1.8. Technology Implementation Plan (TIP)

Being a mandatory requirement of MAST contracts a TIP has been filed with the EC, but it is blank. Being a scientific programme, BIOMAERL has no commercially exploitable outputs.

2) DETAILED SCIENTIFIC & TECHNICAL REPORT

2.1. SCIENTIFIC REPORT

The available option of compiling publications and /or manuscripts to create this section has been adopted here. The following MSS are included:

Scientific papers published in peer-reviewed journals

Grall, J. & Glémarec, M., 1997. Biodiversité des fonds de maerl en Bretagne: approche fonctionelle et impacts anthropiques. *Vie Milieu*, 47, 339-349.

Hall-Spencer, J.M., 1998. Conservation issues relating to maerl beds as habitats for molluscs. *J.Conchol.*, 36(1) (Special Publ.2), 271-286.

Papers currently in press with peer-reviewed journals

Barberá, C., Valle, C., Bordehore, C., Patiño, J.L., Martinez, M.C., Sánchez-Jérez, P.& Ramos-Esplá, A.A., in press. Caracterización de los fondos de maërl y macrofauna asociada de la Reserva Marina de Tabarca (Alicante, SE Península Ibérica). *Graellsia*

Borg, J.A., Lanfranco, E., Mifsud, J.R., Rizzo, M. & Schembri, P.J., in press. Does fishing have an impact on Maltese maerl grounds? *ICES J.Mar.Sci.*,

Hall-Spencer, J.M. & Atkinson, R.J.A., in press. *Upogebia deltaura* (Crustacea Thalassinidea) in Clyde Sea maerl beds, Scotland. *J.Mar.Biol.Ass.U.K.*

Hall-Spencer, J.M., Moore, P.G. & Sneddon, L.U., in press. Observations on the striking anterior coloration pattern of *Galathea intermedia* (Crustacea: Decapoda: Anomura) and its possible function. *J.Mar.Biol.Ass.U.K.*,

Hall-Spencer, J.M. & Moore, P.G., in press. Scallop dredging has profound, long-term impacts on maerl habitats. *ICES J.Mar.Sci.*,

Hall-Spencer, J.M. & Moore, P.G., in press. Impacts of scallop dredging on maerl grounds. In, Kaiser, M.J. & de Groot, S.J.(Eds) *Effects of fishing on non-target species and habitats: biological, conservation and socio-economic issues.* Fishing News Books, Oxford, *Scientific papers and abstracts published in non peer-reviewed journals or conference proceedings*

Abella, F.E., Sánchez-Mata, A., de la Huz , Ch. & Mora, J., 1998. Caracterización fisiogeoquimica de los fondos de maerl de la Ria de Vigo. *Resumos X Simpósio ibérico de estudos de bentos marinho (Playa do Carvoeiro, Algarve, Portugal),* p.128.

Aranda López, A. & Solano García, I., 1998. Composición florística y estructura de los fondos detríticos del SE Ibérico. *Resumos X Simpósio ibérico de estudos de bentos marinho (Playa do Carvoeiro, Algarve, Portugal),* p.106.

Barberá, C., Valle, C., Martínez, M.C., Patiño, J.L , Bordehore, C. & Ramos-Esplá, A.A., Contribución al conocimiento de la macrofauna asociada a los fondos de maërl de la Reserva marina de Tabarca (Alicante, SE Península Ibérica). *Resumos X Simpósio ibérico de estudos de bentos marinho (Playa do Carvoeiro, Algarve, Portugal),* p.131.

BIOMAERL team, 1998. Maerl grounds: habitats of high biodiversity in European seas. *Third Europ. Mar.Sci.Tech.Conf., Lisbon, 23-27 May 1998,* Vol.1 *Marine Systems*, pp.170-178.

Guillén Nieto, J. & Barberá Cebrián, C., Variación de las poblaciones de crustáceos decápodos en las comunidades del detrítico del SE Ibérico afectadas por el impacto de la pesca de arrastre. *Resumos X Simpósio ibérico de estudos de bentos marinho (Playa do Carvoeiro, Algarve, Portugal),* p.144.

Mora, J., Sánchez-Mata , A.& Lastra, M., 1998. Variación estacional de la fauna bentónica de un fondo de maerl bajo la influencia de un polígono de bateas de mejillón. *Resumos X Simpósio ibérico de estudos de bentos marinho (Playa do Carvoeiro, Algarve, Portugal),* p.96.

Sánchez-Mata, A., Abella, F.E. & Mora, J., 1998. Biodiversidad especifica de los fondos de maerl (*Lithothamnion corallioides* (P.& H..Crouan) P.& H.Crouan and *Phymatolithon calcareum* (Pallas) Adey & McKibbin de la Ria de Vigo. *Resumos X Simpósio ibérico de estudos de bentos marinho (Playa do Carvoeiro, Algarve, Portugal),* pp.168-169.

Sánchez-Mata, A., Abella Rey, F.E. & Mora Bermúdez, J., 1998. Cambios estructurales en la composicion de dos fondos de maerl sujetos a diferentes condiciones ambientales. *XIII Congreso bienal de la Real Sociedad Española de Historia Natural*, p.48.

Sánchez-Mata, A., Grall J.& Hall-Spencer,J., 1998. Diferencias estrucurales biogeográficas de los fondos de maerl en aguas del Atlántico Norte entre las latitudes 42° y 56°, *Resumos X Simpósio ibérico de estudos de bentos marinho, (Playa do Carvoeiro, Algarve, Portugal),* p.124.

Schembri, P.J., 1998. Maerl ecosystems of the Maltese Islands. In, Dandria, D. (ed.) *Biology abstracts M.Sc., Ph.D. 1998, and contributions to marine biology*; pp. 35-37. Msida, Malta: Department of Biology, University of Malta; iv + 38pp.

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Papers in various stages of preparation destined for peer-reviewed journals

[these MSS are not included below. However, a provisional text for the paper marked (*) below is incorporated into Task 5 below, as per EC instructions]

BIOMAERL team, Environmental characterization of maerl beds in NE Atlantic and Mediterranean waters (BIOMAERL project). ? for *J.Exp.Mar.Biol.Ecol.*,

BIOMAERL team , Functional analysis of maerl bed biota from the NE Atlantic and the Mediterranean. ? for *Estuar.Cstl & Shelf Sci.*

BIOMAERL team, A comparative assessment of anthropogenic inputs on NE Atlantic and Mediterranean maerl grounds. ? for *Océanol.Acta*

BIOMAERL team, Structuring of sedimentary habitats by unattached rhodophytes: a comparative study from the NE Atlantic and the Mediterranean. ? for *FACIES*

BIOMAERL team, Conservation and management of maerl beds. ? for *Aquatic Conserv.: Mar & Freshwat. Ecosyst.*,

BIOMAERL team, Total biomass, biomass spectra and size-frequency of key species from European maerl beds. ? for *Mar.Ecol.Prog.Ser.*

BIOMAERL team, Inventory of biota from maerl beds in the NE Atlantic and Mediterranean. ?for *Paris Museum Publns*

BIOMAERL team, A biogeographical analysis of major taxa of European maerl-bed biota. ? for *J.Biogeogr.*

(*)BIOMAERL team, The characteristics of, threats to and management of, European maerl beds: a BIOMAERL project overview. ? for *J.Aquat.Ecosyst. Health* or *Aquat. Conserv.*

As can be seen from the above list, the output of the BIOMAERL programme will be extensive. This project has allowed us to greatly advance knowledge of this unique and neglected ecosystem, and in so doing to become the leading European repository of expertise on this habitat. The BIOMAERL team has maximized all data-gathering and scientific opportunities which this contract represented. It should be clear that the outputs of the programme already achieved (detailed above, and as anticipated), will exceed substantially the demands of the original proposal.

VIE MILIEU, 1997, 47 (4) : 339-349

BIODIVERSITÉ DES FONDS DE MAERL EN BRETAGNE : APPROCHE FONCTIONNELLE ET IMPACTS ANTHROPIQUES

Biodiversity of Maerl beds in Brittany : functional approach and anthropogenic impacts

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COMPLEXITÉ ARCHITECTURALE
BANCS DE MAERL
BIODIVERSITÉ SPÉCIFIQUE
BIODIVERSITÉ FONCTIONNELLE
MACROBENTHOS
LITHOTHAMNIÉES

RÉSUMÉ. – La complexité architecturale de l'habitat est un facteur physique qui peut expliquer la forte diversité spécifique des fonds de maerl, en outre ceux-ci sont aussi caractérisés par une diversité fonctionnelle élevée. La structure physique de l'habitat offre un refuge à de nombreux prédateurs, et les interactions biotiques basées sur la prédation, la perturbation, la compétition... empêchent toute monopolisation des ressources par quelques espèces dominantes. La comparaison des structures benthiques installées en rade de Brest sur les fonds sédimentaires homogènes par rapport à celles du maerl, fournit une première explication à cette diversité élevée. L'examen des fonds de maerl, perturbés par des actions anthropiques (eutrophisation dans le bassin nord de la rade de Brest, turbidité par exploitation directe aux Glénan), permet d'évoquer les liens existant entre diversité spécifique et fonctionnelle.

ARCHITECTURAL COMPLEXITY
MAERL BEDS
FUNCTIONAL BIODIVERSITY
SPECIFIC BIODIVERSITY
MACROBENTHOS
CORALLINE ALGAE

ABSTRACT. – In maerl beds, architectural complexity is a physical factor which can explain the high specific diversity, and these habitats are moreover characterized by a high functional diversity. The physical structure of this habitat consists in providing refuges for a lot of predators and biotic interactions founded on predation, disturbance, competition... prevent any ressources monopolisation by only a few dominating species. Comparison of macrobenthic structures on homogeneous muddy bottoms and maerl beds in the Bay of Brest gives a first explanation to this high diversity. A second comparison between Control and Impacted maerl beds stations (eutrophication in the northern basin of the Bay of Brest, turbidity by direct exploitation of coralline algae in Glenan) suggests the existing links between specific and functional diversities.

Problème

Le terme de maerl désigne des accumulations d'algues Corallinacées non fixées vivantes ou mortes. Ces algues, dont la croissance est très lente, participent ainsi à la construction d'habitats géographiquement bien localisés dans l'étage infralittoral des mers tempérées. Dans ce milieu littoral très productif, les fonds de maerl hébergent une flore et une faune très diversifiée, mais cette forte diversité taxonomique est aussi fonctionnelle. Le problème posé est de rechercher les causes possibles d'une telle biodiversité spécifique et fonctionnelle.

La biodiversité fonctionnelle peut se référer à la structure de l'habitat. En effet, un fond de maerl offre une complexité architecturale remarquable. Cette composante physique est liée au caractère arbusculaire des thalles du maerl, les espaces entre ces structures biogéniques vivantes ou mortes servent de refuges aux animaux mobiles qui peuvent échapper ainsi à la prédation épibenthique. Les thalles de maerl servent de substrat solide pour les épibiontes et la production épiphytique sous forme de fragments est transférée par les herbivores et détritivores au sein de ce milieu cavitaire. En Bretagne, ces habitats sont situés très peu profondément (3 à 10 m) et les courants de marée y maintiennent une circulation interne permettant

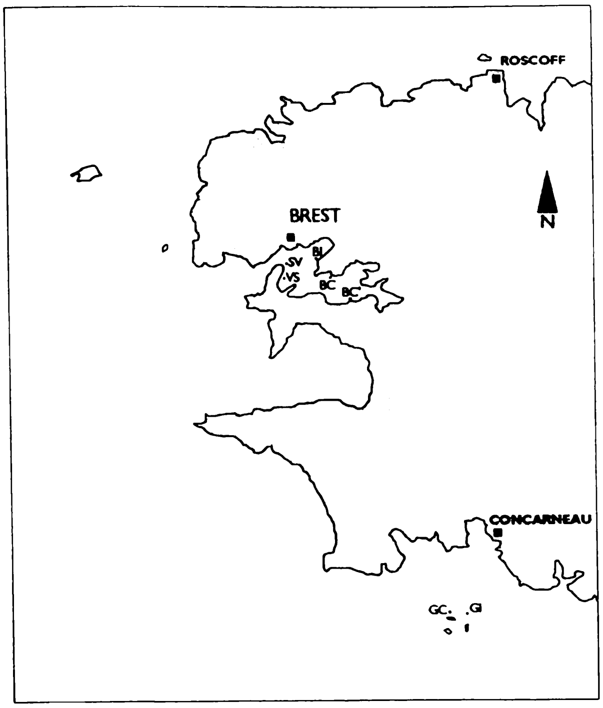


Fig. 1. – Localisation des sites étudiés en rade de Brest (B) et aux Glénan (G). C : station de contrôle, I : station impactée. SV : sables fins envasés, VS : vases sableuses, BC : maerl de Rozegat, BC' : maerl de Loumergat.

Sampling stations within the bay of Brest (B) and the Glenan archipelago (G). C : control site. I : impacted site. SV : muddy sands, VS : sandy muds, BC : maerl bank of Rozegat, BC' : maerl bank of Loumergat.

aux animaux résidents de vivre en profondeur dans le sédiment. Par leur activité incessante, ces animaux fouisseurs et perturbateurs évitent ainsi une stratification physico-chimique (Aller 1982) et le colmatage des cavités, ce qui limiterait alors les espaces disponibles pour cette faune. Nous aurions, dans cette complexité de la structure physique de l'habitat une première explication à cette forte diversité fonctionnelle, puisque ce milieu héberge le plus grand nombre de groupes trophiques : herbivores, suspensivores, détritivores, carnivores et nécrophages...

Le deuxième aspect de la diversité est d'évaluer le nombre d'espèces à l'intérieur de chaque groupe trophique (diversité spécifique). Dans un tel habitat complexe, la présence de nombreux prédateurs et perturbateurs maintiendrait les espèces à des niveaux de densité inférieurs au seuil où apparaît l'exclusion compétitive. Ce concept de Gause (1934) a été largement évoqué en milieu intertidal rocheux tout d'abord (Paine 1966 par ex.), puis en milieu abyssal par Dayton et Hessler (1972). Dans un peuplement de maerl, les interactions biotiques basées sur la prédation, la perturbation, la compétition..., sont nombreuses, si bien qu'aucune espèce n'a la possibilité de monopoliser les deux ressources essentielles, l'habitat et la nourriture. Cet habitat complexe est utilisé de multiples façons (support, abri, refuges...), le maerl lui-même et les algues épiphytiques peuvent être consommés de façon très diverse, par les diverses espèces d'herbivores, de brouteurs, de mangeurs de détritus végétaux.

Dans cette phase préliminaire d'exploitation des résultats, nous tentons de répondre à ces deux aspects de la diversité en examinant les peuplements de maerl situés dans des conditions écologiques différentes et deux comparaisons sont ainsi présentées :

– la comparaison du peuplement d'un banc de maerl, habitat hétérogène par rapport aux peuplements de sédiment homogène les plus proches sur le plan édaphique et géographique, ceux des sables envasés et des vases sableuses en rade de Brest ;

– la comparaison des peuplements de bancs de maerl en situation normale par rapport aux mêmes peuplements sous l'influence d'un impact anthropique. En rade de Brest, l'impact se traduit par une eutrophisation générale avec augmentation de la couverture végétale. En baie de Concarneau, le banc de maerl des Glénan subit une exploitation directe, avec une destruction totale du biotope et une turbidité plus élevée pour les stations voisines.

MATÉRIEL ET MÉTHODES

1. Les sites

En rade de Brest, les bancs de maerl sont essentiellement composés de *Lithothamnion corallioides* (P. & H. Crouan) P. & H. Crouan, dont les thalles sont finement ramifiés. Aux Glénan, il s'agit surtout de *Phymatolithon calcareum* (Pallas) Adey & McKibbin à l'architecture plus grossière avec des thalles arbusculaires épais, parfois arrondis. Chaque espèce est représentée par des formes différentes et, dans cette phase préliminaire d'exploitation, nous n'avons pas tenté d'évaluer la complexité de l'habitat sous forme d'une expression numérique comme l'ont fait Gee et Warwick (1994).

En rade de Brest (Fig. 1), les sables envasés et les vases sableuses des stations SV et VS sont situés dans l'anse de Roscanvel entre 3 et 5 m de profondeur, à l'abri de toute atteinte anthropique notable (Grall & Glémarec 1997). Les bancs de maerl de référence sont ceux de Rozegat (BC) et de Loumergat (BC'), dans le bassin sud de la rade à une profondeur moyenne de 3 à 5 m. Le banc de Rozegat est utilisé comme contrôle (BC) par rapport au banc du bassin nord ou banc de Plougastel (BI) situé à la même profondeur, face à l'agglomération et à l'ensemble portuaire de Brest, responsables de perturbations (Grall et Glémarec 1997).

Dans l'ensemble des stations de la rade, les températures sur le fond oscillent au cours de l'année entre 9° et 18°. La station BC située dans l'axe du Chenal de l'Aulne peut subir une dessalure hivernale qui peut atteindre 30 PSU sur le fond, ce qui correspond toujours à des conditions euhalines. Dans le bassin nord (BI), ces conditions sont très peu différentes.

Le banc des Glénan a fait l'objet d'une intense exploitation dans les 40 dernières années. Le site d'exploitation est aujourd'hui très limité, c'est en quelque sorte un puits d'extraction, le banc ayant 10 m d'épaisseur à cet endroit (Augris & Berthou 1986). Tout autour de ce site, façonné de cratères, toute forme de vie macrofaunique a disparu. Nous avons donc choisi 2 stations (Fig. 1) à profondeur équivalente (10 m) : la première GI, la plus proche du site d'extraction où des peuplements macrofauniques existent ; la deuxième GC, plus éloignée, à proximité immédiate des massifs rocheux des Glénan, où l'exploitation n'a jamais été effective. Les conditions hydrodynamiques sont typiquement marines et infralittorales.

2. *Obtention des données*

Pour éviter toute variation liée à une possible cause temporelle, les comparaisons entre les peuplements de la rade de Brest sur sédiments envasés et fonds de maerl sont faites sur des données automnales (novembre). L'estimation des atteintes anthropiques est obtenue à partir de données printanières (mai 1996), ceci sur les 2 sites de Brest et des Glénan.

Les échantillons biologiques sont réalisés à la benne Smith-McIntyre (0,1 m^2). Six replicats sont effectués à chaque station, ce qui représente une surface échantilonnée de 0,6 m^2. Les contenus des bennes sont tamisés ur une maille de 1 mm et les reliquats sont préservés au formol à 4 %. Les identifications se font au labora-oire après coloration au rose bengale. Les espèces sont déterminées sauf pour les groupes de Nématodes et Némertes. Les animaux sont comptés, puis pesés après échage à 60° durant 24 heures. Les biomasses (B) sont xprimées en g de poids organique sec (POS) par m^2

L'estimation de la richesse spécifique S représente e cumul des espèces recueillies dans les six bennes éalisées par station. L'abondance A est exprimée par m^2.

Pour l'analyse granulométrique du sédiment, un pré-èvement supplémentaire est réalisé : 100 g de sédiment ont séchés à 80 °C pendant 24 h au maximum, puis vés à l'eau douce sur un tamis de 63 µm. Le refus st tamisé sur une colonne de 14 tamis (de 63 à) 000 µm). En tenant compte des 3 fractions : pélites, bles et graviers, il est possible de placer chaque élèvement sur le diagramme de Shepard (1954).

Traitement des données biologiques

Les analyses factorielles des correspondances (AFC ll 1974) sont réalisées sur les abondances des espèces ur aider à l'interprétation des comparaisons entre itions et visualiser les associations spatiales d'es-ces, ceci sur les données non transformées. Seules espèces dont le pourcentage de contribution est supérieur à 1 % sont prises en compte dans l'interprétation. C'est la distance moyenne du Chi^2 qui est utilisée comme coefficient de similitude (Le Bris 1988). Les groupes trophiques sont représentés par la projection de leur barycentre. L'examen de la diversité fonctionnelle suppose en effet la reconnaissance de types écologiques basés sur le comportement trophique des espèces, ce qui inclut la source de nourriture, mais aussi le mode de nutrition. Afin de mieux cerner l'approche de cette diversité fonctionnelle, au sein d'un herbier de *Zostera marina*, Hily et Bouteille (1996) croisent 3 critères : la source alimentaire, le type comportemental et le microhabitat où l'espèce exerce l'essentiel de son activité trophique. Sans aller aussi loin dans la caractérisation très précise de ces niches trophiques, nous adoptons la classification de ces auteurs en nous aidant des données trouvées dans la littérature, tout en l'amendant et en tenant compte de la spécificité de l'habitat étudié.

Les premiers groupes trophiques, consommant de grosses particules alimentaires, sont appelés macrophages, parmi lesquels il est possible de reconnaître :

— les prédateurs ou carnivores (C), chassant des proies mobiles ou sessiles,

— les nécrophages (N), mangeurs de chair morte,

— les herbivores (H), broutant des algues dont le maerl,

— les détritivores (Dt), animaux vagiles consommant les détritus essentiellement d'origine végétale et transfèrant ces détritus au sein de l'habitat.

Les groupes suivants sont dits microphages. Ce sont des animaux essentiellement sédentaires :

— les suspensivores (S) ou sestonophages sont liés aux apports de la couche d'eau sus-jacente,

— les brouteurs (µB), se nourrissent des microphytes, bactéries et détritus colonisant les surfaces solides (maerl et coquilles),

— les déposivores de surface (Ds) utilisent ce même triple ensemble de ressources, déposées à la surface sédimentaire,

— les déposivores de subsurface ou limivores (Li consomment ces mêmes ressources mais enfouies au sein de la carcasse sédimentaire.

L'indice de diversité (H') de Shannon (Shannon et Weaver, 1949) est calculé. Le modèle DIMO (Quinghong, 1995) visualise, en une seule expression graphique, la richesse spécifique $\log_2$ (S), l'indice de Shannon H', la régularité (de Pielou (1966) H'/log (s) et l'indice Q de Quinghong où Q = H'/sin (a). Il est défini comme la longueur du vecteur du point-station à l'origine. Ceci permet donc d'évaluer laquelle (ou lesquelles) de ces caractéristiques traduit mieux l'impact sur la structure.

RÉSULTATS

1. *Données granulométriques*

Si l'on se réfère à la classification des catégories granulométriques d'après la définition de

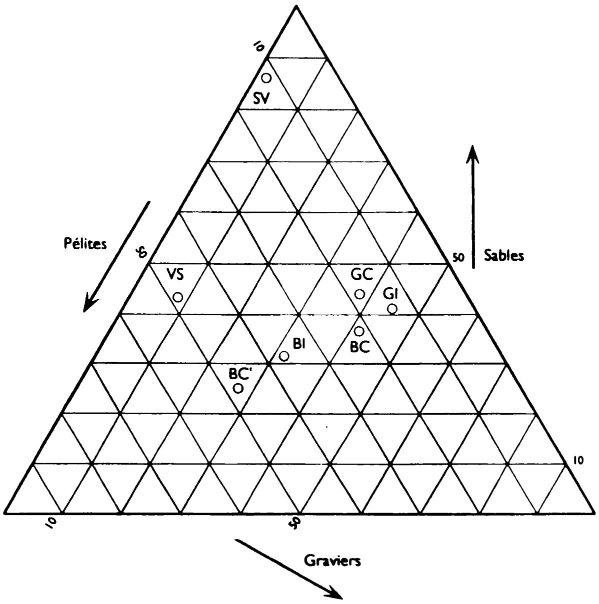


Fig. 2. – Utilisation du diagramme de Shepard pour caractériser les stations, selon les trois fractions granulométriques : graviers, sables et pélites. SV : sables fins envasés, VS : vases sableuses, BC : maerl de Rozegat, BC' : maerl de Loumergat.

Shepard diagram used to characterize the sampling stations, in function of three granulometric fractions : gravels, sands and fine particles. SV : muddy sands, VS : sandy muds, BC maerl bank of Rozegat, BC' : maerl bank of Loumergat.

Shepard (1954), le diagramme triangulaire (Fig. 2) permet de distinguer :

— les sables envasés SV (entre 10 et 30 % de pélites) et les vases sableuses VS (entre 30 et 80 % de pélites), avec un taux de graviers toujours inférieur à 10 % (5 % le plus souvent) ;

— les fonds de maerl de la rade de Brest. Ce sont des sédiments mixtes où les 3 fractions granulométriques peuvent apparaître de façon équivalente. Le site de Loumergat (BC') montre cependant une fraction fine plus importante (46 %).

— les fonds de maerl des Glénan. Ce sont des sables graveleux où les sables et les graviers sont en proportions équivalentes et où la fraction fine est inférieure à 20 %.

Dans ces deux cas de maerl, à fraction sableuse égale (32 % pour Brest, 44 % pour les Glénan), la différence entre la station de contrôle et la station impactée apparaît dans l'accroissement de la fraction fine par rapport à la fraction grossière : de 24 à 36 % en rade de Brest, de 13 à 18 % aux Glénan.

Ainsi est précisée grossièrement la part des facteurs édaphiques dans la variation attendue des peuplements benthiques installés sur les fonds homogènes (sables fins envasés et vases sableuses) et les fonds hétérogènes (maerl) d'une part, entre les stations de maerl en situation de contrôle (C) et situation impactée (I) d'autre part.

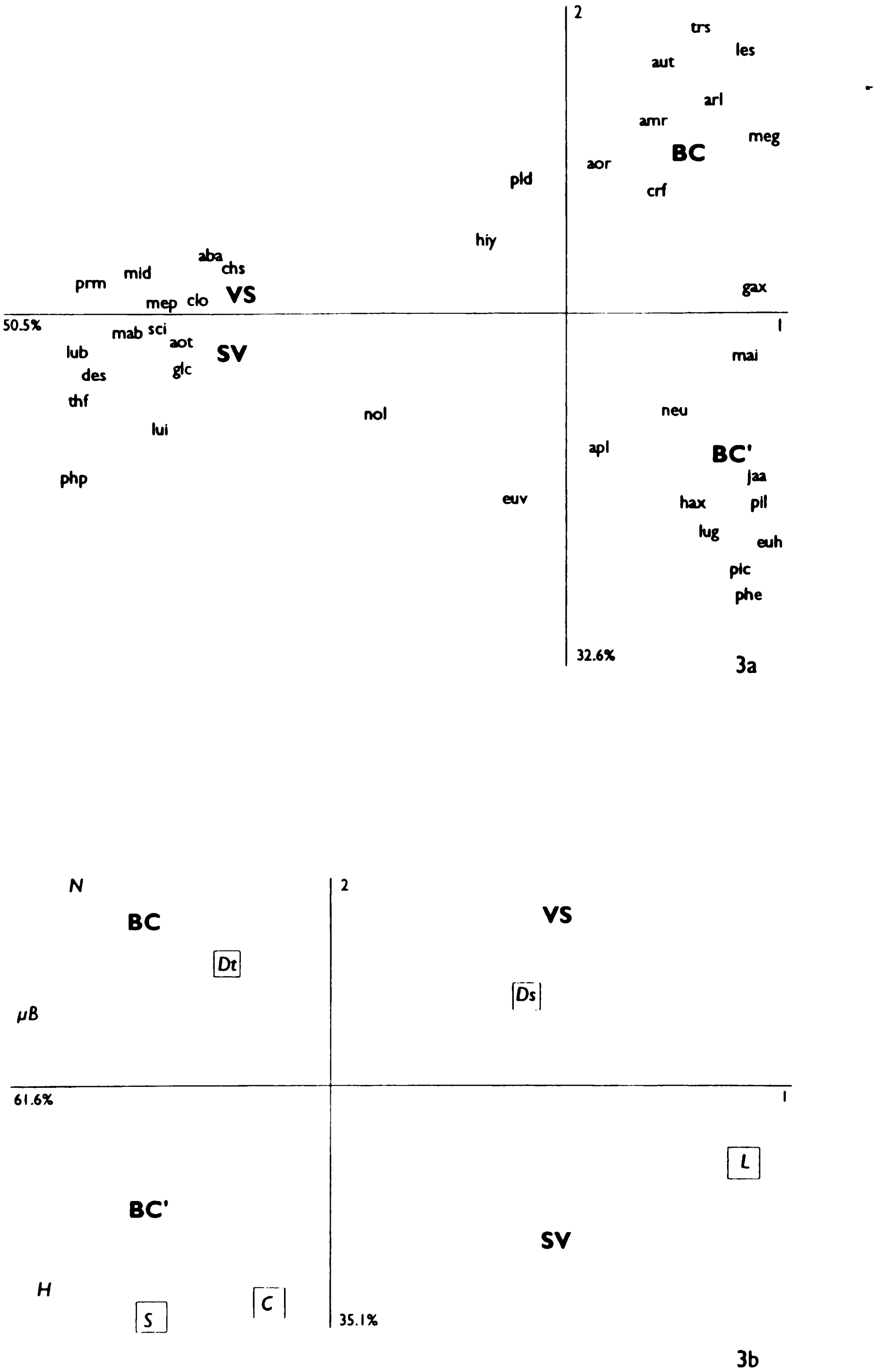
2. *Comparaison des peuplements des fonds homogènes et hétérogènes en rade de Brest*

L'AFC réalisée sur les 2 stations SV et VS et sur les 2 stations de maerl BC et BC' (Fig. 3a) révèle que les 2 premiers axes représentent respectivement 50,5 et 32,6 % de la variance totale. Les 2 stations de sédiment homogène, dont la contribution à l'axe 1 est de 70 %, sont situées dans la partie négative de cet axe. Elles sont caractérisées par des espèces vasicoles ou sabulicoles-vasicoles au sens de Glémarec (1969), comme les Polychètes *Chaetozone setosa, Clymene oerstedii, Marphysa belli, Melinna palmata, Notomastus latericeus, Prionospio malmgreni, Scalibregma inflatum*; les Bivalves *Abra alba, Lucinoma borealis, Thyasira flexuosa*; les Amphipodes *Aora typica, Dexamine spinosa, Microdeutopus damnionensis*... La partie positive du même axe isole les 2 stations de maerl (contribution de 28 % à cet axe) avec une faune qui peut être dite caractéristique de tels fonds hétérogènes : les Polychètes *Eunice harassii, Nematonereis unicornis, Pista cristata*; le Bivalve *Parvicardium exiguum*; les Crustacés *Melita gladiosa, Maera grossimana, Pisidia longicornis*. L'axe 1 sépare donc très nettement les peuplements des sédiments homogènes avec dominance de Polychètes sédentaires et de Bivalves Lucinidés déposivores de surface, de ceux des sédiments hétérogènes avec des Polychètes errantes carnivores, des Bivalves suspensivores et des Amphipodes détritivores. L'axe 2 permet de séparer les 2 stations de maerl. La station de Rozegat (BC) est caractérisée par tout un ensemble d'espèces d'Amphipodes détritivores tandis que la station de Loumergat (BC') voit la dominance de Polychètes Eunicidés carnivores et de suspensivores.

Aux mêmes stations, une AFC identique est réalisée sur les groupes trophiques représentés par leur barycentre (Fig. 3b), elle apporte les enseignements suivants :

L'axe 1 (61,6 % de la variance) isole dans sa partie positive, c'est-à-dire ici dans les stations de sédiments homogènes, les déposivores de subsurface ou limivores (L) et ceux de surface (Ds). Dans la partie négative au contraire, apparaissent les détritivores (Dt), les carnivores (C) et les suspensivores (S), caractéristiques des stations de maerl. Les microbrouteurs (µB) herbivores (H) et nécrophages (N) sont également situés dans cette partie négative de l'axe, mais leur contribution à l'axe n'est pas statistiquement significative.

Cette différence entre sédiments homogènes et hétérogènes est donc mise en évidence par les



g. 3. – a, Plan 1 et 2 de l'analyse de correspondance (AFC) réalisée sur l'ensemble des espèces échantillonnées ıns les 4 stations de la rade de Brest. SV : sables fins envasés, VS : vases sableuses, BC : maerl de Rozegat, BC' : aerl de Loumergat. Seules sont indiquées les abréviations des espèces (*cf.* Annexe) qui représentent plus de 1 % de variance. b, Plan 1 et 2 de l'AFC réalisée sur les groupes trophiques dans les 4 stations de la rade de Brest (*cf.* ;. 3a). C : carnivores, Ds : déposivores de surface, Dt : détritivores, L : limivores, N : nécrophages, S : suspensivores, 3 : microbrouteurs.

Axes 1 and 2 of the factorial correspondence analysis (AFC) performed on all the species sampled in the four ıtions of the bay of Brest. SV : muddy sands, VS : Sandy muds,BC : marl bank of Rozegat, BC' : maerl bank of umergat. Only representative species are represented. b, Axes 1 and 2 of the factorial correspondence analysis FC) performed on the trophic groups of the four stations of the bay of Brest (cf. fig. 3a). C : carnivorous, Ds : rface deposit feeders, Dt : detritic feeders, L : subsurface deposit feeders, N : scavengers, S : suspension feeders, : micrograzers.

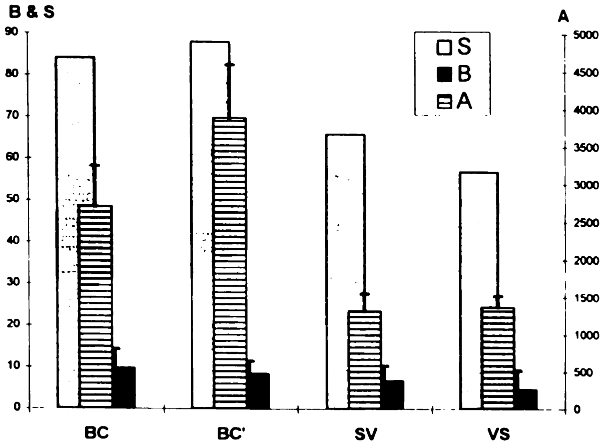


Fig. 4. – Variation des trois paramètres synthétiques dans les 4 stations de la rade de Brest (*cf.* fig. 3a). A : moyenne du nombre d'individus par m^2, B : biomasse exprimée en g.POS m^2, S : richesse spécifique en nombre d'espèces recensées dans 6 bennes de 0,1 m^2

Variation of the three synthetic descriptors in the four stations of the bay of Brest (cf. fig. 3a). A : abundance (mean per m^2), B : biomass mean in g.POS m^{-2}, S : specific richness established by six grabs per station.

axes 1 des 2 AFC. Cette validation statistique peut être confortée par l'examen des paramètres synthétiques, S, A, B, réalisé d'abord sur l'ensemble des peuplements, puis sur les différents groupes trophiques.

La richesse spécifique est 1,4 fois plus élevée dans les peuplements de maerl (la moyenne est de 86 espèces) que dans les peuplements de sédiments homogènes (la moyenne n'est que de 60 espèces), il en est de même pour les abondances et les biomasses qui représentent des rapports respectifs de 2,4 et 2 (Fig. 4).

La richesse spécifique au sein des groupes trophiques (Fig. 5) est supérieure dans les fonds de maerl, sauf pour les déposivores de surface. L'abondance des carnivores, détritivores et suspensivores est nettement plus forte dans les fonds de maerl comme l'avait déjà révélée l'AFC (Fig. 3b). Ceci est confirmé par la biomasse qui montre aussi que cette différence apparaît également dans le cas des déposivores de surface, tandis que les limivores sont inversement plus importants dans les sédiments homogènes. Quant aux microbrouteurs, ils sont naturellement absents de ce type de fond.

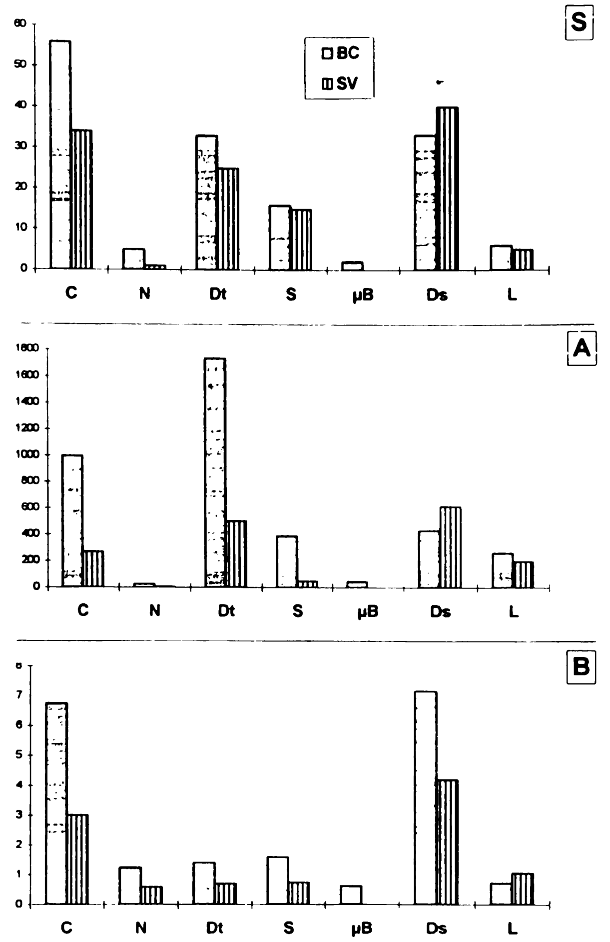


Fig. 5. – Variation des paramètres synthétiques S, A et B au sein des groupes trophiques (*cf.* Fig. 3b) dans le cas des sédiments homogènes (SV et VS) et des fonds de maerl (BC).

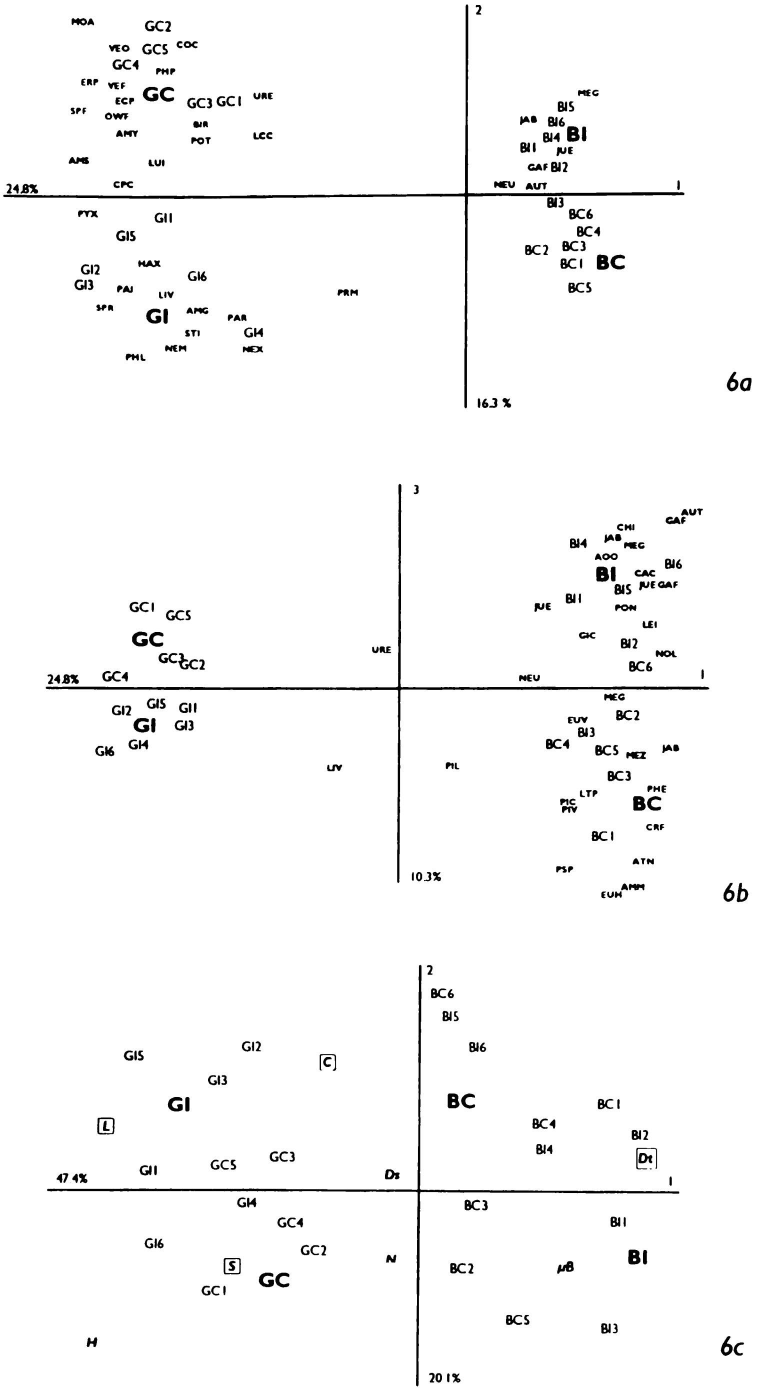
Variation of the synthetic descriptors S, A and B within the trophic groups for the homogeneous sediments (SV and VS) and for the maerl beds (BC and BC').

3. *Comparaison des peuplements des fonds de maerl dans les stations de contrôle et d'impact*

Les 3 premiers axes de l'AFC (Fig. 6a) représentent respectivement 24,8, 16,3 et 10,3 % de la variance. Les 2 stations des Glénan contribuent à 75 % à l'explication du 1^{er} axe et à 73 % celle du 2^{e} axe. Il faut faire appel à l'axe 3 (Fig. 6b) pour voir apparaître la contribution des stations de Brest (69 %).

L'axe 1 isole dans ses valeurs négatives les stations des Glénan avec un lot d »espèces composé des Polychètes : *Capitella capitata, Glycera capitata, Harmothoe sp., Lumbrineris impatiens, Owenia fusiformis, Prionospio malmgreni, Spio filicornis*; les Crustacés *Urothoe elegans, Ampelisca typica*; le Bivalve Venus fasciata; le Gastropode *Bittium reticulatum*; le Phoronidien *Phoronis psammophila*, l'Oursin *Echinocyamus pusillus*.

Dans les valeurs positives de cet axe, les stations de Brest sont caractérisées par un petit nombre d'espèces parmi lesquelles les Polychètes *Audouinia tentaculata* et *Nematonereis unicornis*;



6. – a, Plan 1 et 2 de l'AFC réalisée sur l'ensemble des espèces échantillonnées dans les 4 stations de maerl. : Brest contrôle, BI : Brest impactée, GC : Glénan contrôle, GI : Glénan impactée. b, Plan 1 et 3 de l'AFC (cf. 6a) permettant de séparer les 2 stations de maerl de la rade de Brest. c, Plan 1 et 2 de l'AFC réalisée sur les ipes trophiques dans les stations de maerl. C : carnivores, Ds : déposivores de surface, Dt : détritivores, L : vores, N : nécrophages, S : suspensivores, µB : microbrouteurs. Les groupes dont la contribution est significative : encadrés.

xes 1 and 2 of the factorial correspondence analysis (AFC) performed on all the species sampled in the four ions of maerl. BC : Brest control, BI Brest impacted, GC : Glenan control, GI : Glenan impacted. b, Axes 1 3 of the AFC (cf fig. 6a) allowing separation of the bay of Brest maerl grounds. c, Axes 1 and 2 of the factorial espondence analysis (AFC) performed on the trophic groups of the four stations of maerl (cf. fig. 6a). C : ivorous, Ds surface deposit feeders, Dt : detritic feeders, L : subsurface deposit feeders, N scavengers, S : ension feeders, µB : micrograzers. Representative trophic groups are framed.

5b

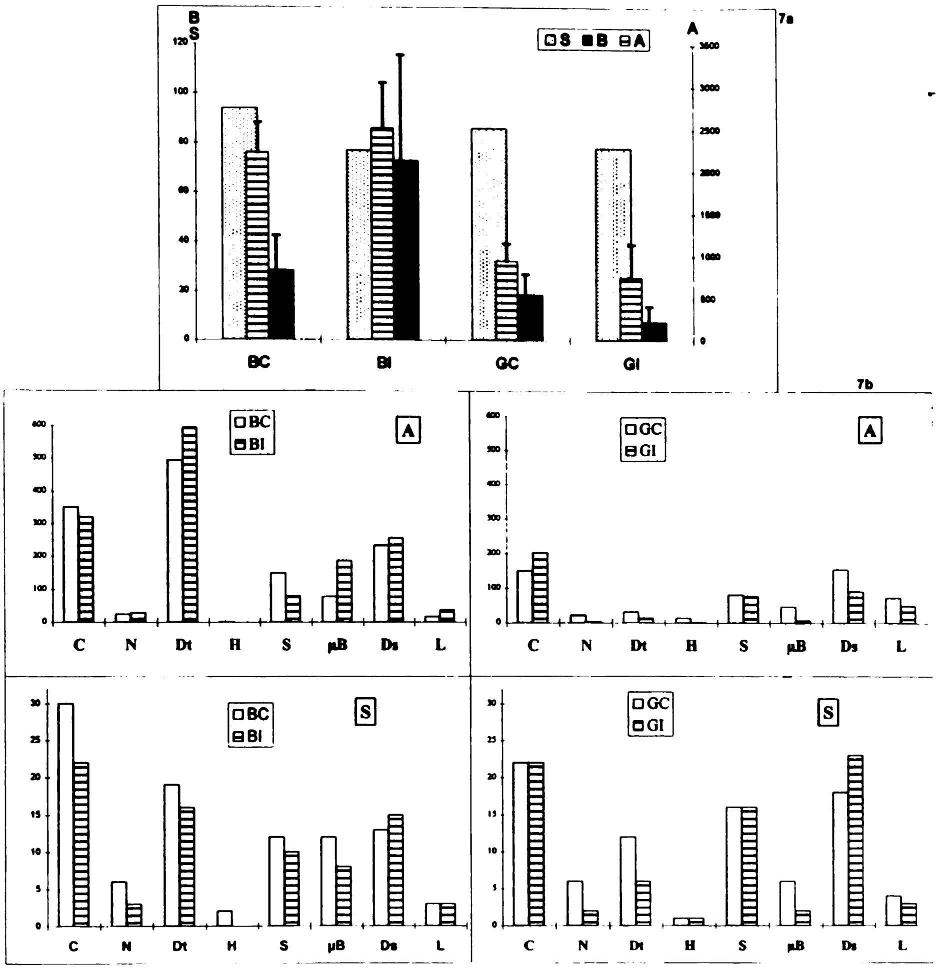


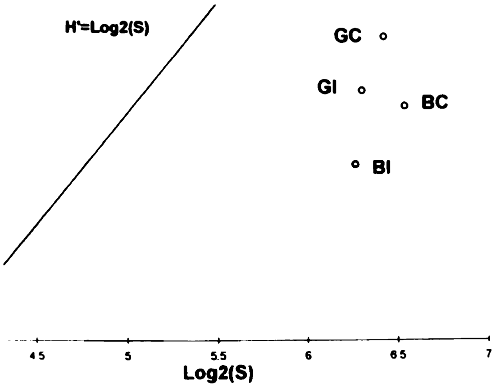
Fig. 7. – a, variation des paramètres synthétiques dans les 4 stations de maerl. A : abondance en nombre d'individus par 0,6 m^2, B : biomasse exprimée en g.POS m^2, S : richesse spécifique en nombre d'espèces recensées dans 6 bennes de 0,1 m^2 b, Variation des paramètres synthétiques S et A au sein des groupes trophiques (*cf.* fig. 3b) dans les 2 stations de maerl de la rade de Brest BC et BI. c, Variation des paramètres synthétiques S et A au sein des groupes trophiques (*cf.* fig. 3b) dans le cas des stations de maerl des Glénan GC et GI.

a, Variation of the three synthetic descriptors in the three stations of maerl (cf. fig. 3a). A : abundance (number of individuals per 0,6 m^2*), B : biomass in g.POS* m^{-2}*, S : specific richness established by six grabs per station. b, Variation of the three synthetic descriptors S, A and B within the trophic groups for the bay of Brest maerl stations (BC and BI). c, Variation of the synthetic descriptors S, A and B within the trophic groups for the Glenan archipelago maerl stations (GC and GI).*

les Crustacés *Gammarella fucicola, M. gladiosa, Janiropsis brevicornis* et le Gastéropode *Jujubinus exasperatus*. Cet axe 1 montre donc les différences entre les deux sites de maerl. Avec les 2 axes suivants, il est possible de séparer au sein de chaque site les stations de contrôle et celles impactées. Aux Glénan (Fig. 6a) la station de contrôle (valeurs positives de l'axe 2) est caractérisée par les Bivalves : *Modiolus adriaticus, Venus ovata, V. fasciata*; les Crustacés *Conilera cylindracea, U. elegans, Eurydice pulchra*; les Mollusques *Bittium reticulatum, Lepidochiton cancellatus*; les Polychètes *S. filicornis, Glycera capitata*, l'Oursin *Echinocyamus pusillus*.

Dans les valeurs négatives de l'axe 2, la station impactée (contribution de 50%) s'identifie grâce aux espèces suivantes : les Polychètes *Ampharete grubei, Paradoneis armata, Prionospio malmgreni, Sthenelais minor*; les Crustacés *Photis longicauda, Sphaeroma rugicaudata, Liocarcinus pusillus*; le Mollusque *Parvicardium minimum*.

L'axe 3 permet donc d'isoler la station de référence de Brest (BC), avec une contribution de 36%, dans les valeurs négatives de l'axe (Fig. 6b) par rapport à la station impactée (BI) dans les valeurs positives (contribution de 33%). Celle-ci est identifiée par les Polychètes, *Audouinia tentaculata, Aonides oxycephala, Capitella capitata,*



Représentation simultanée, pour les 4 stations , de la richesse spécifique log$_2$ (S), de l'indice non H' et de la régularité a. L'indice Q est mme la longueur du vecteur du point-station ine. Cet indice est inférieur dans le cas des impactées.

eous representation of the specific richness , of the Shannon index H' and of the evenness dex is defined as the vector length from the o the point of the station. Note that this index r on the impacted grounds.

astus latericeus, Polymnia nebulosa; par nphipodes, *Cheirocratus intermedius, Gam- a fucicola, Leucothoe incisa, Melita gla-* les Gastéropodes *Gibbula cineraria, nus exasperatus.*

station de référence (BC) isole très nettement olychètes, *Eunice vittata, Eunice harassii, cristata*; les Crustacés *Pisidia longicornis, as nitescens, Pseudoprotella phasma, Jani- breviremis;* le Mollusque *Crepidula forni-* le Sipunculien *Phascolosoma elongatum.*

AFC sur les groupes trophiques (Fig. 6c), ré- que l'axe 1 représente 47,4 % de la variance. pose le site de Brest caractérisé par les dé- ores au site des Glénan caractérisé par les ores et suspensivores. L'axe 2 (20,1 % de la nce) est défini par les microbrouteurs et les ivores dans les valeurs négatives de l'axe ion GC), opposés aux carnivores dans les urs positives de cet axe (station GI).

'examen des paramètres synthétiques (Fig. 7a) le que la richesse spécifique n'est pas diffé- e entre les quatre stations de maerl avec une ur moyenne de 83 espèces, récoltées dans 6 nes de 0,1 m^2 Sur chaque site les stations actées montrent une baisse de cette richesse cifique de l'ordre de 10 % aux Glénan, contre % en rade de Brest. Sur ce site, l'impact se luit par une augmentation des 2 autres para- tres : l'abondance (11 %) et la biomasse (60 %). x Glénan, l'impact se traduit de façon inverse une baisse de 20 % pour l'abondance et de % pour la biomasse. Il est à noter que sur ce site, les abondances sont réduites des 2/3 par rapport à celles de la rade de Brest.

Les différences existant entre stations de contrôle et impactées sont aussi mises en évidence par l'analyse des groupes trophiques réalisée au travers des 2 descripteurs S et $A^{(1)}$. Sur le site impacté de Brest (Fig. 7b), la richesse spécifique est moindre dans l'ensemble des groupes trophiques, à l'exception de celui des déposivores de surface. La tendance est inversée pour l'abondance avec l'accroissement des 2 groupes détritivores et microbrouteurs, comme l'avait déjà montré l'AFC (Fig. 6c).

Sur le site des Glénan, les différences avec la station de contrôle semblent moindres. Comme en rade de Brest, la baisse de la richesse spécifique affecte tous les groupes, sauf les déposivores de surface. Les carnivores ne varient pas en richesse spécifique, cependant leur abondance croît. La tendance est inverse pour les herbivores et les microbrouteurs (Fig. 6c).

Le modèle DIMO (Fig. 8) illustre aussi de façon très claire, lorsque l'on passe des stations de contrôle aux stations impactées, la baisse conjointe de la diversité spécifique log^2(S), de l'indice Q, de la diversité H' et de la régularité (angle α). Les peuplements des Glénan restent cependant les mieux structurés avec une régularité supérieure à ceux de la rade de Brest et plus proche de la régularité maximale, c'est-à-dire H' = log^2(S).

DISCUSSION

Les fonds de maerl sont caractérisés par une forte diversité spécifique comme en témoigne la liste des 200 espèces recensées sur les 2 sites. Les groupes taxonomiques les mieux représentés sont les Polychètes (76 espèces) et les Crustacés (67 espèces) parmi lesquels 41 sont des Amphipodes. Les Bivalves (26 espèces) et les Gastéropodes (23 espèces) participent également à cette diversité spécifique.

Cette diversité est d'abord fonctionnelle puisque 8 groupes trophiques peuvent coexister et il nous appartient de discuter ici les enseignements des 2 types de comparaisons effectuées. La première – celle entre fonds homogènes et fonds hétérogènes – montre que 2 groupes trophiques sont absents des fonds homogènes, les microbrouteurs et les herbivores. Dans les fonds de maerl, les groupes trophiques représentés par plus de 5 espèces sont au nombre de 6, contre 4 dans les fonds homogènes.

La diversité spécifique totale est également plus élevée dans les fonds de maerl, mais c'est là aussi que les prédateurs sont les plus abondants.

ainsi que les nécrophages, les détritivores, les suspensivores et les microbrouteurs. Il y a donc une relation entre diversité spécifique et diversité fonctionnelle qui apparaît aussi grâce au deuxième type de comparaison. A la station de contrôle aux Glénan, 6 groupes trophiques présentent plus de 5 espèces contre 4 à la station impactée et les carnivores y sont plus abondants à cette station. En rade de Brest, la diversité fonctionnelle est peu différente entre les 2 stations, au vu du nombre d'espèces, par contre l'abondance des détritivores et des microbrouteurs témoignent bien d'un accroissement des sources de nourriture végétale (production épiphytique et de diatomées). Ce sont là les premiers signes de l'eutrophisation. En effet, la méthode des indices biotiques utilisée en rade de Brest (Grall et Glémarec 1997) montre un état de déséquilibre du bassin nord de la rade lié au complexe portuaire et urbain de l'agglomération brestoise et aux apports du bassin versant de l'Elorn. Dans la station de contrôle, l'augmentation de la richesse spécifique au sein des carnivores est suivie de celle des autres groupes (nécrophages, détritivores, suspensivores et microbrouteurs). Cette caractéristique des fonds de maerl, qui abritent et protègent les prédateurs d'un super-prédateur épibenthique potentiel (Poissons par exemple), illustre donc le principe de Gause (1934). Les carnivores contrôlent les autres groupes en les maintenant en dessous de leur seuil d'exclusion compétitive. De nombreuses espèces, notamment de détritivores et de microbrouteurs, peuvent ainsi coexister sans proliférer, utilisant les ressources de façon complémentaire. La complexité de l'habitat contribue donc à la diversité fonctionnelle du système, mais celle-ci est très liée à la diversité spécifique. Un cas comparable de complexité architecturale a été décrit dans un herbier de Zostères où la réduction expérimentale de la pression d'un Poisson épibenthique montre le véritable effet structurant de cette complexité (Mattila 1995). Cet effet structurant serait d'éviter l'exclusion compétitive. Selon Mc Coy et Bell (1991), la structure de l'habitat est un facteur écologique dont l'importance a été minimisée jusqu'ici par rapport à d'autres facteurs d'ordre biotique comme la compétition et la prédation. Les résultats présentés ici montrent que tous ces facteurs sont très liés entre eux.

Au-delà des critères de diversité, les AFC révèlent aussi que des changements plus subtils sont intervenus au sein des peuplements; ils sont à mettre en relation avec les changements des facteurs environnementaux (matière organique, taux de pélites, turbidité...). Sans développer ici cet aspect, il est intéressant de noter des changements d'espèces au sein des groupes trophiques. Aux Glénan, par exemple, *Venus fasciata* et *Modiolus adriaticus* de la station de contrôle sont remplacés par *Corbula gibba* et *Parvicardium minimum*, espèces connues dans les milieux à forte turbidité, ceci à l'intérieur du groupe des suspensivores. Par ailleurs, si l'on fait appel à la notion de groupes écologiques liés à l'excés de matière organique (Glémarec et Hily 1981), on s'aperçoit que, parmi les déposivores de surface et limivores, aux Glénan des espèces tolérantes deviennent prépondérantes sur les espèces sensibles lorsque l'on passe de la station GC à la station GI. Parallèlement en rade de Brest des espèces opportunistes remplacent les espèces tolérantes, ce qui témoigne bien d'un accroissement de la matière organique et de l'eutrophisation évoquée ci-dessus. Les travaux engagés sur ces 2 sites en situation « normale » ou d'impact anthropique se poursuivant sur deux années, avec une fréquence trimestrielle, il est clair que seule une étude incluant les variations saisonnières de la production végétale (épiphytes et diatomées) permettra de mieux cerner le rôle de la complexité de l'habitat dans le maintien d'interactions biotiques nombreuses, qui devraient expliquer la diversité spéficique et fonctionnelle de ces fonds de maerl.

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CONSERVATION ISSUES RELATING TO MAERL BEDS AS HABITATS FOR MOLLUSCS

J. HALL-SPENCER[1]

Abstract *Maerl beds are little studied shallow marine habitats that have a patchy distribution around the British Isles. They are mixed sediment deposits built by a surface layer of slow growing coralline seaweeds that are of international conservation significance. Baseline information is provided on the high diversity and abundance of mollusc assemblages associated with Scottish maerl deposits. Commercial extraction and the use of towed demersal fishing gears kills the plants upon which survival of this habitat depends. The molluscan fauna of a site impacted by scallop dredging is compared with that of an unimpacted site. The need to conserve maerl habitats is highlighted as there is concern over the extent to which maerl beds are being disturbed in Europe and how activities such as scallop dredging affect the ecology of these fragile nearshore habitats.*

Key words *Maerl Beds, Mollusca, Commercial exploitation, Scallop Dredges, Conservation*

INTRODUCTION

The Breton term 'maërl' (Lemoine 1910) is used to describe unattached nongeniculate Corallinaceae (Rhodophyta) that have an algal core. These chalky plants accumulate to form sea-bed deposits that have a patchy geographical distribution, but occur worldwide (see review by Bosence 1983; Littler *et al.* 1991; Steller & Foster 1995). Maerl beds in the northeast Atlantic are concentrated on the westernmost coasts of Europe, being rare in the English Channel, Irish Sea, North Sea and Baltic. Maerl occurs in discrete areas from the Canaries and Madeira (McMaster & Conover 1966; Cabioch 1974), NW Spain (Adey & McKibbin 1970), Brittany (Cabioch 1970; Gautier 1971), western coasts of the British Isles (references in Irvine & Chamberlain 1994; plus Hiscock 1984; Little & Hiscock 1987; Scoffin 1988; Nunn 1993; Howson *et al.* 1994), Denmark (King & Schramm 1982), along the Norwegian shelf (Freiwald 1995) to the Arctic (Kjellmann 1883; Adey & Adey 1973). Major constraints on the distribution of living maerl species are their poor tolerance to desiccation, which restricts them to the low intertidal zone, and their requirement for light which restricts them to depths shallower than 32m in the relatively turbid waters of northern Europe. Growth of maerl-forming species is impaired at salinities <24%, and consequently they are absent from brackish areas (Adey & McKibbin 1970; King & Schramm 1982). The plants also require a degree of shelter from wave action, to prevent burial and dispersal into deep water, and they need enough water movement to prevent smothering with silt. These requirements usually restrict maerl to places such as the sills of fjords in Norway and Scotland, the lee shores of headlands and islands, or drowned river valleys such as the Fal estuary in Cornwall and the rias of NW Spain.

Where the above conditions are met, maerl-forming plants produce an heterogeneous, hard substratum in various depositional environments including muddy, sandy and gravel substrata, or mixtures of these. The few faunal studies that have been made have shown that maerl beds form isolated habitats of high benthic biodiversity and biomass (Cabioch 1968; Keegan 1974; Hardiman *et al.* 1976; Bosence 1979; Mora Bermúdez 1980; Nunn 1993) and that some support rare, unusual or endemic species of macroalgae,

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polychaetes and amphipods (Southward 1957; Cabioch 1969; Blunden *et al.* 1977, 1981; Myers & McGrath 1980, 1983; Maggs & Guiry 1982, 1987, 1989; Maggs 1983; O'Connor & Shin 1983).

The present impetus to study maerl beds has arisen since their listing in European Community Council Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Fauna and Flora (1992) with the inclusion of two of the main European maerl forming species (*Phymatolithon calcareum* (Pallas) and *Lithothamnion corallioides* (P. & H. Crouan) under Annex V and of maerl as a habitat under Annex 1. A main reason for concern over the vulnerability of maerl to damage from any source is its very slow rate of growth (Adey & McKibbin 1970; Potin *et al.* 1990; Hall-Spencer 1994). Several activities threaten these habitats, including commercial extraction for use as a conditioner on acid soils (Blunden *et al.* 1977), the use of demersal fishing gear (Hall-Spencer 1995), sewage discharge and fertilizer inputs (Hily *et al.* 1992) together with activities such as boat mooring and mariculture. Within Europe, commercial supplies of maerl are obtained from around the coasts of Brittany, where 300,000 to 500,000t yr^{-1} are dredged (Blunden 1991), and off Falmouth Harbour in Cornwall where extraction is around 20,000t yr^{-1} (Martin 1994). The first licence for the extraction of maerl in Scotland was granted in 1996 to dredge 20,000 m^3 over five years from Wyre Sound in Orkney. Applications are pending for commercial extraction from other sites in west Scotland (Donnan 1996; pers. comm.) but basic background information is lacking for these habitats, no quantitative faunal surveys having been published for Scottish maerl beds to date. An area of increasing concern is the long-term effects that demersal fishing gear may have on sensitive habitat types around the British Isles (e.g. Brown 1989; Fowler 1989; Devon Wildlife Trust 1993; Hall 1994). The degree to which maerl beds are disturbed by towed demersal fishing gear is unknown, but it may occur on a wide scale since maerl often supports populations of the commercially important molluscs *Pecten maximus* (L., 1758) and *Aequipecten opercularis* (L., 1758) (Thouzeau 1991; references in Howson *et al.* 1994; present study).

This paper relates the results of a quantitative study into the diversity and abundance of molluscs on maerl beds (*inter alia*) in southwest Scotland and highlights the impacts of scallop dredging recorded by Hall-Spencer (1995).

METHODS

The collection of molluscan specimens and experimental scallop dredging took place on two maerl grounds in the Firth of Clyde (Fig. 1). The sites were Creag Gobhainn (Site 1) in Loch Fyne (56°00.601'N 005°22.148'W determined by Magellan `Global Positioning System') where maerl occurs parallel to the shore along a gently sloping strip over an area of 17.5ha between -6m and -14m CD, and Stravanan Bay (Site 2) (55°45.323'N 005°04.265'W) where maerl covers an area of 6.75 ha from -6m to -14.7m CD on a shoal situated *c.* 500m off the coast of the Isle of Bute. Site 1 was unimpacted by commercial scallop dredging (pers. obs.), possibly due to the prohibitive presence of a charted telecommunications cable, whilst Site 2 was used by scallop fishermen during 1994–96 (pers. obs.) and has been impacted by scallop dredges historically (G.A. Fisher unpubl.).

ASSESSMENT OF MOLLUSC DIVERSITY & ABUNDANCE

At both sites, stations were marked with a permanent buoy placed between -9 and -10m CD as a datum for divers equipped with SCUBA. Throughout 1996 the author made qualitative molluscan records and hand-collected voucher specimens in plastic bags. Three hand-held circular cores (20 cm long, 10.3 cm diameter) were taken of the sedi-

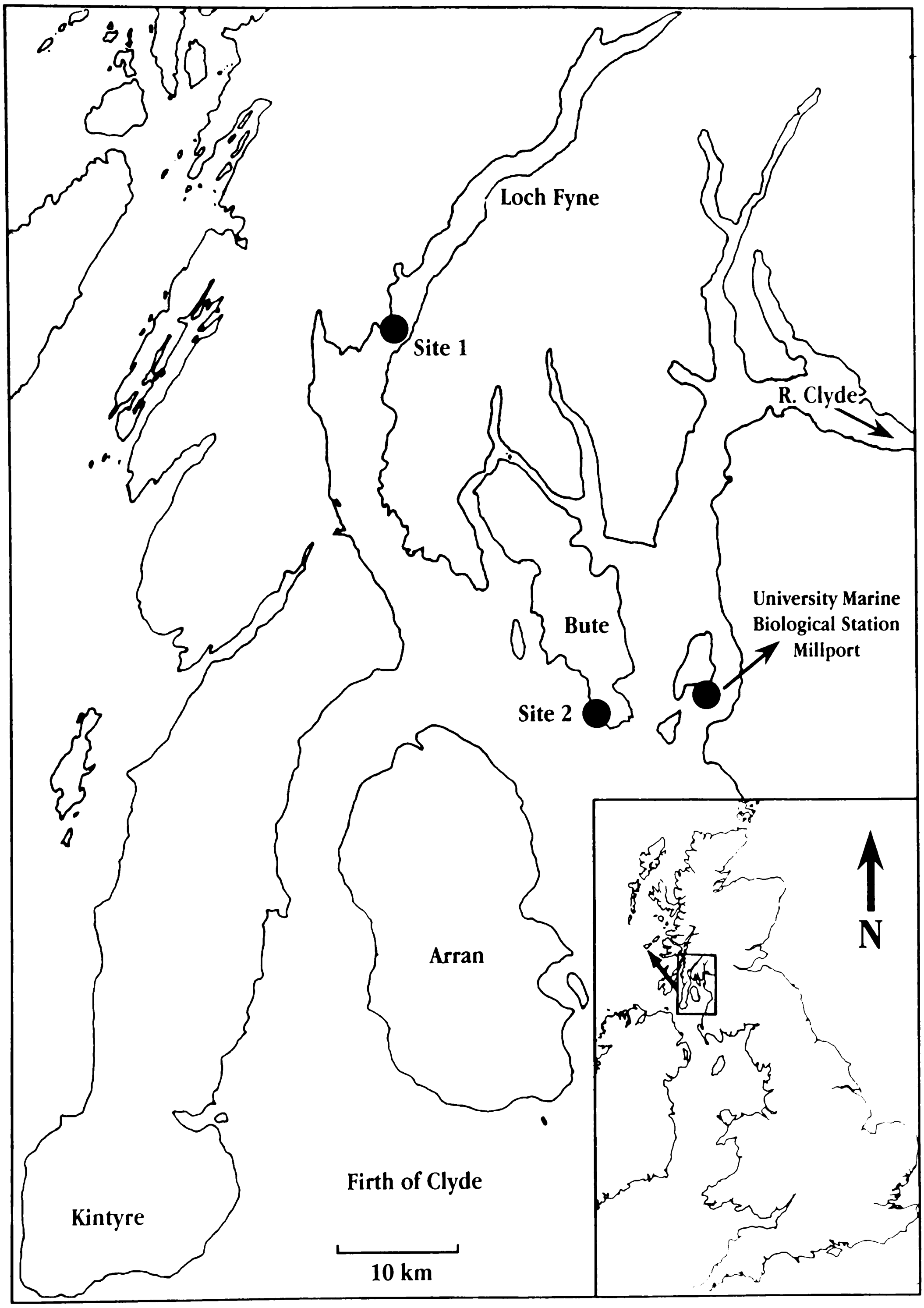

Figure 1 Positions of marine station and maerl study sites in south-west Scotland.

ment in July 1996 at Site 1 and in August 1996 at Site 2. The samples were sieved through a 0.5 mm mesh and live molluscs picked out, identified and counted. Abundances of surface-dwelling molluscs were recorded *in situ* within 1 m^2 quadrats placed on transects within 20m radii of the permanent buoys in June, July, October and December 1996 at Site 1 and in March, June, July, August, September and November 1996 at Site 2. The number of quadrats taken on each occasion ranged from 11–94 depending upon the underwater time available. Deep-burrowing molluscs were obtained during dives in July 1996 at Site 1 and in July and August 1996 at Site 2, stratified samples of the sediment were obtained from six 1 m^2 areas excavated to 0.7 m depth using a diver operated air-lift, following methods described by Keegan & Könnecker (1973).

Molluscs were also collected in maerl that was sampled remotely within a 150 m radius of the permanent marker buoys. Single 0.5 m wide ring dredge samples were taken in June, July, October and December 1996 at Site 1 and in March, July, August, September, November and December 1996 at Site 2. Data from 8-15 replicate 0.1 m^2 Van Veen grab samples taken in February and July 1996 at Site 1 and in February, March and July 1996 at Site 2 are also reported here. Grab samples were sieved through a 1 mm mesh then preserved in 8% buffered seawater formalin. Prior to sorting, the formalized samples were drained and preserved using 70% alcohol. Sediment was then poured into white trays and picked through using fine forceps to remove molluscs that were visible to the naked eye. Shells were checked for contents, identified and counted. Various sources were used for information on the identification and ecology of these molluscs, key works being those of Tebble (1966), Jones & Baxter (1987), Graham (1988), Thompson (1988), Picton & Morrow (1994) and Fretter & Graham (1994).

SCALLOP DREDGING ON MAERL GROUNDS

Experimental scallop fishing took place at both sites in 1994 using a single set of three dredges (manufactured by John Reid & Son of Tarbert and Islay) of a design that is now standard in Scotland (Melhuish 1994). The gear was filmed using a television camera mounted on a bracket that could be swivelled to view the dredges from various angles (Hall-Spencer 1995). The dredges each weighed around 85 kg, with 10 cm long, 0.8 cm wide teeth mounted 8 cm apart (9 per dredge) on spring loaded pawls. A bag of linked 7 cm diameter steel rings extended behind each tooth bar to retain the catch. Dredging of experimental plots involved tows of about 100m (giving dredged areas of *c.* 231 m^2) passing between two marker buoys, set 10 m apart (a little more than the beam of RV *Aora*). Divers subsequently recorded physical disturbances to the sea bed, damage to uncaught benthos and the aggregation of scavenging animals along the tracks of the gear following methods outlined in Hall-Spencer (1995). Notes were made routinely of the contents of catches at both sites. In May 1994, eight replicate cores (20 cm long, 10.3 cm diam.) were taken by divers on an area marked for dredging, and a further eight were taken in the adjacent area outside the buoys. The next day the site was dredged and core samples (8 replicates each) were taken on the dredge track and the adjacent area, coring was repeated 4 months later. On each occasion, the numbers of live maerl thalli were counted in the top 3 cm of the cores.

RESULTS - MOLLUSCAN MAERL FAUNA

Table 1 gives the total list of 130 molluscan species observed within the two small (150 m radius) areas of maerl in the Firth of Clyde during 1996. The molluscan diversity of both sites was high but fewer species were recorded at Site 2 (5 chiton, 36 gastropod, 9 opisthobranch, 30 bivalve, one scaphopod and one cephalopod species) despite the fact that it was sampled more intensively than Site 1 where 6 species of chiton, 50 gastropod spp., 22 opisthobranch spp., 38 bivalve spp. and one species of cephalopod were recorded.

Table 1 shows that there were several differences between the molluscan faunas of the two sites. Scallops were significantly more abundant at Site 1 where mature *Pecten maximus* (8+/-1 to 11+/-1 yrs) were common. Scallops of this age were absent from Site 2. Another major difference was that nests of live *Limaria hians* (Gmelin) were numerous at Site 1, with a covering of macroalgae (e.g. *Phycodrys rubens* (L.) Batters), sponges (e.g. *Esperiopsis fucorum* (Esper)), hydroids (e.g. *Tubularia indivisa* L., *Nemertesia antennina* (L.)), and tunicates (e.g. *Diplosoma listerianum* (Milne-Edwards), *Ascidiella aspersa* (O.F. Muller)) which provided food for epifaunal molluscs. Dead shells of *L. hians* were abundant at Site 2 but no live animals were found. Molluscs listed as 'vagile epifauna' in Table 1 were more species rich at Site 1 (87 spp.) than at Site 2 (53 spp.). Many of the vagile gastropods could equally be considered to be shallow infauna as they were found crawling under the loosely packed branches of the upper maerl layer. For example, *Buccinum undatum* L. and *Neptunea antiqua* (L.) burrowed through the maerl in search of infaunal prey with only their siphons showing at the sediment surface. Crabs (*Cancer pagurus* L.) and starfish (*Asterias rubens* L., *Marthasterias glacialis* (L.)) were also seen dug into the maerl surface, feeding on large individuals of the bivalves *Dosinea exoleta* (L.), *Paphia rhomboides* (Pennant) and *Laevicardium crassum* (Gmelin).

Quantitative sampling revealed that molluscs were abundant on Clyde maerl grounds. Abundance data for the commonest species are given in Table 1. Species indicated as present (+) were only recorded qualitatively (sampled using ring dredges and by diving). The abundances given in Table 1 were estimated using techniques best-suited to the size and dispersion pattern of the molluscs concerned, thus these estimates relate to different sampling areas. Small molluscs (e.g. *Caecum* spp. which pass through 1 mm sieves when fully grown) were enumerated from 0.08 m^2 cores. Information obtained from 1 mm sieved 0.1 m^2 grabs is given to estimate the abundances of molluscs that were common on or near to the sediment surface, e.g. *Leptochiton asellus* (Gmelin), *Tectura virginea* (Muller) and *Clausinella fasciata* (da Costa). The abundances of sparsely distributed, large epifaunal molluscs such as *Pecten maximus* were best estimated using 1 m^2 surface quadrats, while estimates of the deep-dwelling molluscs, such as *Mya truncata* L., are based on samples obtained by airlift sampling. The siphons of most infaunal bivalves could not be seen by divers as these species drew water from within the open lattice zone of branched maerl thalli. Excavations using an airlift showed that some infaunal molluscs lived a considerable distance below the maerl bed surface. The maximum depths recorded were 26 cm for *Clausinella fasciata* and *Laevicardium crassum*, 28 cm for *Thracia villosiuscula* (Macgillivray), 42 cm for *Dosinea exoleta*, 48 cm for *Ensis arcuatus* (Jeffreys), 50 cm for *Lutraria angustior* Philippi, 56 cm for *Mya truncata* and 62 cm for *Mysella bidentata* (Montagu) (this species was associated with the burrow linings of the burrowing thallasinidean decapod *Upogebia deltaura* (Leach)). Biomass studies await completion, but at this stage it can be said that the molluscan biomass per unit area was far higher at Site 1 that at Site 2, and that at both sites most of this biomass was made up of infaunal bivalves.

TABLE 1

Live molluscs (listed according to lifestyle) identified from dredge, grab and *in situ* collections by divers on two maerl beds in the Firth of Clyde during 1996. '+' indicates species which were seen but did not occur in quantitative samples, numbers are means (± SE) counted in 1m^2 surface quadrats taken throughout 1996 (Q), in 1m^3 air-lift samples taken in July and August 1996 (A), in 0.1 m^2 Van Veen grabs which penetrated the maerl to about 0.1m taken from February-July 1996 (G), and in 0.08 m^2, 20cm long cores taken in July and August 1996 (C). Taxonomic authorities given in Smith & Heppell (1991).

TAXA	LIFE MODE	SITE 1	SITE 2
VAGILE EPIFAUNA			
POLYPLACOPHORA			
Leptochiton asellus	Omnivorous grazer	0.444±0.246 (G, n=18)	0.970±0.277 (G, n=33)
Leptochiton cancellatus	Omnivorous grazer	+	+
Ischnochiton albus	Omnivorous grazer	+	
Lepidochitona cinereus	Omnivorous grazer	+	+
Tonicella marmorea	Omnivorous grazer	0.167±0.090 (G, n=18)	+
Tonicella rubra	Omnivorous grazer	+	+
GASTROPODA			
Emarginula fissura	Carnivore (sponges)	+	+
Tectura testudinalis	Herbivore	+	+
Tectura virginea	Herbivore	0.222±0.129 (G, n=18)	0.152±0.078 (G, n=33)
Helcion pellucidum	Herbivore		+
Iothia fulva	Detritivore	+	+
Margarites helicinus	Herbivore/Detritivore	+	
Jujubinus miliaris	Herbivore/Detritivore	0.4588±0.0894 (Q, n=85)	
Gibbula magus	Herbivore/Detritivore	0.1294±0.0436 (Q, n=85)	0.4152±0.0466 (Q, n=224)
Gibbula tumida	Omnivorous grazer	0.0471±0.0230 (Q,, n=85)	0.0670±0.0200 (Q, n=224)
Gibbula cineraria	Herbivore/Detritivore	+	0.0177±0.0089 (Q, n=224)
Gibbula umbilicalis	Herbivore/Detritivore	+	0.061±0.042 (G, n=33)
Calliostoma zizyphinum	Omnivorous grazer		+
Skenea serpuloides	Detritivore	3.67±1.33 (C, n=3)	2.67±1.76 (C, n=3)
Tricolia pullus	Herbivore	+	+
Lacuna crassior	Carnivore (sponges)	+	
Lacuna vincta	Herbivore	+	0.152±0.124 (G, n=33)
Rissoa lilacina	Herbivore/Detritivore		+
Rissoa rufilabrum	Herbivore/Detritivore	+	
Rissoa interrupta	Herbivore/Detritivore	+	+
Rissoa parva	Herbivore/Detritivore	0.333±0.333 (C, n=3)	
Pusillina inconspicua	Herbivore/Detritivore	+	
Alvania beanii	Detritivore	0.333±0.333 (C, n=3)	0.333±0.333 (C, n=3)
Alvania punctura	Micrograzer	8.33±2.60 (C, n=3)	
Onoba aculeus	Detritivore	0.333±0.333 (C, n=3)	+
Onoba semicostata	Detritivore	10.67±3.53 (C, n=3)	6.33±3.84 (C, n=3)
Obtusella alderi	Detritivore	+	
Skeneopsis planorbis	Herbivore	0.333±0.333 (C, n=3)	+
Caecum glabrum	Micrograzer	2.33±1.86 (C, n=3)	3.33±1.76 (C, n=3)
Caecum imperforatum	Micrograzer	0.333±0.333 (C, n=3)	0.333±0.333 (C, n=3)
Bittium reticulatum	Predator/Scavenger	+	+
Marshallora adversa	Carnivore (sponges)	+	

Cerithiopsis tubercularis	Carnivore (e.g. sponges)/ Detritivore	+	+
Chrysallida decussata	Parasite (on molluscs)	+	-
Chrysallida indistincta	Parasite (on molluscs)	+	
Chrysallida obtusa	Parasite (on molluscs)	0.333±0.333 (C, n=3)	
Partulida spiralis	Parasitic (on polychaetes)	+	
Ondina divisa	Parasitic (host unknown)	+	
Odostomia turrita	Parasitic (on polychaetes)	0.667±0.667 (C, n=3)	0.333±0.333 (C, n=3)
Brachystomia eulimoides	Parasite (on molluscs)	8.33±1.86 (C, n=3)	
Eulima bilineata	Parasite (on ophiuroids)	-	+
Melanella alba	Parasite (on ophiuroids)	+	0.061±0.042 (G, n=33)
Vitreolina philippi	Parasite (on echinoderms)	+	
Aporrhais pespelecani	Detritivore	0.1882±0.0637 (Q, n=85)	
Capulus ungaricus	Suspension feeder/molluscan commensal	+	+
Trivia monacha	Carnivore (ascidians)	+	+
Erato voluta	Carnivore (ascidians)		+
Velutina velutina	Carnivore (ascidians)	+	+
Polinices montagui	Predator (molluscs)	0.0118±0.0118 (Q, n=85)	0.0045±0.0045 (Q, n=224)
Polinices polianus	Predator (molluscs)	0.0353±0.0201 (Q, n=85)	0.0084±0.0084 (Q, n=224)
Buccinum undatum	Predator/Scavenger	0.2235±0.0484 (Q, n=85)	0.0357±0.0124 (Q, n=224)
Neptunea antiqua	Predator/Scavenger	0.0353±0.0201 (Q, n=85)	
Colus gracilis	Predator/Scavenger	+	
Hinia incrassata	Predator/Scavenger	+	+
Mangelia brachystoma	Predator		+
Raphitoma linearis	Predator (e.g. polychaetes)	0.333±0.333 (C, n=3)	
Raphitoma purpurea	Predator (e.g. polychaetes)		+
OPISTHOBRANCHIA			
Philine aperta	Carnivore (e.g. polychaetes)	+	
Philine punctata	Carnivore (e.g. polychaetes)	+	
Diaphana minuta	Carnivore	+	
Retusa truncatula	Carnivore (molluscs)	+	
Elysia viridis	Herbivore	+	
Aplysia punctata	Herbivore	+	+
Pleurobranchus membranaceus	Carnivore (ascidians)	+	
Lomanotus marmoratus	Carnivore (hydroids)	+	-
Doto ?coronata.	Carnivore (hydroids)	+	+
Doto fragilis	Carnivore (hydroids)	+	+
Onchidoris bilamellata	Carnivore (brozoans)	+	+
Onchidoris muricata	Carnivore (brozoans)	+	+
Limacia clavigera	Carnivore (bryozoans)	-	+
Polycera quadrilineata	Carnivore (bryozoans)	+	+
Archidoris pseudoargus	Carnivore (sponges)	+	+
Coryphella lineata	Carnivore (hydroids)	+	-
Flabellina pedata	Carnivore (hydroids)	+	-
Cuthona caerulea	Carnivore (hydroids)	+	-
Catriona gymnota	Carnivore (hydroids)	+	-
Eubranchus sp.	Carnivore (hydroids)	+	-
Eubranchus tricolor	Carnivore (hydroids)	+	
Facelina auriculata	Carnivore (hydroids)	+	
Facelina bostoniesis	Carnivore (hydroids)	+	+
PELECYPODA			
Lunaria hians	Suspension feeder	0.056±0.056 (G, n=18)	-
Aequipecten opercularis	Suspension feeder	0.2706±0.0589 (Q, n=85)	+

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Pecten maximus	Suspension feeder	0.0588±0.0257 (Q, n=85)	0.0134±0.07 (Q, n=224)
CEPHALOPODA			
Sepiola atlantica	Predator/Scavenger		+
Eledone cirrhosa	Predator/Scavenger	+	
SESSILE EPIFAUNA			
PELECYPODA			
Mytilus edulis juv.	Suspension feeder	+	+
Modiolus modiolus juv.	Suspension feeder	0.167±0.090 (G, n=18)	+
Palliolium tigerinum	Suspension feeder	+	+
Chlamys varia	Suspension feeder	+	+
Pododesmus patelliformis	Suspension feeder	0.056±0.056 (G, n=18)	+
Heteranomia squamula	Suspension feeder	0.056±0.056 (G, n=18)	0.030±0.030 (G, n=33)
BURROWING INFAUNA			
GASTROPODA			
Turritella communis	Selective deposit/ Suspension feeder	+	
SCAPHOPODA			
Antalis entalis	Suspension feeder		+
PELECYPODA			
Nucula nucleus	Deposit feeder	0.056±0.056 (G, n=18)	0.182±0.068 (G, n=33)
Modiolarca tumida	Suspension feeder	+	
Glycymeris glycymeris	Suspension feeder	+	
Limatula subauriculata	Suspension feeder	+	
Lucinoma borealis	Suspension feeder	+	+
Limatula sulcata	Suspension feeder	+	
Semierycina nitida	Suspension feeder	+	
Kellia suborbicularis	Suspension feeder	+	
Mysella bidentata	Suspension feeder	16.00±8.33 (C, n=3)	6.67±3.71 (C, n=3)
Goodallia triangularis	Suspension feeder	0.056±0.056 (G, n=18)	
Tridonta montagui	Suspension feeder	+	
Parvicardium ovale	Suspension feeder	+	0.030±0.030 (G, n=33)
Parvicarium scabrum	Suspension feeder	+	0.091±0.051 (G, n=33)
Laevicardium crassum	Suspension feeder	+	+
Lutraria angustior	Suspension feeder	+	0.167±0.167 (A, n=6)
Ensis arcuatus	Suspension feeder	0.333±0.211 (A, n=6)	0.167±0.167 (A, n=6)
Arcopagia crassa	Deposit/Suspension feeder		+
Arcopella balaustina	Deposit/Suspension feeder	+	
Moerella donacina	Deposit/Suspension feeder	0.111±0.762 (G, n=18)	0.061±0.042 (G, n=33)
Gari tellinella	Deposit/Suspension feeder		0.030±0.030 (G, n=33)
Abra alba	Selective deposit feeder	+	
Circomphalus casina	Suspension feeder	+	+
Gouldia minima	Suspension feeder	+	0.033±0.104 (G, n=33)
Dosinia exoleta	Suspension feeder	7.667±0.558 (A, n=6)	3.500±0.619 (A, n=6)
Paphia rhomboides	Suspension feeder	0.500±0.224 (A, n=6)	0.333±0.211 (A, n=6)
Venerupis senegalensis	Suspension feeder	+	+
Clausinella fasciata	Suspension feeder	0.056±0.056 (G, n=18)	0.788±0.155 (G, n=33)
Timoclea ovata	Suspension feeder	+	+
Mya truncata	Suspension feeder	1.500±0.428 (A, n=6)	0.833±0.477 (A, n=6)
Thracia villosiuscula	Suspension feeder	+	0.606±0.238 (G, n=33)
Cochlodesma praetenue	Suspension feeder		+
BORING INFAUNA			
PELECPODA			
Hiatella arctica	Suspension feeder	0.278±0.226 (G, n=18)	0.030±0.030 (G, n=33)

RESULTS - SCALLOP DREDGING ON MAERL

Video studies revealed that boulders up to 1 m^3 were dislodged and overturned as they were hit by the tow bar or the dredge mouths. The dredge teeth projected fully into the maerl (10 cm) and jerked on spring-loaded pawls creating a billowing cloud of suspended sediment in the wake of the gear. Untrawled areas at both sites had coralline gravel surfaces with heterogeneous features such as crab feeding pits and silty loci around animals such as *Upogebia deltaura* and the polychaete *Eupolymnia nebulosa* (Montagu). Surface sediments at Site 1 had an added level of habitat complexity provided by patches of *Limaria hians*, while at Site 2, the sediment was megarippled. Scallop dredges erased these natural bottom features, sculpting the maerl surface into a series of parallel mounds and furrows along 2.54 m wide tracks and removing the byssus nests of *L. hians* from Site 1. The surface layer of living maerl was churned over and finer sediments (sand and silt) were brought to the sediment surface. Overturned rocks buried some epilithic organisms (e.g. *Phycodrys rubens*) and exposed others (e.g. *Dendrodoa grossularia* (van Beneden)). Slow-moving and sessile members of the large epibiota were seen smashed along the dredge paths and large members of the infauna were exposed and broken (e.g. *Chaetopterus variopedatus* (Renier), *Ensis arcuatus, Laevicardium crassum, Spatangus purpureus* O.F. Muller and *Echinocardium pennatifidum* Norman). Thick shelled animals that were small enough to pass between the dredge teeth usually survived; for example *Gibbula magus* (L.) was often buried by the trawl but later re-emerged whilst *Clausinella fasciata* was raked out of the sediment but later reburied itself. Some apparently undamaged bivalves were seized upon by *Buccinum undatum* before they could dig themselves in.

Comparisons of core samples before and after dredging revealed a 73% drop in the number of nodules of maerl-forming *Phymatolithon calcareum, Lithothamnion glaciale* and *L. sonderi* Hauck in the top 3 cm of the sediment. Four months later there were fewer than half the number of live plants on the dredge track compared with the adjacent area which remained at pre-dredge densities of live maerl. Monitoring by divers revealed that the dredge tracks were clearly visible after a year on deeper parts of the deposit (-12 to -14 m CD).

DISCUSSION

These studies confirm past reports that maerl beds support an outstanding diversity of molluscs. Totals of 117 spp. at Site 1 and 82 spp. at Site 2 are by far the highest on record for maerl beds (Cabioch 1968; Hardiman *et al.* 1976; Keegan 1974; Bosence 1979; Mora Bermúdez 1980; Nunn 1993). Rather than suggesting that the Clyde maerl deposits have a more diverse molluscan fauna than any other, this probably reflects the greater detail of this study. The records given here of *Lutraria angustior* from Sites 1 & 2 and of *Arcopella balaustina* (L.) and *Lacuna crassior* (Montagu) from Site 1, however, are noteworthy as they represent new records for the Firth of Clyde and the presence of *Erato voluta* (Montagu) at Site 2 is the first Clyde record for this species this century (Allen 1962; Seaward 1982).

The high diversity of molluscs found associated with Clyde maerl deposits is a reflection of the heterogeneity of these habitats which are intermediate between soft and hard grounds with examples of the faunas of both. Conditions on the surface of the sediment suit animals adapted for life on rock and seaweed, whilst the upper layer of interlocking maerl thalli has an open, three-dimensional lattice that harbours crevice-dwelling animals. Sediments within the habitat grade from soft muds to coarse gravels; they are generally coarser in the uppermost layer but the activity of a range of animals creates fine sediment patches so that suitable conditions for a diverse range of infaunal species are created. In agreement with the findings of Nunn (1993), none of the molluscs found in this study is specific to the habitat; all may be found associated with other sea-bed types, but the diversity and abundance of molluscs that exist on a maerl bed are impressive.

The main components of the Clyde maerl faunas are similar to those described by Cabioch (1968) from Brittany who considered maerl faunas to be basically similar to the '*Venus fasciata* community' of Ford (1923) with the addition of a rich epifauna. There are also similarities between these faunas and those from shell gravels of the English Channel (Jones 1950; Holme 1966; Howell & Shelton 1970). The most detailed previous study of the molluscan fauna of maerl beds is that of Nunn (1993) who made site records of 10–55 spp. around Scotland, Northern Ireland and Eire. Her total list for nine sites is similar in composition to the 130 spp. found during this study, the main difference being that she recorded species with intertidal foci (e.g. *Patella vulgata* L. and *Littorina* spp. Ferussac) which were absent at -9 to -10m CD on Clyde grounds.

An argument has been put forward, in support of commercial extraction, that predominantly dead maerl deposits are faunistically barren (Cornish Calcified Seaweed Co. Ltd Report 1993). This is untrue of Site 2 which had a 98% cover of dead maerl but rich fauna. The vagile epifauna of this site was sparse compared to Site 1 (which had 25% live maerl cover), which agrees with other work that showed predominantly dead deposits had a poorer epifauna than areas where live maerl was common (Keegan 1974; Bosence 1979; Hardiman *et al.* 1976; Nunn 1993). However, Site 2 was far from barren as it had a diverse infauna; airlift sampling revealed that large molluscs were numerous below the sampling depth of Van Veen grabs in line with findings on maerl deposits in Eire (Keegan & Könnecker 1973).

It cannot be stated unequivocally that the lower diversity and abundance of the molluscan fauna of maerl at Site 2 compared with Site 1 was due to scallop dredging. The sites are similar, each being located on level areas of sea bed within sheltered parts of the northern Firth of Clyde with no differences in depth, salinity, temperature or tidal amplitude. However, bottom currents at Site 1 were generally faster (<54 cm s^{-1}) than at Site 2 (<11 cm s^{-1}) which will play a part in determining faunal differences between the sites. For example, stronger currents may favour the growth of hydroids which are in turn food for nudibranch spp. Experiments using dredges at both sites provided strong evidence that faunal differences can also be linked to commercial scallop fishing pressure on Site 2. For example, it is likely that the abundances of *Aequipecten opercularis* and *Pecten maximus* were far lower there because it was a dredged site. The abundance of dead shells but absence of live *Limaria hians* at Site 2 also suggests that scallop dredging has been responsible for the local demise of this species. This evidence is strengthened by experimental observations at Site 1 where *L. hians* was found to be particularly susceptible to scallop dredging, being easily scraped from the maerl surface within its byssus nests.

Scallop dredging resulted in high disturbance and mortality to populations of bottom-dwelling organisms associated with Clyde maerl beds, as shown in other types of benthic communities (Caddy 1973; Chapman *et al.* 1977; Peterson *et al.* 1983, 1987; Fonseca *et al.* 1984; Bullimore 1985; Eleftheriou & Robertson 1992; MacDonald 1993). Diving in the wake of the gear showed that only the most resilient species survived (e.g. small, strong shelled animals) and that virtually all of the large, fragile epifauna were killed or removed. No study was made of the effects of scallop dredges on deep-burrowing infauna, but the abundance of these species at Site 2 suggests that survival rates may be high below the maximum extent of dredge penetration (10 cm). Disturbance to the physical nature of the maerl beds was similar but more pronounced than that noted for scallop dredges on muddy, sandy and gravelly sediments (see Caddy 1973; Aschan 1988a, 1988b, 1989; Eleftheriou & Roberston 1992), the overall effect being one of homogenization along the tracks, by removing much of the patchiness that was a feature of the undisturbed maerl surfaces. Maerl beds are particularly sensitive to physical disturbance since their viability depends upon the surface layer of living plants. It is of serious concern that over half of the living maerl can be buried and killed through lack of light by a single passage of scallop dredges as this limits the ability of disturbed beds to regenerate. This study is the first to report the persistence of scallop dredge disturbance, with gross changes in sediment topography clearly visible to divers for over a year at depths below the influence of wave action.

SUMMARY

In summary, this paper provides detailed baseline information on the molluscan fauna associated with unimpacted and impacted maerl habitats in SW Scotland. Experiments showed that scallop dredging on maerl grounds can cause long-term reductions in the cover of living maerl, alter sediment structure and reduce the diversity and abundance of the associated fauna. Shifts in community structure are also likely since parts of the fauna are selectively removed or killed besides the target species. Long-term changes in favour of commercially valueless opportunistic species have been blamed directly on demersal fishing and shellfish culture in other marine habitats (Reisen & Reise 1982) while de Groot (1984) and Lindley & Williams (1994) speculate that trawling is the cause of shifts in the composition of the macrobenthos of the North Sea. Maerl beds, which support a rich molluscan fauna, are currently affected by a range of human activities and require tighter management controls in the UK and other European countries if these areas are to be protected in compliance with Council Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Fauna and Flora (1992).

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GRAELLSIA

Caracterización de los fondos de maërl y macrofauna asociada de la Reserva Marina de Tabarca

(Alicante, SE Península Ibérica)

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Resumen

El presente estudio se ha llevado a cabo para caracterizar los fondos de odófitas calcáreas libres (maërl *s.l.*) y conocer la macrofauna asociada (a nivel de *phylum*, clase u orden) de un área del SE de la Península Ibérica Alicante), mediante muestreos estacionales y durante un periodo anual. Las muestras de cores y cuadrados (0.05m^2) se han recolectado en inmersión a profundidades entre 37 y 40m en una zona de 20 ha de la Reserva Marina de a isla de Tabarca. El fondo ha sido predominantemente de arenas gruesas y gravas organógenas, cubierto por bandas más o menos paralelas de pequeños alos de coralináceas (media de 11.8mm) con un recubrimiento medio del 21% el fondo. *Lithothamnion cf: corallioides*, *Phymatolithon calcareum*, *ithophylum duckeri* y *Mesophyllum lichenoides* han sido las especies de lgas calcáreas más abundantes. Respecto a la macrofauna, presenta una relativamente alta densidad (media de 632.4 individuos/0.05m^2), que participa de organismos de fondos duros (coloniales) y blandos (poliquetos, bivalvos); destacando Polychaeta (39.5%) y Ascidiacea (18.3%) como taxones predominates. Los posibles cambios intra-anuales de la macrofauna se han analizado por análisis multivariante no paramétrico (ANOSIM, SIMPER), no encontrando diferencias significativas entre las estaciones del año, siendo Bivalvia, Amphipoda y Decapoda los taxones que han presentado una menor variación estacional. Los fondos de maërl del Mediterráneo poseen una alta diversidad biológica y presentan una distribución en manchas muy localizada. Además, son altamente vulnerables al impacto antropogénico (pesca de arrastre, dragados), siendo por ello objeto de necesarias medidas de protección.

Palabras clave: Bentos, Circalitoral, Detrítico costero, Maërl, Macrofauna, Mediterráneo, Península Ibérica.

Abstract

Characterisation of the maërl beds and the associated macrofauna from the Marine Reserve of Tabarca (Alicante, SE Iberian Peninsula).

The present study has been carried out to a characterisation of the free-living calcareous rohodophyte algae bottom (maërl beds *s.l*) and the associated macrofauna (at level of phylum, classe or order) from a zone of the South-eastern Iberian Peninsula (Alicante), it was studied during an annual period. SCUBA diving cores and quadrates (0.05m2) were collected from depths of

37-40m from an area of approximately 20 ha from the Marine Reserve of Tabarca Island. The bottom was predominantly organogenic coarse sand and gravel cover by more or less parallel strips of small corallinacea thales (mean of 11.8mm) with a mean bottom cover of 21%. *Lithothamnion cf. corallioides*, *Phymatolithon calcareum*, *Lithophylum duckeri* and *Mesophyllum lichenoides* were the predominant calcareous algae. With regard to the macrofauna, it has a relatively high density (mean of 632.4 ind./0.05m^2), that participate of the hard (colonial organisms) and the soft bottoms (polychaetes, bivalves) organisms, the Polychaeta (39.5%) and Ascidiacea (18.3%) were the numerical predominant taxons. The possible macrofaunal intra-annual changes were analysed through non-parametric multivariate tests (ANOSIM, SIMPER), it were not found significant differences between the seasons, Bivalvia, Amphipoda and Decapoda have been the taxons with a less seasonal variation. The maërl beds in the Mediterranean sea support a high biological diversity and they present a very localised patchy distribution. Moreover, they are high vulnerable to the anthropic impacts (mainly by trawling and dredging), that means a necessity of the measures for their preservation.

Keywords: Benthos, Circalittoral, Coastal detritic, Maërl, Macrofauna, Mediterranean Sea, Iberian Peninsula.

Introducción

Los fondos de maërl *s.l.* pertenecen a la biocenosis del detrítico costero (Pérès y Picard, 1964) y están estructurados por rodofitas calcáreas libres, principalmente, de las familias Corallinacea y Peyssonneliacea. A pesar de su amplia distribución mundial (Bosence, 1983), en el Mediterráneo se encuentran muy localizados, situándose en el piso circalitoral entre 30 y 100 m de profundidad (Pérès y Picard, 1964), y formando manchas discontinuas en zonas con un hidrodinamismo moderado (Jacquotte, 1962). La presencia de estas formaciones de algas calcáreas perennes modifican la granulometría del sedimento y la estructura espacial, consiguiendo una mayor heterogeneidad de hábitat. Ecológicamente se caracterizan por una elevada diversidad biológica tanto en el Mediterráneo (Jacquotte, 1962; Falconetti, 1970), como en el Atlántico NE (Cabioch, 1968; Keegan, 1974). Presentan una gran fragilidad frente a los impactos antrópicos (en el Mediterráneo por pesca de arrastre y dragados, Bellan-Santini *et al*, 1994), ello ha supuesto que sean considerados como "paisaje amenazado del Mediterráneo" (UNEP/IUCN/GIS Posidonie, 1990) y hábitat objeto de medidas de gestión por la Unión Europea (Directiva 92/43 CEE del Consejo).

A pesar de su elevado interés biológico y vulnerabilidad, los estudios descriptivos y ecológicos sobre la macrofauna de los fondos de maërl en el Mediterráneo son relativamente escasos (Jacquotte, 1962 , Falconetti, 1970). En las costas españolas se ha centrado principalmente en la flora (Ballesteros, 1988, 1994 ; Soto, 1990), o en una descripción general (Ramos-Esplá, 1985 ; García Carrascosa, 1987 ; Ballesteros *et al*, 1993). En el presente estudio, se aborda una caracterización de los fondos de maërl localizados en la Reserva Marina de Tabarca, considerando tanto el componente algal calcáreo como la macrofauna asociada. Respecto a la macrofauna bentónica, aparte de determinar los principales grupos a nivel de taxones superiores (*phylum*, clase, orden), se ha analizado su posible variación intra-anual.

Material y métodos

El área se localiza en el SE Ibérico dentro de la Reserva Marina de Tabarca. Dicha zona se ha elegido basándose en el estudio de Ramos-Esplá (1985) que situaba una zona de maërl de aproximadamente 20 ha al SE de la Isla de Tabarca (coordenadas : 38° 09.0' N - 00° 26.5' W) y entre 34 y 41 m de profundidad (fig. 1). Por otro lado, el carácter de área protegida (reserva marina) asegura que los fondos de maërl no están perturbados, especialmente por la pesca de arrastre, frecuente en la zona. Dentro del sector estudiado se han elegido al azar cuatro estaciones de muestreo (una por cada periodo estacional del año) entre diciembre de 1996 y agosto de 1997 (tabla 1), que fueron posicionadas por medio de G.P.S.

Los muestreos han sido directos, en inmersión con escafandra autónoma, entre 37 y 40 m de profundidad, realizándose 3-4 réplicas/estación mediante un cuadrado de 0.05m^2 provisto de una bolsa de malla de 1mm de diámetro, penetrando en el sedimento 3-4 cm (fig. 2), por lo que toda la capa de maërl fue recolectada. Para el estudio granulométrico y la composición porcentual de la capa de maërl (vivo, muerto, grava organógena, grava inorgánica) se extrajeron 1-2 cores/estación, mediante un cilindro de acero de 8 cm de diámetro y 15 cm de longitud. La columna de sedimento (10-12cm) se ha separado en fracciones de 2cm. Paralelamente, se han analizado los parámetros hidrológicos de la columna de agua : temperatura y salinidad (termosalinómetro Hugrún Seamon CT), transparencia (disco de

Secchi), corrientes (correntímetro Kahl 231WA550), y seston en superficie y próximo al fondo (2.5 dm^3 por botella Niskin; y determinación según Strickland y Parsons, 1986).

Las muestras obtenidas por cuadrados se anestesiaban (mentol, congelador) y se fijaban en formol neutralizado al 10%. Posteriormente, se tamizaban a 1mm considerándose los organismos de diámetro superior a dicha malla, y se separaban las fracciones de algas calcáreas, algas blandas y macrofauna, sea de *visu* o mediante lupa binocular. La macrofauna (∅ ≥ 1mm) se ha identificado a nivel de *phylum*, clase u orden, y se ha cuantificado en función de su abundancia numérica. Los grupos coloniales Porifera, Cnidaria y Ascidiacea han sido cuantificados según el número de colonias. Briozoa, a pesar de ser muy abundante, se ha excluido del análisis debido a la dificultad de su cuantificación, dada la abundante presencia de trozos de colonias; así como, Foraminifera dada la imposibilidad de separar los ejemplares vivos y muertos. Para la comparación de muestras se han realizado análisis de similitud con los datos de las abundancias de los distintos grupos, excluyendo Briozoa por los motivos expuestos, y Pisces y Mysidacea por ser el método utilizado no adecuado a su captura. Para comprobar la posible variación estacional se ha realizado un análisis multivariante con los programas ANOSIM y SIMPER del paquete estadístico PRIMER (Clarke, 1993).

Resultados

a) Columna de agua y sedimento

El rango de variación de la temperatura en el fondo ha oscilado entre 14°C y 17°C, con una marcada termoclina entre 15 y 19m (mayo-octubre). La salinidad medida en el fondo se ha mantenido relativamente constante a lo largo del año, entre 38.2 y 38.6 ‰. La profundidad del disco de Secchi ha oscilado entre 12 y 30 m de profundidad. La cantidad media de seston ha sido de 1.134 mg MO/l (desviación estándar, DS=1.12) en superficie, y en el fondo de 1.450 mg MO/l (DS= 1.26). Se ha constatado la existencia de corrientes moderadas de fondo (< 0.1 nudos). Sin embargo, la distribución espacial de los talos de corallináceas formando bandas (Hily et al, 1992) sugieren una importante influencia del oleaje de fondo.

La fracción de arenas en los primeros 10cm de sedimento ha sido la predominante, con una media del 66.1 % (DS=9.2), seguida de las gravas (media=29.0%, DS=10.4); y con una escasa fracción pelítica (media=4.9, DS=2.1). La capa gris (RPDL *red-ox potential discontinuity layer*) se ha situado entre 5 y 6 cm de profundidad. El tamaño de grano varía entre los primeros dos centímetros y los siguientes, con el predominio de la grava (dada la presencia de talos vivos y restos organógenos), donde se observa claramente la separación de la capa superfical del resto de la columna de sedimento (fig. 3). Respecto al origen de la composición de las gravas de dicha capa superficial, la fracción organógena de naturaleza animal (restos de conchas y esqueletos de moluscos, madreporarios, briozoos, equinodermos, etc.) ha sido la predominante (media=28.2%; DS=24.9); si bien, los porcentajes de maërl vivo (27 7%; 11.2) y de maërl muerto (27.6%; 10.8) han sido semejantes; siendo el resto, grava de naturaleza mineral (16.5%; 10.5).

b) Caracterización del maërl

Las especies algales más representativas del maërl de Tabarca han sido: *Lithothamnion cf. corallioides, Phymatolithon calcareum, Lithophyllum duckeri* y *Mesophyllum lichenoides*. Entre las macroalgas erectas acompañantes cabe citar a *Osmundaria volubilis, Phyllophora nervosa, Halopitys incurvus, Dictyota dichotoma, Halopteris filicina*, y *Valonia macrophysa*.

Como se ha comentado en el apartado anterior, las coralináceas aparecen formando bandas más o menos paralelas que alternan (fig. 2), unas con alta presencia de algas (bandas de 25-30 cm de ancho) y otras con arena gruesa y grava sin apenas talos vivos (bandas de 50-60 cm). Esta disposición aparece más marcada durante el periodo estival, observándose un valor medio de recubrimiento por superficie de fondo (m^2) del 21% (DS=23); siendo del 56% (DS=30) en las bandas con mayor densidad de algas. En relación a la dimensión máxima de los talos, se ha obtenido una media de 11.83 mm (S.D.=4.79, n=200), siendo *Lithophyllum duckeri*, el de mayor longitud con 30mm (tabla 2). Estas medidas han sido menores que en otras localidades del Mediterráneo español, como Columbretes (García Carrascosa, 1986), Costa Brava (Ballesteros, 1988) y Baleares (Ballesteros, 1994; Ballesteros *et al*, 1993). La esfericidad media de los talos estudiados ha sido de 6.68 (DS=1.21, n=200), valor que indica un hidrodinamismo medio o moderado (según Krumbein & Sloss, 1963). Ello viene a corroborar las observaciones *in situ* y la información que al respecto han aportado otros autores (p.e. Jacquotte, 1962), sobre uno de los factores (hidrodinamismo) que condiciona la presencia de maërl en el Mediterráneo.

c) Macrofauna

La macrofauna asociada a los fondos de maërl de la Reserva Marina de Tabarca ha mostrado una alta riqueza en taxones superiores (a nivel de *phyla*, clases u órdenes), 27 en total (tabla 3), con una densidad relativamente elevada (media: 632.4 individuos o colonias/0.05 m^2; D S=236.0 ; n=15). Una de las principales características de la macrofauna observada ha sido su pequeño tamaño (normalmente inferior a 10mm), y donde determinados taxones de la megafauna (Crinoidea, Asteroidea y Holothuroidea) sólo se han observado en inmersión al encontrarse muy dispersos. Entre los taxones identificados, cabe destacar los organismos con estrategia solitaria, principalmente, Polychaeta (39.5%), Gastropoda (6.4%), Amphipoda (4.6%), Nematoda (3.8%), Decapoda (3.0%) y Bivalvia (2.5%) que han sido los más abundantes (fig. 4 y 5). No obstante, se ha observado un alto porcentaje de especies coloniales (Porifera, Hidrozoa, Anthozoa, Briozoa, Ascidiacea coloniales), siendo Ascidiacea la más abundante con una media del 18.3% del total de individuos contados.

Respecto a su posible variación anual, el análisis no detectó diferencias significativas (ANOSIM, R global = 0.11) entre estaciones. El análisis del porcentaje de similitudes (SIMPER) mostró que la estructura de la comunidad medida a los niveles taxonómicos estudiados fue muy similar entre las muestras pertenecientes a cada estación (tabla 4). Los grupos más importantes en la similitud entre réplicas fueron Polychaeta, Ascidiacea, Gastropoda, Amphipoda y Decapoda. Así mismo, la disimilitud entre las réplicas pertenecientes a distintos periodos estacionales no fueron muy diferentes entre ellas con valores entre 13.53 % y 8.11 %. Las diferencias entre estaciones fueron principalmente resultado de las variaciones en la abundancia de Hidrozoa, Ascidiacea, Sipuncula y Gastropoda (tabla 5), presumiblemente debido a la heterogeneidad de sus patrones de distribución espacial (especialmente, Hydrozoa que parece presentar una marcada distribución en mosaico). Por otro lado, cabe destacar Bivalvia, Amphipoda y Decapoda que han presentado una menor variación estacional entre los taxones más abundantes.

Discusión

La comunidad estudiada corresponde a la biocenosis de los fondos detríticos costeros, consistente en gravas y arenas organógenas derivadas de algas y animales actuales (Pérès, 1985; Bellan-Santini *et al*, 1994), y con predominio de corallináceas libres (principalmente, *Lithothamnion cf. corallioides*, *Phymatolithon calcareum* y *Lithophyllum duckeri*) que corresponde a la facies de maërl (Pérès y Picard, 1964) con un relativo pequeño tamaño de los talos, en comparación con otras localidades del Mediterráneo. Al respecto, conviene señalar que la zona estudiada ha sido objeto de pesca de arrastre antes de su declaración como reserva marina en 1986. Dado el plazo transcurrido desde su protección (unos 11 años), puede haber condicionado el pequeño tamaño actual (media de 11.8mm; si bien se han recolectado talos aislados de tamaño de 50mm por medio de draga). Respecto a la tasa de crecimiento anual (aprox.

1mm/año, Irvine y Chamberlain, 1994) y el tamaño medio de los talos, se puede intuir que la comunidad algal podría encontrase en un estado de evolución hacia estadios más maduros, lo que supondría un progresivo mayor tamaño medio e incremento de la cobertura.

Los resultados preliminares en relación a la macrofauna asociada a los fondos de maërl de Tabarca, y probablemente debido a su compleja heterogeneidad espacial, demuestran una alta riqueza en taxones, que participa tanto de fondos duros (abundancia de especies coloniales) como de blandos (poliquetos, bivalvos). Sin embargo, Pérès (1985) considera los fondos de maërl ('nullipores') del Mediterráneo occidental con una fauna 'relativamente pobre', que contrasta con los resultados del presente estudio. Ciertamente, si lo comparamos con los bloques de concrecionamiento algal circalitoral ('coralígeno'), la fauna puede parecer más bien escasa; no obstante, la intrincada ramificación de los talos procura un elevado número de microhábitats, y puede condicionar la abundancia observada y el tamaño relativamente pequeño (< 10mm) de la macrofauna. Por otro lado, la relativa constancia climática del ambiente podría suponer una cierta constancia estacional en la presencia y abundancia de los grupos zoológicos, como se ha observado en el análisis multivariante; si bien, ello se ha comprobado para taxones superiores, es necesario llegar a nivel de taxones inferiores (familia, género, especie).

Nos encontramos ante una comunidad escasa, de distribución muy localizada, con una compleja estructura espacial que mantiene una alta diversidad biológica, y que participa de los fondos duros y blandos. Ello supone que sean especialmente vulnerables a los impactos de origen antrópico (pesca de arrastre, dragados) por lo que se debería tomar medidas preventivas para evitar su degradación.

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Código	fecha	Coordenadas	prof. (m)	T°C fondo	cuadrados	cores
UAC-12	03.12.96	38°09.14'N-00°25.81'W	40	17.0	4	1
UAC-19	20.02.97	38°08.58'N-00°25.75'W	37.5	14.0	3	1
UAC-26	09.06.97	38°09.18'N-00°26.05'W	37	16.9	4	2
UAC-33	29.08.97	38°08.90'N-00°25.74'W	39	16.4	4	2

Tabla 1.- Características de las estaciones de muestreo.

Especie	**Tamaño (mm)**			**Frec. aparición**	
	Max.	**Media**	**DS_{n-1}**	**media**	**DS_{n-1}**
Lithophyllum duckeri	30	17.81	4.82	8.5	7.72
Lithophyllumcf. Corallioides	26	15.84	4.61	13.0	4.76
Phymatolithon calcareum	21	13.94	3.06	10.0	8.16

Tabla 2.- Dimensiones y frecuencia de aparición de las especies más representativas del maërl.

Abundancias medias / 0.05 m2

	Otoño	(D S)	Invierno	(D S)	Primav.	(D S)	Verano	(D S)	Total	(D S)
ERA	20.50	8.50	16.55	6.89	20.75	10.63	11.50	3.50	17.33	3.30
RIA	42.50	20.25	17.65	3.11	16.25	5.38	13.50	10.50	22.48	10.01
a	14.50	8.00	14.95	1.78	14.75	5.25	10.25	8.88	13.61	1.68
oa	28.00	24.00	2.70	1.33	1.50	1.50	3.25	3.25	8.86	9.57
ELLARIA	0.00	0.00	0.55	0.00	2.75	4.13	0.25	0.38	0.89	0.93
TODA	21.50	9.25	20.00	4.44	44.00	27.50	18.75	7.25	26.06	8.97
CULA	3.75	3.25	6.00	2.00	12.00	9.50	4.50	1.25	6.56	2.72
CHAETA	196.25	48.75	231.20	39.56	261.00	136.50	334.00	46.50	255.61	41.89
TACEA	64.00	14.50	67.45	8.67	89.25	28.25	69.25	10.38	72.49	8.38
ipoda	25.75	5.25	32.60	10.67	36.00	13.50	29.25	6.75	30.90	3.40
idacea	5.50	3.50	6.65	0.44	12.25	3.75	6.25	2.88	7.66	2.29
cea	1.75	1.25	1.75	0.00	1.75	1.63	0.25	0.38	1.38	0.56
lacea	0.00	0.00	1.40	2.44	0.00	0.00	0.75	1.13	0.54	0.54
da	3.75	3.25	2.60	1.11	3.00	2.50	6.00	1.00	3.84	1.08
poda	1.25	1.88	3.40	2.89	9.00	9.00	2.00	2.00	3.91	2.54
poda	20.00	3.00	16.70	4.22	21.50	6.75	22.75	3.63	20.24	1.89
coda	6.00	8.50	2.35	0.67	5.75	4.13	2.00	2.00	4.03	1.85
OGONIDA	0.75	0.38	1.70	0.44	2.50	1.25	0.25	0.38	1.30	0.80
LUSCA	100.25	20.75	63.90	8.44	54.50	7.75	48.00	8.00	66.66	16.79
placophora	6.00	2.50	6.20	2.67	5.00	2.50	10.25	2.38	6.86	1.69
ropoda	74.25	20.75	41.20	7.11	33.00	9.00	22.00	6.00	42.61	15.82
lvia	18.50	4.25	16.30	1.56	16.50	1.75	15.50	8.00	16.70	0.90
hopoda	1.50	0.75	0.20	0.44	0.00	0.00	0.25	0.38	0.49	0.51
CHIOPODA	0.00	0.00	1.20	1.11	1.00	1.00	0.50	0.50	0.68	0.43
INODERM.	5.25	1.38	6.45	2.44	6.25	1.25	4.75	0.88	5.68	0.68
iuroidea	4.50	1.50	5.55	2.89	4.75	0.88	4.75	0.88	4.89	0.33
inoidea	0.75	0.38	0.90	0.89	1.50	0.50	0.00	0.00	0.79	0.41
IDIAS	163.00	69.00	96.50	43.11	40.50	11.00	179.25	176.88	119.81	51.31
RANIA	0.25	0.38	0.30	0.00	0.50	0.50	0.25	0.38	0.33	0.09
CES	1.25	0.38	0.05	0.00	0.25	0.38	1.25	0.75	0.70	0.55

Tabla 3.- Densidades medias de los distintos taxones considerados para las diferentes estaciones y densidad media del total. (D S = desviación estándar).

Estación	Grupo	Xt	Xe	%S	%Sac
Otoño **%Sm= 90.54**	Polychaeta	255.61	196.25	16.37	16.37
	Ascidiacea	119.81	163.00	14.97	31.34
	Gastropoda	42.61	74.25	12.78	44.11
	Amphipoda	30.90	25.75	10.03	54.14
	Decapoda	20.24	20.00	9.54	63.68
Invierno **%Sm=94.30**	Polychaeta	255.61	265.33	17.85	17.85
	Ascidiacea	119.81	132.67	14.23	32.08
	Gastropoda	42.61	42.67	11.27	43.35
	Amphipoda	30.90	33.00	10.26	53.61
	Anthozoa	13.61	14.67	8.75	62.36
Primavera **%Sm=87.12**	Polychaeta	255.61	261.00	18.13	18.13
	Ascidiacea	119.81	40.50	12.39	30.53
	Gastropoda	42.61	33.00	11.82	42.35
	Amphipoda	30.90	36.00	11.63	53.97
	Nematoda	26.06	44.00	10.86	64.83
Verano **%Sm=89.38**	Polychaeta	255.61	334.00	21.11	21.11
	Ascidiacea	119.81	179.25	14.05	35.15
	Amphipoda	30.90	29.25	11.32	46.47
	Decapoda	20.24	22.75	10.85	57.32
	Gastropoda	42.61	22.00	10.24	67.56

Tabla 4. Análisis de porcentajes de similtud (SIMPER) para cada una de las estaciones del año y respecto a los principales taxones: (% Sm), porcentaje de similitud medio para cada tipo de hábitat; (Xt), abundancia promedio para la totalidad de las muestras; (Xe), abundancia promedio en la estación del año; (% S), porcentaje de similitud medio; (% Sac), porcentaje de similitud acumulado.

Grupos	Ot / Inv %D= 8.11	Ot / Pri %D= 13.53	Ot / Ver %D= 12.29	Inv / Pri %D= 10.48	Inv / Ver %D= 9.01	Pri / Ver %D= 11.74
Hidrozoa	18.82	24.11	24.49	17.21	20.81	15.19
Sipuncula	16.13	15.22	10.31	15.32	5.07	14.89
Ascidiacea	12.56	16.32	15.13	18.02	19.17	15.33
Gastropoda	9.58	8.65	13.94	4.82	10.36	6.00
Polychaeta	9.77	9.50	9.82	12.16	7.35	12.13
Porifera	7.68	5.40	6.54	6.13	6.76	6.59
Anthozoa	7.57	4.97	9.00	3.66	13.18	10.19
Nematoda	7.15	8.91	5.71	12.16	6.75	11.12
Amphipoda	5.53	5.54	2.96	5.85	--	5.20
Decapoda	--	2.39	--	4.67	5.65	3.35
%Dac	95.08	100.00	97.90	100.00	95.10	100.00

Tabla 6. Resultados de los porcentajes de disimilitud entre pares de estaciones (% D) (SIMPER). Se indica, en tanto por ciento, la importancia de cada grupo taxonómico en las diferencias en la estructura de la comunidad en las distintas estaciones. %Dac: disimilaridad acumulada.

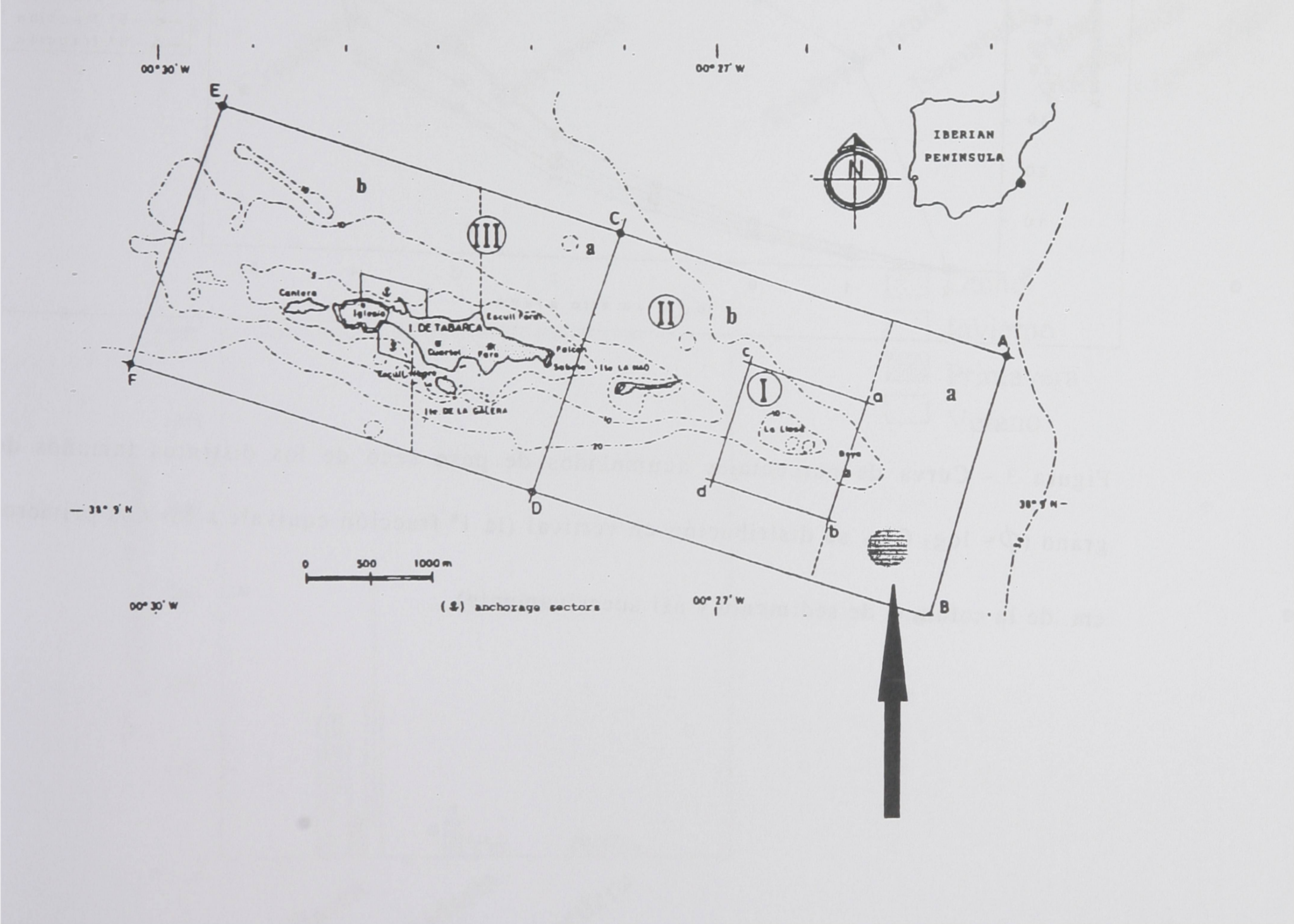


Figura1. Localización del área de muestreo. El rectángulo exterior (ABCD) indica los límites externos de la reserva marina de Tabarca. El rectángulo interno (abcd) corresponde al área de reserva integral.

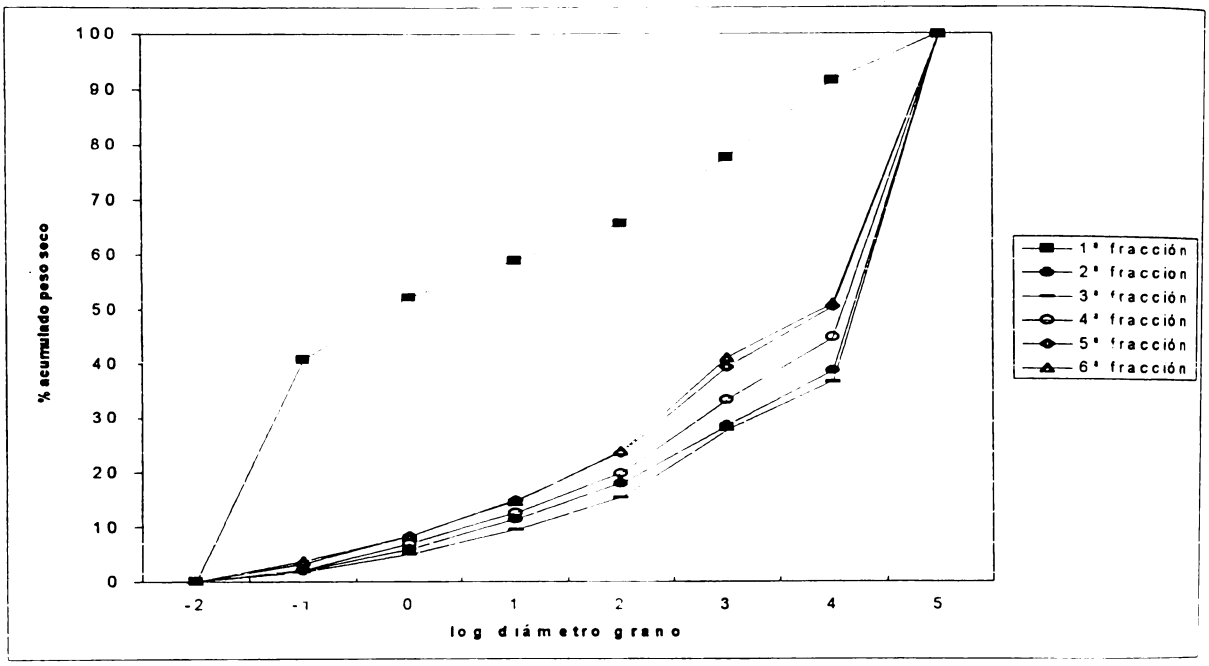


Figura 3. Curva de porcentajes acumulados de peso seco de los distintos tamaños de grano ($\phi = \log_2 \emptyset$) y su distribución en vertical (la 1ª fracción equivale a los dos primeros cm. de la columna de sedimento y así sucesivamente).

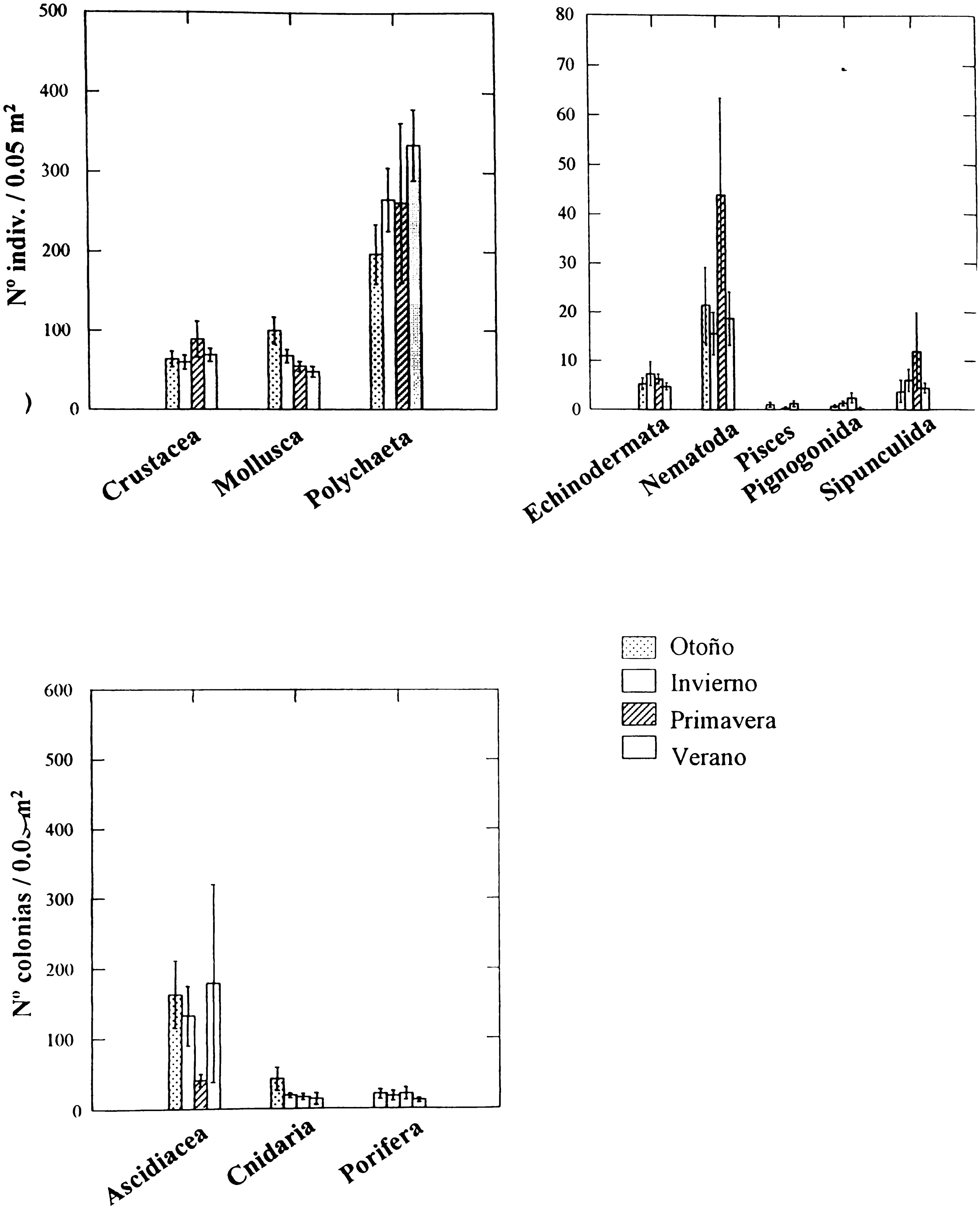
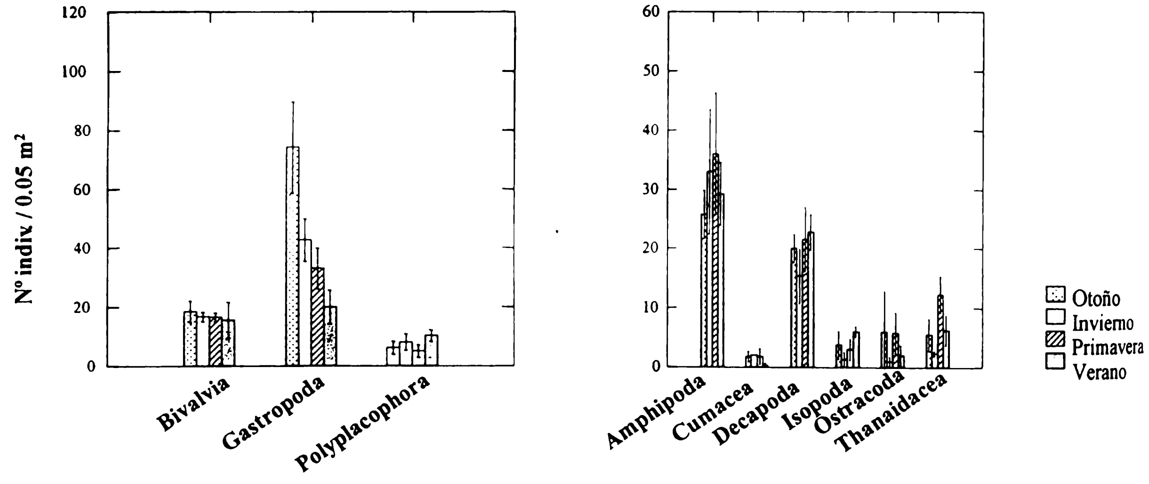


Figura 4. Variación estacional de las densidades de los principales taxones recolectados (con el error standard).



ra 5.- Variación estacional de las densidades de moluscos y crustaceos recolectados
el error standard).

DOES FISHING HAVE AN IMPACT ON MALTESE MAERL GROUNDS ?

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Abstract

The sedimentary bottoms off the northeastern coast of the Maltese Islands are important inshore fishing grounds. Between depths of 45m and 80m, these bottoms are characterized by accumulations of unattached calcareous rhodophytes, forming maerl beds. The complex structure of these free-living thalli (rhodoliths) introduces heterogeneity to the otherwise homogenous sedimentary bottoms, thus increasing biotic diversity. Maerl deposits may take decades to accumulate and their development is strongly correlated with the current and sedimentary regimes and with bottom disturbance, making such beds susceptible to anthropogenic disruption. Two fishing techniques used locally may have an impact on maerl bottoms: 'parit' fishing (bottom-set gill-nets) and bottom trawling using otter trawls. We investigated the effect of the former by experimental fishing on maerl, and that of the latter by studying rhodolith structure, sediment granulometry, and benthic biodiversity of two adjacent maerl beds, one of which is regularly trawled. 'Parit' fishing may remove the larger rhodoliths but its impact depends greatly on the strength of the bottom current. The trawled site had more abundant rhodoliths and coarser sediments than the non-trawled site, but a lower sediment organic content. Rhodolith morphology was also different at the two sites. Both sites had a high species richness but low abundance and biomass. Differences in species composition were also noted. These results are discussed in relation to the different environmental characteristics of the two sites, including the role of disturbance, but the relative importance of anthropogenic activities and natural perturbations is not yet clear.

Keywords : maerl, rhodoliths, coralline algae, trawling, gill-nets, human impact, Maltese Islands, Mediterranean

Introduction

The term maerl is used to describe biogenic sediments composed mainly of live and dead unattached, non-geniculate, coralline algae. The maerl-forming algae occur as rhodoliths, which take the form of nodules and unattached branched growths (Bosence, 1983b). Maerl grounds occur worldwide, being known from tropical to polar environments (Bosence, 1983b; Freiwald, 1995). The depths at which these grounds occur vary geographically: in the Atlantic they are found from very shallow waters down to 20m (Basso, 1995), in the Western Mediterranean they occur down to 90-100m, and in the Eastern Mediterranean down to depths greater than 180m (Basso, 1996). The distribution of coralline algae is primarily controlled by temperature and light (Adey, 1970) and depth distribution probably depends on light penetration (Bosence, 1976). Within the control of light and temperature, the distribution of rhodoliths depends on the type of substratum and on the hydrodynamic properties of the seabed (Bosence, 1983b). Maerl grounds require moderate water movement to overturn the algae thus allowing a concentric or radial growth which is typical of rhodoliths, and to prevent abrasion by fine particles (Bosence, 1983b; Basso & Tomaselli, 1994; Hall-Spencer, 1998). However, they also require a degree of shelter to prevent burial and dispersal into unsuitable environments (Hall-Spencer, 1998). The complex architecture of maerl grounds provides a heterogeneous environment with a high biodiversity (Bosence, 1976; Biomaerl, 1998), in contrast to surrounding homogenous sedimentary bottoms. Maerl grounds are particularly rich in vagile epifauna which find shelter and food among the three dimensional structure of the algal thalli (Bosence, 1979). Thus, maerl beds form fragile habitats which support many rare and unusual species (Biomaerl, 1998).

The episodic movement required for the formation and growth of rhodoliths (Harris et al., 1996) can be achieved either by bottom currents or by wave-induced water movement during storms. When currents are not enough to overturn rhodoliths, bioturbation may become very important (Basso & Tomaselli, 1994; Freiwald, 1995; Piller & Rasser, 1996). Organisms can have a considerable effect on the sediment. Pits and depressions related to foraging or burrowing activities may offer sites where turbulence is generated and large epifauna such as fish, especially those that feed on the bottom, cause substantial sediment disruption (Hall, 1994).

Some maerl grounds are exploited commercially. Direct exploitation of maerl is well known in most Western European countries, where it is used as a soil conditioner (Blunden et al., 1975, 1977; Blunden, 1991). Due to their productivity, maerl beds are also important fishing grounds. They are fished for various benthic fauna including scallops as in Scotland (Hall-Spencer, 1998) as well as demersal fish as for example *Mullus surmuletus* Linnaeus and *Spicara smaris* (Linnaeus) off Majorca (Massutí et al., 1996).

There are very few studies on the effect of demersal fishing on maerl grounds (Hall-Spencer, 1995, 1998). Towed demersal fishing gear inevitably has an impact on benthic communities, either through the modification of the substratum or by decreasing the abundance of benthic organisms (Lindeboom & de Groot, 1998). Trawling on hard bottoms results in evident damage to the benthic epifauna (Van Dolah et al., 1986). Since maerl grounds provide a substratum that is intermediate between hard and soft bottoms (Biomaerl, 1998; Hall-Spencer, 1998), trawling can have profound effects on the rich biodiversity of this fragile ecosystem. The effect of scallop dredging on maerl grounds on the western coast of Scotland has been documented by Hall-Spencer (1998). Apart from direct mechanical damage to biota, resuspended sediment from this activity resulted in over half of the living maerl being killed through reduced light penetration. Demersal fishing gear may also reduce habitat features such as pits and depressions related to feeding or burrowing activities (Hall-Spencer, 1998; Lindeboom & de Groot, 1998). These natural features of the sediment can be sites where turbulence is generated (Hall, 1994), which may be important for rhodolith entrainment.

Maltese maerl grounds are well-known to local fishermen, who refer to them as "ramel haj" which literally translated means "living sand", referring to the high productivity of this habitat. They are mainly fished using non-towed fishing gear, however, trawling is also known to take place. These grounds have only recently

(1993) started being scientifically investigated (Borg et al., in press). Although rhodoliths have been recorded from various places round the Maltese islands, the most extensive and important maerl ground, covering about 20km^2 of the seabed, is found off the northeastern coast of the island of Malta (Figure 1).

Maltese maerl grounds are fished using bottom-set gill-nets, known locally as 'parit', and by otter trawling. The 'parit' nets have a height of c.2m and are kept perpendicular to the seabed by small floats of c. 4cm diameter along the top and by lead weights (c. 250g each) along the bottom edge. In strong currents the gill-nets are deflected from their normal vertical position to come to lie horizontally on the bottom, thus in direct contact with the sediment. When this happens large rhodoliths get entangled in the nets. The rhodoliths tear up the nets causing considerable damage to the fishing gear. Since they are difficult to release from the nets, fishermen often crush the rhodoliths by spreading the nets on the ground and driving a road vehicle over them. From interviews we have conducted with fishermen, it appears that professional fishermen rarely set their nets on maerl grounds due to the potential for damage to the gear and the time-consuming clean-up operations afterwards.

Trawling within three nautical miles off the coast is illegal in the Maltese Islands, however, it still takes place (interviews with fishermen) and occasionally fishermen are apprehended and prosecuted (see for example, The Times [Malta] 10 January, 1997). Being an illegal activity it is very difficult to obtain information about the frequency of trawling on the maerl grounds. On the other hand it is very important to assess the impact of such fishing activities on this fragile habitat, since maerl is an important resource for off-bottom fisheries as well. From our interviews with fishermen, it resulted that the area lying Northwest of Sikka l-Bajda (Figure 1) is regularly fished by towed demersal fishing gear, while that to the southeast of Sikka l-Bajda is not, due to the presence of rocky shoals. These areas were designated as impacted and control sites respectively and the aim of this study was to identify any differences in sediment characteristics and biota between the impacted and control maerl grounds, and to see whether these differences can be attributed to fishing activities. The effect of 'parit' fishing was assessed by experimentally deploying nets on the maerl grounds, while the effects of trawling were assessed by studying maerl morphology and sediment composition.

Materials and Methods

The areas designated as control and impacted were located within the maerl ground off the northeastern coast of Malta (Figure 1). Routine monitoring of water column physico-chemical parameters showed no significant difference during the study period between the control and impacted sites in temperature, salinity, turbidity and suspended matter.

Samples were collected using a $0.1m^2$ van Veen grab [Khalisco] deployed from a traditional Maltese fishing vessel. Positions at sea were determined using a GPS navigational system [Raytheon 790].

On both control and impacted sites a shore-normal transect was established. For a preliminary survey of the two grounds, samples were collected from a number of stations along each transect during April 1996 (Figure 1). The maerl beds were best developed towards the central part of both transects at depths between 45m and 80m and live rhodoliths became sparser away from the centre. For this reason, only samples from the central stations were analysed in detail and are reported upon here. Apart from the samples collected in April 1996, others were collected in November 1996 specifically to study maerl and sediment composition. Additionally, two stations close to the centre-point of each transect (UMC for the control ground and UMI for the impacted ground) were sampled approximately once every three months between July 1996 and April 1998 to study seasonal variation.

The April 1996 samples were sieved through a 1mm mesh on deck, while the grab samples collected in November 1996 and the seasonal samples were not sieved. Otherwise, all samples were treated in the same manner. The samples were preserved in 10% formalin and hand-sorted. All biota larger than 1mm and live (pink) rhodoliths were picked out and the rest of the sediment (non-living sediment) was dried. The biota were identified to species level or where this was not possible to the lowest possible taxon.

The live coralline algae were air-dried and weighed, and their percentage coverage was determined by placing the rhodoliths on a tray of area equal to that of the van Veen grab ($0.1m^2$) with a grid attached to its base.

A weighed subsample of the rhodoliths was fractionated through nested Endecott test-sieves (8mm, 4mm, 2mm and 1mm) and each fraction was weighed separately. The rhodoliths were identified on the basis of gross morphology using published keys (Preda, 1908; Hamel & Lemoine, 1952; Giaccone, 1972/3) and these identifications were later checked by scanning electron microscopy of voucher specimens (J. Hall-Spencer, University Marine Biological Station Millport).

The sphericity of 100 randomly picked rhodoliths from each station was determined using the method of Krumbein (1941). Rhodoliths were classified into 10 morphotypes (Figure 2), and the collective weight of each morphotype was determined.

Sediment granulometry was determined using Endecott test-sieves (8mm, 4mm, 2mm, 1mm, 500μm, 250μm, 125μm and 63μm) according to the method of Buchanan & Kain (1971). The organic content of the sediment was determined by ashing the <0.5mm sediment fraction at 450ºC for four hours in a muffle furnace, and measuring the weight loss.

To study the effect of 'parit' fishing on the maerl, two gill-nets were deployed, one each on the control and impacted ground and left to fish overnight (c. 12 hours) between 9 and 10 December 1997. Each net had a height of 2m and a 3cm stretch mesh; 400m of net were deployed on the control bottom and 440m on the impacted bottom. All biota and rhodoliths entangled by the nets were collected. The biota were identified and counted and the longest axis and the weight of each rhodolith were determined.

Results

Characterisation of the live rhodoliths

Table 1 gives the total mass of sediment collected from each station and the abundance of live rhodoliths in terms of mass and cover. Overall, control stations had much less rhodoliths than the impacted stations (C4 is an exception). Mass of sediment collected was always higher for the impacted stations than the control ones, reflecting the degree of penetration of the grab and hence the different nature of the two grounds.

Figure 3 shows the size distribution of rhodoliths in the six stations. Most rhodoliths from both grounds had a diameter greater than or equal to 8mm. Rhodoliths of this size class were more abundant in the impacted stations, implying that overall larger rhodoliths are present in the impacted than in the control ground. Measurements of the longest axis of individual rhodoliths from the two grounds confirm this (Figure 4).

Table 2 gives the species composition of rhodoliths from the two grounds, based on gross morphology of the thalli. It must be noted that gross morphology is at best only indicative and that certain identification of rhodolith-forming coralline algae can only be made on details of microscopic structure, especially of the conceptacles. Voucher specimens of each tentative species except for *Neogoniolithon brassica-florida* were identified using scanning electron microscopy by Dr. J. Hall-Spencer (University Marine Biological Station Millport) and our identification were generally confirmed except for *Phymatolithon calcareum* and *Lithothamnion minervae*, which proved difficult to distinguish using gross morphology alone. Therefore, in our analysis these species were lumped together. In the impacted ground *Phymatolithon calcareum/Lithothamnion minervae* is more abundant than *Lithothamnion corallioides*, while the reverse is true for the control ground.

For both grounds the majority of the rhodoliths had a sphericity index in the range 0.7-0.8, which is not high but indicates that the rhodoliths show a tendency towards a spherical shape. A higher percentage of rhodoliths from the impacted ground tended to be spherical, than for the control ground (Figure 5).

The frequency distribution of morphotypes for the six stations is shown in Figure 6. In both control and impacted sites morphotype F is the most abundant. However, morphotypes C, D, F, G and K have a higher frequency in the impacted ground than in the control, while the reverse is true for morphotypes B, E, I and J.

Sediment composition

The results of the sediment granulometry are given in Table 3. Note that the mud fraction is underrepresented for stations I1, I2, C3, C4 since the bulk sample was sieved on deck. However, on the basis of the results for stations UMI and UMC, which were not sieved, mud does not contribute more than 7% at either site. In general, stations from the impacted site have coarser sediment than those from the control site, although both sites are in effect gravelly sands. The samples for granulometry included also live and dead rhodoliths and since as already shown, the impacted site had larger rhodoliths than the control, a higher proportion of gravel at the impacted station is to be expected.

Values of quartile deviation (QD) based on the non-living sediment only (Table 3) show that the sediments from both grounds are poorly to moderately sorted but there are no obvious differences in sediment homogeneity between the control and impacted sites. In general, with the exception of C4, the median particle size for the impacted ground is higher than that for the control ground, reflecting a coarser sediment at this site, independent from the presence of rhodoliths.

The organic content of the sediment was found to be 45.34mg g^{-1} for UMI and 59.23mg g^{-1} for UMC. The slightly higher organic content at the control ground can be attributed to the higher mud content at this site.

Species richness

From the seasonal samples, 114 species of biota have been recorded from the impacted site and 129 species from the control. Thus the species richness is slightly higher for the control site. On the other hand, it is clear that both grounds are very rich in biodiversity.

Bottom-set gill-net experimental fishing

Large numbers of live rhodoliths were entangled with the nets on both grounds; 188 rhodoliths (total weight 5684.6g) were obtained from the impacted site and 110 rhodoliths (total weight 150.0g) from the control. It is significant that many of these rhodoliths were much larger than any sampled by grab. The largest rhodolith from the impacted ground had a maximum length of 85.90mm (weight 132.26g), while for the control site, the largest rhodolith had a long axis of only 46.50mm (weight 11.07g). Figure 7 shows the size distribution of rhodoliths fished from the impacted and control grounds. It is evident that rhodoliths from the impacted site are much larger than those from the control.

Fourteen species of fish were caught by the bottom-set gill-nets, of which twelve species were caught from the impacted site and three from the control (Table 4). Fish were clearly more abundant at the impacted site, while only *Mullus surmuletus* was common to both grounds.

Discussion

Disturbance can be defined as a group of processes that lead to the disruption or movement of sediments (Hall, 1994). These processes may include hydrodynamic action, bioturbation and churning caused by human activities, such as fishing (Hall, 1994). There are many pieces of evidence suggesting that the impacted ground is subjected to higher degrees of disturbance than the control ground, even if the source of this disturbance is difficult to identify. In turn, this disturbance seems to be enhancing rhodolith growth on the impacted ground since this has more, and larger, rhodoliths than the less disturbed control .

Mud content is higher at the control site. Since it is the hydrodynamic regime which determines the sedimentary characteristics of the seabed (Hall, 1994), the higher mud content of the control ground probably reflects quieter environmental conditions (Bosence, 1976). However the sorting coefficient of the sediments did not show any pattern.

The fact that more sediment was obtained by the van Veen grab at the impacted site than at the control reflects the difference in structure of the sediments. From the seasonal samples it resulted that erect algae occur more frequently in the control ground. Some algae were found exclusively at the control site; one example is *Codium bursa* J. Agardh. This species is a very slow growing alga (Vidondo & Duarte, 1995) and most of the specimens found attained large sizes (c. 8cm diameter). This, together with the higher abundance of erect algae at the control ground, also indicates relatively more stable conditions at this site. Additionally, although *Flabellia petiolata* (Turra) Nizamuddin is common at both sites, the binding of the sediment by rhizoids of this species and by the filamentous thalli of *Polysiphonia setacea* Hollenberg, is more evident in the control ground. This may explain the greater penetration of the grab at the impacted site.

A higher percentage of large rhodoliths (>8mm) was found at the impacted site. Algal growth continues until rhodoliths are of such a size that water movement is just enough to roll them and therefore the maximum size attained by a given rhodolith is determined by the strength of water movement (Harris et al., 1996). This implies that there is higher water movement at the impacted site than at the control site. However, Basso & Tomaselli (1994) caution against relating the size of the rhodoliths to water energy, since size is not a good indicator of weight. The latter varies depending on the internal structure of the rhodoliths, which may have a stone core.

The gross morphology of rhodoliths can be important in understanding the adaptive strategies of the species in response to their environment and variations in rhodolith morphology can be related to the intensity of disturbance in the environment (Steneck, 1986; Basso, 1996). Bosence (1976, 1983a) related the shape of rhodoliths to hydrodynamic properties of the seabed. He explained that spherical, densely branched rhodoliths are generally found in exposed areas, while open-branched rhodoliths are found in more stable environments. Dense branching is thought to arise from the continuous overturning of the rhodoliths and subsequent damage to the apical meristem (Bosence, 1976; 1983a). Other authors agree with Bosence (e.g. Bosellini & Ginsburg, 1971; Steneck, 1986; Di Geronimo & Giaccone, 1994; Basso, 1996), however some question the validity of relating shape to environmental conditions (Freiwald & Henrich, 1994; Freiwald, 1995; Steller & Foster, 1995) and the situation can be more complex.

In both the impacted and control sites, most of the rhodoliths showed a tendency towards a spherical shape and the most abundant morphotype was morph F, which has closed or compact branching. Thus, in both grounds there seems to be a degree of disturbance. However, the tendency for spherical, compact-branched rhodoliths is much more pronounced in the impacted site; here a greater percentage of rhodoliths have a higher sphericity and morphotype F is more abundant. Also, in the impacted ground, there is a higher proportion of morph D than in the control ground. Morph D encompasses spherical rhodoliths with a smooth surface, again indicative of high water movement. Steneck (1986) states that under high water movement, unbranched rhodoliths occur, due to abrasion with sediment. Morph E and B are more abundant in the control ground than in the impacted one. Morph E comprises rhodoliths with open branching while morph B includes delicate rhodoliths with very fine branches. Both are indicative of less disturbance at the control site.

Disturbance might be due to three main factors: (i) currents or episodic storm-induced turbulence, (ii) bioturbation and (iii) trawling.

Current data for the maerl grounds is not available, however currents measured 6.3m above the seabed in water 35m deep off the Northeastern coast of Malta only reached a maximum of 30cm s^{-1}, the average being 13cm s^{-1} (Drago, 1995). These currents were not related to weather conditions. Harris et al. (1996) state that a current of c. 80cm s^{-1} (at 100cm above the seabed) is needed to move a rhodolith c. 50mm in diameter at depths of 40-140m. The threshold velocity at which the rhodoliths would move increases with size, i.e. higher velocities are needed for larger rhodoliths (Harris et al., 1996). Since the mean size of the rhodoliths at the impacted ground is less than 25mm, it is possible that bottom currents can reach values which would be able to initiate rhodolith movement. Taking into consideration the maximum size of rhodoliths from the impacted ground (see bottom-set gill-nets results) however, the velocities required to move these would be much higher than 80cm s^{-1} and such currents are not likely around the Maltese Islands. Therefore, the water movement required to move these rhodoliths is probably not generated by bottom currents. Although bottom currents might not be enough to roll the larger rhodoliths, occasional violent storms might create enough bottom disturbance to move them (Bosellini & Ginsburg, 1971; Di Geronimo & Giaccone, 1994; Harris et al. 1996).

During foraging macroinvertebrates may move or fragment rhodoliths, or create pits and depressions in the sediment in which turbulence is generated (Hall, 1994; Basso & Tomaselli, 1994; Freiwald & Henrich, 1994; Freiwald, 1995). Large animals such as fish, especially species such as *Mullus surmuletus* and *Pagellus erythrinus* which feed on benthic organisms by rooting on the bottom (Fischer et al., 1987), are likely to move the rhodoliths during feeding. Since these two species were much more abundant on the impacted ground, rhodolith movement here may in part be an effect of a greater abundance of bioturbators.

The binding of sediment by algal rhizoids (as in *Flabellia petiolata*) or by the filamentous algae (as in *Polysiphonia setacea*) may also have a significant effect on the structure of the control ground by stabilising the surface and making the rhodoliths less susceptible to overturning. The settlement of algae on rhodoliths may also create competition for light (Wehrmann et al., 1995), while epiphytic algae growing on the maerl can trap mud thus smothering and limiting algal growth (Bosence, 1976). The relatively extensive algal cover on the control ground may actually be harmful to the maerl. Conversely, this implies that disturbance may have a positive effect on the impacted ground by disrupting maerl-binding algae and thus leaving the maerl free to roll over.

The impact of demersal fishing gear depends on the frequency of the event, the type of gear used and the nature of the seabed (Hall, 1994; Lindeboom & de Groot, 1998). In general, the passage of otter trawls results in flattening and reduction in complexity of the sea bottom, as well as in resuspension of fines (Lindeboom & de Groot, 1998). This indicates that otter trawling can have a severe impact on maerl beds, either by breaking the rhodolith thalli and reducing the complex structure of the beds, or through burial and abrasion of the rhodoliths by resuspended sediments. However, from the size and abundance of rhodoliths at the impacted site, it is hard to attribute a negative impact to otter trawling. Instead the rhodoliths at this site seem to be larger and more abundant than at the control.

Since bottom trawling within three nautical miles off the Maltese coast is illegal, trawling activities on these maerl beds may occur sufficiently infrequently to give enough time for the maerl to recover after each trawling event. In Malta there are only nine registered bottom trawlers, which represent c. 3% of the total number of licensed fishing vessels (Department of Fisheries and Aquaculture, personal communication). Thus the frequency of trawling anywhere around the Maltese Islands is probably low especially since trawling in Malta is seasonal (Department of Fisheries and Aquaculture, personal communication).

All bottom trawlers in Malta use otter trawls designed to catch demersal fish and epifaunal invertebrates (e.g. cephalopods) (Department of Fisheries and Aquaculture, personal communication). In such otter trawls contact with the bottom is mainly restricted to the otterboards, which penetrate the bottom; the groundrope on the other hand slides over the seabed (Lindeboom & Groot, 1998). That no significant negative impact on maerl beds was observed might be attributed to the low penetration of the otter trawls. Van Dolah et al. (1991) have recorded no impact of otter trawling on sandy and muddy bottoms in South Carolina and attributed this to the fact that the gear only slightly skims the bottom. Also, the coarser sediments at the impacted site mean that there is very little fine sediment which can be resuspended by the passage of trawling, resulting in little danger of rhodoliths becoming buried.

On the other hand the low intensity trawling that takes place locally might even have a positive effect on the maerl. If otter trawls simply skim the surface of the seabed, they might create the disturbance needed to roll but not damage the large rhodoliths. Trawling might also promote rhodolith growth by preventing the settlement of fleshy non-coralline algae on the maerl ground, which tend to bind the rhodoliths and prevent them from rolling.

Even if no significant negative impacts of trawling were evident in this study, the damage that demersal fishing gear can have on maerl beds must not be underestimated. Maerl grounds are very fragile habitats and where trawling is even of moderate intensity, severe deterioration of maerl beds may occur. It is thus very important to protect this habitat and the low impact of trawling on Maltese maerl ground studied here is mainly due to it being fortuitously situated within the three nautical mile no-trawling zone.

The impacts of bottom-set gill-nets are quite evident. Large rhodoliths (up to 85.9mm longest diameter) get entangled with the nets and are removed and destroyed, thus this type of fishing would definitely deplete the rhodolith stock. Due to the slow growth rate of rhodoliths (Bosence, 1983b), this type of fishing activity might have a severe impact on the maerl grounds in the long term. How much rhodoliths a gill-net entangles depends on the currents present since it is these that cause deflection of the net from the vertical and contact with the bottom. Thus, the fact that less rhodoliths were entangled at the control site, may also reflect differences in the current regimes of the two sites.

Although this type of fishing can have a severe negative impact on the maerl beds, the frequency of occurrence is probably low since it is not favourable for fishermen to set their nets on maerl grounds due to the resulting damage to the gear.

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Figure 1	Location of maerl beds (shaded area) off the Northeastern coast of the Maltese Islands (inset) and the location of the transects off St. Paul's Islands and off Qawra/Ghallis. Sikka l-Bajda is a submerged rocky shoal lying c. 10m below the surface at its shallowest point; the map shows the shoal's 20m depth contour. Only those stations that contained live rhodoliths are shown.
Figure 2	The ten morphological types used to classify rhodoliths.
Figure 3	Graph showing the % weight of live coralline algae in each sieve for impacted (I1; I2; UMI) and control (C3; C4; UMC) stations.
Figure 4	The mean longest axis of 100 randomly picked rhodoliths from impacted (I1; I2; UMI) and control (C3; C4; UMC) stations. Error bars represent standard deviations.
Figure 5	The mean percentage frequency of the rhodoliths in each sphericity class for impacted (I1; I2; UMI) and control stations (C3; C4; UMC). Error bars represent standard deviations.
Figure 6	The mean percentage frequency of each morphotype in impacted (I1; I2; UMI) and control (C3; C4; UMC) stations. Error bars represent standard deviations.
Figure 7	The size distribution of rhodoliths entangled by the bottom-set gill-nets at the impacted and control sites.

Table 1

The total mass of sediment and of the live coralline algae collected from the impacted and control stations sampled in April and November 1996. The percentage live coralline algae by weight and the percentage cover are also given.

Site	Station Code	Date Sampled	Depth (m)	Mass of sediment (g)	% live coralline algae	% cover of live coralline algae
mpacted	I1	7 April 1996	46	4556.0	18.35	>100
	UMI	6 November 1996	46	3515.3	10.96	58.40
	I2	7 April 1996	61	4205.5	35.80	>100
Control	C1	8 April 1996	49	1734.9	2.01	8.77
	C2	8 April 1996	47	1695.3	2.08	6.82
	UMC	6 November 1996	53	1695.5	4.45	24.8
	C3	8 April 1996	54	1413.8	10.88	17.20
	C4	8 April 1996	62	3530.0	18.4	>100
	C5	8 April 1996	65	1540.5	0.03	0.78
	C6	8 April 1996	75	1940.4	0.02	0.59
	C7	8 April 1996	102	1423.5	8.88	11.7

Table 2

The species composition of rhodolith-forming coralline algae for stations I2 and C4. Note that *Phymatolithon calcareum* and *Lithothamnion minervae* could not be distinguished on gross morphology alone.

Site	Species	% of total live coralline algae
Impacted (I2)	*Lithothamnion corallioides* Crouan P.L. & Crouan H.M.	13.4
	Phymatolithon calcareum (Pallas) Adey & McKibbin /*Lithothamnion minervae* Basso	46.7
	Neogoniolithon brassica-florida (Harvey) Setchell et Mason	12.3
	Neogoniolithon brassica-florida (Harvey) Setchell et Mason based on other rhodoliths	27.6
Control (C4)	*Lithothamnion corallioides* Crouan P.L. & Crouan H.M.	42.0
	Phymatolithon calcareum (Pallas) Adey & McKibbin /*Lithothamnion minervae* Basso	2.5
	Peyssonnelia rosa-marina Boudouresque & Denizot	0.4
	Mesophyllum sp.	16.0
	Neogoniolithon brassica-florida (Harvey) Setchell et Mason	39.0

Table 3

The relative proportions of gravel (sediment >2mm), sand (sediment 2mm-63µm) and mud (sediment <63µm), in the total sediment (living and non-living), and the sorting coefficient (quartile deviation, QD) and median particle diameter for the non-living fraction, for control and impacted stations.

Site	Station	% gravel	% sand	% mud	Median particle diameter (mm)	QD	Sorting class (Giere, 1993)
Impacted	I1	41.23	58.69	0.10	1500	0.64	moderately well sorted
	I2	53.75	46.17	0.09	1000	1.20	poorly sorted
	UMI	44.78	53.24	1.79	1680	0.83	moderately sorted
Control	C3	34.02	65.20	0.78	980	1.04	poorly sorted
	C4	40.91	58.35	0.72	1480	0.72	moderately sorted
	UMC	27.61	65.38	6.75	1200	0.93	moderately sorted

Table 4

The species and abundance of fish sampled by bottom-set gill-nets.

Species	**Abundance**	**Station**
Aulopus filamentosus (Bloch)	1	Control
Boops boops (Linnaeus)	1	Impacted
Dactylopterus volitans (Linnaeus)	1	Impacted
Diplodus vulgaris (E. Geoffroy St. Hilaire)	1	Impacted
Echiichthys vipera (Cuvier)	1	Impacted
Mullus surmuletus Linnaeus	15/1	Impacted/Control
Mustelus mustelus (Linnaeus)	2	Impacted
Pagellus erythrinus (Linnaeus)	35	Impacted
Pagrus pagrus (Linnaeus)	2	Impacted
Scyliorhinus stellaris (Linnaeus)	1	Control
Seriola dumerili (Risso)	1	Impacted
Serranus cabrilla (Linnaeus)	3	Impacted
Spondyliosoma cantharus (Linnaeus)	3	Impacted
Trachinus sp.	1	Impacted

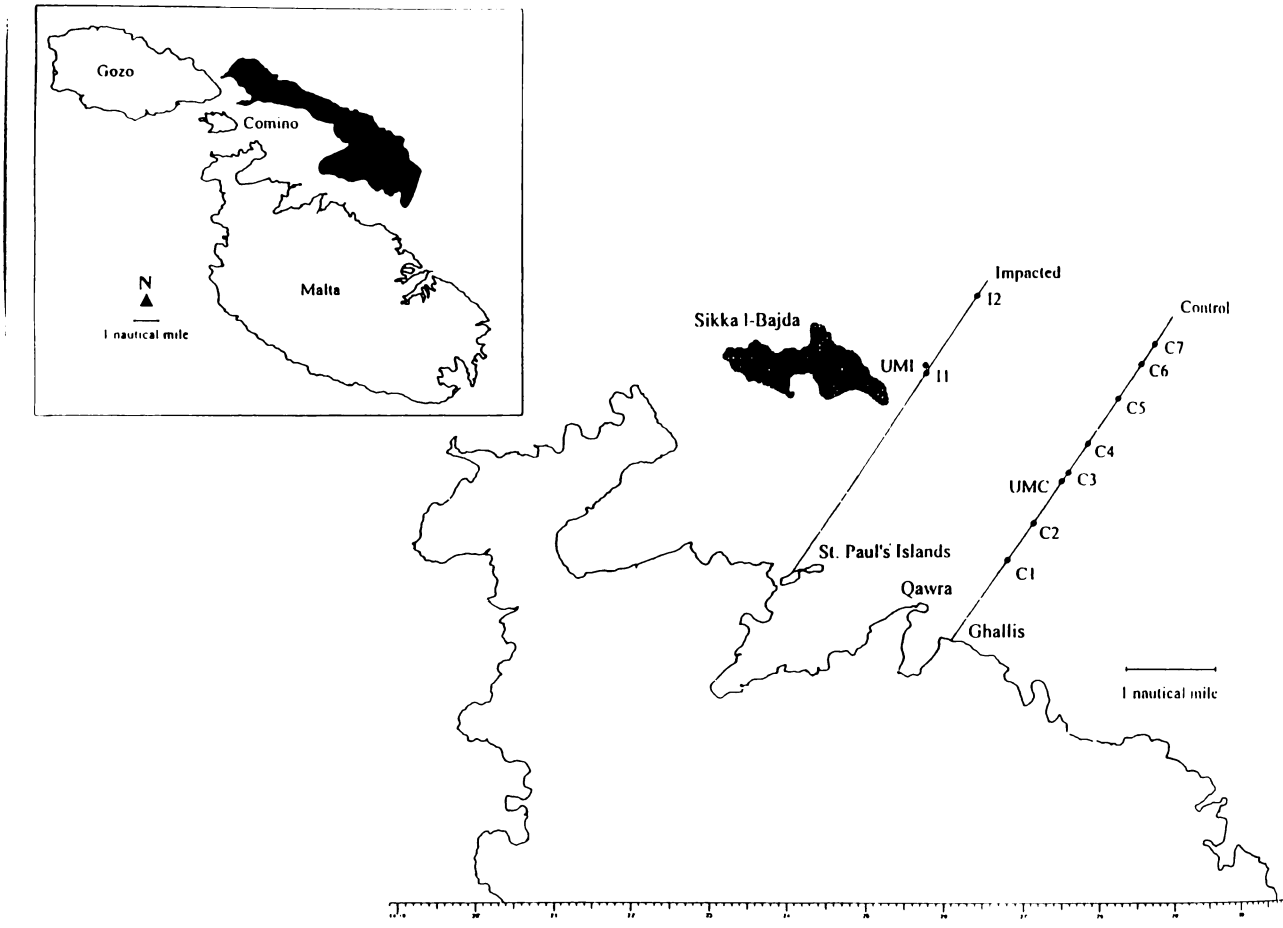


Figure 1 Location of maerl beds (shaded area) off the Northeastern coast of the Maltese Islands (inset) and the location of the transects off St. Paul's Islands and off Qawra/Ghallis. Sikka l-Bajda is a submerged rocky shoal lying c. 10m below the surface at its shallowest point; the map shows the shoal's 20m depth contour. Only those stations that contained live rhodoliths are shown.

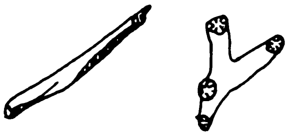
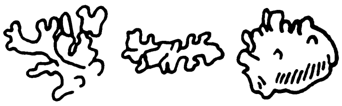
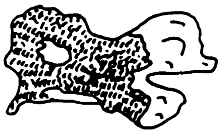
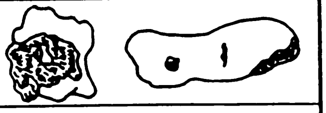
Morph type	Description	Drawing of morph type
A	Thin encrusting growth of 'pink' coralline on an animal substratum (e.g. a bryozoan colony)	
B .	Very delicate, fine, thin branches	
C	Laminar (sheet-like)	
D	Spherical rhodoliths with a smooth surface, covered by 'pink' coralline	
E	Long, medium - thin branches (open branching)	
F	Short, finger-like branches (compact/closed branching)	
G	Rhodoliths with a very rugged and rough surface	
I	Dark red smooth rhodoliths	
J	Tiny rhodoliths covered by a "mix" of "colours" (different species of corallines)	
K	Large coralline colony growing on an animal	

Figure 2 The ten morphological types used to classify rhodoliths.

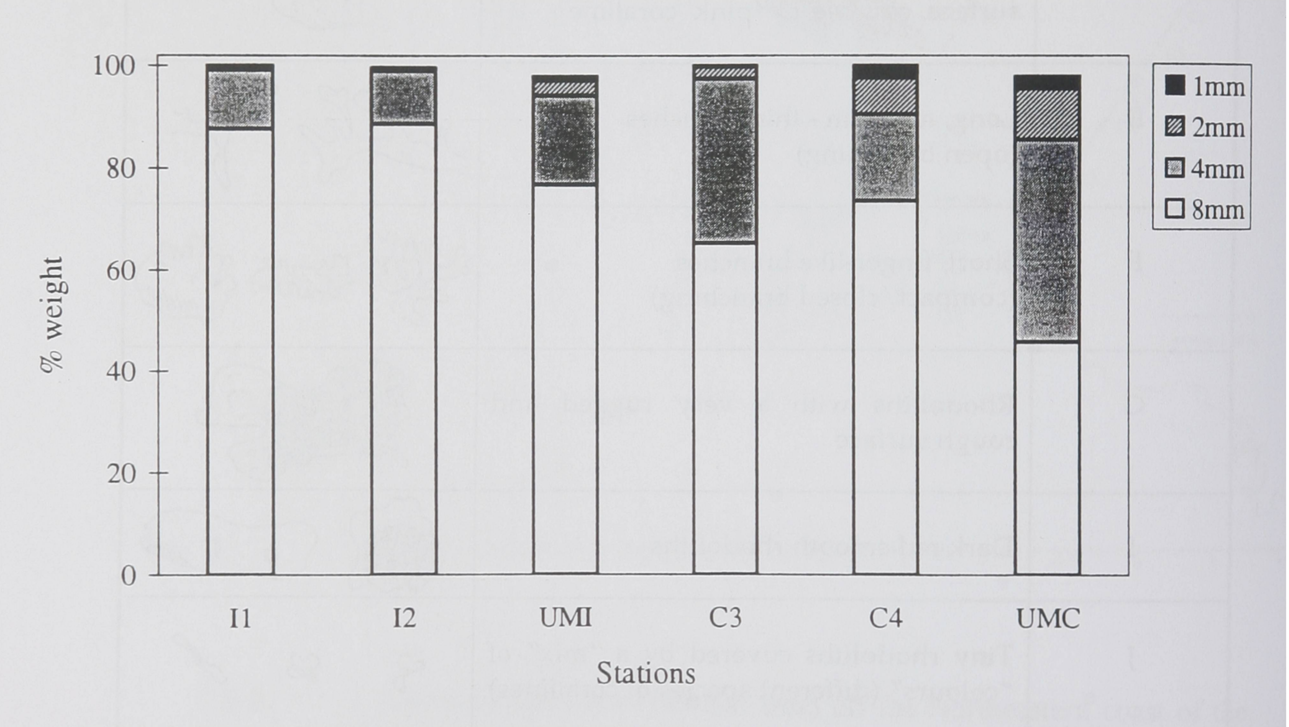


Figure 3 Graph showing the % weight of live coralline algae in each sieve for impacted (I1; I2; UMI) and control (C3; C4; UMC) stations.

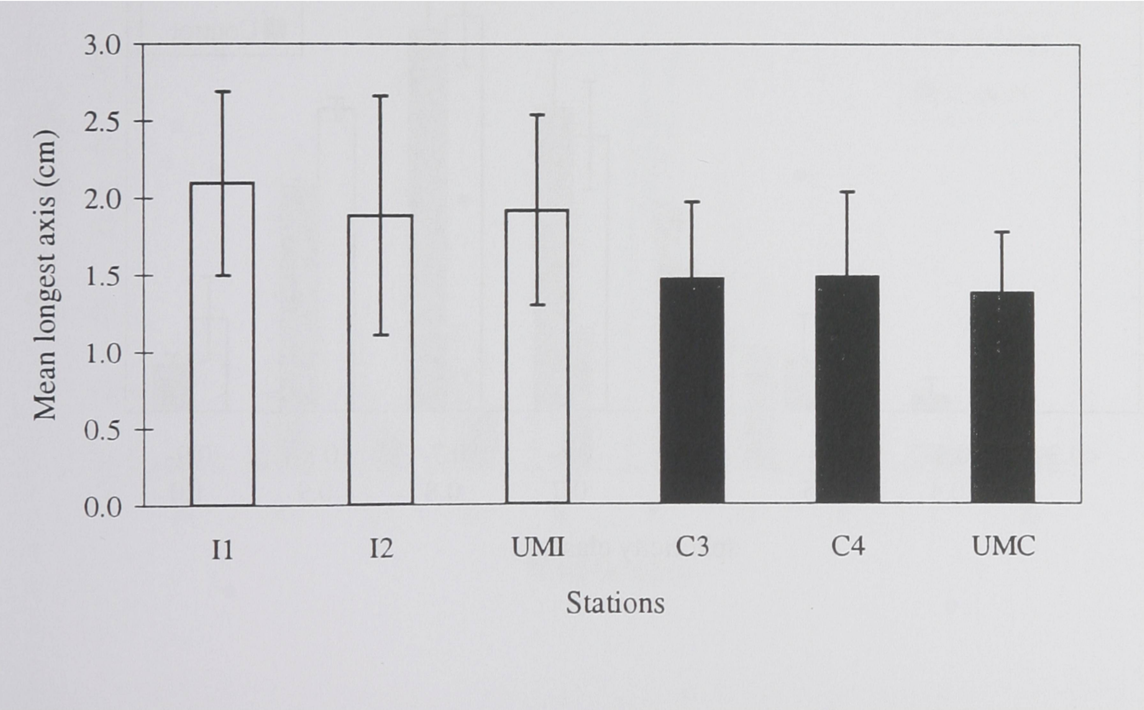


Figure 4 The mean longest axis of 100 randomly picked rhodoliths from impacted (I1; I2; UMI) and control (C3; C4; UMC) stations. Error bars represent standard deviations.

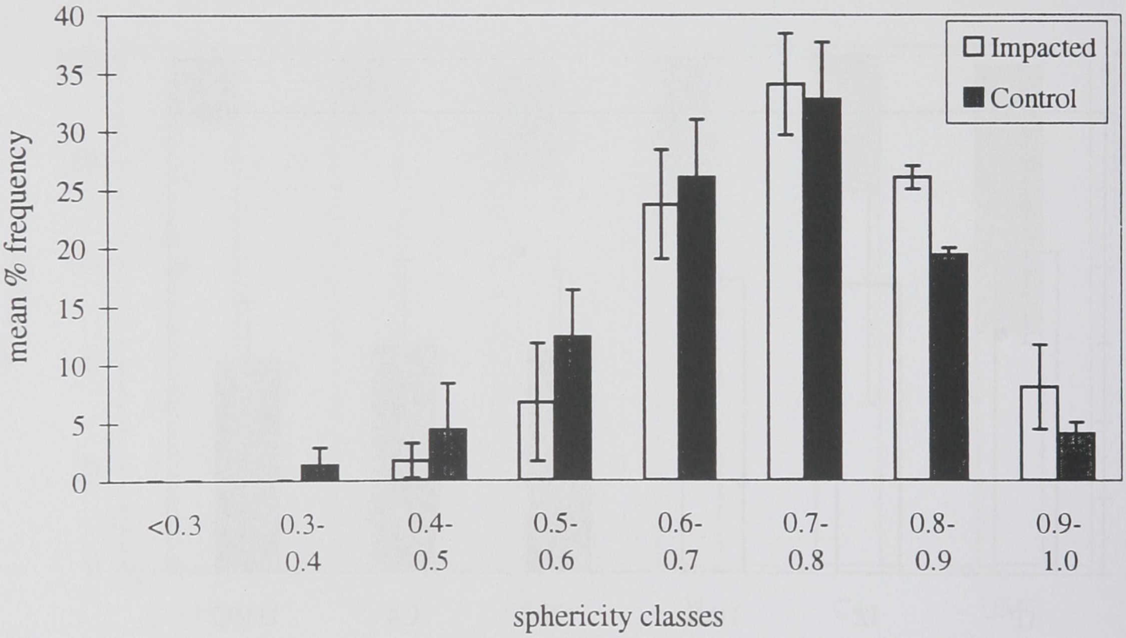


Figure 5 The mean percentage frequency of the rhodoliths in each sphericity class for impacted (I1; I2; UMI) and control stations (C3; C4; UMC). Error bars represent standard deviations.

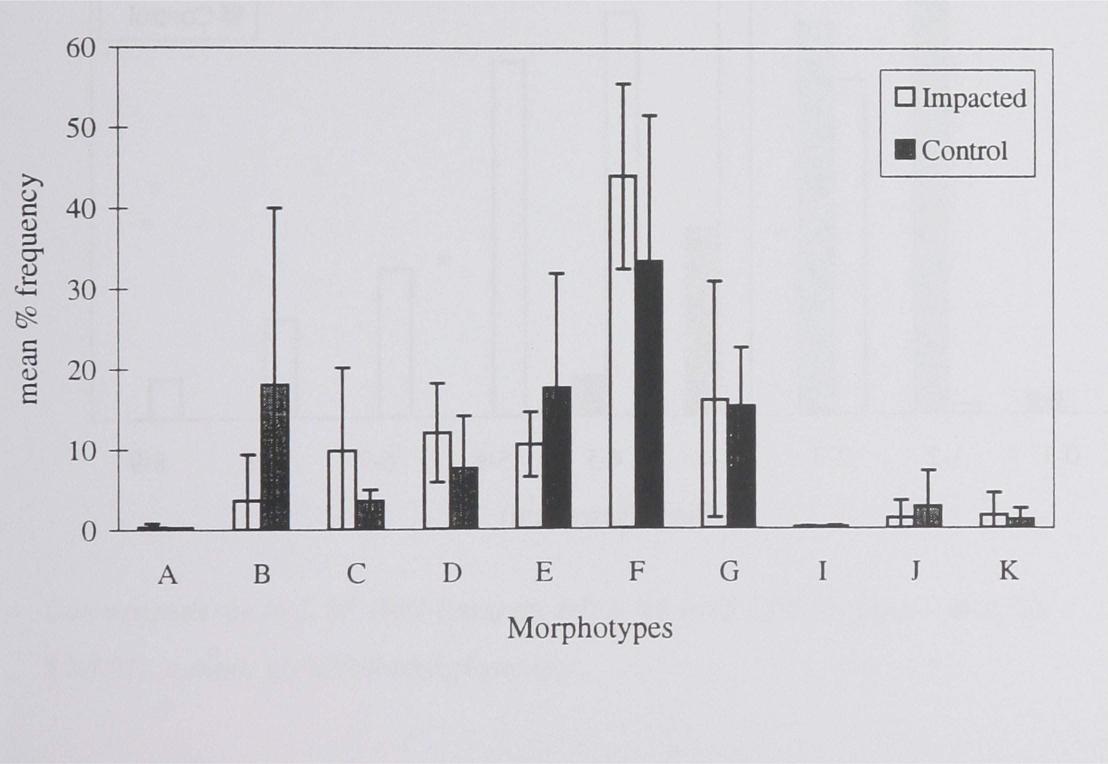


Figure 6 The mean percentage frequency of each morphotype in impacted (I1; I2; UMI) and control (C3; C4; UMC) stations. Error bars represent standard deviations.

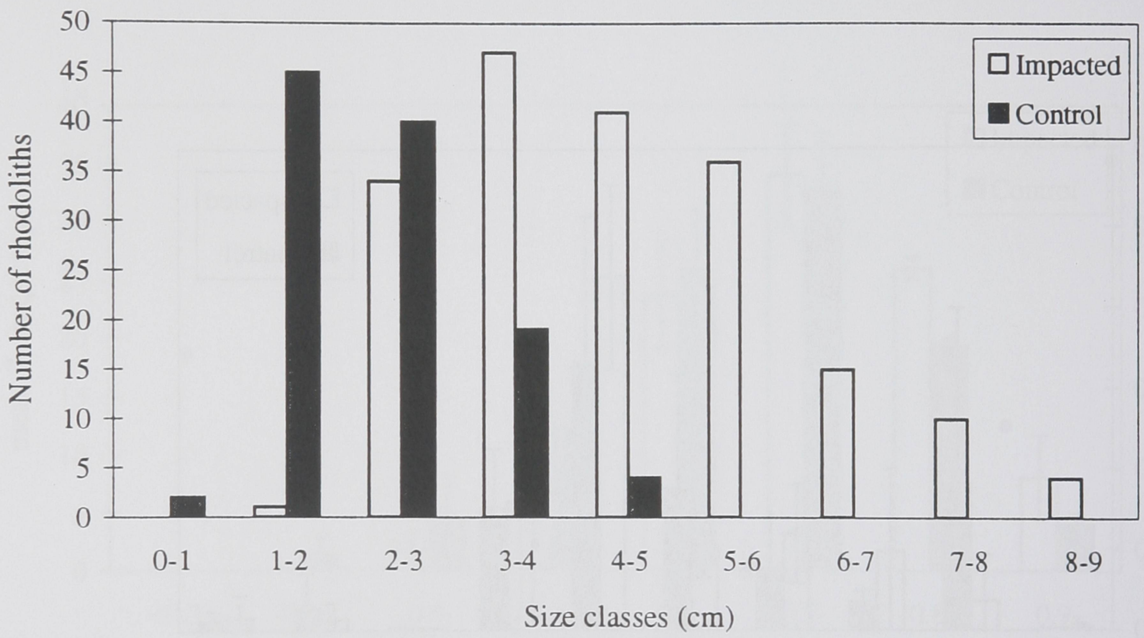


Figure 7 The size distribution of rhodoliths entangled by the bottom-set gill-nets at the impacted and control sites.

Upogebia deltaura (Crustacea, Thalassinidea) in Clyde Sea maerl beds, Scotland

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ABSTRACT

Burrows inhabited by *Upogebia deltaura* (Crustacea: Thalassinidea) were studied over a two-year period on two maerl beds at 10 m below Chart Datum (CD) in the Clyde Sea area, Scotland. Labelled burrows proved to be stable features on each ground, with animals able to withstand the impacts of scallop dredging and storm disturbance by re-building the damaged upper sections of their burrows. Resin casts excavated using an air-lift showed that these burrows were inhabited by single individuals. Burrows were deeper, larger and more complicated than was previously thought typical for *U. deltaura* and other members of the genus. Mapping of burrow systems revealed average densities of 2.9 individuals m^{-2} with up to ten openings m^{-2}. These elusive animals were the deepest burrowing megafauna (to 68 cm) and the most abundant large crustaceans within the maerl bed habitat.

INTRODUCTION

Maerl beds are calcareous gravels built up over 100s–1000s of years by the accumulation of unattached nongeniculate Corallinaceae (Rhodophyta). They occur worldwide (Bosence, 1983; Foster et al., 1997) forming near-shore habitats that typically exhibit high benthic biodiversity and biomass (Cabioch, 1968; Keegan, 1974; Bosence, 1979; Mora Bermúdez, 1980). European maerl beds are of conservation importance (Council Directive 92/43/EEC, 1992) although numerous activities currently threaten these habitats, notably direct exploitation (Cabioch et al., 1997), eutrophication (Grall & Glémarec, 1997a,b) and towed demersal fishing gear (Hall-Spencer, 1995, 1998). The present study was carried out as part of a wider investigation into the impacts of scallop dredging on the ecology of maerl habitats (BIOMAERL, 1998).

Preliminary *in situ* observations on maerl grounds at several sites in Scotland revealed that large burrows of similar external appearance were common and important features of the habitat. Use of a range of remote sampling gear on maerl beds in the Clyde Sea area failed to capture the organisms responsible but subsequent use of a diver-operated air-lift, following methods developed on Irish maerl grounds

(Keegan & Könnecker, 1973), revealed that these burrows were occupied by the thalassinidean shrimp *Upogebia deltaura* (Leach).

Thalassinideans are commonly known as mud-shrimps since most species, including *Upogebia* spp., are found in muddy sediments. *Upogebia deltaura*, however, has been recorded in association with coarser sediments (gravels and shell-sands) for example in Norway (Samuelsen, 1974), Sweden (Gustafson, 1934; Tunberg, 1986), Scotland (Astall et al., 1997) and the Irish Sea (Swift, 1993; Hughes & Atkinson, 1997). A search of records show that maerl beds may be an important habitat for *U. deltaura*, since these shrimps have been located amongst maerl throughout the north-east Atlantic with records from Kilkerrin Bay, Ireland (Keegan, 1974), the Fal Estuary, England (Hardiman et al., 1974), the Bay of Brest, France (Grall, personal communication) and the Ria de Arosa, Spain (Sánchez Mata, personal communication). The southern extent of *U. deltaura* is not known due to sparse records and taxonomic confusion. Dworschak (1983) described three burrows attributed to *U. deltaura* from the Adriatic Sea, but indicated, based on unpublished information, that they could have been those of *U. mediterranea* which was subsequently confirmed (Dworschak personal communication). The situation is now further complicated by the possibility that *U. mediterranea* Noel (Noel, 1992) may be a subspecies of *U. nitida* (A. Milne Edwards) (d'Udekem d'Akoz, 1995).

There have been few published studies on the biology of *U. deltaura* in contrast with those carried out on other upogebiids (e.g. Ott et al., 1976; Dworschak, 1983, 1987a,b, 1988, 1992; Mukai et al., 1984; Posey et al., 1991; Nickell & Atkinson, 1995). Recent work on the behaviour and physiology of *U. deltaura* (Astall et al., 1997) emphasized difficulties experienced with investigating their burrows *in situ*. Attempts to cast burrows in the field using polyester resin were only partially successful due to difficulties in extracting casts from the coarse substratum. The present contribution describes a successful adaptation of the methods used by Astall et al. (1997) to obtain burrow casts of these elusive animals. The prevalence and dynamics of these burrow systems were investigated on Clyde maerl grounds and monitored to determine the effects of natural (storms) and human (scallop dredge) disturbances.

MATERIALS AND METHODS

Sampling sites

This study was carried out on two maerl beds in the Clyde Sea area, Scotland (Figure 1) where tides are semidiurnal with a mean range of 3.1 m on springs and 1.8 m on neaps. The sites were Creag Gobhainn (Site 1) in Loch Fyne (56°00.601'N 005°22.148'W, position determined by Trimble Differential Global Positioning System) and Stravanan Bay (Site 2) (55°45.323'N 005°04.265'W) off the Isle of Bute. Site 2 had been heavily impacted by scallop dredging in recent years whereas Site 1 was unimpacted due to the prohibitive presence of a seabed telecommunications cable lain in 1968. Visual inspections of the distribution of *Upogebia deltaura* burrows were carried out during ~70 SCUBA dives in these areas during 1996–98. Each bed was marked with a permanent buoy at -10 m CD as a datum for diving operations and the sites were investigated at approximately two monthly intervals from May 1996 – June 1998.

On each sampling occasion, salinity and temperature were measured 10 cm above the bottom and a current meter (Model 308, Valeport Ltd, Devon) was deployed on spring, neap and mid-tides for periods of 5–36 hours, 1 m above the bottom.

Granulometry

Sediment samples were taken at -10 m CD on both sites using 10 cm diameter, 25 cm long hand-held cores. Three replicate cores were taken at Site 1 which was level and relatively homogeneous, Site 2 was megarippled (see below); three replicate cores were taken on peaks of the megaripples and three on the troughs to quantify differences in their granulometry. Cores were horizontally sectioned at 4 cm intervals and subjected to granulometric analysis following Folk (1974).

Remote sampling

The two maerl deposits were sampled bimonthly during 1996–98 using replicate 0.1 m^2 van Veen grabs (totals of 85 taken at Site 1 and 105 at Site 2) and a 75 cm-wide ring-dredge (totals of 12 taken at Site 1 and 14 at Site 2). On one occasion divers took measurements of the pits excavated by these sampling devices at Site 2.

Appearance of burrow openings

Throughout, the external appearance of burrows were photographed using a Nikonos V camera, 35 mm lens, 64 ASA Kodachrome film, YS-60 Sea & Sea strobe and standard close-up attachments. At Site 2, three hand-held stainless steel Senckenberg box cores (8x15 cm area, 20 cm long; Bouma, 1969) were used to retrieve the top sections of *U. deltaura* burrows in September 1996. On return to the laboratory, these box cores were sectioned vertically to reveal burrow lumens and organisms embedded in the burrow lining.

Air-lifting

Methods for the use of an air-lift on maerl sediments followed those of Keegan & Könneker (1973). At each site, six 1 m^2 quadrats were excavated at 4 cm intervals to give depth-stratified samples to 72 cm below the surface of the deposit in June–July 1996. The density and orientation of *U. deltaura* burrows were recorded together with the burrowing depth of other species of megafauna.

Burrow casts

Burrow casts were made at both sites using techniques adapted from those described by Atkinson & Chapman (1984). Polyester resin (manufactured by Scott Bader, marketed as SP701PA by Trylon Ltd, Wollaston, UK) was thinned using 10% by volume of styrene monomer and mixed with peroxide catalyst (2% by volume) in a 7 l plastic watering can. In initial casting exercises (September/October 1996) divers slowly poured the resin directly into the narrow burrow openings, a process that took up to an hour per burrow. Subsequently (November/December 1996) the top 4 cm of maerl was scraped aside to remove the narrow openings and reveal the wider lumen of the descending shaft. Ten centimetre diameter plastic collars were then placed around selected burrow openings to minimize spillage of resin. Burrow openings were identified by pushing numbered flags (constructed from PVC tape attached to lengths of aluminium welding rod) into the sediment beside burrow openings, within each collar. Casts were recovered the day after the resin was poured, with divers using an air-lift to excavate the casts and a Nikonos V camera (see above) to photograph burrow orientation *in situ*. In the laboratory, casts were photographed, measured and weighed. Burrow volume was computed from cast weight and resin density (1.2). Burrow terminology follows that of Nickell & Atkinson (1995), based on that of Frey (1973). Thus, 'opening' describes an aperture at the sediment surface, 'shaft' describes a vertical or dominantly vertical structure, 'tunnel' describes a structure with an oblique to horizontal orientation, 'sump' describes a downwardly directed blind-ending shaft and 'burrow system' refers to a relatively complex individual burrow.

On retrieval, some casts contained embedded *U. deltaura* these specimens were injected with 4% formalin and their size was determined from X-ray photography of the cast. Measurements of carapace length were taken from the tip of the rostrum to the posterior edge of the carapace, following the methods of Tunberg (1986).

Burrow mapping

A 2x5 m area of seabed was marked out using pegs to give a grid of ten 1 m^2 quadrats at each site. The densities of burrows and burrow openings were surveyed in November/December 1996. Each quadrat was investigated for visible openings. When one was located it was irrigated using a hand-operated pump (Alvey Reels, Australia) fitted with a nozzle of 1 cm internal diameter. Connected openings were indicated by a plume of fine sediment which was forcibly ejected from the lumen of the burrow system. These openings were mapped on a writing 'slate' and the distances between openings were measured. This process continued over several dives until all of the burrows within the 10 m^2 area had been mapped. Where burrows connected to openings outside a quadrat, the proportion of the burrow within the area was estimated. For example, where burrows had two openings within a quadrat and one outside, this was counted as 0.67 of a burrow within that quadrat.

Effects of wave disturbance

At each site, a gauge (Figure 2) designed to measure changes in sediment macro-topography due to wave action (see Napier, 1993), was used approximately bimonthly between May 1996 and June 1998. The 2.4 m long gauge was photographed 15 times along a 32 m transect running south-west starting from a permanent site marker on each maerl bed. Resulting photographs were used to record changes in seabed topography along the two transects. Divers recorded the effects of wave-induced sediment transport on the appearance and spatial arrangement of *U. deltaura* burrow openings. Ten of the burrows mapped within each 2x5 m area (above) were selected haphazardly and marked with pre-labelled aluminium rods in November/December 1996. These marked burrows were re-examined bimonthly up to June 1997 to monitor changes in burrow density and position.

Effects of scallop dredging

In May 1996 a gang of three standard Newhaven scallop dredges (each 75 cm wide) were towed between marker buoys layed out at -10 m CD at each site, following methods given by Hall-Spencer (1995). They were towed at the usual commercial speed of 3.5 km h^{-1} over approximately 100 m which left dredged areas of ~250 m^2. Immediately after dredging, divers equipped writing slates counted *U. deltaura* burrow openings in 40 1 m^2 quadrats on dredge tracks and 40 1 m^2 quadrats on the adjacent maerl. Quadrat placement was haphazard. Notes were also made on damage to visible fauna and changes in seabed topography. These surveys of dredge tracks and adjacent seabed were repeated approximately bimonthly at each site over a subsequent period of 12 months.

RESULTS

Sampling sites

At both sites, *in situ* visual inspections of the distribution of *Upogebia deltaura* burrows in the period 1996–98 revealed that they were strongly associated with the maerl substratum. At Site 1 the *U. deltaura* burrows occurred within maerl that formed a bank running parallel to the shore along a gently sloping strip covering an area of 17.5 ha between -6 m and -14 m CD. At Site 2 the *U. deltaura* burrows occurred within maerl over an area of 6.75 ha from -6 m to -14.7 m CD on a shoal situated ~500 m off the coast of the Isle of Bute. The depth distribution of *U. deltaura* was similar at both sites. Maerl graded into sandy and rocky areas shallower than -6 m CD where there were no burrowing thalassinideans present. Below -15 m CD, the maerl at both sites became more muddy and air-lifting in the area showed that *U. deltaura* was replaced by *Upogebia stellata* (Montagu). The only thalassinideans present in the permanently marked areas at -10 m CD were *U. deltaura*.

Salinity and temperature were very similar at the two sites, variations in bottom water salinity were slight (31–33 psu) and temperature readings ranged from 6.0°C (February 1997) to 14.1°C (September 1997). Bottom currents at Site 1 were generally faster (up to 54 cm s^{-1}) than at Site 2 (up to 11 cm s^{-1}).

Granulometry

The top 4 cm of sediment collected in cores at both sites was very coarse (40–70% gravel) with the proportion of sand and mud increasing with depth into the cores. The megarippled topography of the maerl at Site 2 (see Figure 2) exhibited pronounced differences in granulometry with clean gravel (<4% fine sand and mud) on the ripple peaks compared with more mixed sediment (~15% fine sand and mud) in the ripple troughs. The subsurface sediment at Site 2 was coarse with 50% gravel, 31% coarse sand, 14% fine sand and 4% mud at 20–24 cm below the surface of the deposit. At Site 1, the sediment surface was level, overlying predominantly coarse sand with 12%

gravel, 49% coarse sand, 24% fine sand and 14% mud at 20–24 cm below the sediment surface.

Remote sampling

Dives made immediately after van Veen grab and ring-dredge sampling revealed that the grabs penetrated <15 cm into the sediment and the ring-dredge <23 cm. Both types of gear often exposed the distinctive lumens of *U. deltaura* burrows (see below) but none of the 190 0.1 m^2 grab samples or the 26 qualitative ring-dredge samples caught *U. deltaura*.

Appearance of openings

At both sites, burrow openings were flush with the sediment surface (cf. the mounds or funnel openings found in some thalassinidean species – see Nickell & Atkinson, 1995) and were markedly constricted to diameters <7 mm. Many burrow openings were not visible to divers since they were occluded by the open lattice arrangement of the surface layer of maerl gravel. The most obvious burrow openings were surrounded by circular patches (to 12 cm in diameter) of fine grey sediment that had been ejected from the burrow (Figure 3A). This ejected sediment contrasted with the pink live maerl and the brown to black maerl gravel that lay dead on the surface. No obvious seasonal differences in external burrow morphology were discerned. When probed, coarse shell and maerl fragments collapsed into the wider, underlying burrow shaft revealing distinctive smooth walls and a circular transverse section (Figure 3B). When these damaged openings were revisited some minutes later, *U. deltaura* were sometimes seen repairing the walls of the openings from within the burrow. Throughout this study (115 hours of *in situ* observations) no mud-shrimps were seen on the sediment surface.

Sub-surface burrow morphology and associated fauna

Each of the vertically sectioned Senckenberg cores showed that burrows were lined with a distinct layer of mud 4–8mm thick that the inhabitants had pushed into the interstices of the surrounding gravel to form a very smooth tube of circular transverse section. The light brown colour of the burrow wall sediment indicated that it was well oxygenated. This colour contrasted with the darker, reduced sediment in deeper parts of the sediment column. The surface shafts averaged 19 mm in diameter and narrowed down to ~7 mm within 2–6 cm of the seabed surface (Figure 4A,B). The narrow conduits to the overlying water column were not mud-lined. Each core contained individuals of the bivalve *Mysella bidentata* (Montagu) (to 3 mm in length) embedded on the innermost surface of the burrow linings.

Air-lifts

At both sites, once the top 4 cm layer of maerl had been removed it was possible to clearly see the mud-lined shafts of *U. deltaura* burrows descending into the sediment below. The six 1 m^2 quadrats at Site 1 contained 2–7 descending shafts in the upper layer, those at Site 2 had 3–10 descending shafts. The burrow walls were firm and could be traced into the sediment using the air-lift. Each burrow had one occupant and separate burrow systems came to within a few centimetres of each other within the three-dimensional lattice of the sediment below, but on no occasion were they observed to join. At both sites, most tunnels were in the 20–32 cm depth range and the deepest sump portions of the burrow systems were up to 68 cm below the sediment surface. Other species of burrowing megafauna (e.g. the holothurian *Neopentadactyla mixta* (Ostergren)) were abundant on both maerl beds and were found at considerable depths within the sediment (Table 1). *Upogebia deltaura* was consistently the deepest-burrowing organism present, followed by mature individuals of *Mya truncata* L. The largest *U. deltaura* collected was an ovigerous female (total length 62 mm).

Burrow casts

The technique initially used, whereby resin was poured directly into the narrow burrow openings, provided casts showing distinctive near-surface constrictions (Figure 4B). However, this method was time-consuming and the openings often became blocked so that only small portions of the burrow were cast. Removal of the top section of burrows allowed resin to be poured more quickly and gave eight casts that were >50% complete. Complete resin casts were not obtained due to blockages created either by the body of the inhabitant, by back filling of the burrow by the animal or due to seawater trapped within the burrow lumen. Typical casts (1 & 4 in Table 2) are shown in Figure 4C–F showing the depth and complicated nature of these structures. Characteristics of the eight >50% complete casts are provided in Table 2. Use of an air-lift enabled the casts to be recovered without breakage. An added advantage was that the tunnels and shafts of the portions of the burrow that had not been cast could be traced through the maerl gravel due to their firm mud-lined walls. Photographs taken with the casts *in situ* (Figure 5) allowed accurate orientation of the casts. Consistent features of the casts were their circular transverse section and regular diameter along shafts and tunnels which constricted at openings to the surface and widened at blind endings. All junctions were bifurcate. Casts of the tunnels and shafts were very smooth, usually with *Mysella bidentata* attached. Sumps, in contrast, were rough with pieces of maerl gravel attached indicating that they were not lined with mud to the same degree.

A combination of resin casting and use of an air-lift showed that each burrow was inhabited by a single individual and did not link up with other burrow systems. Four of the eight >50% complete resin casts had a *U. deltaura* embedded within the resin, the lengths of which are given in Table 2.

Burrow mapping

Table 3 shows the numbers of burrow systems encountered in 2x5 m areas marked out on each site. Use of a pump revealed the position of openings that were occluded by surface maerl when a plume of fine sediment was ejected from the burrow system.

At both sites, the majority of burrows had two openings (68%) and the remainder had three. Two-holed burrows covered a smaller area, on average, with openings as little as 11 cm apart, whereas some of the structures with three openings were very extensive with openings up to 145 cm apart. Site 2 had the highest density of *U. deltaura* with a mean of 2.9 burrows m^{-2} and 3–10 openings m^{-2}. Site 1 had a mean of 1.9 burrows m^{-2} and 2–7 openings m^{-2}.

Effects of wave disturbance

At both study sites, burrow densities remained remarkably stable over the 1996–1998 period. At Site 1, ten marked burrow openings remained in the same configuration throughout a seven-month monitoring period. This site was relatively sheltered and remained undisturbed by wave action throughout the survey; no changes were recorded in the gross topography of the ground from 1996–1998 with dead *Aequipecten opercularis* (L.) shells seen lying in the same position on the sediment surface throughout. By contrast, Site 2 was more exposed to prevailing southwesterly winds. For most of the period the sediment remained stable but large-scale shifts in the coarse upper layer of maerl occurred during two storms in the winter of 1996/1997 and one in January 1998 leading to a rearrangement of the gravel megaripples (Figure 2). Observations in the weeks after these storms showed that the mixed sediments of the subsurface (>12 cm) layer of maerl had been unaffected allowing *U. deltaura* to remain in place. Seven burrow markers were relocated after the storms of 1996/1997, the adjacent *U. deltaura* had rebuilt the surface portions of their burrows to conform to the shifted maerl topography.

Effects of scallop dredging

At both sites, dives undertaken immediately after fishing revealed distinctive 2.5 m wide tracks where teeth on the three dredges had raked through the top 10 cm of sediment, bringing fine sediments to the surface and leaving a trail of smashed sessile megafauna such as the bivalve *Ensis arcuatus* (Jeffreys) and the heart-urchin *Spatangus purpureus* O.F. Müller. Bodies of *U. deltaura* were not amongst the carrion visible on the sediment but nearly all burrow openings had been erased. The shrimps rebuilt the upper sections of their burrows within a week. After one month there were no significant differences in the densities of burrow openings on impacted and unimpacted areas of the maerl beds (ANOVA, $P>0.05$). At Site 1, a mean density of 4.52 m^{-2} openings (SE = 1.3, N = 40) were recorded on the dredge track compared with 4.02 m^{-2} (SE = 0.9, N = 40) on the adjacent control area. At Site 2, a mean of 7.70 m^{-2} openings (SE = 2.5, N = 40) were recorded on the dredge track compared with 6.64 m^{-2} (SE = 2.1, N = 40) on the adjacent control area.

The dredge tracks were easily visible to divers for 12 months after the initial disturbance at Site 1 whereas they were erased by shifting sediment during winter storms in 1996/1997 at Site 2. Thus at both sites, while many large, sessile organisms on or near the sediment surface were killed by the scallop dredges, the density of newly constructed burrow openings showed that survival rates of *U. deltaura* were high.

DISCUSSION

This study showed that *Upogebia deltaura* was abundant in maerl beds of the Clyde Sea area with complex and extensive burrows that affected the structure of these habitats. Although *U. deltaura* are relatively large animals (up to 62 mm total length in this study) and can be abundant in near-shore sediments [e.g. Tunberg (1986) found mean densities of 5.0 individuals 0.1 m^{-2}], even basic aspects of their biology such as growth rates, longevity and reproductive habits are poorly known because the animals are so difficult to collect. The importance of deep-burrowing megafauna can often be overlooked since most sampling methods (e.g. grab sampling, coring, Naturalist's dredge, surveys with cameras/divers) rarely reveal their presence, leading to underestimates of their distribution and abundance. Even heavy equipment such as 20x28 cm by 45 cm deep Reineck box corers cannot be relied upon to capture *U. deltura* quantitatively (Swift, 1993). Thus records are sparse, but coarse near-shore sediments appear to be the preferred substrata of *U. deltaura* (see introduction and below). Many of the records for *U. deltaura* come from maerl beds occuring from Scotland to Spain (Hardiman et al., 1976; Keegan, 1974; Grall & Sánchez Mata, personal communication). The main maerl-forming species in this region of the north-east Atlantic are *Phymatolithon calcareum* (Pallas) Adey & McKibbin, *Lithothamnion glaciale* Kjellman and *L. corallioides* (P. & H. Crouan) P. & H. Crouan which colonize sedimentary substrata and build calcareous gravel banks through fragmentation and growth (BIOMAERL, 1998; Hall-Spencer, 1998). Thus these maerl-forming species may be an important source of habitat for *U. deltaura*.

The two species of *Upogebia* known to occur in Scotland overlap in their sediment preferences, with *U. stellata* obtained from fine muds (Nickell & Atkinson, 1995) to muddy gravels (present study) and *U. deltaura* found in fine muds (personal observation) to coarse gravels (present study). These two species are reported to occur together at Salcombe, southern England (de Morgan, 1910) and in shallow Norwegian waters (Samuelsen, 1974). However, Gustavson (1934) noted that they occurred at different depths in Gullmarfjord, Sweden. He recorded a distinct *U. deltaura* zone at 10–14 m depth in 'clay-mixed sand, often mixed with coarse gravel' with a *U. stellata* zone at depths below 25 m in 'clay-mixed sand'. It is clear from Poulsen (1940), however, that *U. deltaura* also occurs at depth (50 m) in Swedish waters. Detailed observations at sites in the Clyde Sea area indicate that where these species occur in the same general area, *U. stellata* is commoner in finer grade muddy sands and *U. deltaura* is commoner in coarser grade muddy gravels which usually results in *U. deltaura* occurring in shallower water than *U. stellata*. The sediment preferences of the juveniles and adults of these species would merit further experimental investigation. Being a large, robust species (de Morgan, 1910) *U. deltaura* may be able to exploit coarse substrata that are difficult to access by smaller species such as *U. stellata*.

Upogebia deltaura is principally a suspension feeder (Pinn et al., in press) and lines its burrow with mud to allow a laminar flow of water as it irrigates the burrow to feed. The method by which *U. deltaura* consolidates the burrow wall has not been investigated but may involve the application of secretions from glands in the hind-gut, as shown for *Upogebia pugettensis* (Dana) by Thompson (1972), and/or by plastering the mud lining with secretions from glands on the appendages used to manipulate burrow walls, as shown in two species of the closely related thalassinidean genus *Callianassa* (Dworschak, 1998).

It is clear from our diving observations and from the literature (Dworschak, 1983; Tunberg, 1986) that upogebiids can be very common and, due to their size, they are likely to be significant contributors to total biomass. Upogebiids have been shown to pass large volumes of water through their burrows during feeding and irrigation activities (Dworschak, 1981). For *U. deltaura*, through burrow flow rates of 4.2–34.1 ml min^{-1} have been reported (Astal et al., 1997). As shown by other workers (Ott et al., 1976; Astal et al., 1997), such extensive, deep burrows increase the area of the water/sediment interface and introduce oxygenated conditions at depth in the sediment column as evidenced by an oxic zone surrounding the burrow wall. A large variety of fauna is associated with *Upogebia* burrows, where they are able to penetrate deeper into the sediment than in the absence of these shrimps (Dworshack, 1983). The burrows also increase the structural complexity of the habitat; within gravelly sediments their mud-lined burrows provide loci for organisms such as *Mysella bidentata* which is known to associate with the burrows of other species (Ockelmann & Muus, 1978; Nickell et al., 1995).

The cryptic, narrow burrow openings of upogebiids result in them being overlooked or underestimated in abundance, especially in coarse sediments like maerl where their burrow openings are often occluded. The present study has shown that the burrows of *U. deltaura* can be far more complicated and extensive than the relatively simple structures described for this species from laboratory observations (Astall et al., 1997), though burrow casts taken in the field by these authors suggested greater complexity. Ugogebiid burrows described in the literature (Dworschak, 1983; Nickel & Atkinson, 1995) are less complex than those described here for *U. deltaura*, but all share common features. These include U or W-shaped upper sections, bifurcate branches and blind-ended descending sumps. The complexity of *U. deltaura* burrows lies in their large size and the amount of branching. In this study, *U. deltaura* were found to live singly in their burrows, a trait that appears to be typical of upogebiids as a group (Dworschak, 1983). In common with most thalassinideans, they probably leave their burrows only rarely. They are predated upon by demersal fish, having been found in the stomachs of rays (*Raja clavata* L.), haddock (*Melanogrammus aeglifinus* (L.)) and cod (*Gadus morhua* L.) (Selbie, 1914; Poulsen, 1941; Tunberg, 1986). Suctorial feeding (Osse & Muller, 1980) may account for this, perhaps when the upogebiid signals its presence when tending a burrow opening.

The depth of these burrows coupled with the ability of the occupants to withstand hypoxia (Astall et al., 1997) makes them resilient to natural perturbances such as large sediment shifts during storms, as observed in this study, or severe cold (0.8°C; Tunberg 1986). While commercial scallop dredges have a high impact on sessile organisms on or near the sediment surface (Thrush et al., 1995; Curry & Parry, 1996; Hall-Spencer et al., in press) our observations have shown that the deep-burrowing habit of upogebiids confers resistance to disruption by towed demersal fishing gear since they are able to repair the upper sections of their burrows and survive at high densities, even on grounds that are dredged extensively for scallops.

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List of Figures

Figure 1. Map showing location of field study areas and the Marine Station in the Clyde Sea area, south-west Scotland.

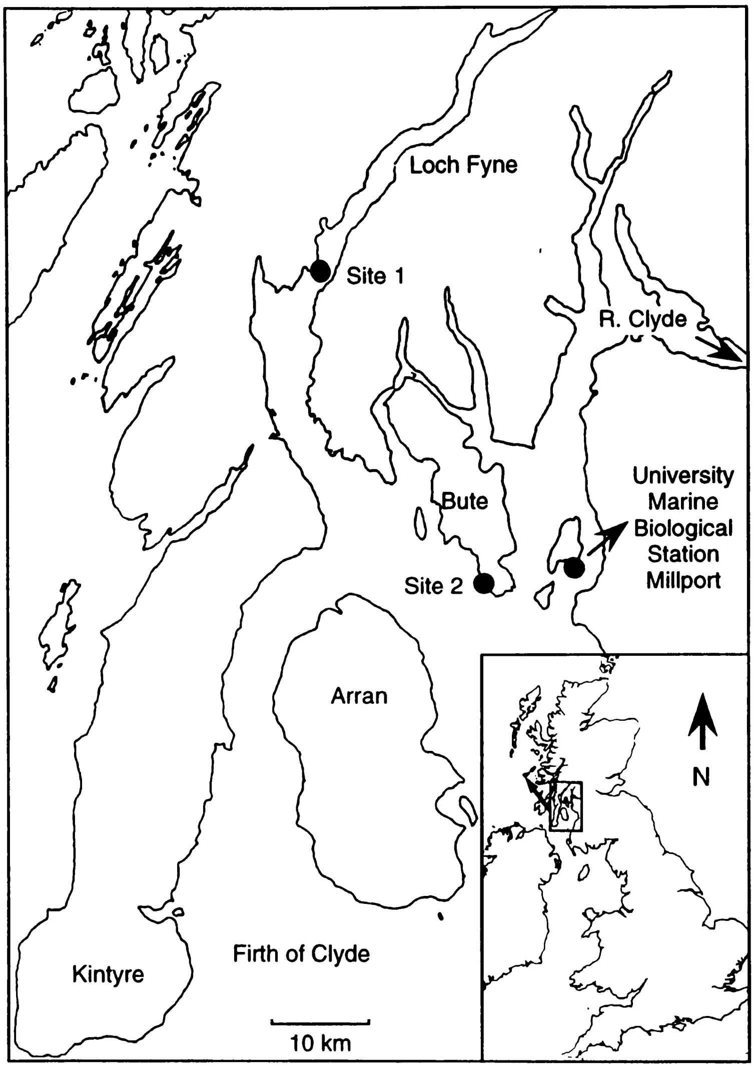
Figure 2. Sediment profile gauge in use at Stravanan Bay (Site 2) one week after storms in February 1997. The coarse surface layer of maerl gravel is thrown into megaripples 11 cm high (λ=1.2 m) overlying a relatively stable layer of sediment with a higher proportion of sand and fines.

Figure 3. Surface view of a *Upogebia deltaura* burrow. (A) Showing constricted aperture (6 mm diameter) flush with the maerl bed surface and surrounded by fine sediment ejected from the burrow below. (B) Surface constriction removed by hand to show circular lumen of burrow shaft descending into the gravel below, lined with a smooth layer of mud.

Figure 4. *Upogebia deltaura* burrow construction. (A) Vertically sectioned box core, note the coarse granulometry of the maerl gravel and the mud-lined burrow lumen (arrow), core width: 15 cm. (B) Resin cast of burrow opening showing surface constriction and decending shaft. (C) Cast 1 side view. (D) Cast 1 surface view with position of trapped *U. deltaura* indicated (arrow). (E) Cast 4 side view with two openings uppermost. (F) Cast 4 surface view. Scale bars: B, 7 cm; C–F, 30 cm.

Figure 5. Resin-cast *Upogebia deltaura* burrow photographed *in situ* after excavation using an air-lift to enable accurate reconstruction of its orientation.

Figure 1.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Bute
Site 2
Arran
N
Kintyre
Firth of Clyde
10 km

Figure 2.

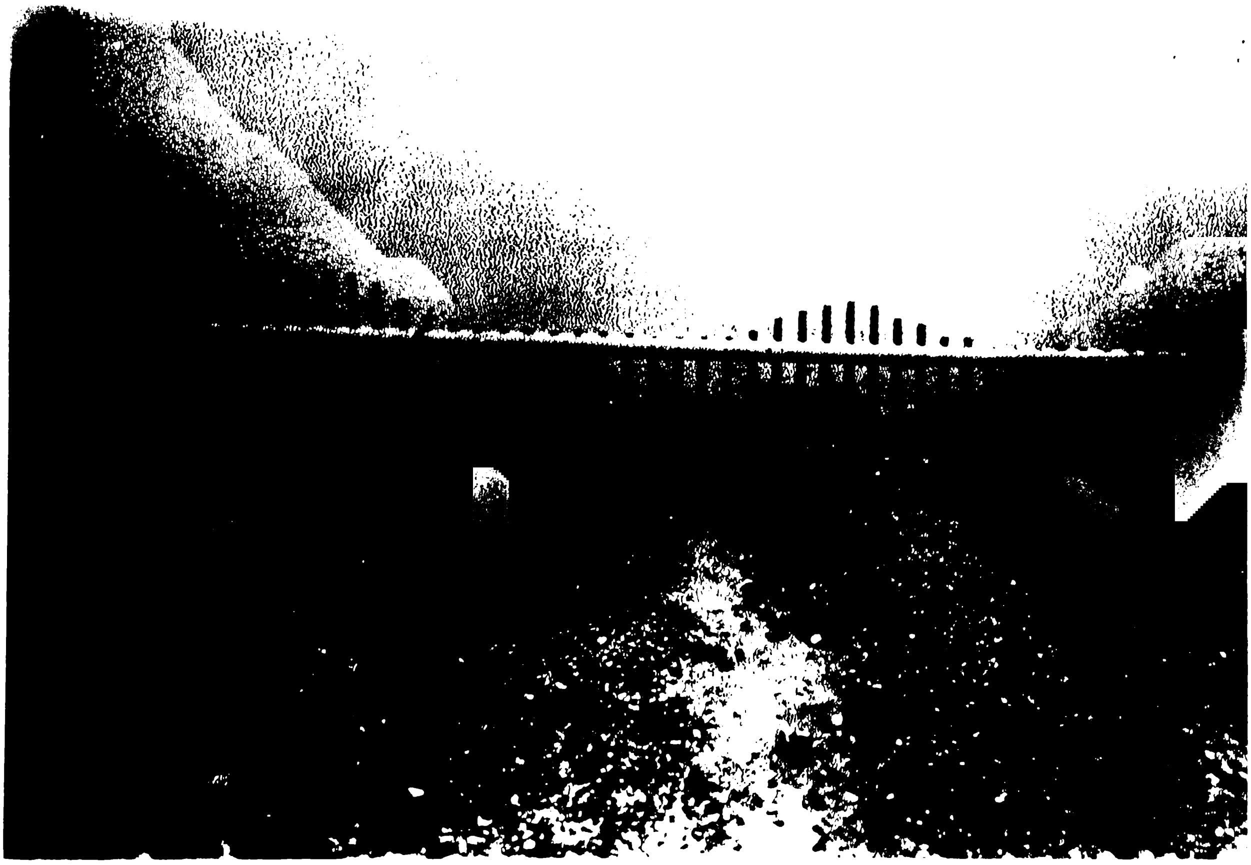

Figure 3.

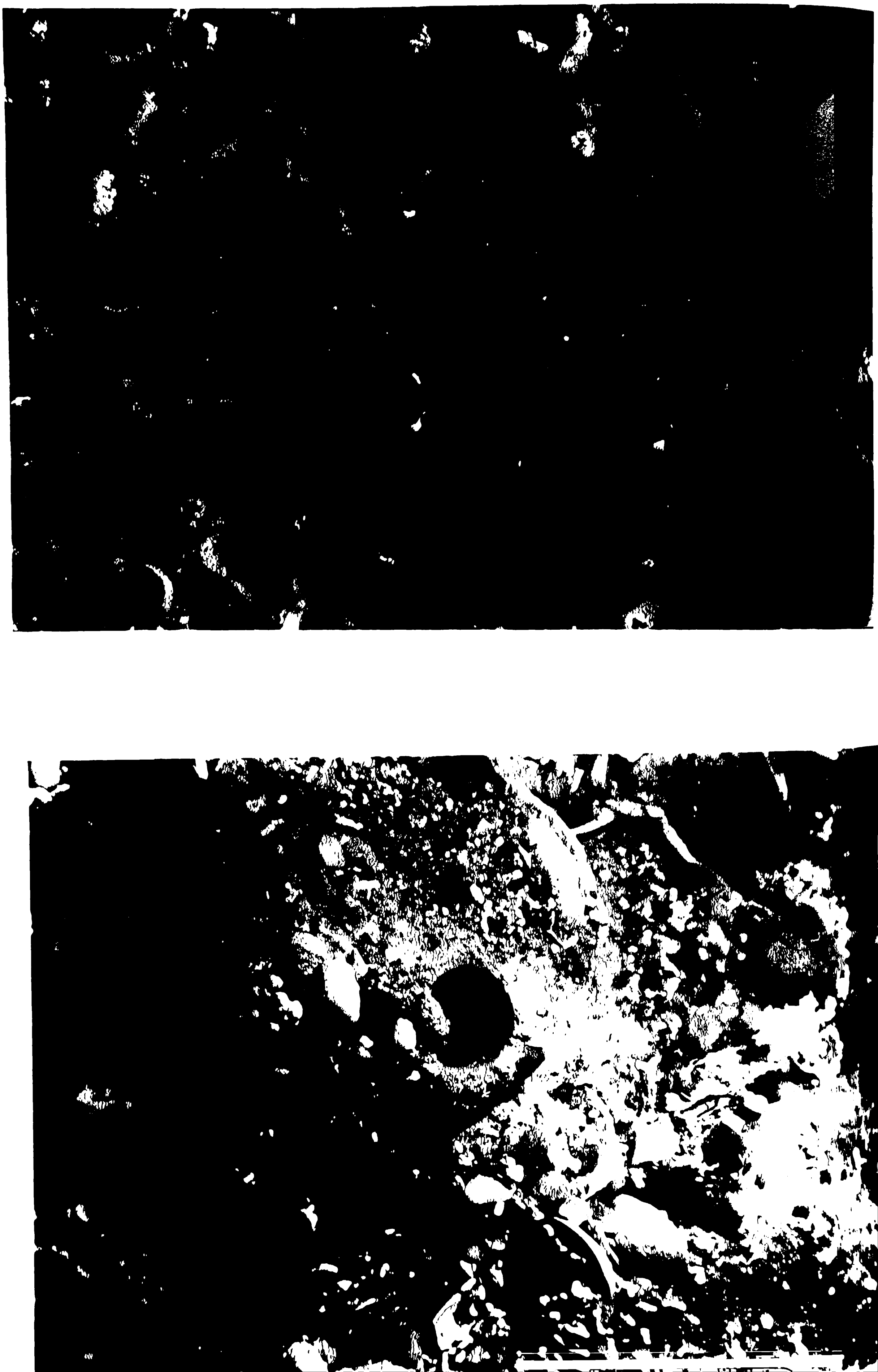

Figure 4.

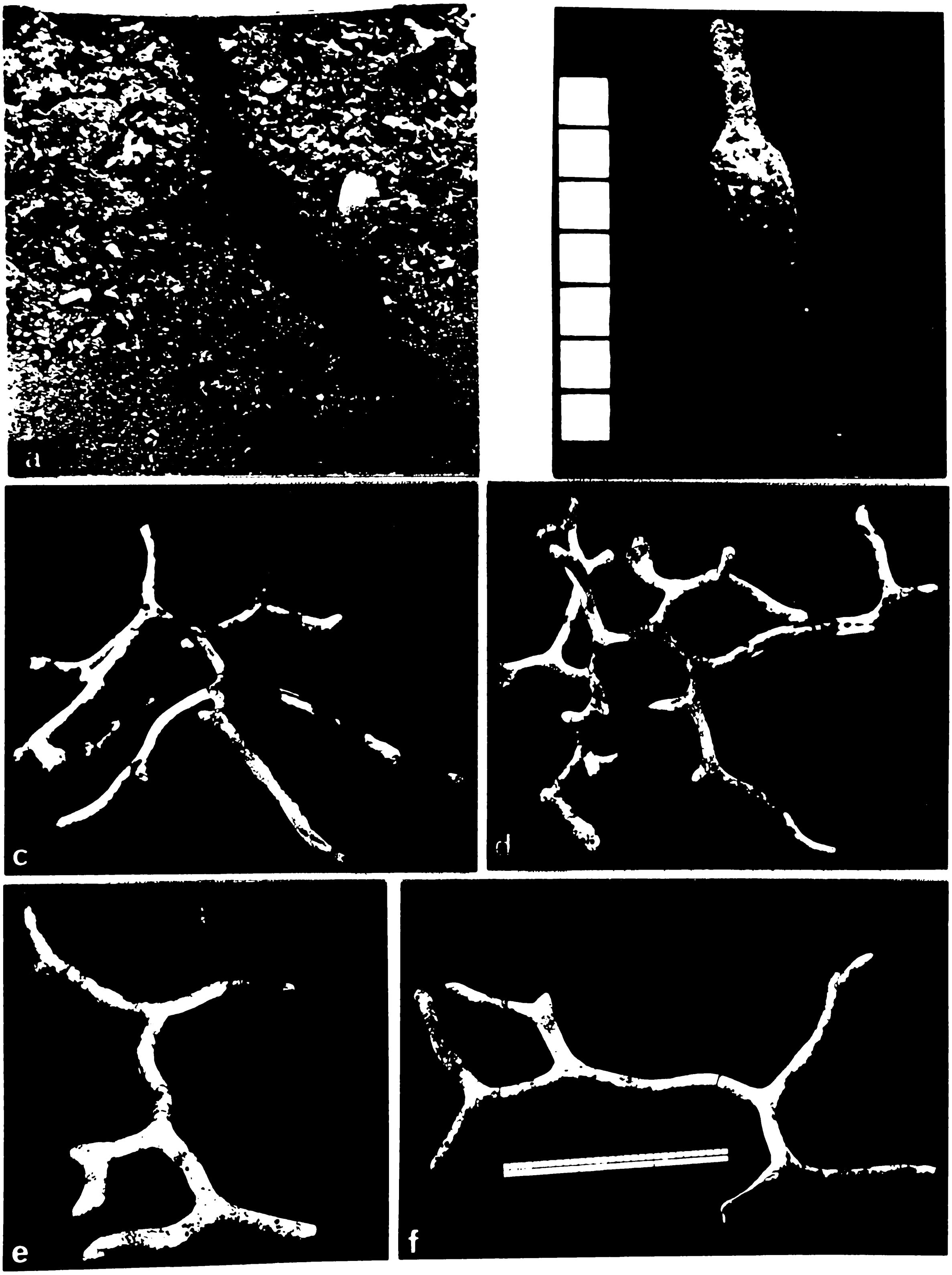

Fig. 5.

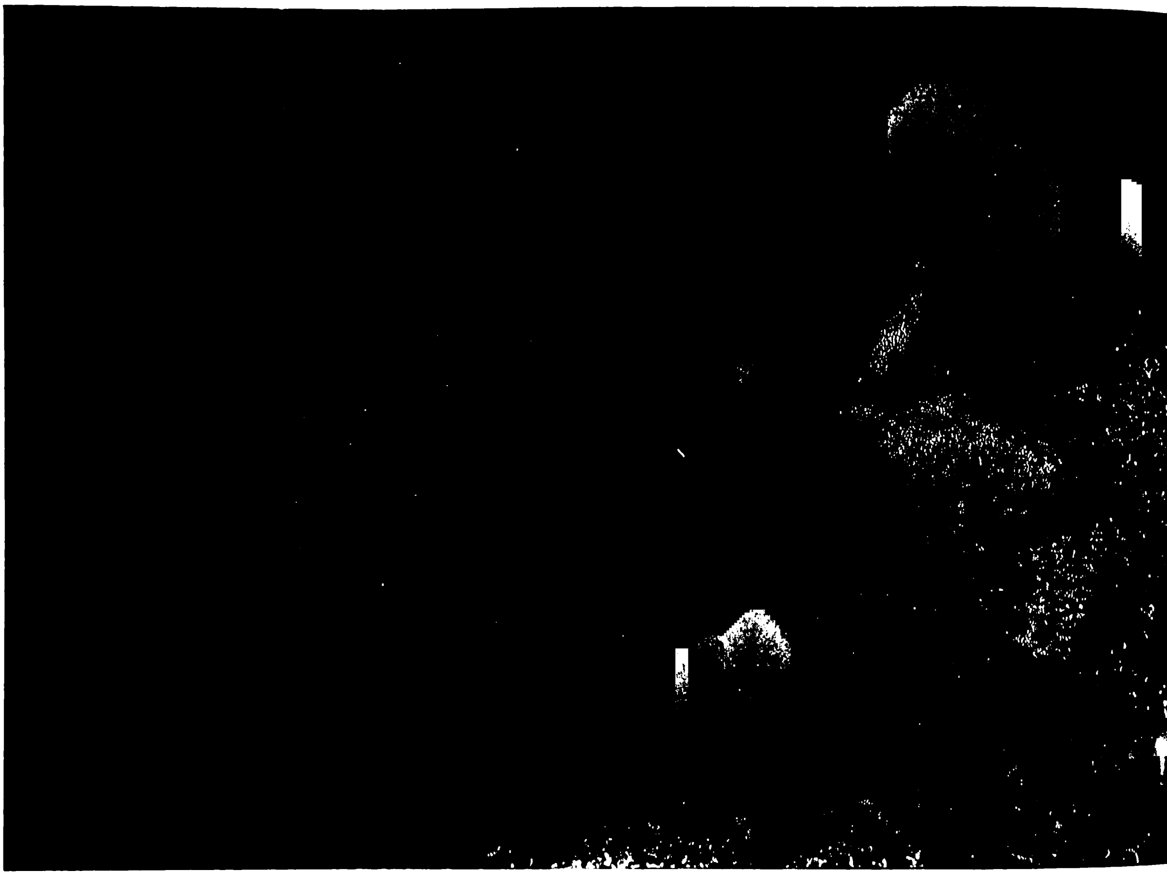

Table 2. *Morphometric data for eight >50% complete casts of* Upogebia deltaura *burrows taken at -10 m CD on maerl at Site 2 (Stravanan Bay, Isle of Bute) in November – December 1996. Apart from number of burrow openings, total burrow depth and % cast completion (based on* in situ *measurements) data refer to measurements taken on cast portions of the burrows.*

Cast	no. of openings	burrow depth (cm)	% cast complete	cast volume (cm^3)	cast opening diameter (mm)	mean cast diameter (mm) ±SD (N=10)	cast length (cm)	no. of cast junctions	no. of cast sumps	animal present in cast	carapace length (mm)
1	3	55	80	1428	-	18.0 ±0.8	321	19	4	+	18.5
2	3	45	90	1176	6.0-6.2	24.7 ±1.2	165	8	3	+	22.0
3	2	44	80	1194	-	22.7 ±2.2	230	11	2	-	-
4	2	40	70	516	6.0-6.4	20.0 ±0.9	112	6	2	-	-
5	2	37	80	282	4.2-6.3	16.2 ±0.7	101	8	3	+	17.4
6	2	31	55	612	3.6-5.0	19.7 ±0.9	123	7	3	-	-
7	2	23	80	552	-	19.3 ±1.2	97	5	1	-	-
8	2	23	55	408	-	23.3 ±2.4	70	2	0	+	17.1

Table 3. *Distribution and abundance of* Upogebia deltaura *burrows recorded in 2x5 m^2 plots on maerl at -10 m CD at Site 1 (Creag Gobhainn, Loch Fyne) and Site 2 (Stravanan Bay, Bute) in November – December 1996.*

site	no. of burrows examined	no. with 2 openings	no. with 3 openings	distance between openings on burrows with 2 openings (cm)			distance between openings on burrows with 3 openings (cm)			no. of openings m^{-2} (N=10)			no. of burrows m^{-2} (N=10)		
				min	mean ±SD	max	min	mean ±SD	max	min	mean ±SD	max	min	mean ±SD	max

1	24	16	8	14	35.1± 25.0	84	14	34.8 ±28.4	111	2	4.5 ±1.4	7	0.6	1.9 ±0.7	3.3
2	38	26	12	11	38.7± 21.2	94	12	32.6 ±23.5	145	3	7.0 ±2.2	10	1.3	2.9 ±0.9	4.3

Table 1. *Burrowing megafauna co-occurring with* Upogebia deltaura *on maerl beds at Site 1 (Creag Gobhainn, Loch Fyne) and Site 2 (Stravanan Bay, Bute), showing the maximum distances at which these animals were found below the sediment surface. Six 1* m^2 *quadrats were excavated at each site during June–July 1996 using an air-lift at -10 m CD. Nomenclature follows that of Picton & Howson (1997).*

Species	Maximum depth below maerl surface (cm)	
	Site 1	Site 2
Cerianthus lloydii Gosse	40	44
Golfingia elongata (Keferstein)	40	-
Golfingia vulgaris vulgaris (de Blainville)	36	-
Glycera rouxi Audouin & Milne-Edwards	44	36
Nereis longissima Johnston	32	16
Nephtys hombergi Savigny	16	28
Chaetopterus variopedatus (Renier)	28	28
Terebellides stroemi M. Sars	24	
Pista cristata (O. F. Müller)	24	
Eupolymnia nebulosa (Montagu)	20	24
Upogebia deltaura (Leach)	68	68
Lutraria angustior Philippi	40	
Ensis arcuatus (Jeffreys)		32
Moerella donacina (Linnaeus)	28	
Clausinella fasciata (da Costa)	20	28
Tapes rhomboides (Pennant)	40	
Dosinia exoleta (Linnaeus)	28	28
Mya truncata Linnaeus	52	52
Echinocardium pennatifidum Norman	28	28
Neopentadactyla mixta (Ostergren)		48
Thyone fusus (O. F. Müller)	40	
Thyonidium drummondii (Thompson)	40	

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SHORT COMMUNICATION

Observations and possible function of the striking anterior coloration pattern of *Galathea intermedia* (Crustacea: decapoda: anomura)

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Galathea intermedia is common, but cryptic, on Clyde maerl deposits where it lives in small groups of mixed sex and age, sharing shelters (typically dead *Dosinia* shells) to avoid predation. Its appearance is marked by six iridescent blue spots which may play an important role in intra- or interspecific interactions.

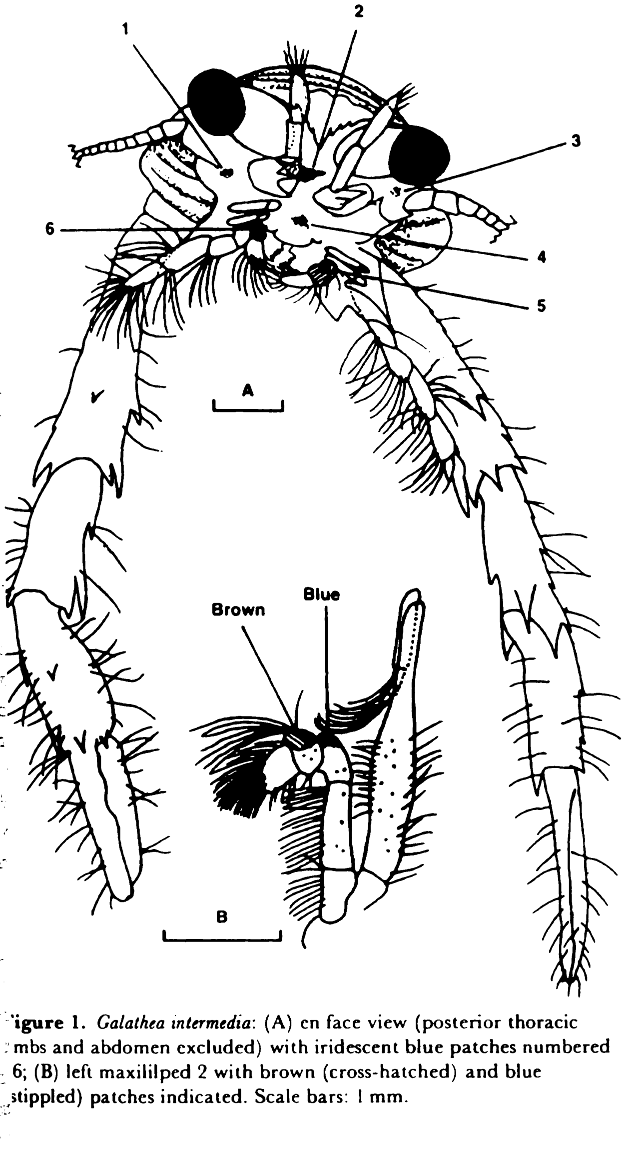
Anomuran decapod crustaceans of the genus *Galathea* are widespread in rocky/gravelly subtidal areas around north-western European coasts (Zariquiey Alvarez, 1968). Recent interest in the group has been stimulated by the growing commercial importance of squat lobsters as the target of an expanding European fishery. However, the biology and ecology of these animals remain poorly studied (De Grave & Turner, 1997). Of the six species of *Galathea* known to occur in coastal waters (to 200 m) around the British Isles (Howson & Picton, 1997), five have been recorded in the Clyde Sea area (Allen, 1967). Our attention was drawn to *Galathea intermedia* Liljeborg, the smallest of these species (carapace length <8·5 mm), during *in situ* observations between 6 and 15 m depth on two maerl grounds in the Clyde Sea (Stravanan Bay 55°45·3301′N 05°4·2601′W and Creag Gobhainn 56°00·6001′N 05°22·2000′W) using SCUBA. *Galathea intermedia* were found in small groups, hiding in the interstices of maerl fragments or with up to three animals sharing the shelter of dead *Dosinia exoleta* (L.) shells. These bivalve shells were common on the sediment surface of the study sites having fallen prey to the star-fish *Marthasterias glacialis* (L.) and *Asterias rubens* L. (J.M.H.-S., personal observation). A previously unrecorded feature of *G. intermedia* is its very conspicuous anterior coloration pattern consisting of six 'neon' blue spots in the frontal region of the head (a triangular epistomial patch medially above a small labral spot, a pair of lateral spots beneath the eyes at the base of the antennae and a pair of spots on the geniculate carpopodite of the second maxilliped endopodite).

Observations on the incidence of this coloration were made on 86 *G. intermedia*, with carapace lengths from 3·4 to 7·9 mm, measured from the tip of the rostrum to the posterior mid-dorsal margin. These animals were collected by removing maerl sediment and dead *Dosinia* shells from a 5 m^2 area at 10 m depth in Stravanan Bay on 25 September 1997. The squat lobsters clung to the collected substratum and few escaped. Previous UK records of *G. intermedia* show that it can be very common on gravelly sediments in the shallow sublittoral, with few records beyond 50 m depth (Marine Biological Association, 1957; Bruce et al., 1963; Crothers, 1966; Allen, 1967). The population density of *G. intermedia* recorded here on coralline gravel (at least 17 ind m^{-1}) is within the range of 3·0–16·6 ind per 0·25 m^{-2} encountered by Samuelsen (1970) at a similar depth (7–9 m) in Norway. He also found that this species was contiguously distributed with its abundance being positively correlated with the amount of coarse substratum.

When placed in aquaria, the squat lobsters hid amongst the shell/maerl substrata. Animals of various sizes settled near to one another with equanimity and began a routine of feeding and self-grooming (recorded using a Panasonic F10 video-camera (film rate 25 fields s^{-1}) fitted with a 50 mm Pentax macro-lens and connected to a Panasonic AG6200 video-recorder). The bright blue iridescent markings were strikingly apparent in *en face* view (Figure 1A). The largest and most conspicuous markings (visible *in situ* to the naked eye of divers) were on the carpopodite of the second maxilliped endopodite above due to limb flexure, but anatomically below a contrasting red/brown patch on the propodite (Figure 1A,B). These features are lost when the animals are fixed in alcohol or formalin, which probably explains why they have been overlooked in previous descriptions of the species (e.g. Liljeborg, 1851; Bouvier, 1940; Zariquiey Alvarez, 1968). The spacing and size of the markings increased with size of the animal but there were no obvious differences in their pattern or intensity depending upon the sex, maturity or egg-bearing status of individuals as this configuration of markings was present on all collected specimens. A few individuals moulted in captivity and the markings were seen before and after ecdysis.

Filmed observations in aquaria showed that *G. intermedia* used its chelae to tear food when presented with scraps of crab flesh but that scavenging was not its normal feeding mode, as shown with *G. squamifera* Leach, *G. strigosa* (L.) and *G. dispersa* Bate (Nicol, 1933). The ability of *G. intermedia* to detect carrion appeared to be limited, as scraps were ignored if lying beyond two body lengths from the animal. The animals fed primarily on detritus, sweeping fine particles from the substratum using the setose third maxillipeds and passing material on to the second maxilliped and thence to the mandibles. The highly reflective spots on the second maxilliped endopodites moved constantly as the animals fed or groomed the head region, this movement ceased when animals were disturbed with forceps and when conspecifics met.

Given the shallow-water and contagious distribution of *G. intermedia*, the highly reflective blue spots may have a function in communication. Their pattern and colour (or contrast in colour) may provide a means of intraspecific recognition



'igure 1. *Galathea intermedia*: (A) en face view (posterior thoracic mbs and abdomen excluded) with iridescent blue patches numbered 6; (B) left maxilliped 2 with brown (cross-hatched) and blue stippled) patches indicated. Scale bars: 1 mm.

nsuring that shelters are only shared with conspecifics. Vannini t Gherardi (1981) demonstrated individual recognition in crabs nd several studies have shown that markings influence inter-ctions between crustaceans (e.g. patches on hermit crab claws, unham, 1978; meral spots in stomatopods, Hazlett, 1979). The istance between the spots may indicate size of an individual nd therefore be important in agonistic interactions, where btaining information on an opponent may influence whether to ngage an opponent; and in affecting the outcome of a fight Parker, 1974). In the hermit crab, *Calcinus laevimanus* (Randall), e size of the white patch on the enlarged left chela influenced e likelihood of winning a fight with crabs being more ccessful if they had a larger patch than their opponent unham, 1978). Alternatively, these morphological traits may ter visual predators or play a role in sexual selection (see odric-Brown & Brown, 1984).

These preliminary observations have highlighted the need for ore detailed behavioural study to elicit the function of these ightly coloured markings. Experimental investigation into the arrangement, colour, size and intensity of these spots and the role they play in communication (analogous to Crane's work (1949) on salticid spiders) would be of great interest.

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Scallop dredging has profound, long-term impacts on maerl habitats

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Abstract

Maerl beds are mixed sediments built by a surface layer of slow-growing, unattached coralline algae. They are of international conservation significance since they form 'hot-spots' of biodiversity. They are patchily distributed throughout Europe (to ~30 m depth around the British Isles and to ~120 m in the Mediterranean) and are impacted by towed demersal fishing gear. Here, we report the effects of Newhaven scallop dredges on a previously unfished maerl bed compared with the effects on a similar maerl ground that has been fished commercially in the Clyde Sea area, Scotland. Sediment cores were taken to assess the population density of live maerl thalli prior to scallop dredging on marked test and control plots. These plots were then monitored biannually over a 4-year period. Live maerl thalli were sparsely distributed at the impacted site and experimental dredging had no discernible effect on their numbers. The unexploited ground had dense populations of live maerl and scallops (both *Aequipecten opercularis* and *Pecten maximus*). While counts of live maerl remained high on the control plot, dredging led to a >70% reduction with no sign of recovery over the subsequent 4 years. The vulnerability of maerl and associated benthos (e.g. *Limaria hians*) is discussed in relation to towed demersal fishing practices.

Key words: scallop dredging, maerl beds, long-term impact, benthos, ecosystem effects.

Introduction

Widespread interest in the ecological effects of current fishing practices has stimulated intense research in recent years (Lindeboom and de Groot, 1998; Jennings and Kaiser, in press). A number of recent studies have established that demersal fishing gear can have dramatic immediate effects on the benthos (reviews by Dayton *et al.*, 1995; Auster *et al.*, 1996). This is particularly true of those types of gear that penetrate the substratum deeply, such as hydraulic dredges (Hall *et al.*, 1990; Pravanovi and Giovanardi, 1994) and scallop dredges (Thrush *et al.*, 1995; Currie and Parry, 1996; Collie *et al.*, 1997; Hall-Spencer *et al.*, in press).

Studies that have involved monitoring the after-effects of gear impact on sedimentary habitats have often been unable to detect effects in the long-term. The effects of gear impact on small areas within dynamic habitats, e.g. sandy sediments, are quickly diluted through the immigration of benthos from the surrounding area or sediment redistribution (Hall *et al.*, 1990; Eleftheriou and Robertson, 1992). Even in large-scale studies, long-term effects of fishing activities have been difficult to differentiate from other sources of variability in the benthos such as population heterogeneity, large seasonal fluctuations and the effects of natural disturbances such as storms (Hall *et al.*, 1993; Currie and Parry, 1996; Kaiser *et al.* 1998). In most cases, such studies have been undertaken in areas already modified by commercial fishing activity. There are now very few suitable grounds that have not been heavily influenced by towed fishing gear (Lindeboom, 1995; Tuck *et al.*, 1998). Consequently, benthic populations remaining in such areas are generally resilient to gear impacts (Currie and Parry, 1996; Kaiser *et al.*, 1996).

The present study forms part of a continuing EC-funded investigation (BIOMAERL) comparing natural variability with the effects of human impacts on the ecology of maerl habitats in Europe (BIOMAERL team, 1998; Grall and Glémarec, 1998; Hall-Spencer, 1998; Borg *et al.*, submitted). Maerl is a living sediment that typically harbours a high biodiversity (BIOMAERL team, 1998) but is very slow growing in European waters (Potin *et al.*, 1990; Canals and Ballesteros, 1997). Scottish maerl beds are characterized by coarse sediment, clean water and appreciable bottom currents and, as such, often provide good scallop fishing grounds. Concerns have been expressed about the sensitivity of this biotope to towed demersal fishing gear

(MacDonald *et al.*, 1996). Here, we report the differences between fished and previously unfished maerl beds on the west coast of Scotland and compare contemporary maerl samples with those collected a century ago. Small-scale scallop dredging experiments are described which were designed to determine a) the immediate physical impacts to maerl habitats, and b) the long-term effects on major habitat-structuring organisms in previously unfished and fished areas.

Methods

Site descriptions

Three maerl grounds in the Clyde Sea area (Fig. 1) were surveyed in detail from 1994-1998 using a combination of Sprint® Remote Operated Vehicle (Perry Tritech Ltd), RoxAnn®, van Veen grab sampling (at least 6 grabs per site per quarter) and >200 h field observations using SCUBA. Site 1 was at Creag Gobhainn, Loch Fyne, where maerl occurred parallel to the shore along a gently sloping strip over an area of 17.5 ha from -6 m to -14 m CD (Chart Datum). This site was unexploited by towed demersal fishing gear due to rocky outcrops, its proximity to shore and the presence of a charted telecommunications cable (laid in 1968) in a designated 'trawling prohibited' area. Site 2 was situated on a shoal in Stravanan Bay ~0.5km off the SW coast of the Isle of Bute where maerl covered an area of 6.75 ha from -6 m to -15 m CD. This site was used by scallop fishermen during 1994-98 (pers. obs.) and had been impacted by scallop dredges over the past four decades (G.A. Fisher, unpubl.). Site 3 was situated near the Tan Buoy SW of Great Cumbrae Island where maerl covered 4.0 ha from -6 to -10 m CD. The Tan Buoy area had also been dredged extensively over the past 40 years both by research vessels and by fishing boats (UMBSM records). Full descriptions of these sites are given elsewhere (Hall-Spencer, 1998; BIOMAERL team, in press).

Fishing and sampling protocol

Experimental fishing took place at Sites 1 and 2. Firstly, surface and subsurface buoys were laid at -10 m CD at each site to provide permanent markers for the 4 year study. Positions of the buoys (determined by Magellan® Differential GPS) were 56°00.601′N 005°22.148′W (Site 1) and 55°45.323′N 005°04.265′W (Site 2). At each site, two buoys were laid 10 m apart to one side of the permanent buoy to delimit the width of an area to be fished (test plot) while the opposite side of the permanent marker was untouched (control plot).

At each site in May 1994, eight replicate sediment cores (20 cm long, 10.3 cm diam.) were taken by divers on the test plot, and a further eight were taken on the control plot. Throughout the study, collected were cores kept upright, frozen within 5 h of collection and stored at -18°C.

The day after coring, test plots were fished from RV Aora (15 m, 260 hp) using a gang of three Newhaven scallop dredges. The dredges were 77 cm wide, weighed 85 kg in air and had 10 cm long, 0.8 cm wide teeth mounted 8 cm apart (9 per dredge) on spring loaded pawls. A bag of linked 7 cm diameter steel rings extended behind each tooth bar to retain the catch. The dredges were towed once over each test plot for ~100 m giving fished areas of ~230 m^2.

Immediately after fishing, a pair of divers equipped with tape measures and writing slates recorded gross changes to surface topography on the test plots and took 8 cores. Changes were also noted on the adjacent control plots where a further 8 cores were taken. Labelled aluminium rods were pushed into the sediment to mark each cored area. This coring routine was then repeated biannually over the next 4 years. The amount of living maerl on the test and control plots was assessed as follows. Cores were first thawed and removed from the PVC pipes to note vertical stratification within the sediment. They were then wet sieved in fresh water through a 5 mm mesh. Maerl thalli that had been living at the time of collection (hereafter referred to as 'live thalli') were removed with forceps and examined using a calibrated dissecting microscope. Live thalli had smooth surfaces and were either pink, due to the presence of phycobilin pigments, or were green if the phycobilins had leached out revealing the presence of chlorophyll. Dead maerl fragments were sometimes smooth and white but more usually had pitted surfaces that were shades of brown and grey to black depending on the degree of deposition of iron and manganese salts. Rarely, dead fragments were pink or green due to the presence of boring algae (the *Conchocelis* stage of *Porphyra* spp. and *Ostreobium quekettii* Bornet et Flahault) but these had pitted, eroded surfaces. Numbers of live thalli were counted in each core and an estimate of the area they covered was obtained by laying the plants in a monolayer on graph paper.

Historical changes at Site 3

Maerl collected in 1885 from Site 3, was found with a collection of byssus nests of the bivalve mollusc *Limaria hians* (Gmelin) in the David Robertson zoological collection at the University of Glasgow. Three more maerl samples from Site 3 were found in the following boxed collections at the British Museum (London); Box 516 (code BM 000005147) labelled "*Lithothamnion calcareum* f. *compressa* Foslie" collected by Mrs Robertson in 1891, Box 519 (code BM 000005180) labelled "*Lithothamnion squarrulosum* Foslie" and "*Lithothamnion corallioides* f. *australis*" collected by E.A.L. Batters in 1891 and Box 521 (code BM 000005182) labelled "*Lithothamnion squarrulosum* f. *australis* Fosl." collected by E.A.L. Batters in 1891. These archived samples were examined microscopically for the criteria outlined above to establish if the maerl had been alive at the time of collection. The thalli were measured (max. length) then identified using a JEOL-JSM 5200 scanning electron microscope, as described in Hall-Spencer (1994).

In 1995-1997, an extensive survey of Site 3 was made using hand-held cores, 60 van Veen grab samples and 11 hours of diver observations to locate living maerl and *L. hians* to compare with collections from the last century. Live plants were washed in fresh water, air-dried, measured and identified to species.

Sediment trapping investigation

As a one-off investigation, a second scallop dredging exercise was carried out away from the test and control plots at Site 2 (-10 m CD; 55°45.37'N 005°04.22'W). As before, two buoys were spaced 10 m apart to mark the north and south sides of a corridor to be fished. A series of weighted, circular plastic tubs (each 17 cm in diam. and 14 cm deep) were labelled and arranged by divers on the maerl bed in pairs at 0, 1, 2, 4, and 8 m on transects running at right angles to the towed corridor, i.e. north of the north buoy and south of the south buoy. These were left for 2 h to collect background levels of settling sediment then sealed with water-tight lids and replaced with a second set of 20 tubs laid out in the same configuration. A gang of three

Newhaven dredges was then towed from east to west along a ~100 m corridor between the buoys. After fishing, the proximity of the '0 m' sediment traps to the dredge track was measured and all tubs were sealed and retrieved 2 h after fishing. Sediment was allowed to settle, excess water was siphoned off and the sediment was washed twice in distilled water. After resettlement, the supernatant was again siphoned-off and the sediment dried in an oven at 50°C. Dried samples were then weighed and the largest particle in each sample was measured using a dissecting microscope.

Results

Differences in experimental sites

Although Sites 1 & 2 were similar in many respects (each maerl bed was located on a level area of sea bed within sheltered parts of the northern Clyde Sea area with no differences in depth, salinity, temperature or tidal amplitude) the sea bed and benthos exhibited important differences that reflected the fact that Site 2 had been fished for scallops for the past 40 years, whereas at Site 1 deployment of demersal fishing gear had been prohibited since 1968. The main differences are summarized in Table 1. Scallop population densities (*Aequipecten opercularis* (L.) and *Pecten maximus* (L.)) were high at the unfished site and mature individuals predominated, whereas scallops were sparser and smaller at the fished site. Scallop dredge marks were common on the fished site, live *Limaria hians* were absent but their dead shells were abundant. At the unfished site, *L. hians* built roughly circular byssus nests that were up to a metre in diameter and stood 20 cm proud of the maerl bed surface. When a short dredge run was made at this site, all of the *L. hians* nests in the path of the dredges were either torn and dragged along the sea bed or were bought up in the dredge bags

Immediate and long-term effects of scallop dredging

Test plots at Sites 1 & 2 showed significant physical disturbance along a 2.54 m wide track with three parallel furrows corresponding to the width of each dredge. Natural bottom features (ripples, crab feeding pits and megafaunal burrows) were eliminated along the tracks and boulders up to 1 m^3 had been dragged along the sediment surface. A shift in granulometric structure of the surface sediment was evident by comparison with adjacent, unfished areas. Mud and sand had been brought to the surface of the tracks and maerl gravel was sculpted into 3 cm high ridges at the edge of each dredge (Fig. 2). Live maerl was buried up to 8 cm below the sediment surface and biogenic carbonate structures (e.g. maerl thalli, echinoid test plates and bivalve shells) were crushed and compacted. The control plots nearby were relatively unaffected, although some silt had settled on the upper surface of the maerl (see below).

The sediment in cores taken prior to fishing was vertically stratified at both experimental sites. Site 1 had a 1-2 cm thick 'open lattice' layer of maerl gravel with a large amount of void space between particles. This open lattice overlaid fine sand and mud mixed with shell and maerl fragments. Site 2 had less fine material and was characterized by a 3-8 cm open lattice layer of maerl gravel overlying coarse sand with pockets of fine sand and mud mixed with shell and maerl fragments. Cores taken on control plots had the same pattern of vertical stratification throughout the study but those taken on test plots immediately after fishing lacked vertical stratification. Thus test plot cores lacked an open lattice layer, had less interstitial space and a greater proportion of fine particles at the surface. Sampling over the subsequent 4 years revealed a gradual return to a clean, gravelly upper layer of maerl at both sites presumably due to winnowing away of fine material by water movement. During spring tides, benthic currents exceed 10 cm s^{-1} at both sites.

Figure 3 shows mean counts and area covered by live maerl thalli in cores taken on test and control plots over 4 years. Live maerl was sparsely distributed in the previously fished area and experimental dredging had no discernible effect either on live thallus numbers or area covered. Table 1 and Fig. 3 show that live maerl was abundant in the previously unfished area (Site 1) and this remained the case on the control plot throughout the study. There was no difference in the amount of live maerl on the test plot immediately after experimental scallop dredging as thalli that had been buried within the sediment were still alive. However, five months after dredging there were 70-80% fewer live thalli in the test cores than in cores taken prior to fishing. There were no signs of recovery in live thallus numbers or area covered over the following 4 years (Fig. 3).

The sculpted ridges and troughs of the dredge tracks remained visible within test plots for 2.5 years at Site 1 and 1.5 years at Site 2. They were gradually erased through bioturbation by large infauna (e.g. the thalassinidean *Upogebia deltaura* (Leach) and the holothurians *Neopentadactyla mixta* (Ostergren) and *Thyonidium drummondii* (Thompson)) and the feeding activities of whelks (*Buccinum undatum* L.), crabs (*Cancer pagurus* L., *Liocarcinus depurator* (L.), *Necora puber* (L.)), starfish (*Astropecten irregularis* (Pennant), *Marthasterias glacialis* (L.), *Asterias rubens* L.) and fish (*Gadus morhua* L., *Pomatoschistus pictus* (Malm), *Pleuronectes platessa* L.). On shallow parts of maerl at Site 2 (-6 to -8 m CD), commercial scallop dredge tracks were erased by wave action during storms (Hall-Spencer and Atkinson, in press).

Historical changes on a Clyde maerl bed

Identifications based on modern taxonomic criteria revealed that the variously labelled maerl thalli obtained between 1885 and 1891 at Site 3 were all *Phymatolithon calcareum* Pallas (Adey et McKibbin). Microscopic examination showed that these plants had been alive at the time of their collection. *Limaria hians* nests collected in 1885 had >100 maerl thalli to 58 mm long entwined with byssus threads to form a protective mat. The three boxed collections at the British Museum had the following contents; Box 516 had >100 thalli (to 38 mm long), Box 519 had 65 thalli (to 50 mm long) and Box 521 had 18 thalli (to 43 mm long).

In 1995-1997, detailed surveys of the entire maerl bed at Site 3 yielded just 16 live *P. calcareum* thalli, all of which were smaller than those collected in the last century (<20 mm long - see Fig. 4). As with Site 2, dead shells of *L. hians* were common, but no live specimens were found.

Sediment trapping investigation

Only small amounts of sediment (0-0.5 g m^{-2}) were collected in traps deployed for 2 h before scallop fishing at Site 2 (Fig. 5), reflecting the prevailing clarity of the water (12 m horizontal visibility recorded by divers). Immediately after fishing, however, suspended sediment had reduced visibility to a few cms in the vicinity of the fished corridor. Two hours later, suspended sediment had settled and the dredged area was clearly visible to divers as a ~2.5 m-wide scoured path along the maerl between the marker buoys. The edge of the dredge track passed 1.5 m from the nearest sediment trap on the north transect and 6 m from the nearest trap on the south transect. Maerl around the dredge path was blanketed by a newly settled layer of silt. Settled particles were largest in the tubs close to the dredge path (max. diam. 4.2 mm) and became progressively smaller with increasing distance from the dredge path (max. diam. 0.8 mm, 15 m away).

The relationship between the amount of sediment collected and distance from the dredge track is shown in Fig. 5. A minimum estimate of the amount of sediment transported to each side of the dredge track was derived by subtracting the area under the pre-dredge curve from that under the post-dredge curve. This calculation indicates that at least 340 g of sediment was lost from each metre of the dredge track. The blanketing effect of the settled sediment was greatest close to the dredge path and was easily detected 15 m away where 4 g m^{-2} of fine silt had settled.

Discussion

Studies on the intensity and area swept by fishing gear in recent years (e.g. Kaiser *et al.*, 1996; Rijnsdorp *et al.*, 1998), indicate that most sedimentary benthic systems on the continental shelf of Europe have been modified by fishing activities in the last 100 years. In some places, such as the southern North Sea, fishing is thought now to be the main ecological structuring force on the benthos (Lindeboom and de Groot, 1998). As a consequence, it can be difficult to design robust field experiments to investigate the long-term effects of fishing on unmodified communities due to the paucity of adequate control grounds (Lindeboom, 1995), through strategies that involve sampling close to sea bed obstructions (Hall *et al.*, 1993), or in areas that are closed to fishing for other reasons (Tuck *et al.*, 1998; present study), do provide useful insights.

Had we restricted our investigation to previously fished maerl grounds of the Clyde Sea area (e.g. Sites 2 and 3), we would have concluded that although scallop dredges had large effects in the short-term (weeks), effects in the long-term (years) could not be detected against a background of natural variation. However, observations on a previously unfished site have revealed significant long-term effects and this adds to a increasing body of evidence that the major impact of towed demersal fisheries occurs the first time an area is subjected to fishery pressure (Jennings and Kaiser, in press).

Scallop dredging began in the Clyde Sea area in the 1930s with Scottish yields of <3 t y^{-1} (Elmhirst, 1945). Landings increased with expansion of the fishery in the 1960s with the advent of more powerful boats, more efficient dredges and better processing facilities (Mason and Fraser, 1986). Local catches per unit effort have since declined in the Clyde Sea area due to dwindling stocks, although scallops remain the most important mollusc fishery in Scotland with 11300 t landed in 1995 (Ministry of Agriculture, Fisheries and Food, 1996). The impacts on local maerl beds are thus likely to have been sustained mainly in the past 30-40 years. Our historical data from Site 3 (Tan Buoy) show extensive changes over the past 100 years from a living maerl bed with abundant large thalli and nests of the gaping file shell *L. hians* to a bed of predominantly dead maerl with few, small live thalli and no *L. hians*.

Our observations on the immediate physical impact of scallop dredging maerl grounds are consistent with those observed on dredge tracks on other types of sedimentary habitat (Caddy, 1973; Eleftheriou and Robertson, 1992). Our calculations of sediment erosion (340 g m^{-1} of dredge track) and area blanketed by redistributed sediment (12x that experiencing contact with the gear) are underestimates, since sediment transported >15 m away was not quantified. Newly settled sediment, however, appeared to have no lasting effect on the benthos adjacent to the dredge tracks. This fauna will be adapted to the periodic sediment redistribution that occurs in shallow sublittoral habitats (Hall, 1994; Hall-Spencer and Atkinson, in press).

The differences we found between an unfished maerl bed and beds that have been impacted confirm that maerl grounds are especially fragile habitats. European legislation under Council Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Fauna and Flora (1992) demands that exploitation of maerl habitats must be compatible with their maintainance at a "favourable conservation status". This may not be the status quo for many European maerl beds since most Clyde grounds, at least, have been extensively modified by scallop dredging.

Maerl beds are perhaps the most sensitive habitat type compared with other sedimentary grounds, e.g. shifting sands especially, where evidence of towed gear impacts is ephemeral (Hall, 1994; Curry and Parry, 1996; Kaiser *et al.*, 1998; Jennings and Kaiser, in press). Parallels can be drawn with the effects of towed demersal fishing gear on *Modiolus modiolus* (L.) communities in the Irish Sea (Magorrian *et al.*, 1995) and seagrass communities in the Mediterranean (Martin *et al.*, 1997), or with blast fishing on coral reefs (Jennings and Polunin, 1996) where impacts are long-lasting since they affect the survival of key habitat-structuring species with poor regenerative abilities.

The integrity of maerl habitats depends upon the survival of a surface layer of slow-growing algae. Our study has shown that these algae are unable to withstand prolonged burial due to lack of light and so they are easily killed by scallop dredging. It is thought-provoking that scallop dredging had effects on our ground (sediment redistribution, live maerl burial) that were clearly discernible 4 years after the event, particularly since our impact (single tows of 3 dredges with ~230 m^2 ground contact) was deliberately limited. The area disturbed by a commercial scallop boat, which typically tows 16 dredges, has been estimated to be 6.6 km^2 per 100 h fishing (Kaiser *et al.*, 1996). Clearly, repeated scallop dredging on the ground studied would considerably reduce the amount of living maerl (given thallus burial, comminution and smothering by silt). However, caution is needed in extrapolating the results of our study to other maerl-bed areas and gear types. Preliminary work on Maltese maerl beds (Borg *et al.*, submitted) has indicated that commercial otter trawling has had no negative impact on the cover of live maerl thalli. The relative hardness of the Maltese ground coupled with a lack of silt and robust, rounded maerl thalli appears to confer resistance to periodic otter trawling.

That we found no discernible recovery from the effects of scallop dredging over 4 years on a previously unimpacted maerl bed in Scotland relates to the slow growth (Potin *et al.*, 1990; Canals and Ballesteros, 1997) and poor recruitment of maerl species. *Phymatolithon calcareum*, which is the main species in the Clyde Sea area and has the widest distribution of the European maerl-forming species (BIOMAERL team, in press), rarely produces reproductive spores and newly settled thalli have never been found in the British Isles (Irvine and Chamberlain, 1994). Our findings add impetus to moves to identify pristine maerl beds for conservation measures in Europe. In SE Spain, the Tabarca Island marine reserve has worked well in protecting local maerl beds from the effects of towed fishing gear (Ramos, 1985; BIOMAERL team, in press; pers. obs.) and a project is currently underway to establish management schemes for three candidate "marine Special Areas of Conservation" containing maerl beds within the UK (Brown *et al.*, 1997).

In the light of our findings, we agree with Lindeboom and de Groot (1998) that more effort should be focused on the impact of towed fishing gear on long-lived and poorly studied communities, and would commend maerl systems as being one such sensitive habitat type.

Acknowledgements

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Figure 4. *Phymatolithon calcareum* maerl thalli collected at Site 3 by Batters in 1891, before scallop fishing began in the Clyde Sea area (upper set), compared with specimens collected from the same site in 1995 (lower set). Scale bar = 2 cm.

Figure 5. Sediment collected in traps 2 h before and 2 h after scallop dredging at Site 2.

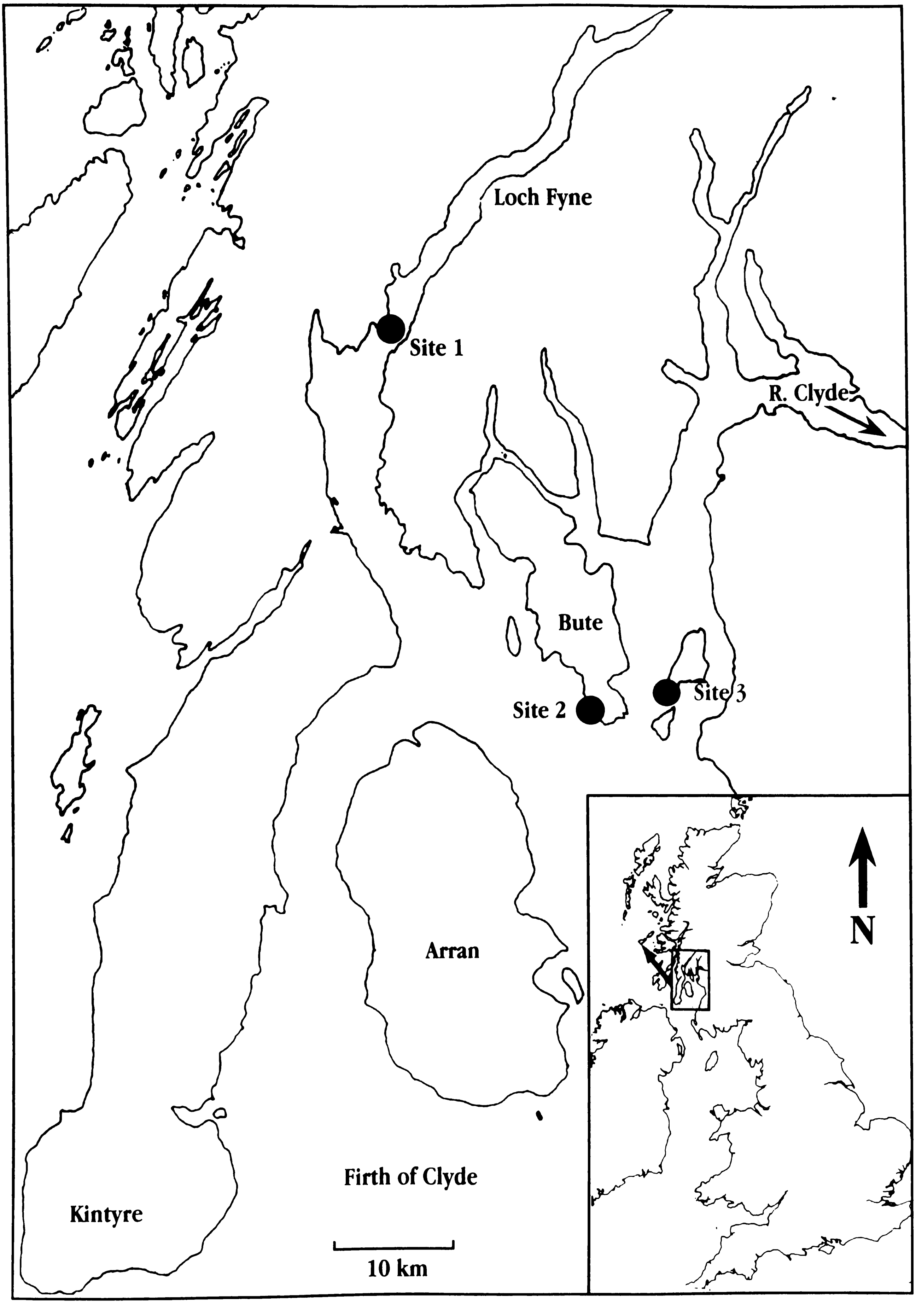


Fig. 1. Positions of maerl study sites in southwest Scotland

Figure 2

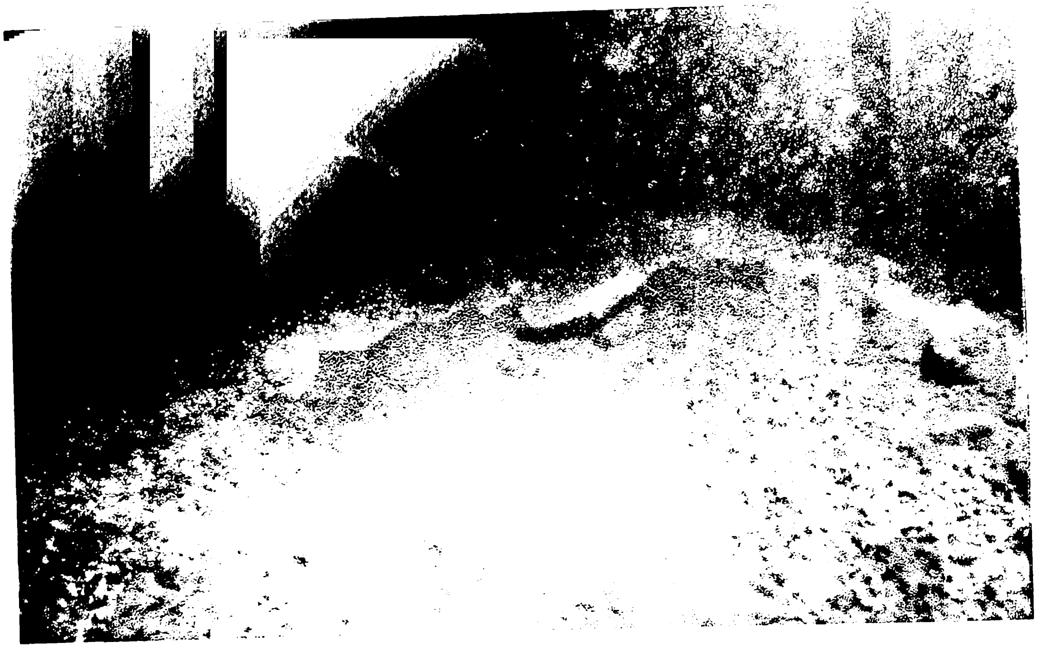


Figure 3

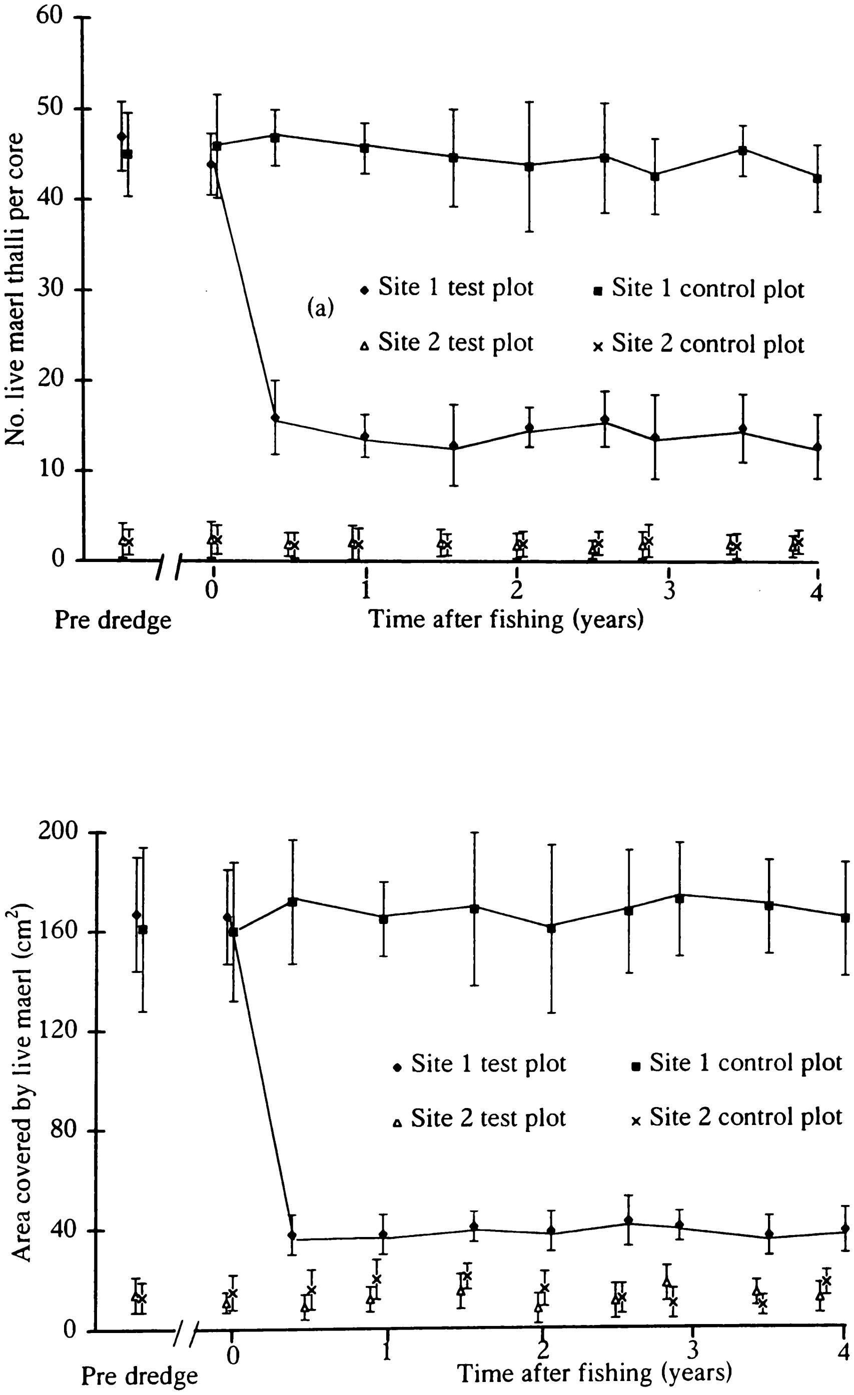

60
50
40
30
20
10
0
No. live maerl thalli per core
(a)
◆ Site 1 test plot
■ Site 1 control plot
▵ Site 2 test plot
× Site 2 control plot
0
1
2
3
4
Pre dredge
Time after fishing (years)
200
160
120
80
40
0
Area covered by live maerl (cm^2)
◆ Site 1 test plot
■ Site 1 control plot
▵ Site 2 test plot
× Site 2 control plot
0
1
2
3
4
Pre dredge
Time after fishing (years)

Figure 4.

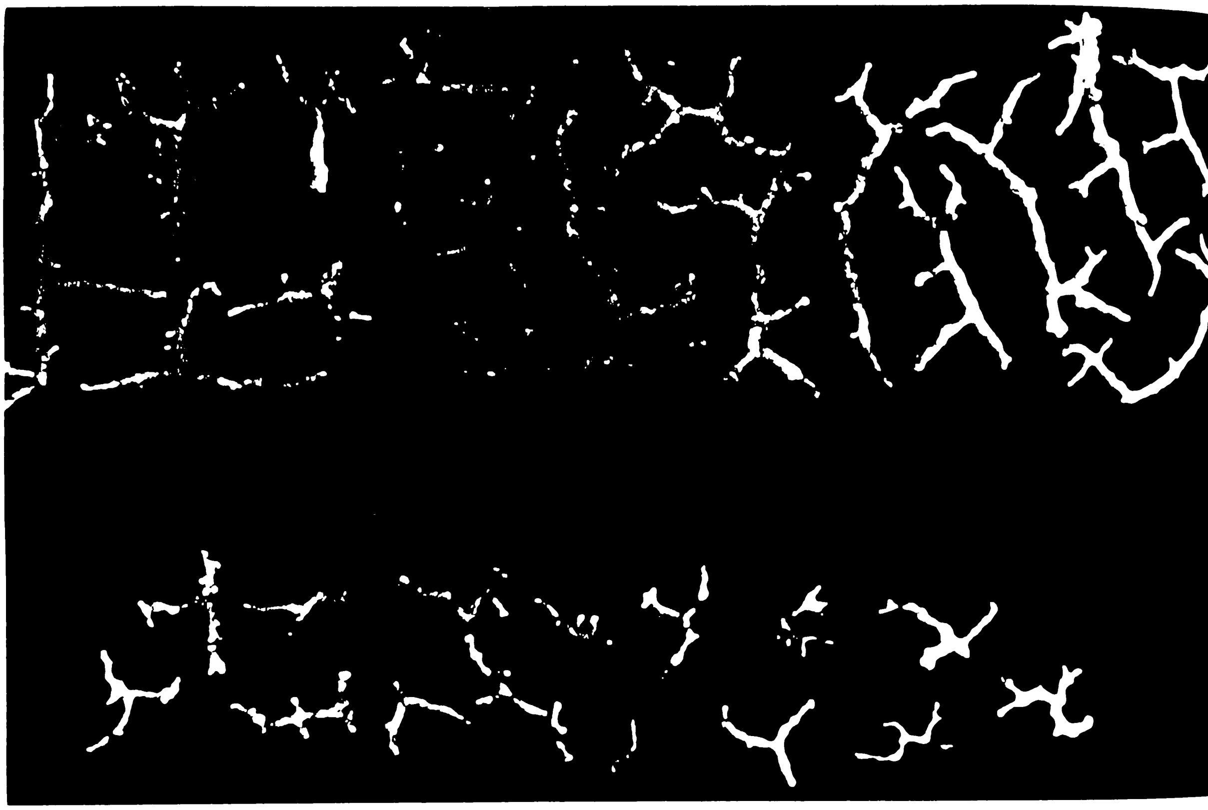
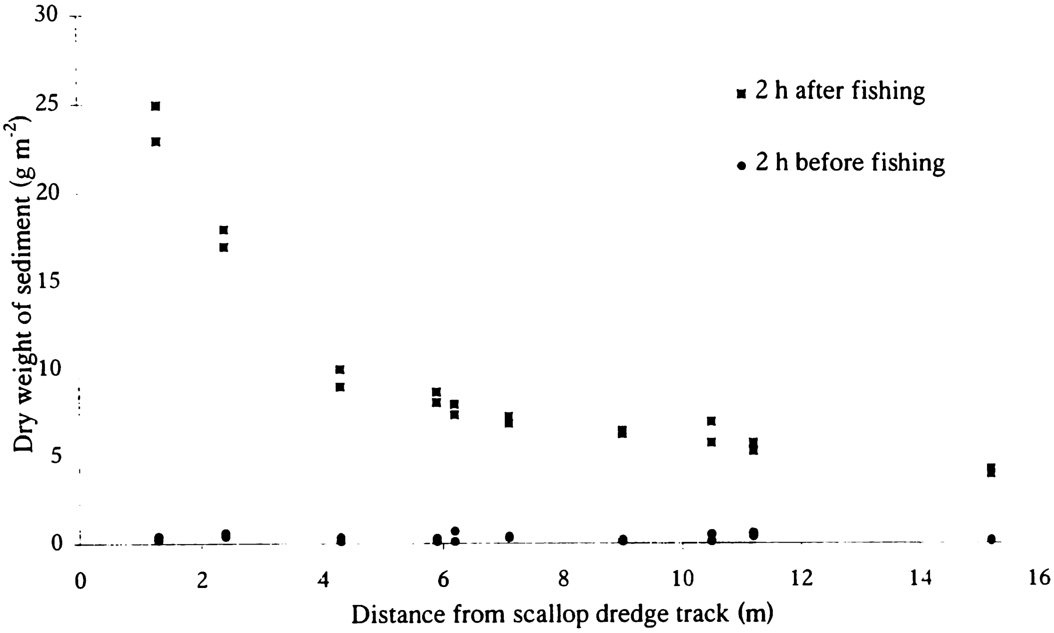


Figure 5



Dry weight of sediment (g m^{-2})
30
25
20
15
10
5
0
0
2
4
6
8
10
12
14
16
Distance from scallop dredge track (m)
■ 2 h after fishing
● 2 h before fishing

Table 1. Differences between the sea bed and benthos of Site 1 (unfished) and Site 2 (fished).

Criteria	Site 1	Site 2
Presence of commercial scallop dredge tracks (seen on diver & ROV surveys)	None	Frequent
Presence of *Limaria hians* byssus nests (seen on diver & ROV surveys)	Frequent	None
Molluscan diversity (data from Hall-Spencer, 1998)	107 spp.	82 spp.
Live maerl cover (in 30 0.1m^2 grab samples)	25.3%	1.8%
Mean population density of *Aequipecten opercularis* (± SD in 1m^2 quadrats)	0.27 ± 0.06 m^{-2} (n=85)	None (n=224)
% *Pecten maximus* over 7 years old (n = number aged)	83% (n= 106)	None (n=57)
Mean population density of *P. maximus* (± SD, in 1m^2 quadrats)	0.06 ± 0.02 m^{-2} (n=85)	0.01 ± 0.07m^{-2} (n=224)

Impacts of scallop dredging on maerl grounds

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Running head: Impacts of scallop dredging on maerl

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Summary

- The single passage of Newhaven scallop dredges can bury and kill 70% of the living maerl in their path and extract *c.* 85% of the scallops present.
- On a dredge track, most of the flora and megafauna to a depth of 10 cm beneath the maerl sediment surface is damaged. Only small, strong-shelled animals are resistant to damage within that stratum.
- For every 1 kg of scallops caught, 8–15 kg of other organisms are captured from maerl habitats.
- Dredge tracks remain visible for up to 2.5 years in maerl habitats.
- Scallop dredging has indirect effects through sediment redistribution, altered habitat structure and modified predator/prey relationships.
- Maerl is a 'living sediment'; it is slow to recover from disturbance by towed gear due to infrequent recruitment and extremely slow growth rates.
- Maerl has an associated deep-burrowing megafauna that is resistant to towed gear impact.
- Pristine maerl communities are highly susceptible to scallop dredging with long-term (>4 year) reductions in the population densities of epibenthic species and decadal consequences for the maerl itself.
- Previously impacted maerl beds support modified benthic communities that recover more quickly from scallop dredging (1–2 years).

Key-words: maerl, benthos, scallop dredging, long-term impacts, Scotland.

Introduction

Maerl beds are unusual coastal benthic habitats derived from living calcareous rhodophytes with structural properties that are intermediate between solid and soft sedimentary environments (Biomaerl team submitted). They typically support a highly diverse flora and fauna (Grall & Glémarec 1998; Hall-Spencer 1998; Birkett, Maggs & Dring in press) but are under immediate threat from human impacts, notably demersal trawling in the Mediterranean (Biomaerl team 1998; Borg *et al.* submitted) and scallop dredges in NE Atlantic coastal waters (Hily, Potin & Floc'h 1992; Hall-Spencer 1995; Hall-Spencer & Moore submitted).

Large maerl thalli are among the oldest marine macrophytes in the N Atlantic and contribute to deposits that take hundreds to thousands of years to accumulate since even optimal growth rates are extremely slow (Potin *et al.* 1990; Birkett, Maggs & Dring in press). For this reason, management of the exploitation of two of the main maerl-forming species in Europe, *Lithothamnion corallioides* and *Phymatolithon calcareum*, is obligatory under the EC Directive on the Conservation of Natural Habitats and Wild Fauna and Flora (1992).

Many maerl beds are productive scallop fishing grounds but concern has been expressed over their vulnerability to dredging disturbance (MacDonald *et al.* 1996). Of 242 maerl beds surveyed around the UK in the past 10 years, 29% were found to support the great scallop, *Pecten maximus* (Marine Nature Conservation Review database 1998). In the UK, scallops are fished using Newhaven dredges (Fig. 1) which are amongst the most robust types of fishing gear used in Europe as they are designed to withstand collision with boulders (cf. Hall-Spencer *et al.* 1999). Short-term effects of this gear have been studied on sand and gravel habitats (Chapman, Mason & Kinnear 1977; Eleftheriou & Robertson 1992; Kaiser *et al.* 1996; Hill *et al.* 1996; Bradshaw *et al.* present publication) but long-term effects and the influence on maerl fauna were hitherto unknown.

We recently showed that scallop dredges have profound and lasting effects on living maerl, since up to 70% of thalli on dredged tracks are killed through burial (Hall-Spencer & Moore submitted). Here we present results obtained by filming dredges in use and monitoring recovery of maerl benthos in previously dredged and undredged areas.

Methods

STUDY SITES

Scallop dredging experiments were undertaken on two maerl beds in the Clyde Sea area, Scotland. A previously undredged area was located at Creag Gobhainn (56° 00.66'N 5° 22.32'W) and an area that had been commercially dredged for scallops over the past 40 years was located in Stravanan Bay (55° 45.32'N; 5° 04.27'W). These sites were surveyed in detail from 1994–1998 using a combination of Sprint® Remote Operated Vehicle (Perry Tritech Ltd), RoxAnn®, van Veen grab sampling (at least 6 grabs per site per quarter) and >200 h field observations using SCUBA. Details relating to the environmental characteristics, scallop dredging history and macrobenthic ecology of these grounds have been presented elsewhere (Hall-Spencer 1995, 1998; Hall-Spencer & Atkinson in press; Hall-Spencer, Moore & Sneddon in press; Hall-Spencer & Moore submitted; Biomaerl team submitted).

FISHING GEAR USED

A gang of 3 Newhaven dredges (dredge mouth width 77 cm, with spring-loaded teeth 10 cm long x 0.8 cm wide mounted 8 cm apart; Fig. 1) was towed by RV *Aora* (260 hp). The dredge mouths were maintained perpendicular to the sea bed by a horizontal metal bar, towed on warps, and held off the sea bed by a rubber roller at each end. A 92 cm-long mat of linked 7 cm diameter steel rings extended behind each tooth bar to withstand abrasion. This chain mail formed a robust belly to the bag and each dredge weighed *c.* 85 kg on land. A 6.0 mm lens colour UWTV camera (Simrad Osprey model OE1362) and compact lamp (Simrad Osprey model OE1132) were mounted on a purpose-built adjustable bracket. This bracket was armoured to protect the camera, cable and lights from collisions with boulders. A submersible TV cable with kevlar braid reinforcement and 2.5 mm thick polyurethane sheath (Hydrocable Systems Ltd, Aberdeen) was used to eliminate problems of cable stretch. Images of the dredge mouths were recorded on videotape (VHS; Ferguson Ltd, UK) with a time/date overlay provided by a video timer (VTG-88; FOR-A Co. Ltd, Japan).

EXPERIMENTAL PROTOCOL

At both sites, three transects approximately 100 m long were dredged using single tows of the gear described above. These transects were dredged during the summer of 1994 at water depths between -10 and -15 m Chart Datum. Immediate effects of the scallop dredges were noted on each transect and one transect at each site was monitored by divers for 4 years. Each transect was marked with buoys laid *c.* 10 m apart to delimit the width of a dredging corridor. The long-term transects were surveyed the day before dredging by divers who deployed 1 m^2 quadrats haphazardly along two parallel strips of sea bed, one situated between the marker buoys (test plot) the other situated 30 m away, outside the buoys (control plot). Visible organisms, megafaunal burrows/tubes and nests of *Limaria hians* were enumerated in 40 replicate quadrats on each plot. *Limaria hians* nests were counted as the communal byssus nests of this thin-shelled bivalve (Fig. 2) were an important structural feature of the previously undredged site (Hall-Spencer 1998).

On each transect, the scallop dredges were towed at 2–3.5 km h^{-1}. On retrieval, *Pecten maximus* were counted, wet weighed and measured. Other elements of catches were sorted into categories (queen scallop *Aequipecten opercularis*, echinoderms, non-target molluscs, tunicates, polychaetes, crustaceans, other invertebrates, fish, macroalgae and stones) and wet weighed. Megafauna were identified, counted and inspected for external signs of damage (cracked shells, missing limbs etc.). Within an hour of dredging, divers measured the length of dredged transects, collected *P. maximus* remaining on dredge paths and recorded the degree of damage to uncaught elements of the affected benthos. To estimate the efficiency of the dredges, the numbers and size of scallops that remained within the dredge paths immediately after fishing were compared with the numbers and sizes of scallops retained in the dredge bags.

The day after dredging, and 2 to 4 times a year over the following 4 years, the benthos of marked test and control plots was monitored by divers deploying 20–40 replicate 1 m^2 quadrats. The number of replicates depended on dive time available. Here we present data on variation with time and between treatments in the numbers of the burrowing anemone *Cerianthus lloydii*, burrows of the crustacean *Upogebia deltaura* and byssus nests of the bivalve *Limaria hians* as examples of contrasting benthic lifestyles. Analyses using ANOVA were performed on log transformed data to test for differences in the abundances of these members of the benthos between treatment and control transects before and at time intervals after fishing.

Results

GENERAL OBSERVATIONS OF IMMEDIATE IMPACTS

Video recordings showed that the gear behaved similarly on both sites. The rollers and chain rings of each dredge were in contact with the sea bed while the dredge teeth projected fully into the maerl substratum (10 cm) and harrowed the sea bed. Maerl was flicked upwards as the dredge teeth jerked back and forward on spring-loaded bars, creating a cloud of suspended sediment. Boulders < 1 m^3 were overturned and cobbles often became wedged between the teeth and were dragged through the sediment or were flicked along ahead of the gear. Large, fragile organisms were usually broken on impact (e.g. the sea urchin *Echinus esculentus* and the starfish *Luidia ciliaris*) whereas strong-shelled organisms usually passed into the dredges intact (e.g. *Pecten maximus* and the gastropod *Buccinum undatum*). Other animals (e.g. *Aequipecten opercularis*, the swimming crab *Liocarcinus depurator* and most fish) swam as the gear approached and often escaped capture.

Direct observations on dredged transects showed profound immediate impacts to the benthos. Each transect consisted of a *c.* 2.5 m wide track along which natural bottom features (e.g. crab pits and burrow mounds) were erased. Sand and silt was brought to the sediment surface and living maerl was buried.

Dislodged rocks lay overturned, exposing crevice-dwelling fauna and burying surface epiliths. Thick-shelled molluscs that were small enough to pass between the dredge teeth remained in the dredge tracks intact (e.g. *Gibbula magus*, *Clausinella fasciata*). However, most megafauna on or within the top 10 cm of maerl were either caught in the dredges or left damaged on the dredge tracks (e.g. the crab *Cancer pagurus*, the bivalves *Ensis arcuatus, Laevicardium crassum* and the sea urchins *Spatangus purpureus*, *Echinocardium pennatifidum* and *Echinus esculentus*). Close examination of dredge tracks also revealed a littering of animal fragments derived from smaller members of the maerl community (e.g. *Cerianthus lloydii* and the polychaete *Terebellides stroemi*).

On each ground, video and direct observations by divers revealed that several species rapidly aggregated to feed along the dredge tracks including whelks (*Buccinum undatum*), crabs (*Liocarcinus depurator*, *Necora puber*, *Pagurus bernhardus*), brittlestars (*Ophiocomina nigra*) and fish (*Pleuronectes platessa, Scyliorhinus canicula, Pomatoschistus pictus, Gadus morhua, Callionymus lyra*). Not only were damaged animals consumed but intact members of the infauna were taken before they could reburrow. Over a 24 h period, less mobile or nocturnal scavengers also moved onto dredge transects (e.g. the isopod *Natatolana borealis* and the starfish *Asterias rubens*) and swarms of lyssianassid amphipods were observed when dead crustaceans were checked by divers. After three days the shells of damaged animals were picked clean and scavengers had begun to disperse. Further details of these general observations are given by Hall-Spencer (1995).

CATCH COMPOSITION ON PREVIOUSLY DREDGED AND UNDREDGED AREAS

The dredges were highly size-selective and none of the *P. maximus* caught was <7 cm in length. Video recordings showed that the brittlestar *Ophiocomina nigra* entered the dredges in their thousands but were not included in the catch as they passed through the 7 cm rings of the dredge bags and littered the dredge tracks immediately after dredging. From an area of 780 m^2 at the previously undredged site; 42 *P. maximus* were caught and 7 were left on the dredge tracks immediately after fishing. From an area of 800 m^2 at the previously dredged site; 9 scallops were caught and 2 were left on the dredge paths. Thus catches were much higher at the previously undredged site and, overall, 86% of the marketable size scallops lying in the paths of the gear were captured. Thus capture rates for scallops in maerl are much higher than for other substrata (Caddy 1973; Dare *et al.* 1993).

On each dredge tow, 8–15 kg of by-catch organisms were caught per 1 kg of *P. maximus*. By-catch quantity and composition varied greatly between sites (Fig. 3). In each faunal category, more organisms were caught at the previously undredged site which reflected higher population densities of macrobiota than in the previously dredged area. A major difference was that byssus nests of *Limaria hians* and associated organisms were abundant in catches from the previously undredged area but were absent from the dredged site. Per unit area, more than 4 times the amount of non-target molluscs, tunicates, anthozoans and polychaetes were dredged from the previously undredged site than from the previously dredged site.

The survivorship of discarded by-catch was not investigated. However, animals protected by thick shells (e.g. *P. maximus*, *B. undatum*, *Pagurus bernhardus*) were mostly unbroken in both areas. Overall though, >50% of by-catch organisms were badly damaged either due to direct impact with the dredges or maceration by cobbles and pebbles that were churned in the chain-mail bags as the gear was towed (Hall-Spencer 1995).

TEMPORAL DYNAMICS OF BENTHOS ON PREVIOUSLY DREDGED AND UNDREDGED AREAS

While no differences were observed between test and control plots prior to experimental scallop dredging, substantial changes were recorded in the months thereafter (Figs 4–6). Immediately after dredging, control plots were unchanged but most sessile macrofauna and flora was removed or damaged on test plots, and an ephemeral increase in abundance of motile scavengers followed (see above). Dredge tracks remained visible for 0.5–2.5 years depending on depth and exposure to wave action. In a shallow, exposed area (Stravanan Bay, -10 m), dredge tracks were erased by sediment redistribution during storms but in deeper and more sheltered areas, tracks remained clearly visible after storms but were gradually erased through bioturbation.

Monitoring over a period of 4 years revealed different rates of recovery for species associated with maerl habitats. After one month, no significant differences were found in the population densities and species diversity of mobile epibenthos (e.g. crabs, gastropods, starfish) between test and control plots. After 6 months, population densities and diversity of fleshy macroalgae were not significantly different on test and control plots. In contrast slow-growing and/or infrequently recruiting sessile organisms (see below) remained depleted on test plots for 4 years after dredging occurred. The temporal dynamics of three species which exemplify contrasting life styles and responses are given in Figs 4–6.

In our study, the thalassinidean shrimp *Upogebia deltaura* was the deepest burrowing animal (to 68 cm) and the most abundant large crustacean found within the maerl substratum at both sites. Monitoring on control plots showed that the density of burrow openings changed little over the 4 year period with only slightly fewer openings at the previously undredged site (3–6 m^{-2}) than at the dredged site (4–10 m^{-2}). An investigation into *U. deltaura* burrow structure at these sites showed that each burrow had a single occupant and *c.* 70% of burrows had two openings while the remainder had three (Hall-Spencer & Atkinson in press). Immediately after dredging, nearly all burrow openings were erased from test plots (Fig. 4). However, the shrimps rebuilt the upper sections of their burrows within a week and no significant long-term differences were found between burrow densities on control and test plots at either site (Fig. 4). At each site, other deep-burrowing megafaunal species (e.g. the bivalve *Mya truncata* and the holothurian *Neopentadactyla mixta*) were also resistant to scallop dredging disturbance, with no long-term changes to their population density.

Effects on sessile organisms living within the surface layer of maerl were more pronounced, as illustrated by the anemone *Cerianthus lloydii*. At both sites, this tube-dwelling anemone was one of the most abundant animals visible to divers. Monitoring of control plots revealed that they were slightly more abundant during the summer at the undredged site (25–35 m^{-2}) than in the dredged area (18–24 m^{-2}) and their observed densities at both sites decreased to 5–10 m^{-2} in winter. These anemones were able to retract deeply (to 44 cm) within the maerl when disturbed and immediately after dredging very few were seen on test plots, although their torn tubes and polyps littered the maerl surface. Repeat surveys one month after fishing revealed that *c.* 25% of the anemones had survived at each site (Fig. 5). On both the test and control plots of each ground, *C. lloydii* were seen reproducing through longitudinal fission in the spring months of 1995–98. Significant differences in the abundance of *C. lloydii* persisted between plots for 14 months at both sites after which the population densities became similar (Fig. 5). The numbers of several species followed this pattern (e.g. the polychaetes *Eupolymnia nebulosa*, *Lanice conchilega* and the ascidian *Ascidiella aspersa*) with a dramatic decrease in population densities immediately after dredging followed by a return to pre-dredge and control plot levels over the following 1–2 years (unpublished data). After two years, no significant differences were found in the population densities of organisms visible to divers between test and control plots at the previously dredged site.

In contrast, at the previously undredged site there was a group of sessile, surface-dwelling species that exhibited consistently lower abundance on test plots for 4 years (e.g. *Phymatolithon calcareum*, sponges, the anemone *Metridium senile*, the bivalves *Modiolus modiolus* and *Limaria hians*). *Limaria hians*, for example, was absent from the dredged site although their dead shells were abundant; – as noted on three other previously scallop dredged maerl beds in the Clyde Sea area (Hall-Spencer 1995). At the previously undredged site, these bivalves built roughly circular byssus nests on the maerl surface that were usually 10–30 cm in diameter. These were covered in a variety of associated fauna (mainly hydroids and tunicates). *Limaria hians* proved to be particularly susceptible to scallop dredging as most of its byssus nests were removed and those that remained were torn, exposing the inhabitants to opportunistic scavengers. The abundance of *L. hians* nests remained significantly depleted post-impact compared with the control plot for 4 years (Fig. 5), as did those organisms that were commonly found on (or in) its nests (e.g. the hydroid *Thuiaria articulata* and the ascidian *Diplosoma listerianum*).

Discussion

The immediate effects of scallop dredging over maerl grounds were similar to those recorded for other shallow sublittoral biotopes (Caddy 1973; Chapman, Mason & Kinnear 1977; Eleftheriou & Robertson 1992) although extensive redistribution of coarse sediment left tracks that lasted up to 2.5 years. Such persistent towed-gear tracks reflect the sheltered conditions of sea lochs (Tuck *et al.* 1998). Collateral damage to sessile/slow-moving organisms was high and attracted aggregations of benthic predators and scavengers; a typical response to towed gear impact (Kaiser & Spencer 1994; Ramsay, Kaiser & Hughes 1998; Bradshaw *et al.* present publication). Video records of dredge behaviour and catch analysis revealed interesting differences compared with findings for other sediments. Thus, the ratio of marketable *Pecten maximus* caught to those left on dredge tracks showed that Newhaven scallop dredges were *c.* 85% efficient on maerl, compared with estimates of 14–27% efficiency on coarse, stony sediments (Gruffydd 1972; Chapman, Mason & Kinnear 1977) up to a maximum of 41% on smooth muddy gravel (Dare *et al.* 1993). The maximum penetration of the dredge teeth (10 cm cf. 3 cm recorded by Chapman *et al.* 1977) and the presence of only a few boulders to cause lifting of the gear are thought to explain the high capture efficiency recorded on maerl grounds. Paradoxically, selectivity of the gear was poor. By-catch organisms constituted >80% of the biomass of dredge contents, cf. 25% recorded for the same gear on gravel grounds in the Irish Sea (Kaiser *et al.* 1996). The proportion of by-catch was highest on a previously undredged ground where sessile, epibenthic organisms were more abundant. As in similar studies undertaken in the Irish Sea (Hill *et al.* 1996), much of the by-catch was fatally injured either by impact with the gear or with stones within the dredge bags.

The high porosity of maerl beds (Biomaerl team submitted) allows a suite of species to occur deep within the sediment (Keegan & Könnecker 1973; Hall-

Spencer & Atkinson in press). We found that deep-burrowing species escaped dredge damage and were relatively unaffected in the long-term whereas species that occurred within more superficial maerl strata or on the substratum surface were progressively more susceptible to damage. Monitoring of surface-dwellers showed patterns predicted by MacDonald *et al.* (1996). That is, species with regular recruitment and rapid growth (e.g. annual macroalgae) recovered quickly whereas numbers of irregularly recruiting, slow-growing species (e.g. *Modiolus modiolus*) remained significantly depleted. Another set of species also remained reduced in numbers due to a lack of suitable substrata provided by *Limaria hians*. A similar situation was reported in Strangford Lough (Service & Magorrian 1997) where *M. modiolus* beds were sensitive to trawling but supported diverse sessile communities in undredged areas.

Our surveys showed that the benthic community present on a previously-dredged maerl bed was heavily modified with no long-lived/fragile organisms on or in the surface layer of sediment. Live *Modiolus modiolus* and *Limaria hians* were absent, for example, although their dead shells were abundant. This suggests that these bivalve species had thrived on this area of maerl in the past since local benthic water currents (up to 11 cm s^{-1} recorded by Hall-Spencer & Atkinson in press) were not strong enough to transport their shells onto the maerl from elsewhere in the bay and surrounding habitats lacked these species or their shells. The previously dredged macrobenthic community proved resistant to further scallop-dredge disturbance since it returned to pre-experimental status within 2 years. In contrast, scallop dredging disturbance had a longer lasting effect on a previously undredged community with changes still discernible after 4 years. As with other types of benthic habitat (Lindeboom 1995; Tuck *et al.* 1998), care is needed when interpreting investigations into the ecosystem effects of fishing since observed impacts vary depending on the past exploitation of the ground.

The contrasting degrees of long-term effect recorded in the present study are particularly noteworthy given the small scale of our experimental impacts (single tows of 3 dredges with *c.* 230 m^2 ground contact per tow). A typical UK scallop boat, towing 16 or more dredges per side, has been estimated to impact

6.6 km^2 of sea bed per 100 h fishing (Kaiser *et al.* 1996). Our experiments were deliberately restrained since manipulations at the scale of a fishing fleet (e.g. Currie & Parry 1996) would have been unnecessarily destructive. That up to 70% of the living maerl can be buried and killed through light deprivation by the single passage of a scallop dredge gang is of serious concern as this limits the ability of disturbed beds to regenerate (Hall-Spencer & Moore submitted). We found that many maerl grounds in the Clyde Sea area had been scallop-dredged sometime in the recent past and only one site was located that remained unaffected (trawling being prohibited due to the presence of an underwater communication cable). It is clear from our studies that maerl beds are particularly vulnerable to scallop dredging disturbance but the present extent of fishing disturbance to such beds is unknown. Not all maerl beds support *Pecten maximus* (MNCR database 1998) and so the risk from scallop dredging in such areas is lower, while others are protected by natural obstructions to trawling (J.H.-S. personal observation). A detailed review of the extent, distribution and status of European maerl beds is needed.

It is vital to the lasting integrity of maerl beds, which represent an essentially non renewable resource, that they be protected both from direct exploitation (Farrow 1983; Biomaerl team 1998) and from the impacts of towed demersal gear (Hall-Spencer & Moore submitted; present study). Even permanent anchorages over protected maerl beds should be restricted since repeated anchoring can create disturbances analogous to towed fishing gear impacts (Hall-Spencer 1995).

Recommendations

- Given the vulnerability of pristine maerl beds, protected areas should be established to incorporate the best examples of this habitat.
- The extent and distribution of maerl beds in European seas should be mapped and appropriate protocols generated to enable assessments to be made of their status.

- Within protected areas, destructive practices such as aggregate extraction, scallop dredging, repeated anchoring and hydraulic dredging for infaunal molluscs should be prohibited.
- Given that many maerl beds support scallop populations, low impact methods of spat collection, ranching and diver-harvest could be managed in selected areas to provide continued employment and revenue to local people.

Acknowledgements

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LIST OF FIGURES

Figure 1. The gang of three 0.77m wide Newhaven scallop dredges used experimentally on maerl.

Figure 2. The thin-shelled bivalve *Limaria hians* removed from its byssus nest on the previously undredged maerl bed. Scale bar = 1cm.

Figure 3. Mean and maximum weights (indicated by histograms and range bars respectively) of scallops, other organisms and stones (cobbles and pebbles) caught in scallop dredges on transects on previously dredged and undredged areas. † denotes categories in which mean catches from a previously undredged site were >4 times higher than on the previously dredged ground.

Figure 4. Numbers of openings of deep burrows of the crustacean *Upogebia deltaura* recorded within test and control plots prior to and over 4 years after experimental scallop dredging at A) previously undredged ground and B) previously dredged ground. Error bars are + SE (n=20), significant differences (ANOVA on log transformed data) are indicated ** $P<0.01$, * $P<0.05$).

Figure 5. Numbers of the tube-dwelling sea anemone *Cerianthus lloydii* recorded within test and control plots prior to and over 4 years after experimental scallop dredging at A) previously undredged ground and B) previously dredged ground. Error bars are + SE (n=20), significant differences (ANOVA on log transformed data) are indicated ** $P<0.01$, * $P<0.05$).

Figure 6. Numbers of byssus nests of the bivalve *Limaria hians* recorded within test and control plots prior to and over 4 years after experimental scallop dredging on the previously undredged ground. Error bars are + SE (n=20), significant differences (ANOVA on log transformed data) are indicated * $P<0.05$).

Figure 1

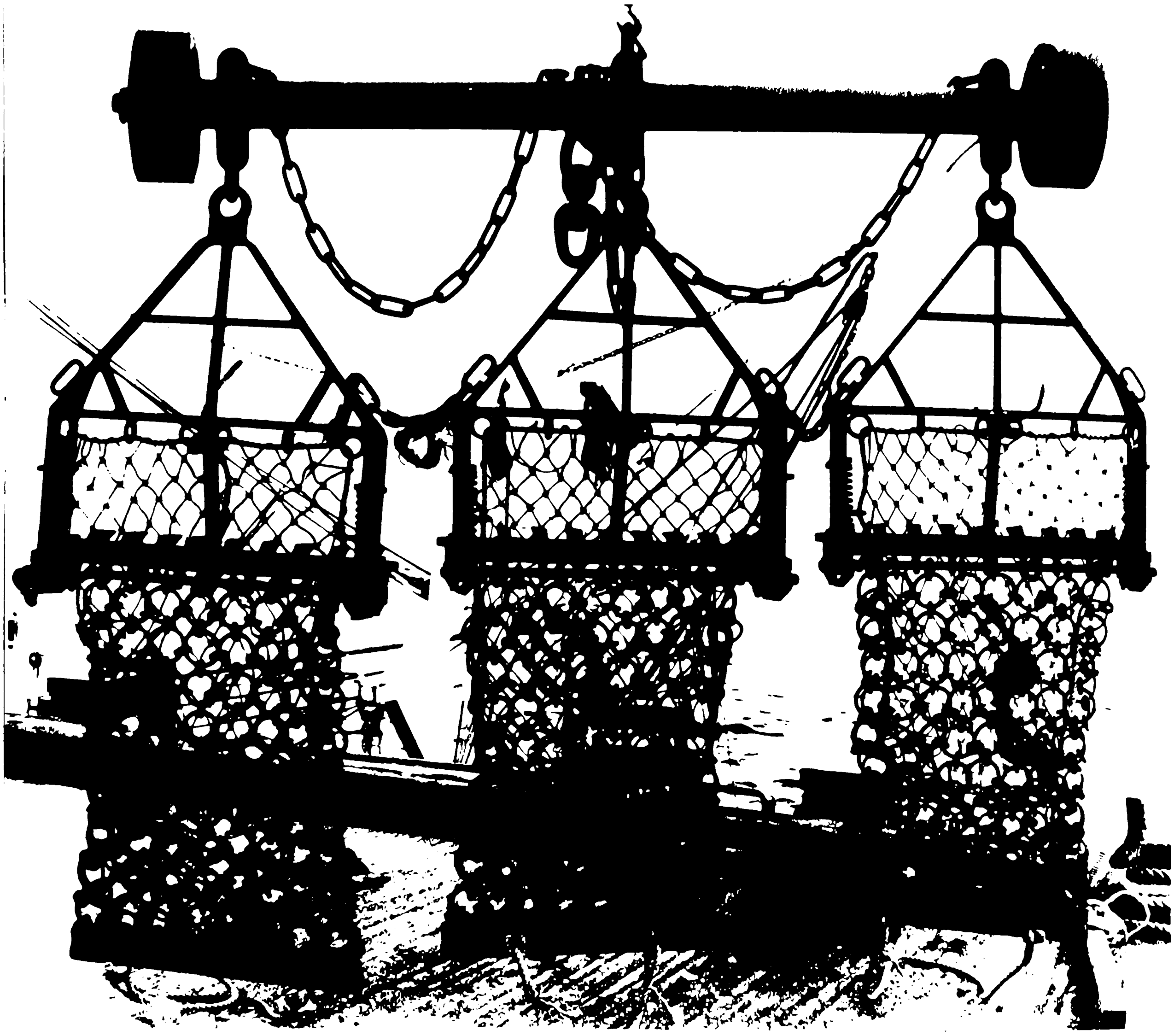
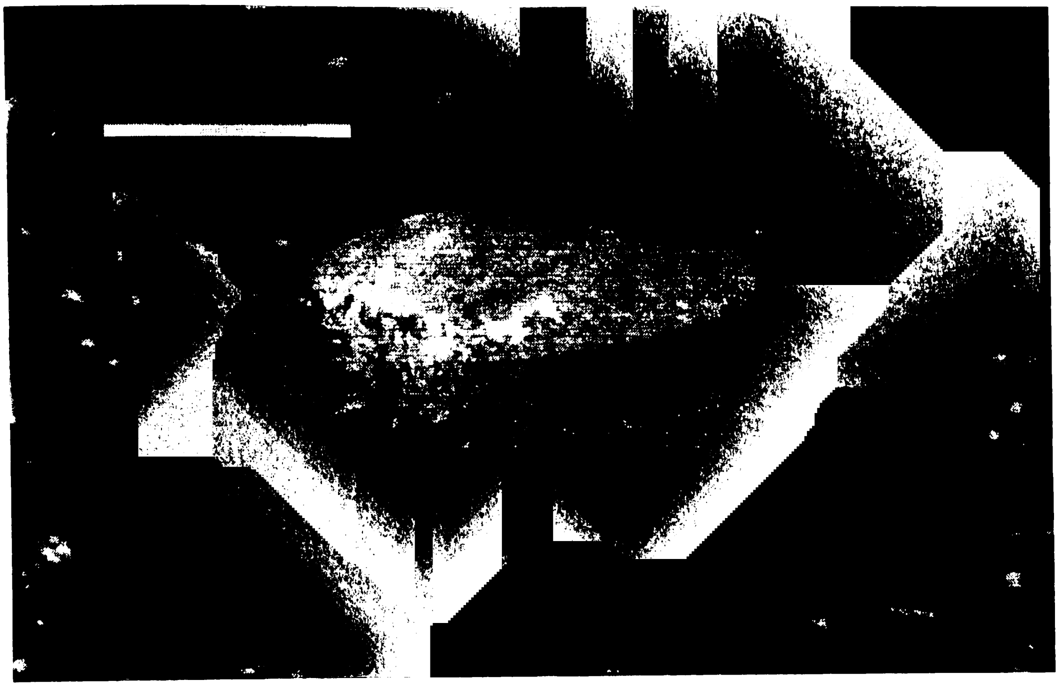


Figure 2



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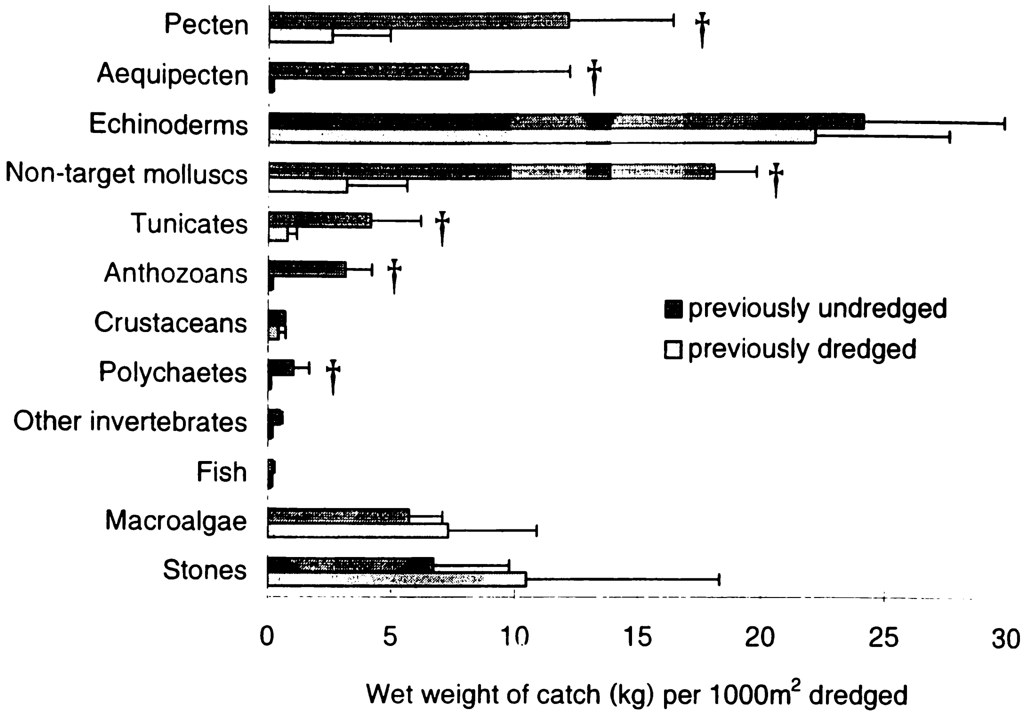
Pecten
Aequipecten
Echinoderms
Non-target molluscs
Tunicates
Anthozoans
Crustaceans
Polychaetes
Other invertebrates
Fish
Macroalgae
Stones
† † † † † †
■ previously undredged
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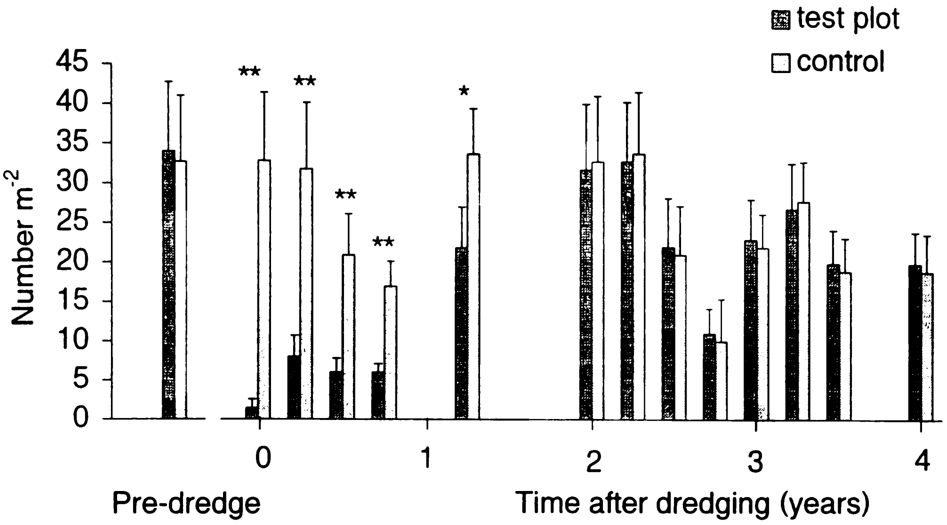
30
Wet weight of catch (kg) per 1000m² dredged

Figure 4


A) *Cerianthus lloydii* previously undredged

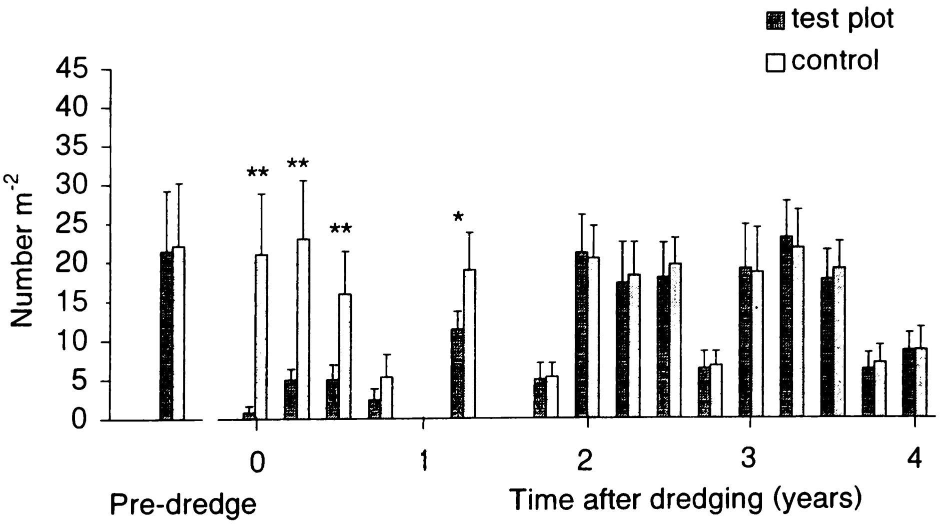
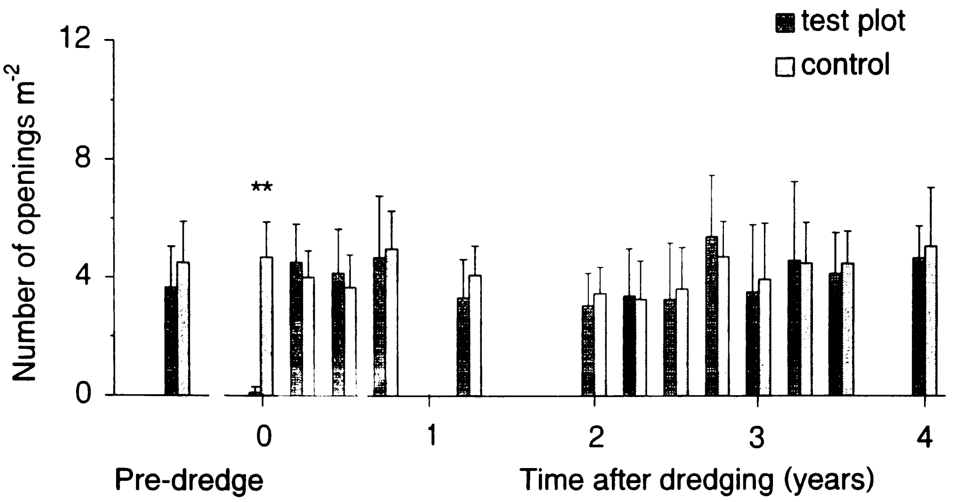

B) *Cerianthus lloydii* previously dredged

Figure 5

A) *Upogebia deltaura* burrows previously undredged



B) *Upogebia deltaura* burrows previously dredged

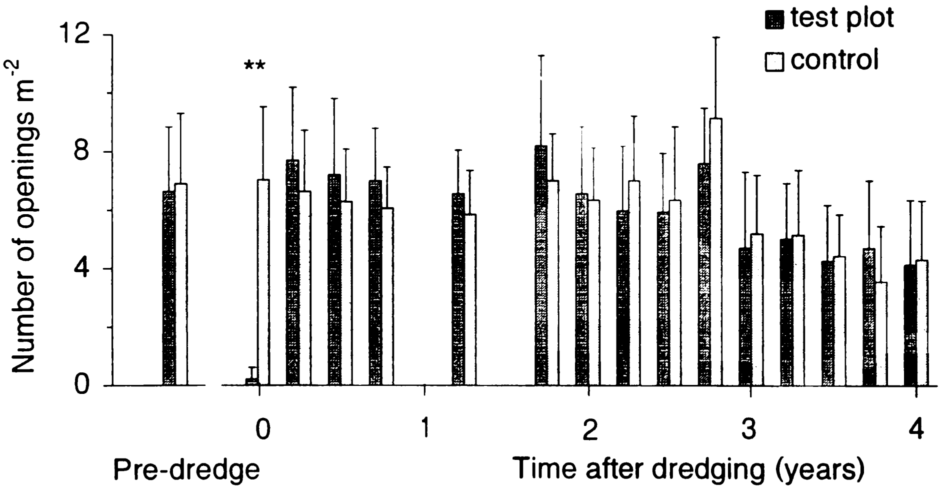
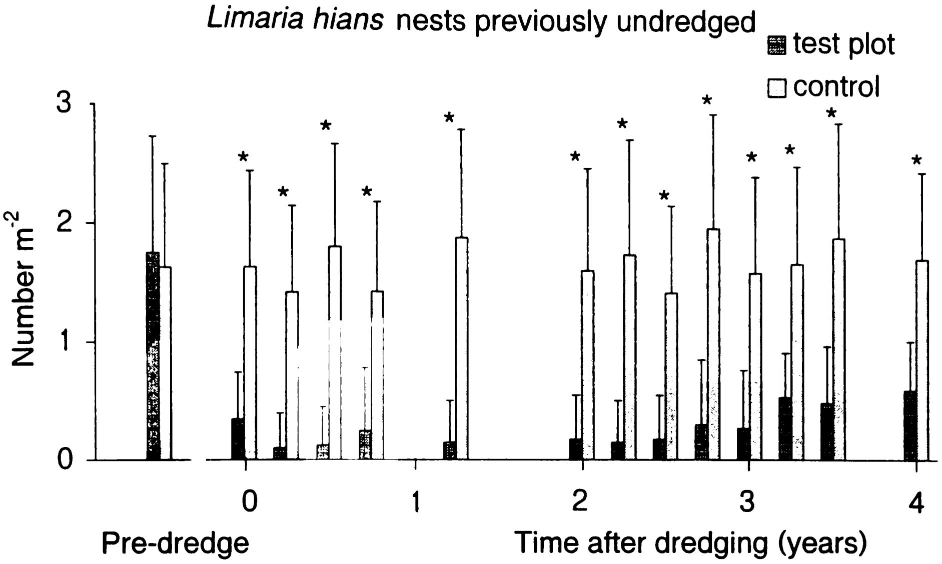


Figure 6


Limaria hians nests previously undredged
▩ test plot
☐ control
Number m^{-2}
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2
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0
1
2
3
4
Pre-dredge
Time after dredging (years)

CARACTERIZACIÓN FISICOGEOQUÍMICA DE LOS FONDOS DE MAERL DE LA RIA DE VIGO.

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El término breton maerl (Lemoine, 1910) designa la acumulación de talos de algas Corallinaceae (Rhodophyta) no geniculadas ni epifitas y que poseen un nucleo algal. Estas algas calcáreas se acumulan en los fondos marinos formando verdaderos depósitos sedimentarios que se distribuyen geográficamente en bancos o zonas acotadas de los mares de todo el mundo. Ecológicamente, los fondos de maerl constituyen un hábitat donde se asientan una de las comunidades animales mas diversas del medio marino de latitudes medias reuniendo una epiflora algal y una epifauna y endofauna característica (Cabioch, 1968). El estudio de los fondos de maerl que aqui se presenta se aborda en base al funcionalmiento de su biocenosis para poder facilitar la evaluación de los impactos antropogénicos y la gestión y estrategias de conservación de este medio. En lo que concierne a esto último existe una actual falta de información acerca de los factores fisicogeoquimicos que estructuran los fondos de maerl y la respuesta de este ecosistema a alteraciones naturales, dejando aparte la actividad humana.

El presente trabajo se realizó en dos estaciones de muestreo localizadas en un fondo de maerl situado en la margen norte de la Ría de Vigo. El seguimiento se realizó en dos estaciones, una control y otra situada en un polígono de bateas para producción de mejillón. La estación control (USC), no sujeta a perturbaciones, se encontraba a 9 m de profundidad frente a la Ensenada de Cangas (42°15'03.2" 08°46'01.6") y la estación sujeta a impacto ambiental (USI), frente a la Ensenada de Limens a 16 m de profundidad. El estudio se desarrolló a lo largo de un ciclo anual y la toma de muestras se llevó a cabo con la draga box-corer, con periodicidad mensual entre los meses de abril de 1996 y abril de 1997. Los parámetros físico-químicos analizados para configurar la caracterización de este ambiente bentónico fueron la granulometría de la columna sedimentaria, la morfología tridimensional de los tipos de maerl encontrados, la composición porcentual de maerl vivo, muerto, material conchífero particulado, materia orgánica, contenido en carbonatos, compactación del depósito sedimentario y potencial de oxidación reducción de la columna sedimentaria. También se analizó la hidrología de la zona de estudio (oxígeno, materia orgánica en suspensión, seston total, pH, Eh, temperatura y salinidad).

Las especies de algas calcáreas encontradas en este fondo fueron, en orden de abundancia *Phymatolithon calcareum* (Pallas) Adey & McKibbin, *Lithothamnion corallioides* (P. & H. Crouan) P. & H. Crouan, *Phymatolithon purpureum* (P. & H. Crouan) Woelkerling & Irvine y *Mesophyllum lichenoides* (Ellis) Lemoine. El recubrimiento de maerl vivo (82.2%) y maerl muerto (5.4%), fue mayor en la estación control que en la impactada (57.1%maerl vivo; 3.7% maerl muerto) con una mayor proporción de material particulado conchífero en esta segunda estación (39.2%) proviniente de la fragmentación de concha de mejillón, que en la control (12.4%). La tasa de carbonatos contenida en el sustrato a lo largo del año osciló para la estación control entre 85.7% (Octubre 96) y 92.4% (Abril 96), siendo los valores encontrados para la estación de batea algo inferiores (76.1% en diciembre 96 y 90.3% en abril 96). La materia orgánica del sedimento registró valores superiores a lo largo del año en la estación sujeta a eutrofización orgánica (máx. valores de 9.45% en octubre 96), pasando a 7.34% en la estación control, para el mismo mes.

Este estudio se llevó a cabo en el marco del proyecto BIOMAERL. maerl biodiversity and anthropogenic impacts, financiado por el Programa de Ciencias Marinas y Tecnología de la Comisión Europea (MAST III) con el contrato MAS3-CT95-0020.

COMPOSICIÓN FLORÍSTICA Y ESTRUCTURA DE LOS FONDOS DETRÍTICOS DEL SE IBÉRICO.

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Los fondos detríticos, descritos por primera vez por PERES & PICARD (1964) como una biocenosis propia de los fondos blandos del piso circalitoral en la que se pueden reconocer diversas facies: la facies de "pralines", la de *Osmundaria volubilis*, la de *squamariaceae libres* y la de *maërl*. Este tipo de fondos se caracterizan por una elevada diversidad, ya que: i) en su biota se integran taxones de sustratos duros y blandos; ii) la arquitectura de las coralináceas permite una elevada heterogeneidad espacial; y iii) una gran variedad de estrategias tróficas. Por la elevada biodiversidad y por la distribución actual muy localizada, concretamente de los fondos de maërl, son considerados como "paisaje amenazado del Mediterráneo" (UNEP/IUCN/GIS Posidonie, 1990) y hábitat que precisa de medidas de gestión por la Unión Europea (Directiva 92/43 CEE del consejo. Las causas principales de su rarefacción en el Mediterráneo son los impactos antrópicos (principalmente pesca de arrastre y dragados).

Los muestreos se han realizado en dos estaciones de la costa de Alicante a profundidades similares y en las que se localizan fondos detríticos en estado de conservación aceptable; la primera de ellas al SE de la reserva marina de Tabarca (38⁰ 09,0' N -00⁰ 26,5' W) entre 35 y 39 m de profundidad. La segunda estación está situada al SW de la isla de Benidorm (38⁰ 29,9' N-00⁰ 08,1' W) a una profundidan de 33 a 36 m. En ambos sectores se eligieron al azar cuatro estaciones de muestreo (una por cada periodo estacional), entre el verano de 1996 y el verano de 1997. En cada muestreo se tomaron mediante SCUBA tres réplicas de la comunidad mediante un cuadrado de 0.05 m^2 de acero con una bolsa de malla de 1 mm. Paralelamente se hicieron mediciones de la columna de agua, tanto en superficie como en profundidad (transparencia, temperatura, salinidad, seston y corriente) y del sedimento (granulometría y porcentaje de maërl vivo).

En la estación de Tabarca se encuentra una facies del detrítico costero de aspecto típico donde son características varias especies de coralináceas de vida libre (maërl): *Lithophyllun duckeri*, *Phymatolithon calcareum* y *Lithothamnion cf. corallioides*, además de otras especies de talo blando entre las que destacan *Polysiphonia subulifera*, *Phyllophora crispa*, *Aglaozonia chilosa "stadium"* y *Halopteris filicina;* su estado de conservación es óptimo por ser un área protegida.

La estación de Benidorm está ocupada por un fondo detrítico que presenta claros indicios de enfangamiento y que podría encuadrarse dentro de la facies de *squamariaceae libres*; en este caso la comunidad está claramente dominada por *Peyssonnelia orientalis*, estando también presente de forma relevante *Lithothamnion corallioides*. El resto de especies presentes tiene una importancia mucho menor, destacando *Aglaozonia chilosa "stadium*, *Halopteris filicina*, *Cryptonemia tunaeformis*, *Rhodymenia delicatula* y *Polysiphonia subulifera*; al contrario que la estación de Tabarca, esta zona presenta una gran heterogeneidad estacional, probablemente por efectos antrópicos.

Este trabajo se desarrrolla dentro del proyecto CE DG XII MASS-CT95-0020. "Maerl Biodiversity"

CONTRIBUCIÓN AL CONOCIMIENTO DE LA MACROFAUNA ASOCIADA A LOS FONDOS DE MAËRL DE LA RESERVA MARINA DE TABARCA (ALICANTE, SE PENÍNSULA IBÉRICA).

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Los fondos de maërl *s.l.* están formados por rodofitas calcáreas libres de la familias Corallinacea y Peyssonneliacea con una repartición mundial en las zonas templadas y tropicales. En el Mediterráneo se sitúan en el piso circalitoral, principalmente, entre 30 y 90m (Pérès y Picard, 1964), presentando una distribución en mosaico y muy localizada, con unas condiciones de iluminación, temperatura, hidrodinamismo y sedimentación atenuados. Se caracterizan por una elevada diversidad biológica, ya que: i) en su biota se integran taxones de fondos duros y blandos; ii) la compleja arquitectura de las rodofitas calcáreas permite una elevada heterogeneidad espacial; y iii) una alta variedad de estrategias tróficas (Grall y Glémarec, en prensa). Dicha elevada biodiversidad, unida a una distribución muy localizada y su fragilidad frente a los impactos antrópicos (principalmente, pesca de arrastre y dragados en el Mediterráneo), ha supuesto que sean considerados como "paisaje amenazado del Mediterráneo" (UNEP/IUCN/GIS Posidonie, 1990) y hábitat objeto de medidas de gestión por la Unión Europea (Directiva 92/43 CEE del Consejo).

Apesar de su elevado interés biológico y vulnerabilidad, los estudios sobre los fondos de maërl en el Mediterráneo son relativamente escasos. Principalmente, han sido realizados en aguas francesas y argelinas (Jacquotte, 1962; Picard, 1965; Falconetti, 1970; Bourcier, 1986). No obstante, recientemente ha sido objeto de estudio en aguas ibéricas (García Carrascosa, 1986; Ballesteros, 1989, 1994; Ballesteros y Zabala, 1993; Ramos *et al.*, 1995). Respecto a la reserva marina de Tabarca, uno de los autores (Ramos, 1985) ha realizado observaciones preliminares sobre estos fondos, abordándose en el presente estudio una caracterización de la macrofauna, a nivel de taxones superiores, dentro del Proyecto de la CE DG XII MAS3-CT95-0020 "Maerl biodiversity". Los muestreos se han localizado al SE de Tabarca (38° 09.0' N 00° 26.5' W), entre 35 y 39m de profundidad, siendo las especies dominantes *Lithophyllum duckeri*, *Phymatolithon calcareum* y *Lithothamnion cf. corallioides*. En dicho sector se han elegido al azar cuatro estaciones de muestreo (una por cada periodo estacional del año) entre el verano-96 y el verano-97, recolectándose en inmersión tres réplicas/estación de 0.05m^2 (cuadrado de acero con malla de 1mm). Paralelamente, se ha analizado la columna de agua en superficie y profundidad (transparencia, temperatura, salinidad, seston, corrientes) y sedimento (granulometría y porcentaje de maerl vivo).

La macrofauna se ha separado a nivel de *phylum*, clase u orden, y se ha cuantificado en función de su abundancia numérica, analizándose la posible variación estacional. Los grupos coloniales (esponjas, cnidarios, briozoos, ascidias), si bien representan un alto porcentaje en el maërl, (un 30% de la macrofauna), no han sido abordados en el presente trabajo por problemas en la separación de individuos (colonias o trozos de las mismas). Respecto a los taxones estudiados, predominan Gastropoda (36.1%) y Polychaeta (35.6); seguidos por Bivalvia (5.7), Amphipoda (5.5), Decapoda (4.2%), Nematoda (2.5%), Tanaidacea (2.2), Polyplacophora (1.8), Echinoidea (1.2) y Ophiuroidea (1.2); el resto de taxones en conjunto sólo ha representado un 4.0% del total. Una de las principales características de la fauna de los fondos de maërl estudiados es su pequeño tamaño (menor de 10mm), siendo la megafauna (>10mm) mucho menos abundante y muy dispersa. Respecto a ésta han predominado Gastropoda (*Bolmia rugosa*, *Turritella turbona*), Crustacea Decapoda (*Paguristes eremita*, *Scyllarus pigmaeus*, *Lissa chiragra*), Asteroidea (*Echinaster sepositus*) y Echinoidea (*Spatangus purpureus*), recolectados o no por los cuadrados. Conviene señalar una cierta constancia estacional en los principales taxones observados

MAERL GROUNDS: HABITATS OF HIGH BIODIVERSITY IN EUROPEAN SEAS

By
BIOMAERL team[1]

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SUMMARY

The BIOMAERL programme is a 3-year collaborative programme between laboratories in UK, Spain, France and Malta which began in February 1996. Its main aims are described in the Workplan. A full inventory of the biological composition (biodiversity) of maerl bed assemblages in these regions therefore has yet to be completed, but progress is outlined below.

1. INTRODUCTION

Maerl beds are characterized by accumulations of unattached thalli of calcareous rhodophytes. They occur worldwide (Bosence, 1983; Carannante *et al.*, 1988; Steller and Foster, 1995), yet few have been studied ecologically in any detail Many such beds are under immediate threat from human impacts: most notably, in Europe, from direct exploitation (Cabioch *et al.*, 1997), towed demersal fishing gear (Hall-Spencer, 1995, 1998) and eutrophication effects (Grall and Glémarec, 1997, in press).

The EC-funded BIOMAERL project, linking laboratories in the United Kingdom, France, Spain and Malta, has set out: a) to examine W.European maerl-bed biodiversity, b) to establish the functional roles played by key elements of the biota, c) to assess the impacts of a variety of anthropogenic assaults on representative grounds, and d) to compile an inventory of NE Atlantic and Mediterranean maerl-bed biota.

In many ways maerl beds are analogous to sea-grass beds or kelp forests. All are structurally complex, perennial habitats formed by marine plants that support a high associated biodiversity. Maerl beds especially form isolated, fragile habitats supporting many rare, unusual or endemic species and, as such, they are of particular international conservation interest (Bosence, 1976, 1979; Blunden *et al.*, 1981; Nunn, 1993; Bellan-Santini *et al.*, 1994; Hall-Spencer, 1998). They may also be of significance as nursery grounds for commercial species of fish and shellfish, e.g. scallops (Thouzeau, 1991; G.A.Fisher, unpubl.).

Large maerl thalli are among the oldest marine plants in the N. Atlantic and contribute deposits that take hundreds, perhaps thousands, of years to accumulate, since even optimal growth rates are extremely slow (Potin *et al.*, 1990; Littler *et al.*, 1991). For this reason, management of the exploitation of maerl-forming *Lithothamnion corallioides* (P. & H.Crouan) P. & H.Crouan and *Phymatolithon calcareum* (Pallas) Adey & McKibben is obligatory under the EC Directive on the Conservation of Natural Habitats and Wild Fauna and Flora (1992).

2. WORKPLAN

Pairs of maerl grounds have been identified for study by participants in the Clyde Sea area (Scotland), Galicia (Spain), Brittany (France), Alicante (Spain) and Malta (Fig. 1). pairs of maerl grounds have been identified for study. Each pair represents a ground that has been impacted anthropogenically and a relatively pristine control ground. In Scotland, Alicante and Malta impacts to maerl habitats derive mainly from the use of towed demersal fishing gears. In the Ria de Vigo (Galicia), the major impacts derive from organic matter falling from moored rafts used in the culture of the edible mussel (*Mytilus edulis* L.). Mussel faeces and pseudofaeces from the extensive culture rafts moored above maerl beds rain down onto the maerl surface, altering sediment structure and compromising the ability of maerl thalli to photosynthesize and grow. In the Bay of Brest (Brittany), maerl beds are also affected by high nutrient and sediment loadings due to eutrophication, with nutrient inputs there deriving both from the industrialized estuary and run-off from surrounding agricultural land. Another major way in which European maerl habitats are impacted by Man is through direct extraction. Maerl is valued commercially as a soil conditioner. So, another pair of sites in Brittany (in the Glenan archipelago) are being compared to assess the impact of maerl extraction practices.

Comprehensive samples have been taken not only of the benthic environment of each maerl ground (including bathymetry, macro- and micro-architecture of the maerl surface, granulometry, calcimetry, organic matter content, pH and Eh profile), but also of the water column overlying the BIOMAERL study sites (including measurements of seawater temperature, salinity, Secchi disc transparency, seston content, current speed as well as chlorophyll and photosynthetically active radiation on occasion). Edaphic measurements have been collected seasonally over one to two years.

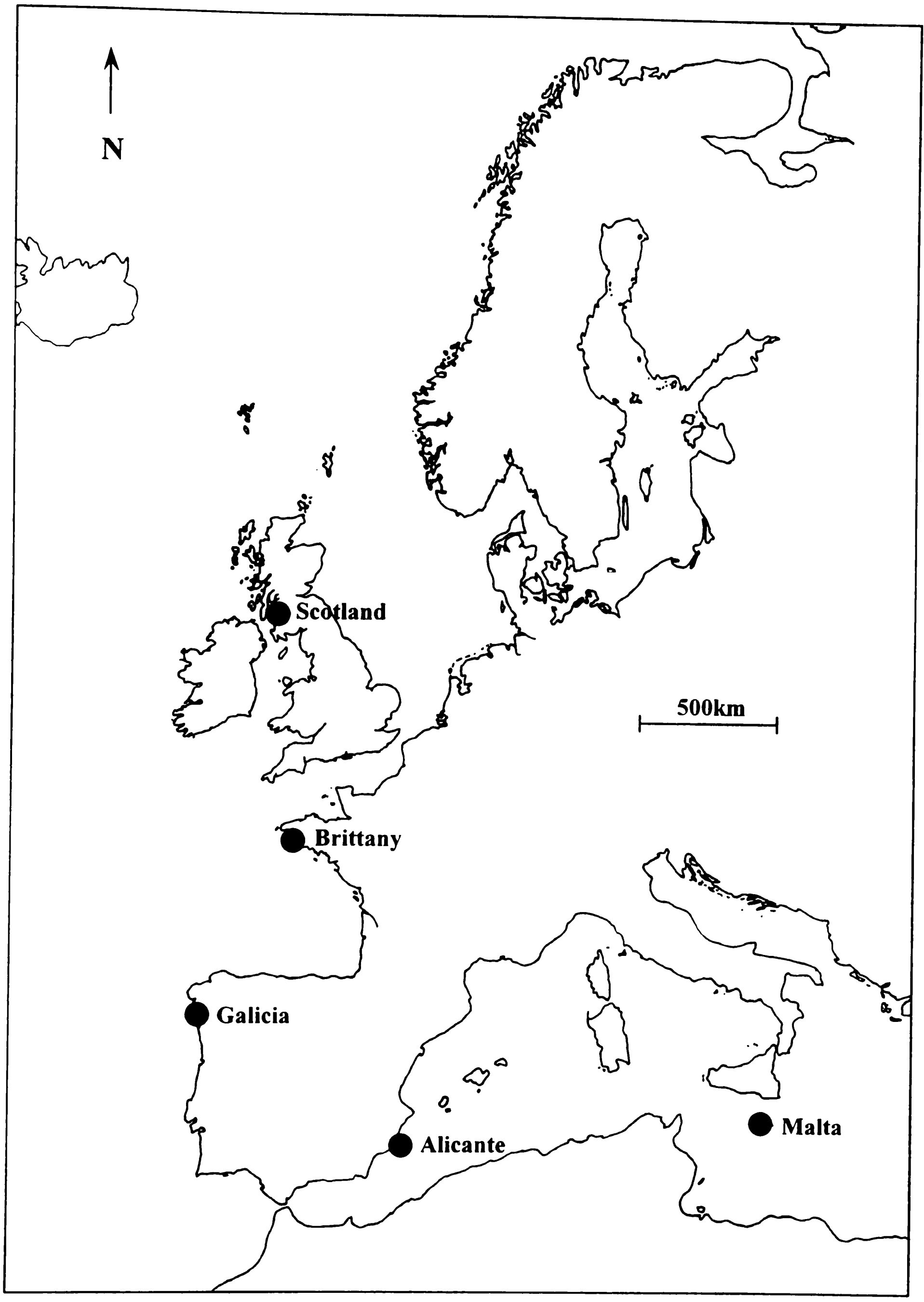

Fig.1. Map of BIOMAERL study sites.

Biological samples of the maerl biota have been taken quantitatively over a two year period, either directly by divers using quadrats and/or cores *in situ*, or by deployment of a variety of indirect sampling gears from ships (grabs, box corers). Megafauna and macrofauna have been compared; infaunal samples being sieved through a 1mm screen as standard. Detailed data on population structure, biomass and population density are being generated for the commonest and/or structurally most important key species from each ground . In addition, semi-quantitative and qualitative faunistic/ floristic data have been gathered using towed dredges and trawls and by direct diver observation. In these

ways we are gradually accumulating a comprehensive inventory of the biota at the study sites.

3. RESULTS

1) Sampling

In order to achieve as comprehensive coverage of the biota as possible, it has been necessary: a) to utilize as many methods of sampling as possible; and b) for sampling to take place over all seasons of the year. This was because not every organism present on the ground was captured in any one type of gear, and there were strong seasonal influences at work both in terms of species occurrences (migrations), and/or population fluctuations (both real and apparent). To illustrate this latter point, Fig. 2 shows the seasonal pattern of population densities recorded by divers for a species of infaunal holothurian (*Neopentadactyla mixta* (Ostergren)) from site UKI (Stravanan Bay, Bute, Scotland).

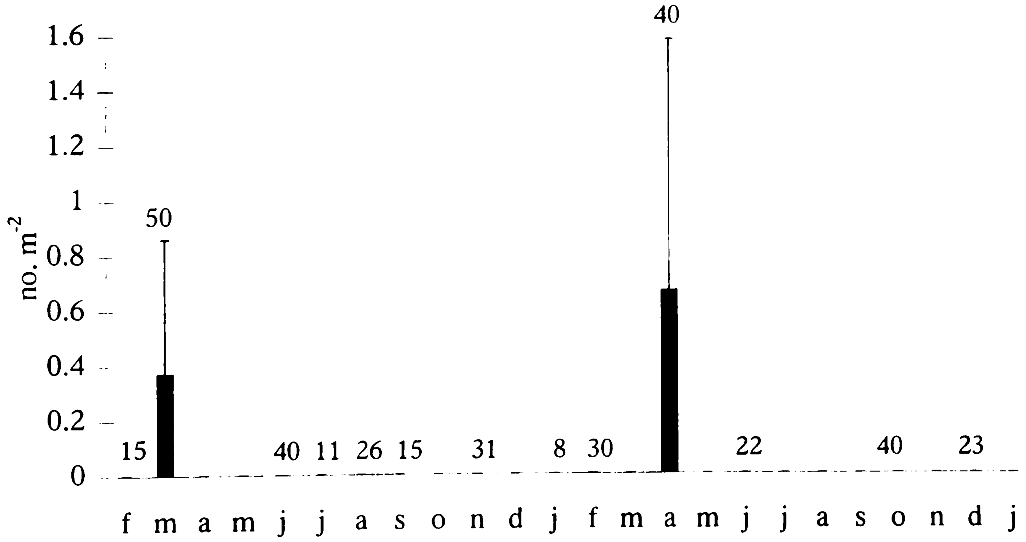

Fig. 2. Mean numbers of the holothurian *Neopentadactyla mixta* counted by divers in replicate 1m^2 quadrats at UKI from February 1996 - January 1998. Error bars are + one standard deviation, *n* values are indicated above each month sampled.

It would be easy to misinterpret such data as showing this species to be absent for most of the year. Use of an airlift to excavate sediment to a depth of 1m (following methods in Keegan and Könnecker, 1973), however, showed that this sea cucumber was present year-round, but was only seen by divers (by virtue of its feeding crown being extended into the water column) at the time of year that planktonic food was available in abundance, i.e. during the spring phytoplankton bloom. The rest of the time it was invisible to divers, at any rate during the day (no night-time observations available).

Contemporaneously with these diving observations, routine Van Veen grab sampling (10 replicates on each sampling occasion) failed to reveal this organism, as it retracts into the sediment beyond the penetration depth of the grab (*ca* 20cm). So, despite its large size and abundance (>4 m^{-2}), it could easily be overlooked, even by intensive sampling with an inappropriate gear.

It is important for the sampling of rare or highly dispersed biota also that maerl grounds are investigated using towed sampling gears. These gears have therefore been used (*inter alia*), but with care to minimize damage to the ground. Thus in the Bay of Brest, species like the sponge *Tethya aurantium* (Pallas), the cnidarian *Aureliania heterocera* (Thompson), the polychaetes *Hermonia hystrix* (Savigny in Lamarck) and *Psammolyce arenosa* (Chiaje), the decapod crustaceans *Thia scutellata* (Fabricius), *Pirimela denticulata* (Montagu), *Maja squinado* (Herbst), *Pisa armata* (Latreille) (to name but a few) have been captured only using an AQUAREVE dredge. Highly mobile species, like mysid crustaceans and most epibenthic fish are capable of avoiding grab samplers. They have been sampled using towed sledges, dredges and trawls and, in Malta, using bottom-set gillnets.

2) Components of maerl-bed biodiversity

European maerl-bed biodiversity has components on widely different scales. The overarching consideration, in such an Atlantic-Mediterranean comparison as ours, is biogeographical. The BIOMAERL partnership covers the whole temperate province from Galicia to Scotland, and encompasses a latitudinal cline from the western Mediterranean to Malta. A few species, e.g. the sea urchin *Echinocyamus pusillus* (O.F.Müller, the amphipods *Leptocheirus hirsutimanus* (Bate) and the crab *Liocarcinus corrugatus* (Pennant), occurred in all (or nearly all) of the BIOMAERL study sites, but the majority of species have geographical limits between different regions considered. The polychaete *Hesione pantherina* (Risso), for instance, reaches its northern limits of distribution in the Bay of Brest area. Some species are Mediterranean endemics, like the amphipod *Urothoe hesperiae* Conradi, Lòpez-Gonzàlez and Bellan-Santini (our record of which off Alicante represents only the second since its description in 1995), others like the anemone *Bolocera tuediae* (Johnston) are northern species, not occurring in BIOMAERL sites further south than Scotland.

The maerl beds investigated have proved to be remarkably heterogeneous in terms of their sediment composition. Some contain deep unstratified maerl, others are made up of a shallow veneer of maerl over mud, sandy mud or coarse sand. Some grounds have a complete cover of living maerl, some are made up of patches (or strips) of maerl and rhodoliths between shelly sands, while others again may be composed exclusively of dead maerl. Some grounds, notably those from open-water sites, have a megarippled surface that is reorientated periodically by storm activity. Some grounds have the maerl thalli bound together by other organisms (e.g. holdfasts of the kelp *Laminaria saccharina* (L.) Lam., and the nests of the bivalve *Limaria hians* (Gmelin) in Scotland; rhizoids of the chlorophyte *Flabellia petiolata* (Turra) Nizamuddin and the rhodophyte *Polysiphonia setacea* Hollenberg off Malta), stabilizing the surface. The activities of deep-burrowing bioturbatory invertebrates (e.g. *Upogebia, Cerianthus, Chaetopterus*) will also modify the properties of maerl sediments.

An understanding of the role and dynamics of habitat structural complexity and three-dimensional heterogeneity will clearly be central to any explanation of maerl bed biodiversity. The high biodiversity of European maerl grounds can be judged from the fact that, to date, over 460 spp of animals and 63 spp. of algae have been recorded from our most northerly (Scottish) sites.

A functional analysis of the maerl bed biota is currently being undertaken, in which the trophic composition of the biota at all BIOMAERL sites will be related to natural hydrodynamism and, subsequently, to the various anthropogenic impacts described in the Workplan. Fig. 3 shows the seasonal variability in population density of one polychaete species in the Bay of Brest maerl grounds investigated, and reveals significant differences in density between the control and impacted sites. This species would seem to be especially sensitive to eutrophication, its density being considerably reduced on the impacted ground. It is often the case that species at their geographical limits prove to be especially sensitive to environmental perturbation.

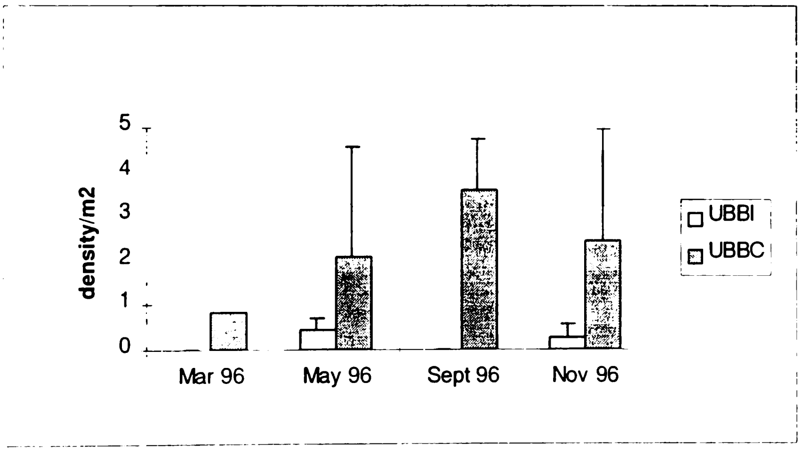

Fig.3. Seasonal variation in the population density of the polychaete *Hesione pantherina* at two sites (UBBI = impacted ground, UBBC = control ground) in the Bay of Brest, Brittany as derived from grab samples. Error bars are +1SD.

DISCUSSION

Maerl beds are unusual benthic habitats, not only because they are derived from living calcareous rhodophytes, but also because they exhibit structural properties that are intermediate between solid and soft sedimentary environments. In some respects (like high permeability, high carbonate content) their structure has resonances with shell-gravel or coral-rubble grounds. In both maerl and shell-gravel habitats, a comparatively open calcareous matrix will facilitate irrigation of interstices (cf. Riedl and Machan, 1972; Webb and Theodor, 1972), promoting a characteristic and diverse infauna.

Previous ecological studies on European maerl beds are scant (Cabioch, 1968; Keegan, 1974), most workers have tended to focus on particular elements of the biota, such as the flora (Maggs, 1987) or particular faunal taxa, like the Mollusca (Nunn, 1993; Hall-Spencer, 1998). The present programme is probably unique in attempting to cover such a wide range of sites and inventory the majority of the macrobiota encountered.

Evolutionary and ecological factors determine the origin and maintenance of biodiversity. While the biodiversity of maerl beds cannot compare with tropical calcareous (coral reef) ecosystems (Reaka-Kudla, 1996), nevertheless, in comparison with other continental shelf habitats in temperate waters, maerl bed biodiversity is impressive. The longevity of maerl thalli, coupled with their complex, open-lattice architecture and need for clean water areas in the euphotic zone with high water exchange rates provides a perennial heterogeneous habitat provide the explanation. Interestingly, that other ecosystem of high biodiversity in European seas, the kelp holdfast, especially that of *Laminaria hyperborea* (Moore, 1973, 1974), is also a long-lived, plant-based habitat in the photic zone. Were data available on the meiofauna of maerl beds (not included in the BIOMAERL programme), then the biodiversity of maerl beds would be even more impressive.

Fortunately, the high fragility and vulnerability of this unique living sediment to human influences (which include direct exploitation for agricultural fertilizer and indirect impacts derived from eutrophication or demersal fishing gear which smashes and erodes maerl beds and increases turbidity) has now been recognized (as witnessed by inclusion of the main maerl-forming algae in the EC Habitats Directive).

Conservation measures need to be established that take cognizance of the role of these grounds: a) as foci for biodiversity (often of specific assemblages of organisms not found elsewhere); and b) as nursery grounds for commercial fish, like juvenile gadoids and shellfish (scallop) species. Maerl grounds are effectively a non-renewable resource, and should be treated as such. The BIOMAERL programme, when complete, will provide the first biogeographical inventory of macrofaunal and floral species in European seas, including identification of key species, their population structure and an analysis of their functional significance in this ecosystem. Assessment of the different anthropogenic threats to this biodiversity experienced over the range of sites considered, will generate recommendations as to the most effective management strategies for this sensitive habitat necessitated by the status of maerl-forming species under the EC Habitats Directive (1992).

We see one way forward as being the establishment of an Environmental Quality Standard for European maerl grounds which is capable of containing, and integrating, all the pertinent structural and functional aspects of the habitat revealed by our studies. Perhaps this might be achievable by allocating a point score to each of the following indicators: edaphic complexity (sediment stratification), basic energy resources (% organic matter, % epifauna / infauna, % macrodetritivores), complex trophic interactions (% predators, % microdetritivores). A summated score would then represent the overall biodiversity status of a particular maerl bed. Such an index would be capable of being monitored over time to provide a check on environmental change, especially any deterioration. It would also supply a mappable, objectively-derived descriptor that, by virtue of being independent of species composition, would be capable of direct comparison at a panEuropean scale. Further funding would be needed, however, to test the validity of these ideas.

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VARIACIÓN DE LAS POBLACIONES DE CRUSTÁCEOS DECÁPODOS EN LAS COMUNIDADES DEL DETRÍTICO DEL SE IBÉRICO AFECTADAS POR EL IMPACTO DE LA PESCA DE ARRASTRE.

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Los fondos detríticos descritos por primera vez por PERES & PICARD (1964) como una biocenosis propia de los fondos blandos del piso circalitoral en la que se pueden reconocer diversas facies: las facies de "pralines", la de *Osmundaria volubilis*, la de *squamariaceae* libres y la de *maërl*. Este tipo de fondos se caracterizan por una elevada diversidad , ya que : i) en su biota se integran taxones de substratos duros y blandos ; ii) la arquitectura de las coralináceas permite una elevada heterogeneidad espacial ; y iii) una gran variedad de especies tróficas. Por la elevada biodiversidad y por la distribución actual muy localizada, concretamente en los fondos de *maërl*, son considerados como "paisaje amenazado del Mediterráneo" (UNEP/IUCN/GIS Posidonie, 1990) y hábitat que precisa de medidas de gestión por la Unión Europea (Directiva 92/43 CEE del consejo). Las causas principales de su rarefacción en el Mediterráneo son los impactos antrópicos (principalmente pesca de arrastre y dragados).

Los muestreos se han realizado en dos estaciones de la costa de Alicante a profundidades similares y en las que se localizan fondos detríticos en estado de conservación aceptable ; la primera de ellas al SE de la reserva marina de Tabarca (38° 09,0' N 00° 26,5'W) entre 35 y 39 m de profundidad. La segunda estación está situada al SW de la isla de Benidorm (38° 29,9' - 00°08,1' W) a una profundidad de 33 a 36 m. En ambos sectores se eligieron al azar cuatro estaciones de muestreo (una por cada periodo estacional), entre verano de 1996 y verano de 1997. En cada muestreo se tomaron mediante SCUBA tres réplicas de la comunidad mediante un cuadrado de 0,05 m^2 de acero con una bolsa de malla de 1mm de luz. Paralelamente se hicieron mediciones de la columna de agua, tanto en superficie como en profundidad (transparencia, temperatura, salinidad seston y corriente) y del sedimento (granulometría y porcentaje de *maërl* vivo).

De la evaluación de los poblamientos de decápodos de ambas estaciones, cabe remarcar la elevada diversidad de especies y alta equirrepartición de éstas (*Paguridae* 10,1%, *Galathea intermedia* 11,6%, *Ebalia edwardsi* 13,7%, *Thoralus cranchii* 17,0%, *Achaeus cranchii* 16,7 %, *Athanas nitescens* 15,5% y otros -18 especies- 15,2%), con presencia de especies de macrofauna con elevados requerimientos de hábitat y alimentación como *Scyllarides pygmaeus* y *Pisa armata*, o bien otras que aprovechan el desarrollo algal estival que se produce en la comunidad, como p.e. *Achaeus cranchii*.

La estación impactada por el arrastre a lo largo del período de estudio fue empobreciéndose especialmente sus especies de mayor tamaño, por simple eliminación de hábitat, dando paso a otras de carácter más oportunista y asociadas a fondos caracterizados por el arrastre intenso, como es el caso de *Paguristes eremita*. En general, se observa una drástica disminución de los valores de diversidad y equirepartición, con claros síntomas de tender a la rarefacción de los decápodos en la comunidad, pasando a ser sustituidos por crustáceos de la infauna, como el tanaidaceo *Apseudes latreilli*.

La eliminación del sustrato vegetal causada por el impacto mecánico de la pesca de arrastre trae consigo la eliminación del hábitat que sustenta a una importante población de crustáceos, que son a su vez un importante recurso trófico en el piso circalitoral.

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VARIACION ESTACIONAL DE LA FAUNA BENTÓNICA DE UN FONDO DE MAERL BAJO LA INFLUENCIA DE UN POLÍGONO DE BATEAS DE MEJILLÓN.

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En este estudio se aborda el análisis del ambiente bentónico de un banco de maerl (*Lithothamnion corallioides* (P. & H. Crouan) P & H. Crouan y *Phymatolithon calcareum* (Pallas) Adey & McKibbin) situado en la margen norte de la Ría de Vigo (42^{0}14'33.6'' 08^{0}47'44.1''), en la Ensenada de Limens a 16 m de profundidad, donde se localiza un polígono de bateas para producción de mejillón. El objetivo del estudio se enfocó hacia la observación de las variaciones sufridas por las comunidades bentónicas de un fondo de maerl a lo largo de un ciclo anual, bajo el impacto de la eutrofización orgánica derivada del cultivo de mejillón en superficie. El seguimiento se realizó a bordo de una embarcación a motor y la toma de muestras se efectuó con ayuda de un muestreador de inserción vertical *box-corer* con cajas de 0.017 m^2 de superficie de ataque. Para el estudio de la fauna se recogieron 6 réplicas en la estación de muestreo, a lo largo de un ciclo anual durante los meses de abril, julio y octubre de 1996 y enero de 1997.

Asimismo, se realizaron medidas de la columna de agua *in situ* referentes a la salinidad, temperatura, oxígeno, pH, Eh y turbidez. Paralelamente, se recogieron muestras de agua en superficie y fondo, para el análisis de la materia orgánica en suspensión y el seston y muestras del sustrato para el estudio granulométrico, el contenido pelítico, la composición porcentual de maerl vivo, maerl muerto, conchas, guijarros y demás material sedimentario que conforma el fondo de maerl. También se procedió al análisis de la materia orgánica total contenida en el sustrato, el contenido en carbonatos del mismo y las medidas del potencial de oxidación reducción y el pH sedimentario

La estación de seguimiento presentaba un contenido en maerl vivo del 58.4%, en maerl muerto del 6.5% y una proporción de material conchífero del 35.6%. Los contenidos en materia orgánica total del sustrato oscilaron entre 4.29% del mes de abril de 1996 y 9.45% del mes de octubre del mismo año. El contenido total en carbonatos para este tipo de fondo se situaba entre 81.82% de octubre y 95.13% de julio, donde gran parte de la contribución de este elemento era debida a material conchífero particulado además de a las algas coralinas que formaban el fondo de maerl. La fracción pelítica en la zona de estudio presentaba valores moderados entre 5.3% de julio y 7.4% de octubre, en fluctuación con las corrientes imperantes y el mar de fondo reinante en algunas estaciones del año, cuyo efecto hidrodinámico sobre le fondo resuspendía y trasladaba el material pelítico depositado en el sustrato

Faunísticamente, los fondos se caracterizaron por las altas densidades de especies asociadas a algas coralinas como el poliplacóforo *Leptochiton cancellatus*, los anfípodos *Ceradocus semiserratus* y *Gammarella fucicola*, el decápodo *Liocarcinus corrugatus*, los equinodermos *Echinocyamus pusillus* y *Psammechinus miliaris* y el arquianélido *Polygordius lacteus*; se ha de destacar la presencia constante a lo largo del ciclo anual de especies no exclusivas de los fondos de maerl sino propias de fondos de batea de mejillón como el decápodo *Pisidia longicornis*, o los poliquetos tubícolas Serpulinae y Spirorbinae fijos en fragmentos de conchas de mejillón

Este estudio se llevó a cabo en el marco del proyecto BIOMAERL, maerl biodiversity and anthropogenic impacts, financiado por el Programa de Ciencias Marinas y Tecnología de la Comisión Europea (MAST III) con el contrato MAS3-CT95-0020

BIODIVERSIDAD ESPECIFICA DE LOS FONDOS DE MAERL *LITHOTHAMNION CORALLIOIDES* (P. & H. CROUAN) P. & H. CROUAN Y *PHYMATHOLITHON CALCAREUM* (PALLAS) ADEY & MCKIBBIN DE LA RIA DE VIGO

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Uno de los problemas ecológicos al que le ha sido asignada prioridad a partir de comienzos de la década de los 90, ha sido la determinación de cómo los cambios medioambientales afectan a la diversidad biológica. Este fue uno de los postulados básicos de la Conferencia sobre Desarrollo y Medioambiente de Río de Janeiro de 1992. Actualmente las zonas costeras aportan el 80% de los recursos marinos, y se estima que en el año 2000, el 60% de la población mundial vivirá y dependerá de la zona costera. Ha de tenerse en cuenta que, sobre estas zonas, el impacto medioambiental debido a la actividad humana es especialmente intenso, y la reducción de la biodiversidad es uno de las consecuencias inmediatas más evidentes.

¿Cómo afectan las reducciónes en la biodiversidad al funcionamiento de los procesos biológicos costeros?. Con objeto de standarizar el método de trabajo tendente a resolver esta cuestión y dada la extrema variabilidad de los tipos de fondos sobre los que actualmente se están desarrollando este tipo de estudios a nivel mundial, la comunidad científica decidió centrar gran parte de las labores de investigación sobre las zonas de máxima biodiversidad.

A este respecto, sobre latitudes templadas, las comunidades de máxima biodiversidad se encuentran en dos ambientes especiales, frágiles y escasos: los fondos sublitorales colonizados por las algas calcáreas *Lithothamnion corallioides* (P. & H. Crouan) P. & H. Crouan y *Phymatolithon calcareum* (Pallas) Adey & McKibbin (maerl), y los fangos intermareales de *Zostera marina* y *Z. noltii*.

En el caso de los fondos de maerl, el motivo de la elevada diversidad biológica es la enorme heterogeneidad de nichos que configura la morfología arbuscular de *Lithothamnium* y *Phymatholithon*, que aportan gran número de abrigos contra depredadores, refugios de estadios juveniles, zonas de puesta y microambientes diversos susceptibles de ser utilizados por un enorme número de especies, como se indica en los estudios de comunidades de maerl de Jacquotte (1961, 1962) y Cabioch (1962) del Mediterraneo y del Canal de la Mancha, respectivamente.

Los factores que determinan el origen y mantenimiento de la biodiversidad en los bancos de maerl son fundamentalmente evolutivos y ecológicos. La longevidad de los talos del maerl, unida a su compleja arquitectura y necesidad de aguas someras, claras y con alta tasa de renovación indica que los bancos de maerl albergan una de las más altas diversidades de vida marina en las zonas costeras europeas. La presencia en sí, de tantos animales residentes, unida a la complejidad del hábitat, crea un mosaico de modelos tridimensionales dentro del entramado del maerl que es lo que le confiere la heterogeneidad a este hábitat. La alta fragilidad y vulnerabilidad de este "sustrato vivo" a la influencia humana (lo cual incluye la explotación directa de los bancos para fertilizante en agricultura y el impacto indirecto derivado de la eutrofización o de las artes de pesca de peces demersales, que rompen, aplastan y erosionan los bancos de maerl, incrementando la turbidez, solamente ha sido constatada en los últimos años. No se trata solamente de uno de los ecosistemas más diversos de los mares europeos, sino que son altamente vulnerables debido a su aislamiento y pequeña extensión. Cada fondo tiene su propio régimen hidrográfico, topografía de superficie, tamaño y profundidad de los depósitos, mobilidad, porcentaje de maerl vivo y fauna asociada.

En los fondos de maerl de la Ría de Vigo, donde se realizó este estudio, se analizó la biodiversidad de especies bentónicas dentro de esta perspectiva, identificando la fauna y flora recogidas con dragas de arrastre de boca circular (*Rallier du Baty*) para la confección del inventario faunístico y algal de este ecosistema.

Este estudio se llevó a cabo en el marco del proyecto BIOMAERL. Maerl biodiversity and anthropogenic impacts, financiado por el Programa de Ciencias Marinas y Tecnología de la Comisión Europea (MAST III) con el contrato MAS3-CT95-0020.

CAMBIOS ESTRUCTURALES EN LA COMPOSICIÓN DE DOS FONDOS DE MAERL SUJETOS A DIFERENTES CONDICIONES AMBIENTALES.

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Los fondos sedimentarios de la Ría de Vigo están formados por diferentes tipos de ambientes que presentan un rango de características granulométricas muy amplio, desde los sedimentos fangosos de la Ensenada de San Simón a las arenas finas de la Ensenada de Bayona. Uno de los tipos sedimentarios mas interesante, en cuanto a la diversidad de especies que lo habitan, lo constituyen los fondos de maerl, término que engloba un sustrato constituido por diferentes especies de algas coralinas; en el caso de la Ría de Vigo las especies de Corallinaceae que constituyen estos bancos son *Lithothamnion corallioides* (P. & H. Crouan) P. & H. Crouan y *Phymatolithon calcareum* (Pallas) Adey & McKibbin.

El objetivo del presente estudio es el de evaluar las diferencias estructurales en la composición, abundancia y biomasa de las especies del macrozoobentos de estos fondos, durante un ciclo anual, con el fin de investigar el efecto de las perturbaciones a que se ven sometidos estos fondos, sobre las poblaciones bentónicas. Para ello y previo un cartografiado de la ría en el que se establecieron los diferentes tipos de sustrato, se eligieron dos fondos de maerl localizados en la margen norte de la ria, uno frente a la Ensenada de Cangas, o estación control, con unas condiciones ambientales naturales y otro frente a la Ensenada de Limens, donde se sitúa un polígono de bateas para producción de mejillón, cuyos aportes orgánicos tienen impacto sobre los fondos.

Se observaron notables diferencias entre los dos bancos estudiados, relativas tanto a la composición específica de las especies clave de los fondos de maerl como a la abundancia de las mismas a lo largo de las diferentes estaciones del año. A título ilustrativo se indican algunas de las diferencias más sustanciales: la estación control presenta como especies lider en abundancia a lo largo de todo el ciclo anual y en orden descendente a las especies *Pisidia longicornis, Polygordius lacteus, Gammarella fucicola, Jujubinus miliaris, Ceradocus semiserratus* y *Leptochiton cancellatus*, todas ellas integrantes habituales de la biocenosis del maerl, mientras que la estación sometida a impacto ambiental presenta como especies lider a aquellas especies que no son tan características de los fondos de maerl sino que principalmente ocupan nichos donde predomina la materia orgánica particulada y los sedimentos finos en conjunción con los talos de maerl, como son *Mediomastus fragilis, Apseudes latreillii* y *Aonides oxycephala*, así como otras especies epífitas de las conchas de mejillón como el serpúlido *Pomatoceros triqueter*, aunque también presentan abundancias elevadas los anfípodos propios del sustrato de maerl como *Gammarella fucicola*.

Este estudio se llevó a cabo en el marco del proyecto *BIOMAERL: maerl biodiversity and anthropogenic impacts*, financiado por el Programa de Ciencias Marinas y Tecnología de la Comisión Europea (MAST III) con el contrato MAS3-CT95-0020.

DIFERENCIAS ESTRUCTURALES BIOGEOGRAFICAS DE LOS FONDOS DE MAERL EN AGUAS DEL ATLANTICO NORTE ENTRE LAS LATITUDES 42° Y 56°.

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Los fondos de maerl son ecosistemas con un interés de conservación particular a nivel internacional debido a que proporcionan hábitats aislados de gran biodiversidad y biomasa bentónica y albergan gran número de especies raras y endémicas. Los grandes talos de mäerl se encuentran entre las plantas marinas mas antiguas en el Atlántico Norte y contribuyen a formar depósitos que tardan cientos de años en ser acumulados ya que las tasas de crecimiento óptimas para este alga son extremadamente lentas. Por esta razón, la gestión de la explotación de *Lithothamnion corallioides* (P. & H. Crouan) P. & H. Crouan y *Phymatolithon calcareum* (Pallas) Adey & McKibbin, las dos especies más importantes que forman los bancos de mäerl en el Atlántico, es obligatoria según dictamen de la Directiva de Conservación de Hábitats Naturales y de la Fauna y Flora Salvajes, de la Unión Europea (1992).

Con el objetivo de estudiar la ecología y biogeografía de este tipo de hábitat y analizar comparativamente su biodiversidad se eligieron tres fondos de maerl no perturbados en aguas del Atlántico Norte: el primero localizado en el Firth of Clyde, Loch Fyne, Escocia (56°00.601'N, 5°22 148'W), el segundo en la Rada de Brest, Bretaña (48°19 31'N, 4°24 63') y el tercero en la Ría de Vigo (Galicia)

La metodología de trabajo en los tres fondos y recogida de muestras se realizó con tecnicas de muestreo similares, utilizando la draga Van Veen y una superficie total de ataque de 0.3 m^2 en cada punto de muestreo. Para el análisis de la fauna se tamizaron las muestras con tamices de 1 mm de luz de malla. Paralelamente al análisis de la fauna bentónica se realizaron determinaciones de contenido total en carbonatos y en materia orgánica del sustrato, así como del tamaño de grano del sedimento, proporción de maerl vivo contenido en el sustrato y morfología de las diferentes especies que conforman los fondos de maerl estudiados. En la interfase agua-sedimento se analizaron el pH, Eh, oxígeno, temperatura, salinidad, materia orgánica en suspensión y seston total

A partir del análisis de la fauna, se establecieron un número de especies clave en los tres fondos estudiados, algunas de ellas, comunes a los tres, como es el caso de los poliquetos *Glycera unicornis* y *G. gigantea*, los moluscos *Gibbula magus*, *Dosinia exoleta* y *Clausinella fasciata* o los equinodermos *Echinocyamus pusillus* y *Psammechinus miliaris*. Otras, fueron escogidas por estar presentes solamente en una de las tres latitudes estudiadas como es el caso de la holoturia *Neopentadactyla mixta* presente en el Firth of Clyde, el gasterópodo *Crepidula fornicata* que presenta altas densidades en los fondos de la Rada de Brest o el decápodo *Liocarcinus corrugatus* de la Ría de Vigo.

Por último, se realizó, a partir del estudio de las especies clave y de cada una de las comunidades presentes en los tres puntos, un análisis comparativo de la estructura espacial del macrozoobentos en cada una de las comunidades estudiadas

Este estudio se llevó a cabo en el marco del proyecto BIOMAERL maerl biodiversity and anthropogenic impacts, financiado por el Programa de Ciencias Marinas y Tecnología de la Comisión Europea (MAST III) con el contrato MAS3-CT95-0020.

MAERL ECOSYSTEMS OF THE MALTESE ISLANDS

Patrick J. Schembri

For the past three years, the Marine Ecology Research Group has been studying the maerl ecosystems of the Maltese Islands as part of an international research project on the biodiversity and structure of these habitats and the impact of human activities upon them.

The term maerl refers to biogenic sediments characterized by accumulations of live and dead unattached coralline algae. The maerl-forming algae can form rhodoliths, which are nodules or unattached branched growths made up of coralline algae. The morphology of rhodoliths varies from open branched thalli to densely branched algal nodules. Their complex structure provides a very heterogeneous habitat. Maerl grounds form a unique habitat with a high benthic biodiversity supporting many rare and unusual species.

Maerl beds have a wide geographical distribution, being known from tropical to polar environments. Their depth distribution varies geographically, mainly depending on the degree of light penetration. For the formation of maerl beds, water movement is needed to overturn the rhodoliths and to prevent burial. However, a degree of shelter is also needed to prevent dispersal of the rhodoliths into non-suitable environments. The processes leading to the development of maerl grounds are not yet fully understood. Rhodoliths can form through the fragmentation of attached branched coralline algae. These coralline algal fragments are then transported by currents and continue to grow at the redeposition sites to form rhodoliths. Rhodoliths can also form by the settlement of asexual spores on suitable sediment particles. Subsequent algal growth completely encloses the particle to form concentric free-living nodules.

In order to achieve their typical concentric growth, rhodoliths need to be regularly overturned so that all their surfaces are periodically exposed to light and would thus be able to photosynthesize. Rhodolith movement can be achieved by various environmental agents including bottom currents, wave-induced bottom disturbance during storms, and bioturbation from benthic organisms during their foraging activities. It is not always clear whether the rhodoliths are being overturned or not; at great depths, bottom currents are probably not strong enough to move the rhodoliths. Some authors state that only slight oscillations are needed for the rhodoliths to survive. It has also been suggested that the lower surfaces of the rhodoliths do not need to be exposed to light, but they survive by means of transport of photosynthetic products from the upper to the lower surfaces.

Rhodoliths show a wide variety of shapes and branching densities. Although the different shapes do not have any taxonomic value, they have a high ecological significance since they provide a range of different microhabitats to benthic organisms. Some authors suggest that the different shapes of rhodoliths are a result of different adaptations to varying intensities of water energy. Thus the shape and branching densities of the rhodoliths can be correlated to the intensity of water movement. Since rhodoliths are common in the fossil record, their morphology has often been used to deduce the palaeoenvironment of the fossil maerl beds. However, other authors have suggested that rhodolith shape may not be solely dependent on the intensity of water movement, but may also depend upon other environmental factors, such as substratum type.

In the Mediterranean and in the North Atlantic, maerl habitats are threatened by various human activities including direct exploitation, demersal fishing, and eutrophication. Commercial collection of maerl is well known in most Western European countries, where it is used as a soil conditioner. Demersal fishing gears can damage maerl beds either by breaking the delicate branches of the rhodoliths or by causing burial of the rhodoliths from resuspended sediments. Being highly productive, many maerl grounds are fished; however, the impact of fishing activities on these grounds is not well documented. Whatever the source of the disturbance, human impact on maerl grounds can have profound effects on this fragile ecosystem, since rhodoliths have a very slow growth rate and cannot be replaced easily.

In Malta, maerl grounds were only recently discovered, during a UNESCO sponsored oceanographic survey in 1993. There is very little scientific information on Maltese maerl grounds and our studies are aimed at improving knowledge of the ecology of this important habitat. The most extensive maerl bed discovered to date in the Maltese Islands covers about $20km^2$ of the seabed and occurs at depths of between 40m and 80m off the Northeastern coast of Malta and Gozo. This maerl ground is well known to fishermen as being highly productive and in fact they refer to it as '*ramel haj*' which literally translated means 'living sand', referring to its importance as a fishing ground for both demersal and pelagic fish.

Two sites within this maerl ground have been chosen for detailed study. One of the sites is impacted by trawling while the other site is not trawled due to the presence of rocky shoals and wartime wrecks which damage the fishing gear. Sampling from these two sites was carried out seasonally for two years (July 1996 - April 1998). A $0.1m^2$ van Veen grab and a biological dredge were used to collect six grabs and one dredge samples from each site every season. The biota and live maerl from these samples were sorted and analysed. Physico-chemical parameters of the water column were monitored at monthly intervals. The sediment characteristics of the two sites have also been analysed.

From our results, it is evident that Maltese maerl grounds have a rich biodiversity and support a wide range of taxa. However, although the species richness is high, abundances are very low. Of particular interest is the presence of two species of algae, *Flabellia petiolata* and *Polysiphonia setacea*, which bind the maerl to form a *pseudo*-hard bottom. Due to this binding effect, it is hard to determine whether the rhodoliths of the maerl ground studied do in fact rotate periodically.

It is evident that the impacted and control sites are different. The impacted site has larger rhodoliths and coarser sediments than the control site. This may reflect a higher degree of disturbance at the impacted site, however the source of this disturbance is not clear. Trawling at this site is likely to contribute to this disturbance but is probably not the major factor. There are also some differences in the abundances of the biota at the impacted and the control sites.

This research has been undertaken in the framework of the BIOMAERL project with support from the European Commission's Marine Science and Technology Programme (MAST III) under contract MAS3-CT95-0020. Maltese participation in the BIOMAERL project has been made possible through grants from the University of Malta, the Malta Council for Science and Technology, and the Ministry of Education, for which we are grateful.

EFECTO DE LOS CAMPOS DE BATEAS DE MEJILLÓN SOBRE LA DISTRIBUCIÓN VERTICAL DE LA INFAUNA EN LOS FONDOS DE MAËRL.

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El término *maërl (Lithothamnium corallioides y Phymatolithon calcareum)* se aplica a un grupo de algas Corallinacea (rodofita) no geniculadas libres, (Irvine y Chamberlain, 1994) que habitan sobre la superficie del fondo en zonas someras (entre 5 y 30 m) tanto en estuarios como en mar abierto. Estas algas crecen muy lentamente, formando ambientes de gran interés ecológico por el hecho de proporcionar microhábitats susceptibles de ser utilizados por un elevado número de especies, zonas de puesta, refugio para estadíos juveniles y lugares de abrigo contra depredadores. A pesar de las frecuentes alteraciones que los fondos de maërl sufren (dragados, arrastres pesqueros, etc.), las diversidades de especies que soportan son las mayores descritas sobre los sustratos móviles de las costas europeas.

El presente estudio trata de analizar el efecto del cultivo intensivo de mejillón *(Mytilus edulis)* en la Ría de Vigo, sobre la estructura y organización de la macrofauna de un fondo de maërl en la vertical sedimentaria.

Se eligieron dos estaciones de muestreo: una que presentase el menor impacto posible, lejos de la presencia de polígonos de bateas (USC) y otra estación (USI) situada en el interior de uno de dichos polígonos, claramente afectada por los biodepósitos del bivalvo.

La recogida de muestras se llevó a cabo, desde una embarcación, con una draga de inserción vertical tipo "Reineck box-corer". El número de réplicas (6) analizado cubría una superficie total de muestreo de 0,1 m^2. Para el estudio de distribución vertical, cada cajetín de muestra se cortó en estratos de 2 cm de espesor. El mismo sistema se siguió para el análisis del apartado sedimentológico. En el laboratorio se llevó a cabo la separación y determinación específica de los ejemplares, así como la analítica granulométrica.

En las dos estaciones muestreadas los grupos taxonómicos mejor representados en cuanto a diversidad específica y número de individuos, son los poliquetos, crustáceos y moluscos. Estos grupos se encuentran desigualmente repartidos en la vertical debido a su movilidad y a su comportamiento trófico. En nuestro estudio se observó que más de un 50% del total de la fauna en la estación alterada (USI) aparece en los dos centímetros superficiales, mientras que en la estación control (USC), dicho porcentaje lo encontramos en los cuatro primeros centímetros. A medida que profundizamos en el sedimento se observa, en las dos estaciones, una clara disminución en el número de especies y de individuos. Así, en la estación USI, a partir de 6-8 centímetros desaparece prácticamente toda la infauna, contrastando con la estación USC, en la que los grupos principales están presentes hasta los 10 cm. Por lo tanto la fauna parece descender en mayor medida en el sedimento en la estación no afectada por la presencia de bateas, probablemente por presentar una granulometría más gruesa, libre de biodepósitos, que permite unos mayores niveles de oxigenación de la vertical sedimentaria.

Este estudio se llevo a cabo en el marco del proyecto "BIOMAERL. Maerl Biodiversity: Functional Structure and Anthropogenic Inputs", financiado por el Programa de Ciencias Marinas y Tecnologia de la Comision Europea (MAST III) con el contrato MAS3 CT95 - 0020

2.2. TECHNICAL REPORT

This report covers the Tasks as set out in the Technical Annex to the BIOMAERL contract, and summarizes information submitted in previous interim Reports. Supplementary information on all Tasks, however, is also provided.

TASK 1 : Sampling sites, identification of key species and sampling protocol

Sub task 1.1: Site selection (pilot surveys)

Objective:

To select from the range of available and accessible local sites, at least two maerl grounds for study: one which is subject to anthropogenic impacts typical of the region and another which typifies pristine conditions (so far as is possible).

Preliminary surveys using various techniques (variously direct and indirect) served to identify suitable grounds and the following sites were selected on the basis of a combination of strategic and practical considerations, viz. suitability for study and accessibility. In the following maps, the maerl grounds are indicated by encircling marks or dotted outlines.

1) CLYDE SEA AREA (UMBSM)

i) Grounds selected

Unimpacted site

Name: Creag Gobhainn, near Otter Spit, west Loch Fyne (Code OS1)

Depth: 6 14m CD (Chart Datum)

Latitude & longitude: 56°00.601'N; 5°22.148'W

Methods of site relocation: Permanent marker buoy used in conjunction with Magellan GPS and photographic records of shore transects.

Spatial extent of maerl: 17.5ha

Map:

Note: position of telecommunications cable indicates a no-trawling area.

Impacted Site

Name: Stravanan Bay, southwest Isle of Bute (Code ST1)

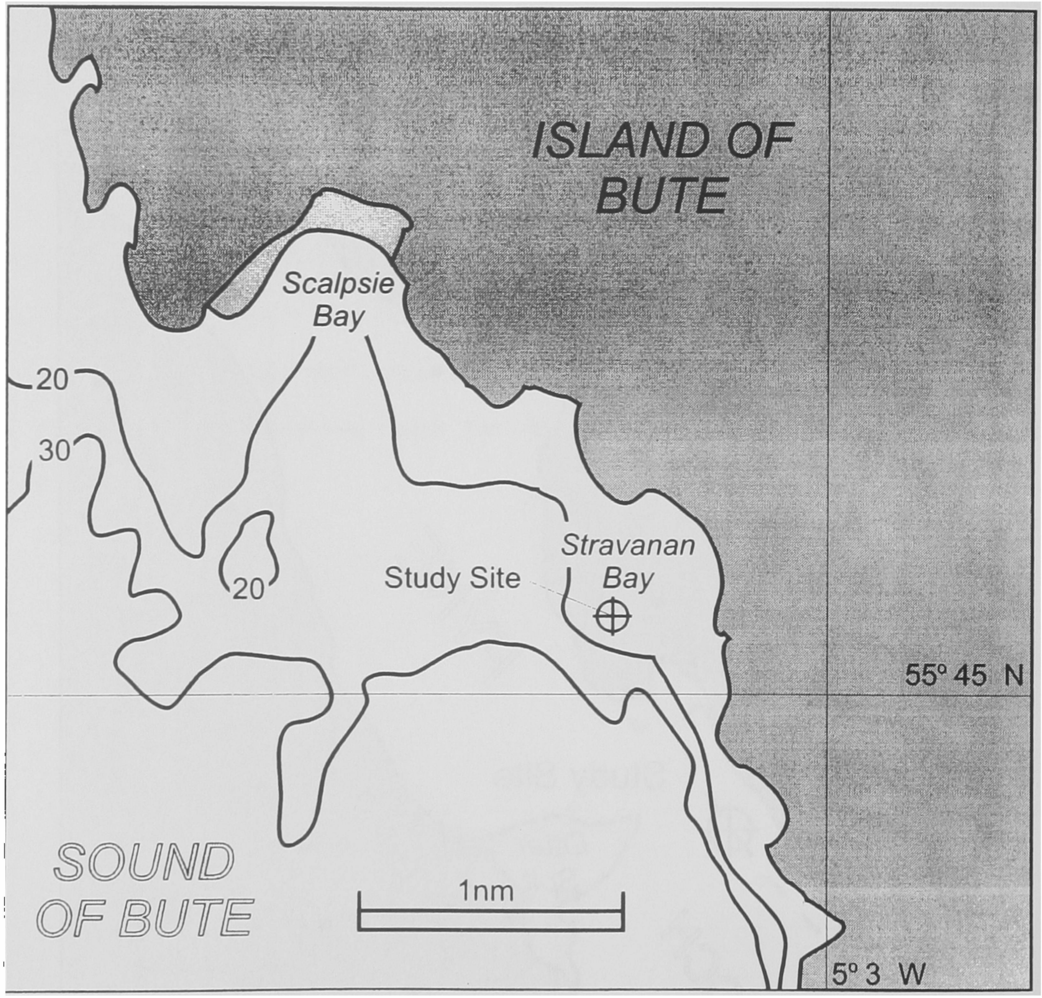
Depth: 6.0 - 14.7m

Latitude & longitude: 55°45.323'N; 5°04.265'W

Methods of site relocation: Permanent marker buoy used in conjunction with Magellan GPS.

Spatial extent of maerl: 6.75ha

Map:



3) GALICIA (USC)

Unimpacted site

Name: Station USC (BZ14 of previous surveys), near Cangas

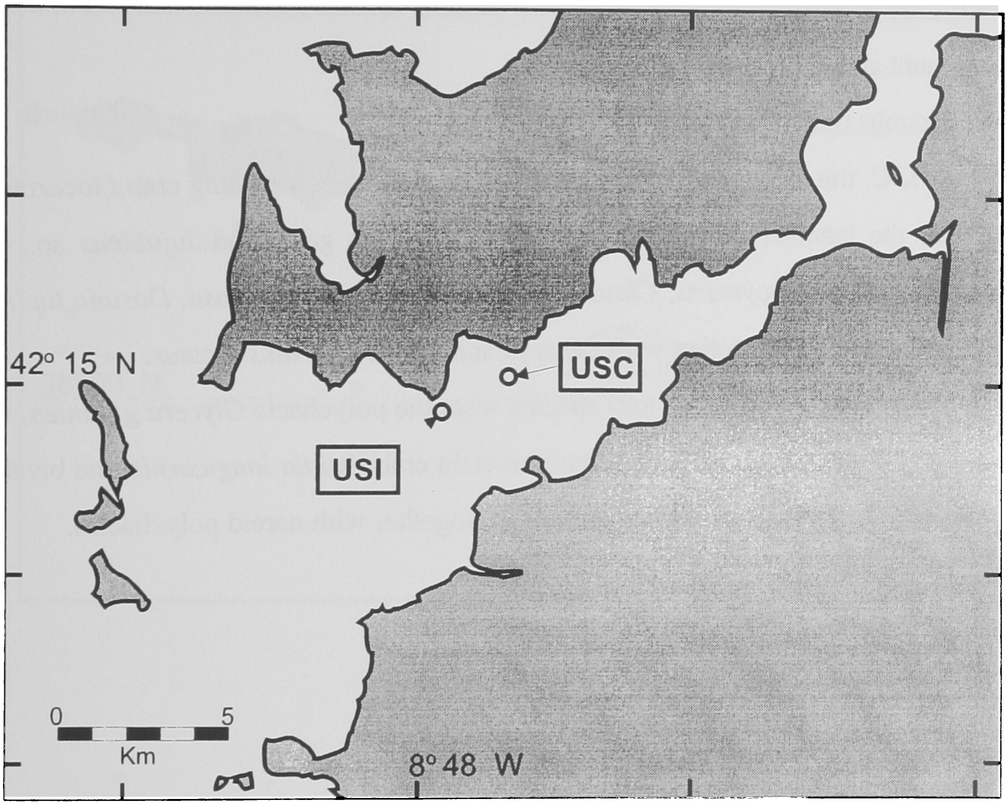
Depth: 8m

Latitude & longitude: 42° 15.13'N; 8° 46.01'W

Methods of site relocation: GPS (Garmin 75)

Spatial extent of maerl: 351ha

Map:



Impacted site

Name: USI (BZB of previous surveys), near Limens

Depth: 18m

Latitude & longitude: 42° 14.88'N; 8° 47.44'W

Methods of site relocation: GPS (Garmin 75)

Spatial extent of maerl: 319ha

Map: see previous page.

ii) Maerl characteristics

See statement at end of Task 1.1 section

iii) Conspicuous macrobiota

At station USC, the most conspicuous macrobiota were the swimming crab *Liocarcinus corrugatus*, the lancelet *Branchiostoma lanceolatus*, the gastropod *Jujubinus* sp., the bivalves *Glycymeris glycymeris, Clausinella fasciata*, *Venus verrucosa*, *Dosinia lupinus* and *Tapes rhomboides*, together with the archiannelid *Polygordius lacteus*.

At station USI, the most conspicuous species were the polychaete *Glycera gigantea*, the sea cucumber *Cucumaria normannii*, the porcelain crab *Pisidia longicornis*, the bivalve *Abra alba* and the crab *Liocarcinus corrugatus*, together with nereid polychaetes.

4) MEDITERRANEAN SPAIN (UA)

Unimpacted site

Name: Tabarca marine reserve

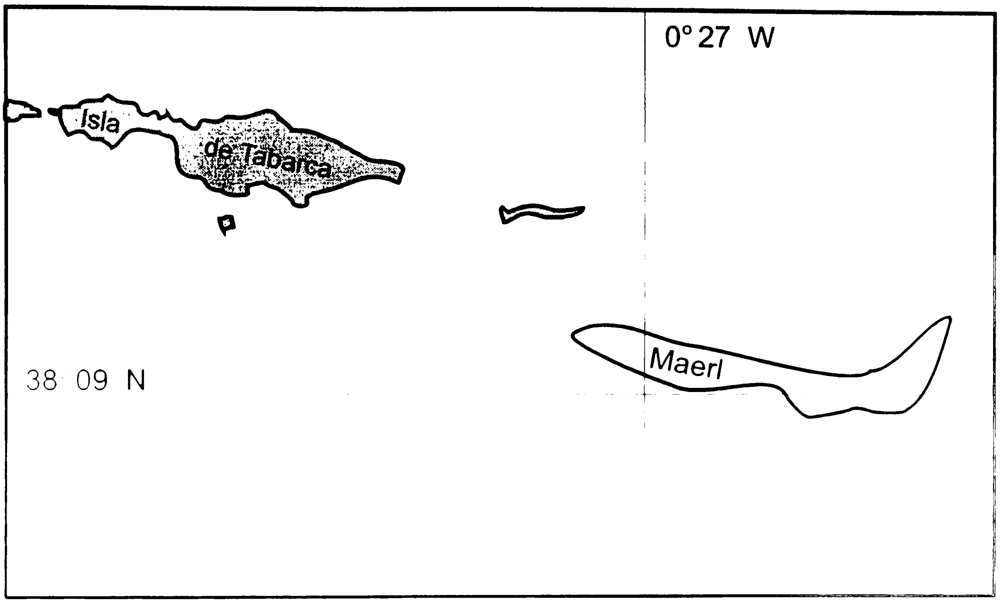
Depth: 30-37m

Latitude & longitude: 38° 09.0'N; 00° 26.5'W

Methods of site relocation: coastal visual marks and GPS

Spatial extent of maerl: 20ha

Map:



Impacted site

Name: Benidorm island

Depth: 33-36m

Latitude & longitude: 38° 29.9'N; 00° 08.0'W

Methods of site relocation: coastal visual marks and GPS

Spatial extent of maerl: 3.5ha

Map:

ii) Maerl characteristics

See statement at end of Task 1.1 section.

iii) Conspicuous macrobiota

There are some differences between control and impacted sites related to maerl species. *Phymatolithon calcareum, Lithothamnion minervae, Lithophyllum racemus* and *Mesophyllum sp.* are abundant on the control site; *Peyssonnelia orientalis, P. rubra* and *Lithothamnion corallioides* at the impacted site. Also there are some differences regarding the erect and soft macroalgae, thus *Osmundaria volubilis* and *Phyllophora nervosa* are abundant on the control site, while *Flavellia petiolata* is at the impacted site. *Polysiphonia subulifera, Halopteris filicina* and *Dictyota dichotoma* are present at both sites.

With regard to the more conspicuous megafauna, the echinoderms *Echinaster sepositus, Sphaerechinus granularis, Spatangus purpureus* and *Holothuria tubulosa* are present at both sites; while the hermit crab *Dardanus arrosor* is at the control site. The main differences regarding macrofauna are the high percentage of colonial species on the control ground: viz. Porifera, tubicolous Polychaeta (*Salmacina dysteri*), Bryozoa (*Margaretta cereoides*, encrusting colonies) and colonial ascidians (*Didemnum* sp.) ; while on the impacted ground such types are rare, only the poriferan *Cliona viridis* and the bryozoan *Beania hirtissima* are abundant.

5) MALTA (UM)

Given that, at the time of writing the original application and the Technical Annex, maerl grounds had only just been discovered in Maltese waters (see Borg *et al.*, 1998), the sites originally proposed (Gozo-Comino channel, Is-Sikka I-Bajda) were subject to reassessment.

The very small (3400m^2) maerl bed in the Gozo-Comino channel, proposed originally, was dismissed since re-examination of sediment samples showed it to be composed almost entirely of dead maerl. In all probability it represents a relict ground.

The Is-Sikka I-Bajda ground has also been resampled in greater detail (see below) and a large maerl ground has been revealed covering an estimated 20km^2. Areas impacted and unimpacted by trawlers were delineated (after discussions with local fishermen): the unimpacted area probably being avoided because of rocky shoals and wrecks which damage fishing gear.

i) Grounds selected

Unimpacted site

Name: off Qawra / Salina Bay (control area in map below)

Latitude & longitude: NW corner 36° 01.10'N; 14° 26.90'E: NE corner 36° 00.90'N; 14° 27.75'E: SW corner 36° 00.50'N; 14° 26.20'E: SE corner 36° 59.90'N; 14° 26.70'N.

Depth: 50-55m

Methods of site location: GPS (Raytheon 790)

Spatial extent of maerl: forms part of a 20km^2 ground

Map:

Impacted site

Name: Off St Paul's islands (impacted area in map above)

Latitude & longitude: NW corner 36° 00.60'N; 14° 28.915'E: NE corner 36° 00.20'N; 14° 28.70'E; SW corner 35° 58.40'N; 14° 26.25'E; SE corner 35° 58.00'N; 14° 26.90'E.

Depth: 45-50m

Methods of site location:GPS (Raytheon 790)

Spatial extent of maerl: forms part of a 20km^2 ground

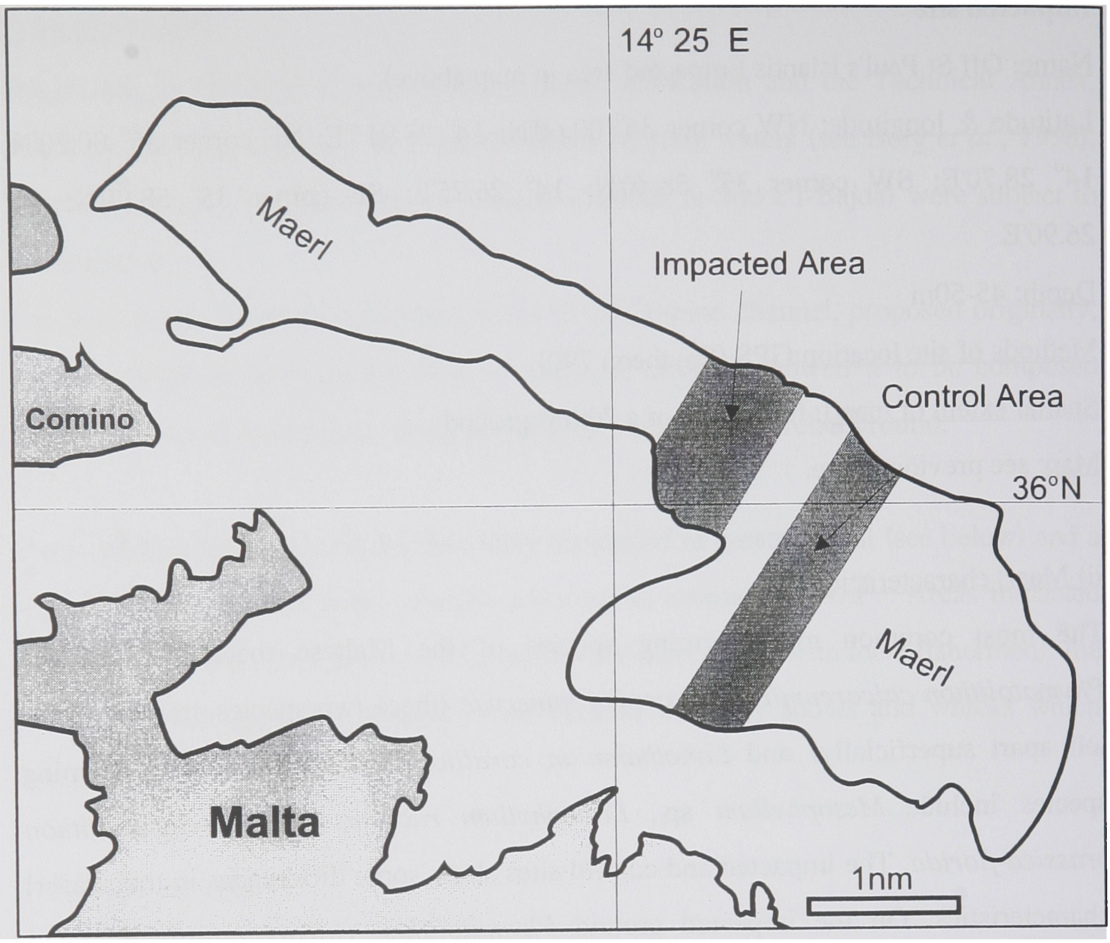
Map: see previous page.

ii) Maerl characteristics

The most common maerl-forming species of the Maltese maerl grounds are *Phymatolithon calcareum/Lithothamnion minervae* (these two species are difficult to tell apart superficially) and *Lithothamnion corallioides*. Additional maerl-forming species include *Mesophyllum* sp., *Lithophyllum racemus* and *Neogoniolithon brassica-florida*. The impacted and control sites show some differences in their maerl characteristics. On the impacted ground *Phymatolithon calcareum/Lithothamnion minervae* is more abundant than *Lithothamnion corallioides*, while the reverse is true for the control ground. Also, rhodoliths at the impacted site seem to attain larger sizes than rhodoliths at the control ground, while in turn rhodoliths from the control ground show more delicate open-branching than rhodoliths from the impacted ground.

(iii) Conspicuous macrobiota

An important element of the macrobiota of the Maltese maerl grounds are fleshy (i.e. non-calcareous) macroalgae. One of the most abundant species which was found in all grab samples from both sites is the chlorophyte *Flabellia petiolata* the rhizoids of which have an important binding effect on the maerl. The rhodophyte *Polysiphonia* (= *Womersleyella) setacea*, the filamentous thalli of which also bind the sediment, is very abundant particularly at the control site but because of its habit, its abundance is very difficult to quantify. Other abundant macroalgae include *Cystoseira corniculata*,


14° 25 E
Maerl
Impacted Area
Comino
Control Area
36°N
Maerl
Malta
1nm

Vidalia (=*Osmundaria*) *volubilis* and *Codium bursa*. *Codium bursa* is common only at the control site.

The most conspicuous and abundant macrofaunal species is probably the echinoid *Stylocidaris affinis* which was collected mostly by the dredge samples. The crinoid *Antedon mediterranea* was collected in most of the grab samples where it was found attached to fleshy algae and to the rhodophytes. However, being very fragile the organism was seldom recovered intact during sample sorting. Other abundant animals included the gastropod *Bittium latreillii* and echinoid *Echinocyamus pusillus*. While the Maltese maerl grounds have a high biodiversity, very few species were found at high population density.

Maerl characteristics

Over the period of the project, material collected by all partners was collated and examined in ultrastructural detail using scanning electron microscopy by Dr J.M.Hall-Spencer. Two of the leading taxonomists in the field of coralline algae, Mdme J.Cabioch and Dr Y.M.Chamberlain, are thanked for their helpful discussions on our findings and opinions on material.

Only a brief summary of these findings is given here as they are explained fully under Task 2 (below). The following figure (Fig.1.1) illustrates the biogeographical distribution of the main maerl-forming species in the coastal seas of the NE Atlantic and W Mediterranean.

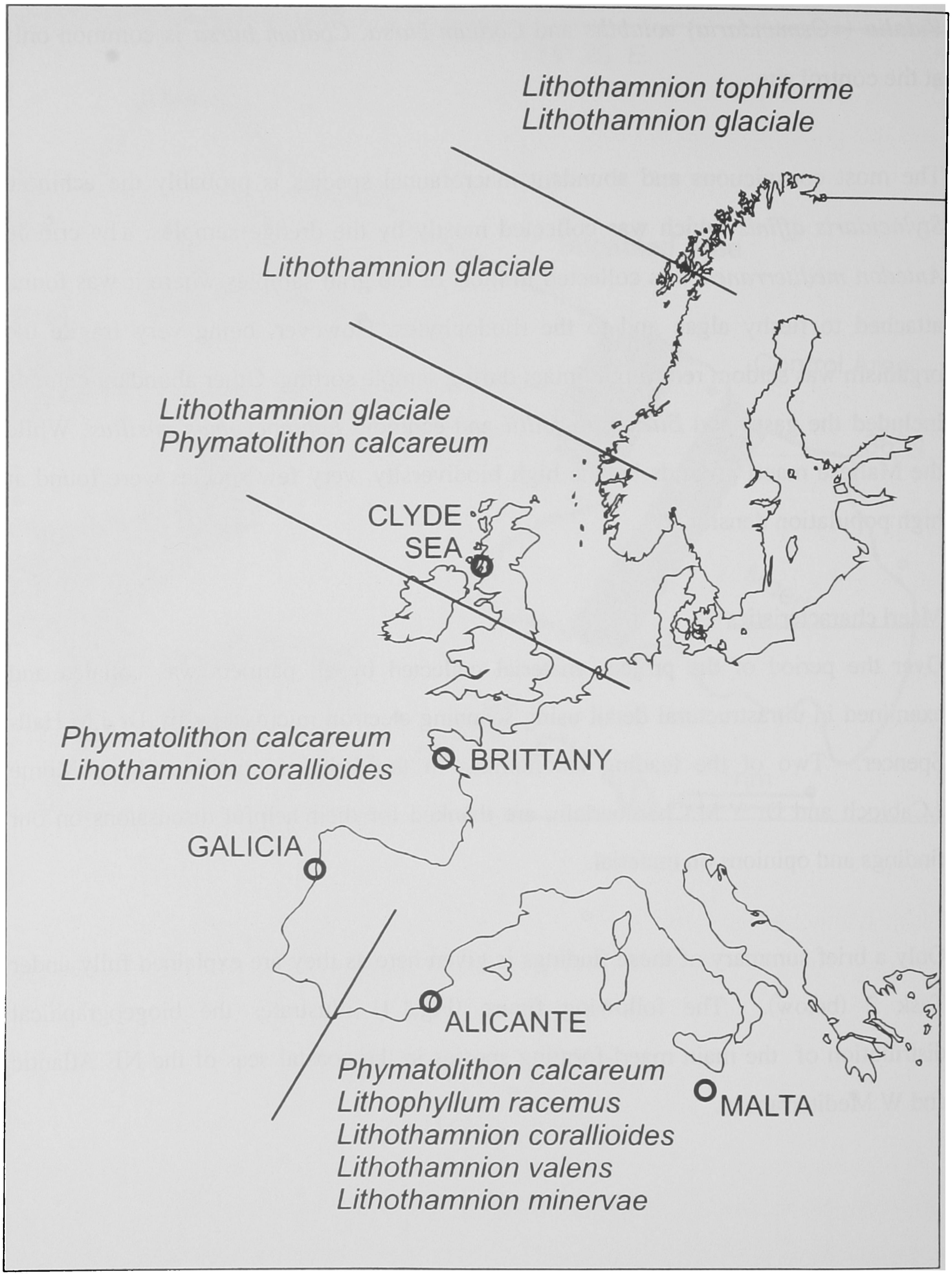


Fig.1.1. The biogeographical distribution of the main European maerl-forming calcareous rhodophytes and the geographical situation of BIOMAERL study sites.

Task 1, sub Task 1.2: Identification of key species

The main objectives of subtask 1.2, as set out in the Technical Annex and as expanded subsequently during BIOMAERL meetings (see Appendices to Interim Reports), were:

To identify a number of key species (10-20) that

(i) determine the structure of the of the maerl community because of one or more of the following community functions, in terms of:

-- binding the maerl together (e.g. stabilize the sediment)

-- acting as bioturbation agents (e.g. disrupt the sediment)

-- being of trophic importance (e.g. are important prey items or predators)

-- being likely to be present consistently.

(ii) are prone to impacts (positive or negative) from anthropogenic activities.

The choice of key species was affected by the desirability that those chosen would be likely to feature in samples over the two-year sampling period, and the need for them to be practicable to quantify. Extensive modification has, perforce, had to be made to our original list of key species over the timespan of the project, as early ideas had to be revised in the light (particularly) of experience at different times of year. Key species selection has been a particular problem for the mediterranean sites, due to the small size and high diversity of the macrofauna slowing up sample processing. Final selection has had to be retrospective and deferred until the final stages of the programme.

The final selection of species are summarized on an area-by-area basis, with an indication given of the functional role of each in the maerl-bed ecosystem, as follows:

1) Clyde Sea area (UMBSM)

Taxon	Role in Ecosystem
Macroalgae	
Phymatolithon calcareum	Primary producer
Lithothamnion glaciale	Primary producer
Laminaria saccharina	Primary producer / binder

Cnidaria

Cerianthus lloydii	Carnivore
Edwardsia claparedii	Carnivore

Polychaeta

Glycera lapidum	Carnivore
Sphaerodorum gracilis	Carnivore
Scalibregma inflatum	Deposit feeder
Owenia fusiformis	Suspension/deposit feeder
Terebellides stroemi	Deposit/suspension feeder

Archiannelida

Polygordius lacteus	Deposit feeder

Crustacea - Decapoda

Upogebia deltaura	Suspension feeder

Mollusca - Bivalvia

Limaria hians	Suspension feeder/binder
Clausinella fasciata	Suspension feeder
Dosinia exoleta	Suspension feeder
Thracia villosiuscula	Suspension feeder

Echinodermata

Ophiocomina nigra	Omnivore
Psammechinus miliaris	Herbivore
Echinocyamus pusillus	Micrograzer
Neopentadactyla mixta	Suspension feeder
Thyonidium drummondi	Suspension feeder

2) Brittany (UBO)

Bay of Brest

Polychaeta

Platynereis dumerilii	Detritivore
Eunice vittata	Carnivore
Nematonereis unicornis	Carnivore
Aonides oxycephala	Deposit feeder
Chaetozone setosa	Deposit feeder
Cirriformia tentaculata	Deposit feeder
Notomastus latericeus	Deposit feeder
Hesione pantherina	Predator

Crustacea - Amphipoda

Abludomelita gladiosa	Detritivore
Maera grossimana	Deposit feeder
Gammarella fucicola	Detritivore

-Decapoda

Pisidia longicornis	Suspension feeder
Liocarcinus arcuatus	Carnivore / scavenger

Mollusca - Gastropoda

Gibbula magus	Herbivore
Jujubinus striatus	Herbivore
Crepidula fornicata	Suspension feeder

-Bivalvia

Parvicardium exiguum	Suspension feeder
Venus verrucosa	Suspension feeder

Echinodermata

Psammechinus miliaris	Herbivore/ detritivore
Paracentrotus lividus	Herbivore

Glenan

Crustacea - Decapoda

Inachus dorsettensis	Carnivore / scavenger
Atelecyclus rotundatus	Carnivore / scavenger
Atelecyclus undecimdentatus	Carnivore/scavenger
Liocarcinus depurator	Carnivore / scavenger
Liocarcinus pusillus	Carnivore / scavenger
Xantho pilipes	Carnivore / scavenger

Mollusca - Gastropoda

Gibbula magus	Herbivore
Turritella communis	Suspension feeder
Buccinum undatum	Scavenger
Hinia reticulata	Scavenger

-Bivalvia

Pecten maximus	Suspension feeder
Timoclea ovata	Suspension feeder
Tapes rhomboides	Suspension feeder

Echinodermata

Psammechinus miliaris	Herbivore/ detritivore

3) Galicia (USC)

Annelida -Archiannelida

Polygordius lacteus	Bacteriophage

- Polychaeta

Mediomastus fragilis	Selective deposit feeder
Notomastus latericeus	Selective deposit feeder
Eunice vittata	Predator
Lumbrineris tetraura	Predator
Glycera lapidum	Predator
Pista cristata	Deposit feeder
Aonides oxycephala	Deposit feeder

Crustacea - Amphipoda

Aora gracilis	Suspension/deposit-feeder
Leptocheirus tricristatus	Suspension/deposit-feeder
Socarnes erythrophthalmus	Scavenger/Predator
Ceradocus semiserratus	Deposit feeder
Gammarella fucicola	Detritivore
Listriella picta	[uncertain]
Maera grossimana	Deposit-feeder
Maera othonis	Deposit-feeder

- Tanaidacea

Apseudes latreillii	Detritivore
Apseudes talpa	Detritivore

- Decapoda

Pisidia longicornis	Suspension feeder
Liocarcinus corrugatus	Predator

Mollusca- Polyplacophora

Leptochiton cancellatus	Micrograzer

- Gastropoda

Gibbula magus	Micrograzer
Jujubinus exasperatus	Micrograzer

Jujubinus miliaris	Micrograzer
Tectura virginea	Coralline grazer
- Bivalvia	
Clausinella fasciata	Suspension feeder
Dosinia exoleta	Suspension feeder
Tapes rhomboides	Suspension feeder
Echinodermata	
Echinocyamus pusillus	Micrograzer
Psammechinus miliaris	Detritivore
Chordata	
Branchiostoma lanceolatum	Suspension feeder
4) Alicante (UA)	
Macroalgae	
Lithothamnion corallioides	Maerl/Primary producer
Lithothamnion minervae	Maerl/Primary producer
Phymatolithon calcareum	Maerl/Primary producer
Peyssonnelia orientalis	Maerl/Primary producer
Polychaeta	
Eunice vittata	Omnivore/ carnivore
Lysidice ninetta	Omnivore/ carnivore
Mollusca - Polyplacophora	
Leptochiton cancellatus	Herbivore
- Gastropoda	
Caecum trachea	Deposit feeder
Crustacea - Isopoda	
Cymodoce truncata	Scavenger/ carnivore
Synisoma carinata	Scavenger/ carnivore
- Tanaidacea	
Apseudes latreillii	Deposit/suspension feeder
- Amphipoda	
Leptocheirus hirsutimanus	Suspension feeder
Lysianassa longicornis	Scavenger / carnivore
Maera knudseni	Deposit feeder
- Decapoda	

Thoralus cranchii	Omnivore
Athanas nitescens	Omnivore
Ebalia edwardsi	Deposit feeder/ carnivore
Galathea intermedia	Deposit/suspension feeder
Echinodermata	
Amphipholis squamata	Carnivore
Ophiothrix fragilis	Suspension feeder
Ophiura grubei	Scavenger/ carnivore
Echinocyamus pusillus	Micrograzer
Ascidiacea	
Didemnum sp.	Suspension feeder

5) Malta (UM)

Macroalgae	
Flabellia petiolata	Primary producer & Sediment-binder
Polychaeta	
Eunice vittata	Omnivore/carnivore
Lysidice ninetta	Omnivore/carnivore
Mollusca - Gastropoda	
Jujubinus exasperatus	Herbivore (micrograzer)
Jujubinus striatus	Herbivore (micrograzer)
Turritella turbona	Suspension-feeder
Bittium latreillii	Detritivore
Volvarina mitrella	Probably microcarnivore
Barleeia unifasciata	Herbivore
Mitrella scripta	Herbivore or carnivore
- Opisthobranchia	
Haminoea hydatis	Carnivore / herbivore?
Mollusca - Bivalvia	
Pteromeris minuta	Suspension-feeder
Digitaria digitaria	Suspension-feeder
Gonilia calliglypta	Suspension-feeder
Crustacea -Tanaidacea	
Leptochelia savignyi	Deposit / suspension feeder.

-Amphipoda	
Maera grossimana	Probably a deposit feeder
Ampithoe ramondi	Herbivore
Lysianassa costae	Scavenger / carnivore
-Decapoda	
Athanas nitescens var. *laevirinchus*	Possible omnivore
Cestopagurus timidus	Omnivore + deposit feeder.
Galathea intermedia	Deposit / suspension feeder.
Echinodermata	
Stylocidaris affinis	Possibly omnivore
Echinocyamus pusillus	Micrograzer
Genocidaris maculata	Deposit-feeder or micrograzer?

No key species were common to all sites studied, although many were of shared significance betweeen two or more sites. Thus *Psammechinus miliaris* was widespread among Atlantic sites; *Glycera lapidum* and *Polygordius lacteus* were shared by Clyde Sea and Brittany; *Eunice vittata, Pisidia longicornis, Maera grossimana* and *Tapes rhomboides* by Brittany and Galicia. In the Mediterranean, the following species were present both off Alicante and Malta: *Eunice vittata, Lysidice ninetta, Athanas nitescens* and *Galathea intermedia*. Some species spanned the Atlanto-Mediterranean divide, like *Eunice vittata, Echinocyamus pusillus, Jujubinus exasperatus, J. striatus, Leptochiton cancellatus, Maera grossimana* and *Apseudes latreillii*. It is also interesting to note that different species of the same genus are perceived to be important in different areas, for example in the amphipod genera *Lysianassa* and *Maera* and *Leptocheirus,* or the gastropod genera *Turritella* and *Jujubinus.* Analyses of such species (in terms of size-frequency determination especially) may convey useful insights into latitudinal differences in rate processes (e.g. growth and reproduction). However, only a few species, like *Echinocyamus pusillus, Galathea intermedia, Phymatolithon calcareum* occurred in all regions studied (and these have not necessarily been designated universally as key species).

Olausson box corer had a poor success rate since pebbles, which were common, prevented adequate penetration of the sediment. Hand-held 0.08m^2 circular cores proved to be ideal for sampling small (<1mm), but very abundant, members of the near-surface maerl fauna (Hall-Spencer, 1998). They were also a useful means of monitoring the abundance of living maerl on experimental plots within each deposit (Hall-Spencer & Moore, in press a). The most difficult group of organisms to sample proved to be the deep-burrowing megafauna which could not be collected using the methods outlined above. However, a combination of air-lifting, Senkenberg box cores and resin-cast burrows provided novel information on these elusive organisms (Hall-Spencer & Atkinson, in press).

By June 1996, preliminary trials had been completed and a 75cm ring dredge, 1m^2 quadrats, 0.08m^2 hand-held cores and a 0.1m^2 van Veen grab were chosen as the most suitable combination of sampling devices to regularly monitor the dynamics of key species on impacted and control grounds over a two year period. To complete Tasks 3 & 4, and in the light of discussion with collaborators at the second BIOMAERL meeting, UMBSM opted for a seasonal sampling programme of three replicate van Veen samples (1mm sieved), three hand-held core samples (1mm sieved), ten sediment-surface quadrats and one ring dredge sample (2mm sieved) per site, giving totals of 48 grabs, 48 cores, 160 quadrats and 16 dredge samples.

As the biological sampling programme progressed it proved possible to achieve the agreed level of sampling and, on many occasions, to include a greater degree of temporal and spatial replication to improve the accuracy of population estimations.

2) <u>Brittany</u>

The limited scope for paying for ship time within the project budget, meant that sampling opportunities were restricted to times when a ship could be borrowed from the CNRS. This restricted the access to the four seasonal sampling trips required by contract each year. On each of these occasions, 6 Smith-McIntyre grabs, 6 AQUAREVE samples and 3 Reineck cores were taken. Grabs were taken for macrofaunal population density estimation. Previous work in the area had shown that six grabs were needed to sample adequately the majority of macrofaunal species. AQUAREVE samples were taken to gain information about the more sparsely distributed megafaunal epibenthos. Reineck cores enabled investigation of the vertical stratification of infauna. The use of a range of sampling techniques thus allowed a more complete picture of the biota to be assembled than would have been the case had reliance been put on a single type of gear.

3) Galicia

The sampling protocol of maerl ground biota that has been followed during the seasonal sampling (April, July, October 1996, January, April, July, October 1997 and January 1998) used the following devices:

Dredges.

A Naturalist's dredge and a Ring dredge (Rallier du Baty dredge) were compared at the start of the sampling period to test sampling efficiency in maerl bottoms. The ring dredge proved to be more efficient in collecting infauna as well as epifauna while the Naturalist's dredge exhibited some tendency to bounce over this bottom, catching mostly epibiota but only a small component of the infauna. Accordingly, the Ring dredge was chosen to take the qualitative samples.

Grabs

A van Veen grab was used to collect quantitative samples, and its efficiency was compared with that of Reineck's box corer. The results obtained were as follows: the van Veen grab was very efficient in catching epibiota but did not penetrate more than 5 to 6 cm into these maerl grounds. For this reason, this grab was just used to take the seasonal seaweed samples (for the study of the seaweed coverage) but not for quantitative sampling of biota. The Reineck's box corer collected the highest number of species, sampling consistently and penetrating deeper (from 10 to 16 cm) than the van Veen grab. The inconvenience of its smaller sampling surface area to catch epibiota was removed by taking a larger number of replicates (six per site) to reach the minimal area required. Only 7 species found in the grab were absent from the box corer, while 24 to 27 species were found in the box corer but not in the grab; these species were mainly deep burrowers and small infaunal polychaete species. For this reason, the quantitative samples for biota were all taken with the box-corer.

4) Alicante

The Alicante team was constrained to use small inflatable boats, due to the cost constraints and problems of availability of large vessels during the sampling period. The first priority of oceanographic research vessels is to work with National Research Institutes and only afterwards with the Universities. The problem with trying to use fishing vessels is that it is not possible to plan any cruise with certainty beforehand, due to the unpredictability of fishing activities, which always take priority. For these reasons the UA team has used the University's own small boats. This has been done with success, but it has limited the type and scale of gear that can be deployed remotely.

Initially, a small van Veen grab($0.05m^2$) was tested but it did not work very well on maerl bottoms (rhodoliths frequently became lodged in the jaws preventing grab closure and precipitating loss of the sample by winnowing). The problem was solved by SCUBA divers deploying *in situ* small quadrats ($0.05m^2$, with 1mm mesh cover bags). Six samples were taken per site at each season ($0.3m^2$), i.e. comparable to the sampling intensity undertaken by other BIOMAERL partners (3 samples by $0.1m^2$ grab). Also, the UA team took *in situ* core samples (9cm diam.) for granulometry.

With regard to qualitative/semi-quantitative sampling for wider assessment of biodiversity, the UA team chose to use a small runner dredge (45 x 25 cm frame) that worked better than a Naturalist's dredge to sample conspicuous, but widely scattered, megabenthos. The area sampled was about $30\text{-}40m^2$ (3 minutes at a towing speed of 0.6-0.7kt), and three replicates were taken per site each season.

Samples were frozen and, after sieving sequentially through 5, 2 and 1mm mesh sieves, were fixed in formalin or alcohol. Afterwards, the biological material wwas sorted into higher taxa (Phylum, Class, Order) and each taxon was then identified to species by a specialist.

5) Malta

Since Maltese maerl beds are found at depths greater than 40m, it was not possible to sample them using SCUBA diving for safety reasons. Therefore remote sampling had to be used and the sampling methods were restricted to the type of sampling gear available: a 0.1m^2 van Veen grab, a biological dredge and a box corer.

Unfortunately, all attempts at using the box corer available were unsuccessful. This failure was initially attributed to insufficient weight of the gear. Lead weights were added to bring the total weight of the corer to over 60kg, but even so, very little penetration of the bottom was achieved. It was not possible to deploy heavier gear from the vessel available. Maltese maerl beds were therefore sampled using the van Veen grab and biological dredge only, both of which performed well on the grounds studied.

On the basis of the species identified in Task 1.1, it became obvious that whereas the dredge collected very much the same relatively abundant small-sized species that were collected by the grab, it collected additional large-sized species not collected by the grab and, in addition, small-sized species that are very sparsely distributed.

From this, two things became clear: (i) no true picture of the biodiversity of the maerl grounds could be obtained by sampling using a grab alone; and (ii) some important (in terms of biomass or community function or susceptibility to anthropogenic impact) species are only adequately sampled using a dredge (for example, *Stylocidaris affinis*, which is a large and fragile sea urchin was found in relatively large numbers in the dredge samples, but only occasionally, and as juveniles, in the grab samples).

For this reason, it was decided that in spite of their semi-quantitative nature, dredge samples would also have to form part of the Maltese protocol. The sampling protocol used was as follows: one sampling trip to each of the 'control' and 'impacted' stations every three months; six van Veen grab samples at each station; one dredge sample at each station.

For the van Veen samples, three were analysed immediately after each trip and the other three were preserved and 'banked' for future analysis if time and finances permit. The dredge samples were analysed immediately after each trip.

As will be clear from the above, each participating laboratory has taken (and worked up) considerably more samples than was originally prescribed in the Technical Annex.

TASK 2 : Factors structuring maerl communities

Objectives:

To characterize the physical structure of the maerl bed at each study site.

To characterize the hydrographic characteristics of the water column at each study site.

To assess seasonal variability of temperature, maerl mobility (natural disturbance) and attempt to assess organic input over one annual cycle.

Sites and sampling

Site details relating to the maerl beds studied are listed in Table 2.1 (see also Fig. 2.1). All sites have been sampled remotely using shipborne grabs, corers, various dredges and beam trawls routinely. Certain grounds have been investigated and photographed (Nikonos V) *in situ* using SCUBA diving (Clyde Sea area and sites off Alicante), others only occasionally so (Malta; Galicia; Bay of Brest monthly post-March 1997).

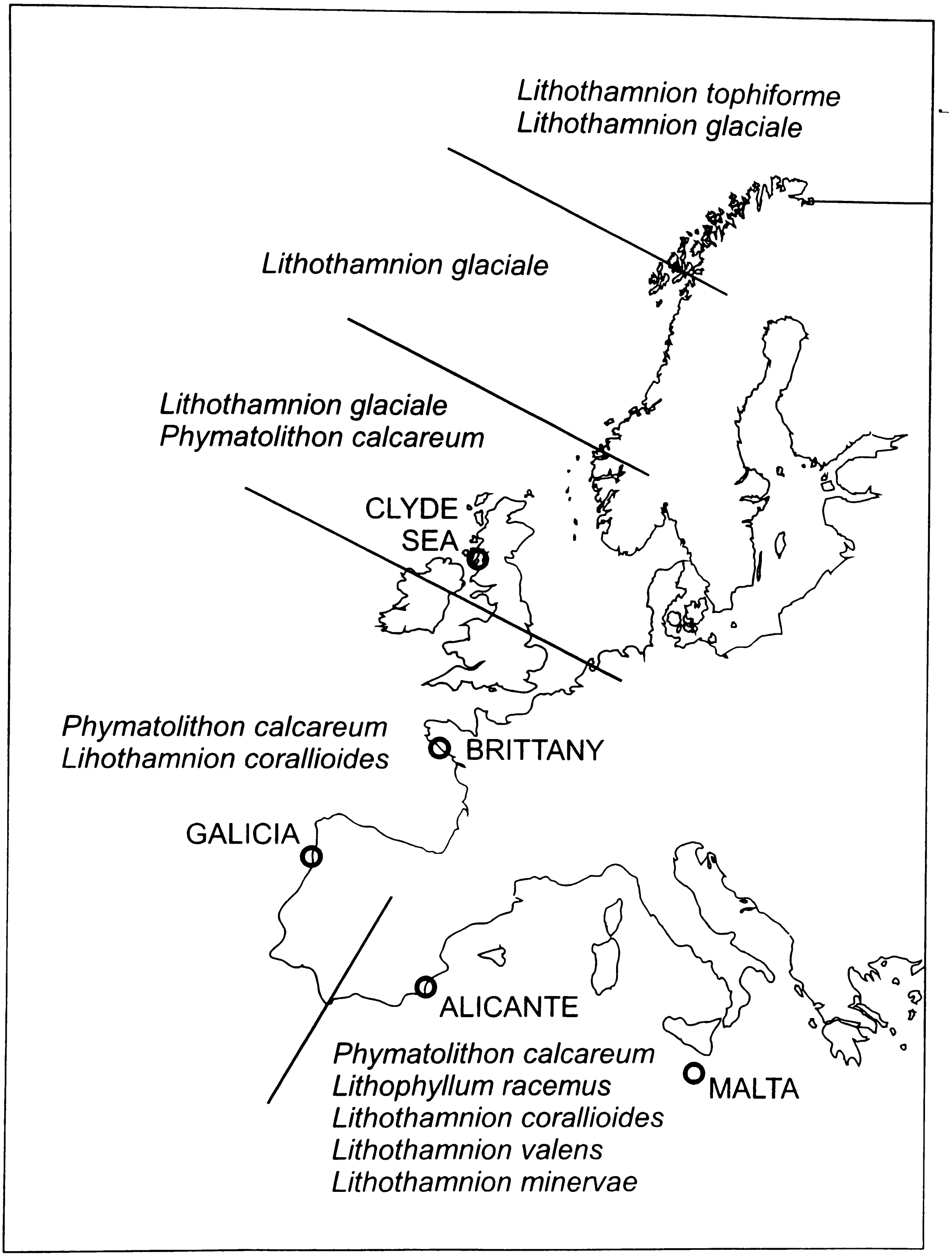


Fig. 2.1. Map showing geographical situation of BIOMAERL partner laboratories (dots) together with phytogeographical information on the dominant maerl-forming coralline algae (see Table 2.1 for sampling site details). Note: demarcation limits of species' distributions are approximate only.

Table 2.1. Sampling site details (Note: codes terminating in `C' are control grounds, those terminating in `I' are grounds variously impacted).

Site name	Site code	Latitude	Longitude	Water depth (m) C.D.	Spatial extent (ha)
Creag Gobhainn, Scotland	UKC	56° 0.60' N	05° 00.60' W	6-14	18
Stravanan Bay, Scotland	UKI	55° 45.32' N	05° 04.27' W	6-14.7	7
Rozegat Bank, Bay of Brest, Brittany	UBBC	48° 19.31' N	04° 24.63' W	2	150
Keraliou Bank, Bay of Brest, Brittany	UBBI	48° 21.94' N	04° 26.25' W	2	80
Ar Gluet, Glenan, Brittany	UBGC	47° 44.05' N	04° 01.06' W	12	9
Guiriden, Glenan, Brittany	UBGI	47° 44.05' N	03° 57.95' W	15	7
Cangas inlet, ria de Vigo, Galicia	USC	42° 15.13' N	08° 46.01' W	8	670
Limens inlet, ria de Vigo, Galicia	USI	42° 14.88' N	08° 47.44' W	18	unknown
Marine reserve, Tabarca, Alicante	UAC	38° 09.00' N	00° 26.50' W	30-37	20
Isla de Benidorm, Alicante	UAI	38° 29.90' N	00° 08.00' W	33-36	3.50
Off Qawra / Ghallis, Malta	UMC	35° 58.93' N	14° 27.46' E	53	extensive
Off St Paul's Islands, Malta	UMI	36° 00.09' N	14° 25.84' E	46	extensive

Water column

Sampling of the water column (1m below surface and 1m above bottom) has been achieved. The following factors have been assessed routinely at all sites:

water temperature (using mercury thermometers or electronic probes) to a precision of at least ± 0.5°C.

salinity (either electronically or using optical refractometry at least to a precision of ± 0.5 p.s.u).

- seston (total dry weight suspended solids) filtered from 2.5 - 5.0l water was determined by Whatman filtration (0.45μm) using the methodology of Strickland & Parsons (1965). In some instances, seston was fractionated into organic and inorganic components (by ashing in a muffle furnace).

- Secchi disc depth (m) using a 20 (Malta) or 30cm disc (the rest).

The following water column factors have been assessed at particular sites as warranted:

- oxygen content of water overlying the bottom was measured in Galicia using a WTW analyser with WTW 191 electrode. In addition, epibenthic oxygen saturation and chlorophyll measurements were made in Scotland in April 1997 using devices described by Glud *et al.* (1994).

Chlorophyll-*a* and phaeopigments were measured in Brittany using a Seatech fluorimeter connected to a Seabird SBE 19 CTD probe.

irradiance was measured in Brittany using a Quantameter OSP2004s [Biospherical Instruments Inc.] giving available light for photosynthesis and information on turbidity.

- current speed and direction were measured in the Clyde Sea using a Valeport model 308 (Valeport, Devon) propeller-type recording current meter (moored 1.5m above the seabed for 12-36h). Off Alicante, surface and bottom currents were measured using a Kalshico propeller-type current meter, but epibenthic current speeds were also measured by divers *in situ* releasing Rhodamine-B dye and timing its passage over a known distance.

Sediment analyses

Where direct observation has been possible, information was gathered on macrotopography of the maerl beds. At Scottish sites, surface features of the sediment were photographed and measured *in situ*, using a specially designed gauge (Napier, 1993; see Fig.2.2).

Fig. 2.2. Megaripple gauge in use at Stravanan Bay, Scotland (gauge is 2.4m in length, constructed of 4cm diam. PVC pipe).

At each site, grabs and coring devices were used to collect sediment samples to obtain information on the identity and morphology of maerl-forming species, percentage live calcareous algae, granulometry, percentage organic matter, carbonate composition, Eh, shear strength and porosity as follows:

-identification and morphology: at each site, large collections of maerl were washed in fresh water and allowed to air-dry. Samples were sorted initially into morphotypes based on external thallus features such as size, shape and branching pattern. At each site certain morphological types predominated and characterized the habitat; these were noted and photographed for comparison. Air-dried specimens selected for scanning electron microscopy (SEM) were carefully cleaned and lightly brushed to remove associated organisms and detritus. Pieces of thallus were either split using a single-edged razor blade or mounted whole for examination of surface features. Samples were glued onto aluminium stubs using an epoxy adhesive (RS Components Ltd, U.K.) and dried in an oven at 44^0C for up to 12 h. A Polaron E5100 series II sputter coater was used to double-coat specimens with a 50 nm layer of gold/palladium. Prepared stubs were viewed in a JEOL JSM 5200 SEM with an accelerating voltage of 15 kV, fitted with a Mamiya camera.

- percentage cover estimates: because the maerl bed off Alicante is formed in strips (control) or patches (impacted), the percentage cover of maerl was estimated from UW photographs using a rectangular overlay subdivided into squares. Percentage cover was estimated in Galicia using a gridded square overlaying undisturbed box-core samples, while elsewhere it was assessed post hoc from reassembling living maerl thalli derived from sorted grab samples into a gridded tray of the same surface area as sampled.

analyses of coarse fractions: the percentages (by dry weight) of living and dead maerl, stones and shells were measured in the coarse fraction (>2mm mesh) of sieved grab samples.

granulometry: sediments were analysed intact for description of gross composition, i.e. without pre-treatment to remove $CaCO_3$ since maerl beds are composed predominantly of particles of biogenic origin. Sediments were sieved using the protocols in Buchanan (1971), using 20cm diam. sieves. Fractions were subsequently considered as fines (<63μm), fine sands (63-250μm), medium sands (250-500μm), coarse sands (500-2000μm) and gravels (>2mm) in conformity with the Wentworth scale. The presentation of granulometric data in the form of a Shepard diagram (Shepard, 1954) allowed the distinction of different maerl facies using three composite sedimentary grades (fines and fine sands; medium and coarse sands; and gravels) as the most appropriate discriminators.

Stratification within maerl sediments was investigated from 7.5 or 10cm diam. cores (variously collected by divers or from ships) sectioned at 2cm intervals (0-2, 2-4, 4-6, 6-8 & 8-10cm). Cumulative percentage frequency curves with increasing particle size were constructed to allow calculation of the standard granulometric parameters: median grain size (MD), Trask index of sorting (Trask, 1931; Buchanan, 1971). Data were also collected on the depth of the RPDL (redox potential discontinuity layer) wherever possible, either visually *in situ* or experimentally (see below).

percentage organic matter: due to the difficulties anticipated in assessing organic matter content of maerl sediments (since carbonates also decompose on ignition), a preliminary series of determinations were made for each ground studied using the following protocol to establish optimal burning conditions (autumn samples). That sediment fraction which passed through a 0.5mm sieve was divided into three replicates of 3g each and either: a) dried for 24h at either 60, 75 or 95°C, then burned at 450°C for either 4,6 or 8h; or b) such material was dried at 95°C then samples burned in a muffle furnace either at 450, 500, 550, 600 or 650°C (all for 4h); or c) sediment was pretreated with dil. HCl until effervescence ceased, washed with distilled water, filtered (Whatman 0.45μm filters), then dried at 95°C and samples burned at 450, 500, 550, 600 or 650°C for periods of either 4, 6 or 8h. In each test, 3 subsamples were used to assess precision of resultant estimates of organic content based on weight loss on ignition. In each series, controls were run simultaneously using a calcium carbonate (AR grade) standard.

carbonate content; was estimated by gasometric determination of the CO_2 delivered from HCl digestion of the sediment sample. Analyses were done with a Bernard's gasometer taking three precision replicates for each sample as described in Guitián &

Carballas (1976). To assess accuracy three $CaCO_3$ replicates (AR grade) were used to standardize each analysis.

redox potential (Eh); was determined at Stations USC and USI over an annual cycle from undisturbed samples collected using a box-corer. The Eh electrode (Ingold Pt4805-DPA-S8/225 combination electrode, used in conjunction with a WTW pH90 analyser) was inserted into the sediment box at 1, 3, 4, 5, 7 and 9cm depth (Pearson & Stanley, 1979). Temperature, pH and apparatus corrections were applied to Eh values.

- porosity; two indirect measures of porosity were used: a) the shear strength of the substratum was measured (6 replicates) using a hand-held compactometer (a Pilcon hand vane tester with a 33mm vane, used for shear strengths lower than 28kPa) at 5 and 10cm depths in core samples taken monthly over one year from USC and USI in Galicia; b) the depth of penetration of specified resin cast into standard cores, as follows. Clear polyester resin (Scott Bader, SP701PA) mixed with styrene monomer thinners (10%) and peroxide catalyst (1% by volume) was poured into wet maerl cores displacing the sea water until the resin made contact with sandy sediment with interstices ≥ 1mm diameter, through which it was too viscous to penetrate. ABS plastic cores (16cm x 8.8cm diam. at USC & USI; 20cm x 10.3cm diam. at other sites) were inserted into the sediment leaving 4cm proud of the surface. Resin was then poured in and allowed to harden for ≥12 h. This was done *ex situ* at UMC, USC and USI, but was poured *in situ* by divers at UAC, UKC and UKI. The cores were then removed from the sediment, washed and later cut into 1cm thick vertical sections using a geologist's diamond saw. These sections were then back-lit and examined to determine the internal structure of the deposit and the extent of resin penetration.

sediment stability was monitored in Scotland by routine *in situ* reassessment over one year of marked megafaunal burrow features (marked using flagged 30cm aluminium rods left permanently in the sediment alongside).

Environmental conditions in the water column over maerl beds in European seas

Table 2.2 summarizes the water column data for each site. Figure 2.3 compares the seasonal variation in bottom water temperatures (primarily at control sites), and allows assessment of the periods when waters were above or below various critical temperatures (6,10, 15, 18, 20°C; see Bayed & Glémarec, 1986). Considerable temperature difference existed between the most northerly and southerly of our study sites (Clyde Sea sites in the N.Atlantic, and Maltese sites in the Mediterranean respectively).

Table 2.2. Summary of data on the main environmental factors recorded at BIOMAERL study sites. Data on current speed for some sites taken from the literature.

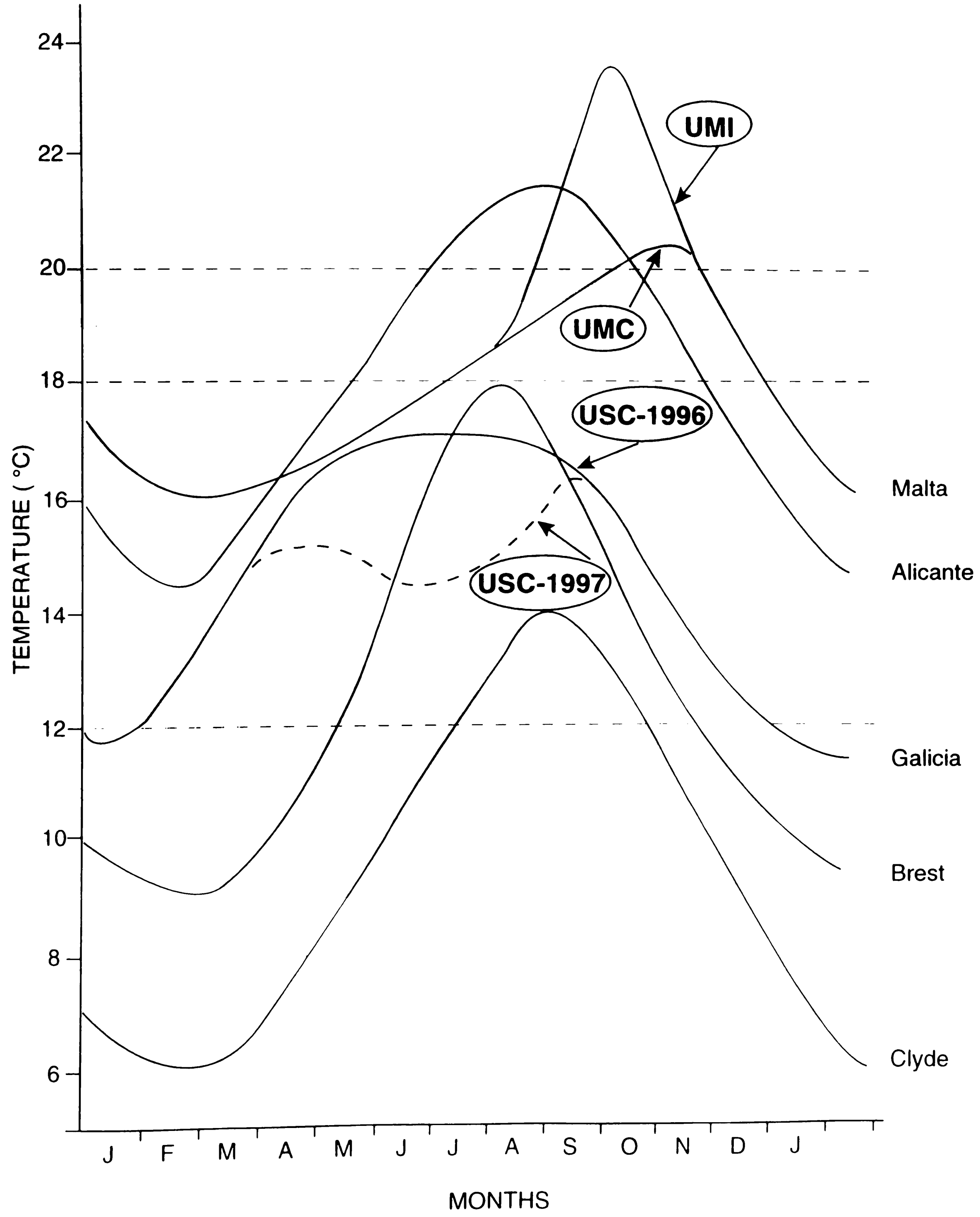
Environmental factor	**Atlantic**	**Mediterranean**
Bottom water temp. (°C)	6-18	14-24
Salinity (psu)	31-36	37-38
Seston (mg.l^{-1})	10^{-1} - 10^{1}	10^{-1}-10^{0}
Current speed (cm.s^{-1})	<60	<35
Secchi depth (m)	1-17	15-32
Maximum depth of maerl occurrence (m)	18	103+

As well as the critical temperatures above, the shapes of the curves reveal interesting differences between sites. In the Clyde Sea, temperatures exceeded 10°C for about 6 months. In Brittany, temperatures of 15°C were exceeded for 3 to 4 months, while in Galicia this situation obtained for 7 to 8 months. When upwelling events occurred off Galicia the duration of the period when temperatures exceeded 15°C was shortened to 3 months, i.e. comparable to the normal situation in Brittany, but this warm period occurred later in the season (autumn) in Galicia. In the Mediterranean, temperatures can exceed 20°C for 3 to 4 months, as witness Alicante in the summer and Malta (impacted) in late summer / autumn. By contrast, at the Malta control site water temperatures rarely exceeded 20°C.

Morphology and taxonomy of calcareous rhodophytes at BIOMAERL study sites

Maerl-forming species could not be identified by eye due to their morphological plasticity. *Phymatolithon calcareum* and *Lithothamnion corallioides* for example, exhibited both open- branched and knobbly forms (Fig. 2.4). Thus two fragments looking superficially identical could represent different species (and *vice versa*).

Fig. 2.3. Seasonal variation in bottom water temperatures (°C) over maerl grounds studied. Data refer to 1996 for all sites, plus 1997 for Galicia. Note differences between years at this site, also differences between impacted (UMI) and control (UMC) sites off Malta. Horizontal dashed lines highlight critical temperatures as referred to in text.



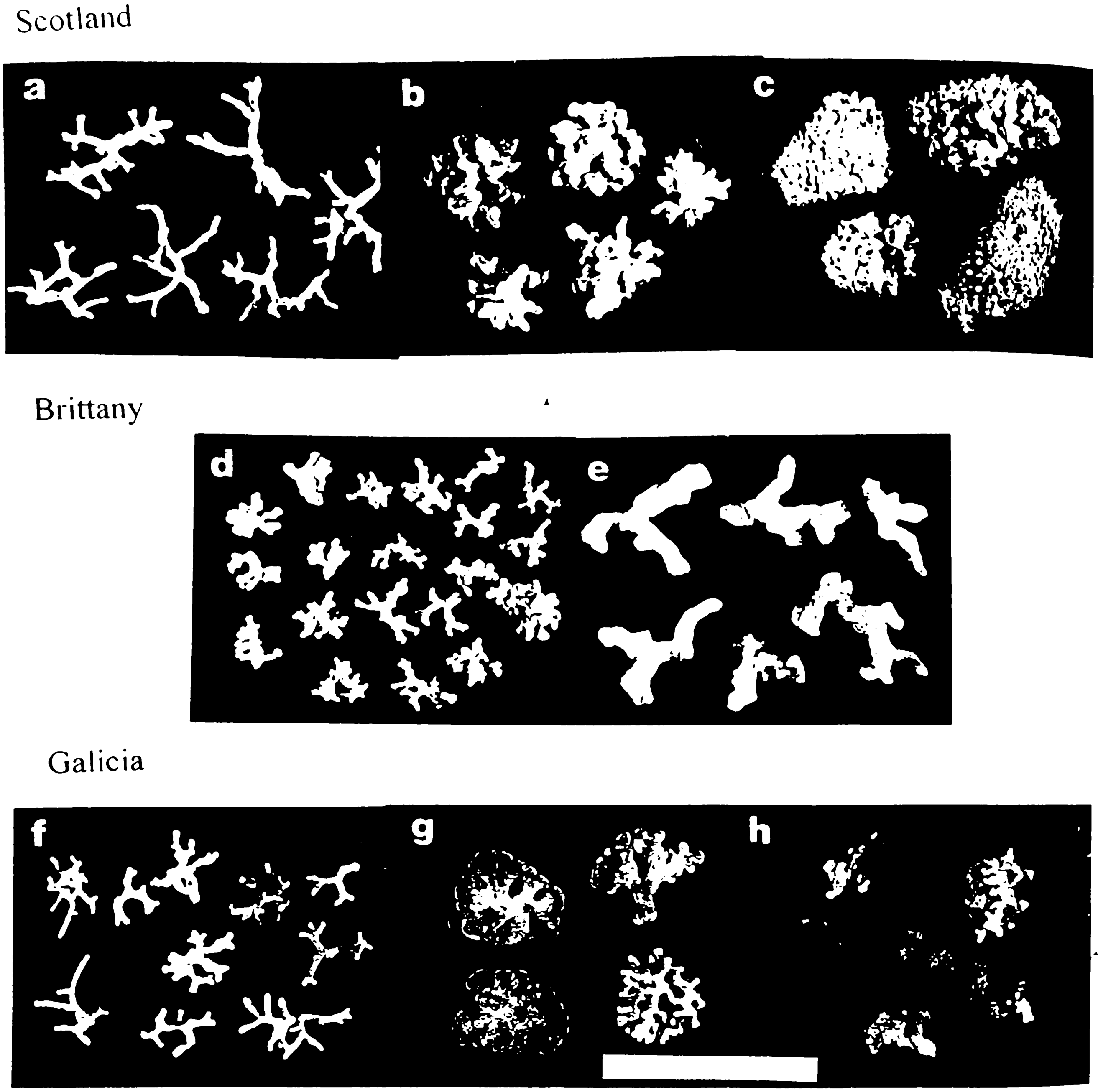
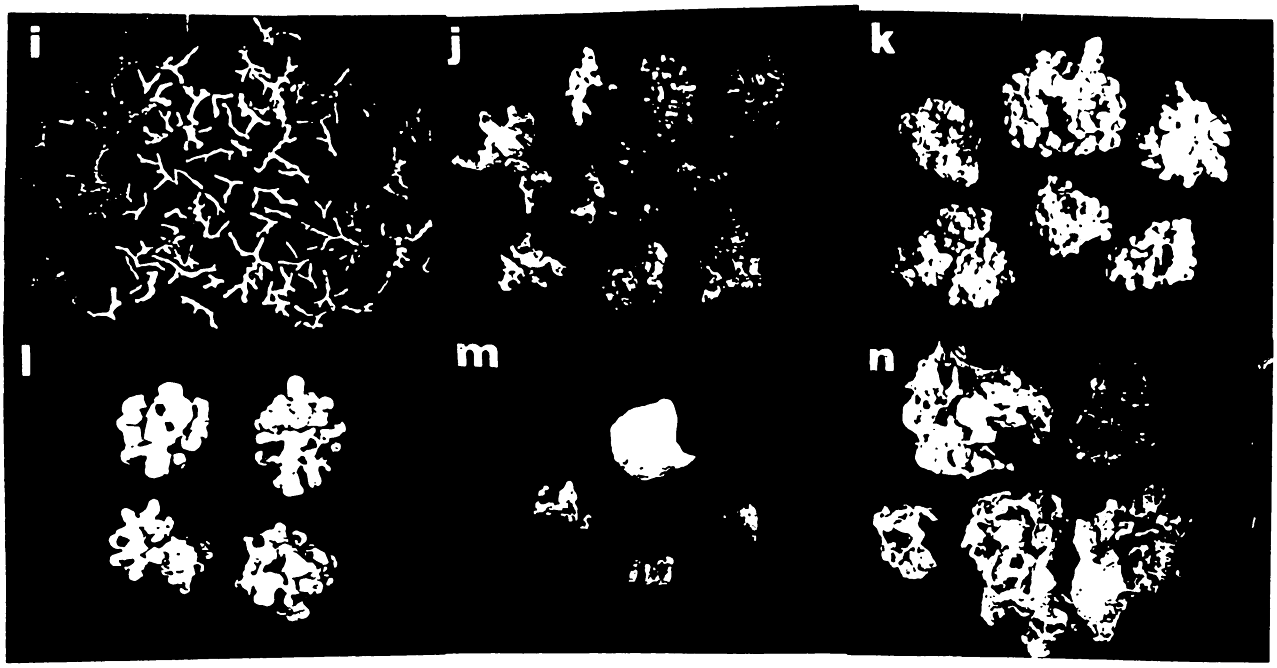
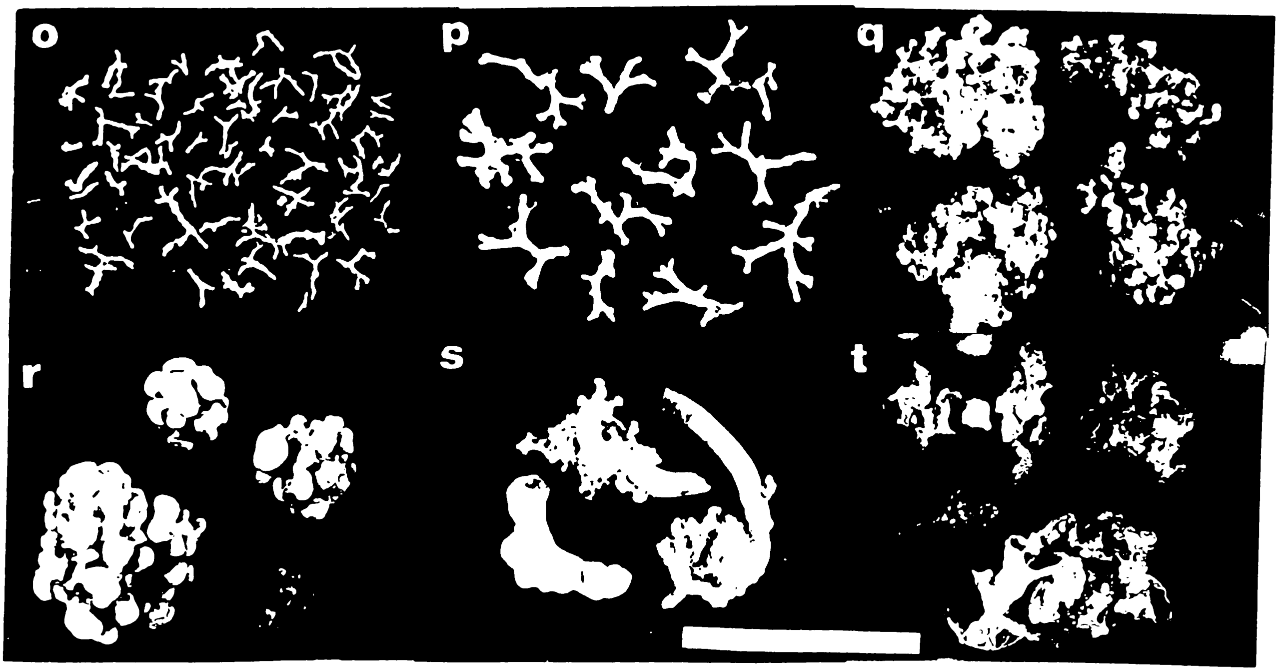


Fig. 2.4. The range of morphological variation typifying maerl and rhodolith form at study sites: a) open branched *Phymatolithon calcareum*, b) rhodoliths of *Lithothamnion glaciale* with a small central core, c) rhodoliths of *L.glaciale* with a large central core, d) open branched *L.corallioides*, e) thickly branched *P.calcareum*, f) open branched *L.corallioides*, g) *P.calcareum* with flattened branching pattern, h) *Peyssonnelia rosa-marina* overgrowing coralline algae, I) thinly branched *L.corallioides*, j) open branched *P.calcareum*, k) knobbly *L.corallioides* rhodoliths, l) knobbly *Lithophyllum racemus* thalli, m) *Peyssonnelia rosa-marina* overgrowing coralline algae, n) laminar growths of *Mesophyllum* sp., o) thinly branched *L.corallioides*, p) open branched *P.calcareum*, q) knobbly *L.corallioides* rhodoliths, r) knobbly *Lithophyllum racemus* thalli, s) *Lithothamnion valens* and other corallines encrusting bryozoans and serpulids, t) laminar growths of *Mesophyllum* sp. All photographs to the same scale, scale bar = 5cm. Note: morphotype (m) was also common off Malta, and (s) was also common off Alicante.


Alicante


Malta

The map of species distributions (Fig. 2.1) relates only to ultrastructurally substantiated records. The distributional limits shown must be regarded as provisional given the paucity of records. It shows the distribution of the main maerl-forming species encountered (viz. *Lithothamnion glaciale* Kjellman, *Phymatolithon calcareum, L. corallioides, L. minervae* Basso, *L. valens* Foslie, *Lithophyllum racemus* (Lamarck) Foslie). *Phymatolithon calcareum* occurred in all our sites accompanied by *Lithothamnion glaciale* in Scotland and *L. corallioides* south of the Irish Sea and into the Mediterrannean. The Mediterranean sites also supported *Lithophyllum racemus*, *Lithothamnion minervae* and *L. valens* as major maerl-formers with *Peyssonnelia rosa-marina* and an, as yet, undescribed species of *Mesophyllum* (J.Cabioch, pers. comm. to J.H.-S.) being common as components of rhodoliths. Minor contributors to the calcareous rhodophyte communities encountered included *Lithothamnion sonderi* Hauck (Scotland), *Corallina officinalis* L. (Scotland; Brittany), *Phymatolithon purpureum* (P. & H. Crouan) Woelkerling & Irvine (Scotland; Brittany; Galicia), *Lithophyllum dentatum* (Kützing) Foslie (Brittany), *Mesophyllum lichenoides* (Ellis) Lemoine (Brittany; Galicia), *Titanoderma pustulatum* (Lamouroux) Nägeli (Mediterranean sites) and *Sporolithon ptychoides* Heydrich (Malta).

A wide range of calcareous rhodophyte morphotypes occurred within and between study areas. The NE Atlantic study sites were dominated by fewer common morphotypes than the Mediterranean grounds, where a wider range of shapes and sizes obtained. Figure 2.4 illustrates the most abundant morphotypes that typified the calcareous rhodophyte community on each of the maerl grounds sampled. A wider range of morphotypes were common at Mediterranean sites than Atlantic sites. Figure 2.4 deliberately excludes the extreme morphotypes, which will be dealt with elsewhere.

Macro- and micro-architecture of maerl beds in European seas

i) Megarippling and other surface features

Megarippling was a feature of certain maerl beds, particularly those in shallow water subjected to prevailing winds with an appreciable fetch. Figure 2.2 illustrates the bottom topography of one such ground (at Stravanan Bay, Scotland [UKI]). There, ripples of 125-138cm wavelength and 8-13cm height, typified the ground and became progressively orientated parallel to the coast by refraction of swells. There was a tendency for living maerl to occur in the furrows, rather than on the crests, of megaripple fields.

Smaller megaripples were noted at Glenan (Brittany) (wavelength 30-50cm), and after a major storm in October 1996 at Cangas (USC), Galicia (wavelength 65cm, height 3-5cm). At other sites studied the maerl beds were insufficiently stressed by swells to bear megaripples. Off Tabarca Is. (UAC), Alicante, maerl tended to occur in strips (30-45cm wide, 2-3cm high) in summer, but was dispersed evenly in winter. No megaripples were apparent on the Maltese grounds inspected by SCUBA diving in Sept. 1997.

Some organisms create localized surface features of differing degrees of permanence, e.g scallops, *Pecten maximus*, and crabs, *Cancer pagurus*, excavate and occupy temporary surface pits in maerl grounds. Deep-burrowing or tubicolous megafaunal taxa (*Chaetopterus, Upogebia, Cerianthus*), however, have longer-lasting impacts on sediment microheterogeneity. Other organisms (e.g. nest-building *Limaria hians*, sponges, *Modiolus* spp., holdfasts of *Laminaria* spp. in the Atlantic, and rhizoids of *Flabellia* or *Polysiphonia* filaments off Malta and Alicante) bind maerl fragments together. Indeed, storm-detached kelp may be a potent agency in redistribution of maerl (holdfast-attached; Hall-Spencer, pers. obs.). To a lesser degree, cephalopods (*Octopus vulgaris*), echinoids (like *Sphaerechinus granularis* and *Spatangus purpureus*) and demersal fish (like *Pagellus erythrinus, Mullus surmuletus* and *Serranus hepatus*) disturb the surface crust of bound maerl off Alicante and Malta, during their bottom-foraging activities.

ii) Analyses of coarse fractions

Some maerl grounds are composed exclusively of dead maerl, e.g. Glenan (Brittany). Others are characterized by a loose tangle of living crustose rhodophytes forming a surface stratum several centimetres thick (Table 2.3). Typically, however, most grounds are formed from a mixture of living and dead maerl in varying proportions (Table 2.3). A major difference concerning the coarse fraction related to the occurrence of stones and shells, which formed a significant proportion of the coarse fraction at some sites, but were insignificant at others (Table 2.3).

Table 2.3. Summary data (typical values) on sedimentological characteristics [median grain size (μm), percentage fines (<63 μm), Trask index of sorting, percentage carbonates, total organic matter, percentage living and dead calcareous rhodophytes, shells and stones (by dry weight)] in maerl grounds studied. For site details, see Table 2.1.

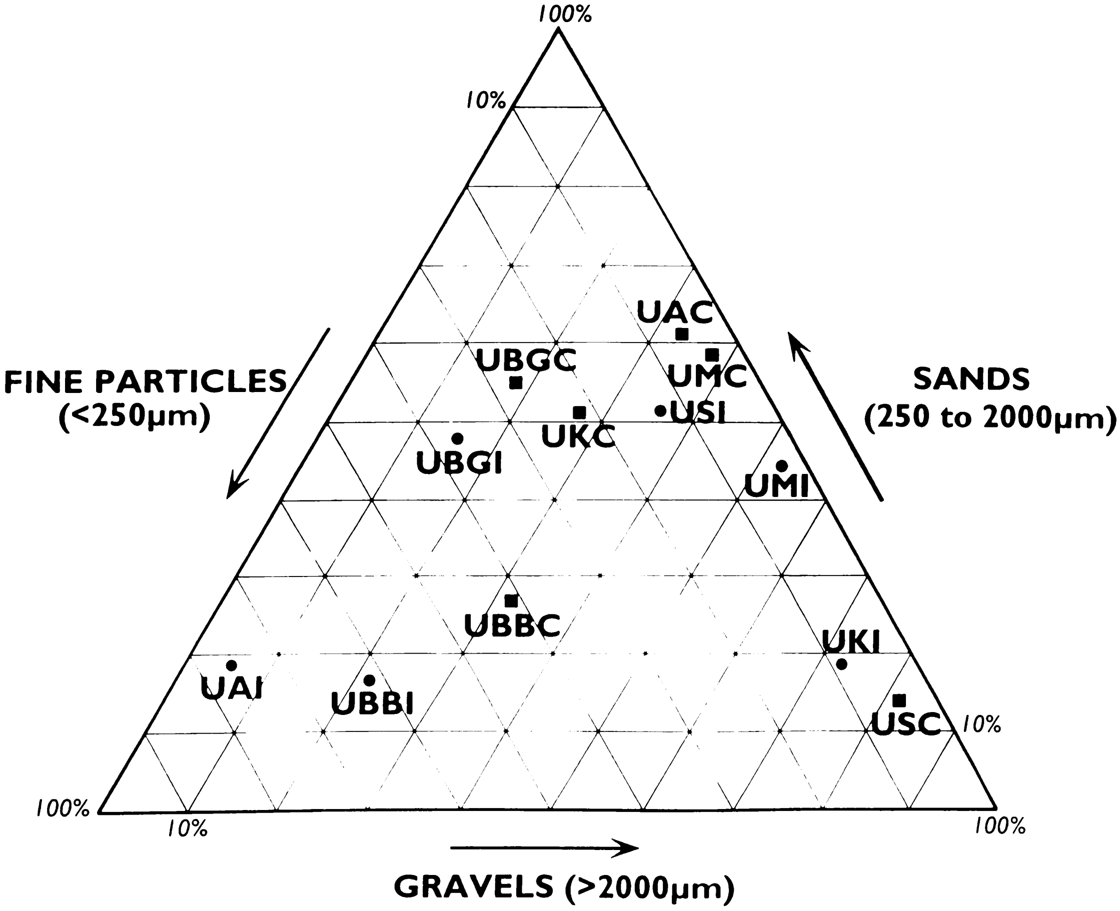
Site	Median grain	% Fines	Trask index	% CO_3	% Organic	% live maerl	% dead maerl	% shells	% stones
UKC	600	22.0	2.7	62.6	4.7	23.0	67.0	8.0	2.0
UKI	1600	7.0	1.4	78.3	2.7	2.0	60.0	16.0	22.0
UBBC	900	24.0	5.2	65.8	11.5	97.0	0.0	0.0	3.0
UBBI	90	35.0	mud	61.1	9.7	92.0	4.0	2.0	2.0
UBGC	900	15.0	2.8	65.6	7.7	7.0	85.0	7.0	1.0
UBGI	900	15.0	3.0	63.4	7.0	0.0	94.0	1.0	5.0
USC	1800	3.5	1.4	89.8	5.6	49.8	39.9	10.3	0.0
USI	800	9.0	1.6	83.3	10.7	57.8	6.6	35.6	0.0
UAC	650	3.0	2.1	79.7	3.0	28.8	40.0	17.0	14.2
UAI	<63	60.0	mud	63.1	5.9	24.6	21.1	50.3	4.0
UMC	1200	6.8	1.8	95.4	7.3	4.5	87.1	3.5	5.2
UMI	1900	1.8	2.0	96.4	9.9	11.0	83.0	1.4	4.5

iii) Maerl bed granulometry

Gross pattern

Due to the often complex branching pattern of thalli, maerl-derived sediments represent difficult material to analyse by sieving. However, using the protocols described above, it has been possible to fractionate maerl samples and the results of these studies are summarized in a Shepard diagram (Fig. 2.5). Such representation emphasizes the coarse granulometry of the habitat.

Fig. 2.5. Shepard diagram relating to gross granulometric composition of mearl ground sediments at study sites. For site codes, see Table 1. Circle = impacted, square = control.



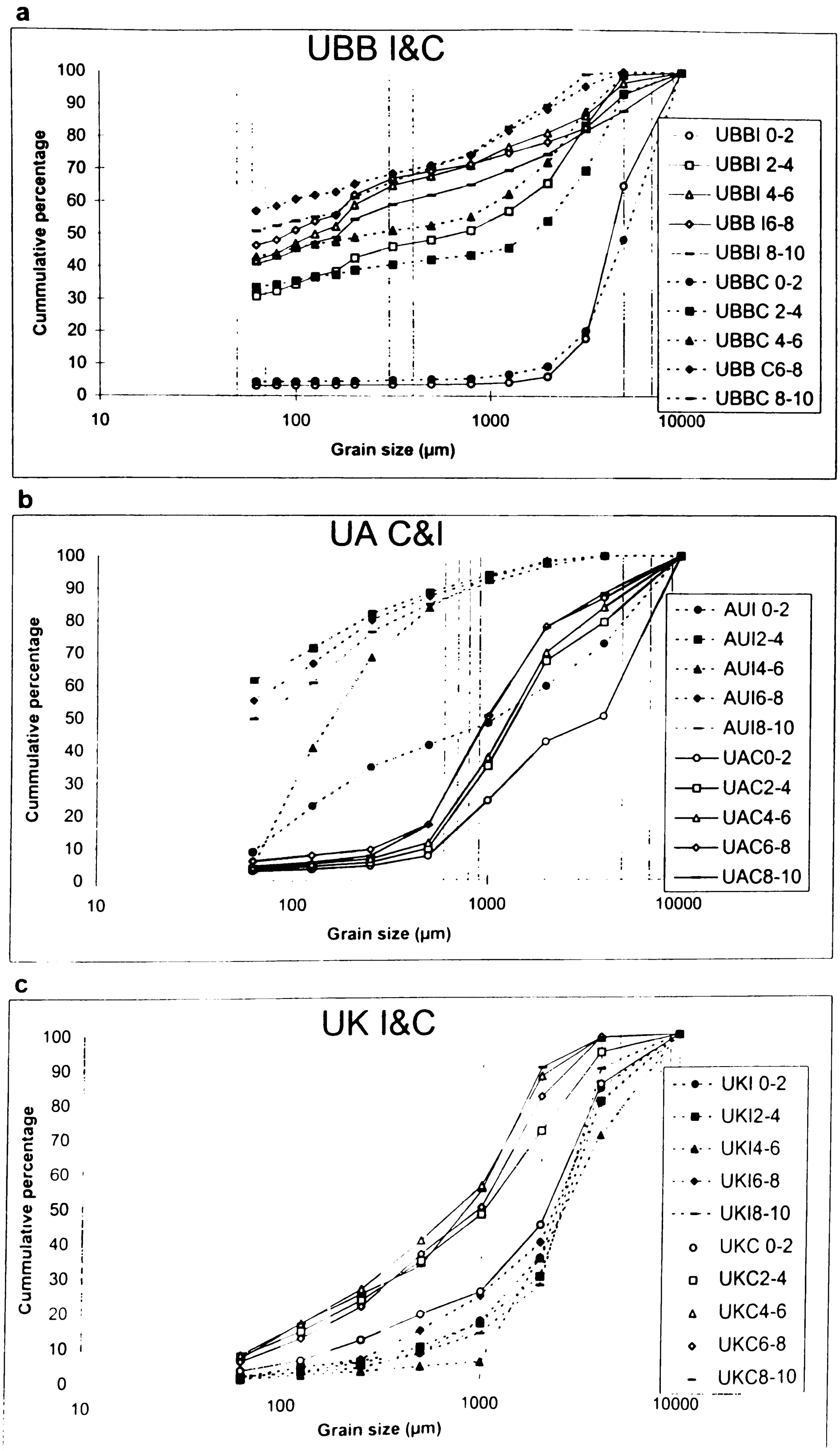
Using three composite granulometric descriptors (see Materials & Methods), four types of maerl bottoms can be distinguished in that diagram (Fig.2.5): 1) sandy mud grades characterize UAI and UBBI; 2) mixed sediments typify UBGC, UBGI and UBBC; 3) equivalent fractions of coarse sands and gravels, with a low proportion of fines, characterized UMI, UMC, UAC and USI [with UKC transitional between groups 2 & 3], and 4) true gravels were found at UKI and USC, where the surface sediments were mainly made up of comminuted maerl fragments (gravel fraction >85%).

Vertical distribution

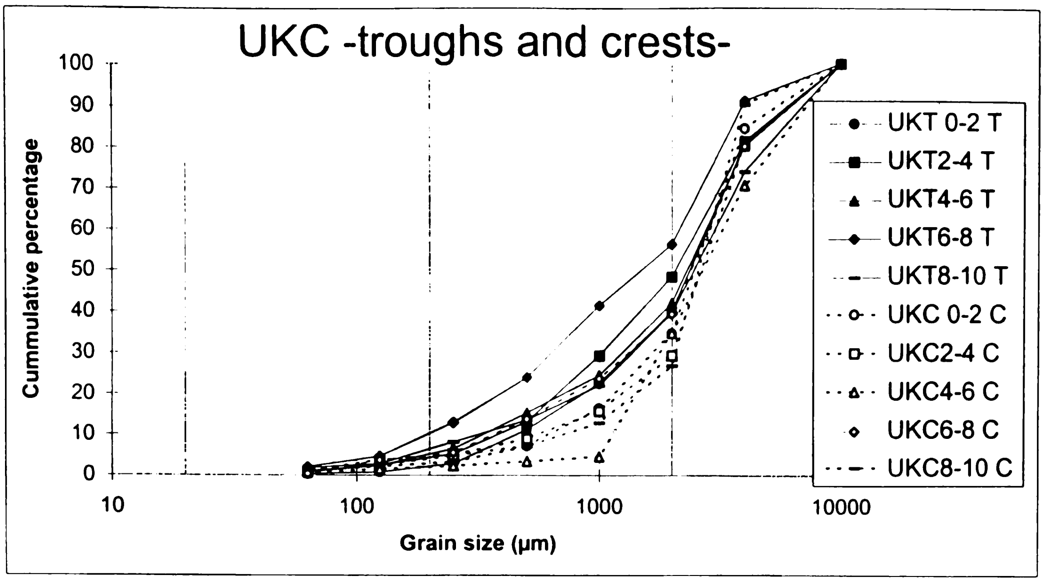
The depth of maerl-derived sediment varied considerably from one ground to another, e.g. from 10m (Glenan, Brittany) to <1cm (Creag Gobhainn, Scotland; Benidorm, Alicante). Interstitial spaces become clogged with sand, mud, or clay (depending on site) with depth into the sediment. Loci of muddier sediments, e.g. pseudofaecal or feacal-pellet derived accumulations, also occurred around large megafaunal tube-dwellers or burrowers creating microspatial heterogeneity.

Figure 2.6a-f shows the cumulative percentage-frequency curves (dry weight) for gross sediments from sectioned cores at the sites studied. Figure 2.7 is a schematic representation of the sediment profile on each ground. Maerl beds are characterized by a surface layer of maerl of very variable thickness, often overlying quite different types of sediments (clays, sands, muds). Thus, sites UAI and UBBI were characterized by deposits of maerl thalli on muddy sediments. On both these grounds, maerl fragments were concentrated in the top two centimetres. Off Alicante, the topmost layer was a very poorly sorted (Trask index (TI), 5.4) coarse sand (MD 600μm). This surface stratum overlay homogeneous mud (all underlying strata to 10cm depth having 60-75% fines). At UBBI, the top layer was also made up of clean maerl with fines (<5%) and was well sorted (TI 1.4). Beneath, the sediment was a heterogeneous sandy mud (30-45% fines, and 50% coarse sands and gravels).

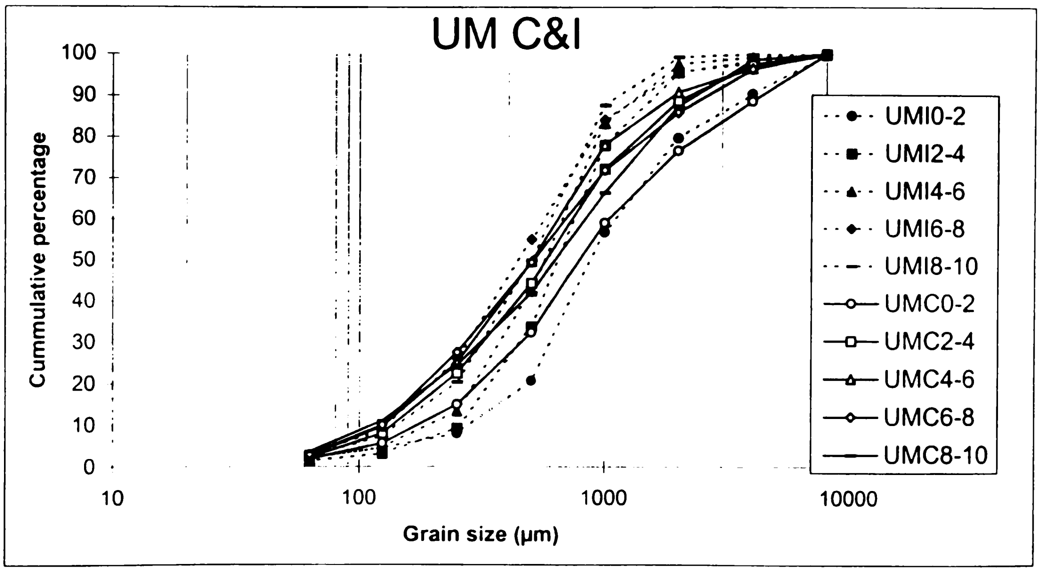
Fig. 2.6. Cumulative percentage-frequency curves (dry weight) relating to granulometry of maerl sediments from sectioned cores at study sites. a) UBBI & C, b) UAC & I, c) UKI & C, d) UKC megaripple troughs and crests, e) UMC & I, and f) USC & I. For site codes, see Table 1.



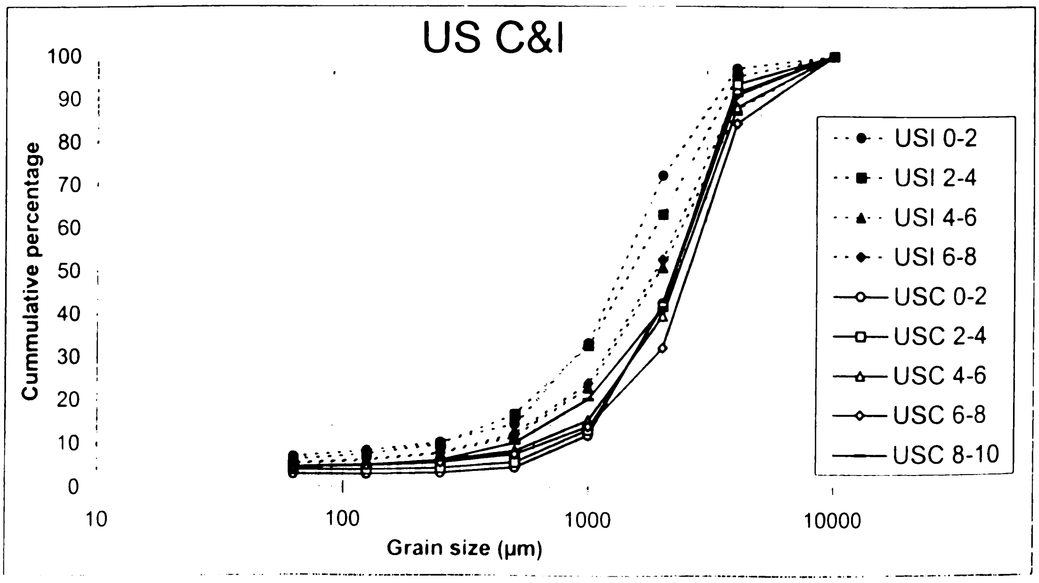
d


UKC -troughs and crests-
Cummulative percentage
100
90
80
70
60
50
40
30
20
10
0
10
100
1000
10000
Grain size (µm)
UKT 0-2 T
UKT2-4 T
UKT4-6 T
UKT6-8 T
UKT8-10 T
UKC 0-2 C
UKC2-4 C
UKC4-6 C
UKC6-8 C
UKC8-10 C

e


UM C&I
Cummulative percentage
100
90
80
70
60
50
40
30
20
10
0
10
100
1000
10000
Grain size (µm)
UMI0-2
UMI2-4
UMI4-6
UMI6-8
UMI8-10
UMC0-2
UMC2-4
UMC4-6
UMC6-8
UMC8-10

f


US C&I
Cummulative percentage
100
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80
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20
10
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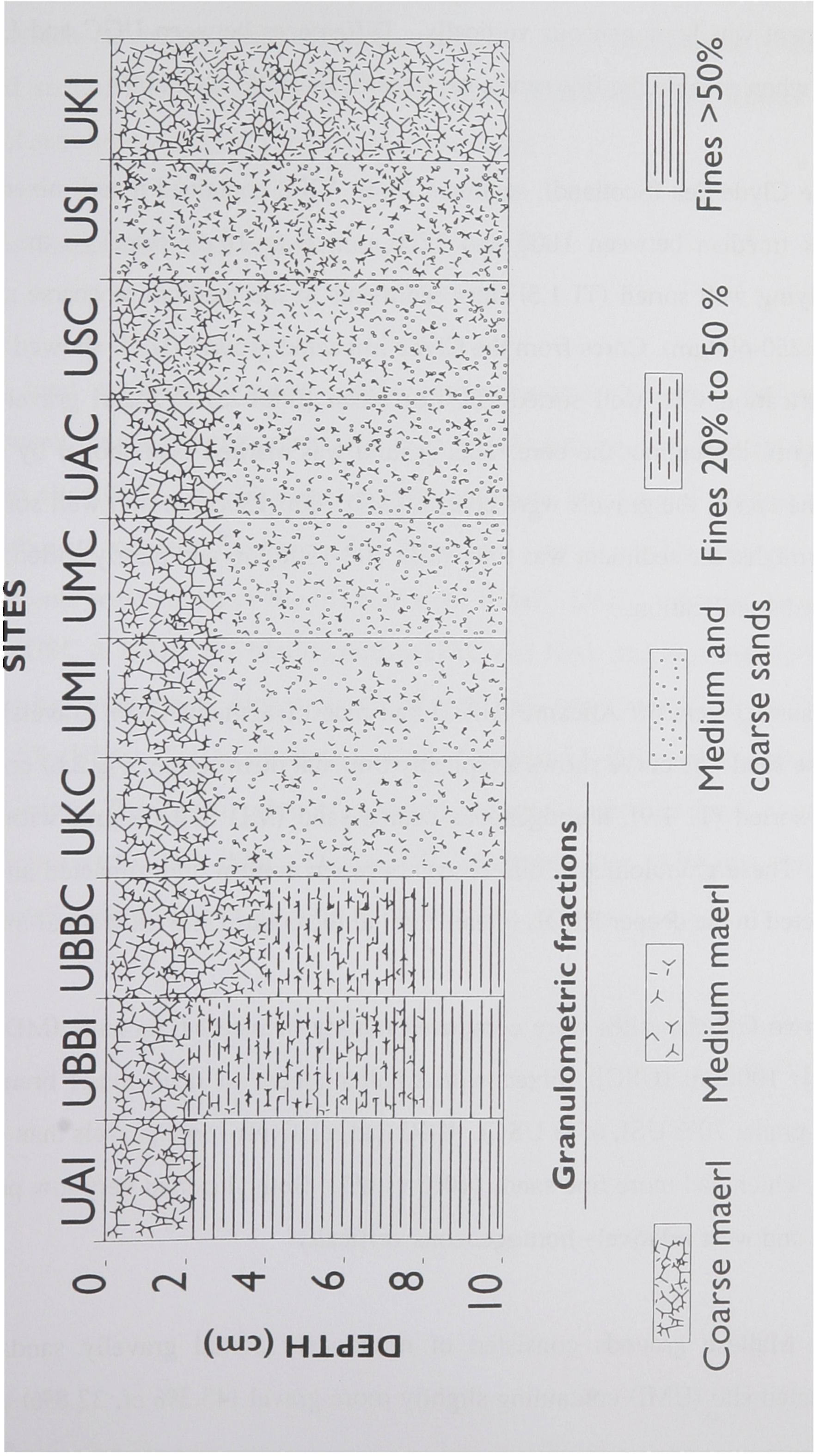
100
1000
10000
Grain size (µm)
USI 0-2
USI 2-4
USI 4-6
USI 6-8
USC 0-2
USC 2-4
USC 4-6
USC 6-8
USC 8-10

Fig. 2.7. Schematic vertical profiles of maerl sediments at study sites. For site codes, see Table 1. Coarse maerl is that fraction retained on a 2mm sieve, medium maerl is <2mm but >1mm, medium and coarse sands are <1mm but >0.5mm. Fines are <63µm. Note: for these purposes the fine fraction has been ignored.



UBBC had a thicker maerl layer than the impacted site (0-4 cm). The surface was well sorted (TI 1.3) and very coarse grade (MD 3-5mm). There, maerl overlaid sandy mud (45-55% fines) with a medium and coarse fraction between 35 and 50%. At Glenan, maerl beds were made up of *ca* 50% coarse sand and *ca* 15% gravels. There the sediment was homogeneous vertically. Differences between UGC and UGI appeared only when considering fine sands and fines (UGC 15%, UGI 20%).

In the Clyde Sea (Scotland), sediment from UKC contained maerl mixed with coarse sands (median between 1000 and 1200 µm; 5 to 10 % fines) in the surface 2cm overlying well sorted (TI 1.5) finer sediments in the medium to coarse sand category (MD 250-600µm). Cores from the Clyde impacted ground (UKI) showed little vertical stratification with well sorted (TI 1.6) clean (fines <3%) maerl gravel (MD 1000-1500µm) throughout the core. This ground was marked (see above) by megaripples. On the crests, the gravels were coarser (MD 1000-1500µm) and well sorted, while in the troughs, the sediment was finer (MD 700-1500µm) and poorly sorted, with a trend toward stratification.

The surface 2cm off Alicante (UAC) had maerl fragments (50% gravels) mixed with coarse sand (the curve shows a typically bimodal distribution, Fig.2.6) covering a less well sorted (TI 1.9), homogeneous coarse sand (MD 500-700µm) with a low fines ratio. These granulometric differences between control and impacted sites were also reflected in the deeper RPDL (mean 7cm) at the control site (cf. 1cm at impacted).

The two Galician sites were composed mainly of maerl fragments (MD 600-900µm [USI]; 1000µm [USC]) mixed with smaller pieces of dead maerl branches (coarse sand grade; 70% USI, 65% USC). USC had relatively more gravels than USI (15% vs 5%), which had more fine sands (10% vs 0%). Both sites had very low proportions of fines and were relatively homogeneous vertically.

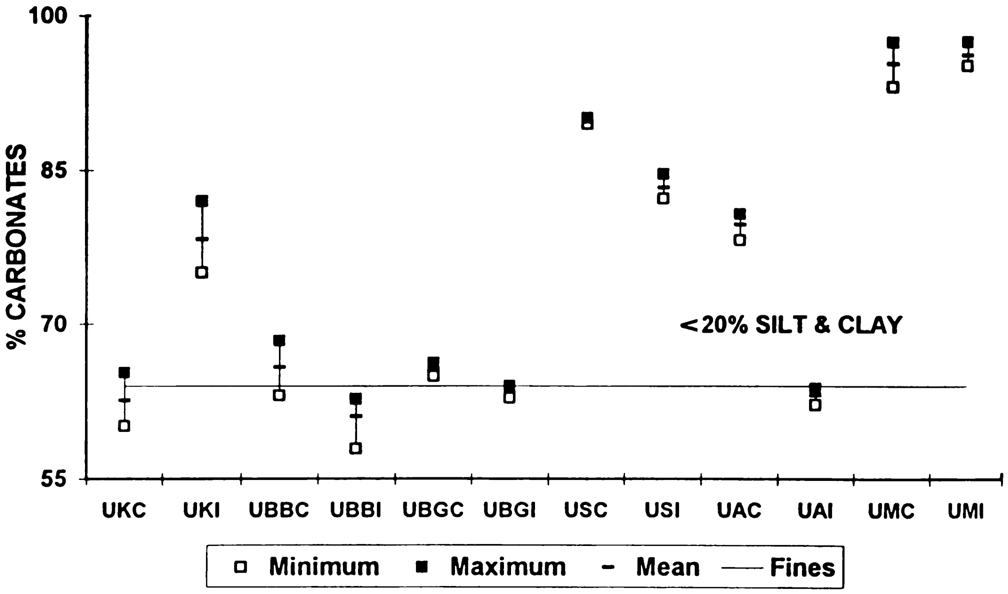
Both Maltese grounds consisted of moderately sorted gravelly sands, with the impacted site (UMI) containing slightly more gravel (45.3% cf. 32.8%) and slightly less sand and mud than the control site (UMC). Cores revealed little vertical stratification, with maerl being present to (at least) 16cm depth. The surface crust, however, was bound together by non-calcareous algae which formed a patchy layer up to 5cm thick on the sediment surface. The main maerl-binding species were *Flabellia petiolata* - the rhizoids of which penetrated through the sediment forming a network to which sediment grains became attached and *Polysiphonia setacea*, which bound sediment to its filaments. These algae effectively immobilized the upper layer of sediment, creating a semi-hard substratum.

iv) Carbonate composition, total organic matter (TOM), Eh

Carbonates

At all sites, total carbonate contents >60% were recorded. No clear differences obtained between the total carbonate contents in maerl sediments from Atlantic and Mediterranean sites (Fig. 2.8). The sites sampled fell into two natural groups; those with low carbonate content having >20% fines and *vice versa*.The highest total carbonate contents were found at the Maltese sites (UMC, UMI), followed by those from Galicia (USC & USI). The Mediterranean UAC and UAI, and the Atlantic UKC and UKI sites had moderately high amounts of total carbonate, ranging from 79.7% (UAC) to 62.6% (UKC). Total carbonate contents between 61-66% were found at the four Brittany sites. The contribution of maerl to the total carbonate fraction varied from 61% (Brittany) to 90% (Malta)(Table 2.3). At other sites (Alicante, Galicia) shells contributed a significant proportion of carbonate.

Fig. 2.8. Carbonate contents of maerl sediments in relation to proportion of fines from N.E.Atlantic and W. Mediterranean sites studied. The horizontal line delimits a silt and clay content of 20%. Samples above the line had <20%, samples below >20%.



Total organic matter (TOM)

The data on TOM content, as revealed by three series of determinations carried out for each ground studied, are presented in Figures 2.9-11 (mean values for TOM(1) were determined without HCl digestion of sediments, while TOM(2) values were determined after HCl digestion). This distinction proved to be necessary due to the high carbonate content of the samples which interfered with TOM determinations (see below). The results of procedural comparisons to establish an optimum analytical technique are detailed below:

a) Sediments dried at 60°, 75° or 95°C and burned at 450°C for either 4, 6 or 8 h.

Figure 2.9a, b and c shows the differences in TOM contents after drying samples at 60°, 75° or 95°C and burning them at 450°C for either 4, 6 or 8h.

The apparent TOM contents decreased slightly with increased drying temperature over the range tested. Also, a lengthier burning time increased the TOM values derived for particular samples. Carbonate decomposition may contribute to this apparent increase with extended burning time, therefore trials at different incineration temperatures were re-run using a standardized burn time of 4h (see following).

b) Sediments dried at 95°C and burned at 450°, 500°, 550°, 600° and 650°C for 4h.

As a general rule, the apparent TOM increased with the increasing burning temperature (Fig. 2.10). A 4.5% increase was found between TOM determined at 450°C and that determined at 550°C, but from 550°C upwards, much greater differences found were recorded, i.e. <24% difference in TOM content registered between results at 550° cf. 600°C and <12% difference between 550° cf. 600°C. This suggested that carbonate transformation was the agency responsible for the differences, leading to spurious results. In order to test this hypothesis, a further series of trials were done involving pre-digestion of the sediment with acid to remove carbonates (see following).

Fig. 2.9. Results of methodology development trials for percentage organic matter determination in maerl sediments, using the following protocols: drying a) at 60, b) at 75 or c) at 95°C, burned at 450°C for 4,6 or 8h.

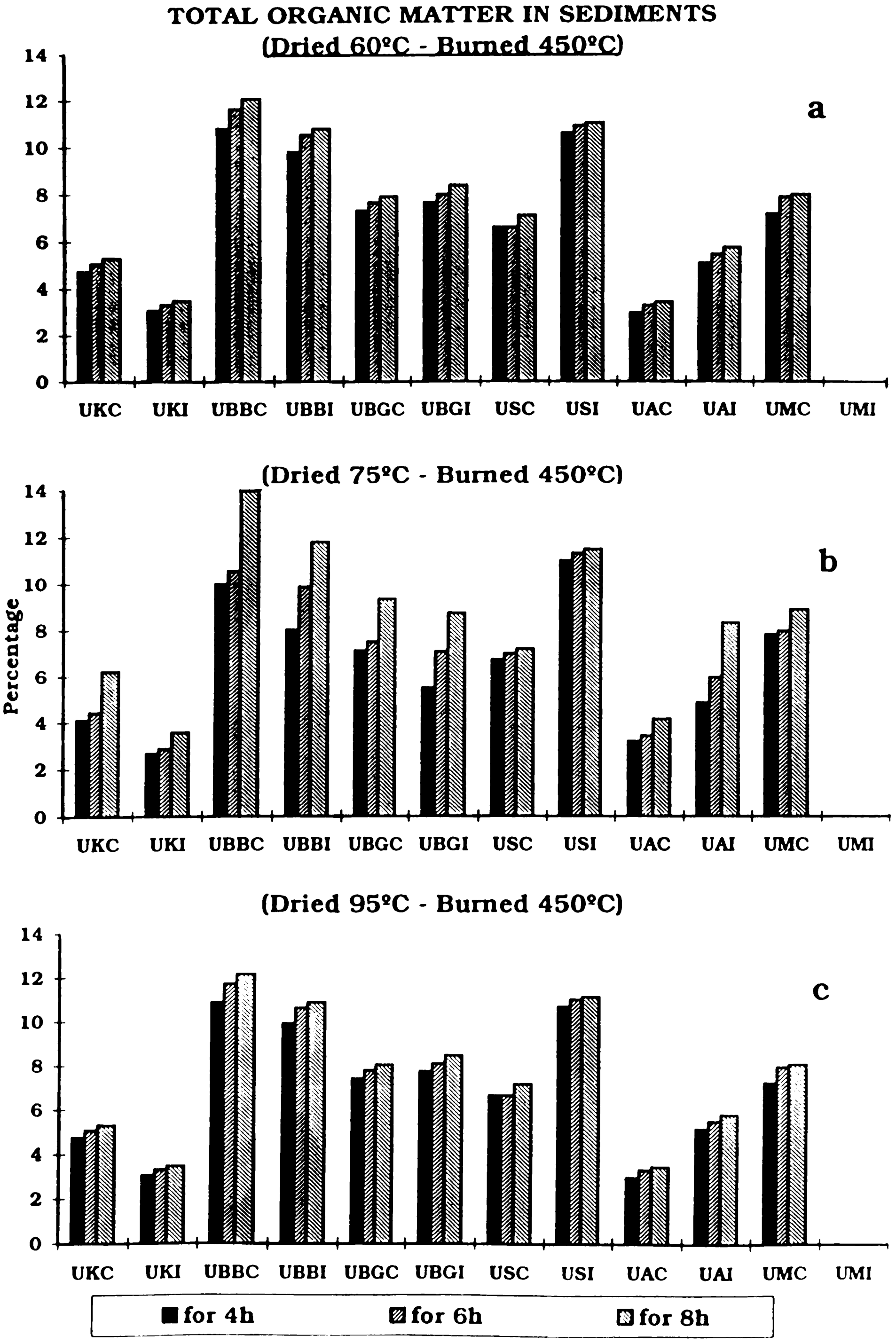


Fig. 2.10. Percentage organic matter determination in maerl sediments dried at 95°C, and burned at either 450, 500, 550, 600 or 650°C, (a) with no acid pretreatment, and (b) with pretreatment with dil. HCl.

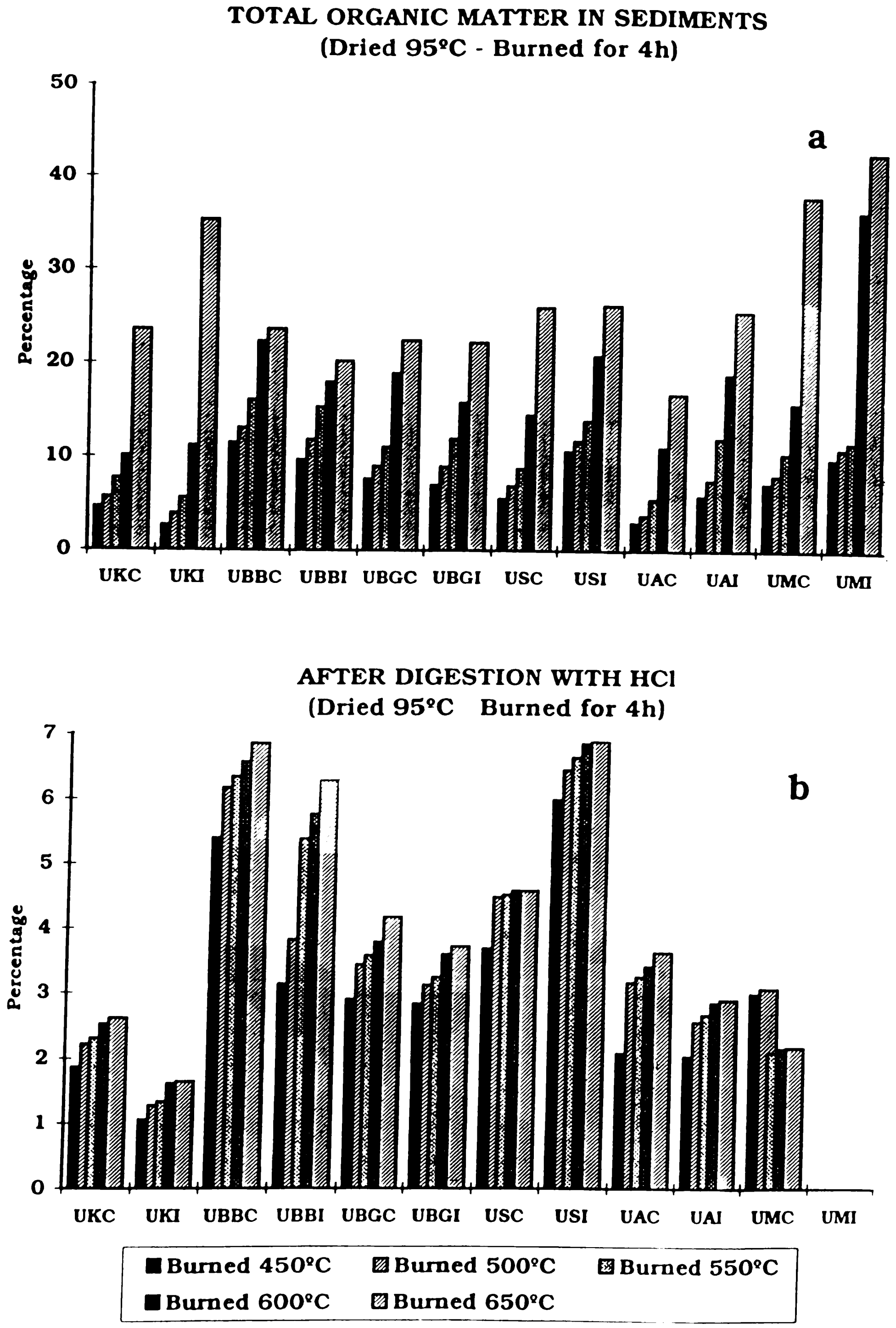
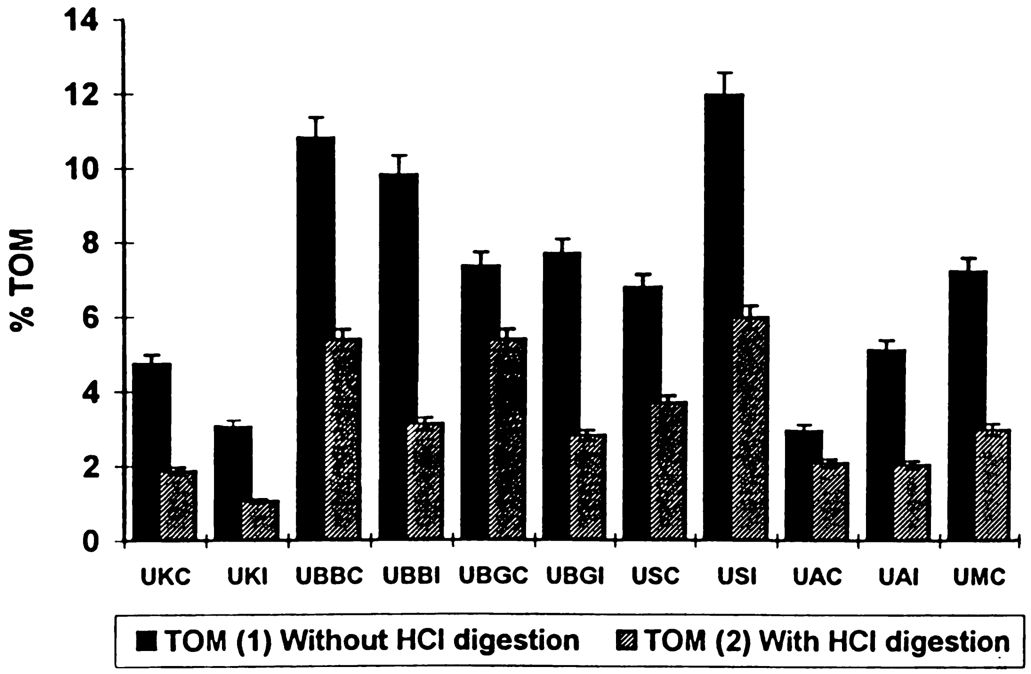


Fig. 2.11. The effect of acidic pretreatment on percentage organic matter estimation using optimized drying (95°C) and burning (450°C) protocol as follows: non predigested (TOM(1)) and predigested (TOM(2)).



c) Sediments previously digested with HCl, dried at 95°C and burned at 450°, 500°, 550°, 600° and 650°C for either 4, 6 or 8h.

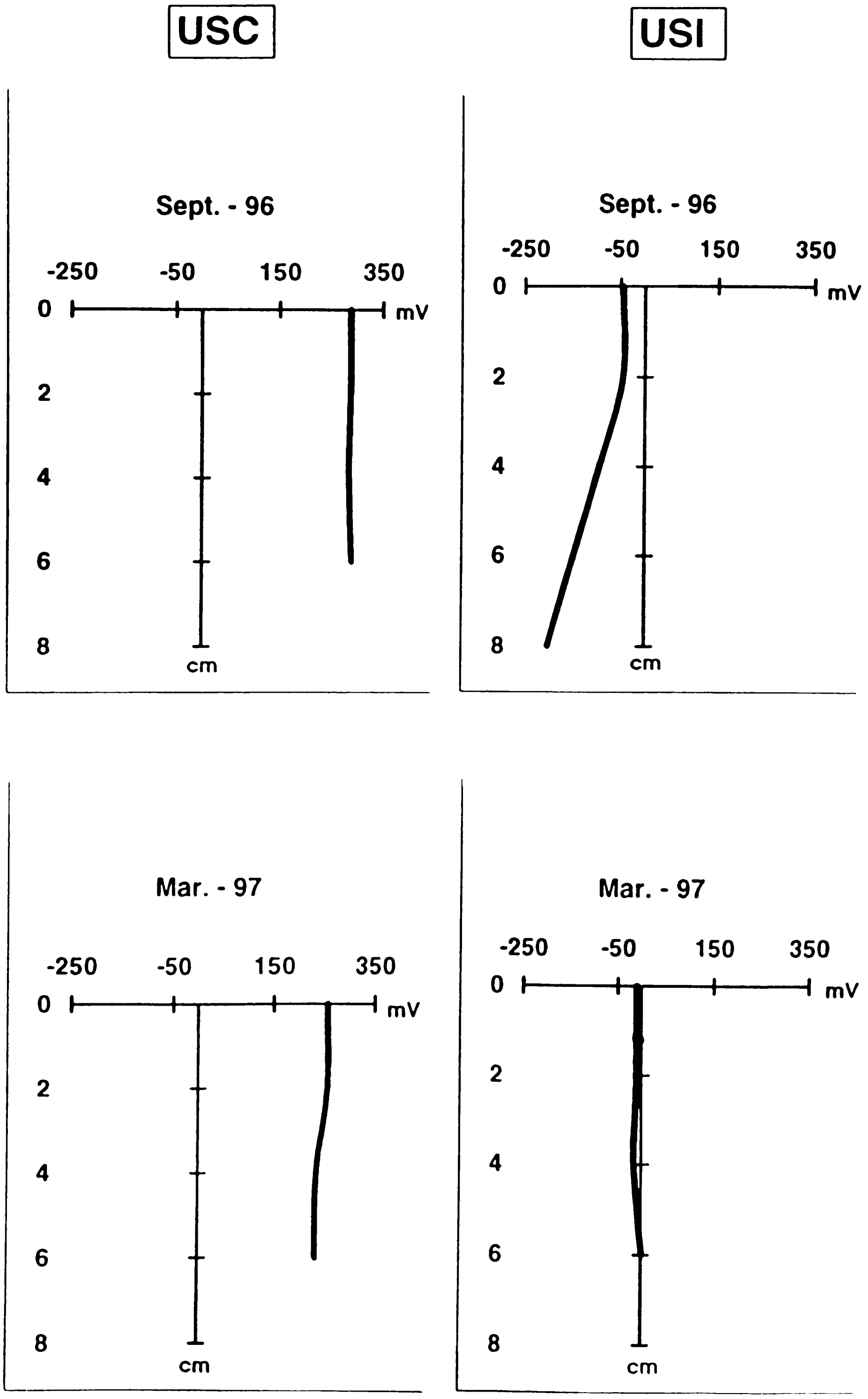
The apparent TOM present in the carbonate-free sediment samples also increased with increasing incineration temperatures but to a much lower degree than in those samples without HCl pretreatment (Fig.2.10a). Most notably, however, values for TOM were approximately halved in pretreated HCl samples compared with untreated ones (Fig. 2.10a, b).

Figure 2.11 shows that TOM2 values were substantially lower than TOM1 values (mean TOM1 = 7.13%, mean TOM2 = 3.08%). The sites with the highest TOM in maerl sediments were those from Brittany and Galicia (>4%). The Mediterranean sites (Malta and Alicante), and Glenan (Brittany) had intermediate organic contents, while the Scottish sites had the lowest TOM contents in sediments.

Eh

Sediment Eh values (surface and at 2cm intervals down the 10cm core) in the form of redox profiles are presented for the Galician sites (USC & USI) in Fig. 2.12. This figure contrasts the situation in September 1996 and March 1997. As a general rule, sediments at the control station (USC) had corrected Eh values ranging from +220 (2-4 cm layer April 1997) to +341 mV (surface layer November 1997). Exceptional conditions obtained in August 1996 when heavy swells redeposited sediments, covering the study area with black mud. Subsequent to this disturbance the redox profile was negative from the surface downwards. In less than one month, however, oxygenation conditions had returned to normality.

Fig. 2.12. Sediment Eh profiles for Galician sites USC and USI (see Table 1) showing the impact of heavy swells in August 1996 when redeposited sediment covered the bottom with black mud.

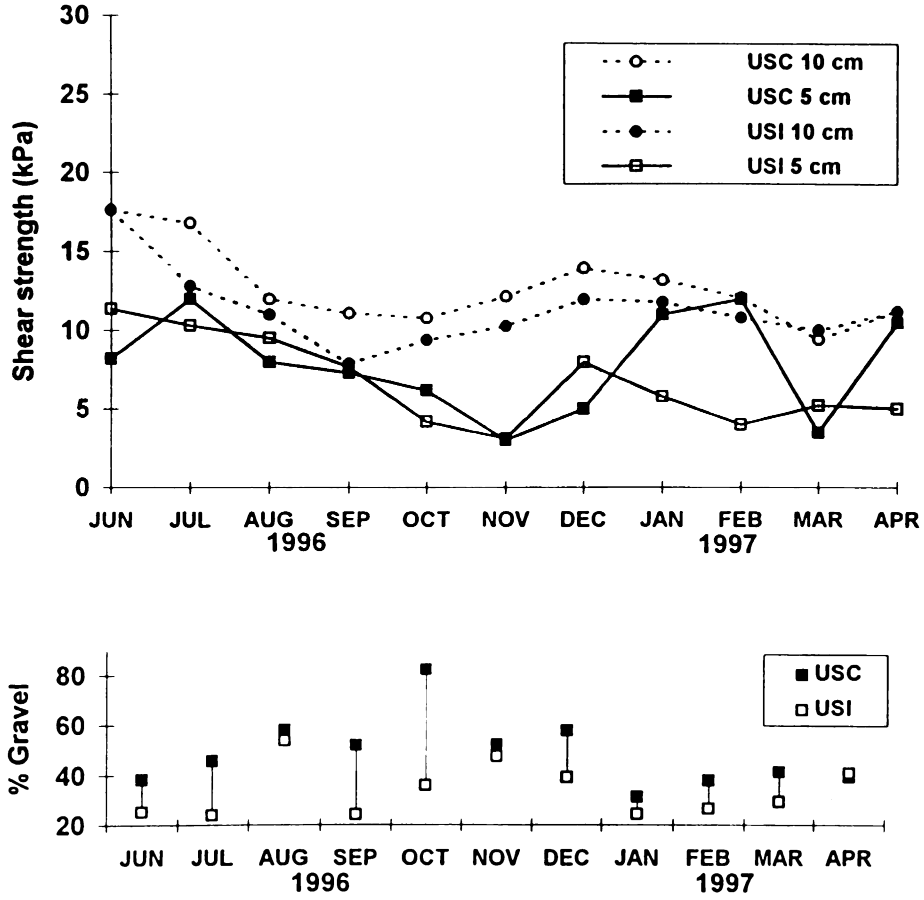


Redox potentials at USI ranged from +325 (surface layer April 1996) to -201 mV though, for most of the months sampled, low and negative values were recorded where the presence of dark, shelly layers were observed and H_2S was detected by smell. The redox potential discontinuity layer (RPDL) was found at the surface in sediments at this station during most months sampled (with the exception of the period April-July 96).

v) Shear strength and interstitial porosity

Shear strength determinations at two depths (5 & 10cm) were made on undisturbed Galician maerl cores from the ria de Vigo (USC & USI). The 5cm measure related to the maerl layer and the 10cm measure to the substratum beneath (mostly shelly sandy mud with dead maerl). The shear strength of sediments at USC was higher than at USI (Fig. 2.13). The 5cm readings revealed lower resistance at USC (min. 3kPa, Nov. 1996; max. 22kPa, Oct. 1996), where a permanent maerl layer was found, than at USI (min. 3.1kPa, Nov. 1996; max. 18kPa, Oct. 1996), where the upper layer of sediment was more heterogeneous, consisting of maerl, shells and mud. This difference between sites was even more evident in the measurements taken at 10cm depth. In this case, USC values were higher (min. 8.5kPa, March 1997; max. 30.0kPa, Oct. 1996), than those recorded from USI (min. 7.9kPa, Sept. 1996; max. 22.0kPa, Oct. 1996).

Fig. 2.13. Shear strength (kPa) at 5 and 10cm depths in undisturbed maerl cores from ria de Vigo (USC and USI), Galicia. Gravel content shown for information.



Shear strengths measured over a one-year period (Fig. 2.13) showed little seasonal change. The higher shear strength was consistently associated with the deeper layer as would be expected on the basis of its greater compaction and higher percentage gravel (including maerl fragments).

The penetration of resin in cast cores confirmed that maerl sediments are highly porous. Differences in the maximum depth of resin penetration into cores illustrated the degree to which porosity varied between grounds: viz. UKC, 2cm; UKI,18cm; USC,12cm; USI, 5cm; UMC,7cm. Universally, void space was highest in the surface layer of sediment, diminishing with sediment depth in inverse proportion to the amount of fines trapped between the maerl fragments. At UAC, these particular cores were taken adjacent to the maerl habitat on a coralligène-type seabed. There, resin penetrated to 4cm between pebbles and shell fragments that were concreted together by nongeniculate Corallinaceae (mostly *Mesophyllum* sp.). The maximum resin penetration occurred in UKI cores taken from megaripple crests where there was little contamination by fines. A thick surface layer of highly porous maerl sediment was also found in cores from USC (situated away from mussel rafts), with considerably less interstitial space being present in the cores taken at USI (close to mussel rafts). There the spaces between maerl fragments and shells were clogged, from 5cm downwards, with black hypoxic sediment derived from mussel faeces and pseudofaeces. Cores from Malta revealed an intermediate degree of resin penetration, with a highly porous surface layer (7cm) overlying hard-packed maerl and calcareous sand. The site with the lowest degree of resin penetration (UKC) had maerl lying in a thin surface layer (1cm) over compacted sandy mud.

Replicate resin-cast cores at UKI illustrated that the internal structure of maerl beds is spatially heterogeneous. For example, porosity decreased with water depth beyond the megarippling influence of wave action (>11m) where silt accumulated in the consolidated maerl. The porosity of sediment cores taken from adjacent areas of maerl was also heterogeneous due to the patchy distribution of infaunal organisms. Silty loci, for instance, built-up within the maerl around sessile filter-feeders (see under vertical distribution, above).

TASK 3 : Dynamics of key species and the impact of natural disturbance

Objectives:

To assess population densities, biomass and size-distributions of key species (selected under Task 1, sub task 1.2).

To assess, on control grounds, at least four times a year for two years, the local impacts of natural perturbations (e.g. storms) in each region and the consistency of year-to-year variation.

To continually update qualitative species records during the course of these samplings to contribute to Task 5.

NOTE: since Tasks 3 & 4 deal with essentially the same information under the first of these objectives for the two types of ground considered (i.e. control and impacted), and in order to facilitate cross-comparison, where information on a particular key species is available for both grounds it is presented sequentially as each species is dealt with below under Task 3. Key species that only occur in impacted sites are dealt with later under Task 4 (below).

For the purposes of these analyses, the four seasons have been designated thus: winter (January, February, March); spring (April, May, June); summer (July, August, September); autumn (October, November, December) to reflect the time lag of temperature fluctuation in the sea cf. aerial conditions.

Data on seasonal variation in population parameters of key species at control cf. impacted grounds

1) Clyde Sea area

Phymatolithon calcareum* and *Lithothamnion glaciale

These two seaweeds are nongeniculate members of the heavily calcified red algal family Coarallinaceae. The present study involved the use of a Scanning Electron Microscope to allow examination of microscopic internal features that are diagnostic in the identification of these algae. Specimens collected at each of the BIOMAERL study sites enabled us to build on recent taxonomic work on UK maerl deposits

(Irvine & Chamberlain, 1994; Hall-Spencer, 1994, 1995) and confirmed that *P. calcareum* and *L. glaciale* are the principal maerl-forming species in Scotland. *Lithothamnion glaciale* replaces the warmer-water *L. corallioides* which is one of the main maerl-forming species around Mediterranean and southern European coastlines with a northern limit in Ireland at around 54°N (BIOMAERL team, submitted).

Phymatolithon calcareum and *L. glaciale* were nominated as key species on both of the Scottish control and impacted grounds since the long-term sustainablility of the maerl habitat depends on the growth and survival of this species pair (Hall-Spencer, 1995; Hall-Spencer & Moore, in press b). Conditions for maerl growth appeared to be sub-optimal on both of the Clyde grounds studied since live coralline algae occurred in a thin and patchy layer. This contrasted with control sites in the Bay of Brest and Galicia and at other sites in Scotland where living maerl thalli form an interlocking mass of thalli that is several centimetres thick (Davies & Hall-Spencer, 1996; Sânchez-Mata *et al.*, 1998; BIOMAERL team, submitted). Given the pivotal importance of these species to the ecology of maerl beds in northern European waters, the growth and reproduction of both *P. calcareum* and *L. glaciale* was given particular attention in the present programme. Their population dynamics was quantified in a carefully designed field experiment that allowed us to elucidate the long-term effects of scallop dredging on *P. calcareum* and *L. glaciale*. Full details are given in the enclosed (see Scientific Report above) paper by Hall-Spencer & Moore (in press a) which has been submitted for publication to *The International Council for Exploration of the Seas* in October 1998. The degree of damage caused depended on individual characteristics of each ground but, in essence, dredging led to the burial of up to 80% of the surface-dwelling thalli which then died due to lack of light for photosynthesis. Such effects were long-lasting due to the slow growth and irregular recruitment of these algae with no discernible recovery over a 4-year period. Of five Clyde grounds investigated, four are now known to have experienced long-term reductions in the abundance of living maerl due to the effects of scallop dredging over the past 40 years.

Cerianthus lloydii Gosse, 1859

This burrowing anemone was the commonest anthozoan present at UKC throughout the 1996-1998 sampling period. It occurred in every van Veen grab sample taken in the area but data obtained by grab sampling underestimated its abundance. Most of the individuals present were large enough to retract below the depth to which the grabs penetrated. Seasonal variation in the abundance of these anemones was therefore assessed by divers using 1 m^2 quadrats. Regular monitoring by divers revealed that the abundance of these anemones peaked each summer (33 m^{-2}) and was lowest (11 m^{-2}) each winter. The polyps were observed reproducing asexually by longitudinal fission in the spring of each year.

Cerianthus lloydii extended their tentacles to feed on animals at the sediment surface within a 4 cm high layer of water overlying the maerl. Their permanent tubes extended vertically downwards to 44 cm below the sediment surface (Hall-Spencer & Atkinson, in press) and wind around stones (Manuel, 1981) helping to stabilize the substratum. The abundance of large *Cerianthus* tubes (silt bound with a felt of nematocyst threads), added to the structural complexity of the sedimentary habitat. None of the fauna associated with the maerl was seen feeding on these anemones during >200 hours of *in situ* observation, probably since the anemones are able to retract rapidly into their tubes when disturbed and were well defended with nematocysts. These anemones and the goby, *Pomatoschistus pictus*, proved to be the most important predators of small animals (e.g. harpacticoid copepods, tanaids) that moved over the maerl surface. This solitary burrowing species of anemone inhabits soft sediments in many coastal areas around the UK (Eleftheriou & Basford, 1983) and is replaced by *Pachycerianthus multiplicatus* on fine sediments in deep or sheltered areas (Howson *et al.*, 1994) and by *C. membranaceus* in the Mediterranean.

The above comments relating to UKC apply equally to UKI. This anemone was also the most abundant anthozoan at UKI with a peak abundance in summer (22 m^{-2}) and the lowest abundance in winter (8 m^{-2}). Experimental scallop dredging at both sites revealed that these anemones were easily damaged as the dredge teeth dragged through the surface 10 cm of sediment. About 30% of the anemones survived the immediate impact, however, and the population slowly became re-established over the following 18 months. Full details of our study of the population dynamics and effects of anthropogenic disturbance to *C. lloydii* are given in the enclosed paper by Hall-Spencer & Moore (in press b) and so are not repeated here.

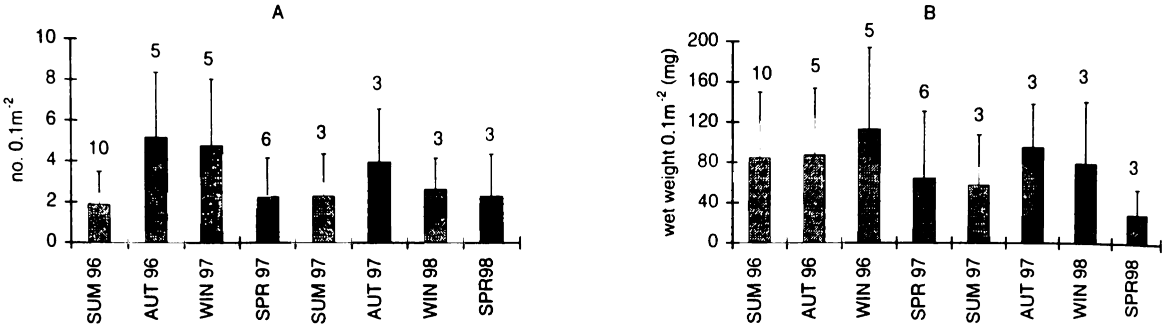
Edwardsia claparedii **(Panceri, 1869)**

This small anemone was common and characteristic of the surface layer of sediment at UKC throughout 1996–1998. It was the second-most abundant anthozoan species present, after *C. lloydii*. *Edwardsia claparedii* was present in most Ring Dredge and core samples from the area and occurred in 32 out of the 38 grab samples analysed. Their abundance varied little throughout the 2–year monitoring programme with seasonal means of 2–5 individuals per 0.1 m^2 (Fig. 3.1A). The anemones were patchily distributed with up to 10 polyps found per grab.

This anemone was not seen by divers since polyps are small and have camouflaged tentacles. Core samples showed that they burrowed into silty loci 1–5 cm below the surface of the maerl. They expanded their tentacles to feed on small organisms that were mobile in water within the maerl interstices and so differed from *C. lloydii* (which fed on animals at the sediment surface). Manuel (1981) considered *E. claparedii* to be the commonest member of the genus in the British Isles, burrowing in mud or muddy sand from LWST to `moderate depths' offshore, but cautioned that records from the North Sea and the Mediterranean were not confirmed and may be the result of taxonomic confusion.

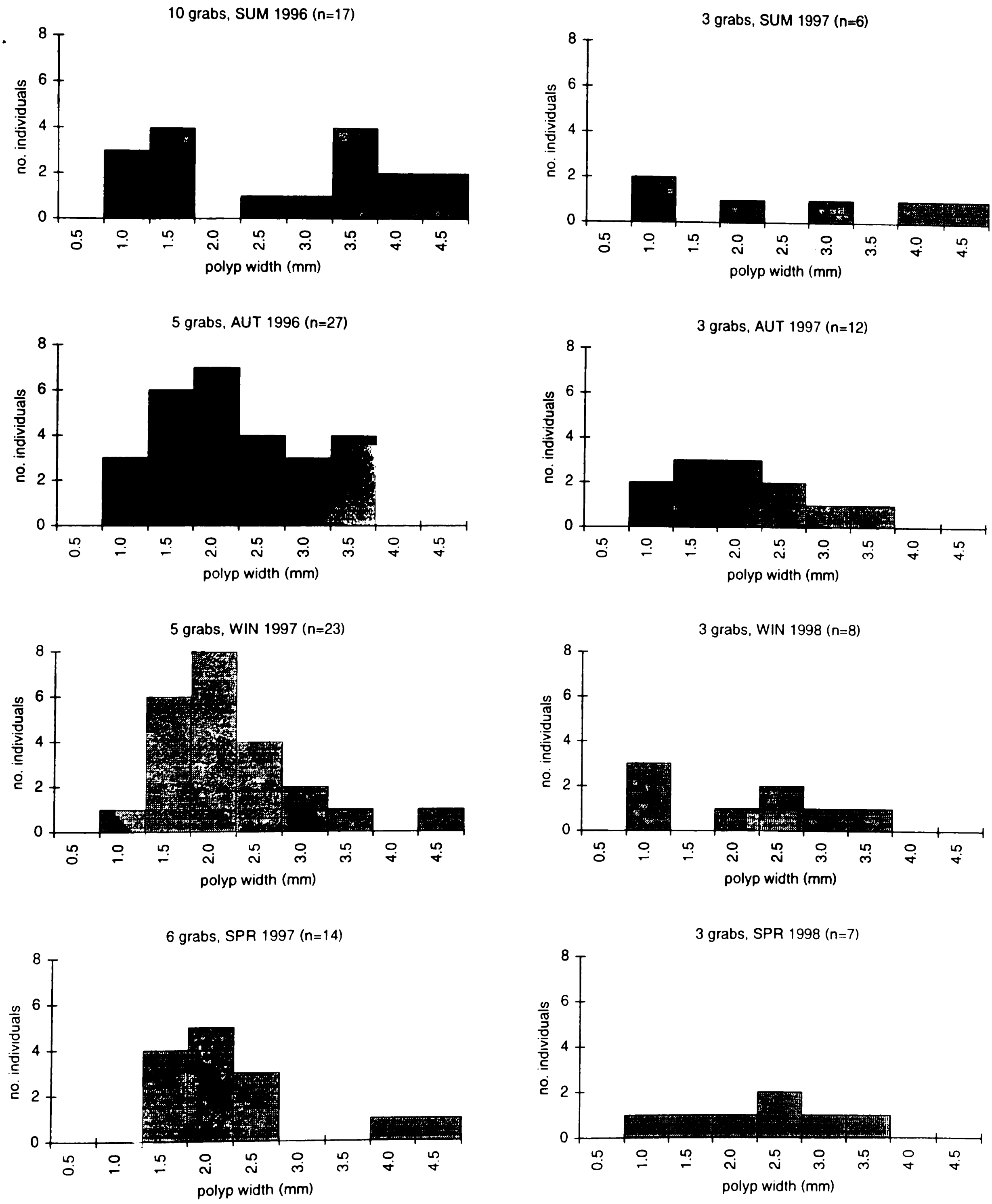
These cryptic anemones made little contribution to overall biomass in grab samples from UKC due to their small size. *Cerianthus lloydii* grew much larger and was the most important anthozoan present in terms of biomass throughout the 2–year monitoring period. *Edwardsia claparedii* made up 0.2% of the wet weight of fauna collected in 38 grab samples analysed from the area. Seasonal estimates of the mean wet weight of this species were variable (30-115 mg per 0.1 m^2 grab; Figure #B) due to its patchy distribution.

Fig. 3.1A) Mean number and B) biomass (mg wet weight) of *E. claparedii* per 0.1 m^2 grab at UKC. Error bars = SD, N = number of grabs analysed.



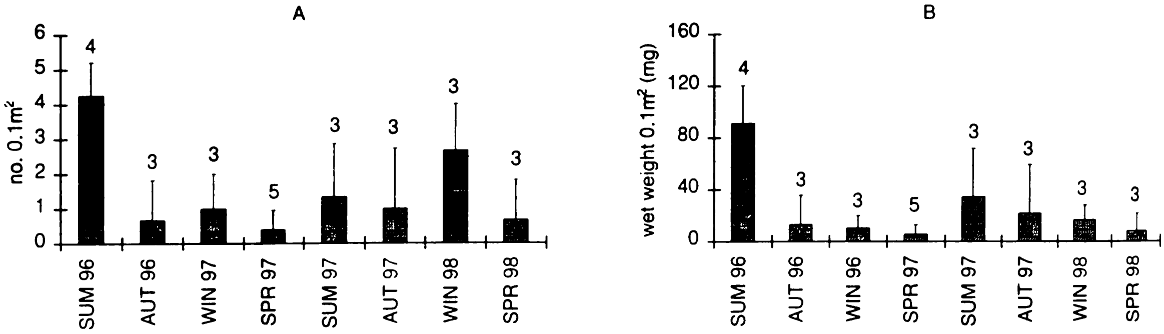
The seasonal variation in size-frequency of *E. claparedii* sampled in grabs at UKC is given in Fig. 3.2. No episodes of recruitment or size-dependent mortality were detected during the monitoring period. Preserved specimens were strongly contracted and ranged from 0.6–4.4 mm column diameter and 4.0–5.3 cm in length. Live specimens were examined in core samples and had column lengths of up to 7.1 cm.

Fig. 3.2. Size-frequency histograms for *E. claparedii* collected seasonally in 0.1 m^2 grabs at UKC from 1996-1998. n = the number of individuals measured.



Edwardsia claparedii was less abundant at UKI than at UKC during 1996–1998 although it was again the second most abundant anthozoan after *Cerianthus lloydii*. These anemones were seen in most Ring Dredge samples and about half of the cores taken in the area. They occurred in 16 out of 27 van Veen grab samples analysed with seasonal means of *ca* 1-4 individuals per 0.1 m^2 (Fig. 3.3A). This species was patchily distributed with 0–5 individuals per grab, the high abundance recorded in grab samples taken in summer 1996 was probably due to chance. These small anemones were only minor contributors to overall biomass with means of *ca* 20-40 mg per 0.1 m^2 grab (Fig. 3.3B).

Fig . 3.3.A) Mean number and B) biomass (mg wet weight) of *E. claparedii* per 0.1 m^2 grab at UKI. Error bars = SD, N = number of grabs analysed.



The seasonal variation in size-frequency of *E. claparedii* sampled in grabs at UKI is given in Fig. 3.4. As at UKC, no seasonal recruitment or mortality were detected during the monitoring period with preserved specimens ranging from 0.6–4.3 mm column diameter.

Fig. 3.4. Size-frequency histograms for *E. claparedii* collected seasonally in 0.1 m^2 grabs at UKI from 1996-1998. SUM = summer, AUT = autumn, WIN = winter, SPR = spring and n = number of individuals measured.

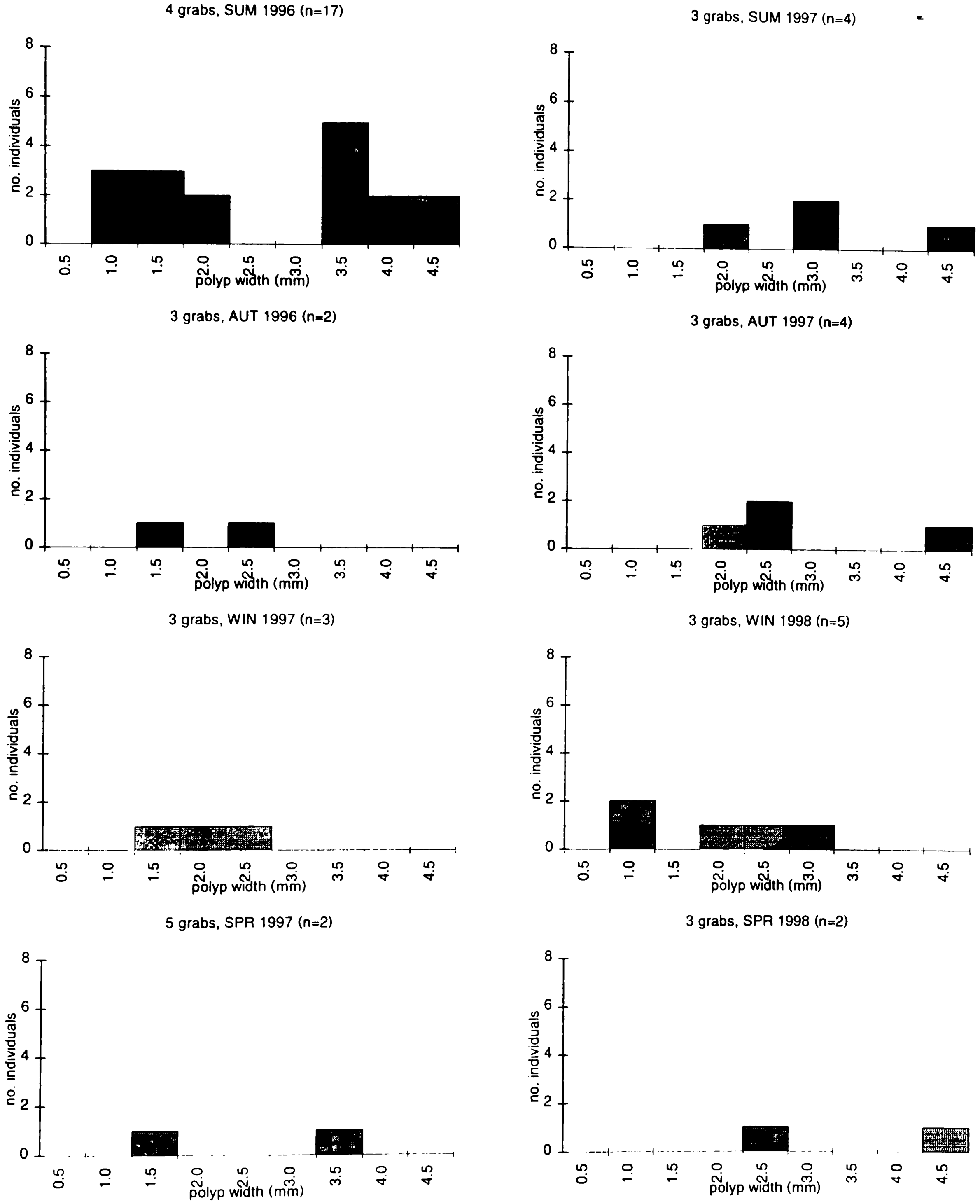
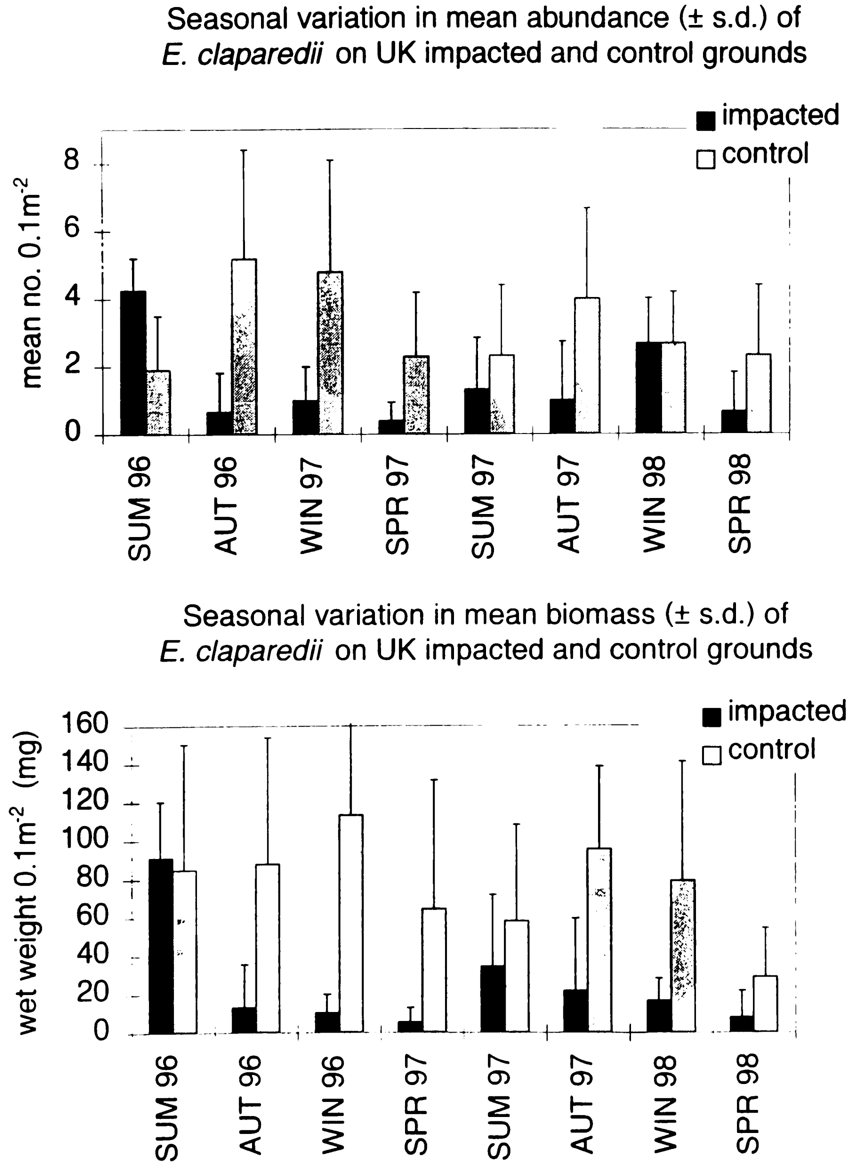


Figure 3.5 compares the abundance and biomass of *Edwardsia claparedii* on the impacted (UKI) and control (UKC) sites. Overall, the abundance and biomass of this anemone was higher at UKC, possibly due to the more stable sedimentary conditions and greater abundance of suitable prey items.

Fig. 3.5.



Seasonal variation in mean abundance (± s.d.) of *E. claparedii* on UK impacted and control grounds

Seasonal variation in mean biomass (± s.d.) of *E. claparedii* on UK impacted and control grounds

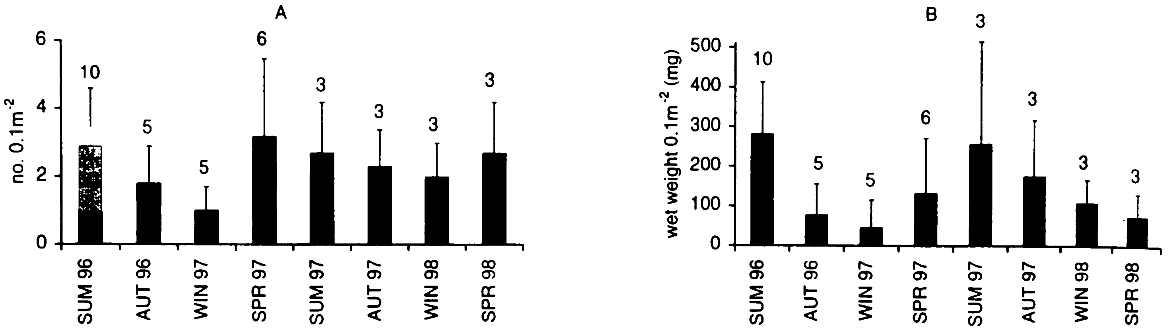
***Glycera lapidum* Quatrefages, 1866**

This polychaete was a common and characteristic member of the maerl fauna at UKC where it was found throughout the 1996–1998 sampling period. It was collected in Ring Dredge and core samples and occurred in 37 out of 38 van Veen grab samples analysed. This species was the 11th most abundant of the 113 annelid species sampled in grabs at UKC. Its abundance varied little throughout the 2-year monitoring period with seasonal means of 1–3 individuals per $0.1m^2$ grab (Fig. 3.6A) with up to 7 of these predatory worms per grab sample.

This species was not seen at the maerl surface although large individuals were occasionally observed as they burrowed to escape when divers disturbed the surface layer of maerl by hand. Core sampling revealed that this worm was a strong burrower and active carnivore, hunting other polychaetes within the upper 15 cm of the maerl sediment. This species seems to thrive in coarse, near-shore sediments such as maerl beds since Fauvel (1923) also recorded *G. lapidum* in sandy gravels off northern France.

In comparison to the much larger bivalve and echinoderm species present, polychaetes had a minor contribution to biomass in grab samples from UKC. *Glycera lapidum* made up 0.4% of the wet weight of fauna collected in the 38 grab samples analysed from this area. It was one of the dominant predatory polychaetes, along with *Harmothoe* spp. Figure 3.6B shows that seasonally, the mean wet weight of this species varied from 75–280 mg per $0.1m^2$ grab with the highest values recorded in the summers of 1996 and 1998.

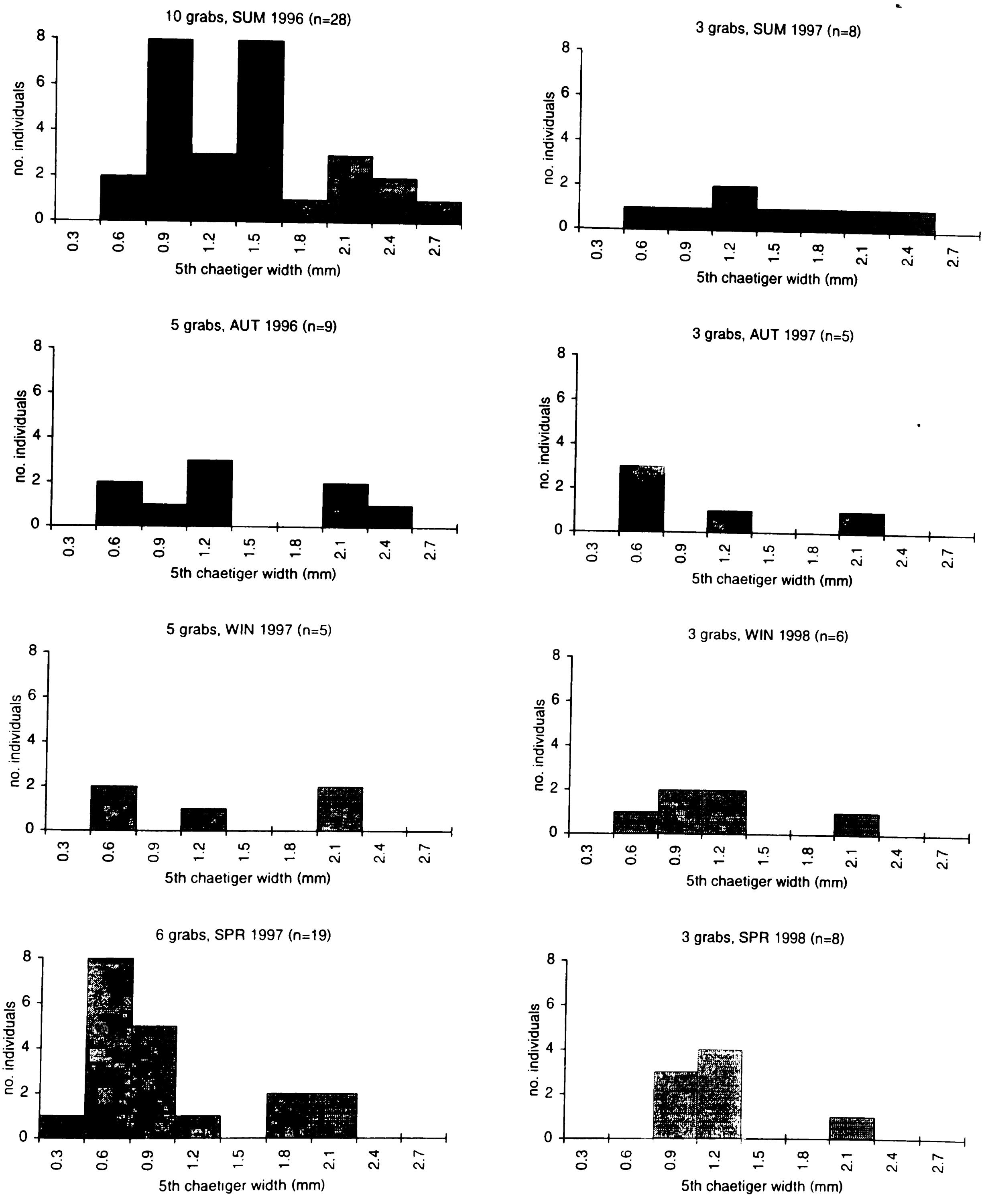
Fig. 3.6.A) Mean number and B) biomass (mg wet weight) of *G. lapidum* per $0.1m^2$ grab at UKC. Error bars = SD, n = number of grabs analysed.



The seasonal variation in size-frequency of *G. lapidum* caught in grabs are given in Fig. 3.7. Most specimens were small (<1.8 mm at the 5th chaetiger) although there was a wide range of sizes present. Preserved specimens ranged from 0.2–2.6 mm wide at the 5th chaetiger and 0.7–5.8 cm long (excluding the proboscis).

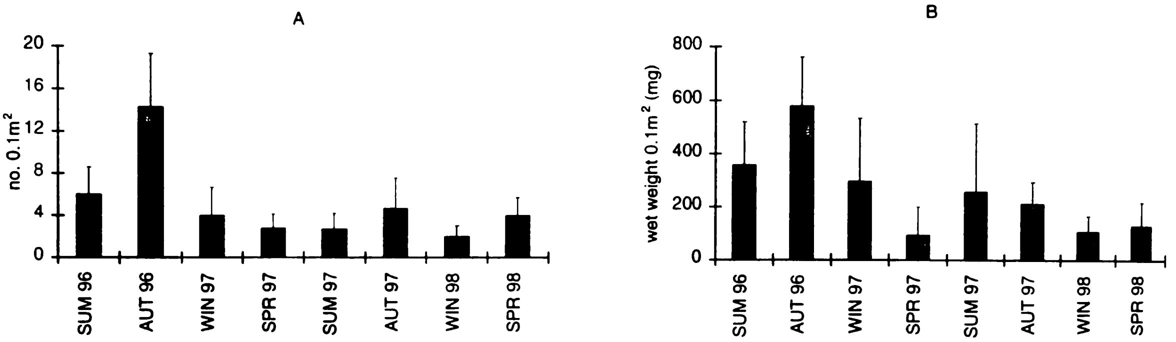
Glycera lapidum was common at UKI and was collected in Ring dredge and core samples from the area. It occurred in all 27 van Veen grabs analysed from the 1996–1998 period. A high abundance was recorded in autumn 1997 (*ca* 15 per 0.1 m^2) when there was a large proportion of small individuals. On all other occasions there were *ca* 4 individuals per 0.1 m^2 (Fig. 3.8A) This was one of the dominant predatory polychaetes present at UKI with *ca* 100–580 mg per 0.1 m^2 grab (Fig. 3.8B).

Fig. 3.7. Size-frequency histograms for. *G. lapidum* collected seasonally in 0.1m^2 grabs at UKC from 1996-1998. n values show the numbers of individuals measured.



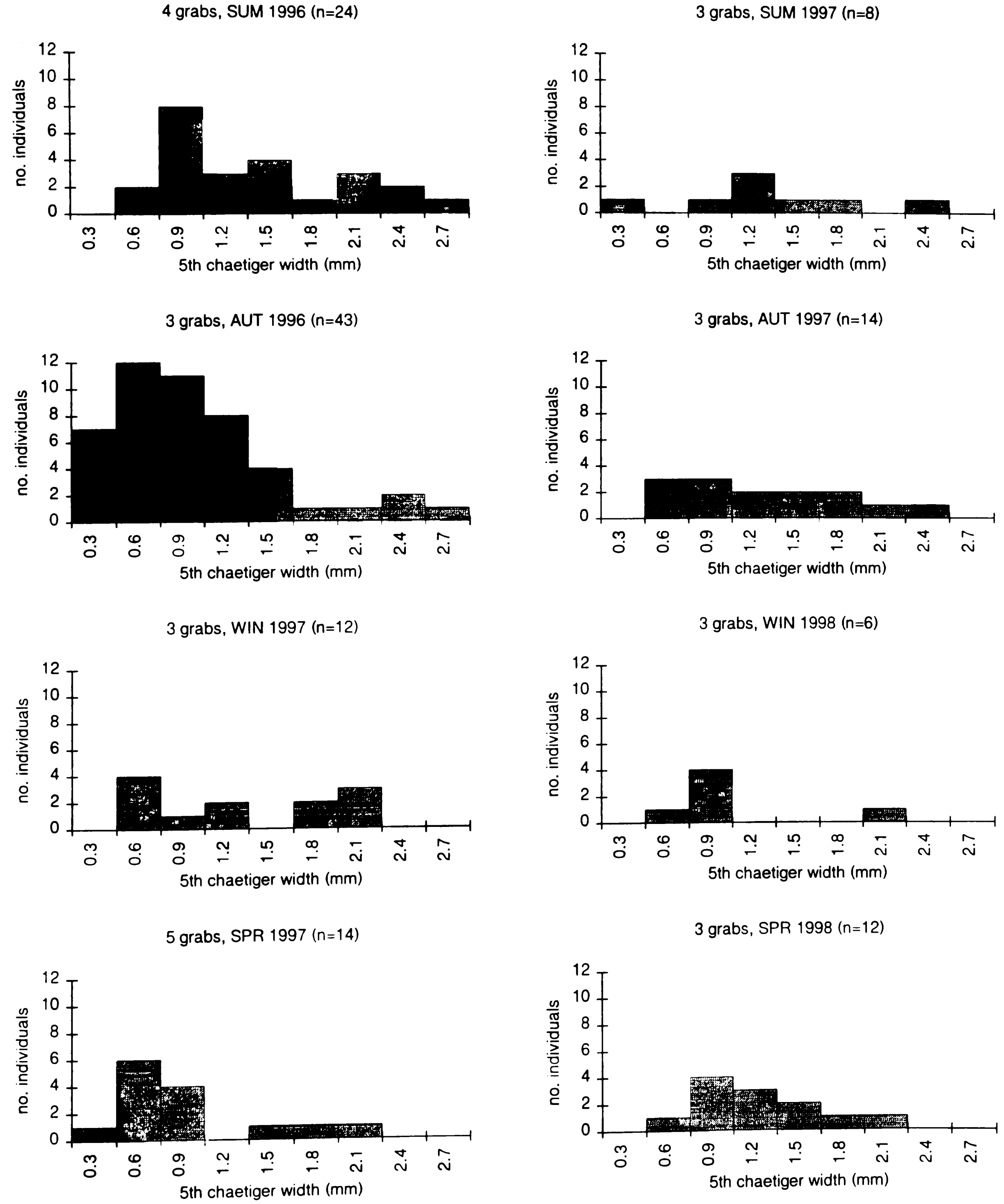
Glycera lapidum has emerged from the BIOMAERL investigations as a common and characteristic member of maerl fauna throughout Europe. It has been widely recorded in European maerl bed habitats from the Mediterranean (Jacquotte, 1962; Falconetti, 1969) to Galicia (Mora, 1980) and Brittany (Cabioch, 1968).

Fig. 3.8.A) Mean number and B) biomass (mg wet weight) of *G. lapidum* per 0.1 m^2 grab at UKI. Error bars = SD. Five grab samples were analysed in spring 1997, four in summer 1996 and three in all other seasons.



The seasonal variation in size-frequency of *G. lapidum* caught in grab samples at UKI is given in Fig. 3.9. A large number of juveniles occurred in 1 mm sieved grab samples taken in autumn 1996, but few members of this cohort apparently survived into the subsequent sampling seasons.

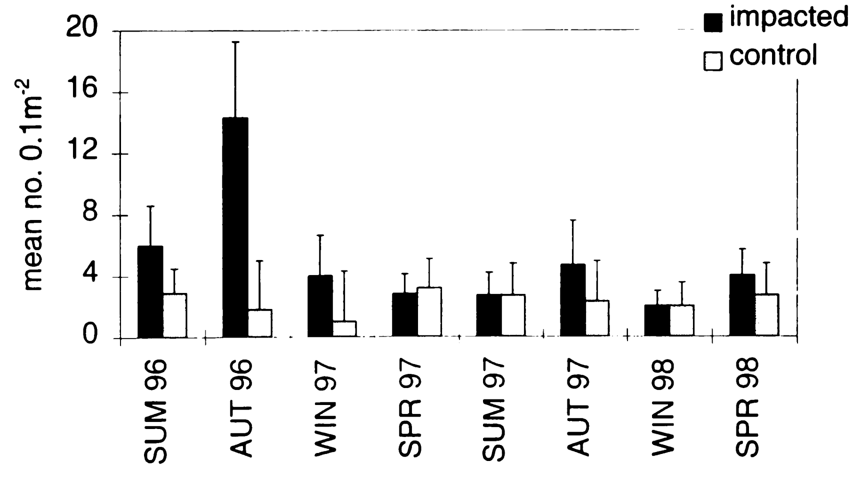
Fig. 3.9. Size-frequency histograms for *G. lapidum* collected seasonally in 0.1m^2 grabs at UKI from 1996-1998. SUM = summer, AUT = autumn, WIN = winter, SPR = spring and n = number of individuals measured.



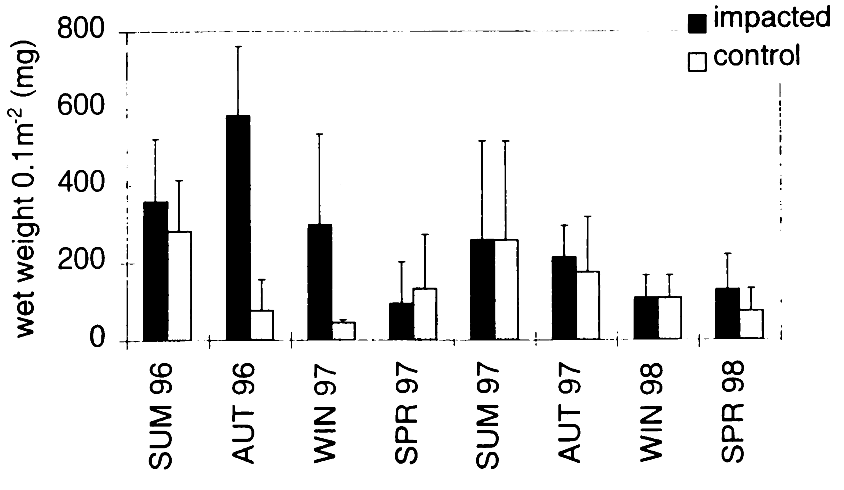
The abundance and biomass of *Glycera lapidum* was similar on the impacted (UKI) and control (UKC) sites, except in autumn 1996 when large numbers of small individuals were recorded at UKI (Fig. 3.10). These data showed a high degree of variability between replicate grab samples, since polychaetes were patchily distributed within the maerl. This reflects the small-scale heterogeneity that occurs within maerl sediments. Variability between grab samples was greater than any seasonal or annual fluctuations, although *G. lapidum* biomass was generally higher in summer and autumn than in winter.

Fig. 3.10

Seasonal variation in mean abundance (± s.d.) of *G. lapidum* on UK impacted and control grounds



Seasonal variation in mean biomass (± s.d.) of *G. lapidum* on UK impacted and control grounds



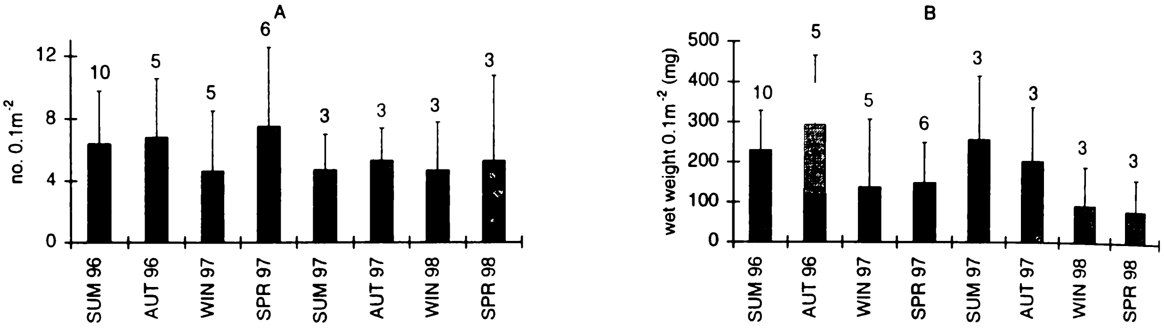
***Sphaerodorum gracilis* (Rathke, 1843)**

This was the fourth commonest annelid in the surface layer of sediment at UKC throughout 1996–1998. It was seen in Ring Dredge and core samples and occurred in 37 out of 38 van Veen grab samples from the area. Seasonal means of between 4–8 and up to 13 individuals were collected per 0.1m^2 grab (Fig. 3.11A).

Divers often saw large individuals crawling slowly over maerl thalli and dead mollusc shells on the sediment surface. Hartmann-Schröder (1971) noted that *S. gracilis* was mainly preyed upon by gastropods and built extensive mucus-lined burrows within a range of sediment types. In the present study this species was not observed to burrow. When sediment cores were transported to aquaria, individuals curled up tightly when disturbed and later moved over the surface of the sediment. *Sphaerodorum gracilis* has been recorded from the eulittoral to depths of 1400 m in Arctic-Lusitanian waters and in cold waters of the southern hemisphere but it appears not to occur in tropical conditions. This species appears may have an affinity for maerl grounds since Fauvel (1923) also recorded *S. gracilis* in association with calcareous algal sediments together with shell gravels and intertidal rockpools lined with *Lithothamnion.*

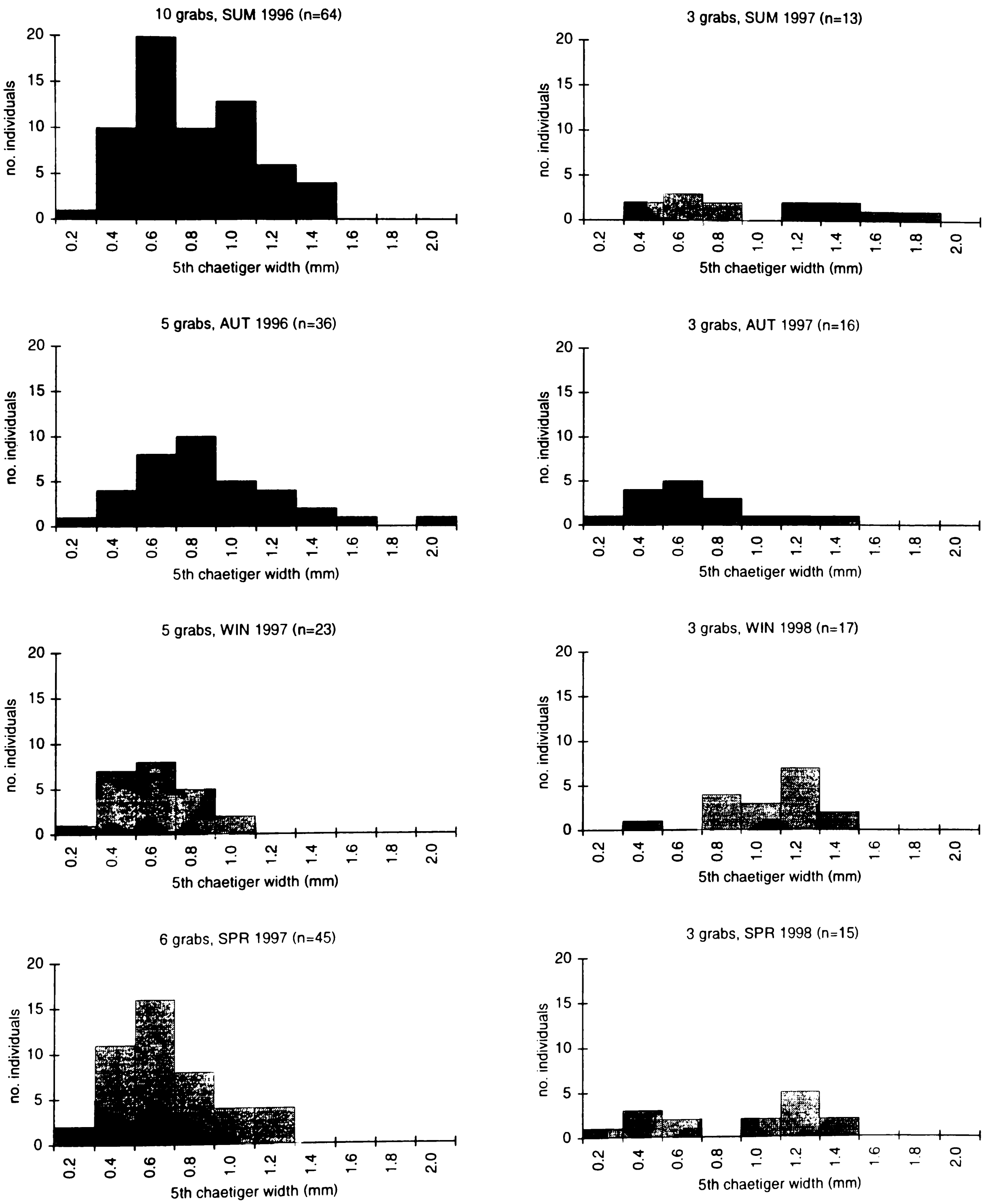
As with other common polychaetes present at UKC, their relatively small size meant that they made a minor contribution to overall biomass in grab samples. It made up 0.6% of the wet weight of fauna collected in the 38 grab samples analysed from this area. Of the 113 species of polychaete present in the grab samples analysed, *S. gracilis* ranked 6th in terms of biomass. Seasonal mean wet weight measurements varied from 80-295 mg per 0.1m^2 grab with the highest values obtained in the summer and autumn both of 1996 and 1997 (Fig. 3.11B).

Fig. 3.11. A) Mean number and B) biomass (mg wet weight) of *S. gracilis* per $0.1 m^2$ grab at UKC. Error bars = SD, N= number of grabs analysed.



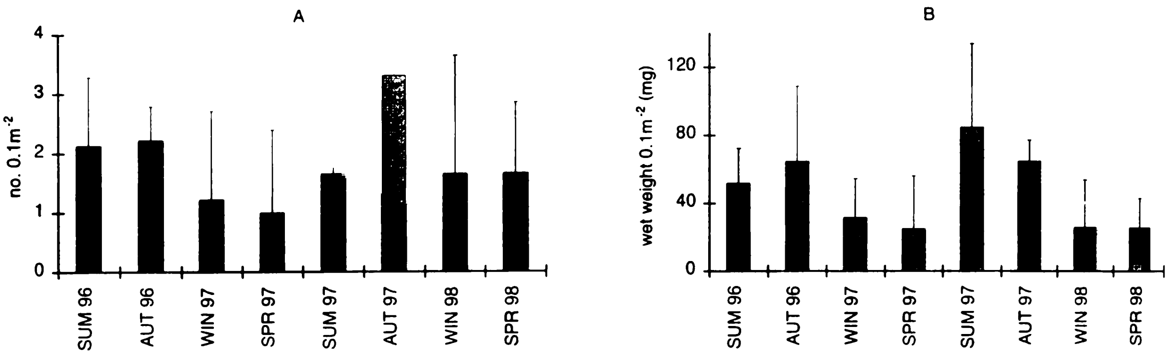
The seasonal variations in size-frequency of *S. gracilis* caught in 1 mm sieved grab samples are given in Fig. 3.12. Preserved specimens ranged from 0.2–1.2 mm wide at the 5th chaetiger and 0.7–6.0 cm in length. Smaller specimens (<1.0 mm wide at the 5th chaetiger) were predominant with large specimens (>1.6 mm wide at the 5th chaetiger) only obtained in the summer and autumn seasons.

Fig. 3.12. Size-frequency histograms for *S. gracilis* collected seasonally in 0.1m^2 grabs at UKC from 1996–1998. n indicates the number of specimens measured.



This polychaete was more sparsely distributed at UKI than the control site although it occurred in Ring Dredge samples, core samples and 22 out of 27 van Veen grab samples. Seasonal means varied between 1–4 individuals per $0.1m^2$ (Fig. 3.13A). Seasonal wet weight measurements varied from 25-85 mg per $0.1m^2$ grab. The highest biomass values were obtained in summer and autumn of 1996–1997 (Fig. 3.13 B).

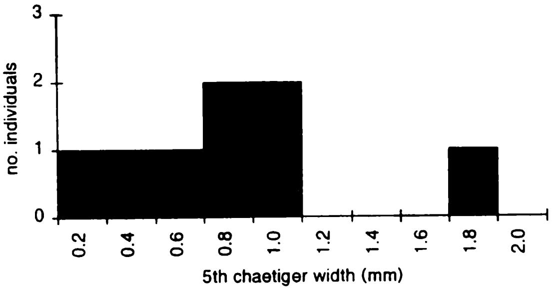
Fig. 3.13. A) Mean number and B) biomass (mg wet weight) of *S. gracilis* per $0.1m^2$ grab at UKI. Error bars = SD. Five grab samples were analysed in spring 1997, four in summer 1996 and three in the other seasons.



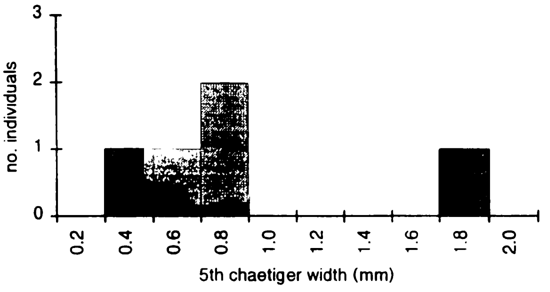
The seasonal variation in size-frequency of *S. gracilis* caught in 1 mm sieved grab samples is given in Fig. 3.14.

Fig. 3.14. Size-frequency histograms for *S. gracilis* collected seasonally in 0.1m^2 grabs at UKI from 1996-1998. SUM = summer, AUT = autumn, WIN = winter, SPR = spring and n = number of individuals measured.

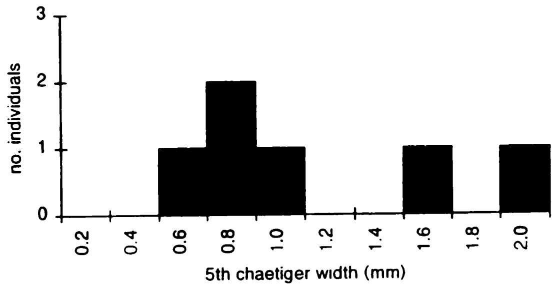
4 grabs, SUM 1996 (n=8)



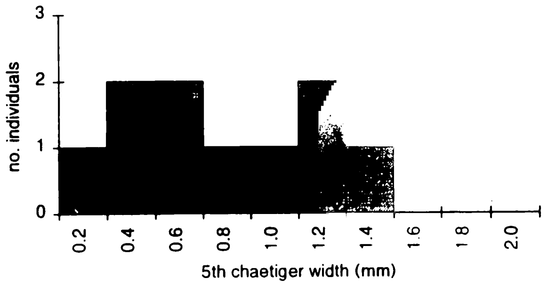
3 grabs, SUM 1997 (n=5)



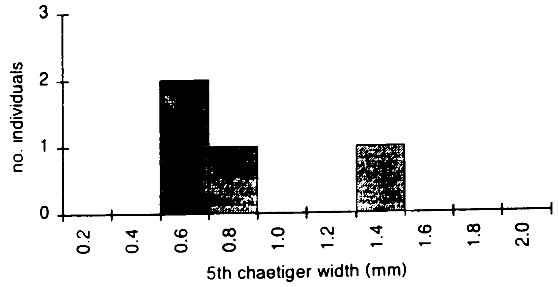
3 grabs, AUT 1996 (n=6)



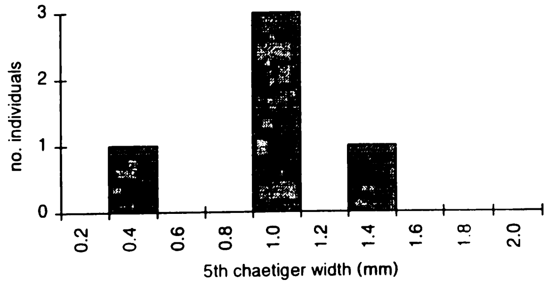
3 grabs, AUT 1997 (n=10)



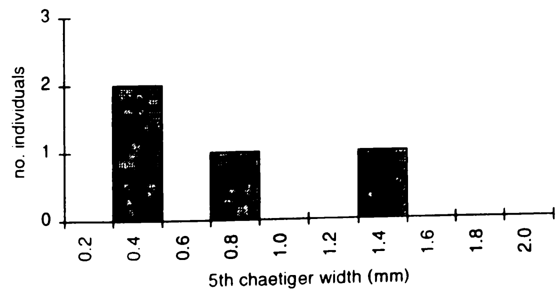
3 grabs, WIN 1997 (n=4)



3 grabs, WIN 1998 (n=5)



5 grabs, SPR 1997 (n=4)



3 grabs, SPR 1996 (n=4)

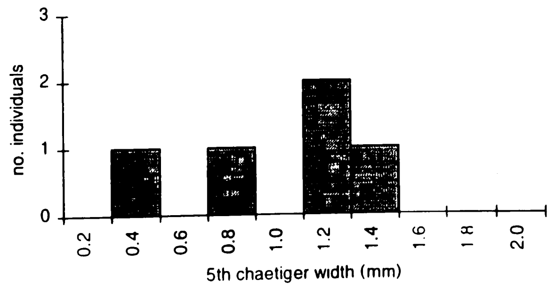
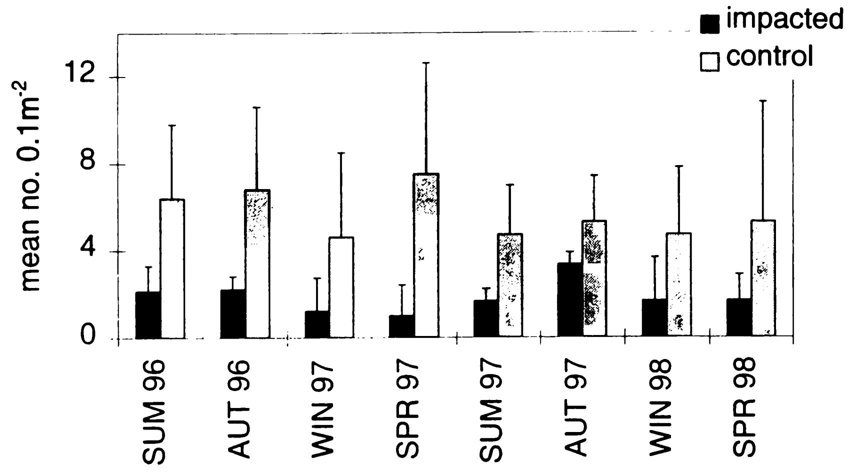
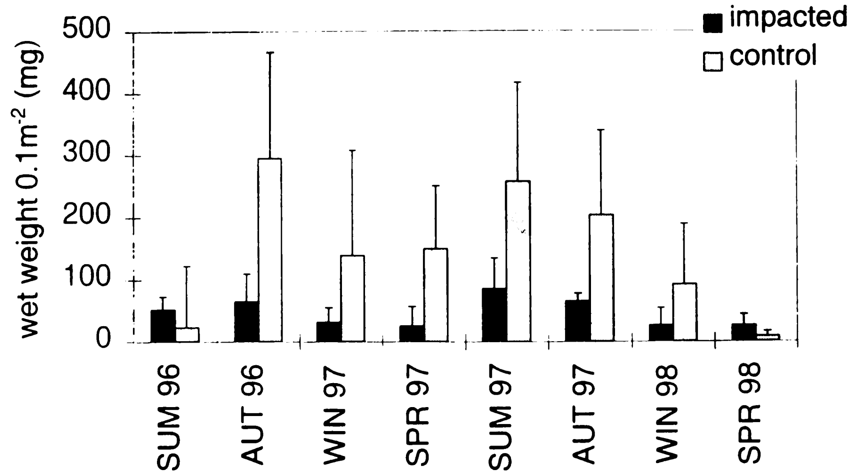


Figure 3.15 allows direct comparison of the abundance and biomass of *Sphaerodorum gracilis* on the impacted (UKI) and control (UKC) grounds. This clearly illustrates the greater abundance of this species on the control ground. Inspection of the lower graph indicates that the biomass of this species fluctuated seasonally with a tendency for high biomass each autumn (October - December) when benthic water temperatures were >9°C.

Fig. 3.15.



Seasonal variation in mean abundance (± s.d.) of *S. gracilis* on UK impacted and control grounds



Seasonal variation in mean biomass (± s.d.) of *S. gracilis* on UK impacted and control grounds

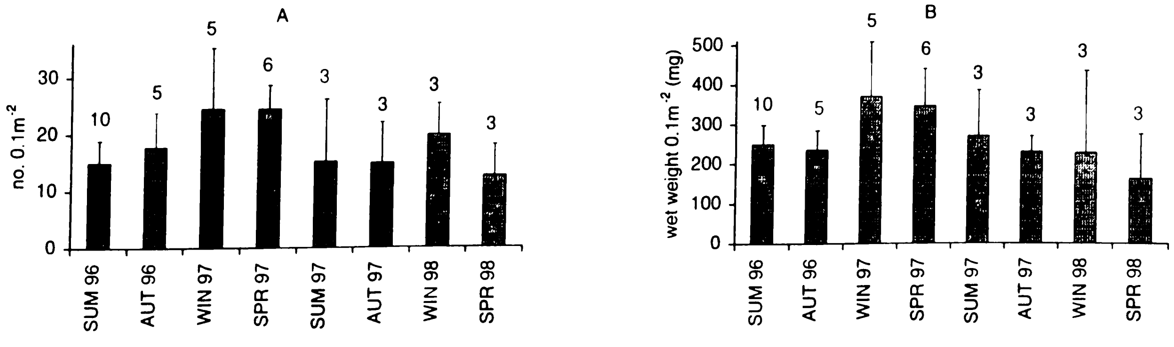
Scalibregma inflatum **Rathke, 1843**

This was the commonest annelid retained on a 1mm sieve in the surface layer of sediment at UKC throughout the 1996–1998 sampling period. It occurred in Ring Dredge and core samples and in all 38 van Veen grab samples analysed with seasonal means of 15–25 and up to 40 individuals per 0.1 m^2 grab (Fig. 3.16A).

It was not seen by divers, due to its small size and burrowing habit, but examination of core samples in aquaria showed that it lived in subsurface sediment between maerl fragments. It ingested sediment to feed and formed irregular, temporary burrows in muddy parts of the top 10cm of maerl. Hartmann-Schröder (1971) noted that this species preferred cold/temperate latitudes with records from the Atlantic coasts of France to the central Baltic and Arctic waters. It occurs in a wide range of sediments from mud to mixed bottoms where mud, sand, shell, gravel and pebbles are present. It can occur in estuarine conditions down to salinities of 8 psu and is found from the upper sublittoral to 4000m depth. Its main predators are juvenile demersal fish (Hartmann-Schröder, 1971).

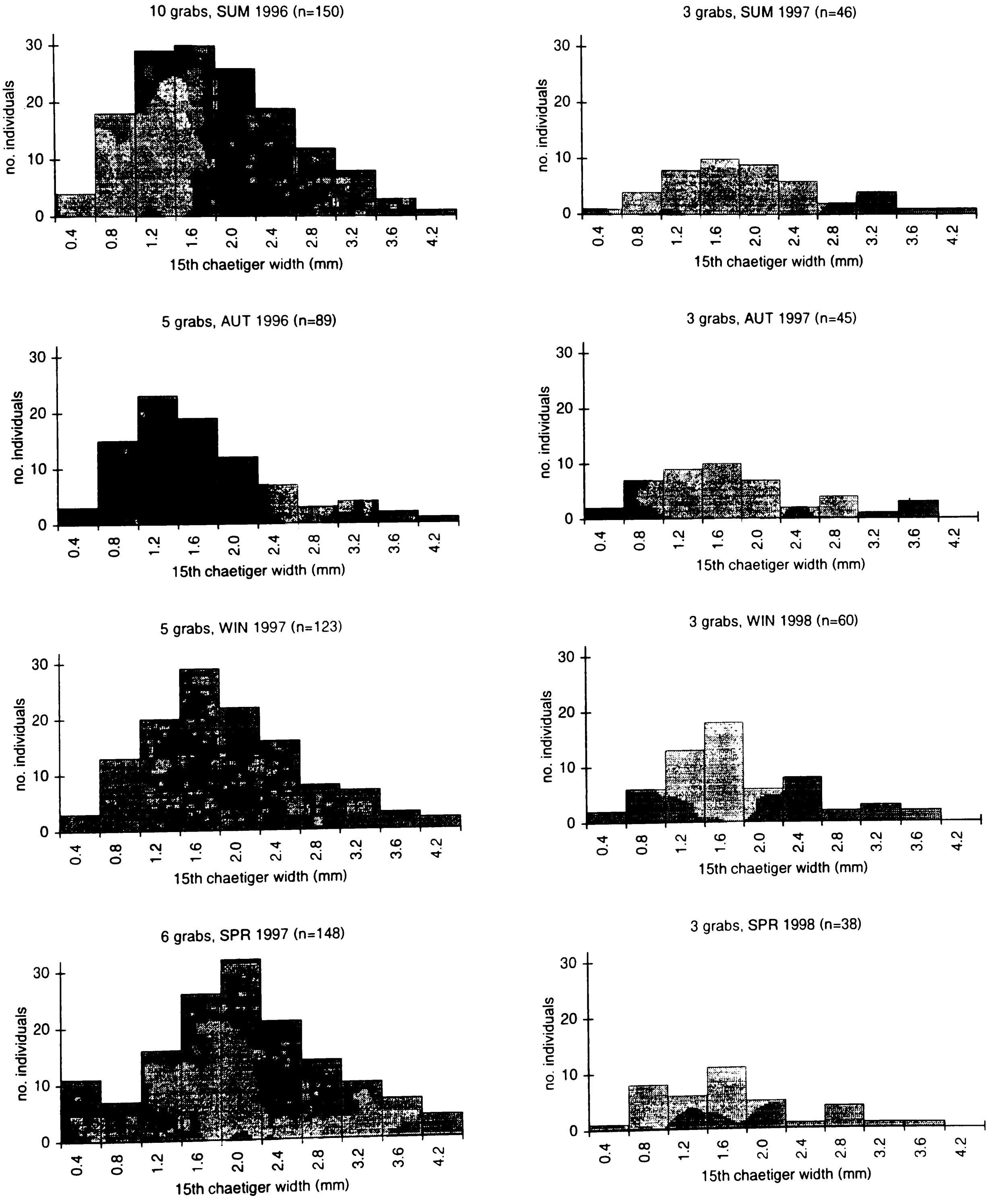
Due to its relatively small size, *S. inflatum* made a minor contribution to overall biomass in grab samples from UKC. It made up 0.85% of the wet weight of fauna collected in 38 grab samples but was the 4th most important annelid in terms of biomass due its high population density throughout 1996–1998. Repeat assessments showed no significant seasonal change in population biomass with mean wet weights varying from 163–370 mg per $0.1m^2$ (Fig. 3.16B).

Fig. 3.16. A) Mean number and B) biomass (mg wet weight) of *S. inflatum* per $0.1m^2$ grab at UKC. Error bars = SD, n = number of grabs analysed.



The seasonal variation in size-frequency of *S. inflatum* sampled in grabs at UKC is given in Fig. 3.17. The preserved specimens ranged from 0.6–4.1 mm wide at the 15th chaetiger and 0.4 – 4.1 cm long. The four histograms on the left of Fig. 3.17 represent measurements of 510 specimens from 26 grab samples. These histograms show a normally distributed population structure with evidence for an increase in the mean size over the summer 1996 spring 1997 period. The same spread in size was found in the second year of monitoring, as shown on the four histograms on the right of Fig. 3.17 based on measurements of 181 animals collected in the 12 grab samples taken.

Fig. 3.17. Size-frequency histograms for *S. inflatum* collected seasonally in 0.1m^2 grabs at UKC from 1996–1998. n values show the number of individuals measured.



10 grabs, SUM 1996 (n=150)

3 grabs, SUM 1997 (n=46)

5 grabs, AUT 1996 (n=89)

3 grabs, AUT 1997 (n=45)

5 grabs, WIN 1997 (n=123)

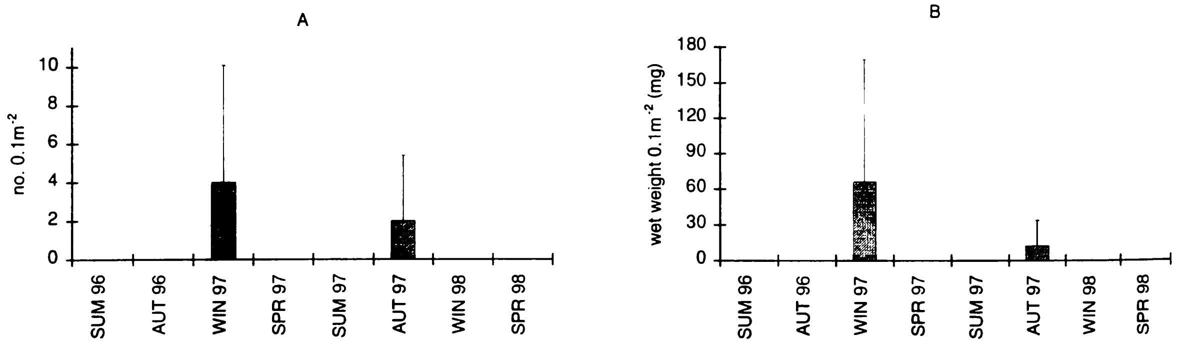
3 grabs, WIN 1998 (n=60)

6 grabs, SPR 1997 (n=148)

3 grabs, SPR 1998 (n=38)

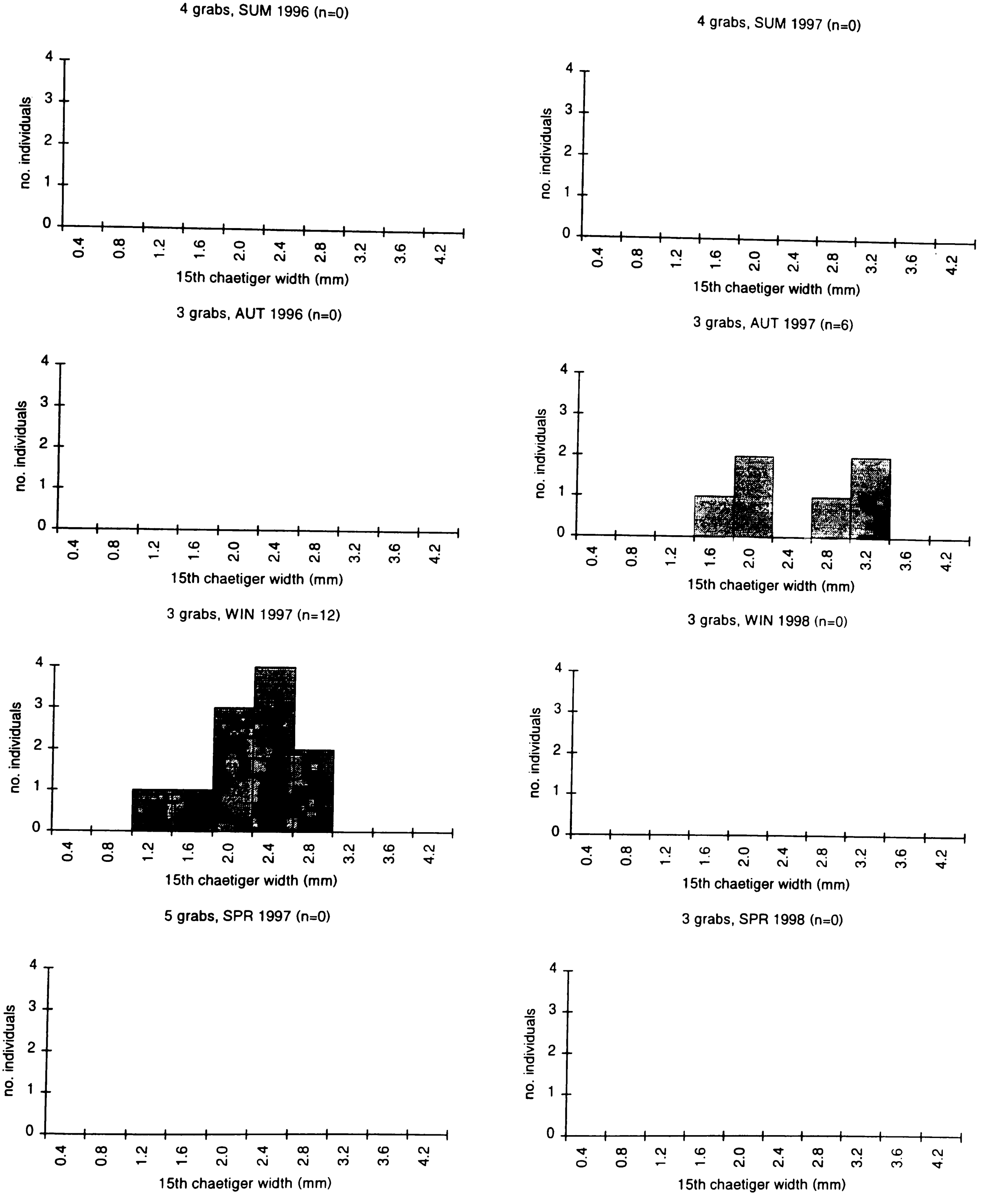
Whereas this species was the commonest annelid retained on a 1 mm sieve at UKC, it was sparsely distributed at the impacted site. Core sampling revealed that it was only found in silty loci in the upper 10cm layer of maerl, such as around the mud-lined burrows of *Upogebia deltaura* and *Eupolymnia nebulosa*. The strongly aggregated distribution of this species was reflected in the grab sampling programme as these annelids only occurred in 3 out of 27 grabs analysed (Fig. 3.18A). Coarse sand and maerl gravel predominated in most grab samples from UKI and this appears to have precluded *S. inflatum*. An average population density in all grabs taken at UKI gave an abundance of 0.6 individuals per 0.1m^2. The small size and low abundance of this species meant that its contribution to overall biomass was low, forming <0.01% of the wet weight of fauna collected in 27 grab samples (Fig. 3.18B).

Fig. 3.18. A) Mean number and B) biomass (mg wet weight) of *S. inflatum* per 0.1m^2 grab at UKI. Error bars = SD. Five grab samples were analysed in spring 1997, four in summer 1996 and three in all other seasons.



The seasonal variation in size-frequency of *S. inflatum* caught in 1 mm sieved grab samples from UKI is given in Fig. 3.19.

Fig. 3.19. Size-frequency histograms for *S. inflatum* collected seasonally in 0.1m^2 grabs at UKI from 1996-1998. SUM = summer, AUT = autumn, WIN = winter, SPR = spring and n = number of individuals measured.



4 grabs, SUM 1996 (n=0)

4 grabs, SUM 1997 (n=0)

3 grabs, AUT 1996 (n=0)

3 grabs, AUT 1997 (n=6)

3 grabs, WIN 1997 (n=12)

3 grabs, WIN 1998 (n=0)

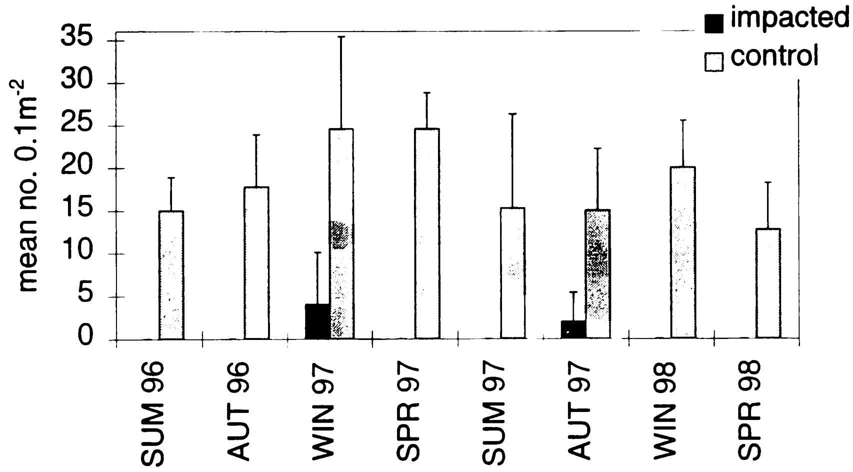
5 grabs, SPR 1997 (n=0)

3 grabs, SPR 1998 (n=0)

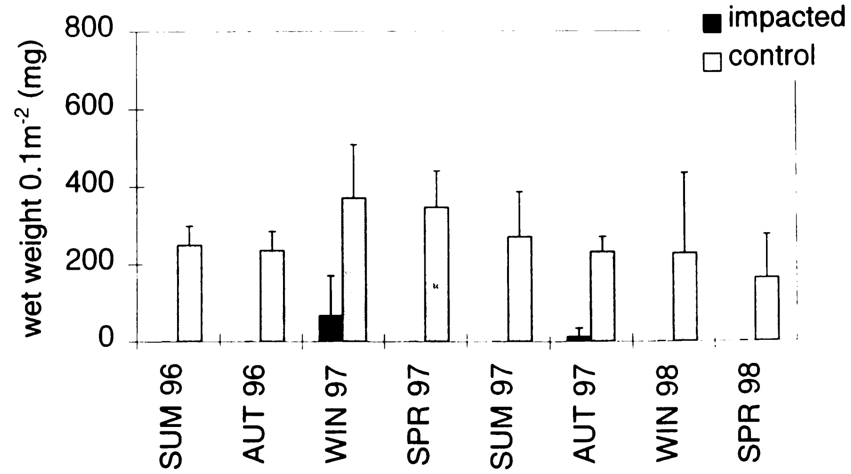
Figure 3.20 below compares the abundance and biomass of *Scalibregma inflatum* on the impacted (UKI) and control (UKC) sites. This species was significantly more abundant at the control site throughout the 1996–98 monitoring period. Anthropogenic and natural disturbance limited the accumulation of muddy loci at the sediment surface of UKI which this species favoured in the undisturbed maerl at UKC. While *S. inflatum* was the fourth most important annelid in terms of biomass at UKC, its contribution to biomass overall at UKI was negligible where species adapted to life in coarse, shifting sediment (e.g. the sand mason worm, *Lanice conchilega*) were more important.

Fig. 3.20.

Seasonal variation in mean abundance (± s.d.) of *S. inflatum* on UK impacted and control grounds



Seasonal variation in mean biomass (± s.d.) of *S. inflatum* on UK impacted and control grounds



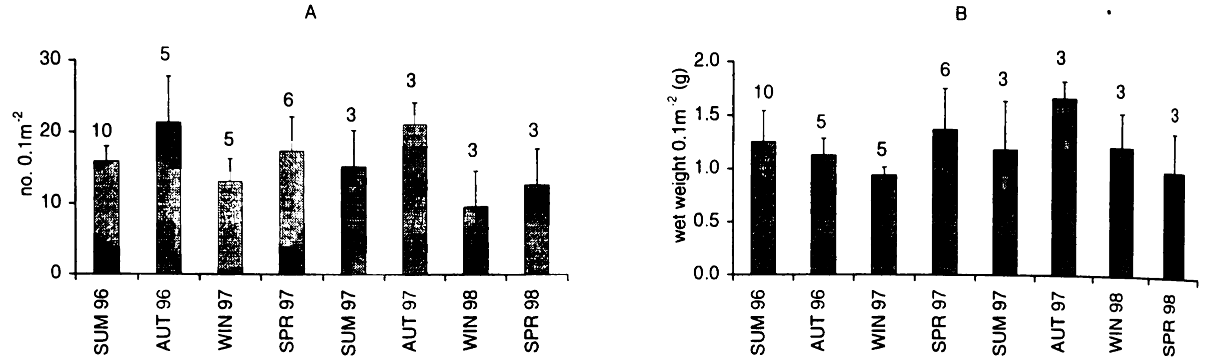
Owenia fusiformis Delle Chiaje, 1841

This polychaete formed dense adult populations in the maerl gravel at UKC throughout the sampling period from 1996-1998. It was the second-most abundant polychaete retained on a 1 mm sieve and occurred in Ring Dredge samples, core samples and all 38 van Veen grab samples analysed with seasonal means of 9–22 and up to 26 individuals collected per 0.1m^2 grab (Fig. 3.21A).

Divers were able to observe large individuals *in situ*. Each occupied a flexible 'S' shaped tube encrusted with a distinctive arrangement of coarse sand and shell particles (see Fauvel, 1927). They were either stationary, filter feeding in an upright position, or were seen bent over toward the maerl substratum moving the anterior part in a sweeping motion as they fed on surface deposits. Core samples revealed that they occurred in the top 10 cm of sediment where they were burrowed into muddy sand located between coarse maerl and shell particles. Hartmann-Schröder (1971) noted that this worm was rarely found intertidally, was common subtidally and was recorded to depths of 5000 m. It is found on a wide range of sediment types from soft mud to coarse sand and gravel. It is cosmopolitan, being found throughout the Atlantic coasts of Europe and the Mediterranean (Fauvel, 1927). The ecological importance of this species, in terms of abundance, biomass and as an agent in sediment stabilization, has been stressed in recent papers (e.g. Dauvin & Gillet, 1991; Ambrogi *et al.,* 1995).

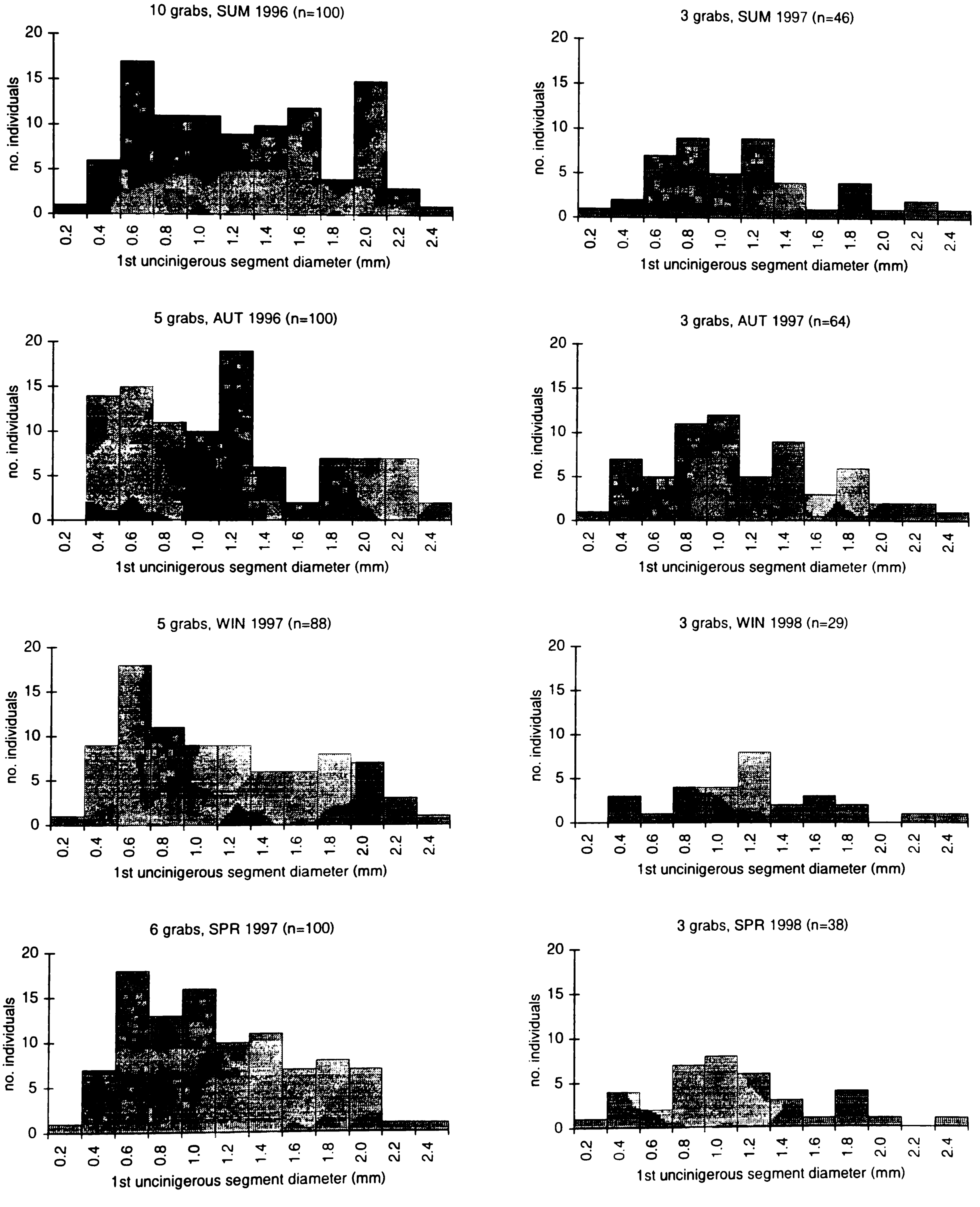
Of the annelids that occurred at UKC, this species was the most important contributor to biomass. It made up 3.3% of the faunal wet weight in 38 grab samples analysed from this area. Mean wet weights varied from 0.9–1.8 g per 0.1m^2 grab (Fig. 3.21B). Although *O. fusiformis* was the second-most abundant polychaete at UKC, it was uncommon at UKI where only 8 specimens were caught. Thus maerl beds in the same vicinity can support very different faunal communities depending on local conditions. The large-scale shifts in surface sediment observed at UKI during scallop dredging and storms prevented sedentary species such as *O. fusiformis* from becoming established in the upper sediment layer.

Fig. 3.21.A) Mean number and B) biomass (g wet weight) of *O. fusiformis* per $0.1m^2$ grab at UKC. Error bars = SD, n = number of grabs analysed.



The seasonal variaion in size-frequency of *O. fusiformis* sampled in grabs is given in Fig. 3.22. This figure indicates that the population was stable throughout the sampling period with no large recruitments or obvious shifts in population size-structure. The polychaetes ranged in size from 0.2–2.2 mm in diameter at the first uncinigerous (abdominal) segment and were 14–73 mm in length.

Fig.3.22. Size-frequency histograms for *O. fusiformis* collected seasonally in 0.1m^2 grabs at UKC from 1996–1998. SUM = summer, AUT = autumn, WIN = winter, SPR = spring. N = number of individuals measured.


10 grabs, SUM 1996 (n=100)

3 grabs, SUM 1997 (n=46)

5 grabs, AUT 1996 (n=100)

3 grabs, AUT 1997 (n=64)

5 grabs, WIN 1997 (n=88)

3 grabs, WIN 1998 (n=29)

6 grabs, SPR 1997 (n=100)

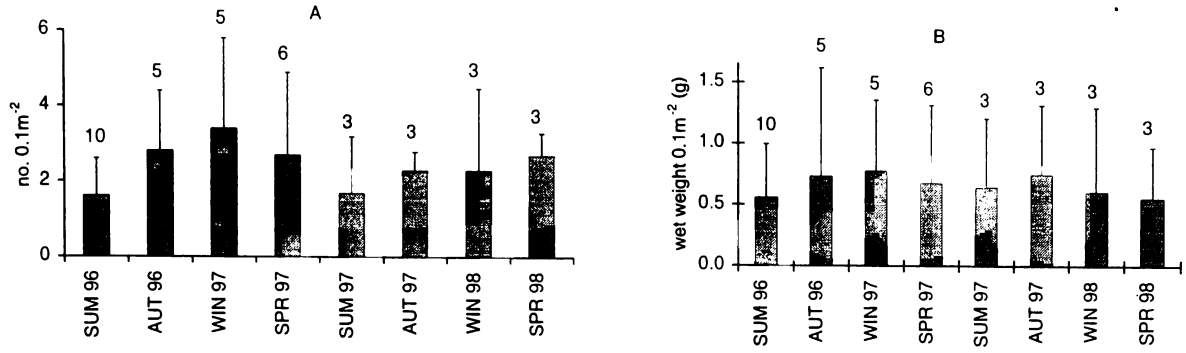
3 grabs, SPR 1998 (n=38)

Terebellides stroemi M. Sars, 1835

This polychaete was a characteristic and perennial member of the fauna in surface sediment at UKC throughout 1996–1998. It was seen in Ring Dredge and core samples and occurred in 33 out of 38 sieved van Veen grabs. It was the 10th commonest of 113 polychaetes recorded, with no significant differences in mean abundance between seasons. Abundance ranged from 1.6–3.4 per $0.1m^2$ with up to 6 individuals collected per grab (Fig. 3.23A).

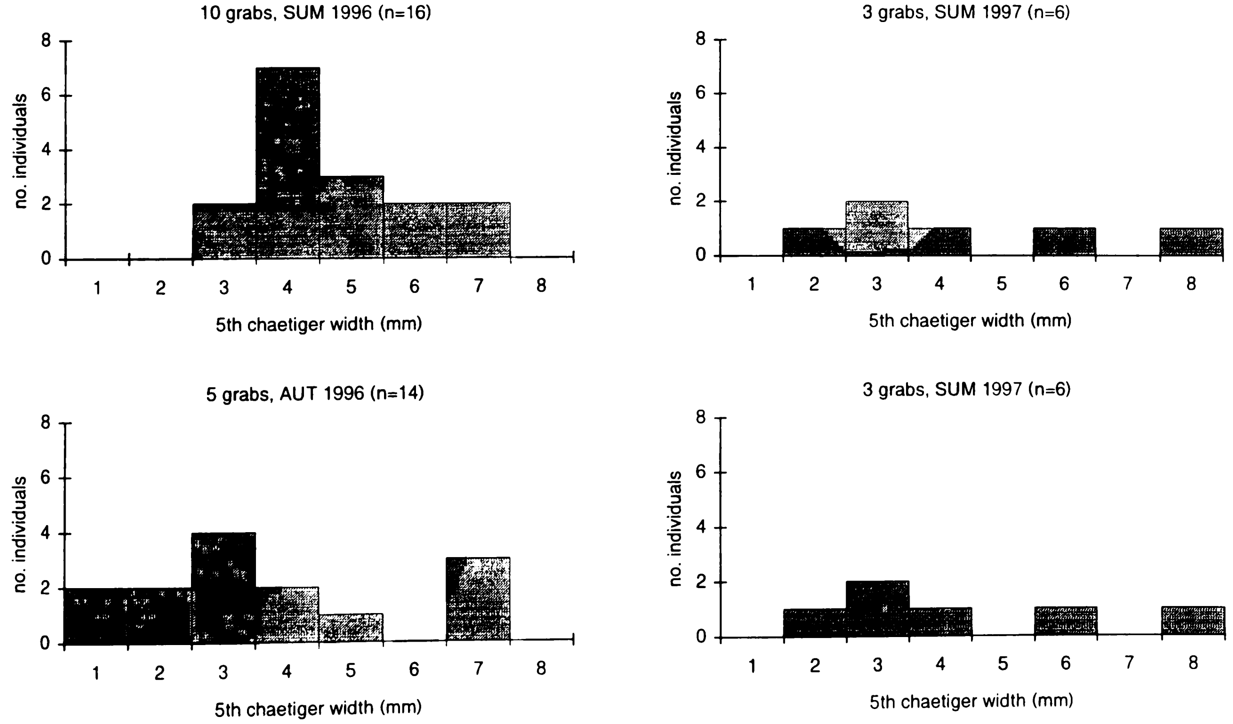
The tentacles of this terebellid were seen collecting detritus from the surface of the maerl. Defaecation and feeding activities created silty loci of 1–5 cm radius around each animal which occupied a mud-lined mucus tube in the top 10 cm of maerl. Experimental scallop dredging revealed that these polychaetes used their feeding tentacles for locomotion when displaced. Some were able to reburrow but most individuals were eaten by demersal fish and crabs. Records show that this terebellid is found in all European waters and is important food for demersal fish. It is found in a variety of sediments but favours conditions found at UKC, where mud is mixed with stones, gravel and/or sand. It occurs from the intertidal to depths of 3000 m and extends into estuarine conditions down to 3 psu (Hartmann-Schröder, 1971). It was one of the largest polychaetes regularly caught in grabs and was the 2nd most important contributor to annelid biomass. It made up 1.9% of the faunal wet weight in 38 grabs from UKC. Mean wet weights varied little from season to season with means of 555–775 mg per $0.1m^2$ grab (Fig. 3.23B). In terms of biomass and abundance, terebellids (e.g. *T. stroemi, Pista cristata*) were much more important at UKC than at UKI. Terebellids feed mainly on settled detritus which was more abundant in the muddier, more sheltered conditions of UKC (BIOMAERL team, in press). UKI was physically disturbed by wave action and scallop dredging which maintained the surface sediment as a clean, mobile gravel that was relatively free of mud (BIOMAERL team, in press; Hall-Spencer & Atkinson, in press). That only two *T. stroemi* were caught in the 1996–98 grab sampling programme at UKI is an example of the important effect that physical disturbance has on the sediment structure and ecology of maerl habitats.

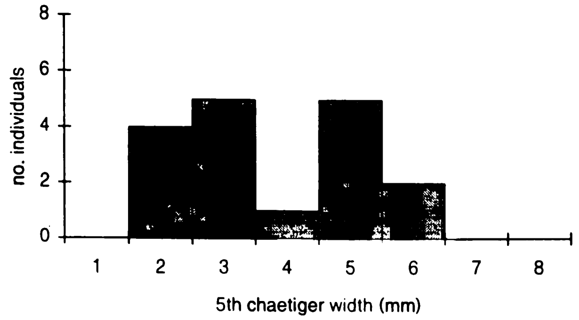
Fig. 3.23. A) Mean number and B) biomass (g wet weight) of *T. stroemi* per $0.1m^2$ grab at UKC. Error bars = SD, n = number of grabs analysed.

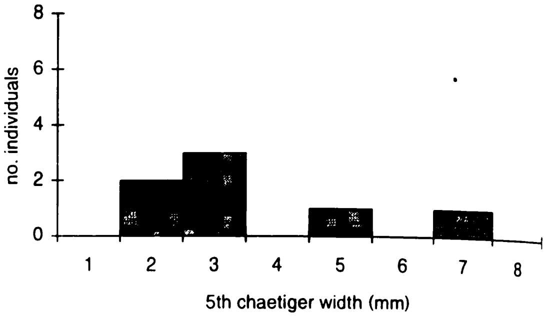


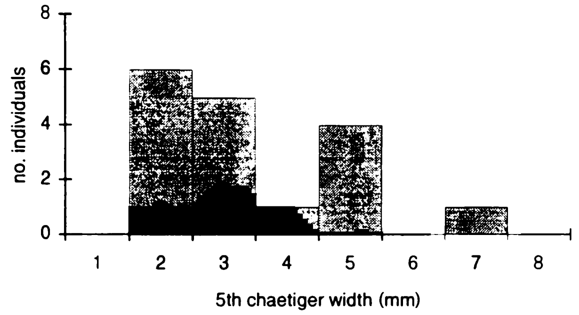
The seasonal variation in size-frequency of *T. stroemi* sampled in grabs at UKC are given below. Preserved specimens ranged from 0.8–7.5 mm wide at the 5th chaetiger and 0.6–6.9 cm long.

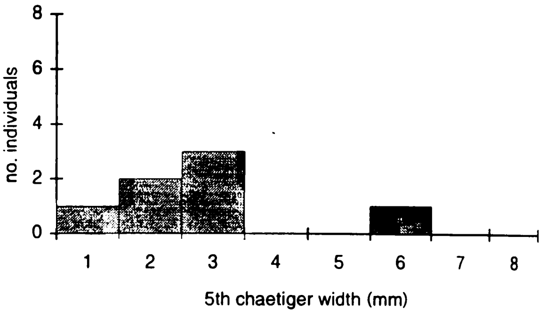
Fig. 3.24. Size-frequency histograms for *T. stroemi* collected seasonally in $0.1m^2$ grabs at UKC from 1996–1998. n = number of individuals measured.




5 grabs, WIN 1997 (n=17)


3 grabs, AUT 1997 (n=7)


6 grabs, SPR 1997 (n=17)


3 grabs, WIN 1998 (n=7)

Upogebia deltaura (Leach, 1815)

This decapod crustacean was common at both UKC and UKI but was not captured in any of the Ring Dredge, core or van Veen grabs deployed during the 1996-1998 sampling period due to the depth to which this species burrowed within the maerl. SCUBA divers were therefore used to assess the abundance and ecology of this species *in situ*. Surface quadrats were used first to locate and map the abundance of the burrow openings, then selected openings were marked to observe their stability and dynamics over time. Senckenberg box cores were used to investigate the near-surface burrow structure and which species were commensal within the burrows. An air-lift was used to capture the inhabitants and excavate burrows which were cast using resin to investigate their 3-D structure within the sediment.

These investigations showed that *U. deltaura* was the most abundant large crustacean within the habitat and the deepest-burrowing member of the macrofauna (to 68 cm) at both sites. UKI had the highest density of *U. deltaura* with a mean of 2.9 burrows m^{-2} and 3–10 openings m^{-2}. UKC had a mean of 1.9 burrows m^{-2} and 2–7 openings m^{-2}. Experimental investigations showed that these decapods were amongst the most resistant species present to disturbance by storms and scallop dredging. Full details of these findings are given in the enclosed papers by Hall-Spencer & Atkinson (in press) and Hall-Spencer & Moore (in press b) and so are not repeated here.

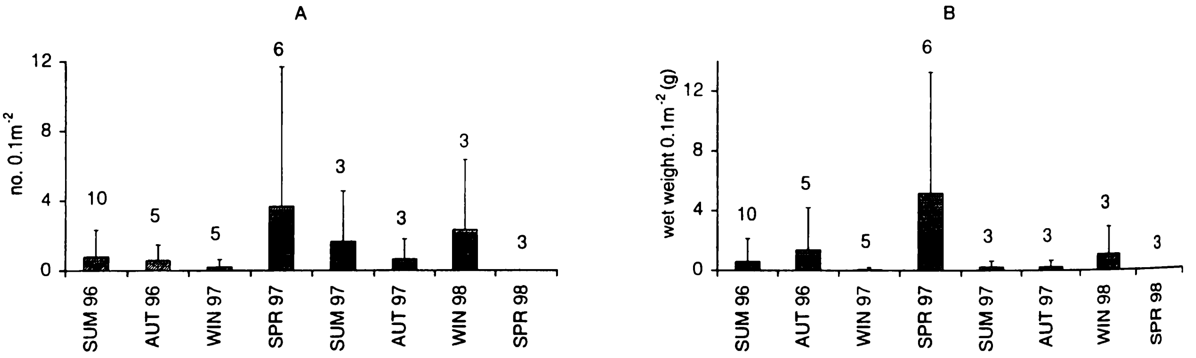
Limaria hians (Gmelin, 1791)

This distinctive mollusc was the most abundant of 27 bivalve species included in regular van Veen grab samples at UKC from 1996–1998. It was gregarious and patchily distributed in the sampling area. It was abundant in all Ring Dredge samples but only occurred in 13 out of 38 grab samples analysed with seasonal means of 0–3.7 and up to 20 individuals collected per 0.1 m^2 (Fig. 3.25A).

These bivalves played a key structuring role at UKC with groups of *ca* 10-120 sharing nests of 10–80 cm diameter and 2–30 cm height. To the south of UKC the habitat graded into one dominated by a continuous sheet of *L. hians* nests. The nests incorporated shell and maerl fragments to form structures that had a rich associated fauna of sponges, hydroids and tunicates. Internally, the nests had a complex system of galleries through which *L. hians* pumped water to feed. These galleries were lined . by a characteristic fauna including species that were rare outside the nests (e.g. *Pherusa plumosa, Flabelligera affinis, Mysella bidentata*). These fed on *L. hians* faeces. The nests protected the inhabitants from brittlestars (*Ophiocomina nigra*) which readily fed on *L. hians* exposed by divers although these bivalves shed extremely sticky tentacles when disturbed as a defence against predators such as crabs and demersal fish.

The aggregated distribution meant that *L. hians* was a major contributor to biomass in some UKC grab samples but was absent from most. It made up 4.8% of the wet weight of fauna collected in 38 grabs from the area. Mean wet weights varied from 0–5152 mg per 0.1 m^2 grab (Fig. 3.25B).

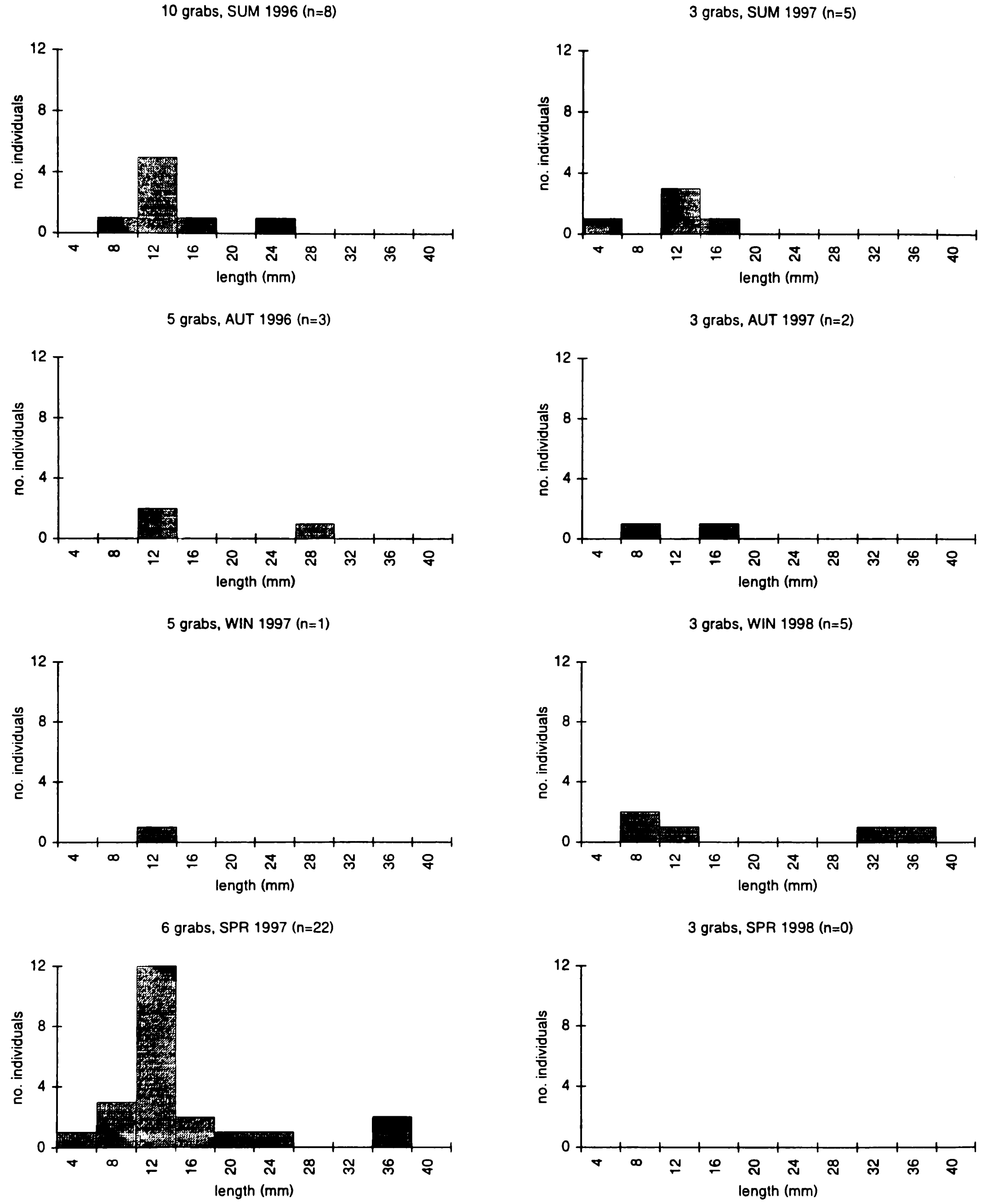
Fig. 3.25. A) Mean number and B) biomass (g wet weight) of *L. hians* per 0.1m2 grab at UKC. Error bars = SD, n = number of grabs analysed.



Seasonal variation in size-frequency of *L. hians* sampled in grabs at UKC is given in Fig. 3.26. Specimens ranged from 4–35 mm in length. Experiments revealed that *L. hians* were highly suceptible to the effects of scallop dredging (Hall-Spencer & Moore, in press b). Their population density was dramatically reduced by the mechanical action of such gear, with no discernible recovery in impacted areas over a four-year period. Study of UKI and several other Scottish maerl beds has indicated a demise of this species on scallop dredged grounds over the past 30 years (Hall-Spencer, 1998; Hall-Spencer & Moore, in press b). The historical elimination of

L.hians on scallop-dredged grounds in the Irish Sea has also been noted (Dr A.Brand, pers.comm.). This species is particularly vulnerable to mechanical impact at the sediment surface.

Fig. 3.26. Size-frequency histograms for *L. hians* collected seasonally in 0.1 m^2 grabs at UKC from 1996-1998. n = number of individuals measured.

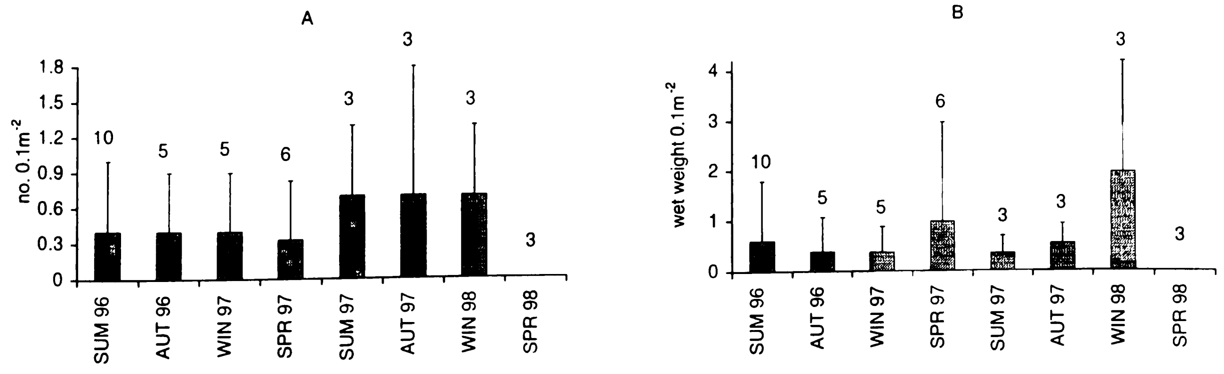


Clausinella fasciata (da Costa, 1778)

This bivalve was sparsely distributed at UKC throughout 1996–1998. It regularly occurred in Ring Dredge samples but was infrequently found in cores which sampled only a small area (0.08m^2). It occurred in 16 out of 38 sieved van Veen grabs and was the 4th most abundant of 27 bivalve species recorded. There were no significant differences observed in the seasonal abundance of this species with *ca* 0.4 individuals per 0.1 m^2 throughout the sampling period (Fig. 3.27A) and up to 2 individuals per grab.

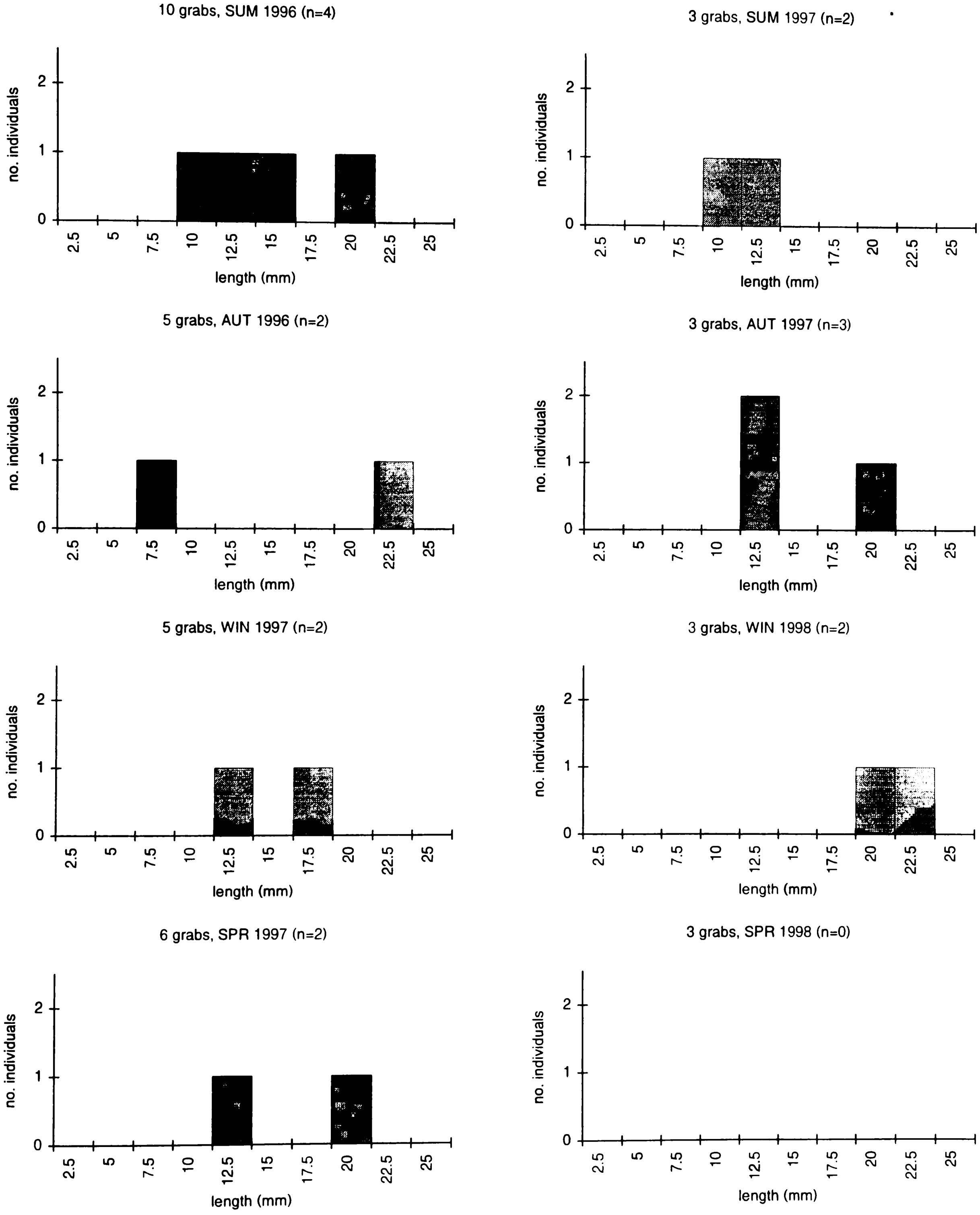
Observations in aquaria revealed that the bivalve's siphons were short and restricted these filter feeders to the upper 5 cm of sediment. Thus grab sampling provided accurate counts for this species *cf.* deep burrowing bivalves (e.g. *Lutraria angustior* and *Mya truncata*) which were seldom caught (Hall-Spencer & Atkinson, in press). This species is widely distributed in coarse deposits around the British Isles from low water to depths of 110 m with records north to Norway and south to the Mediterranean and Morocco (Tebble, 1966). The sparse distribution of *C. fasciata* meant that it was a minor contributor to biomass in grab samples from UKC. It made up 1.7% of faunal wet weight in 38 grabs from the area while mean wet weight (including shells) varied from 0-700 mg per 0.1 m^2 (Fig. 3.27B).

Fig. 3.27. A) Mean number and B) biomass (g wet weight) of *C. fasciata* per 0.1 m^2 grab at UKC. Error bars = SD, n = number of grabs analysed.



The seasonal variation in size-frequency of *C. fasciata* collected in grab samples at UKC is given in Fig. 3.28. Little can be deduced concerning the population dynamics of this species due to the low numbers obtained by quantitative means. The shells in grab samples ranged from 5.0–24.9 mm long and specimens of 2–27 mm long were collected by Ring Dredging. Thus a range of year classes had successfully recruited to this area of maerl.

Fig. 3.28. Size-frequency histograms for *C. fasciata* collected seasonally in 0.1 m^2 grabs at UKC from 1996-1998. n = number of individuals measured.

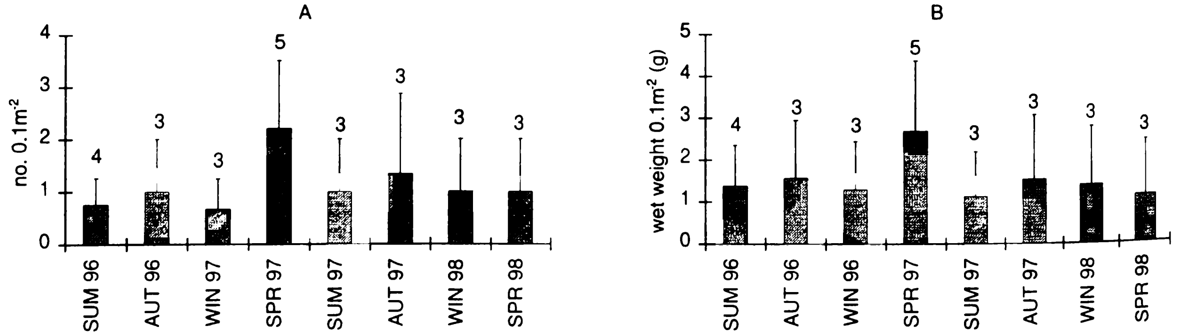


Clausinella fasciata was more abundant at UKI than at UKC which was perhaps a reflection of the coarser nature of the sediment at the UKI site.

These bivalves were again associated with the very surface layer of maerl gravel and were readily preyed upon by gastropods (*Polinices montagui* and *P. pulchellus*) and starfish (*Asterias rubens* and *Marthasterias glacialis*) regularly fed on it (Hall-Spencer *et al.,* 1999). *Clausinella fasciata* was one of the most resilient species to large-scale disturbance of the surface layer of sediment brought about by storms (Hall-Spencer & Atkinson, in press) and scallop dredging (Hall-Spencer & Moore, in press b).

This species occurred in 20 out of 27 sieved van Veen grabs and was chosen as a key species since it was the most abundant bivalve collected in grab samples at UKI. There were no significant differences observed in its seasonal abundance with *ca* 1 individual per 0.1 m^2 throughout the sampling period (Fig. 3.29A) and up to 4 individuals per grab. Bivalves made the largest contribution to faunal biomass at this site and the mean wet weight of *C. fasciata* was 1.1–2.7 g per 0.1 m^2 (Fig. 3.29B). Other, larger bivalves were common below the depth sampled by van Veen grabs.

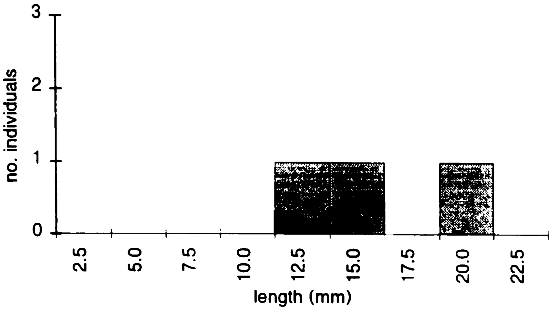
Fig. 3.29. A) Mean number and B) biomass (g wet weight) of *C. fasciata* per 0.1m^2 grab at UKI. Error bars = SD, N = number of grabs taken.



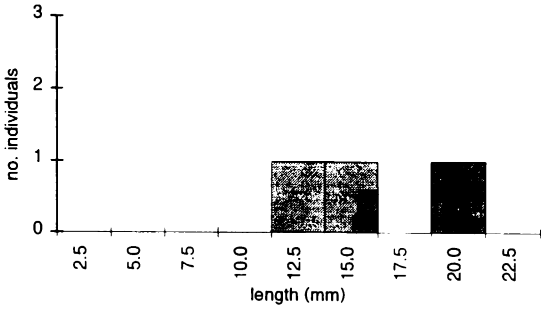
The seasonal variation in size-frequency of *C. fasciata* collected in grab samples at UKI is given in Fig. 3.30. The shells caught in grab samples ranged from 1–22 mm long although larger specimens (to 27 mm long) were collected by divers.

Fig. 3.30. Size-frequency histograms for *C. fasciata* collected seasonally in 0.1m^2 grabs at UKI from 1996-1998. SUM = summer, AUT = autumn, WIN = winter, SPR = spring and N = number of individuals measured.

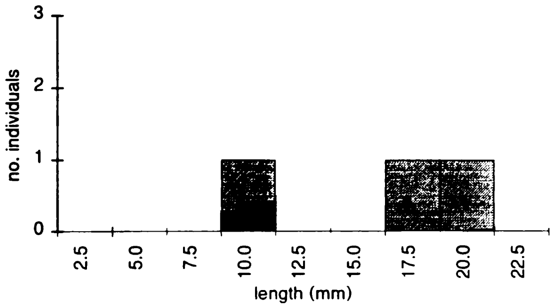
4 grabs, SUM 1996 (n=3)



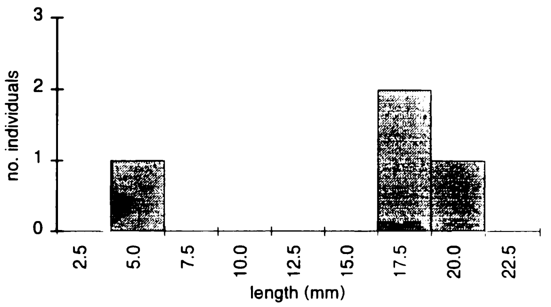
3 grabs, SUM 1997 (n=3)



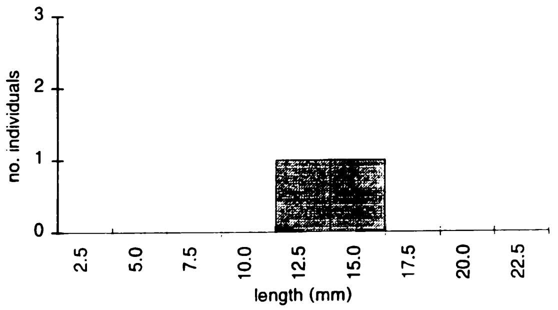
3 grabs, AUT 1996 (n=3)



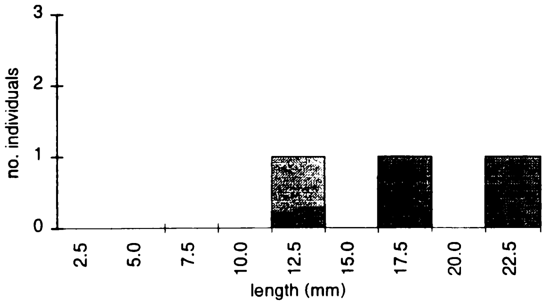
3 grabs, AUT 1997 (n=4)



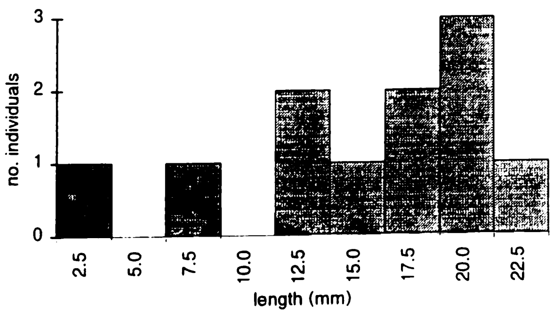
3 grabs, WIN 1997 (n=2)



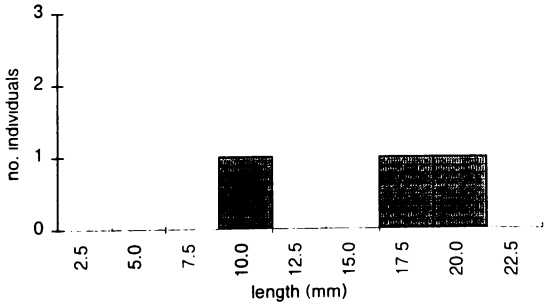
3 grabs, WIN 1998 (n=3)



5 grabs, SPR 1997 (n=11)



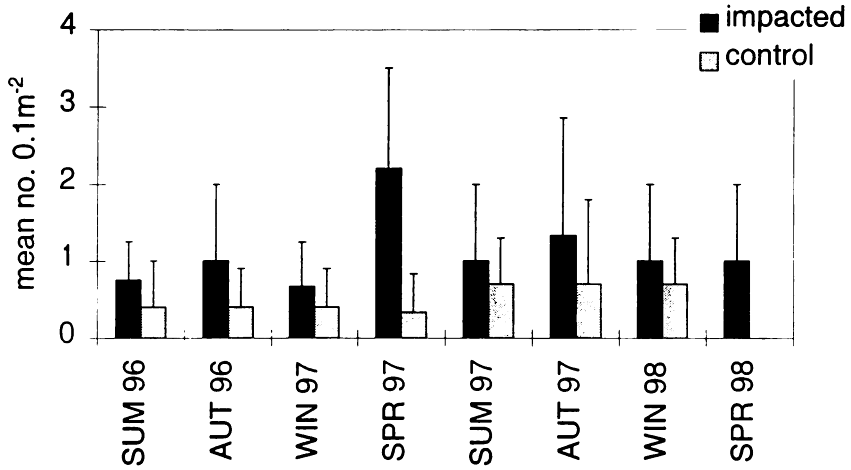
3 grabs, SPR 1998 (n=3)



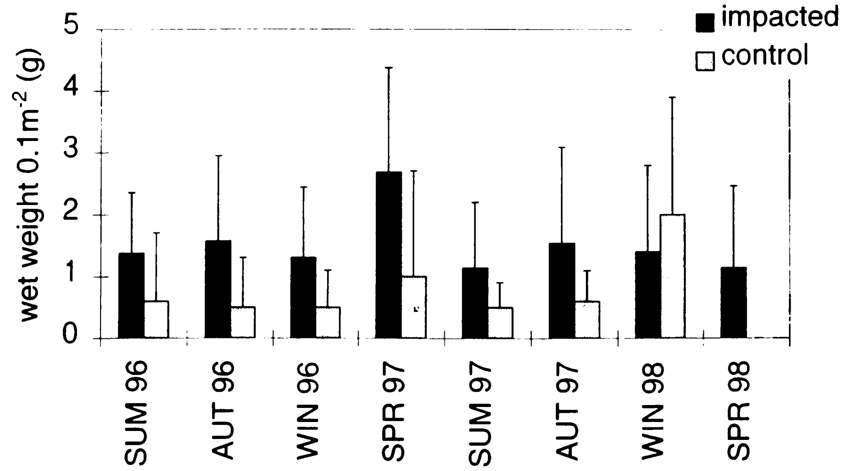
There was little difference in the abundance and biomass of *Clausinella fasciata* between the two Clyde maerl grounds studied (Fig. 3.31). These bivalves were regularly included in grab samples on both grounds, although they were consistently . more abundant at UKI with *ca* 1 individual per 0.1 m^2 as opposed to *ca* 0.4 individauals per 0.1 m^2 at UKC. The coarse maerl gravel at UKI may be better suited to *C. fasciata* than the maerl at UKC which had a higher silt content. Annual recruitment to both of the grounds studied was low. 90% of the bivalves collected in the two year grab sampling programme were >10 mm diameter and only one individual was <2.5 mm long.

Fig. 3.31

Seasonal variation in mean abundance (± s.d.) of *C. fasciata* on UK impacted and control grounds



Seasonal variation in mean biomass (± s.d.) of *C. fasciata* on UK impacted and control grounds



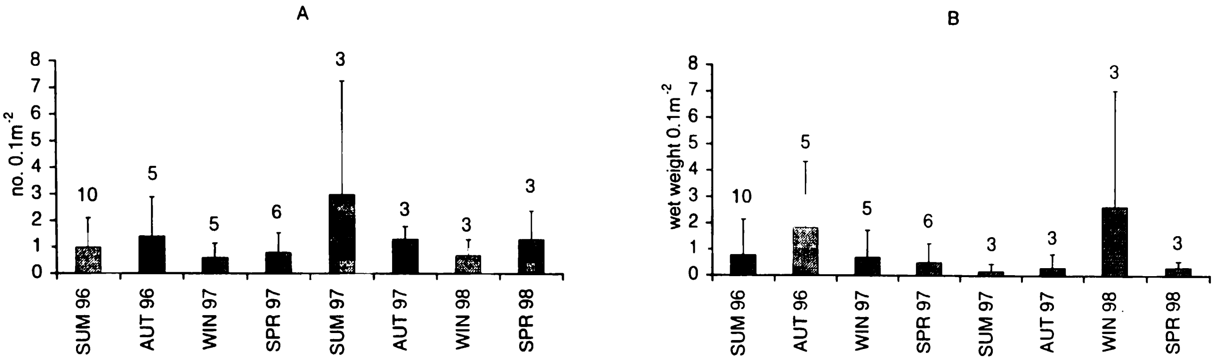
Dosinia exoleta (Linnaeus,1758)

This was the most abundant bivalve at UKC although more *L. hians* were collected in van Veen grabs (as they occurred on the sediment surface and so were sampled more efficiently). *Dosinia exoleta* was common in Ring Dredge and core samples and occurred in 26 out of the 38 grab samples analysed with seasonal means of 0.6–3.0 and up to 8 individuals per 0.1 m^2 (Fig. 3.32A). Air-lifting revealed 2–5 individuals per 0.1 m^2 with small individuals (<2 cm long) located near the maerl surface and larger ones (<6 cm long) common to a maximum of 28 cm (Hall-Spencer & Atkinson, in press).

Divers saw that these and other infaunal bivalve species did not extend their siphons to the sediment surface but suspension fed on interstitial water increasing circulation within the upper 5 cm of maerl sediment. In this manner the bivalves avoided loss of their siphon tips to demersal fish and were able to live deeper within the sediment and so were more difficult for predators to extract. The main predators of juveniles were *Polinices montagui* and *P. pulchellus* while *Cancer pagurus, Asterias rubens* and *Marthasterias glaciale* fed upon the adults. The occurrence of *D. exoleta* in Scottish maerl beds was expected, given their known distribution and sediment preferences. This bivalve has been recorded throughout Europe from Norway in the north and to Congo in the south (Fischer-Piette 1967). Tunberg (1984) noted that *D. exoleta* burrowed deeply into shelly or muddy gravels from low in the intertidal zone to depths of about 140 m.

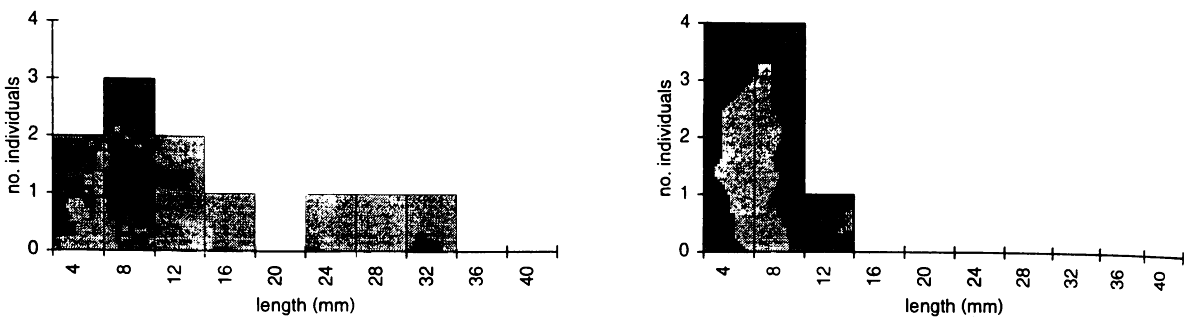
The contribution that this species made to biomass in grab samples from UKC was variable as a few samples contained one or two large specimens but in the majority of grabs only juvenile specimens and siphon tips were collected. Overall, *D. exoleta* made up 2.6% of the wet weight of fauna collected in 38 grabs from the area. Mean wet weight (including shells) varied from 0.2–2.7 mg per 0.1 m^2 grab (Fig. 3.32B).

Fig. 3.32. A) Mean number and B) biomass (mg wet weight) of *D. exoleta* per 0.1 m^2 grab at UKC. Error bars = SD, n = number of grabs analysed.

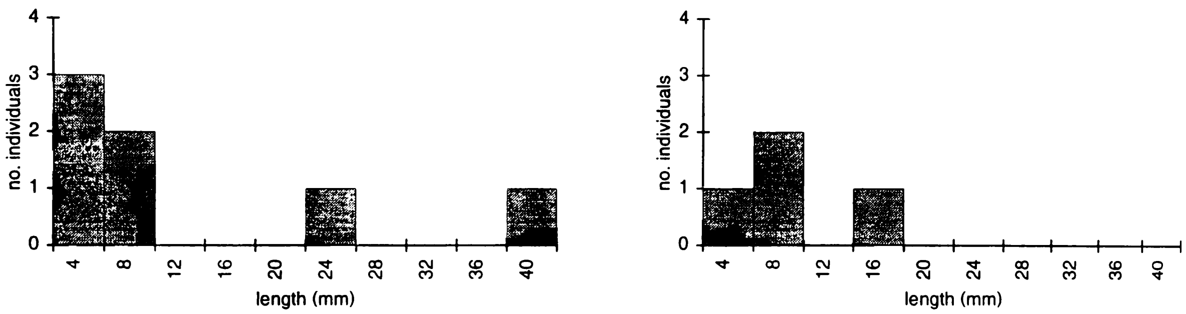


The seasonal variation in size frequency of *D. exoleta* sampled in grabs at UKC are given in Fig. 3.33. The animals collected in grabs ranged from 2–40 mm in length with individuals up to 60 mm long collected in air-lift samples from the area.

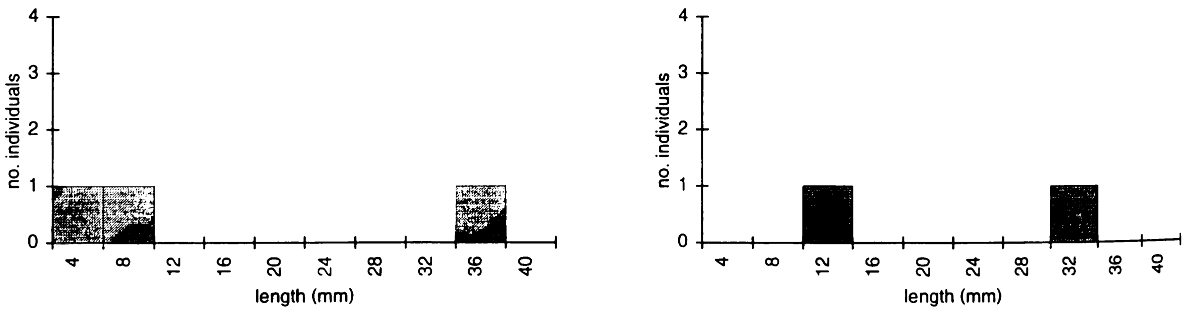
Fig.3.33. Size-frequency histograms for *D. exoleta* collected seasonally in 0.1 m^2 grabs at UKC from 1996–1998. n = number of individuals measured.


10 grabs, SUM 1996 (n=11)

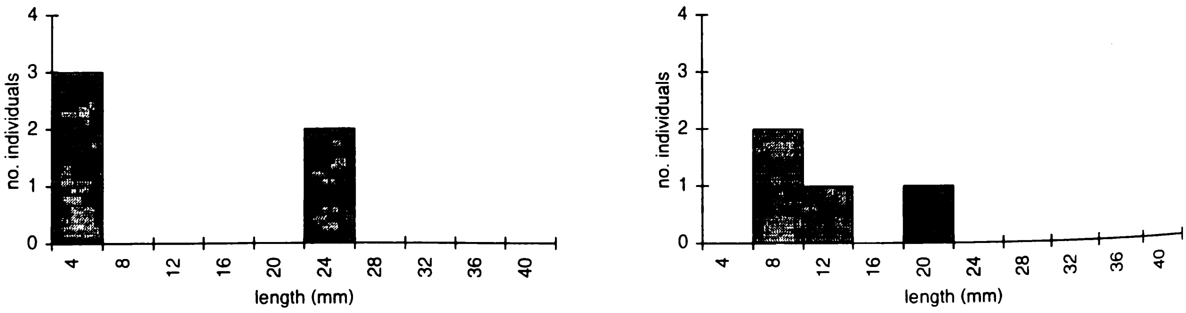
3 grabs, SUM 1997 (n=9)


5 grabs, AUT 1996 (n=7)

3 grabs, AUT 1997 (n=4)


5 grabs, WIN 1997 (n=3)

3 grabs, WIN 1998 (n=2)

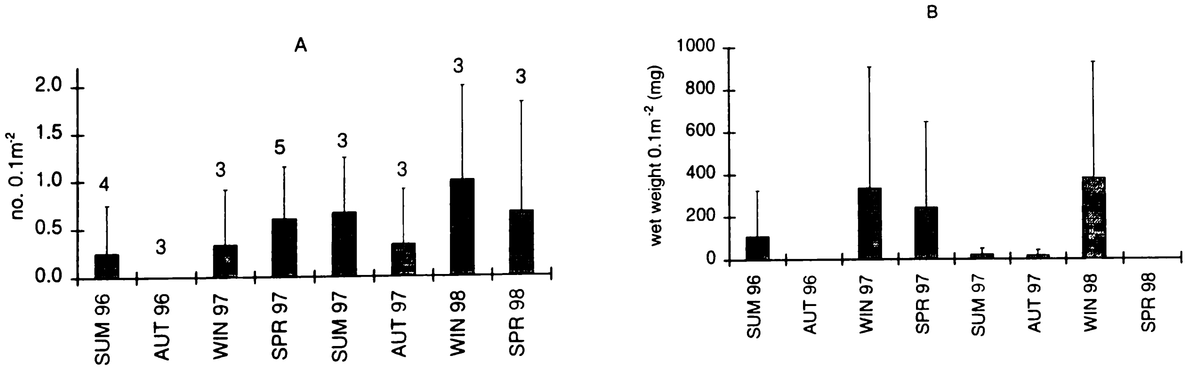

6 grabs, SPR 1997 (n=5)

3 grabs, SPR 1998 (n=4)

As at UKC, this was also the most abundant species of bivalve present at UKI. *Dosinia exoleta* were common in Ring Dredge and core samples and occurred in 11 out of 27 grab samples analysed with means of 0.25–1.0 and up to 2 individuals per · 0.1 m^2 (Fig. 3.34A). This species was one of the deepest burrowing molluscs at UKI (Hall-Spencer & Atkinson, in press) and so its abundance was underestimated by grab sampling. Use of a diver-operated air-lift revealed 15–40 individuals per m^2.

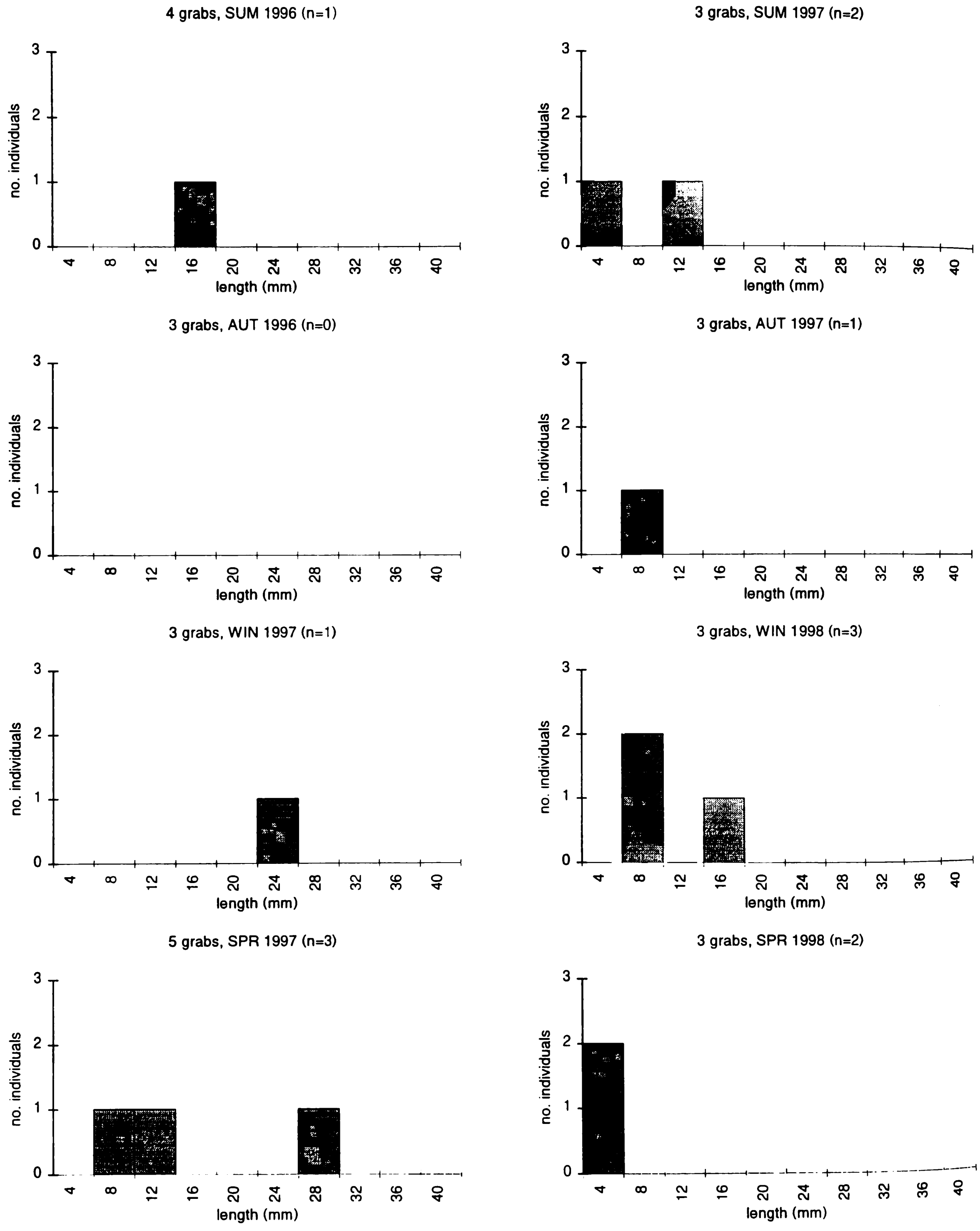
Empty shells of *D. exoleta* littered the maerl surface providing hard substrata for the attachment of sessile organisms such as serpulids, barnacles and bryozoans. The empty bivalves were also inhabited by a variety of benthic animals (e.g. *Galathea intermedia*, *Pisidia longicornis*, juvenile *Aequipecten opercularis* and *Diplecogaster bimaculata*) as protection from predators. The biomass estimates given in Fig. #B represent minimum values since large individuals occurred below the depth to which the grab sampler penetrated.

Fig. 3.34 A) Mean number and B) biomass (mg wet weight) of *D. exoleta* per 0.1m^2 grab at UKI. Error bars = SD, N = number of grabs taken.



The seasonal variation in size-frequency of *D. exoleta* collected in grab samples at UKI is given in Fig. 3.35. The shells caught in grab samples ranged from 1–30 mm long since grab sampling was biased towards the smaller size spectra. Larger specimens (to 60 mm long) were collected by diver-operated air-lift.

Fig. 3.35. Size-frequency histograms for *D. exoleta* collected seasonally in $0.1 m^2$ grabs at UKI from 1996-1998. SUM = summer, AUT = autumn, WIN = winter, SPR = spring and N = number of individuals measured.



4 grabs, SUM 1996 (n=1)

3 grabs, SUM 1997 (n=2)

3 grabs, AUT 1996 (n=0)

3 grabs, AUT 1997 (n=1)

3 grabs, WIN 1997 (n=1)

3 grabs, WIN 1998 (n=3)

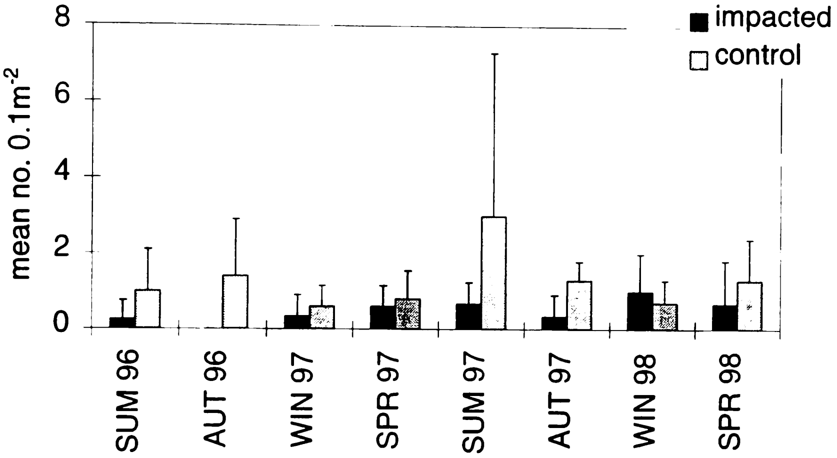
5 grabs, SPR 1997 (n=3)

3 grabs, SPR 1998 (n=2)

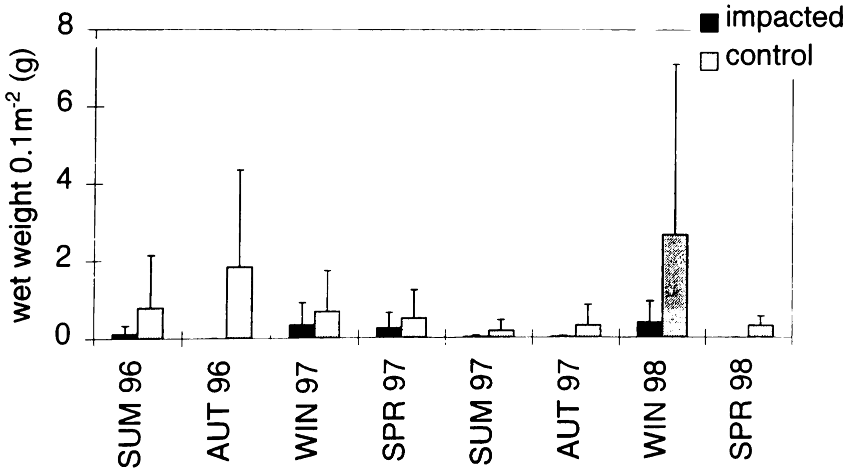
A direct comparison of the abundance and biomass of *Dosinia exoleta* collected in grab samples from UKI and UKC is given in the figure below (Fig. 3.36). This species was more numerous at UKC, possibly since UKI experienced more physical disturbance.

Fig. 3.36

Seasonal variation in mean abundance (± s.d.) of *D. exoleta* on UK impacted and control grounds



Seasonal variation in mean biomass (± s.d.) of *D. exoleta* on UK impacted and control grounds

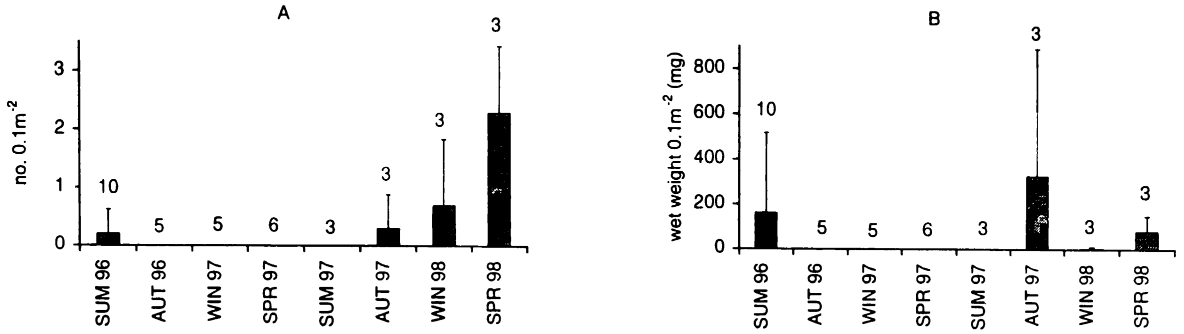


Thracia villosiuscula (Macgillivray, 1827)

This bivalve mollusc was more sparsely distributed than the other key bivalve species at UKC (*Limaria hians*, *Dosinia exoleta* and *Clausinella fasciata*) but was seen in Ring Dredge, core and air-lift samples of the surface sediment throughout the 1996–1998 period. It occurred in 7 out of 38 van Veen grabs with seasonal means of 0–2.3 individuals (and a maximum of 3 individuals) collected per 0.1 m^2 grab (Fig.3.37A). The apparent increase in abundance towards the end of the monitoring programme (Fig. 3.37A) is an artefact resulting from the patchy distribution of this species. Ring Dredge and air-lift sampling indicated that the population density of this species remained similar throughout the monitoring period.

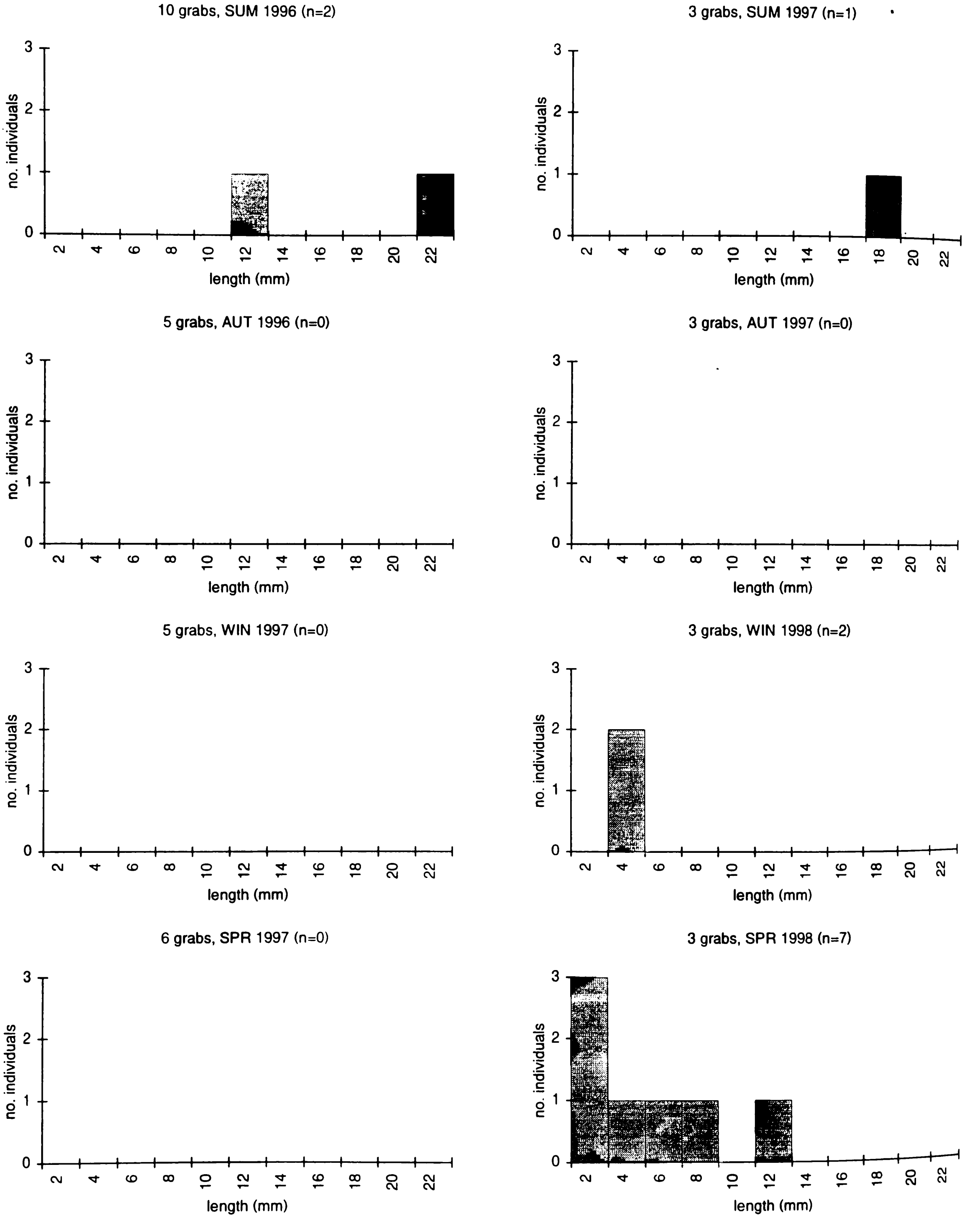
Divers found this suspension-feeding bivalve living in sandy loci within the upper 10 cm of the maerl. The dead shells of this species were often drilled by *Pollinices* spp. Tebble (1966) noted that *T. villosiuscula* lived in coarse sand and fine gravel from low in the intertidal zone to *ca* 55m offshore. It has been recorded from most parts of the British Isles (Seaward, 1982) and is known northwards to northern Norway and southwards to Madeira and the Mediterranean (Tebble, 1966). Despite its relatively thin shell, it was amongst a suite of organisms that were resistant to disturbance by experimental scallop dredging. The gastropod *Buccinum undatum* fed on some of the disrupted individuals, but most were able to reburrow and escape predation. This small species was a minor contributor to biomass in grab samples from UKC. It made up 0.18% of the wet weight of fauna collected in 38 grabs from the area. Mean wet weights (including shells) varied from 0–327 mg per 0.1 m^2 grab (Fig. 3.37B).

Fig. 3.37. A) Mean number and B) biomass (mg wet weight) of *T. villosiuscula* per 0.1 m^2 grab at UKC. Error bars = SD, n = number of grabs analysed.



The seasonal variation in size-frequency of *T. villosiuscula* sampled in grabs at UKC are given in Fig. 3.38. The range in shell sizes (2–22 mm in length) indicated that several year classes were present with no single size class dominating the samples. Several small specimens were collected in one grab sample in spring 1998 reflecting the patchy distribution of this species.

Fig. 3.38. Size-frequency histograms for *T. villosiuscula* collected seasonally in 0.1 m^2 grabs at UKC from 1996-1998. n = number of individuals measured.



10 grabs, SUM 1996 (n=2)

3 grabs, SUM 1997 (n=1)

5 grabs, AUT 1996 (n=0)

3 grabs, AUT 1997 (n=0)

5 grabs, WIN 1997 (n=0)

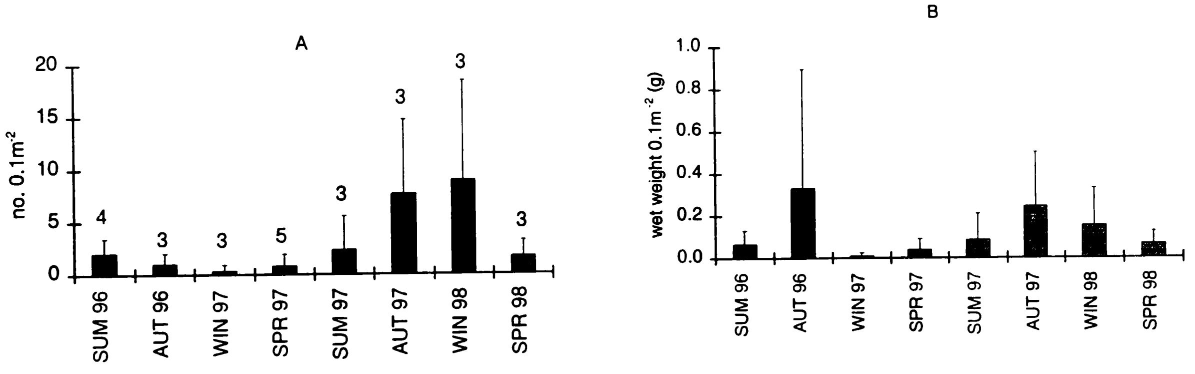
3 grabs, WIN 1998 (n=2)

6 grabs, SPR 1997 (n=0)

3 grabs, SPR 1998 (n=7)

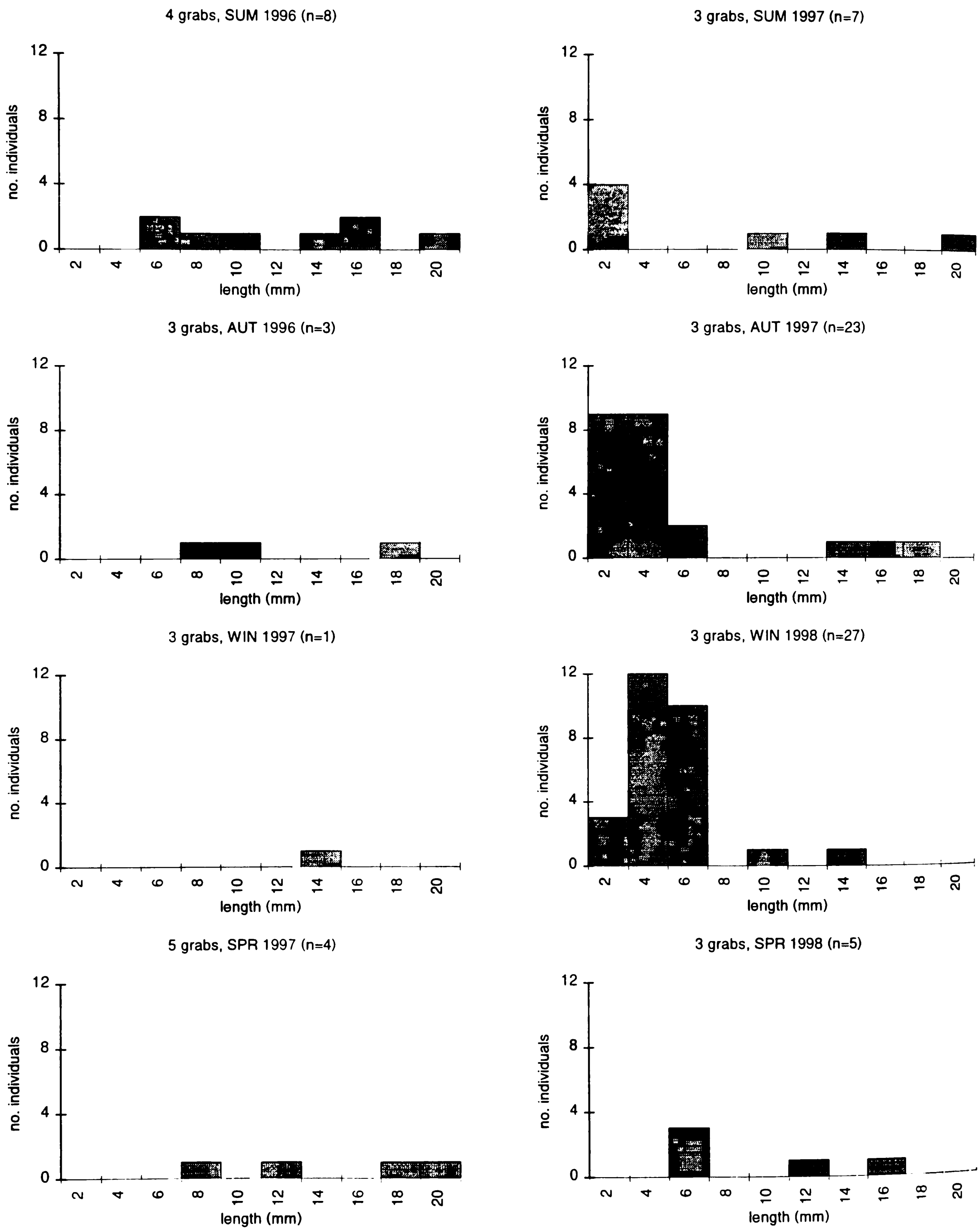
This species was one of the commonest bivalves at UKI. It occurred in the upper 10 cm layer of maerl and was seen in Ring Dredge, air-lift and core samples. It ocurred in 19 out of 27 van Veen grab samples taken in the area with seasonal means of 0.3–9.0 individuals (and a maximum of 20 individuals) collected per 0.1 m^2 grab (Fig. 3.39A). The biomass of this species varied between 0.1–0.3 mg wet weight per 0.1 m^2.

Fig. 3.39. A) Mean number and B) biomass (mg wet weight) of *T. villosiuscula* per 0.1m^2 grab at UKI. Error bars = SD, N = number of grabs taken.



The seasonal variation in size-frequency of *T. villosiuscula* sampled in grabs at UKI are given in Fig. 3.40. There was a range of adult shell sizes present throughout the 2 year monitoring period. Juveniles became abundant in October 1997 to March 1998, although few survived into the spring of 1998.

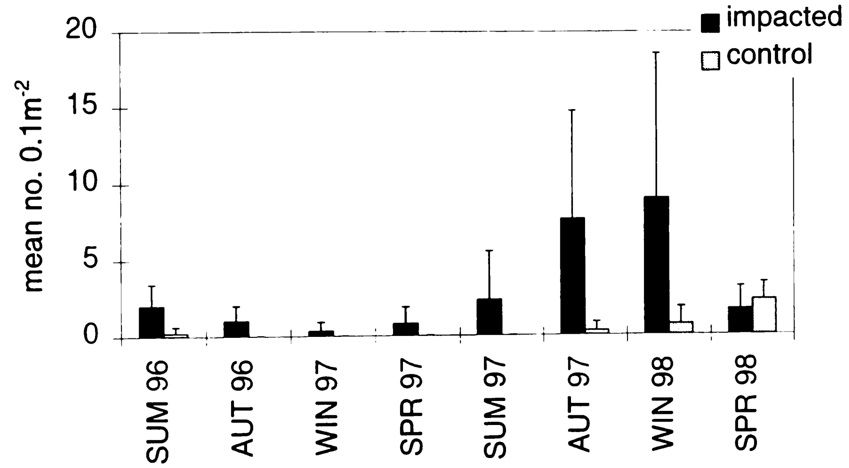
Fig. 3.40. Size-frequency histograms for *T. villosiuscula* collected seasonally in 0.1m^2 grabs at UKI from 1996-1998. SUM = summer, AUT = autumn, WIN = winter, SPR = spring and N = number of individuals measured.



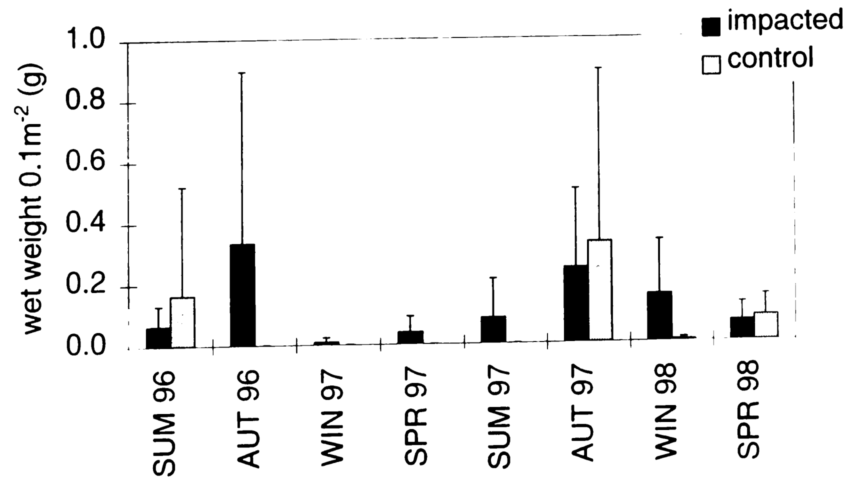
The figure below (Fig. 3.41) compares the abundance and biomass of the small, thin shelled bivalve, *Thracia villosiuscula* caught in grabs over a two-year period on two maerl grounds in the Firth of Clyde. Supplementary sampling using diver-operated air-lifts and Ring Dredges revealed that this species was present year-round at both sites with about 5–10 individuals per m^2. Juveniles settled in large numbers at UKI the Summer of 1997 although few survived to the following spring.

Fig. 3.41.

Seasonal variation in mean abundance (± s.d.) of *T. villosiuscula* on UK impacted and control grounds



Seasonal variation in mean biomass (± s.d.) of *T. villosiuscula* on UK impacted and control grounds



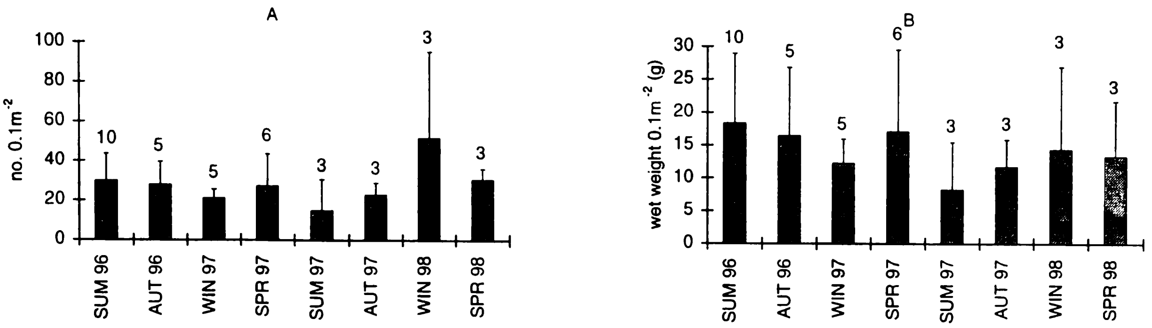
Ophiocomina nigra (Abildgaard, 1789)

One of the main differences between the two study sites was that this brittlestar was densely aggregated over the surface of maerl gravel at UKC throughout the sampling period from 1996–1998 whereas adults of this species were absent from UKI. It was common in Ring Dredge, core and air-lift samples and was present in all 38 van Veen grab samples analysed from UKC with means of 16–55 and up to 108 individuals collected per $0.1m^2$ (Fig. 3.42A).

This species normally lay on the maerl sediment surface with arms extended into the water column to feed but when tidal streams were strongest (>40 cm s^{-1}), the brittlestars entwined arms and lay flat against the sea bed, apparently to prevent dislodgement. Immediately after scallop dredging, they switched to a scavenging mode of feeding, moving onto the dredge tracks to feed on damaged polychaetes, molluscs and crustaceans. The only predator seen feeding on these brittlestars was *Luidia ciliaris*, although *O. nigra* often had regenerating arm tips that are known to be a source of food for demersal fish and hermit crabs. Commensal copepods (*Collocheres elegans*) were noted, living amongst the spines of their host.

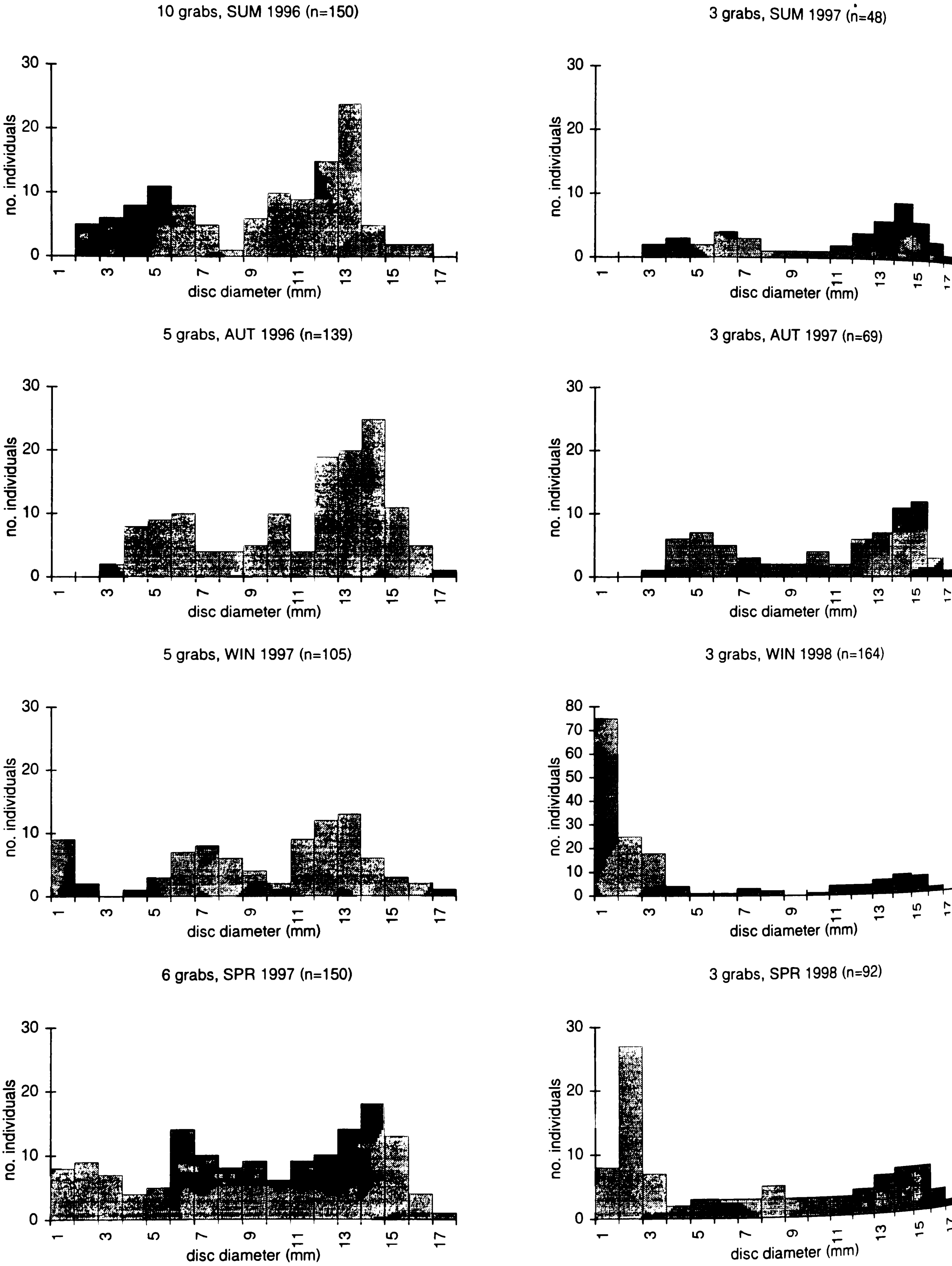
Ophiocomina nigra was the dominant contributor to biomass in grab samples from UKC since it was large, abundant and surface-dwelling. Other high biomass elements of the fauna (e.g. *Dosinia exoleta, Thyonidium drummondi*) were underestimated by grab sampling (see BIOMAERL team, 1998; Hall-Spencer & Atkinson, in press). *Ophiocomina nigra* made up 46.7% of the wet weight of organisms collected in 38 grab samples analysed from this area. Mean wet weights varied from 8–18 g per $0.1m^2$ grab (Fig. 3.42B).

Fig. 3.42. A) Mean number and B) biomass (g wet weight) of *O. nigra* per 0.1m^2 grab at UKC. Error bars = SD, n = number of grabs analysed.



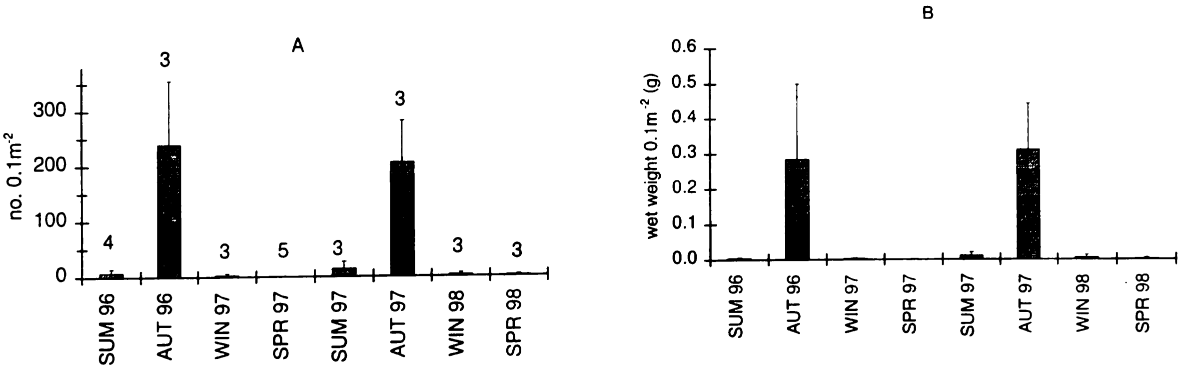
The seasonal variation in size-frequency of *O. nigra* sampled in grabs are given in Fig. 3.43. The largest individuals had disc diameters of 16.5 mm which suggests an age of *ca* 8 years based on known growth rates for the area. A Clyde-based study by Gorzula (1976) showed that this species lives up to 14 years and that the disc grows about 2 mm y^{-1} to a maximum of 26 mm. Disc diameter was chosen for biometric measurements as the arms were frequently damaged. In summer and autumn months of each year the population had a bimodal structure centred around size classes of 6 mm (*ca* 3 years old) and 14 mm (*ca* 7 years old). In winter and spring months the population had a trimodal structure as juveniles were retained on a 1 mm sieve. We infer from Fig. 3.43 that juveniles present early in 1997 had poor survival rates since few small *O. nigra* (disc diameter <3 mm) were collected later in the year. Recruitment of small brittlestars (<3 mm) was high in the winter of 1998 (*ca* 40 per 0.1 m^2 grab) but again their mortality appeared high since <15 per 0.1 m^2 grab were sampled the following season. This pattern is similar to that described by Gorzula (1976) who found that *O. nigra* beds typically had a uni- or bimodal size distribution patterns and postulated that high population densities of adults inhibit further recruitment to the population through predation of conspecific larvae.

Fig. 3.43. Size-frequency histograms for *O. nigra* collected seasonally in 0.1m^2 grabs at UKC from 1996–1998. SUM = summer, AUT = autumn, WIN = winter, SPR = spring. n = number of individuals measured



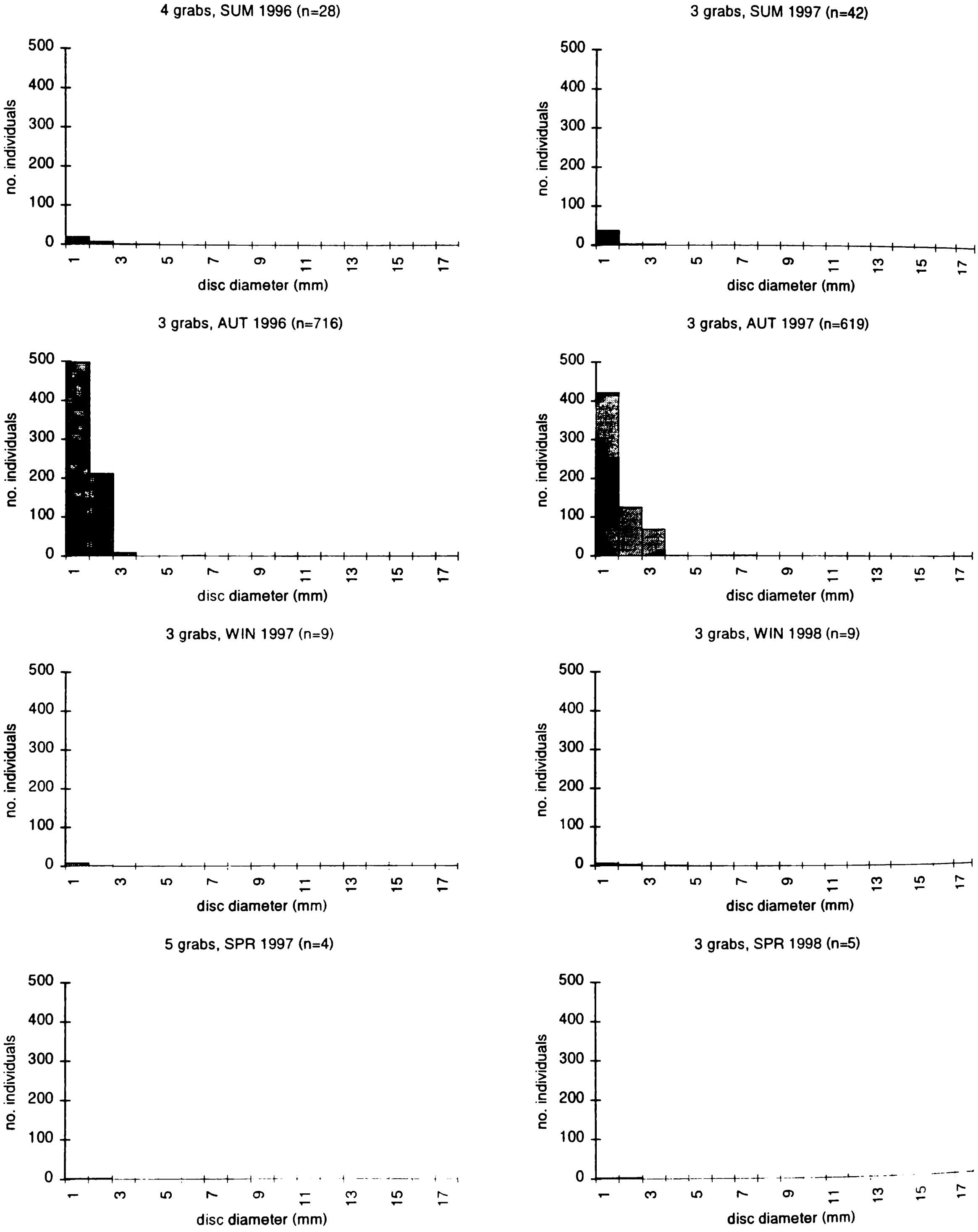
Adult *Ophiocomina nigra* did not occur on the maerl at UKI, yet they were the most abundant and highest biomass element of the fauna at UKC. Reasons for this major discrepancy in the ecology of these grounds may relate to a history of scallop dredging at UKI but also appear to be strongly linked to the degree to which the UKI site was disturbed by storms each winter. Enormous numbers of juvenile *O. nigra* recruited to UKI in the summer of 1996 and 1997, although most of these were not retained by the 1mm sieve used (Hall-Spencer, pers. obs.). In the autumn of 1996 and 1997 *ca* 200 juveniles per 0.1 m^2 were retained in 1 mm sieved grab samples (Fig. 3.44A). Linked to this settlement was a small increase in the biomass of *O. nigra* present to *ca* 0.3 g wet weight per 0.1 m^2 (Fig. 3.44B). In both years there was mass mortality of these juveniles with no recruitment to the adult population, possibly due to the extensive shifts in surface sediment that were recorded each winter (see Hall-Spencer & Atkinson, in press), or to predation.

Fig. 3.44. A) Mean number and B) biomass (g wet weight) of *O. nigra* per 0.1m^2 grab at UKI. Error bars = SD, N = number of grabs taken.



The seasonal variation in size-frequency of *O. nigra* sampled in grabs at UKI are given in Fig. 3.45. It is evident from these histograms that juvenile recruitment was high in the autumn of each year, but that few survived each winter. This was supported by regular *in situ* diving observations. No adult *O. nigra* were ever found on the maerl ground although adult *Ophiothrix fragilis* and *Ophiopholis aculeata* were sparsely distributed. The behaviour of these other species probably conferred protection from the effects of wave action since they lived in the crevices of dead mollusc shells and *Laminaria saccharina* holdfasts.

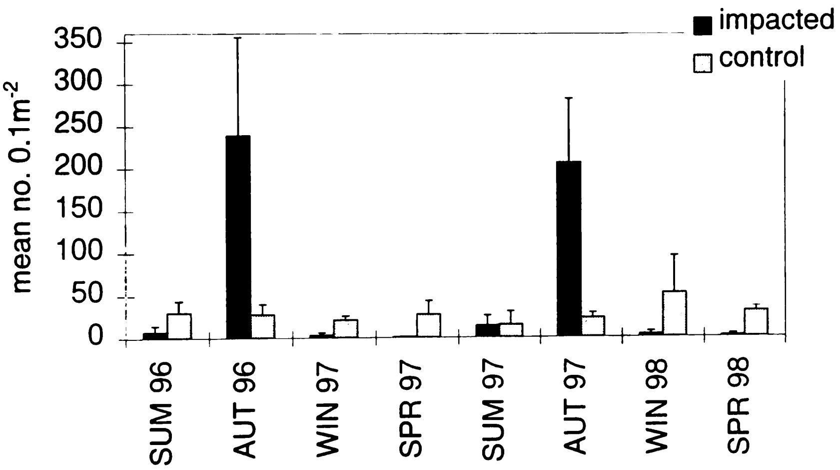
Fig. 3.45. Size-frequency histograms for *O. nigra* collected seasonally in 0.1 m^2 grabs at UKI from 1996-1998. SUM = summer, AUT = autumn, WIN = winter, SPR = spring and N = number of individuals measured.



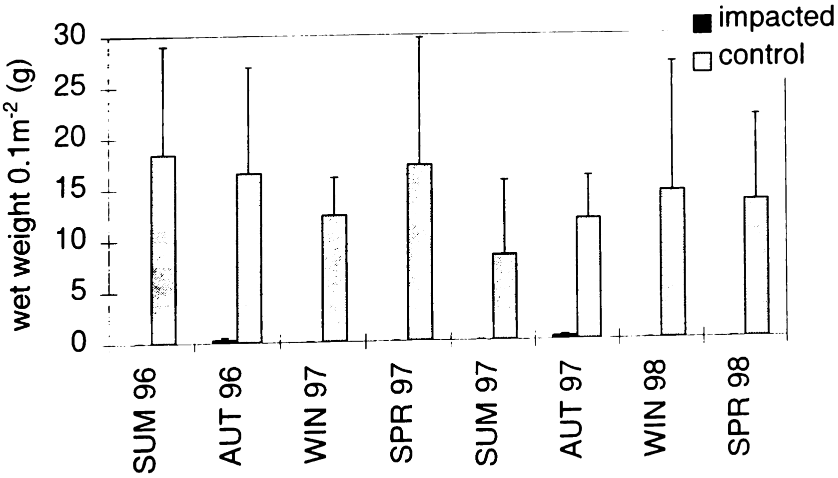
A comparison of abundance and biomass of *Ophiocomina nigra* between the impacted and control grounds is provided in the figure below (Fig. 3.46). A large influx of juveniles occurred each year at UKI and survived to a size of 3 mm disc diameter but mass mortality followed each winter. No adults were found at this site throughout the 2- year monitoring period. At UKC the situation was far more stable with *ca* 25 individuals per 0.1 m^2 throughout. Juvenile recruitment appeared to be suppressed by the adult population on the UKC ground (see also Gorzula, 1976).

Fig. 3.46.

Seasonal variation in mean abundance (± s.d.) of *O. nigra* on UK impacted and control grounds



Seasonal variation in mean biomass (± s.d.) of *O. nigra* on UK impacted and control grounds



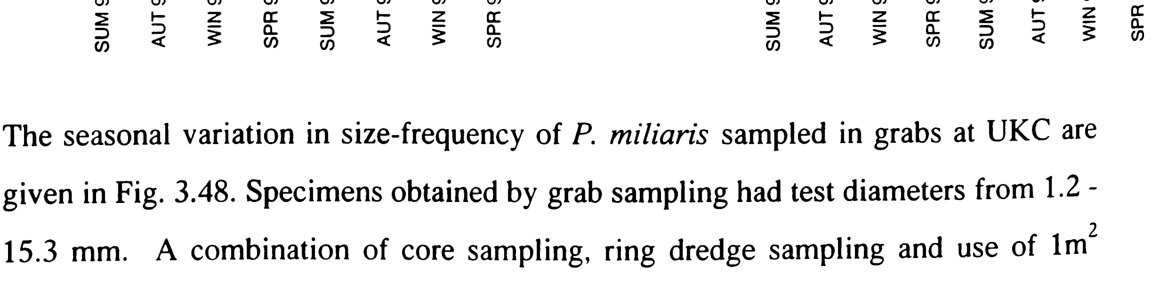
***Psammechinus miliaris* (Gmelin, 1778)**

This sea urchin was common on and amongst the surface layer of maerl at UKC throughout the 1996-1998 sampling period. It occurred in 33 out of the 38 grab samples with up to 14 per 0.1m^2 grab sample (Fig. 3.47A). *Paracentrotus lividus* appears to take the place of *Psammechinus miliaris* on maerl beds in Galway Bay where densities of over 1600 m^{-2} have been reported (Keegan, 1974).

Divers observed these omnivorous sea urchins grazing over and amongst the surface 2 cm layer of maerl. Morse & Tyler (1990) noted that this species was frequently recorded from the intertidal and shallow sublittoral with occasional records down to about 100 m. It is common on all coasts of the British Isles and is distributed elsewhere from Iceland, Scandinavia, Baltic, North Sea, southwards to Morocco and the Azores. It is not present in the Mediterranean, where a separate species (*P. microtubercularis* (Blainville)) occurs and extends to Portugal.

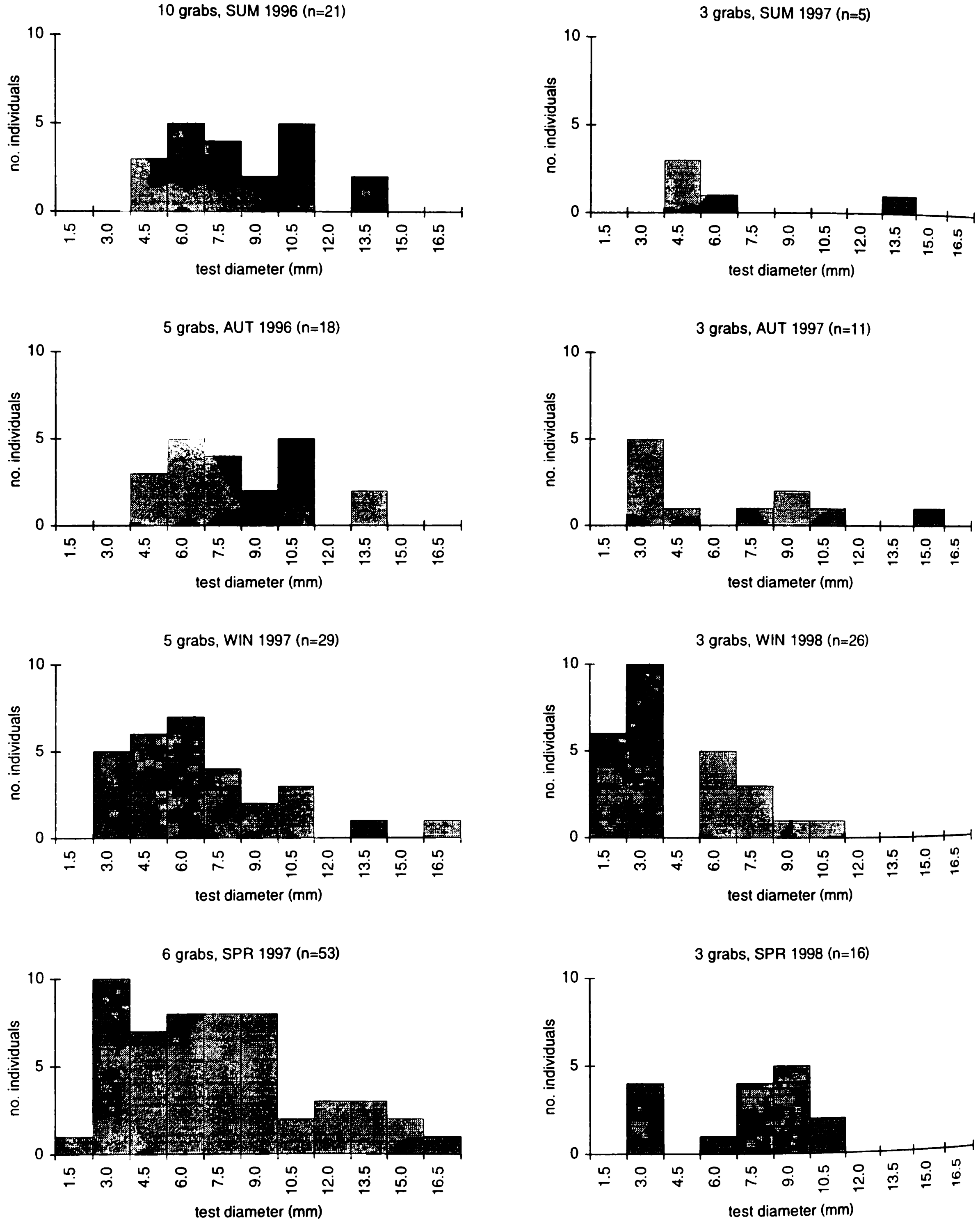
This species made a significant contribution to the biomass obtained in grab samples from UKC. It made up 2% of the faunal wet weight in 38 grab samples analysed from the area. Mean wet weights varied from 326-1430 mg per 0.1 m^2 grab (Fig. 3.47B).

Fig. 3.47. A) Mean number and B) biomass (mg wet weight) of *P. miliaris* per 0.1 m^2 grab at UKC. Error bars = SD, N = number of grabs analysed.



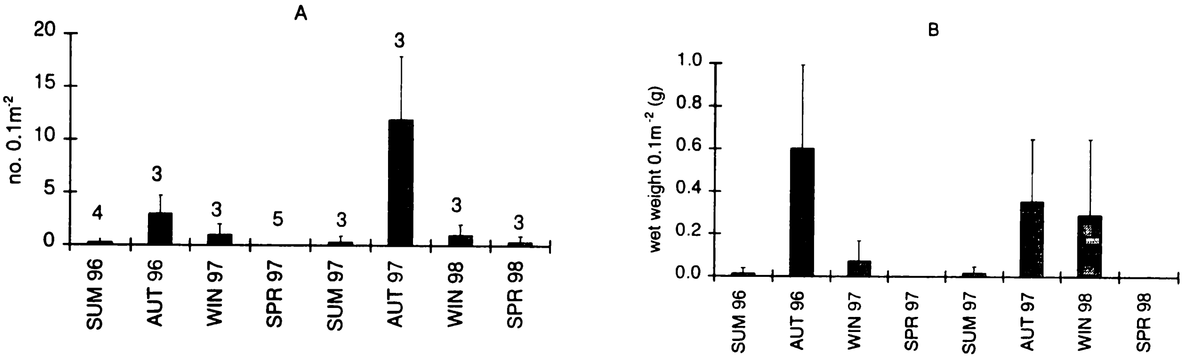
The seasonal variation in size-frequency of *P. miliaris* sampled in grabs at UKC are given in Fig. 3.48. Specimens obtained by grab sampling had test diameters from 1.2 - 15.3 mm. A combination of core sampling, ring dredge sampling and use of 1m^2 quadrats in direct diver observations revealed that most specimens were juvenile and that all were <30 mm in diameter. Test diameters typically reach 50 mm in diameter for adults which were common on rocky habitats surrounding the maerl bed. Thus maerl beds may be favourable recruitment grounds for juvenile *P. miliaris* which . move onto rocky substrata as they grow larger. The abundance of these sea urchins decreased each summer, possibly as they moved away from the maerl habitat. In W.Ireland, maerl beds have been reported as being nursery grounds for the black sea urchin, *Paracentrotus lividus* (Minchin, 1997; Birkett *et al.*, 1998).

Fig. 3.48. Size-frequency histograms for *P. miliaris* collected seasonally in 0.1m2 grabs at UKC from 1996-1998. SUM = summer, AUT = autumn, WIN = winter, SPR = spring and n = number of individuals measured.



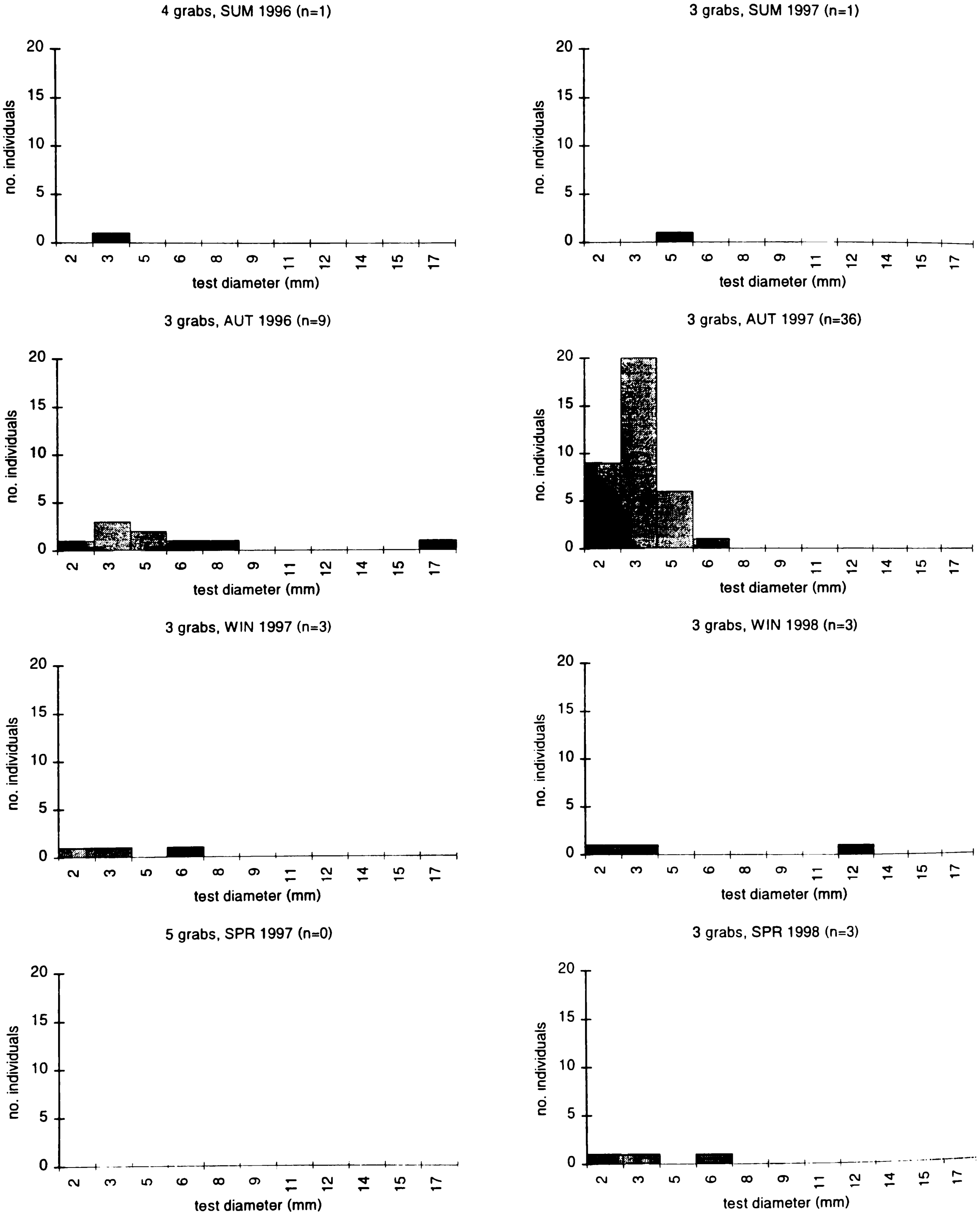
Divers noted that this sea urchin was much less common at UKI than at UKC (Fig. 3.49) and this was reflected in the regular van Veen grab sampling programme. It occurred in 14 out of 27 grab samples taken in the area and frequently occurred in . Ring Dredge samples.

Fig. 3.49. A) Mean number and B) biomass (g wet weight) of *P. miliaris* per $0.1m^2$ grab at UKI. Error bars = SD, N = number of grabs taken.



As Fig. 3.50 illustrates, the *P. miliaris* present at UKI tended to be juvenile specimens <6 mm in test diameter. These sea urchins, together with small *Echinus esculentus*, grazed amongst the interstices of maerl thalli and had high recruitment success to the area. Judging by the abundance of dead tests amongst the maerl, many of the juveniles perished while others moved away as they became larger. As at UKC, juveniles were common in the maerl but rare on surrounding rocky areas while the converse was true of the adults.

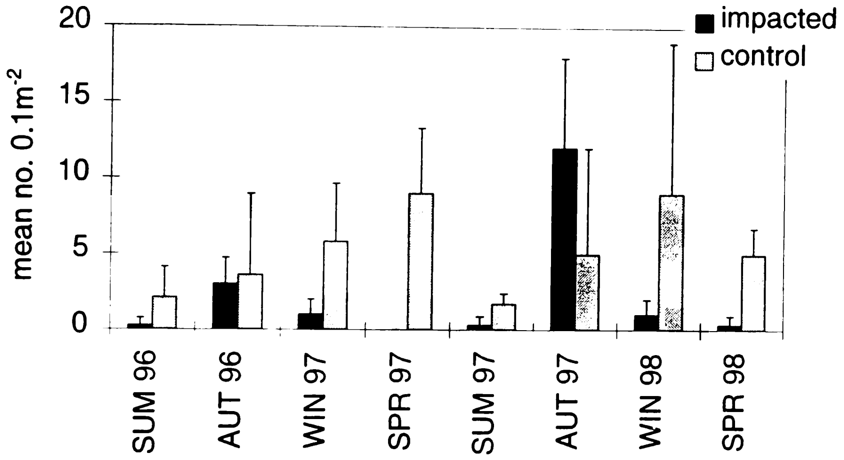
Fig. 3.50. Size-frequency histograms for *P. miliaris* collected seasonally in 0.1 m^2 grabs at UKI from 1996-1998. SUM = summer, AUT = autumn, WIN = winter, SPR = spring and N = number of individuals measured.



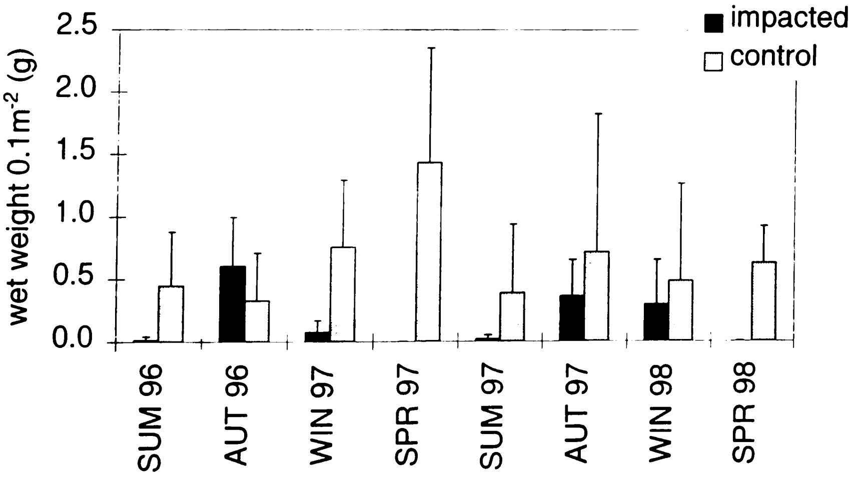
Psammechinus miliaris were more abundant and had a higher biomass at the control site than at the impacted site (Fig. 3.51). Collections made by hand from 1 m^2 quadrats revealed that population densities of *ca* 100 individuals per m^2 were usual at UKC whereas *ca* 10 individuals per m^2 were usual at UKI. This may relate to the increased degree of physical disturbance at UKI where numbers of individuals fell each winter.

Fig. 3.51.

Seasonal variation in mean abundance (± s.d.) of *P. miliaris* on UK impacted and control grounds



Seasonal variation in mean biomass (± s.d.) of *P. miliaris* on UK impacted and control grounds



Echinocyamus pusillus **(O. F. Müller, 1776)**

These small echinoids are the Clypeasteroidea in the British Isles. They have strong shells and are intermediate in form between sea urchins and sand dollars. They were a characteristic member of the fauna at UKC, being present in Ring Dredge, Air-lift, core and van Veen samples from the area. They were the 3rd most abundant out of 18 species of echinoderm present in grabs (after *O. nigra* and *P. miliaris*) and occurred in 34 out of 38 grabs with means of 2-8 per season and up to 10 individuals per 0.1 m^2 (Fig. 3.52A).

Echinocyamus pusillus burrowed actively through the surface 5 cm layer of maerl. Their guts contained small particles (<1 mm) from a range of sources, including multicellular algae and foraminiferans although diatoms formed the greatest part of recognizable material. This was one of the few organisms that was recorded in each of the BIOMAERL study areas. It has been recorded from the intertidal zone down to 1250 m and occurs north to Finmark, Iceland, south to the Azores and Cape Bojador in the Atlantic and east into the Mediterranean as far as the Marmara Sea (Mortensen, 1927, 1948). Our finding that *E. pusillus* is prevalent in the maerl beds of Europe fits in well with what is known of its habitat preferences. Studies on the west coast of Scotland showed that *E. pusillus* was commonest in shallow water (10-20 m) and very sparse below 50 m (Telford *et al.*, 1983). Several workers have noted that *E. pusillus* is found on coarse, clean sediments and is absent from muddy conditions (e.g. Mortensen, 1948; Nichols, 1959, Ghiold, 1982), while Telford *et al.* (1983) noted that these echinoids were most frequently found in sediments exposed to wave and tidal activity.

This echinoid made a low contribution to overall biomass due to its small size. Air-lifting revealed that large the infaunal echinoderms *Echinocardium pennatifidum* and *Thyonidium drummondi* were much more important in their contribution to biomass but burrowed too deeply to be quantitatively sampled using grabs. *Echinocyamus pusillus* made up 0.72% of the wet weight of fauna collected in 38 grab samples analysed from the area. Mean wet weights varied from 150-480 mg per 0.1 m^2 grab (Fig. 3.52B).

Fig. 3.52. A) Mean number and B) biomass (mg wet weight) of *E. pusillus* per 0.1 m^2 grab at UKC. Error bars = SD, N = number of grabs analysed.

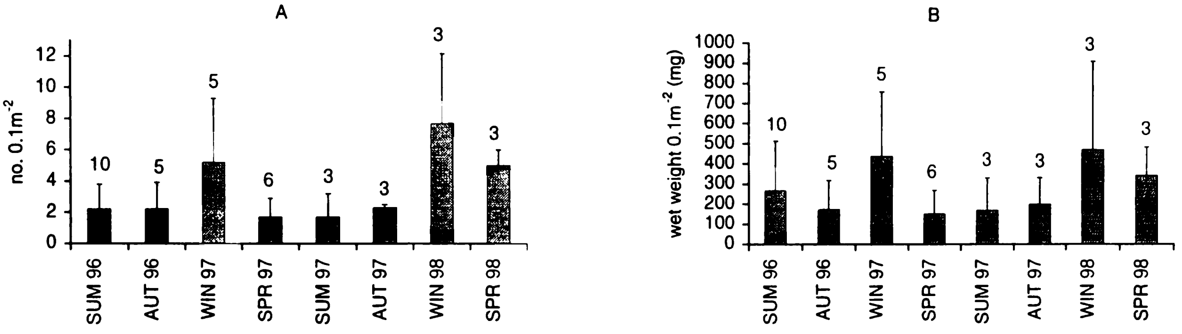
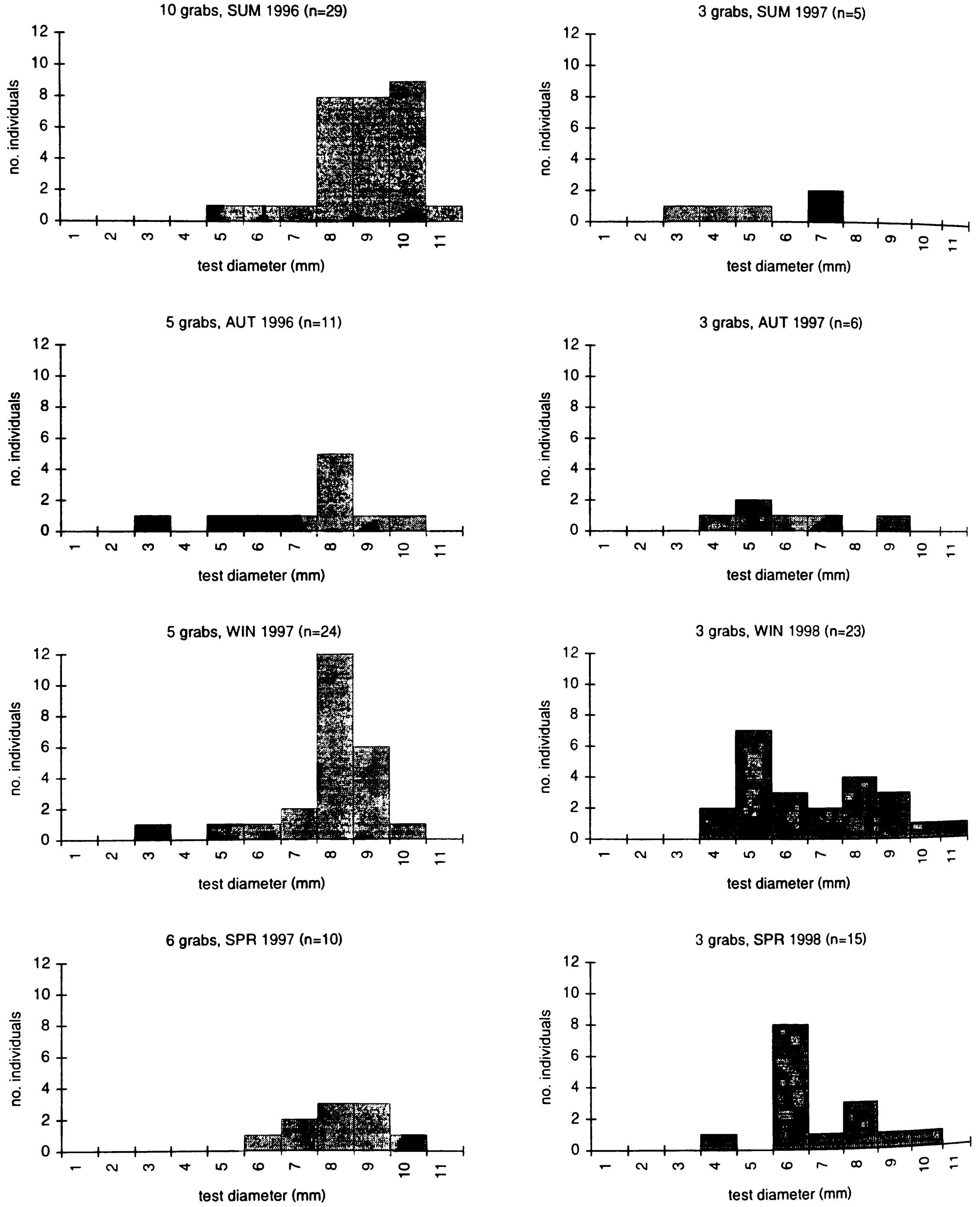


Fig. 3.53. Size frequency histograms for *E. pusillus* collected seasonally in 0.1 m^2 grabs at UKC from 1996-1998. N = the number of individuals measured.


10 grabs, SUM 1996 (n=29)

3 grabs, SUM 1997 (n=5)

5 grabs, AUT 1996 (n=11)

3 grabs, AUT 1997 (n=6)

5 grabs, WIN 1997 (n=24)

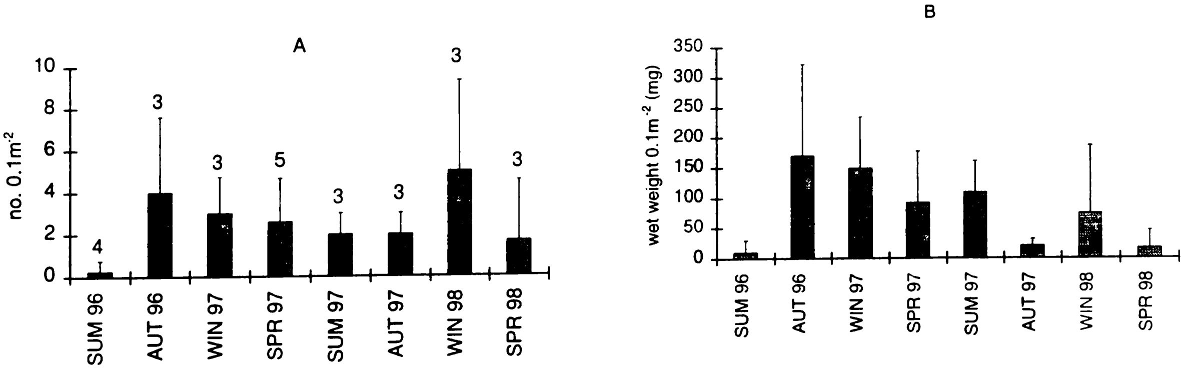
3 grabs, WIN 1998 (n=23)

6 grabs, SPR 1997 (n=10)

3 grabs, SPR 1998 (n=15)

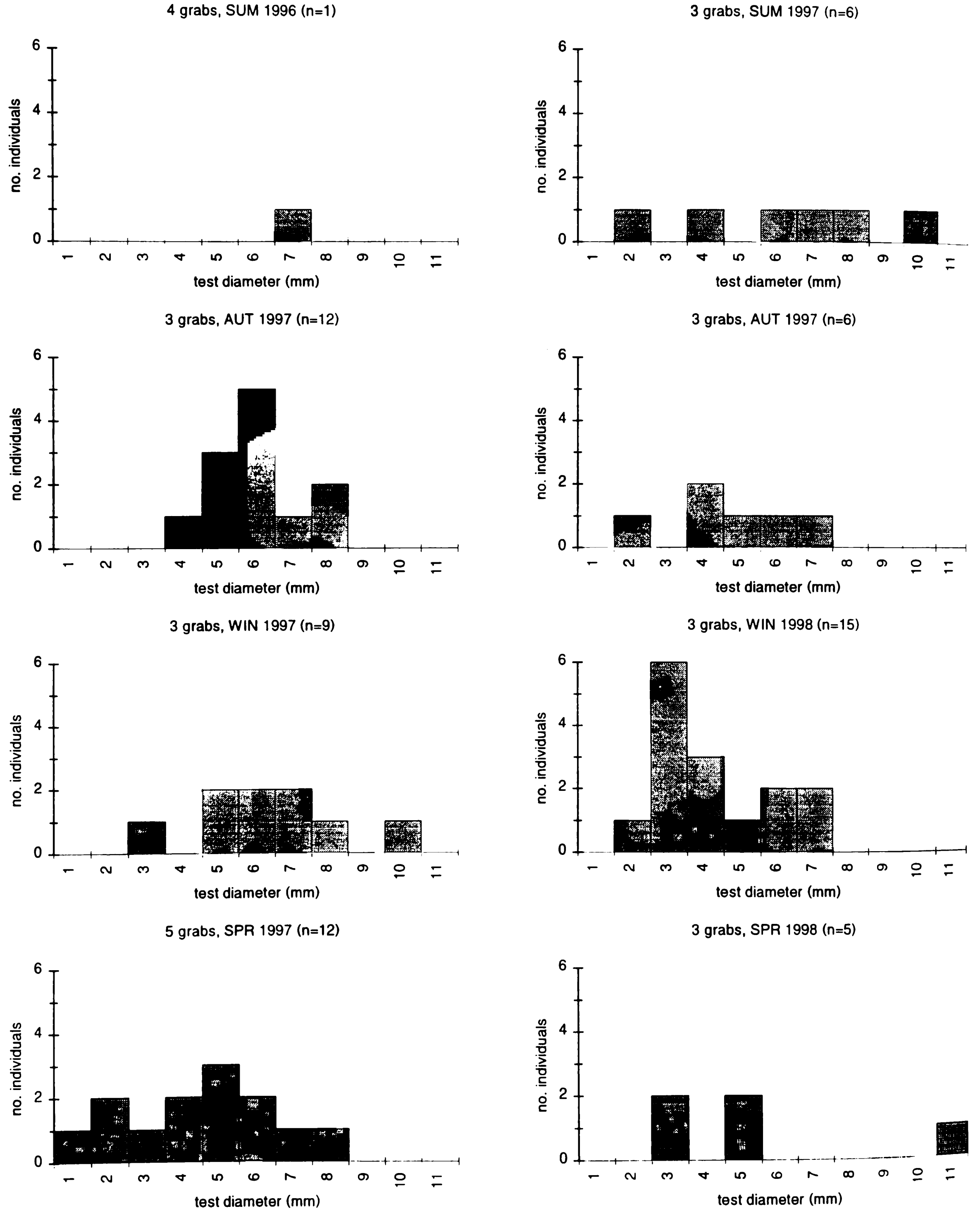
As at UKC, *Echinocyamus pusillus* was common at UKI where it characterized the coarse near-surface layer of maerl gravel. After *Ophiocomina nigra* juveniles, this was the second most abundant echinoderm species present and occurred in 22 out of 27 grab samples analysed. It was also common in Ring Dredge and core samples from the area. Little is known about the population dynamics of this species. The seasonal fluctuation in abundance shown in Fig. 3.54A (0.5–5.5 individuals per $0.1m^2$) is not significant and was probably due their patchy distribution pattern with *ca* 2 individuals per $0.1\ m^2$ on average. The same is true for the estimates of biomass given in Fig. 3.54B with *ca* 50 mg wet weight per $0.1\ m^2$ being the average amount year-round. As at UKC, large but less abundant echinoderms contributed more to biomass but often occurred below the depth to which the van Veen grab penetrated (Hall-Spencer & Atkinson, in press). The main contributors to echinoderm biomass at UKI were *Spatangus purpureus*, *Echinocardium pennatifidum* and *Neopentadactyla mixta*.

Fig. 3.54. A) Mean number and B) biomass (mg wet weight) of *E. pusillus* per $0.1m^2$ grab at UKI. Error bars = SD, N = number of grabs taken.



The seasonal variation in size-frequency of *E. pusillus* sampled in grabs at UKI are given in Fig. 3.55. As at UKC, a wide range of sizes were collected, from juveniles 0.8 mm in diameter to fully grown adults 10.7 mm in diameter. Too few were collected to be able to infer the longevity of this species from the histograms given in Fig.3.55 although application of techniques employed by Gage (1987) to age echinoids could prove a useful insight into the population dynamics of these animals.

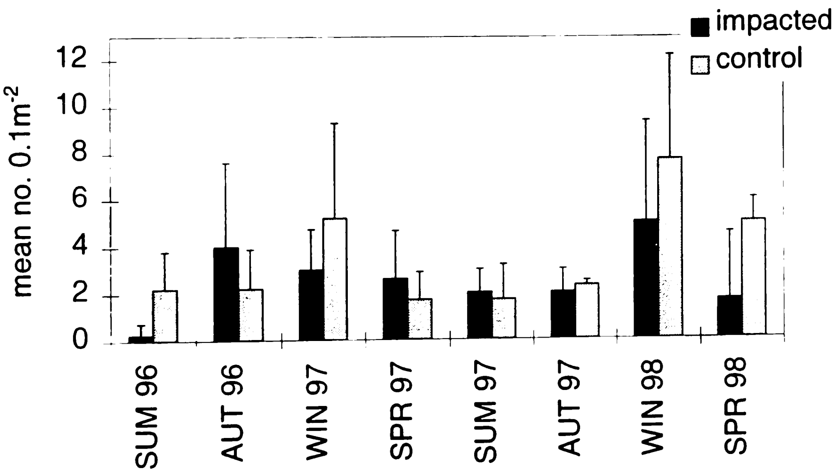
Fig. 3.55. Size-frequency histograms for *E. pusillus* collected seasonally in 0.1m^2 grabs at UKI from 1996-1998. SUM = summer, AUT = autumn, WIN = winter, SPR = spring and N = number of individuals measured.



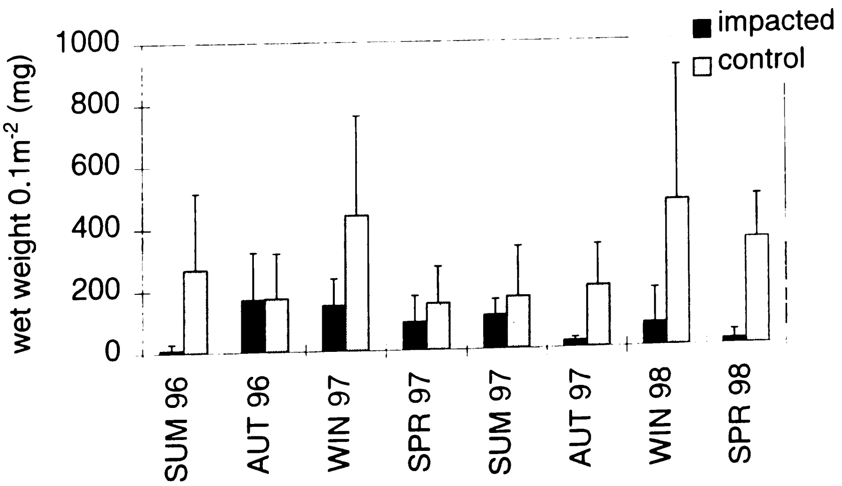
The abundance of *Echinocyamus pusillus* was similar between the impacted and control grounds, despite differences in physical disturbance to the sites (Fig. 3.56). It appears that this species is well adapted to periodic shifts in the surface sediment and favours coarse deposits such as maerl. The biomass of these echinoids was higher at UKC since more large individuals were present. It is interesting to note that *E. pusillus* grew much larger on Clyde grounds than on maerl in the Mediterranean (cf. Maltese data below). This could be an example of a trend that has been noted in many marine invertebrates whereby gigantism occurs with increasing latitute, or may represent growth inhibition under oligotrophic conditions.

Fig. 3.56.

Seasonal variation in mean abundance (± s.d.) of *E. pusillus* on UK impacted and control grounds



Seasonal variation in mean biomass (± s.d.) of *E. pusillus* on UK impacted and control grounds



2) Brittany

A) Bay of Brest

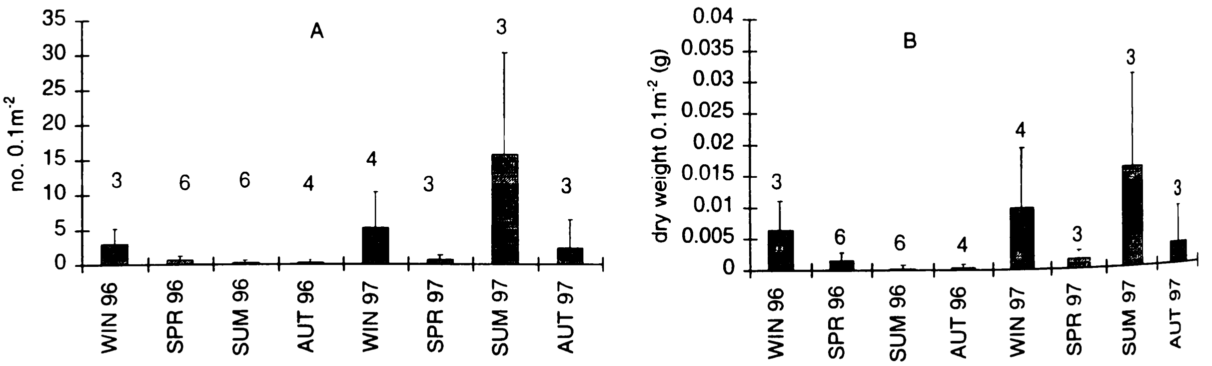
***Platynereis dumerilii* (Audouin & Milne Edwards, 1833)**

This polychaete worm was rather sporadic on the control ground of the Bay of Brest maerl beds (UBBC) throughout the period sampled (from 1996-1997). It occurred in 15 grabs of the 30 total samples analysed. Mean abundances (0.25-15 individuals per 0.1m^2 grab) were low compared to the total abundance of animals in the grabs. The maximum of individuals sampled in one grab was 29 (Fig. 3.57A).

P. dumerilii feeds on decaying macrophyte detritus (Bedford & Moore, 1985a) and it is therefore dependent on the presence of benthic macrophytes. It builds its tubes from fragments of algae. Low epiphytic algal abundances on the control ground may therefore explain the low abundances observed there.

As with abundance, biomass are also reduced, the maximum contribution of *P. dumerilii* to one grab being 0.12%, while mean dry weight varied from 0.2 to 16 mg per 0.1m^2 grab (Fig. 3.57B).

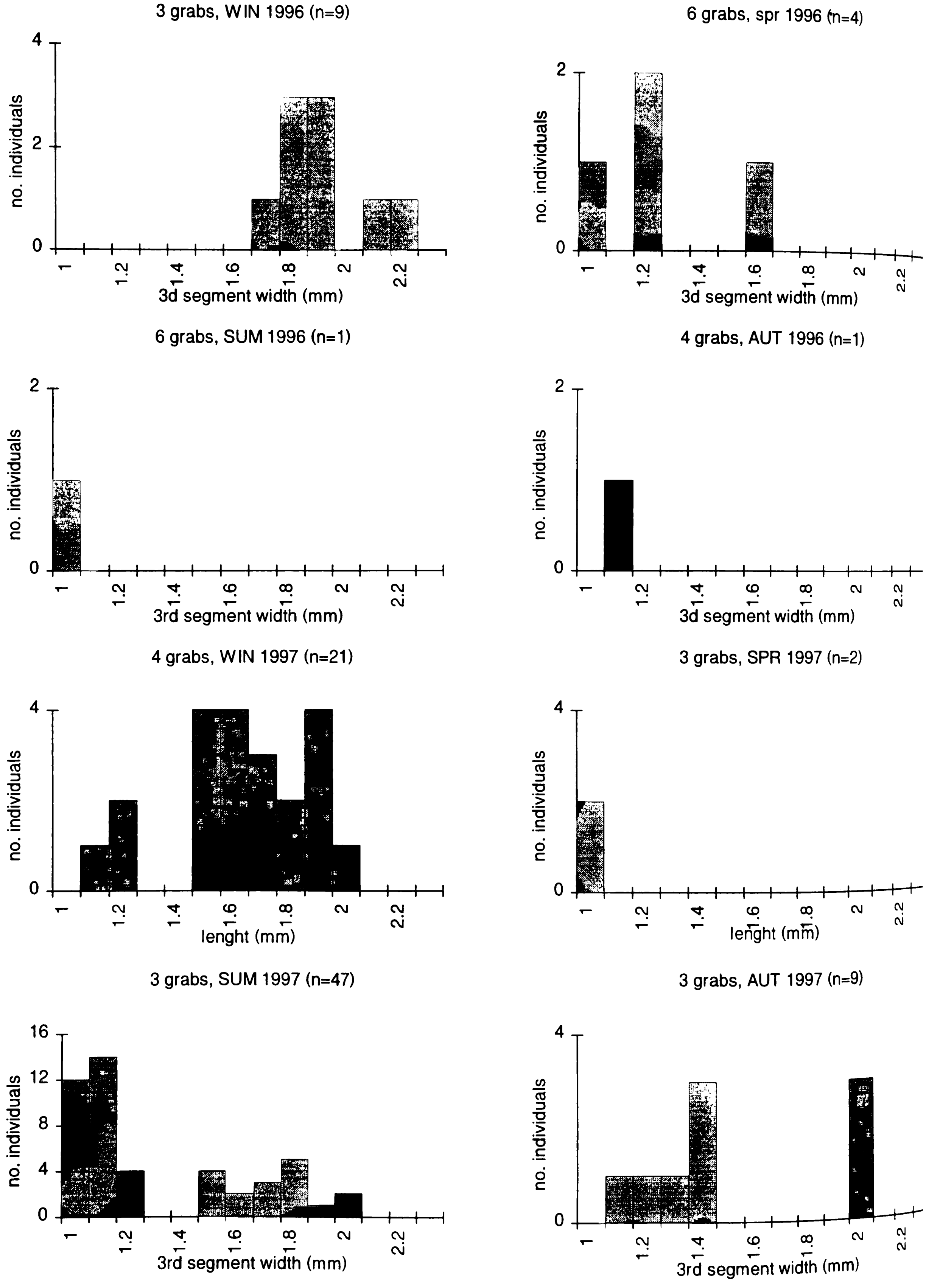
Fig. 3.57.A) Mean number and B) biomass (g dry weight) of *P. dumerilii* per 0.1m^2 grab at UBBC. Error bars = SD, N = number of grabs analysed.



Since abundances were very low, little can be said about the seasonal variations of the size structure of this worm (see data in Fig. 3.58). Sizes varied from 1mm to 2.4 mm (third setiger width). Winter samples gave the largest animals in both 1996 and 1997. Recruitment of juveniles seems to have occurred during summer 1997, but the abundance of this size class was much lower in the following season, suggesting mortalities of the small *P. dumerilii* during the autumn of 1997.

However, *P.dumerilii* was more abundant in the 1997 samples, suggesting environmental differences between the two years of the sampling period. This could be related to higher macrophytic production on the control ground during summer 1997 .

Fig. 3.58. Size-frequency histograms for *P. dumerilii* collected seasonally in 0.1m^2 grabs at UBBC from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.



3 grabs, WIN 1996 (n=9)

6 grabs, spr 1996 (n=4)

6 grabs, SUM 1996 (n=1)

4 grabs, AUT 1996 (n=1)

4 grabs, WIN 1997 (n=21)

3 grabs, SPR 1997 (n=2)

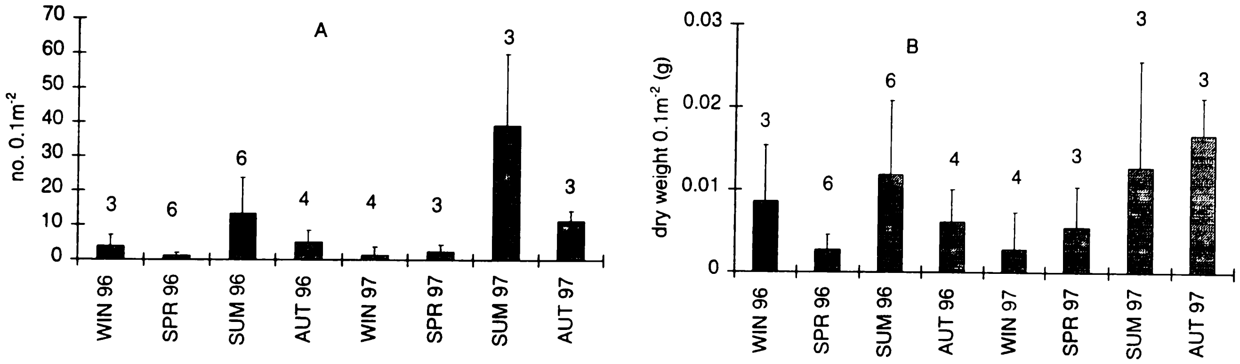
3 grabs, SUM 1997 (n=47)

3 grabs, AUT 1997 (n=9)

This polychaete worm was rather rare on the impacted ground of the Bay of Brest maerl beds throughout the sampling period from 1996-1997. It only occurred in 22 grabs of the 30 total samples analysed. Mean abundances ranged between 1 and 39 individuals per 0.1m^2 grab. The maximum number of individuals sampled in one grab was 62 (Fig. 3.59A).

Maximum contribution to dry weight biomass of *P. dumerilii* in one grab was 0.46%, while mean dry weight varied from 2.8 to 16.8 mg per 0.1m^2 grab (Fig. 3.59B).

Fig. 3.59. A) Mean number and B) biomass (g dry weight) of *P. dumerilii* per 0.1m^2 grab at UBBI. Error bars = SD, N = number of grabs analysed.



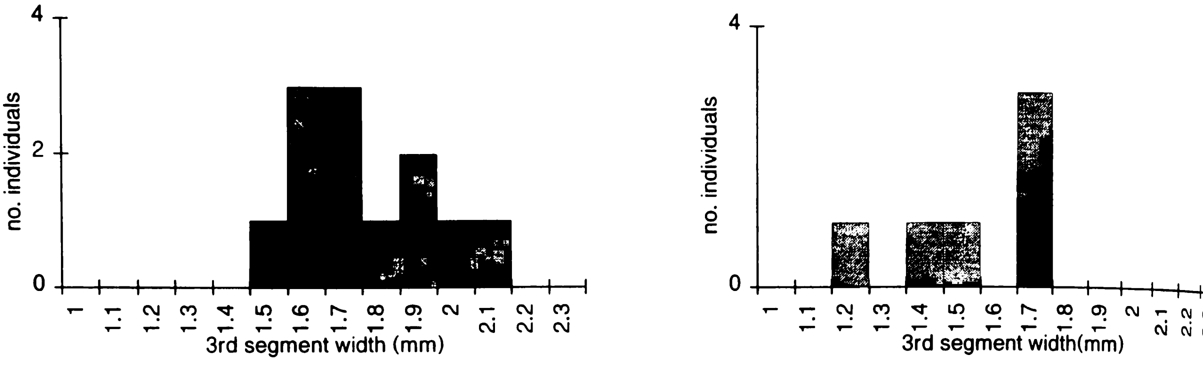
The winter and spring size modes of *P. dumerilii* were centred around size class 1.7 mm (third segment width) for both sampling years (Fig. 3.60). Massive recruitment occurred in spring with the juvenile fraction of the population reaching 70% in spring but dropping to 30% in the autumn months. This suggest high juveniles mortalities during late summer and autumn.

Seasonal variations in density were obvious for this species, maxima being reached during summer months in 1996 and 1997, densities of this season being from 5 (1996) to 10 (1997) times higher than during the other seasons. Biomass differences were not so obvious showing that high summer abundances were due to the recruitmant of small individuals.

Fig. 3.60. Size-frequency histograms for *P. dumerilii* collected seasonally in 0.1m^2 grabs at UBBI from 1996–1997. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.

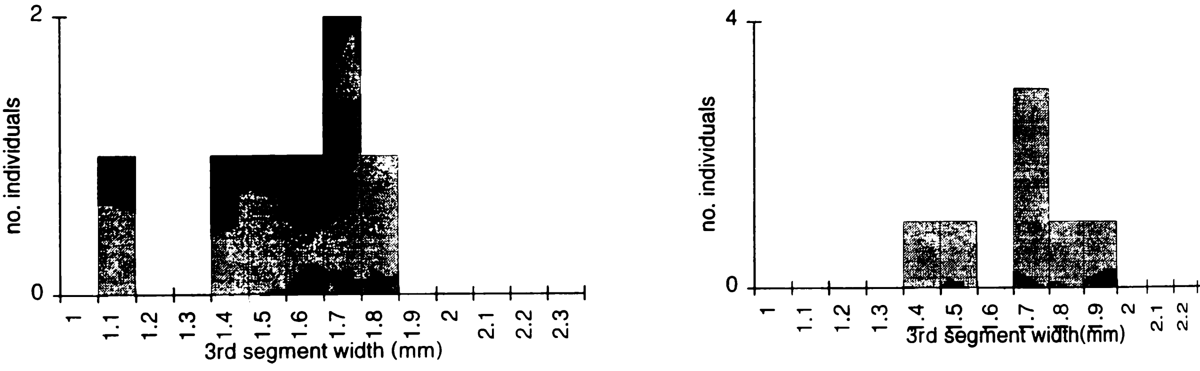
3 grabs, WIN 1996 (n=12)

4 grabs, WIN 1997 (n=6)



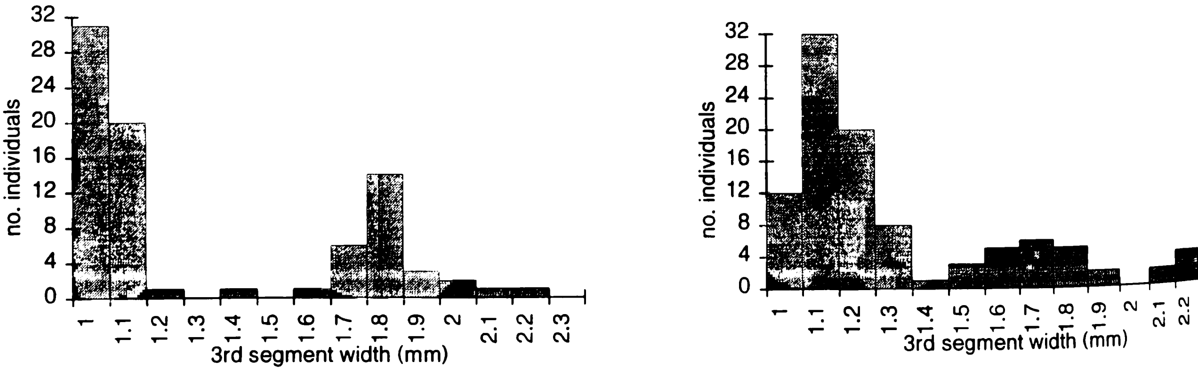
6 grabs, SPR 1996 (n=7)

3 grabs, SPR 1997 (n=7)



6 grabs, SUM 1996 (n=81)

3 grabs, SUM 1997 (n=100)



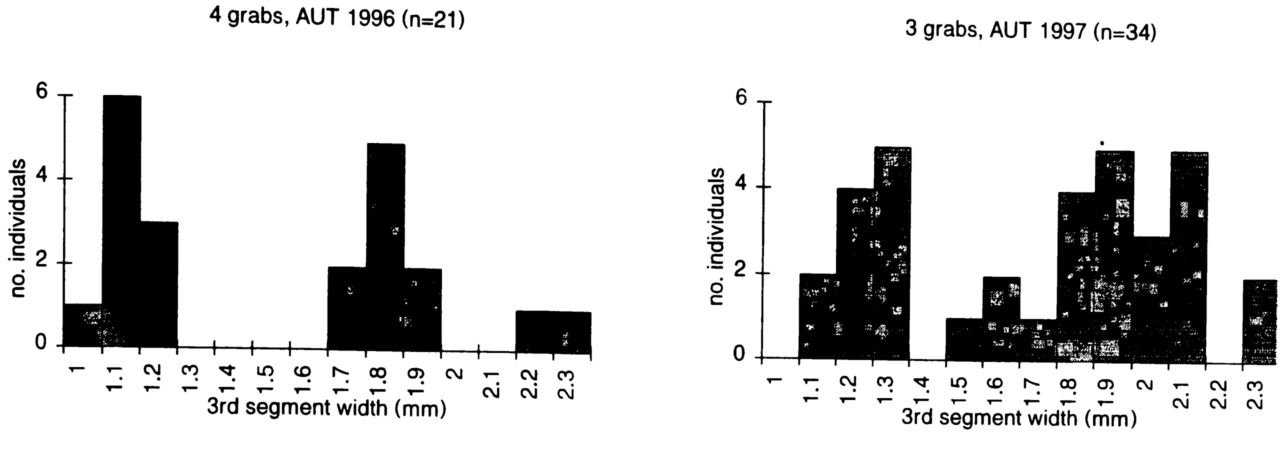
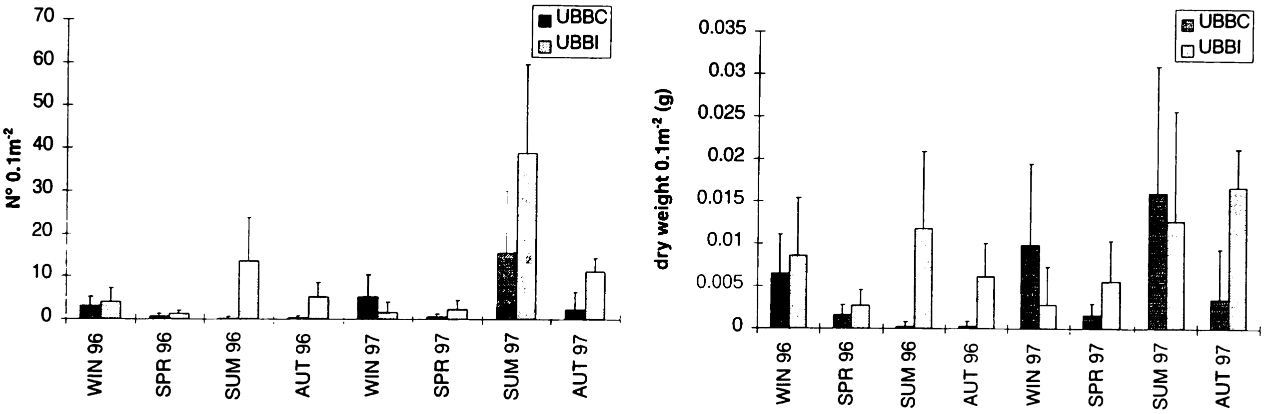


Fig. 3.61. Comparison between control and impacted sites in the Bay of Brest for 1996 and 1997 for *P. dumerilii.*



Site-to-site comparison (Fig. 3.61) shows that abundances of *P. dumerilii* were higher on the impacted ground than on the control throughout the entire sampling period 1996-1997. This was not true for the biomass as this was higher on the control ground in winter and summer 1997. Densities, however, were higher in 1996 than in 1997.

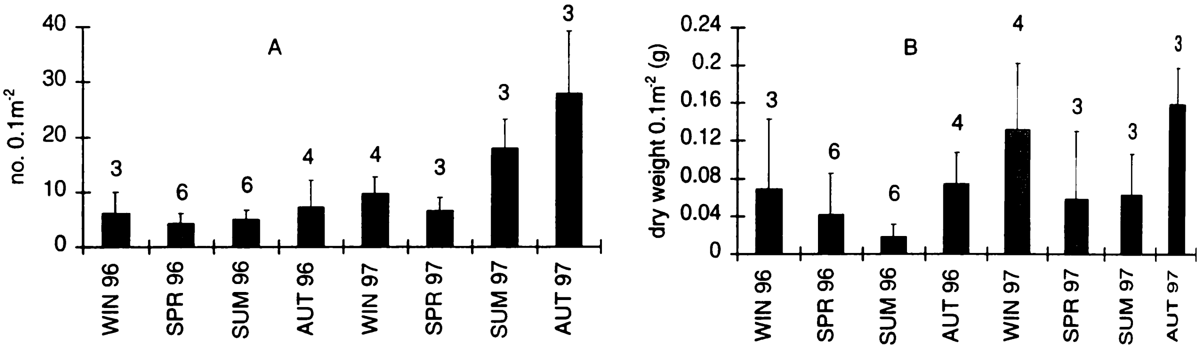
Eunice vittata Chiaje, 1828

Eunice vittata was a very common polychaete in the Bay of Brest maerl beds. It was present in all the 30 grabs analysed, reaching mean densities from 4 to 28 individuals per $0.1m^2$ grab with a maximum of 41 individuals caught in autumn 1997 (Fig. 3.62A).

It is a predator, crawling among the maerl thalli in search of food (small polychaetes, crustaceans and molluscs). It may live preferentially in gravels or maerl beds.

It can reach 20 cm, but such large individuals were rare. The contribution of this species to the total dry weight biomass of the sampled grabs was relatively low (Fig. 3.62B) but consistent in summer: with means of 18-160 mg dry weight per 0.1m^2 grab and a maximum contribution of 4%.

Fig.3.62.A) Mean number and B) biomass (g dry weight) of *E. vittata* per 0.1m^2 grab at UKC. Error bars = SD, N = number of grabs analysed.

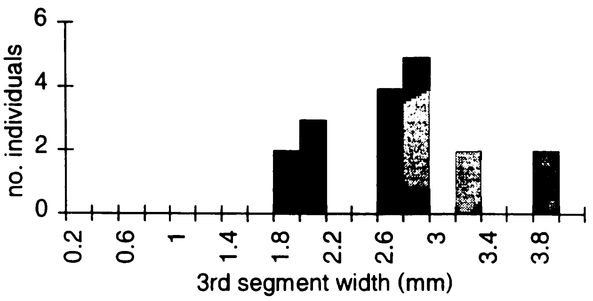


Analysis of the seasonal size structures of *E. vittata* showed no obvious growth trend of bigger individuals during the year (Fig. 3.63), the mode of these individuals remaining in the range 1.8-3.2 mm (based on 3rd segment width). Recruitment of juveniles was observed during summer and autumn of 1996 as well as 1997. In this season, juveniles could make up half the population.

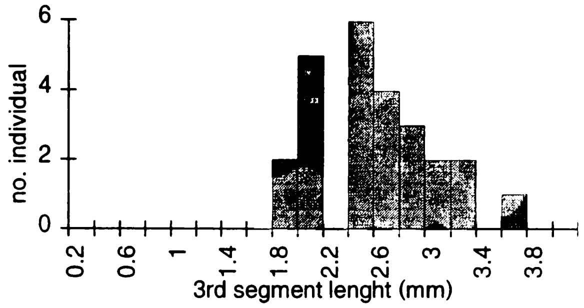
The two sampling years had similar structures in term of biomass and density: winter and autumn showed higher density, while biomasses were higher in summer and autumn, after juvenile recruitment. Differences appeared, however, between the two years, *E. vittata* being twice to three times more abundant in 1997 than in 1996. Such differences could be related to differences in the abundance of prey in the maerl grounds between these two summers and autumns.

Fig. 3.63. Size-frequency histograms for *Eunice vittata* collected seasonally in 0.1m^2 grabs at UBBC from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.

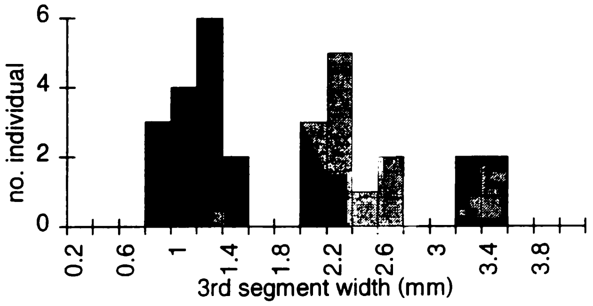
3 grabs, Win 1996 (n=18)



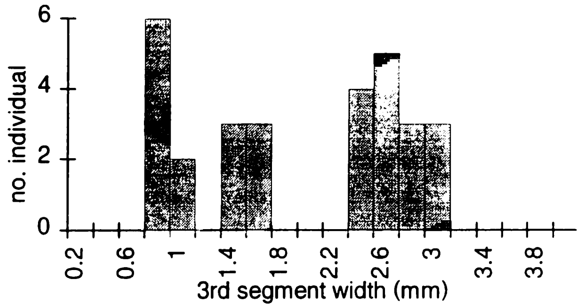
6 grabs, SPR 1996 (n=25)



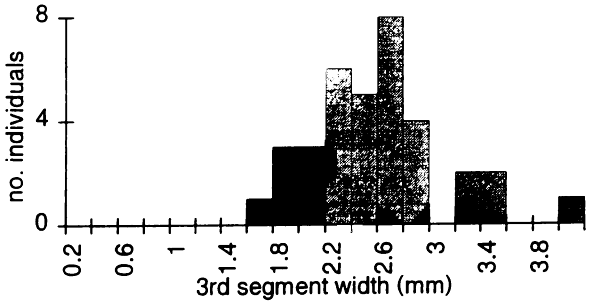
3 grabs, SUM 1996 (n=30)



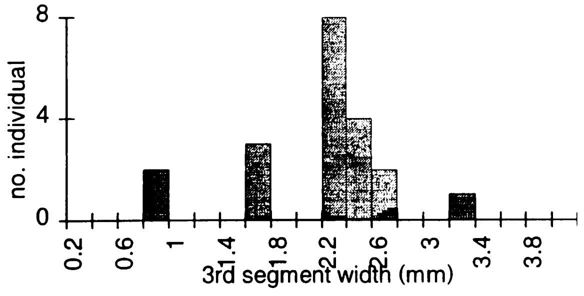
4 grabs, AUT 1996 (n=29)



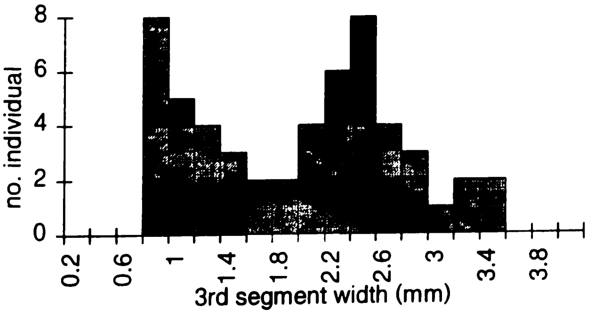
4 grabs, WIN 1997 (n=35)



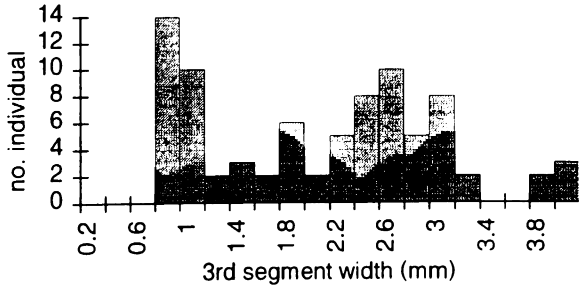
3 grabs, SPR 1997 (n=20)



3 grabs, SUM 1997 (n=54)



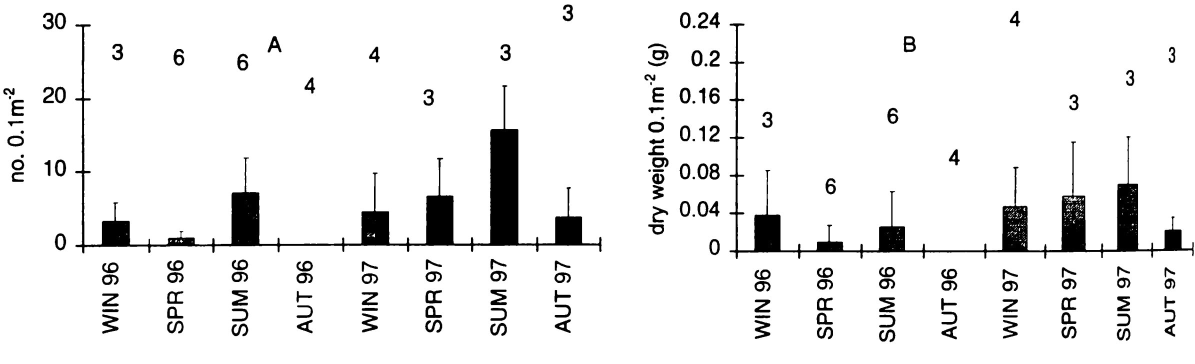
4 grabs, AUT 1997 (n=82)



E. vittata was, however, less common on the impacted site maerl ground since it was only sampled in 22 of the 30 grabs analysed. Mean densities ranged from 0 to 16 . individuals per 0.1m^2 grab (Fig. 3.64A) with a maximum of 22 individuals observed in a grab in summer 1997.

This species was quite small in size on the impacted ground. Its contribution to the total dry weight biomass of the sampled grabs was thus very low (Fig. 3.64B), with means of between 9-70 mg dry weight per 0.1m^2 grab, and a maximum contribution of 2%.

Fig. 3.64.A) Mean number and B) biomass (g dry weight) of *E. vittata* per 0.1m^2 grab at UBBI. Error bars = SD, N = number of grabs analysed.

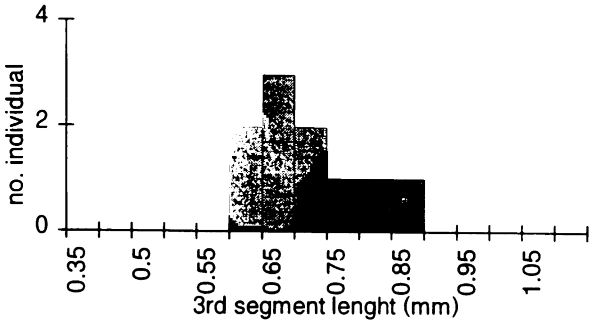


Analysis of the seasonal size structures of *E. vittata* was difficult to interpret due to the low number of animals sampled (Fig. 3.65). However, the population seemed unimodal (centred on size class 0.7 mm) in the winter and spring months of 1996, and bimodal in the summer months of 1996 (centred on size classes 0.5 mm and 0.7 mm), with smaller individuals appearing in the population at this time. In 1997, the population showed no modal structure, individuals being spread into several size classes. No recruitment pattern was then apparent for that year.

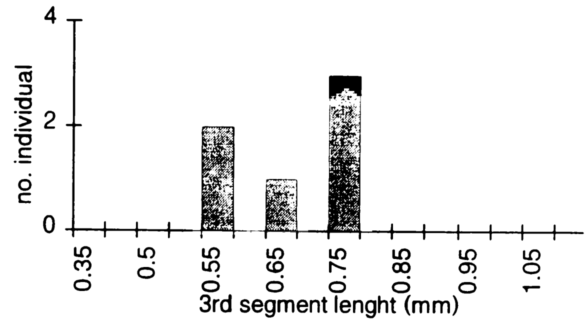
Beyond the differences between the two years in term of size structure, it seems that biomasses and densities were higher in 1997. Maxima were reached in summer

Fig. 3.65. Size-frequency histograms for *Eunice vittata* collected seasonally in $0.1m^2$ grabs at UBBI from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.

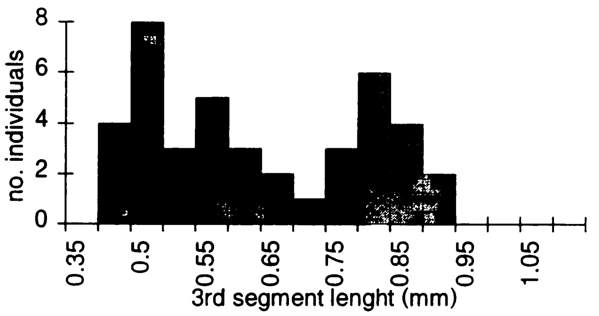
3 grabs, WIN 1996 (n=10)



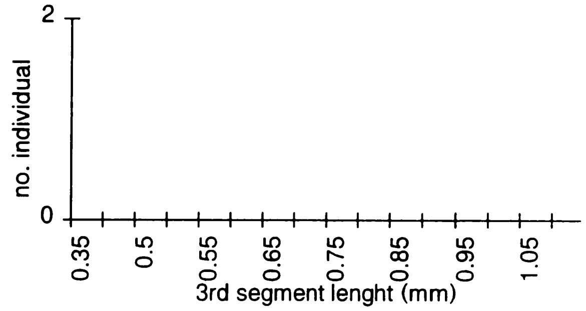
6 grabs, SPR 1996·(n=6)



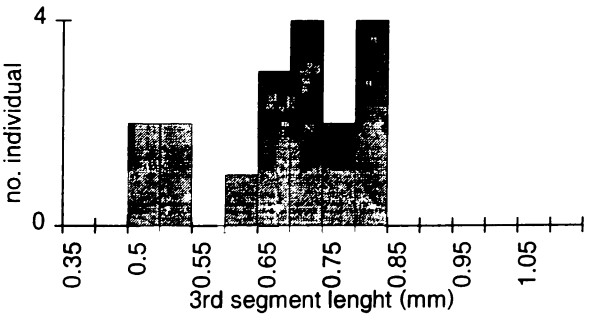
6 grabs, SUM 1996 (n=41)



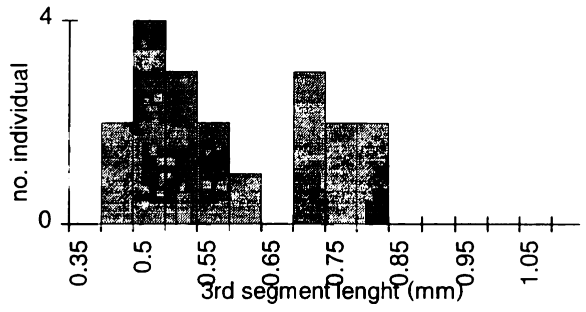
4 grabs, AUT 1996 (n=0)



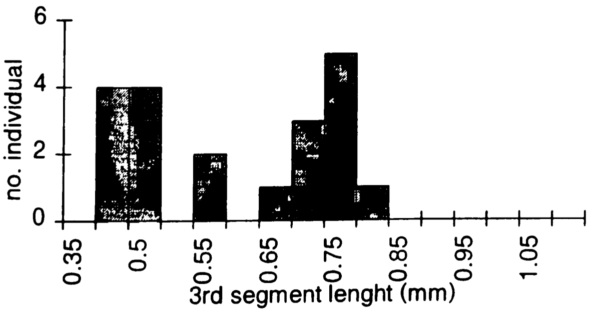
4 grabs, WIN 1997 (n=18)



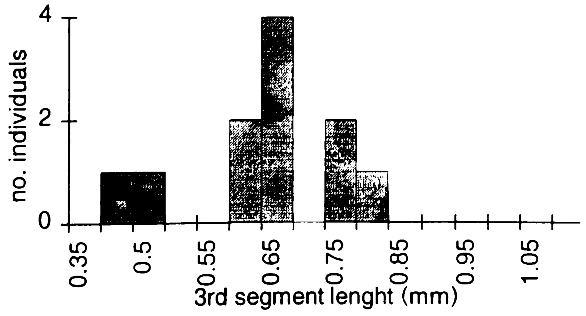
3 grabs, SPR 1997 (n=19)



3 grabs, SUM 1997 (n=20)

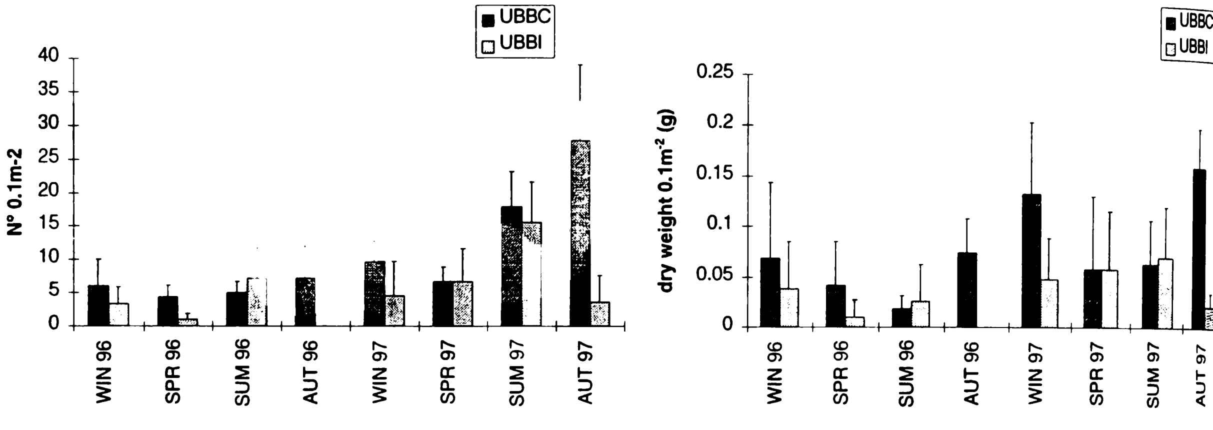


3 grabs, AUT 1997 (n=11)



months for both years and a drop in the two parameters was observed during the autumn months of both years.

Fig. 3.66. Comparison between control and impacted sites in the Bay of Brest for 1997 and 1998 *for E. vittata.*



Densities and biomasses were similar on both sites for the two sampling years, except during autumn months when the impacted ground showed dramatic drops for these parameters (Fig. 3.66). This could be related to hypoxic conditions at the end of the year on UBBI when epiphytic macroalgae were decaying on the ground.

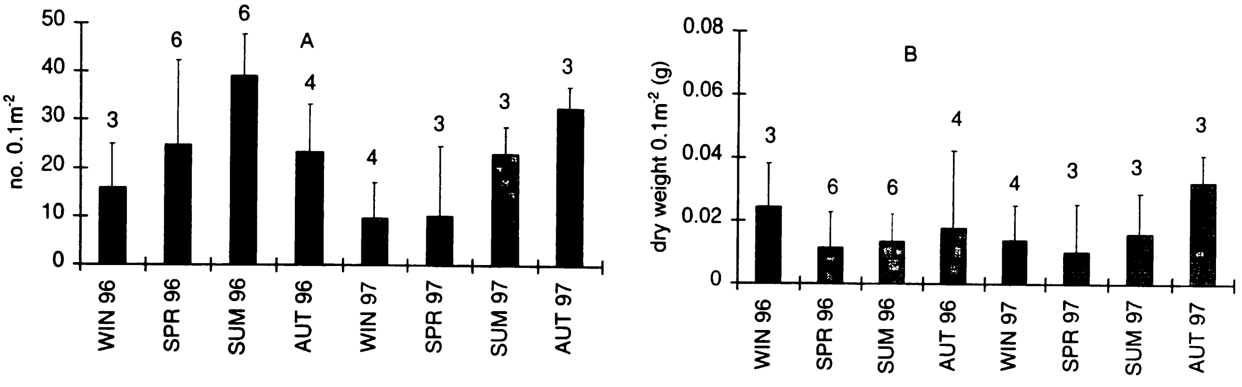
Nematonereis unicornis (Grube, 1840)

This eunicid polychaete was very common on the UBBC ground throughout the sampling period 1996-1997. It occurred in all the 30 grabs samples analysed, with means of 9-40 up to 59 individuals collected per 0.1m^2 grab (Fig. 3.67A).

This errant polychaete with strong jaws is a carnivore, feeding on small polychaetes and crustaceans. Its relatively small size allows it to move into the maerl structure in search of food while being protected from fish predation. It therefore reached high densities on our maerl grounds.

Being small, the contribution to biomass in grab samples was rather low, reaching a maximum of 0.8% of the total dry weight biomass of a single grab in summer 1996. Mean dry weight varied from 11 to 32 mg per 0.1m^2 grab dry weight. (Fig. 3.67B) .

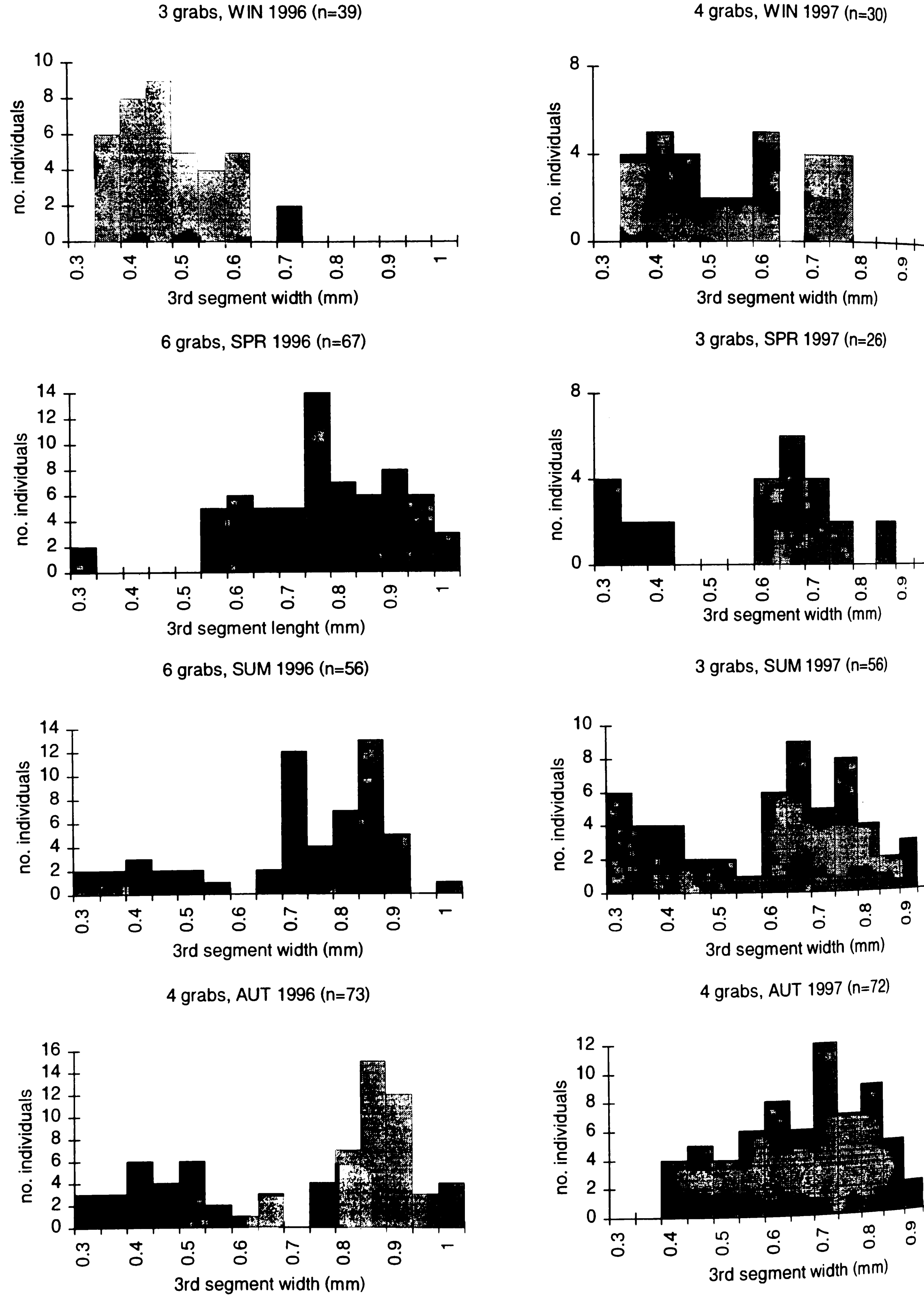
Fig. 3.67. A) Mean number and B) biomass (g dry weight) of *N. unicornis* per 0.1m^2 grab at UBBC. Error bars = SD, N = number of grabs analysed.



The population of *N. unicornis* showed a wide range of size structures (Fig. 3.68) during the year, with no obvious mode appearing. Individuals of 0.5 to 0.9 mm (3rd segment width) were sampled all year round. Smaller individuals are recruited continually from spring to autumn, with no maximum of recruitment appearing between these seasons. Both autumn graphs showed a wide range of sizes with no clear pattern appearing. However, summer 1997 showed a high density in juveniles but these did not dominate the population at this season.

Comparison of the two sampling years showed very similar patterns, maximum densities and biomasses being reached during late summer and autumn, with recruitment of juveniles from spring to autumn.

Fig. 3.68. Size-frequency histograms for *N. unicornis* collected seasonally in 0.1m^2 grabs at UBBC from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.



3 grabs, WIN 1996 (n=39)

4 grabs, WIN 1997 (n=30)

6 grabs, SPR 1996 (n=67)

3 grabs, SPR 1997 (n=26)

6 grabs, SUM 1996 (n=56)

3 grabs, SUM 1997 (n=56)

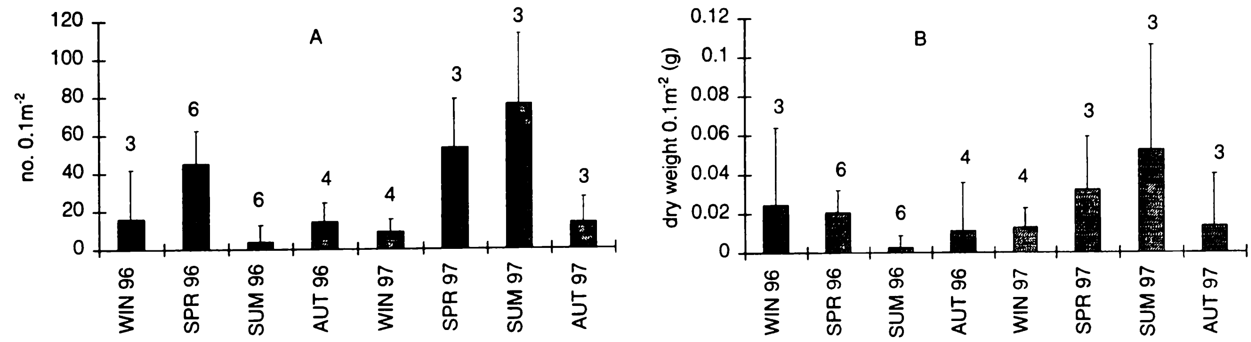
4 grabs, AUT 1996 (n=73)

4 grabs, AUT 1997 (n=72)

N. unicornis was common on the impacted ground UBBI troughout the sampling period 1996-1997, but showed considerable variations seasonally. It occurred in 28 of the 30 grabs samples analysed, with means of 4-77 and up to 111 individuals collected per 0.1m^2 grab (Fig. 3.69A).

Its contribution to the biomass in grab samples was again rather low, reaching a maximum of 2% of the total dry weight biomass of a single grab in summer 1997. Mean dry weight varied from 3 to 52 mg per 0.1m^2 grab dry weight. (Fig. 3.69B)

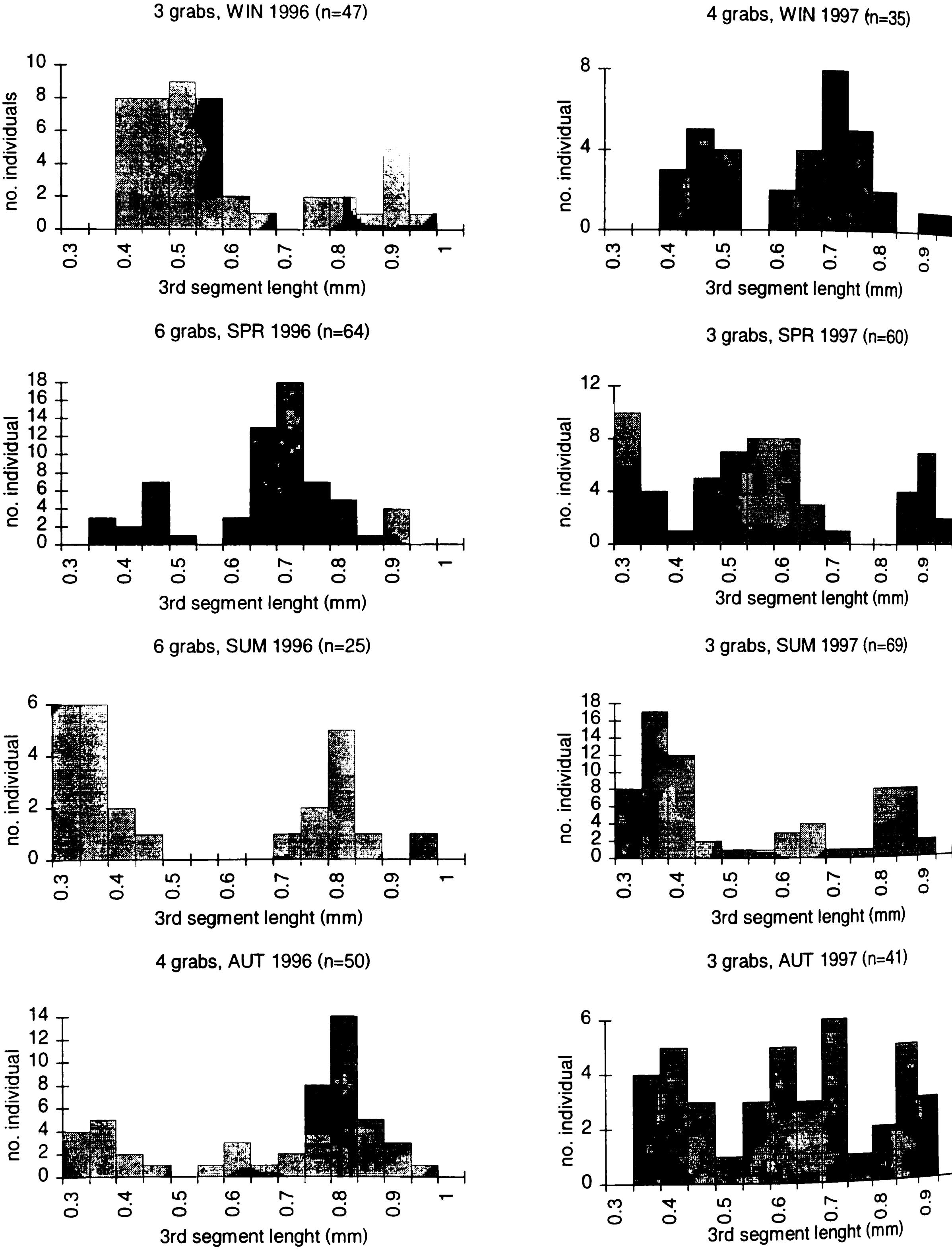
Fig. 3.69.A) Mean number and B) biomass (g dry weight) of *N. unicornis* per 0.1m^2 grab at UBBI. Error bars = SD, N = number of grabs analysed.



Analysis of the seasonal trends in size-frequency (Fig. 3.70) in the UBBI population of *N. unicornis* showed a bimodal structure during almost every sampling season. The mode of larger individuals mode was centred around size classes 8-0.9, while smaller individuals were centerd around size class 0.35-0.4 mm. Recruitment of juveniles seemed to occur from late winter and spring months.

Comparison of the two sampling years thus showed completely different patterns; maximum densities and biomasses being reached during winter and spring for 1996, cf. in spring and summer in 1997. The autumn months of both years showed drops in the abundances and biomasses of this species.

Fig. 3.70. Size-frequency histograms for *N. unicornis* collected seasonally in 0.1m^2 grabs at UBBI from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.


3 grabs, WIN 1996 (n=47)

4 grabs, WIN 1997 (n=35)

6 grabs, SPR 1996 (n=64)

3 grabs, SPR 1997 (n=60)

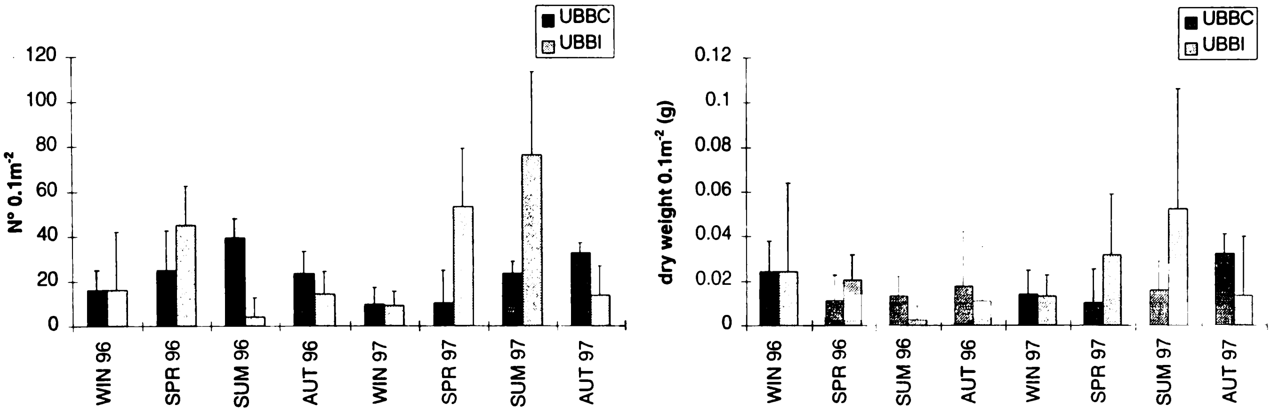
6 grabs, SUM 1996 (n=25)

3 grabs, SUM 1997 (n=69)

4 grabs, AUT 1996 (n=50)

3 grabs, AUT 1997 (n=41)

Fig. 3.71. Comparison between control and impacted sites in the Bay of Brest for 1996 and 1997 for *N. unicornis*.



Abundances and biomasses were very similar between the two sites (Fig. 3.71) except for spring and summer 1997 where the data for UBBI were higher than for UBBC. It seems, howeve,r that during the autumn months, these parameters were higher on the control than on the impacted ground suggesting summer mortalities on the latter ground.

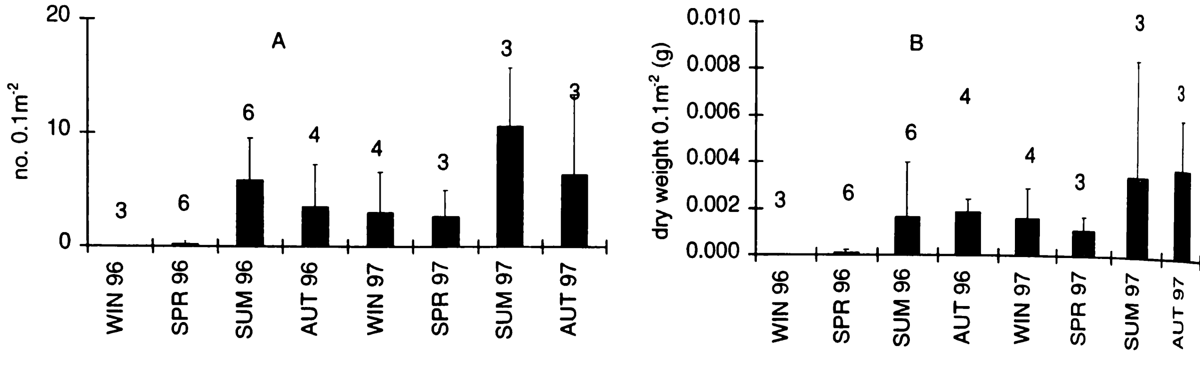
Aonides oxycephala **(M. Sars, 1862)**

This spionid polychaete was seasonally present on UBBC with mean densities of 0-11 and up to 15 individuals per 0.1 m^2 grab (Fig. 3.72A). The species occurred in 20 grabs of the 30 total analysed.

Aonides oxycephala is a surface deposit feeder, feeding on organic matter laying on the sediment around its tube by way of its palps. It burrows into the sediment, generally in muds or sandy muds. This species is tolerant to organic enrichment and is locally common in harbour muds or under fish farm cages.

Being not very common on the control maerl ground, this species did not contribute to a large part of the biomass of the control ground. Maximum contribution was less than 0.1% of the total dry weight biomass. Mean dry weights ranged from 0 to 4mg per 0.1m^2 grab (Fig. 3.72B).

Fig. 3.72.A) Mean number and B) biomass (g dry weight) of *A. oxycephala* per 0.1m^2 grab at UBBC. Error bars = SD, N = number of grabs analysed.



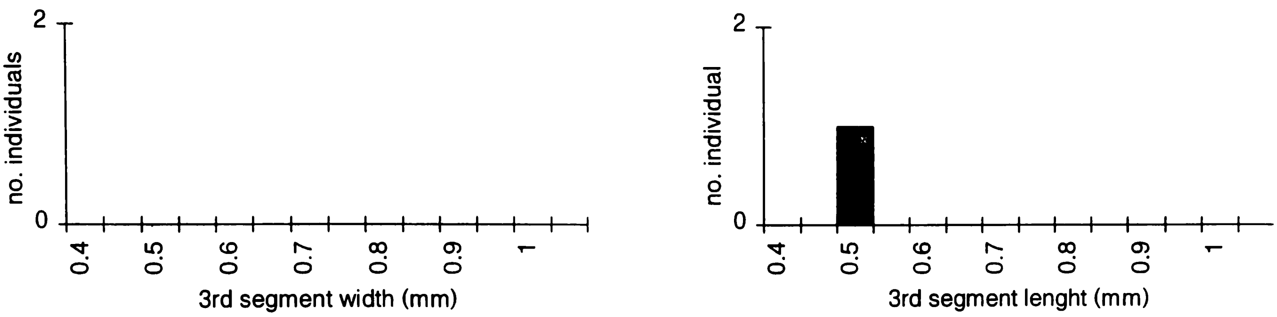
Interpretation of size frequency variation is difficult because of the low abundances observed for this species. However, differences between the two years appear as recruitment of juveniles in summer 1996 total disappearance in autumn, while in 1997 recruitment occurred in both seasons (Fig. 3.73).

As found for *Cirriformia tentaculata*, it appears that biomasses and population densities in 1997 were higher than those in 1996. However, for both years, maximum densities were reached during summer, i.e. after juvenile recruitment. The explanation for differences between the two years remains obscure in the case of this species.

Fig. 3.73. Size-frequency histograms for *A. oxycephala* collected seasonally in 0.1m^2 grabs at UBBC from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.

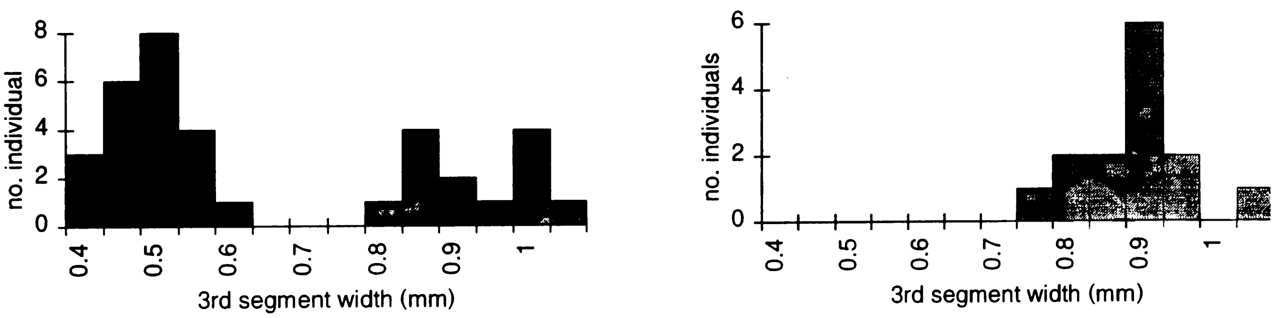
3 grabs, WIN 1996 (n=0)

6 grabs, SPR 1996 (n=1)



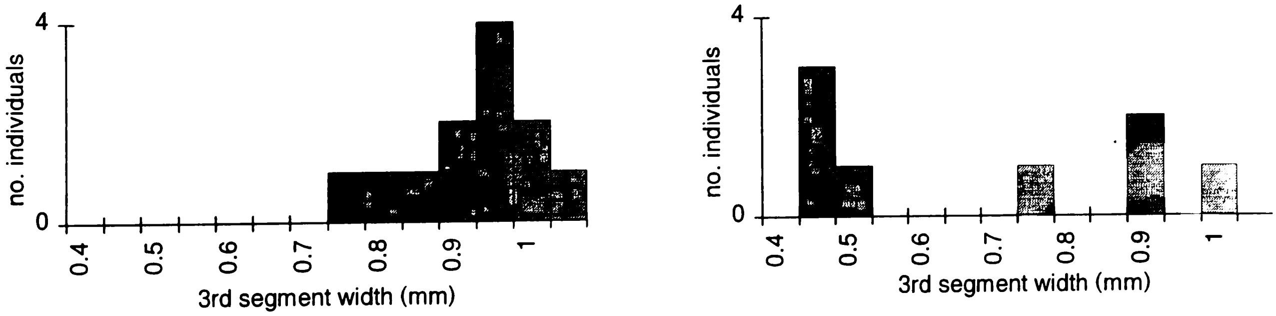
3 grabs, SUM 1996 (n=35)

4 grabs, AUT 1996 (n=14)



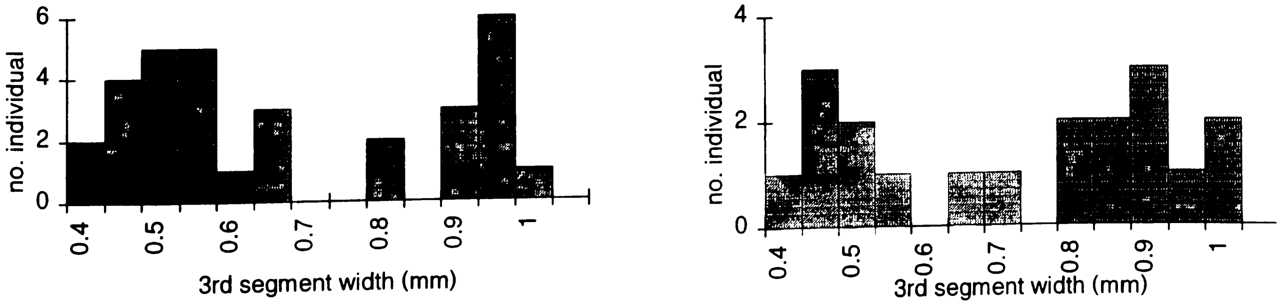
4 grabs, WIN 1997 (n=12)

3 grabs, SPR 1997 (n=8)



3 grabs, SUM 1997 (n=32)

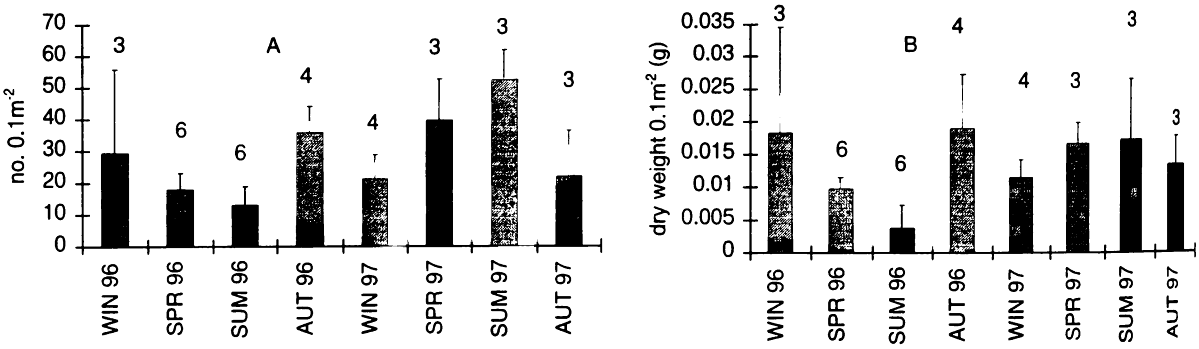
4 grabs, AUT 1997 (n=19)



This spionid was found in high densities on the impacted ground (UBBI) with mean densities of 13-53 and up to 15 individuals per 0.1 m^2 grab (Fig. 3.74A). It occurred in all 30 samples analysed.

Although very common on the control ground, this species made only a small contribution to the biomass of the impacted ground. Maximum contribution was less than 1 % of the total dry weight biomass. Mean dry weights ranged from 3 to 19mg per $0.1m^2$ grab (Fig. 3.74B).

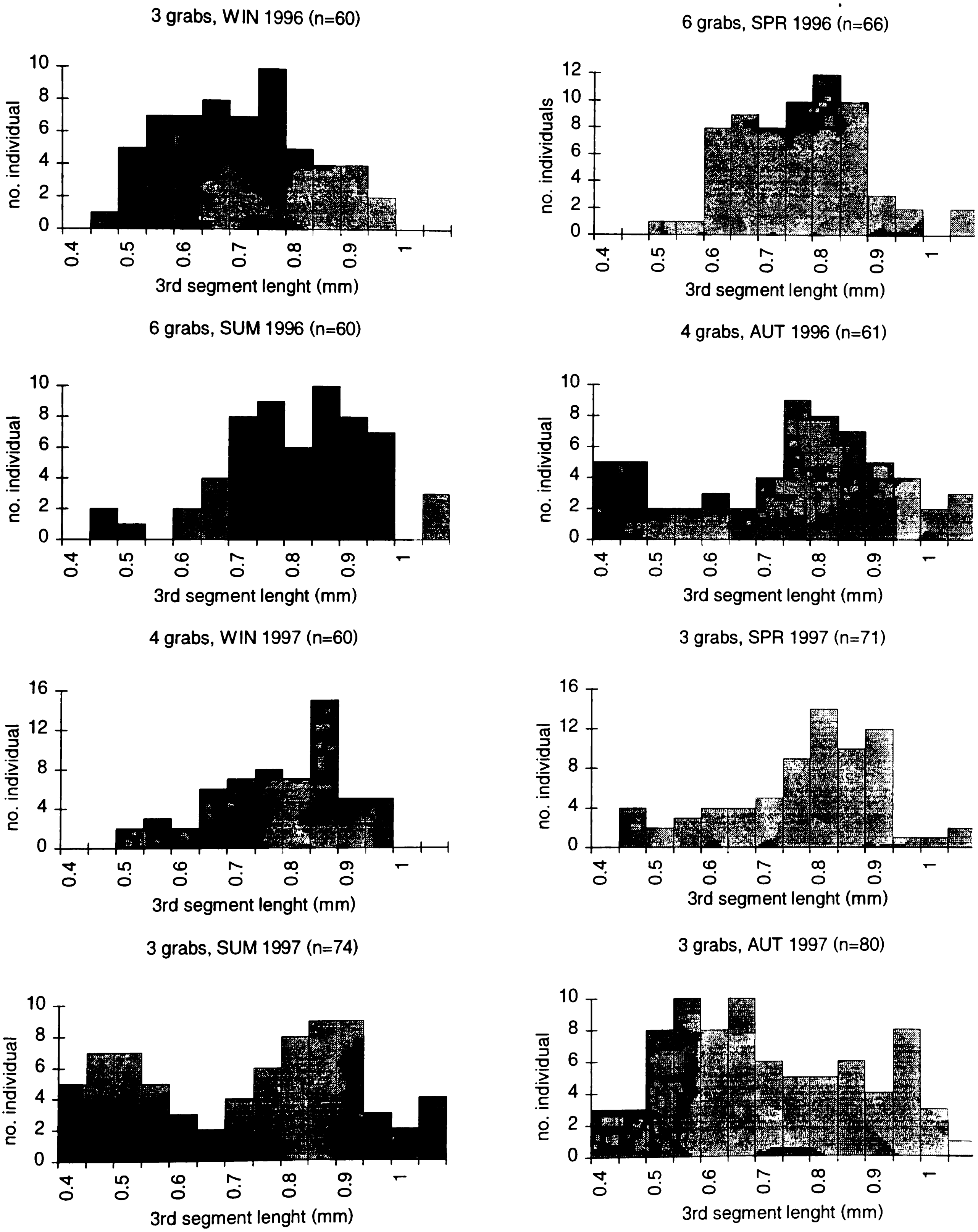
Fig. 3.74.A) Mean number and B) biomass (g dry weight) of *A. oxycephala* per $0.1m^2$ grab at UBBI. Error bars = SD, N = number of grabs analysed.



Analysis of the size-frequency histograms (Fig. 3.75) showed a unimodal structure of the population during winter and spring of the two years sampling, with all individuals having a third segment width between 0.7 and 0.9mm. During the summer and spring months, however, the population had a bimodal structure, small individuals (size classes 0.4-0.6 mm) being found during these months. Recruitment seems therefore to occur from summer to autumn, decreasing at the end of the year.

Population densities and, on a smaller scale biomasses, were higher during 1997 than during 1996. Minima were reached during summer 1996, while maxima were reached in summer 1997. However, for both years, *A. oxycephala* was very common on the impacted ground in late summer and autumn.

Fig. 3.75. Size-frequency histograms for *Aonides oxycephala* collected seasonally in $0.1m^2$ grabs at UBBI from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.


3 grabs, WIN 1996 (n=60)

6 grabs, SPR 1996 (n=66)

6 grabs, SUM 1996 (n=60)

4 grabs, AUT 1996 (n=61)

4 grabs, WIN 1997 (n=60)

3 grabs, SPR 1997 (n=71)

3 grabs, SUM 1997 (n=74)

3 grabs, AUT 1997 (n=80)

Fig. 3.76. Comparison between control and impacted sites in the Bay of Brest for 1997 and 1998 for *A. oxycephala*.

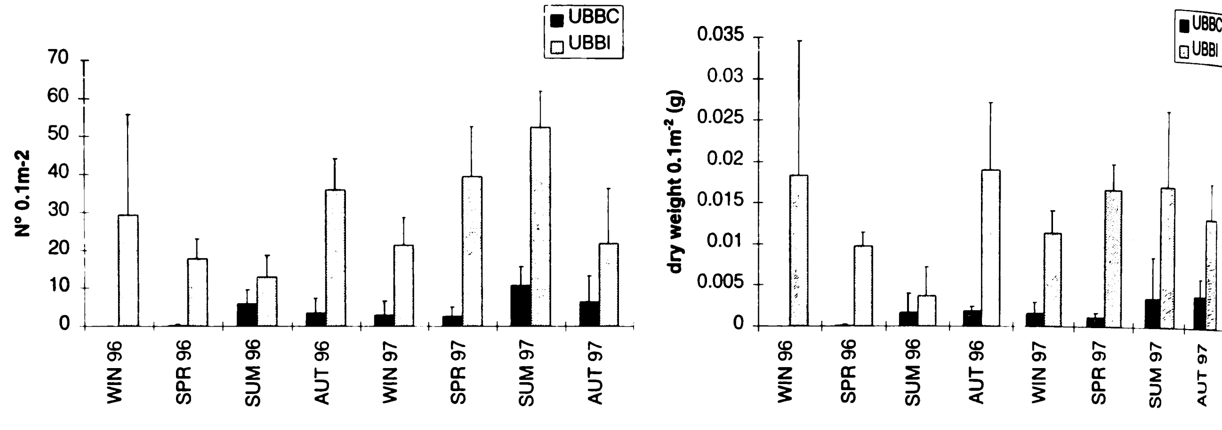


Fig. 3.76 shows clearly that *A. oxycephala* population densities were about ten times higher on the impacted ground than on the control. This can be related to higher organic matter inputs to UBBC during the sampling period.

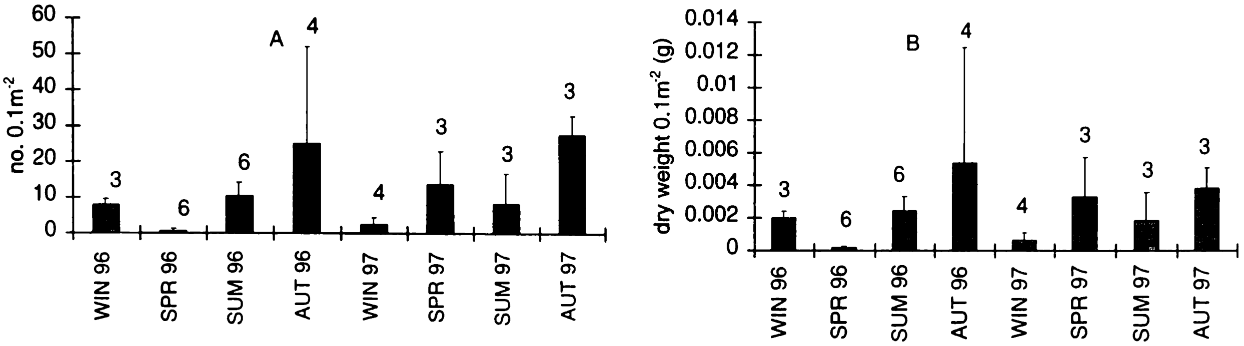
Chaetozone setosa **Malmgren,1867**

This cirratulid polychaete was common on the control site in the Bay of Brest. It occurred in 28 grabs out of a total of 30 analysed. Mean densities ranged from 0.7 to 28 individuals per $0.1m^2$ grab, with a maximum of 34 individuals in one grab sampled in autumn 1997 (Fig. 3.77A).

Chaetozone setosa is an opportunistic species, feeding on deposited organic matter. It can reach densities of several thousand per m^2 in polluted or eutrophic areas. It is able to live in hypoxic conditions and high abundances of this species can therefore indicate pollution.

Though it can reach high densities, this species made only a low contribution to the biomass on the control ground. Mean dry weight biomasses ranged from 0.2 to 5.4 mg per 0.1m^2 grabs and its maximum contribution to one grab reached only 0.2 % of the total biomass of that grab in autumn 1997 (Fig. 3.77B).

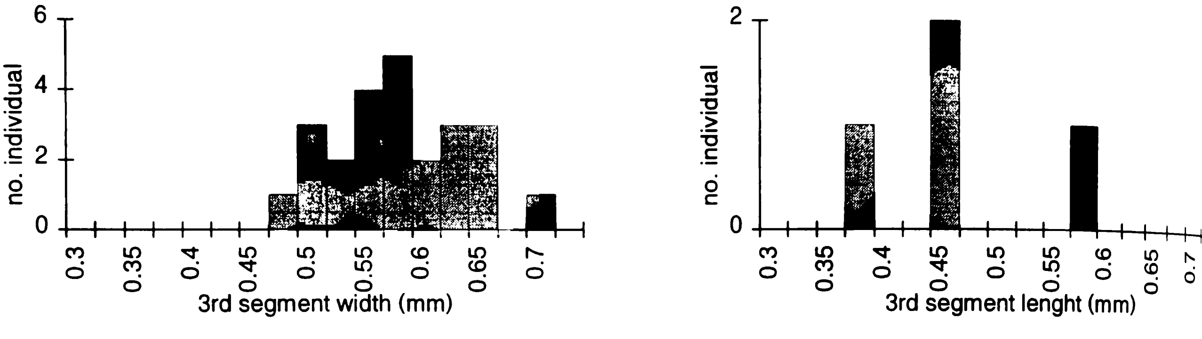
Fig. 3.77.A) Mean number and B) biomass (g dry weight) of *Chaetozone setosa* per 0.1m^2 grab at UBBC. Error bars=SD, N=number of grabs analysed.



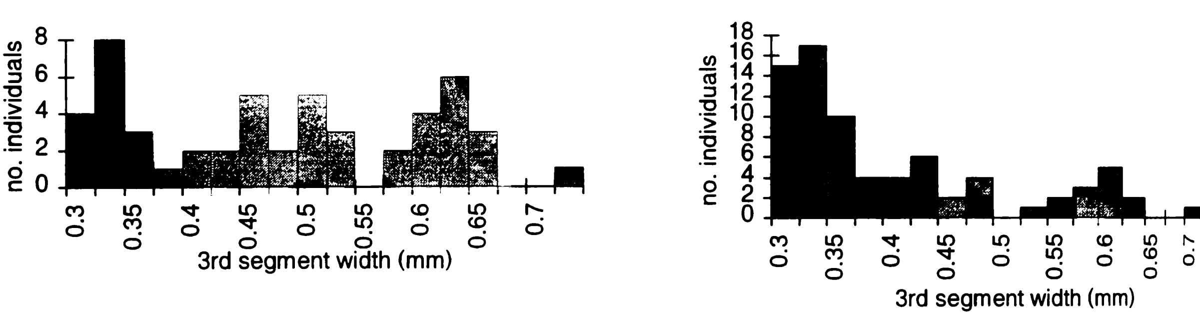
The seasonal variations of the size frequency of *C. setosa* sampled are given in Fig. 3.78. No growth was observed for the mode of larger individuals through time. It remained between 0.5 to 0.7 mm (third segment width). Recruitment appeared to be in summer and autumn for 1996 and began in spring in 1997. This recruitment seemed to be continuous throughout the year (except in winter), with no clear juvenile mode appearing. Juveniles represented up to 80% of the population during both autumns.

Seasonal variations of this species were very high on our maerl banks. Maximum densities was reached during the autumn in 1996 while densities were more regular in 1997 during spring, summer and autumn. These differences could be interpreted in terms of different organic matter (macroalgal) inputs to the beds between the years.

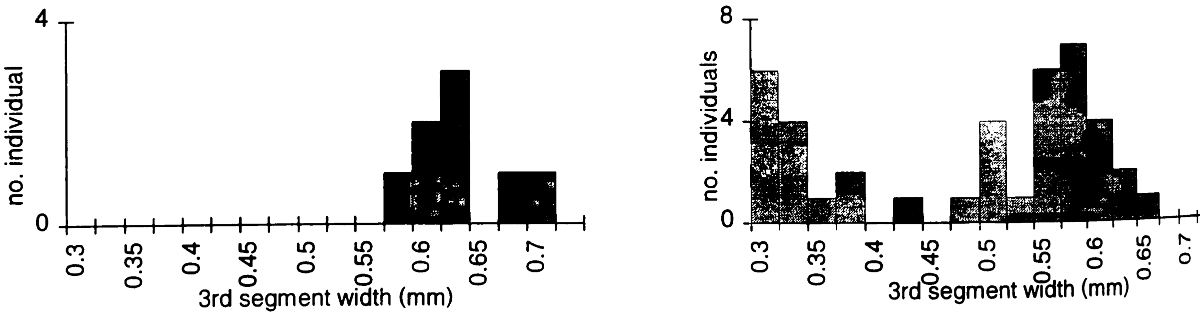
Fig. 3.78. Size-frequency histograms for *Chaetozone setosa* collected seasonally in 0.1m^2 grabs at UBBC from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.


3 grabs, Win 1996 (n=24)

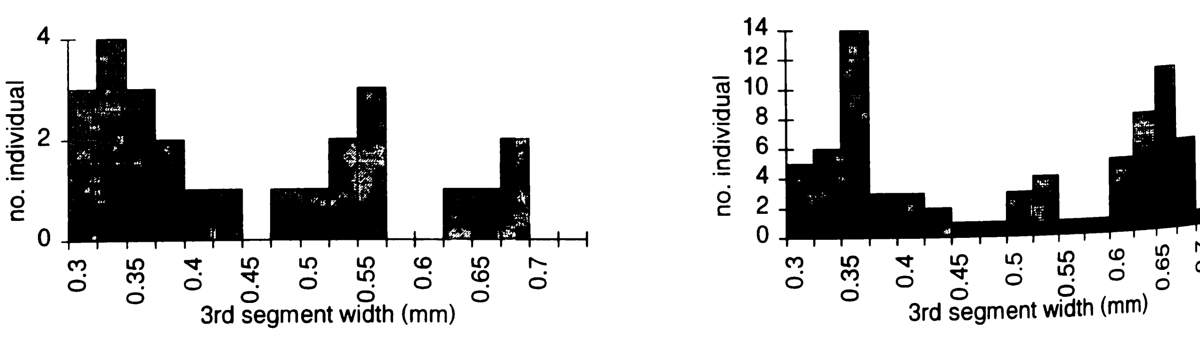
6 grabs, SPR 1996·(n=4)


3 grabs, SUM 1996 (n=51)

4 grabs, AUT 1996 (n=77)


4 grabs, WIN 1997 (n=8)

3 grabs, SPR 1997 (n=40)

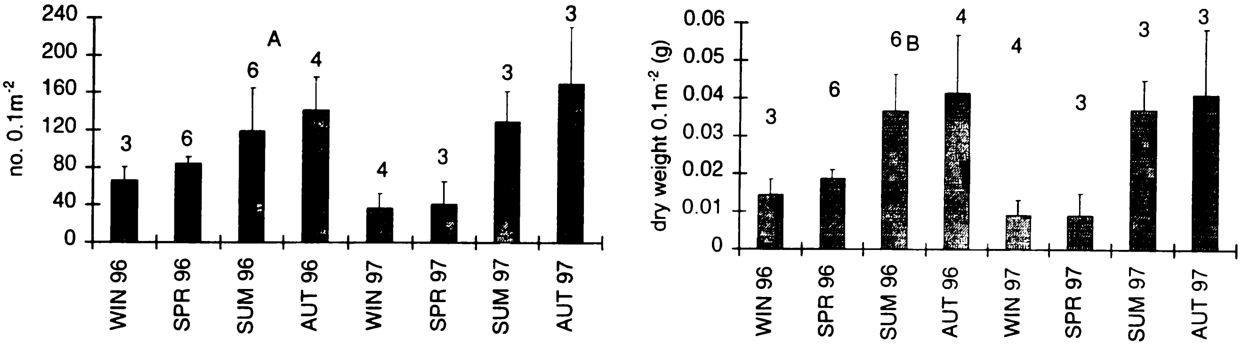

3 grabs, SUM 1997 (n=25)

4 grabs, AUT 1997 (n=77)

This species was very common on the impacted site of the Bay of Brest. It occurred in all of the 30 analysed grab samples. Mean densities ranged from 37 to 171 individuals per 0.1m^2 grab, with a maximum of 222 individuals sampled in one grab in autumn 1997 (Fig. 3.79A).

Though it can reach high densities, this species made a rather low contribution to the biomass of the impacted ground. Mean dry weight biomasses ranged from 9 to 42 mg per 0.1m^2 grabs and maximum contribution to one grab reached only 1.5 % of the total biomass in autumn 1996 (Fig. 3.79B).

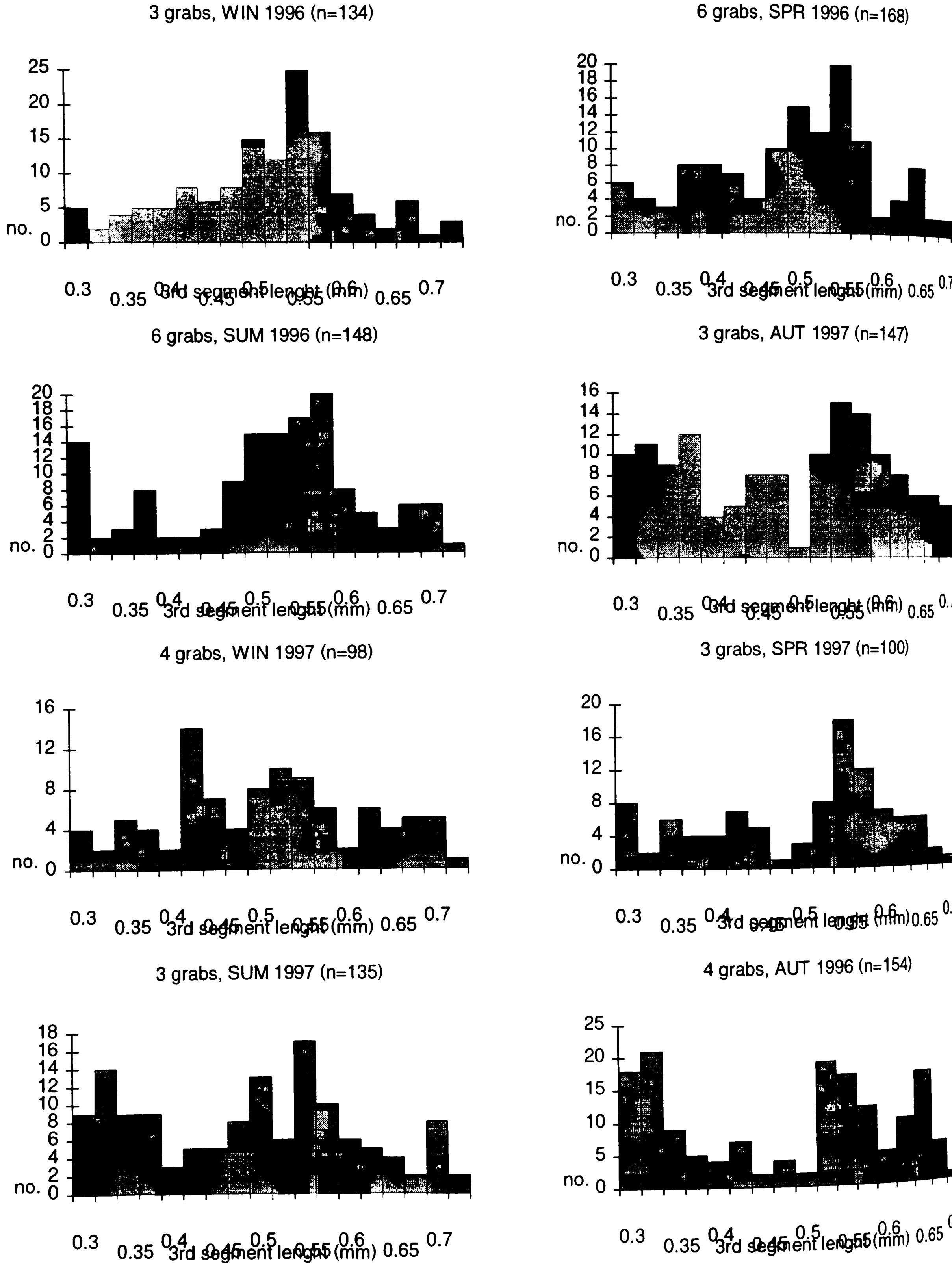
Fig. 3.79.A) Mean number and B) biomass (g dry weight) of *Chaetozone setosa* per 0.1m^2 grab at UBBI. Error bars = SD, N = number of grabs analysed.



The seasonal variations of the size frequency of *C. setosa* sampled are given in Fig. 3.80. No modal structure was obvious from these analyses, and individuals af all size classes were sampled at each season. However, large individuals (size classes 0.5-0.6 mm) dominated the population in winter 1996 and in spring 1997. Otherwise, small individuals (size classes 03-0.4 mm) were also sampled in the population. This may show a continuous recruitment during all year, small individuals entering the population at any season.

Year-to-year comparison shows very similar patterns for 1996 and 1997. Densities and biomasses remained low during the winter and autumn months and increased

Fig. 3.80. Size-frequency histograms for *Chaetozone setosa* collected seasonally in 0.1m^2 grabs at UBBI from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.



3 grabs, WIN 1996 (n=134)

6 grabs, SPR 1996 (n=168)

6 grabs, SUM 1996 (n=148)

3 grabs, AUT 1997 (n=147)

4 grabs, WIN 1997 (n=98)

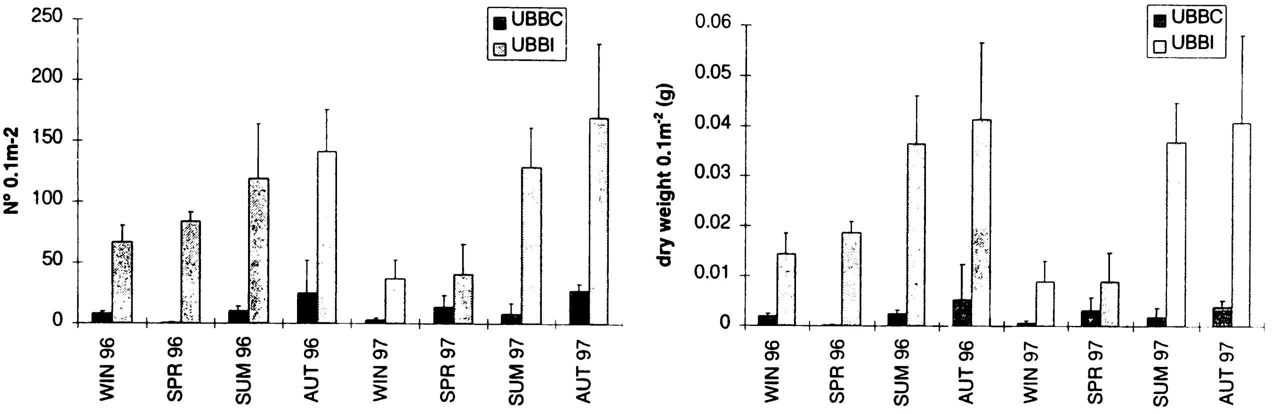
3 grabs, SPR 1997 (n=100)

3 grabs, SUM 1997 (n=135)

4 grabs, AUT 1996 (n=154)

strongly in summer and autumn months. This could be related to organic matter inputs to the grounds from the end of spring to the end of the year.

Fig. 3.81. Comparison between control and impacted sites in the Bay of Brest for 1997 and 1998 for *C. setosa.*



Density and biomass of *C. setosa* were ten times higher on the impacted ground than on the control, for both sampling years (Fig. 3.81). Maxima were reached during autumn months for both sites but the increase of the population was much higher on UBBI (x4 in 1997) than on UBBC.

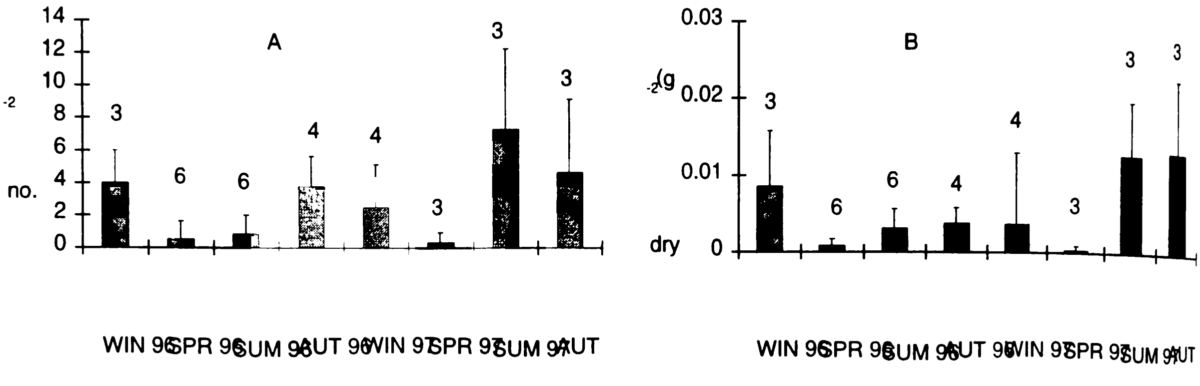
Cirriformia tentaculata (Montagu, 1808)

This cirratulid polychaete was moderatly common on the control ground of the bay of Brest as it occurred in 15 grabs of the 30 grabs analysed. Mean density was low, varying varied from 0.5 to 7 individuals per $0.1m^2$ grab, with a maximum of 13 individuals in one grab (Fig. 3.82A).

Like *Chaetozone setosa, Cirriformia tentaculata* is an opportunistic species tolerating hypoxic conditions. It is often found on the shore under the stones amongst decaying macroalgae. Population densities were much lower than those for *C. setosa,* but since this animal can reach 15cm, its biomass can be higher than that of *C. setosa.*

Mean dry weight biomasses were low in spite of the large body size of this species : 0.7-13 mg dry weight per $0.1m^2$ with a maximum contribution of 0.17% (Fig. 3.82B).

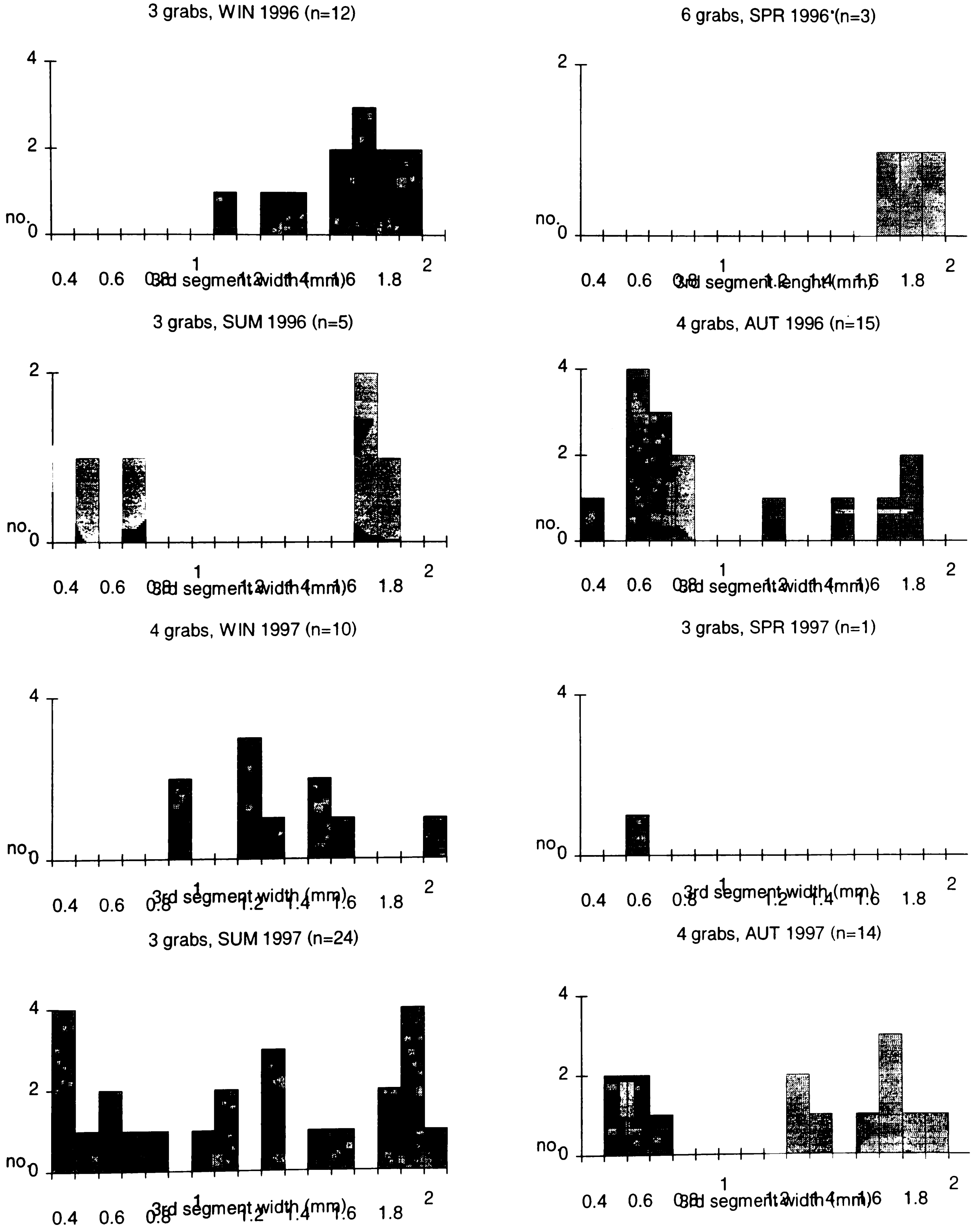
Fig. 3.82.A) Mean number and B) biomass (g dry weight) of *C. tentaculata* per $0.1m^2$ grab at UBBC. Error bars=SD, N=number of grabs analysed.



Due to the low abundances of this species on the control ground, seasonal variations are not apparent. Recruitment, however, seemed to occur during summer and autumn of the two years sampled (Fig. 3.83).

The sampling year 1997 showed higher densities and biomasses than 1996. Maximum densities and biomasses were reached during summer and autumn.

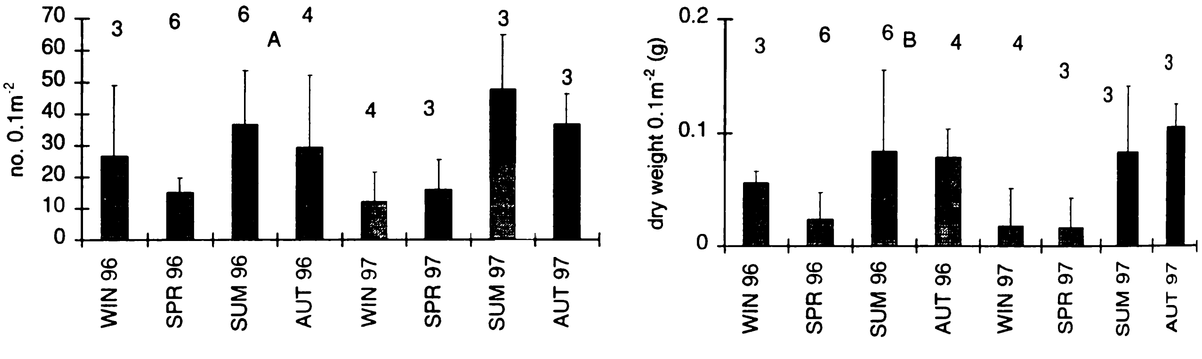
Fig. 3.83. Size-frequency histograms for *Cirriformia tentaculata* collected seasonally in 0.1m^2 grabs at UBBC from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.



This cirratulid was common on the impacted ground of the Bay of Brest as it occurred in all 30 samples analysed. Mean density was high, varying between 12 to 48 individuals per 0.1m^2 grab, with a maximum of 66 individuals in one grab (summer 1997) (Fig. 3.84A).

Mean dry weight biomasses were high compared with those of the other cirratulid polychaetes but remained low as a contribution to the total biomass of the grab: 16-106 mg dry weight per 0.1m^2 with a maximum contribution of 3 % (Fig. 3.84B).

Fig. 3.84.A) Mean number and B) biomass (g dry weight) of *C. tentaculata* per 0.1m^2 grab at UBBI. Error bars = SD, N = number of grabs analysed.



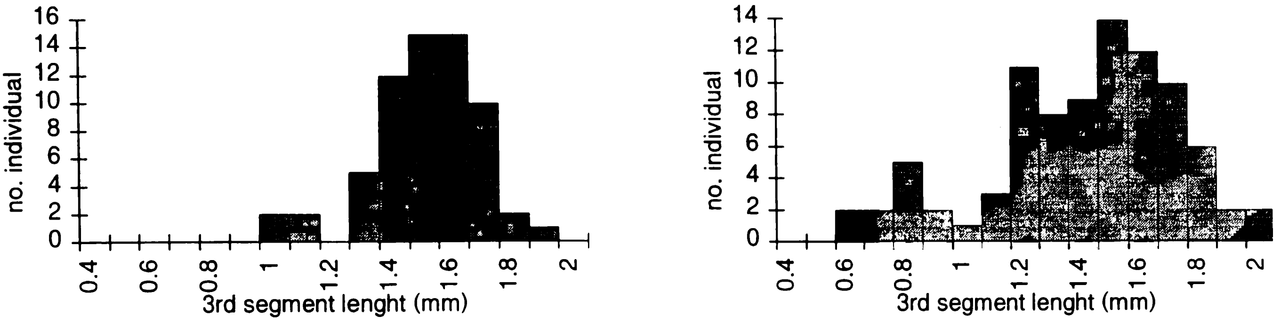
The seasonal variations in size frequency of *C. tentaculata* are given in Fig. 3.85. The population had a unimodal structure centred on size class 1.6 mm during the winter months. Then during the spring and summer months, the population had a bimodal structure with size classes centred on 1.4-1.6 mm for the largest and 0.5 mm for the smallest individuals. Finally, the autumn months showed no modal structure, the population having individuals of all sizes in similar proportions. This suggests that juvenile recruitment began in spring and continued until autumn, with small individuals reaching adult size in less than one year.

The two sampling years showed very similar patterns between years, the population remaining low during winter and spring months and increasing in summer after

Fig. 3.85. Size-frequency histograms for *Cirriformia tentaculata* collected seasonally in 0.1m^2 grabs at UBBI from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.

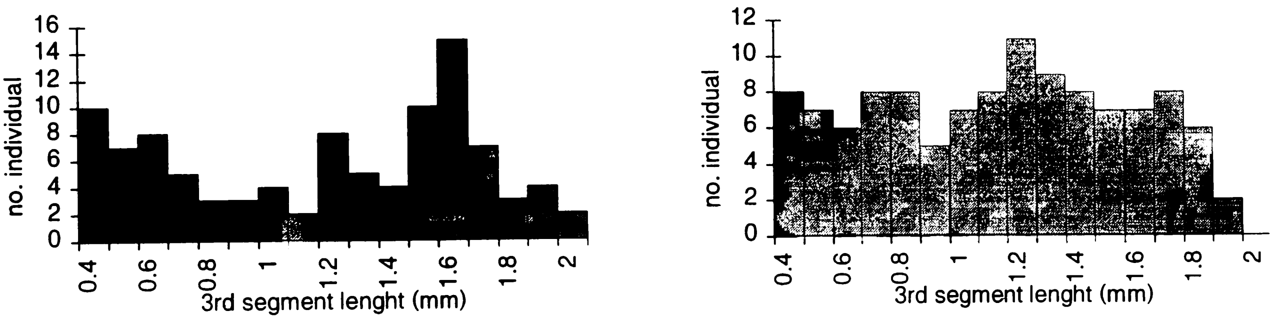
3 grabs, WIN 1996 (n=64)

6 grabs, SPR 1996 (n=89)



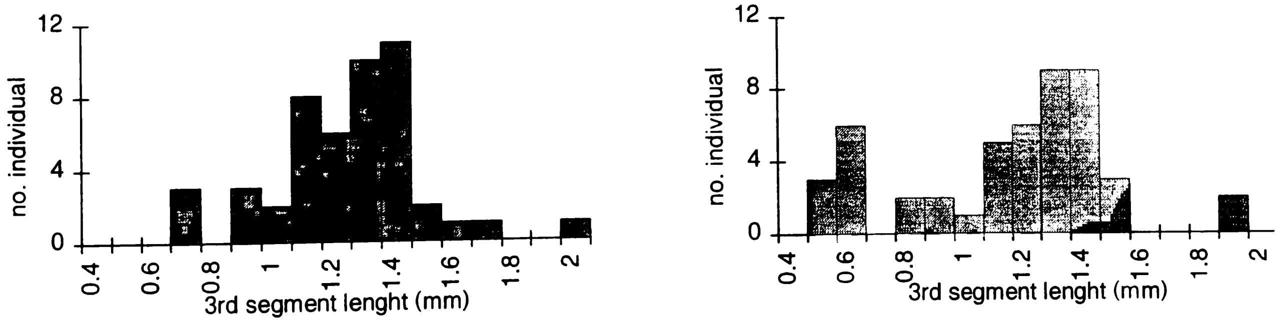
6 grabs, SUM 1996 (n=100)

4 grabs, AUT 1996 (n=115)



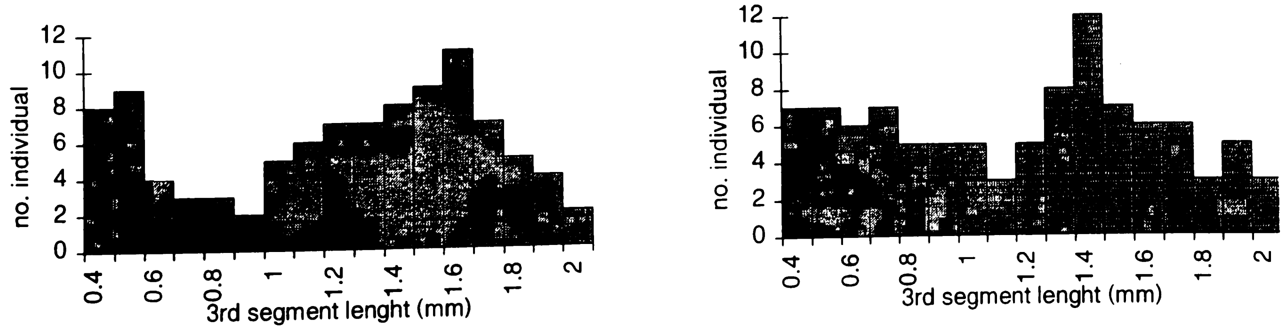
4 grabs, WIN 1997 (n=48)

3 grabs, SPR 1997 (n=48)



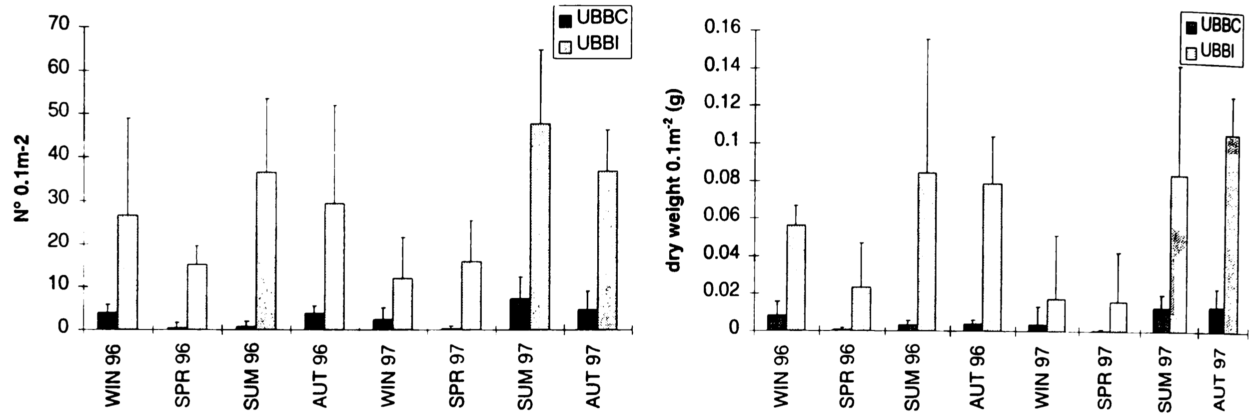
3 grabs, SUM 1997 (n=100)

3 grabs, AUT 1997 (n=100)



juvenile recruitment. Maxima in both density and biomass were reached during summer and autumn of 1997. However, differences between the two years were slight. .

Fig. 3.86. Comparison between control and impacted sites in the Bay of Brest for 1997 and 1998 for *C. tentaculata.*



Cirriformia tentaculata was ten times more abundant on UBBI than on UBBC (fig. 3.86). Biomasses were also much higher on the impacted ground than on the control, especially at the end of the year. Being an opportunistic species, *C. tentaculata* indicates high oragnic imputs on UBBI during summer and autumn months.

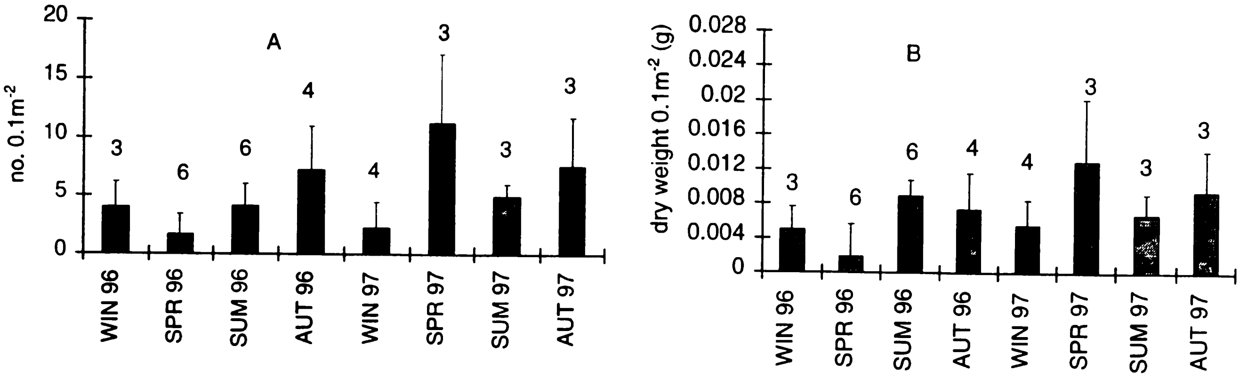
Notomastus latericeus M. Sars, 1851.

This capitellid polychaete was common on the control ground at the Bay of Brest as it was found in 29 of the 30grabs analysed for UBBC during the sampling period 1996-1997. Maximum density observed was 18 individuals per 0.1m^2 grab while mean densities ranged from 1.7-11.3 individuals per 0.1m^2 (Fig. 3.87A)

N. latericeus is a deep-deposit feeding polychaete living in sediment varying from muddy sands to muds. It burrows into the sediment, creating a contorted burrow and extracting organic matter from the sediment for feeding. This species is tolerant to organic enrichment and can survive in hypoxic sediments for a while. It can be found in high densities under fish farm cages or in harbour muds, but also lives in cleaner areas.

It has a wide range of size, animal length ranging from 5 to 150 mm, but bigger animals were rather rare. Mean dry weight varied from 2 to 12 mg per $0.1m^2$ grab on the control site (Fig. 3.87B). Maximum contribution of this species to the total biomass of one grab of the samples analysed was however low at 0.5 %.

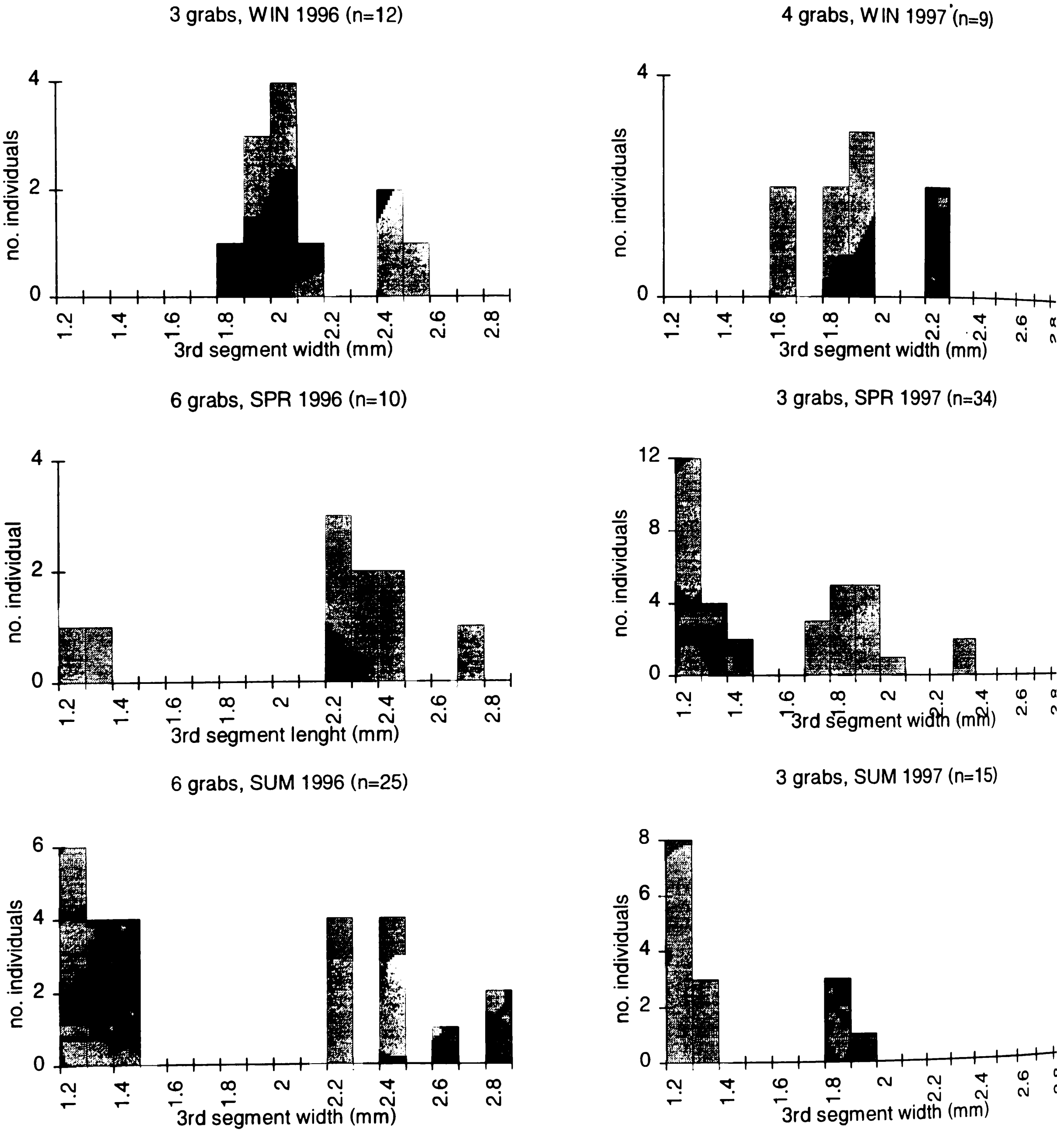
Fig. 3.87.A) Mean number and B) biomass (g dry weight) of *N. latericeus* per $0.1m^2$ grab at UBBC. Error bars = SD, N = number of grabs analysed.



The size-frequency structure of *N. latericeus* did not vary much during the sampling period (Fig. 3.88). Animals of 2 to 2.5 mm (3rd segment width) were regularly observed and this size seems to be the normal range of size for adults of this species. Recruitment of juveniles was observed during summer and autumn mainly, but also occurred on a smaller scale in spring. Late summer and autumn was the period of maximum recruitment for this species, with juveniles contributing half of the population at this season.

The two sampling years showed very similar patterns in term of abundances, biomass, these parameters increasing regularly during the year and dropping in winter. However, spring 1997 showed the highest densities and biomasses. This can be related to a very high juvenile recruitment (as shown in Fig. 3.88), such juveniles were lacking the following season.

Fig. 3.88. Size-frequency histograms for *N. latericeus* collected seasonally in 0.1m^2 grabs at UBBC from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.


3 grabs, WIN 1996 (n=12)

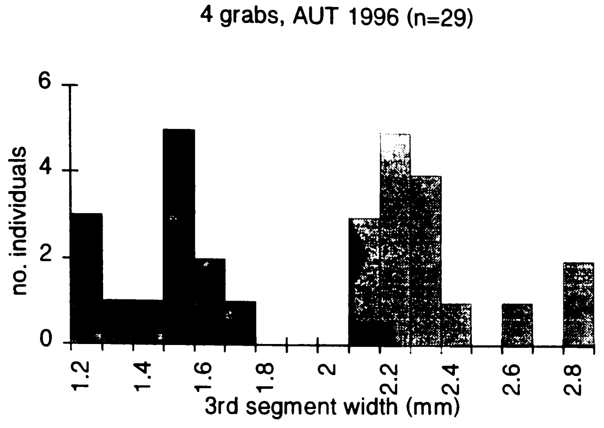
4 grabs, WIN 1997 (n=9)

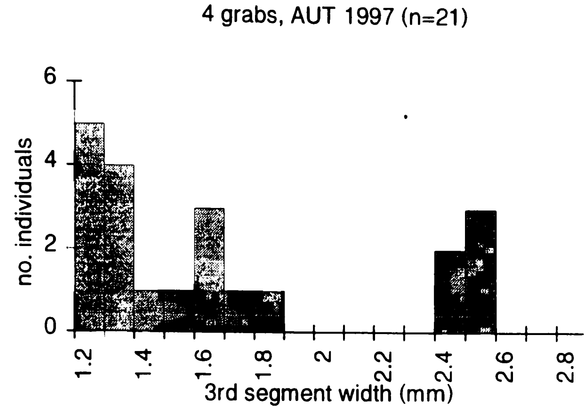
6 grabs, SPR 1996 (n=10)

3 grabs, SPR 1997 (n=34)

6 grabs, SUM 1996 (n=25)

3 grabs, SUM 1997 (n=15)

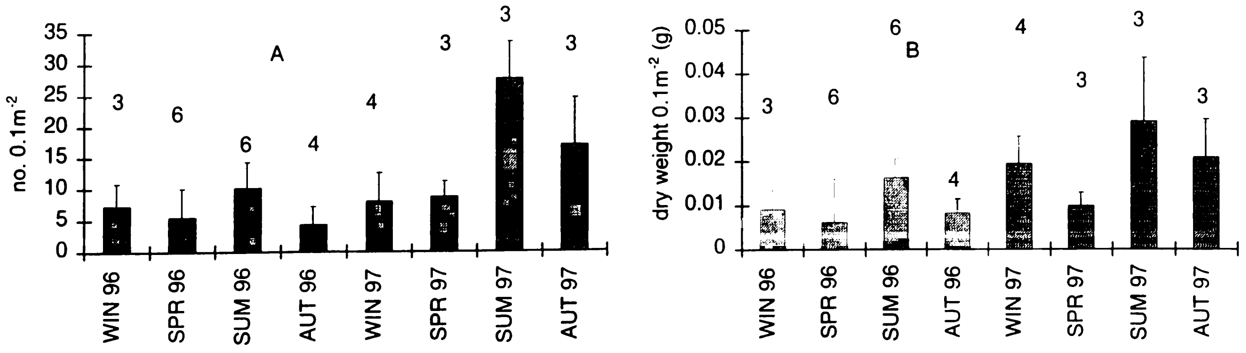




This capitellid polychaete occurred in great densities on the impacted ground UBBI and was observed in all the 30 grabs analysed during the sampling period 1996-1997. Maximum density observed was 34 individuals per 0.1m^2 grab while mean densities range between was 4-28 individuals per 0.1m^2 (Fig.3.89A)

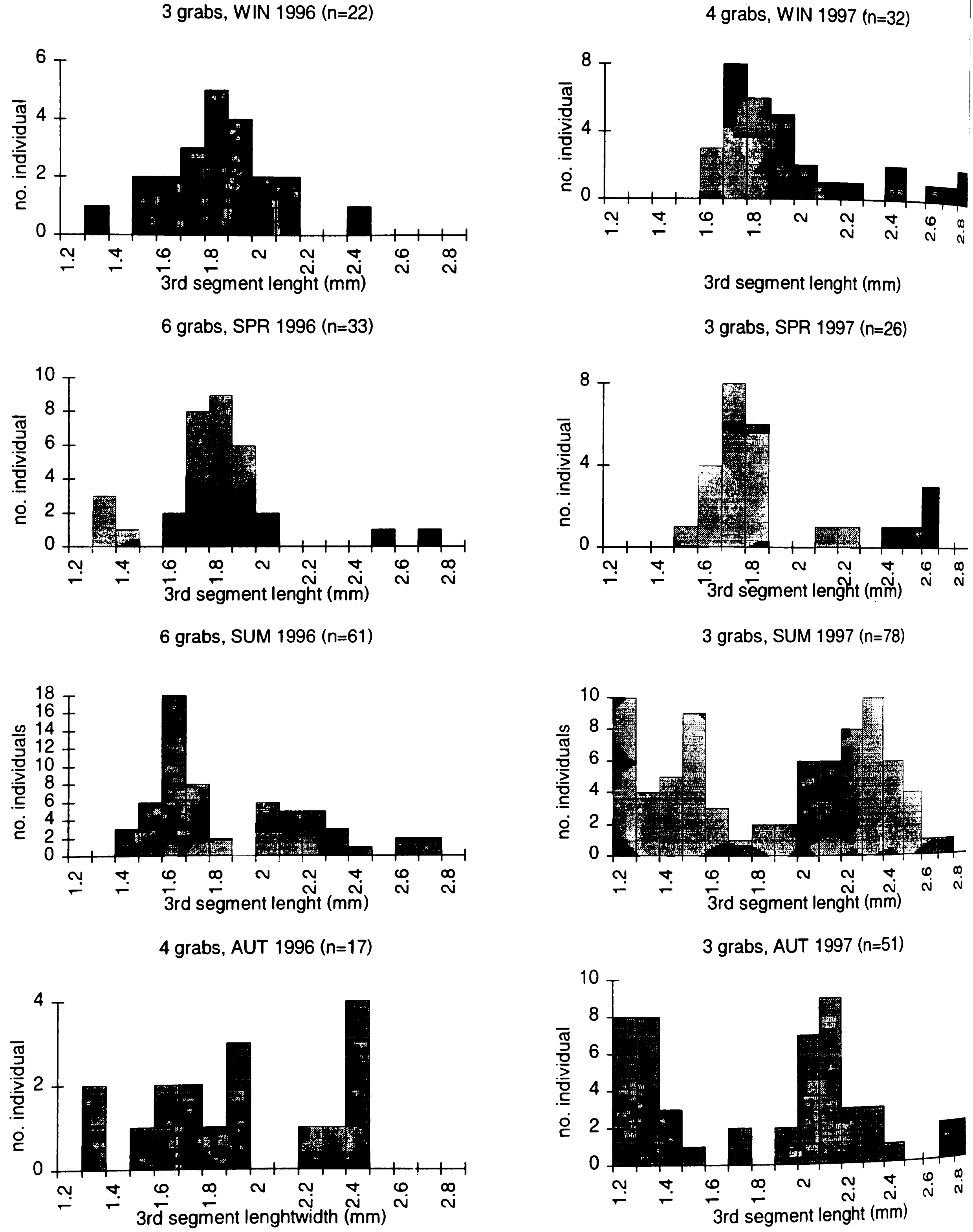
Mean dry weight varied from 6 to 30 mg per 0.1m^2 grab on the control site. Maximum contribution of this species to the total biomass one grab of the samples analysed was however low, at 1% (Fig. 3.89B).

Fig. 3.89.A) Mean number and B) biomass (g dry weight) of *N. latericeus* per 0.1m^2 grab at UBBI. Error bars = SD, N = number of grabs analysed.



Seasonal variations in size frequency of *N. latericeus* were apparent at UBBI (Fig. 3.90), with a unimodal distribution centred around size classes of 1.8mm during winter and autumn months. During the summer and autumn months, more bimodal distributions were observed, modes being centred around size classes of 1.5 mm and 2.2 mm. Recruitment seems therefore to have occurred in summer and, on a smaller

Fig. 3.90. Size-frequency histograms for *N. latericeus* collected seasonally in 0.1m^2 grabs at UBBI from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.



3 grabs, WIN 1996 (n=22)

4 grabs, WIN 1997 (n=32)

6 grabs, SPR 1996 (n=33)

3 grabs, SPR 1997 (n=26)

6 grabs, SUM 1996 (n=61)

3 grabs, SUM 1997 (n=78)

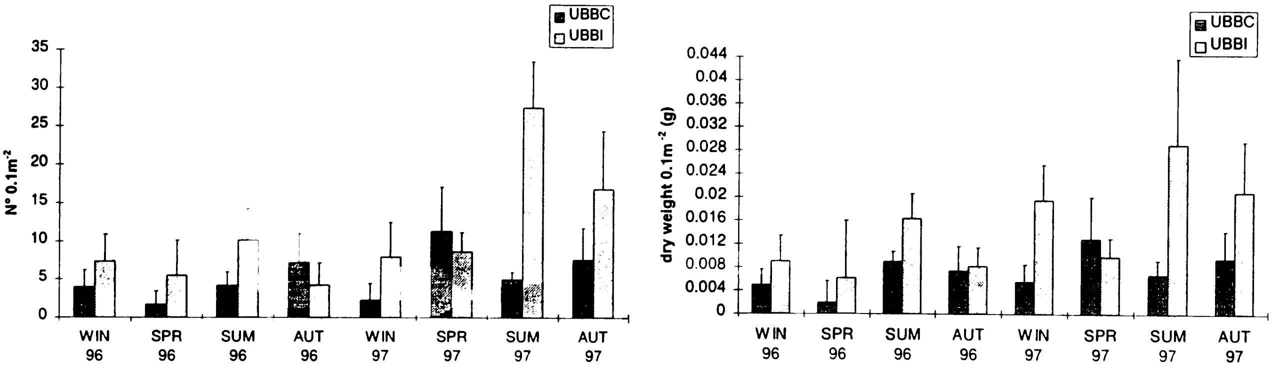
4 grabs, AUT 1996 (n=17)

3 grabs, AUT 1997 (n=51)

scale, in autumn. Growth of the large part of the population is also observed during the year.

Comparison of the two sampling years showed different patterns between densities and biomasses: maximum densities were observed during summer months while biomasses were more variable, high values being observed in summer 1996 and in winter, spring and summer 1997.

Fig. 3.91. Comparison between control and impacted sites in the Bay of Brest for 1996 and 1997 for *N. latericeus.*



A comparison of control and impacted sites (Fig. 3.91) shows that density and biomass were very similar except for the summer months of 1996 and 1997 and for autumn 1997. These parameters showed greater seasonal variations on the impacted than on the control ground.

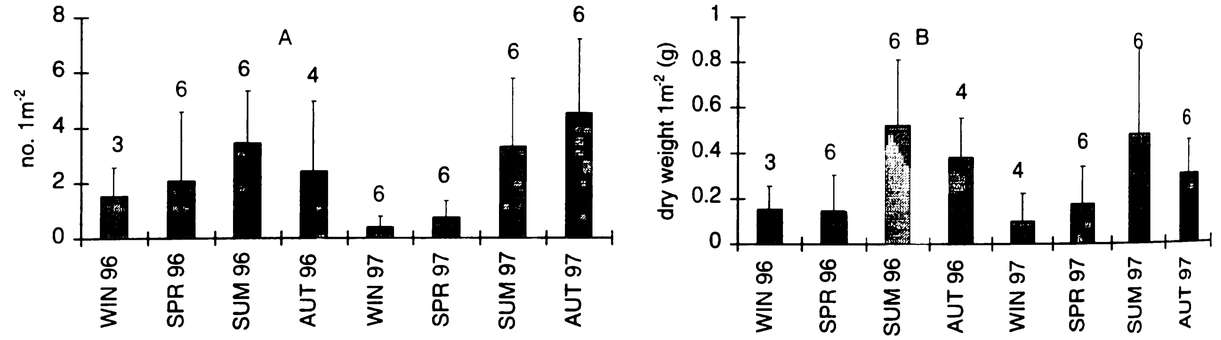
Hesione pantherina (Risso, 1826)

Hesione pantherina is a hesionid polychaete typical of the Bay of Brest maerl grounds. It was, however, only sparsely distributed and has therefore had to be sampled using the AQUAREVE. It occurred in 38 of the 43 total samples analysed, reaching maximum densities of 12 individuals per m^2 with means of 0.4 4 individuals per m^2 (Fig. 3.92A).

Hesione pantherina is a predatory polychaete well adapted to insinuate itself into gravels or maerl grounds. Direct observations in an aquarium showed that this species crawls very rapidly between maerl fragments and can therefore predate on motile invertebrates living between maerl fragments. It has been reported from the Mediterranean to the Atlantic coasts of France, but it seems to reach its northern geographical limits in the Bay of Brest as we could not find any reference of it occurring in it in the English Channel or the Irish Sea.

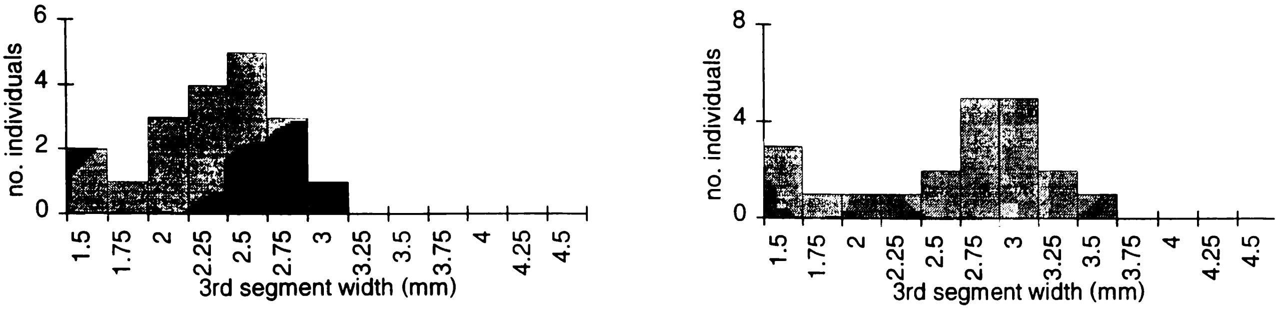
Since the main organisms caught by the AQUAREVE were bivalves and gastropods, the contribution of this speies to the biomass of the samples was low. However, at maximum densities, the contribution reached 6% of the total biomass of one sample in summer 1996. Mean dry weight biomasses ranged from 0.1 to 0.52 g per m^2 throughout the sampling period (Fig. 3.92B).

Fig. 3.92.A) Mean number and B) biomass (g dry weight) of *Hesione pantherina* per AQUAREVE analysed at UBBC. Error bars = SD, N = number of AQUAREVE analysed.



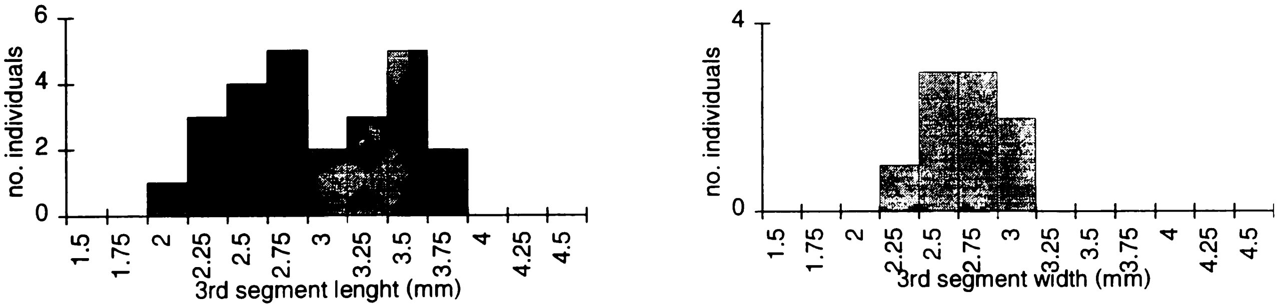
Seasonal size-structure analysis of the *H. pantherina* data showed growth of the population during the year (Fig. 3.93), the size range increasing from 2-3 mm (based on third segment width) in the winter to 3-4 mm in autumn. Recruitment of smaller individuals occurred in summer and autumn, as a single mode in 1996 while it seemed to be spread through in 1997. It also seemed as if large individuals disappeared in autumn. This could be due to mortalities after spawning.

Fig. 3.93. Size-frequency histograms for *H. pantherina* collected seasonally at UBBC from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.



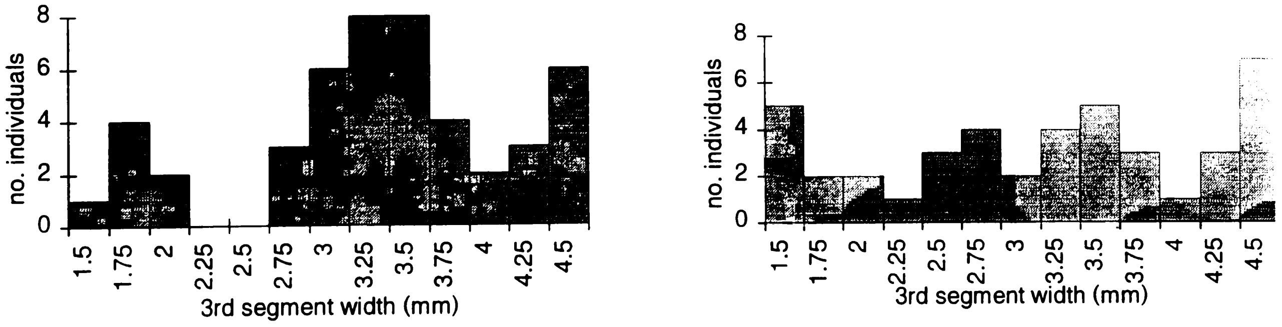
3 AQUAREVE, Win 1996 (n=19)

6 AQUAREVE, WIN 1997 (n=21)



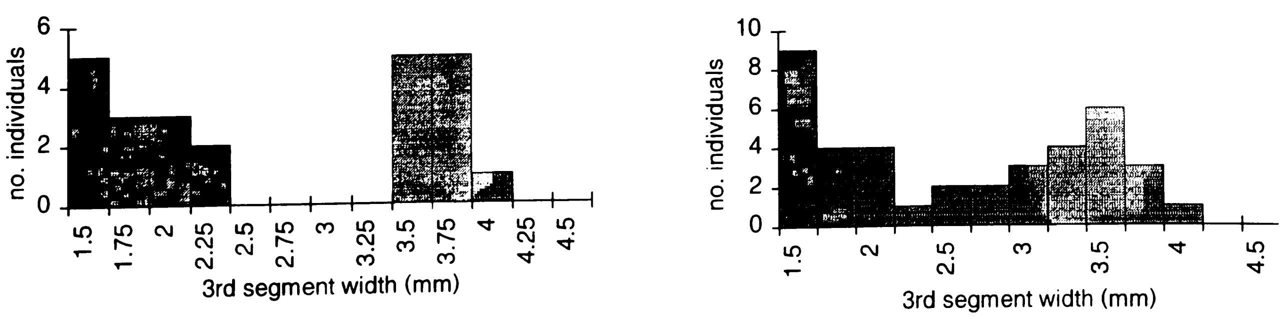
6 AQUAREVE, SPR 1996 (n=25)

6 AQUAREVE, SPR 1997 (n=9)



6 AQUAREVE, SUM 1996 (n=47)

6 AQUAREVE, SUM 1997 (n=42)



4 AQUAREVE, AUT 1996 (n=24)

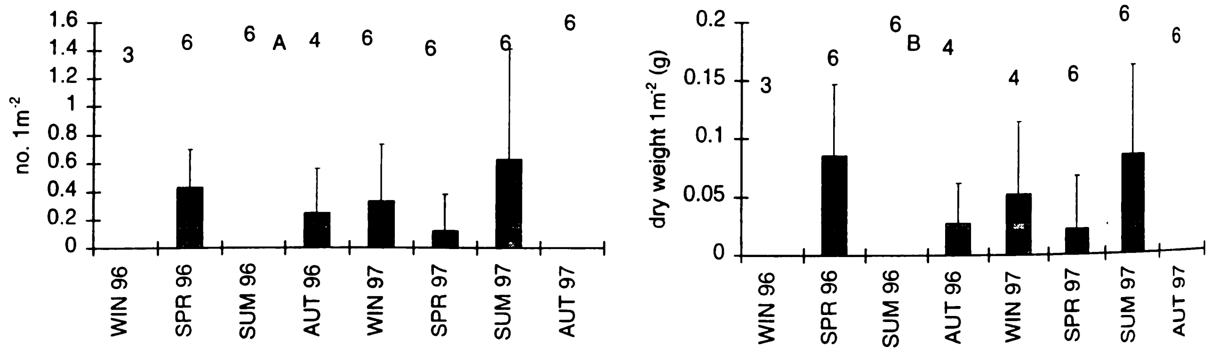
6 AQUAREVE, AUT 1997 (n=39)

Comparison of the sampling years showed differences in term of abundances, and similarities in terms of biomass for this species. In 1997, the maximum density was reached in summer while for 1997 this maximum is reached in autumn. On the other hand biomasses were very similar, being maximal during the summer (probably when animals were mature) and then decreasing in the autumn after recruitment of smaller individuals.

Hesione pantherina was rare on the impacted ground of the Bay of Brest (UBBI). It was only taken in 22 samples of the 43 AQUAREVE samples analysed. It had a maximum density of 4 individuals per m^2 with means of 0 -0.6 individuals per m^2 (Fig. 3.94A).

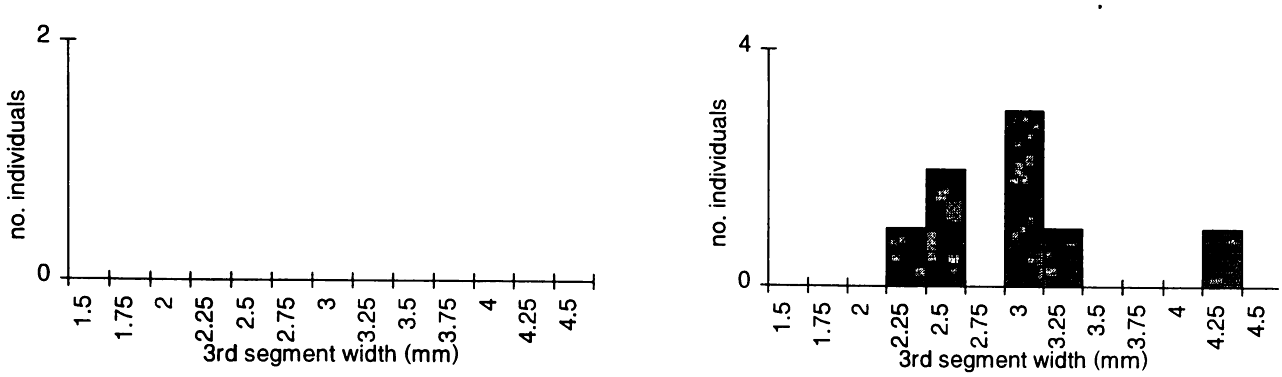
As densities of this species were very low on the impacted ground, its contribution to the total biomass of the samples analysed was also very low. Its maximum contribution to a single sample was 0.5% while mean dry weight biomasses ranged from 0 to 85 mg g per m^2 throughout the sampling period (Fig. 3.94B).

Fig. 3.94.A) Mean number and B) biomass (g dry weight) of *Hesione pantherina* per 0.1m^2 grab at UBBI. Error bars = SD, N = number of grabs analysed.



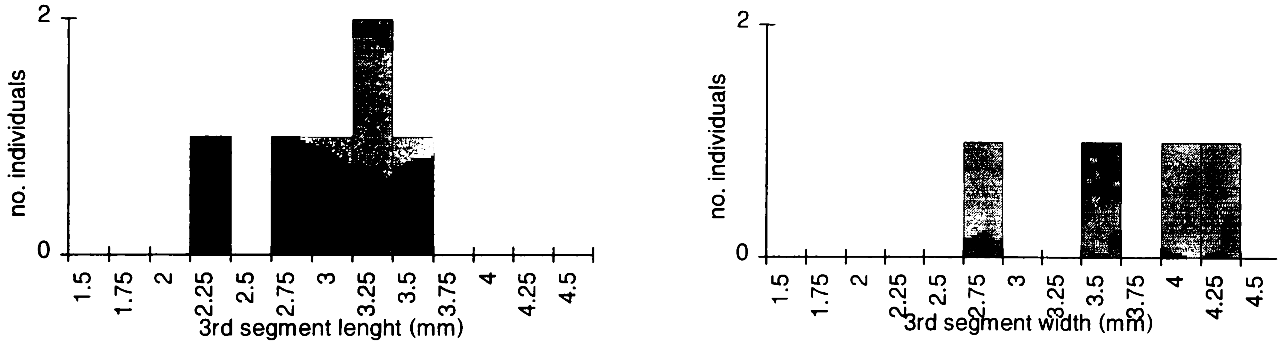
Due to the low abundances of this species on the impacted ground, seasonal variations are difficult to interpret (Fig. 3.95). However, animals of size classes of 3 to 3.5 mm (3rd segment width) were the most commonly sampled. A recruitment of *H. pantherina* seems to have occurred during the summer of 1997 months but these

Fig. 3.95. Size-frequency histograms for *H. pantherina* collected seasonally at UBBI from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.



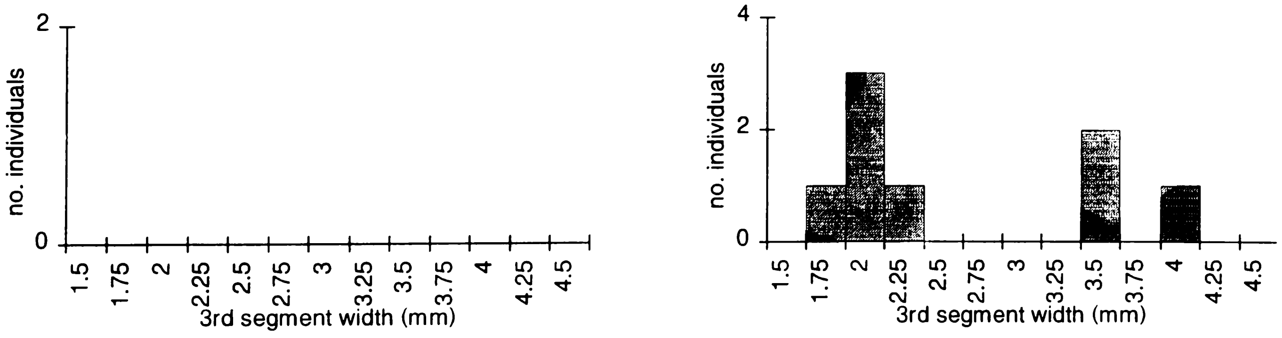
3 AQUAREVE, Win 1996 (n=0)

4 AQUAREVE, WIN 1997 (n=8)



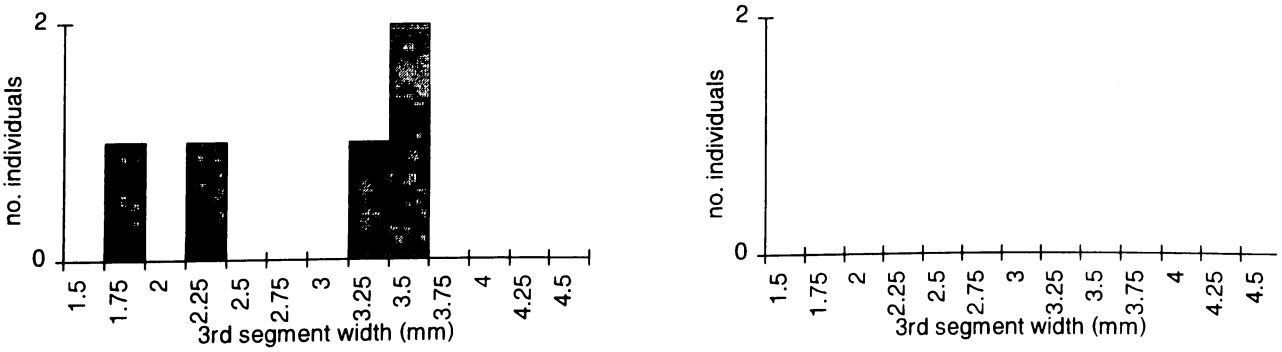
6 AQUAREVE, SPR 1996 (n=6)

3 AQUAREVE, SPR 1997 (n=4)



3 AQUAREVE, SUM 1996 (n=0)

3 AQUAREVE, SUM 1997 (n=8)



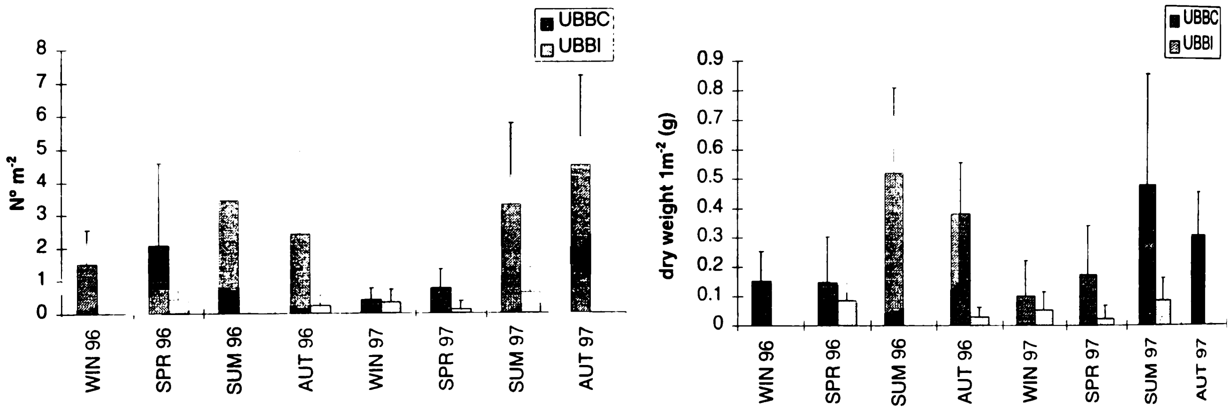
4 AQUAREVE, AUT 1996 (n=5)

4 AQUAREVE, AUT 1997 (n=0)

individuals had very poor survival rates, as they were not detected the following season.

Year-to-year comparison of biomasses and densities for *Hesione pantherina* showed no clear pattern (Fig. 3.96). Densities are probably too low to allow accurate interpretation.

Fig. 3.96. Comparison between control and impacted sites in the Bay of Brest for 1996 and 1997 for *H. pantherina.*



It is clear that abundances of *H. pantherina* were much higher on the control than on the impacted ground (Fig. 3.96). Seasonal differences were observed on the control ground, with maximum population density occurring during the summer-autumn months.

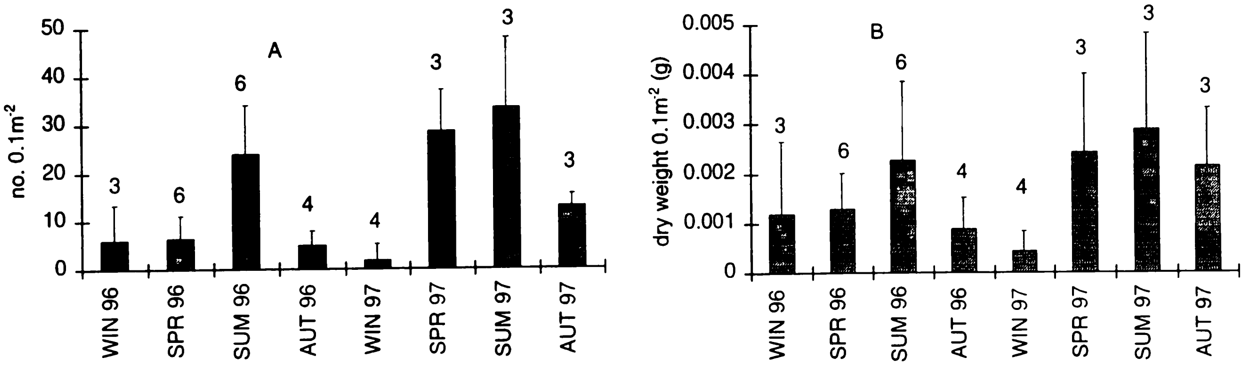
Abludomelita gladiosa (Bate, 1862)

This melitid amphipod was observed in high densities on the control ground of the Bay of Brest (UBBC) during the summers of the sampling period 1996-1997. It occurred in 26 grabs out of the total of 30 samples analysed, reaching mean densities of 2-34 individuals per 0.1m^2 grab, with a maximum of 44 individuals for one grab in summer 1997 (Fig. 3.97A).

This deposit-feeding amphipod is assumed to feed on decaying macroalgal fragments. Its abundance should therefore be related to macrophytic production on our maerl banks. Maerl beds provide a suitable habitat for this species, protected from fish predation and facilitating access to their source of food.

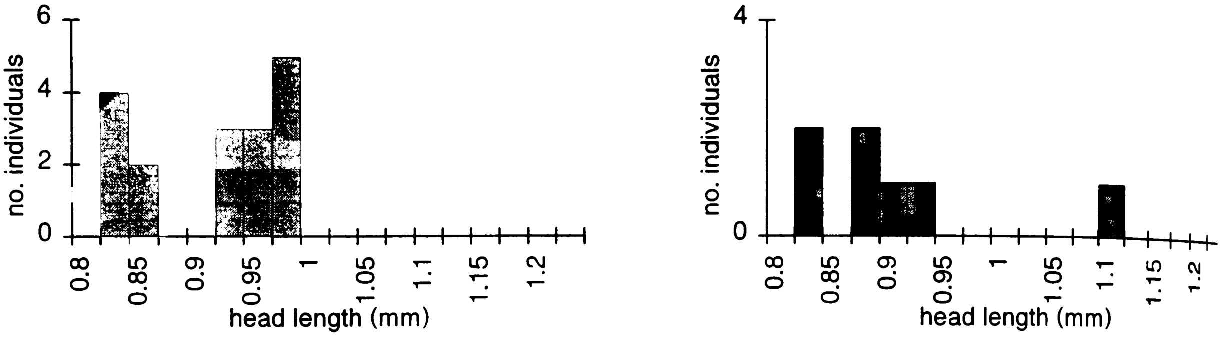
Although reaching high densities, this species made a low contribution to the total dry weight of the 0.1m^2 grabs sampled, reaching a maximum of 0.25% . Mean dry weight biomasses were low, ranging from 0.4 to 2.5 mg per 0.1 m^{2}grab (Fig. 3.97B).

Fig. 3.97.A) Mean number and B) biomass (g dry weight) of *A. gladiosa* per 0.1m^2 grab at UBBC. Error bars=SD, N=number of grabs analysed.

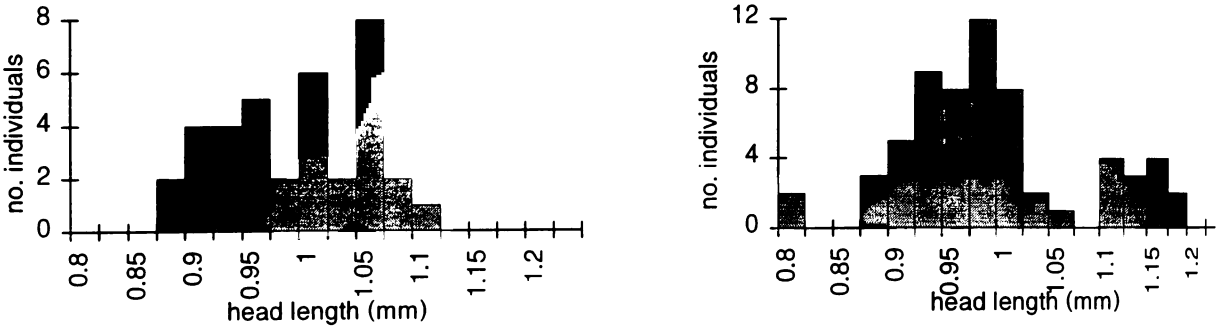


Analysis of the size-frequency distribution of *A. gladiosa* shows growth of adults in the population during the year (Fig. 3.98). From a range of head length of 0.9 to 1.1 in the winter, they reached a range of 1.1 to 1.3 in autumn. Recruitment of juveniles clearly occurred in summer, with small individuals constituting half of the population then. Recruitment continued until autumn. The two sampling years 1996-1997 showed very similar patterns, *A. gladiosa* reaching maxima of density and biomass in summer, and dropping in autumn. Factors involved in this decrease of the population are not obvious but could be related to predation by carnivorous polychaetes and/or competition with other amphipods with the same trophic niche.

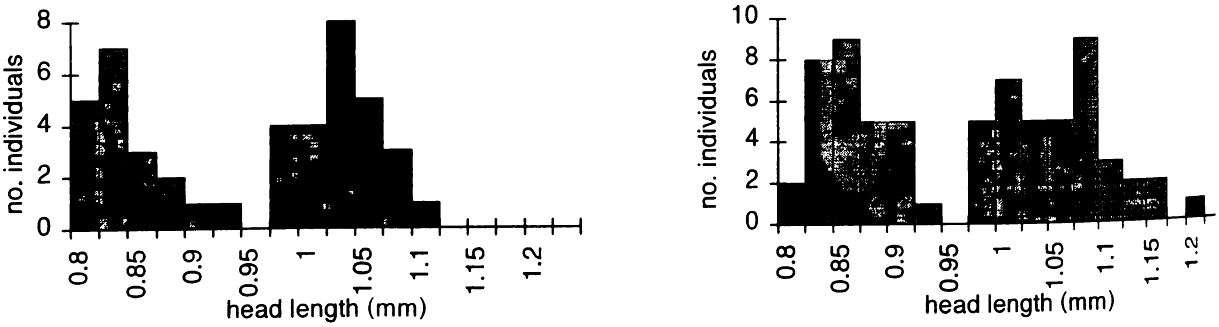
Fig. 3.98. Size-frequency histograms for *A. gladiosa* collected seasonally in 0.1m^2 grabs at UBBC from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.


3 grabs, WIN 1996 (n=17)

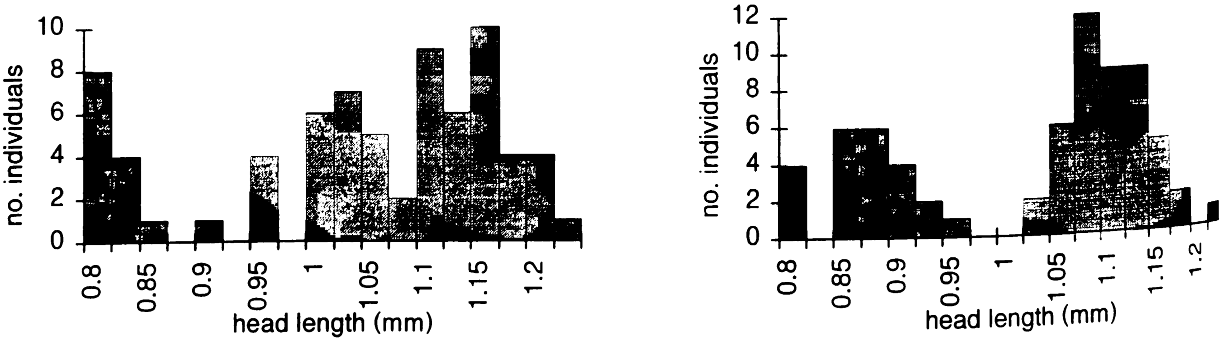
4 grabs, WIN 1997 (n=7)


6 grabs, SPR 1996 (n=36)

3 grabs, SPR 1997 (n=63)


10 grabs, SUM 1996 (n=44)

3 grabs, SUM 1997 (n=69)

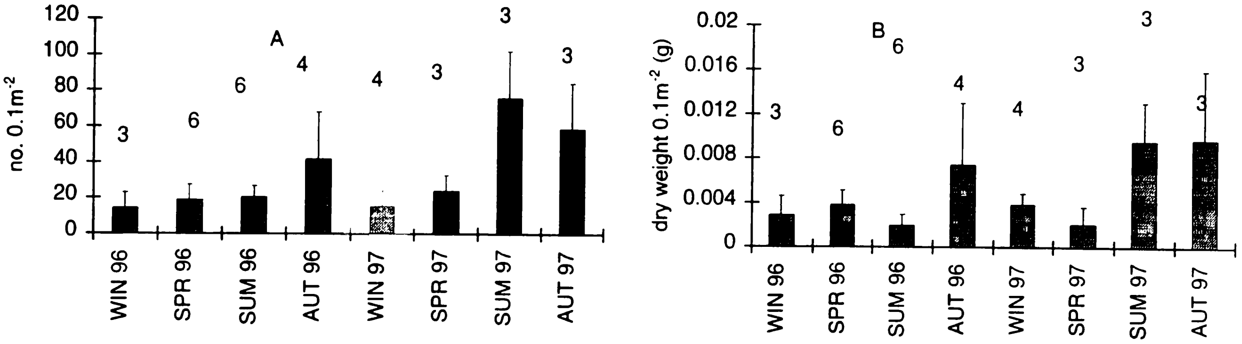

4 grabs, AUT 1996 (n=72)

4 grabs, AUT 1997 (n=69)

This melitid amphipod occurred in considerable abundances on the UBBI maerl ground during the sampling period 1996-1997. It occurred in 27 grabs out of the total of 30 samples analysed. Mean densities varied from 14-76 individuals per 0.1m^2 grab, with a maximum of 106 individuals in a single grab in summer 1997 (Fig. 3.99A).

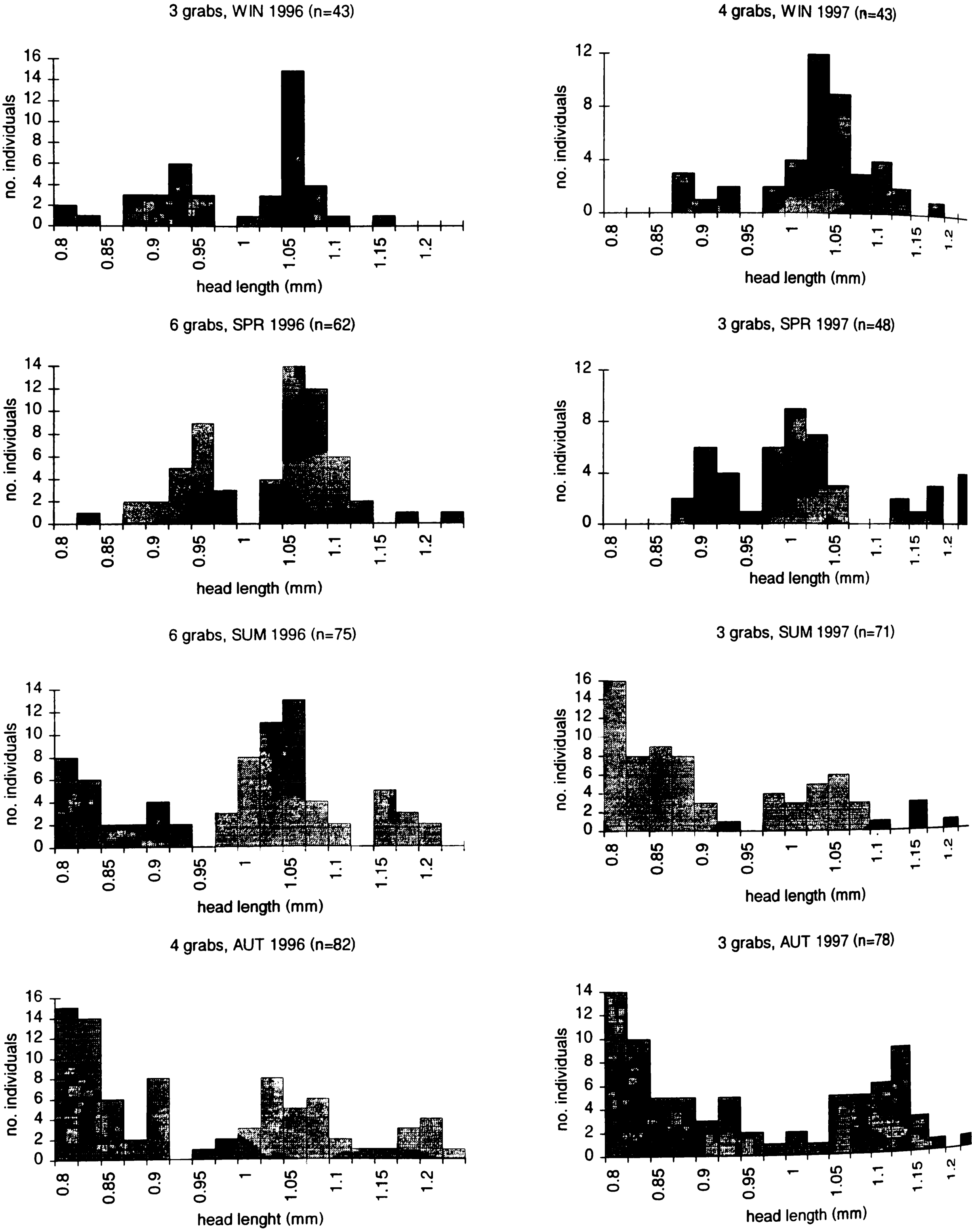
It made a low contribution to the total dry weight of the 0.1m^2 grabs sampled on the impacted ground, reaching a maximum of 0.35 % . Mean dry weight biomasses were low, ranging from 2 to 10 mg per 0.1 m^{2}grab (Fig. 3.99B).

Fig. 3.99.A) Mean number and B) biomass (g dry weight) of *A. gladiosa* per 0.1m^2 grab at UBBI. Error bars = SD, N = number of grabs analysed.



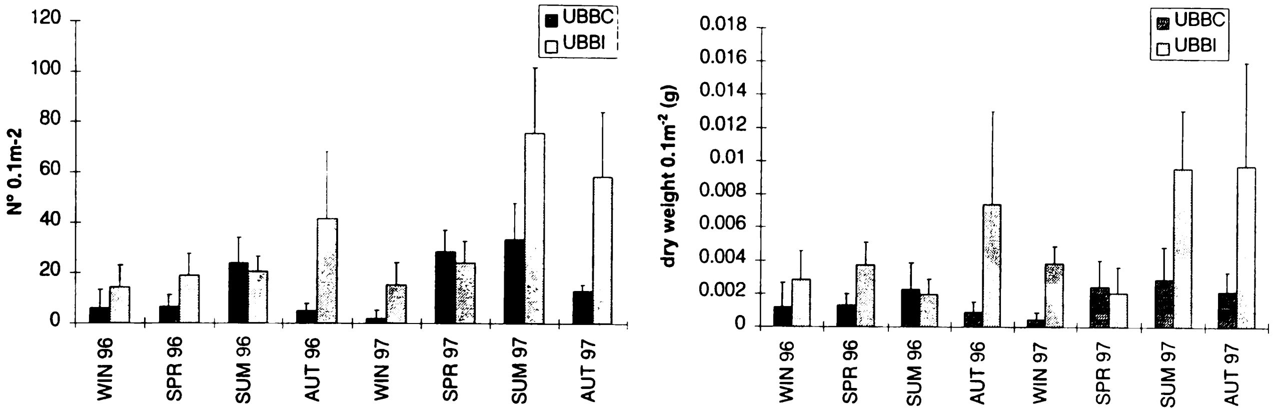
Variations in the size structure (head length) of *A. gladiosa* are shown in Fig. 3.100. Bimodal structure of the population occurred in winter and summer months with modes centred around size classes of 0.95 and 1.05 mm classes in 1996. In 1997 at the same seasons, the population showed a unimodal structure, centred around the size class 1mm. During the summer and autumn periods, recruitment of smaller individuals occurred, the size of the smaller individuals being centred around 0.8 mm size class while a mode of larger individuals remained centred around size class 1.1mm. The proportion of juveniles was more than 50% of the population during autumn 1996 and summer and autumn 1997. Recruitment therefore occurred in summer in both sampling years at this site.

Fig.3.100. Size-frequency histograms for *A. gladiosa* collected seasonally in 0.1m^2 grabs at UBBI from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.



Differences between the two sampling years appeared in the summer months: in 1996, abundance remained low while it reached a maximum in summer 1997. However, biomasses were at their maximum during the autumn and minimal densities occurred in winter for both sampling years.

Fig. 3.101. Comparison between control and impacted sites in the Bay of Brest for 1996 and 1997 for *A. gladiosa.*



Site-to-site comparison (Fig. 3.101) shows the much higher density and biomass of *A. gladiosa* on the impacted ground during the summer and autumn months. On the other hand, during winter and spring months populations on both grounds were similar in structure.

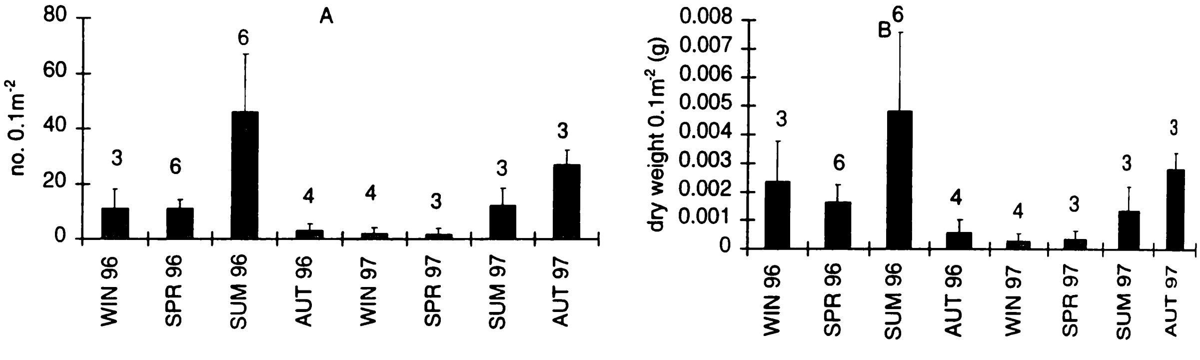
Maera grossimana (Bate, 1862)

This amphipod was observed in high densities on the control ground of the Bay of Brest UBBC during part of the sampling period 1996-1997. It occurred in 25 grabs out of the total of 30 samples analysed, reaching mean densities of 3-46 individuals per 0.1m^2 grab, with a maximum of 69 individuals for one grab in summer 1996 (Fig. 3.102A).

M. grossimana is a deposit-feeding amphipod, feeding on macrophytic detritus coming from decaying macroalgae. Its abundance should therefore be related to macrophytic production on our maerl banks. Maerl beds provide a suitable habitat for this species, the maerl structure protecting it from fish predation and giving access to their source of food.

Although reaching high densities, this species made a low contribution to the total dry weight since mean dry weight in the grabs ranged between 0.3 to 4.8 mg per 0.1m^2, while the maximum contribution of this species to the dry weight of fauna from one grab was 0.2% (Fig. 3.102B).

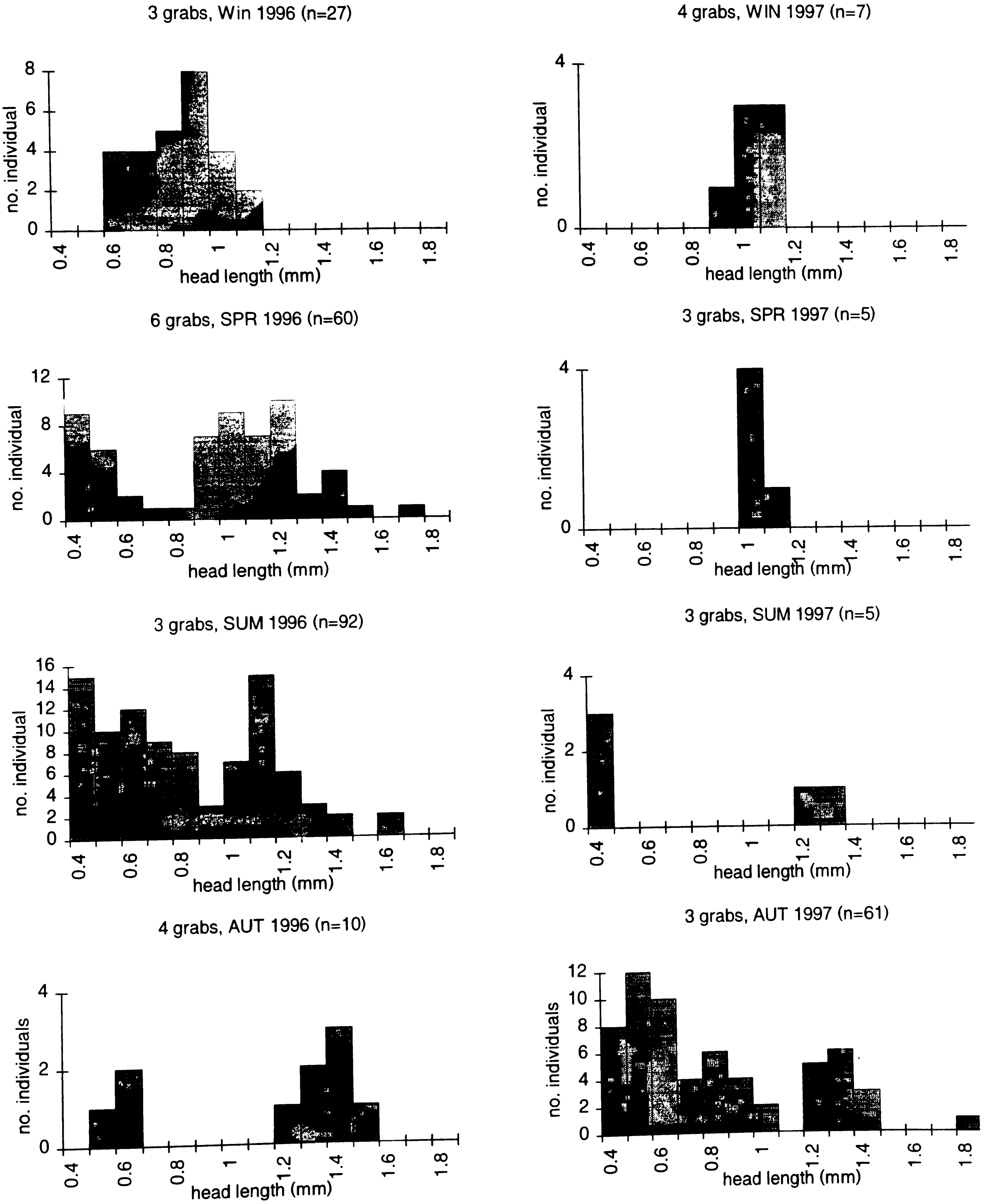
Fig. 3.102.A) Mean number and B) biomass (g dry weight) of *M. grossimana* per 0.1m^2 grab at UBBC. Error bars = SD, N = number of grabs analysed.



For 1996, the size structure (based on head length) of *M. grossimana* shows an increase in the mode of larger animals during the year, maximum range being reached in autumn 1996 (Fig. 3.103). Very high abundances (due to e recruitment) were observed during summer of 1996. In 1997, however, a different pattern appeared, as no increase in the 'large individuals' mode appeared (but abundances were low and size structures may be not accurate) while massive recruitment was only observed in autumn 1997.

Comparison of the two years shows differences. In 1996, maximum abundances were reached in the summer. On the other hand, 1997 showed abundances and biomasses increasing throughout the year, reaching their maximum in autumn 1997. Differences in these patterns could be related to differences in the epiphytic algal biomass/production between the two years.

Fig. 3.103. Size-frequency histograms for *Maera grossimana* collected seasonally in $0.1m^2$ grabs at UBBC from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.



3 grabs, Win 1996 (n=27)

4 grabs, WIN 1997 (n=7)

6 grabs, SPR 1996 (n=60)

3 grabs, SPR 1997 (n=5)

3 grabs, SUM 1996 (n=92)

3 grabs, SUM 1997 (n=5)

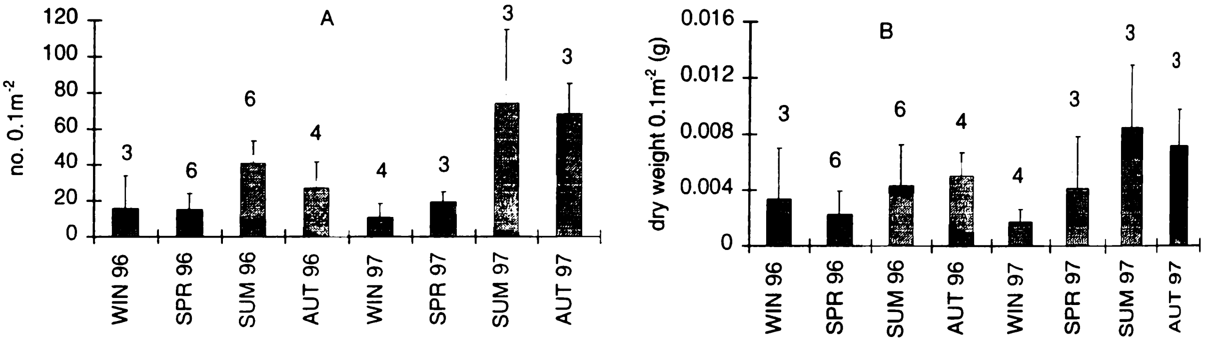
4 grabs, AUT 1996 (n=10)

3 grabs, AUT 1997 (n=61)

This amphipod was observed in high densities on the impacted ground UBBI during the sampling period 1996-1997. It occurred in 28 out of the total of 30 grab samples analysed. Mean densities were in the range of 10-75 individuals per $0.1m^2$ grab, reaching a maximum of 104 individuals in a single grab in summer 1997 (Fig. 3.104A).

Although reaching high densities, this species made a low contribution to the total dry weight with mean dry weight in the grabs ranging between 1.5 to 9 mg per $0.1m^2$ while maximum contribution to the dry weight of one grab was 0.3% (Fig. 3.104B).

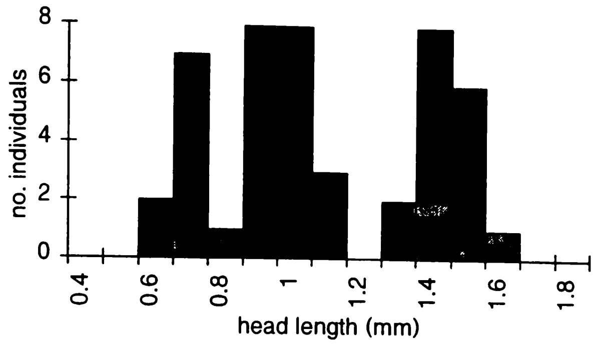
Fig. 3.104.A) Mean number and B) biomass (g dry weight) of *M. grossimana* per $0.1m^2$ grab at UBBI. Error bars = SD, N = number of grabs analysed.



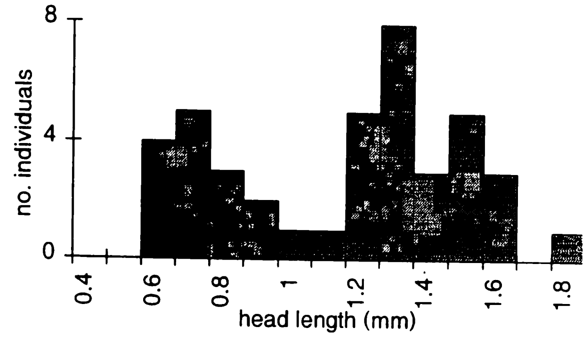
Seasonal variations in the size structure (based on head length) of *M. grossimana* showed a clear mode of larger animals centred around size class of 1.4 mm (Fig. 3.105). However, little growth of these individuals could be detected during 1997; this mode being centred around size class 1.6 while in 1996, it remained centred around size class 1.4mm. Bimodal structure of the population appeared from the spring months in both years, the smaller individual mode being around 0.4 to 0.6 mm. The greatest proportion of these smaller amphipods was reached during autumn months in both sampling years. the winter months showed bimodal structure too, with the mode of smaller individuals being centred around size class 0.7-0.8 mm.

Fig. 3.105. Size-frequency histograms for *Maera grossimana* collected seasonally in $0.1 m^2$ grabs at UBBI from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.

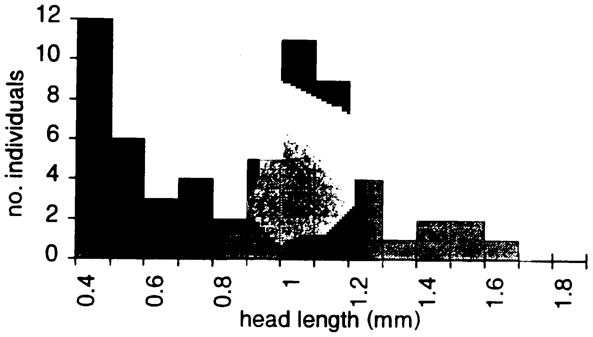
3 grabs, WIN 1996 (n=46)



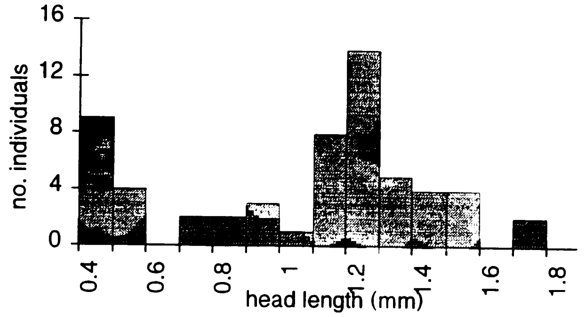
4 grabs, WIN 1997 (n=41)



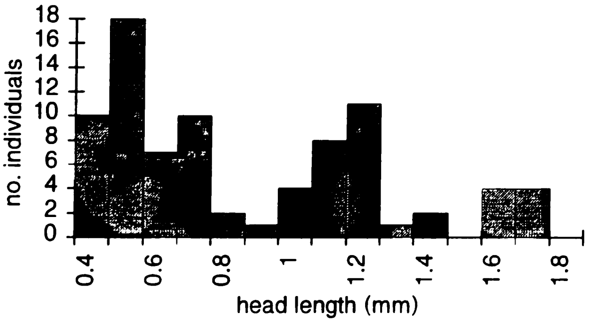
6 grabs, SPR 1996 (n=62)



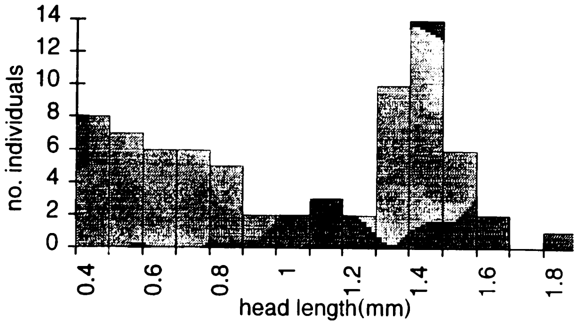
3 grabs, SPR 1997 (n=58)



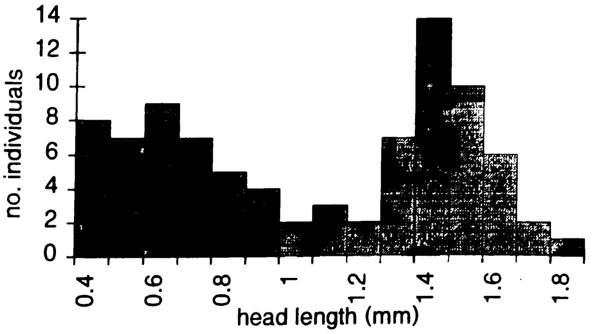
6 grabs, SUM 1996 (n=82)



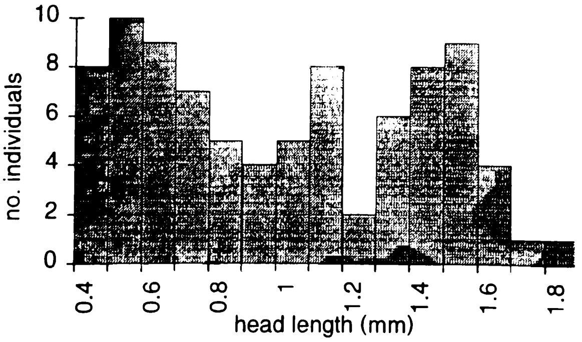
3 grabs, SUM 1997 (n=74)



4 grabs, AUT 1996 (n=87)

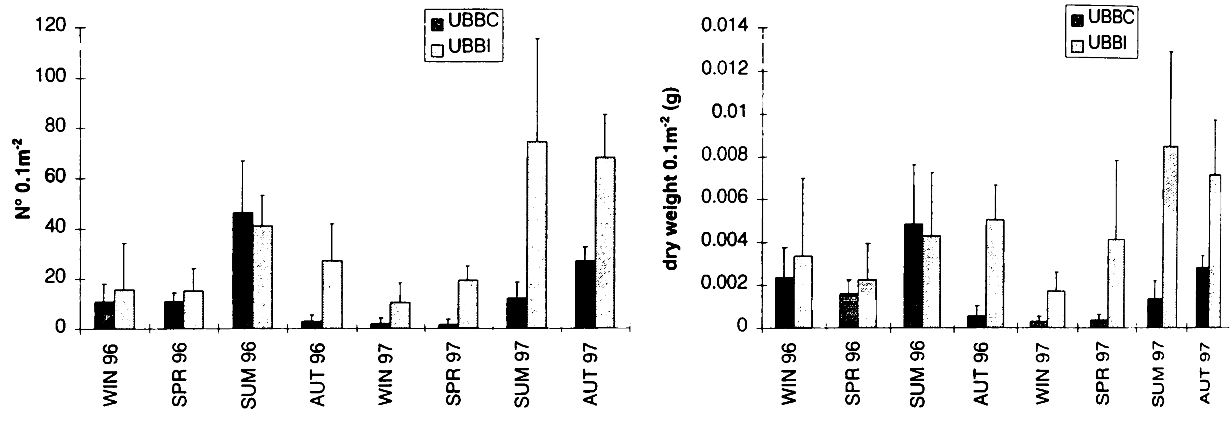


3 grabs, AUT 1997 (n=87)



Year-to-year comparison of abundances and biomasses showed that the same pattern occurred seasonally during the sampling period (Fig. 3.106). Maxima were reached in summer and autumn months, but these maxima were twice as high in 1997 than in 1996.

Fig. 3.106. Comparison between control and impacted sites in the Bay of Brest for 1996 and 1997 for *M. grossimana.*



Slight differences were observed in 1996 for the two sites, except in autumn. The year 1997 showed higher densities and biomasses on the impacted ground than on the control.

Gammarella fucicola (Bate, 1862)

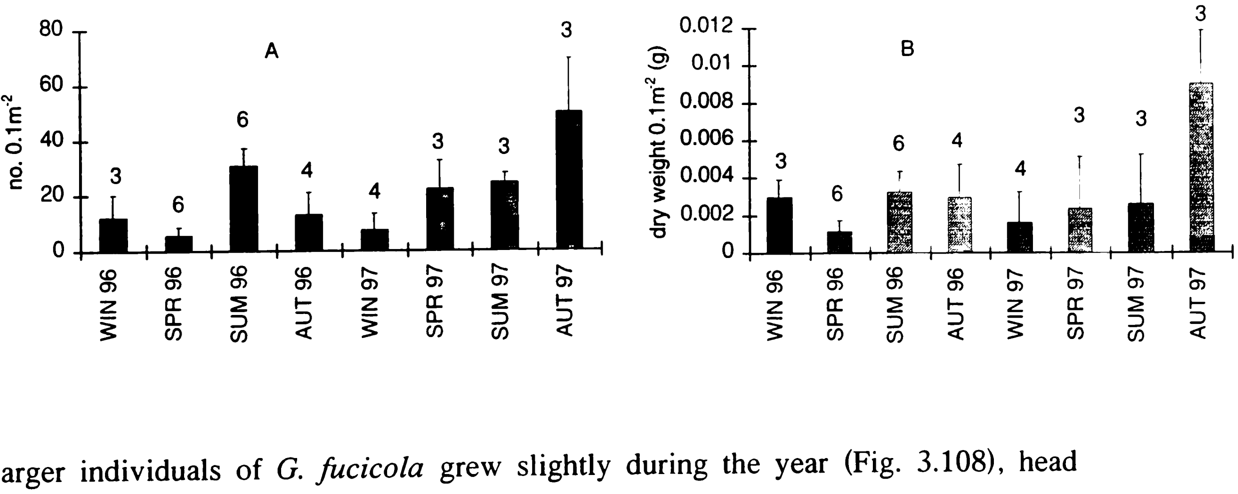
This melitid amphipod was observed in high densities on the control ground of the Bay of Brest during the whole sampling period 1996-1997. It occurred in 29 grabs of the total of 30 samples analysed, reaching mean densities of 8-50 individuals per $0.1m^2$ grab (reaching a maximum of 69 individuals for one grab in summer 1996)(Fig. 3.107A).

It is very common littorally and in shallow waters in Brittany, where it occurs in high densities in rich algal cover. It feeds on macroalgal detritus, and its abundance will likely be related to the presence or absence of epiphytic algae on our maerl grounds.

Again, as for *Abludomelita gladiosa* or *Maera grossimana*, maerl beds provide a suitable habitat for these species, the maerl structure providing protection from fish predation and giving access to a ready supply of food.

Even though population densities were high, this species still only made a small contribution to the total biomass of the grabs analysed, contributing a maximum of 0.8% of the total dry weight biomass. Mean biomasses varied from 1 to 9 mg dry weight per 0.1m^2 grab (Fig. 3.107B).

Fig. 3.107.A) Mean number and B) biomass (g dry weight) of *G. fucicola* per 0.1m^2 grab at UBBC. Error bars=SD, N=number of grabs analysed.

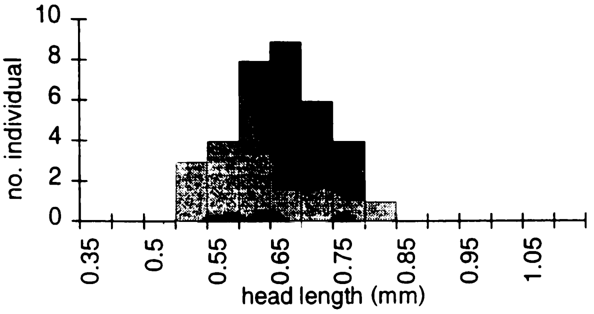


Larger individuals of *G. fucicola* grew slightly during the year (Fig. 3.108), head length increasing from 5.5-7.5 mm to 7.5-9.5 mm in autumn, for the two years of the sampling period. Massive recruitment of juvenile was also observed at the same timw of year (summer and autumn) for the two years. However, very small individuals, were sampled in great numbers in spring 1997.

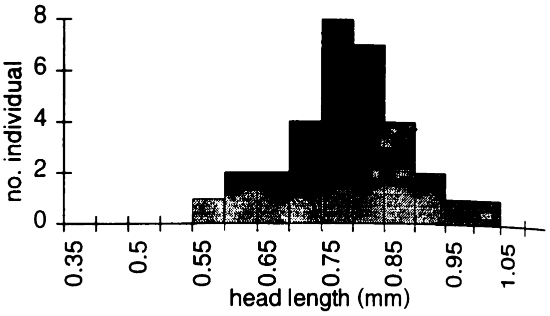
The year 1996 revealed maximum abundance and biomass in summer, while in 1997 this maximum was reached during autumn. Winter and spring were comparable in this these respects for the two years. The autumn 1997 samples, however, showed the highest densities and biomass (twice as large as autumn or summer 1996). This could be related to increased macroalgal epiphytic production during summer of 1997.

Fig. 3.108. Size-frequency histograms for *Gammarella fucicola* collected seasonally in 0.1m^2 grabs at UBBC from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.

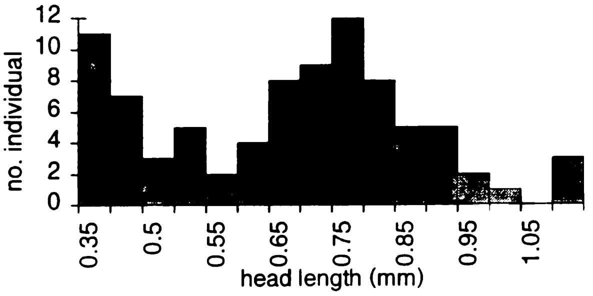
3 grabs, Win 1996 (n=35)



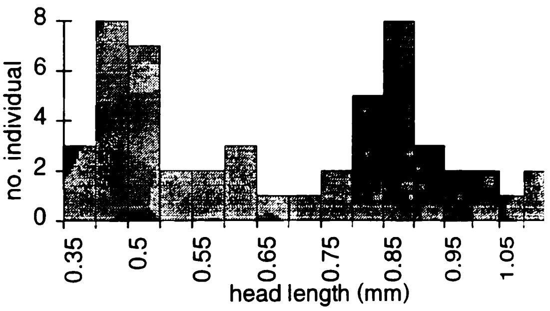
6 grabs, SPR 1996 (n=32)



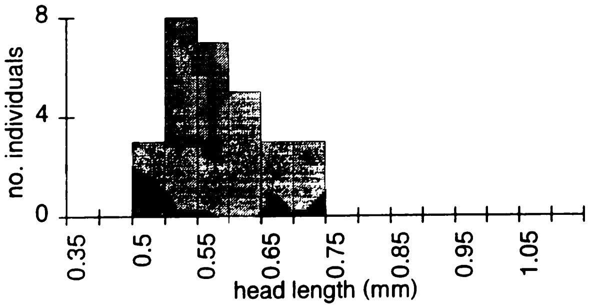
6 grabs, SUM 1996 (n=85)



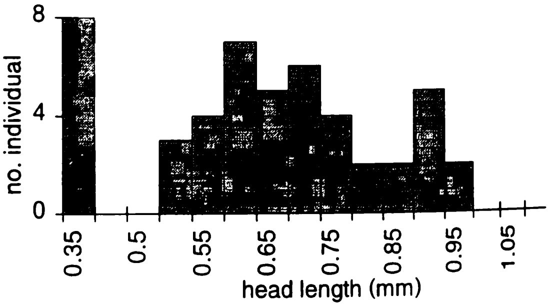
4 grabs, AUT 1996 (n=52)



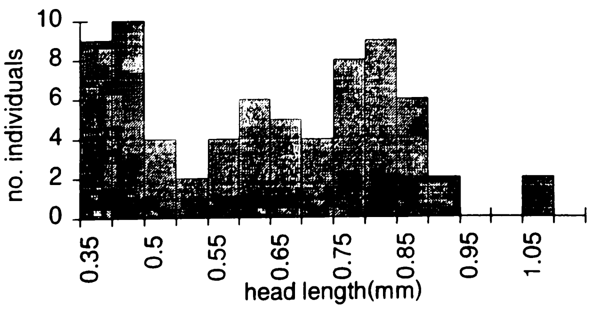
4 grabs, WIN 1997 (n=29)



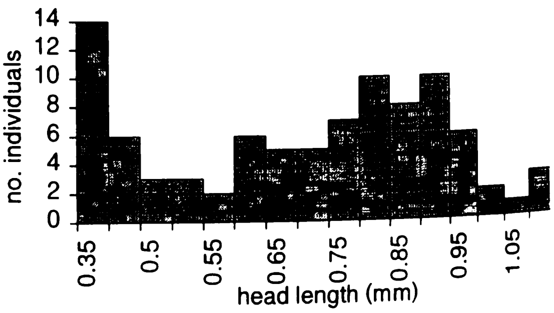
3 grabs, SPR 1997 (n=48)



3 grabs, SUM 1997 (n=71)



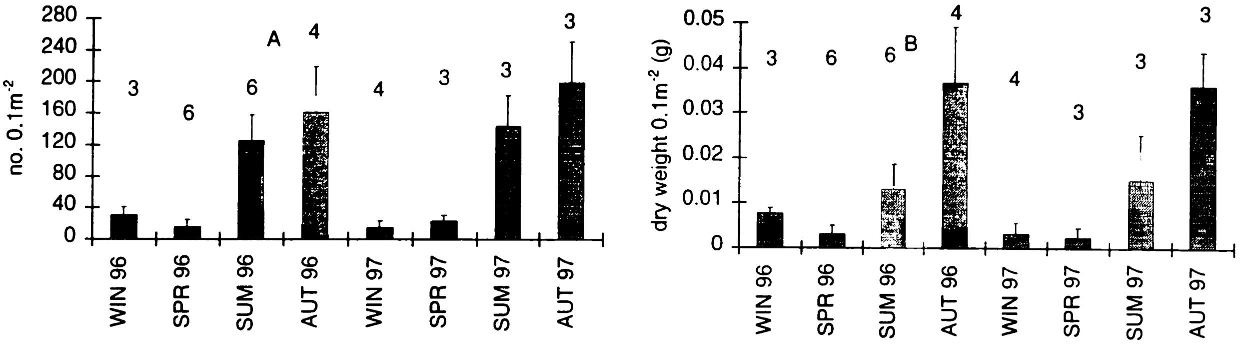
3 grabs, AUT 1997 (n=91)



This amphipod was observed in very high densities on UBBI seasonally over the sampling period 1996-1997. It occurred in all the 30 samples analysed, reaching mean densities of 15-200 individuals per 0.1m^2 grab, and a maximum of 259 individuals sampled in one grab in autumn 1997 (Fig. 3.109A).

As before, in spite of high population densities, this species made a rather low contribution to the total biomass of the analysed grabs, with a maximum of 2% of the total dry weight biomass. Mean biomasses varied between 2 to 36 mg dry weight per 0.1m^2 grab (Fig. 3.109B).

Fig. 3.109.A) Mean number and B) biomass (g dry weight) of *G. fucicola* per 0.1m^2 grab at UBBI. Error bars = SD, N = number of grabs analysed.

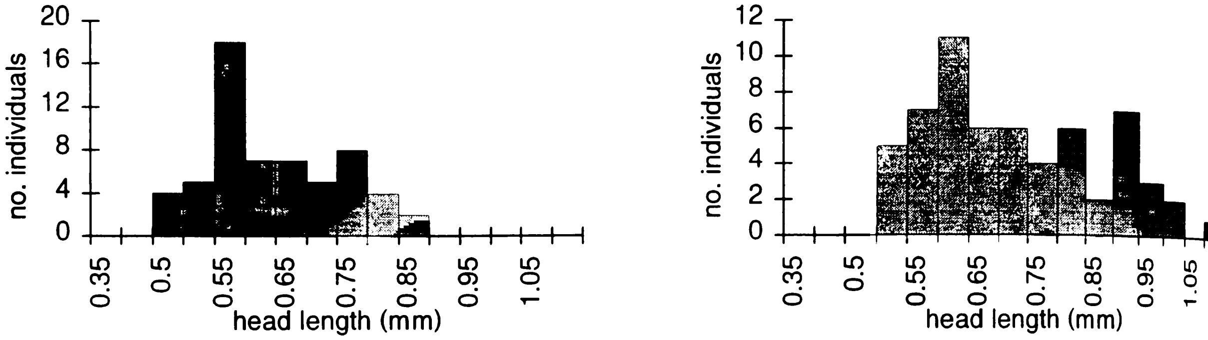


Analysis of the size-frequency structure (Fig. 3.110) of *G. fucicola* shows that small individuals recruited massively during the summer and autumn months, with a mode centred on size classes of 0.4 mm (head length). Juveniles can reach 60 % of the total population. Larger individuals showed no clear modal structure through the sampling period, size classes ranging from 0.6 to 0.9 mm. In spring 1997 however, a modal structure, centred on 0.7 mm, appeared but this pattern was not observed the following season. The two sampling years had very similar structures in term of densities and biomasses (Fig. 3.111), these parameters remaining low in winter and spring and increasing 4 to 5 times in summer and autumn. Biomasses were twice as high in autumn than in summer for both years.

Fig. 3.110. Size-frequency histograms for *Gammarella fucicola* collected seasonally in 0.1m^2 grabs at UBBI from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.

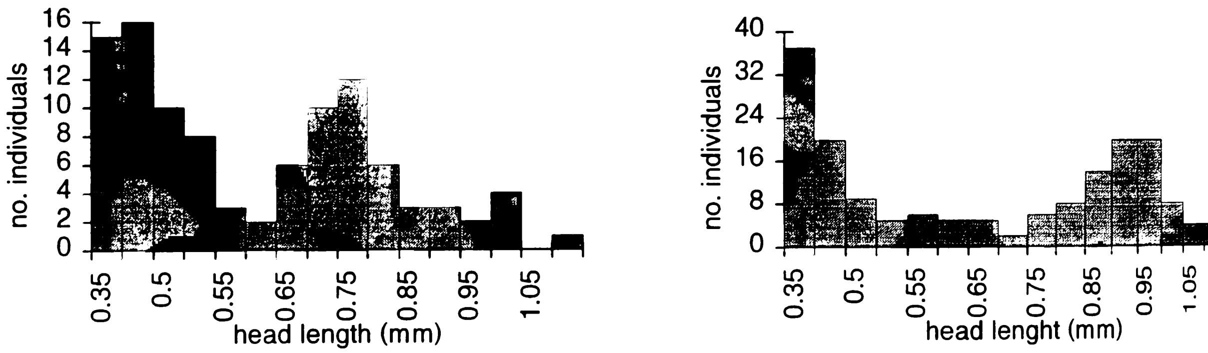
3 grabs, WIN 1996 (n=60)

6 grabs, SPR 1996 (n=60)



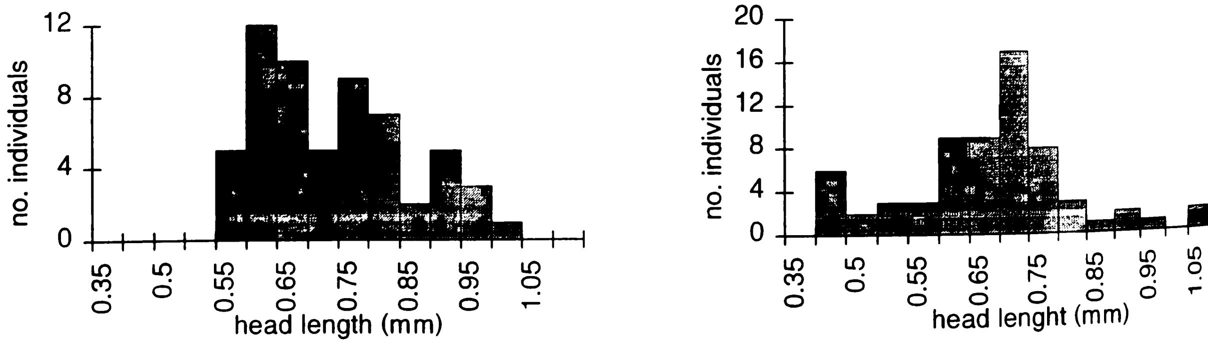
6 grabs, SUM 1996 (n=101)

4 grabs, AUT 1996 (n=173)



4 grabs, WIN 1997 (n=59)

3 grabs, SPR 1997 (n=66)



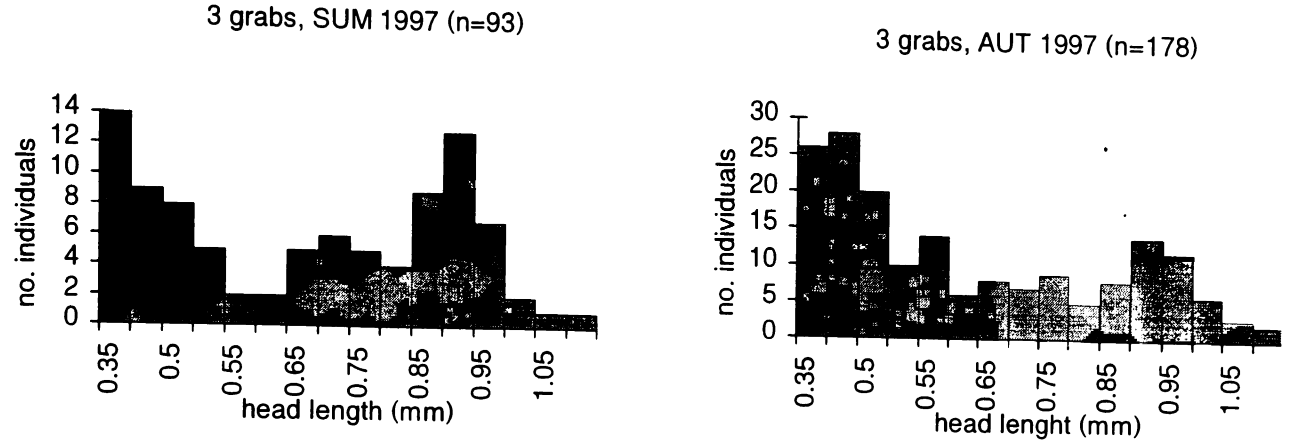
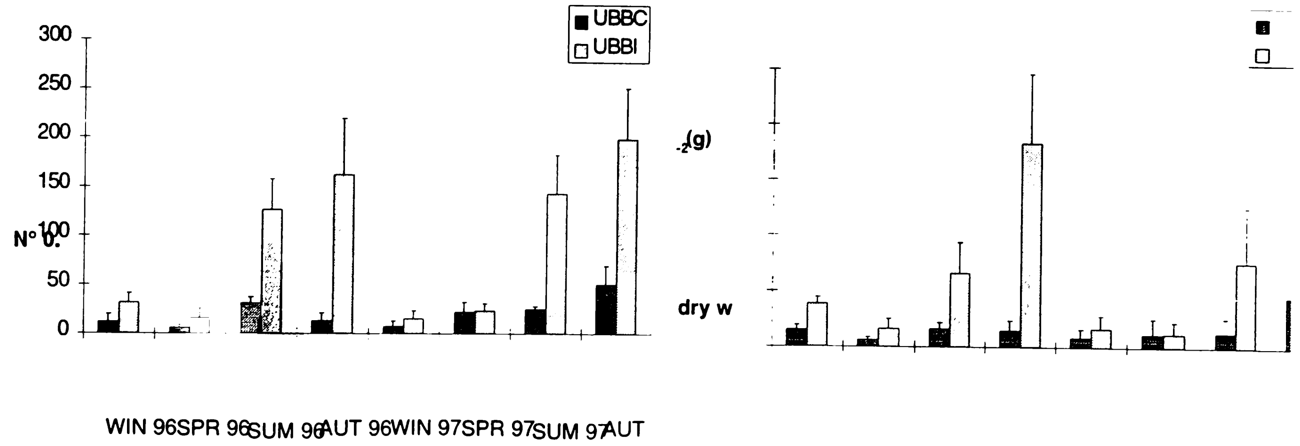


Fig. 3.111. Comparison between control and impacted sites in the Bay of Brest for 1997 and 1998 for *G. fucicola.*



Differences appeared between the two sites (control and impacted) mostly in summer and autumn, with densities and biomasses being from 4 to 5 times higher on the impacted ground (Fig. 3.111). This may be related to the high biomass of epiphytic algae on UBBI during the summer and autumn months.

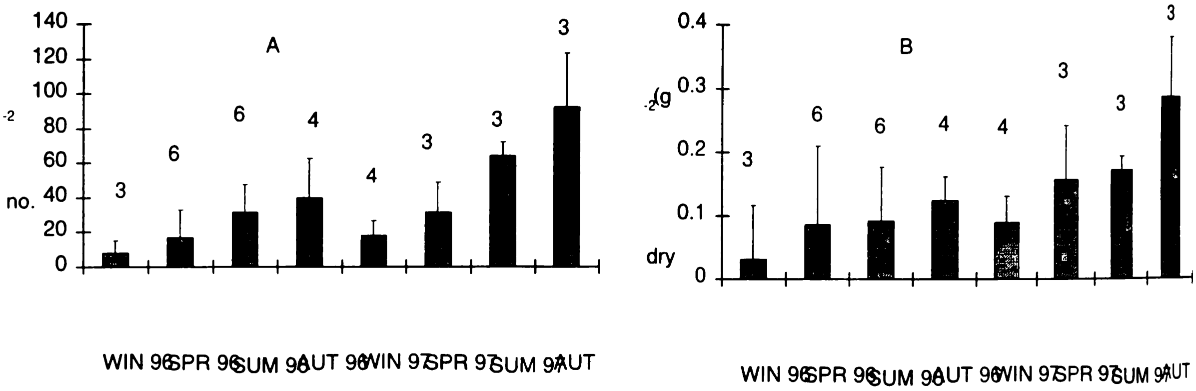
Pisidia longicornis (Linnaeus, 1767)

This anomuran decapod was very abundant in the living maerl layer during summer and autumn on UBBC in 1996 and 1997. It occurred in all 30 grabs analysed with means of 8 -97 and up to 121 individuals collected per 0.1 m^2 grab (Fig. 3.112A).

This suspension-feeding species requires hard substrata on which to cling during feeding. It is very common under stones and dead shells. The structure of maerl is ideal for it, giving access to the water column and protecting these porcelain crabs . from fish predation.

Being very common on the maerl beds, it contributed consistently to the biomass. It made up to 5% of the total biomass from the grabs collected during the summer. Mean dry weight varied from 0.12 -0.29g per 0.1m^2 grab. However, during winter, its contribution to the biomass dropped to 0.2% of the total biomass (Fig. 3.112B).

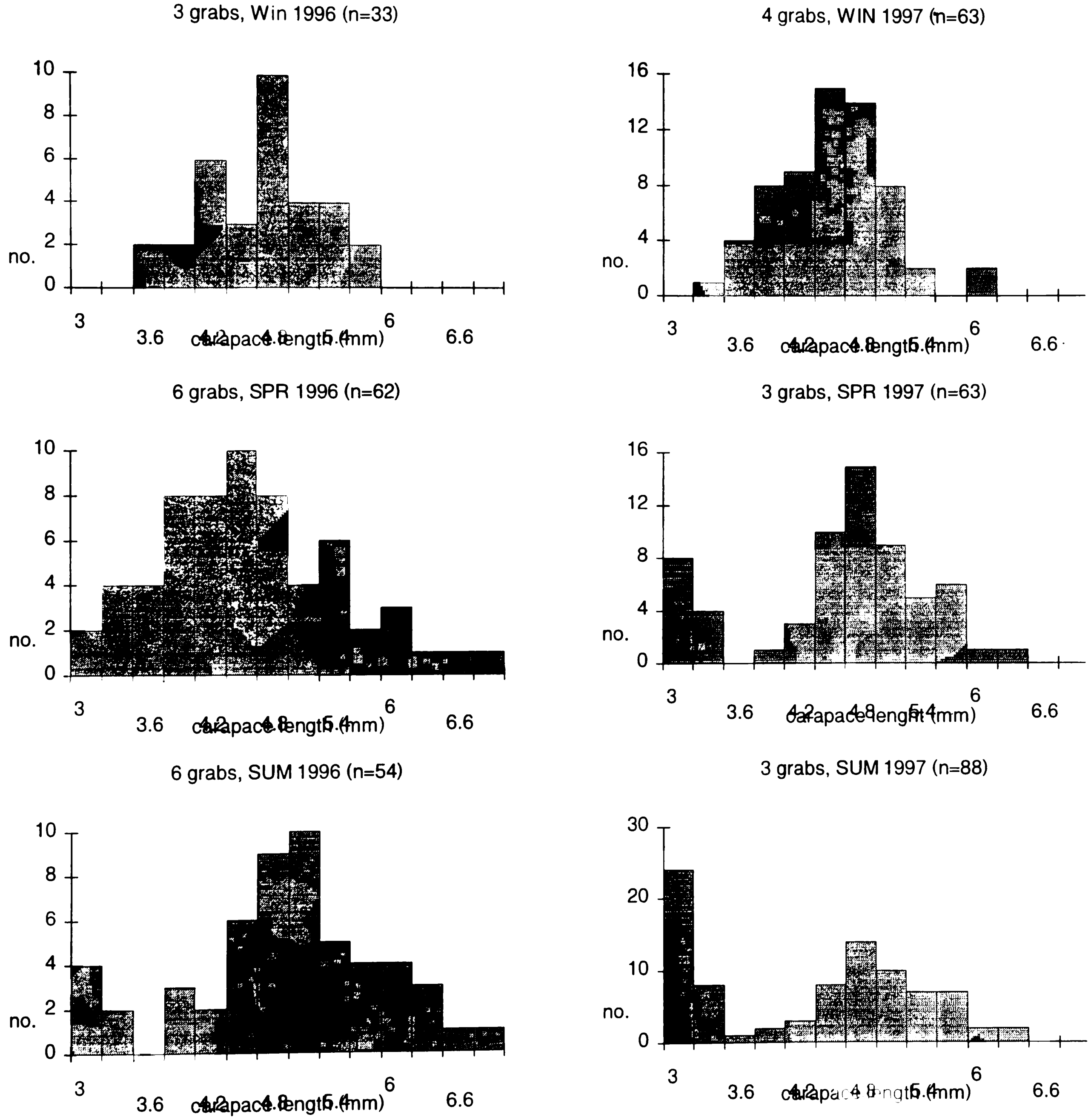
Fig. 3.112.A) Mean number and B) biomass (g dry weight) of *P. longicornis* per 0.1m^2 grab at UBBC. Error bars = SD, N = number of grabs analysed.



The variation in abundance, biomass and size frequency (see Fig. 3.113) of *P.longicornis* are obviously seasonal. Small individulas were recruited during late spring, summer and autumn. Adult individuals of this species had a carapace length of 4.8 to 5.4 mm even if some individuls reached 7 mm in November. Each winter and spring, the population had the same structure being centred on 5 mm length. Winter biomasses and abundances were low, suggesting seasonal mortalities and lack of recruitment during this period. However differences between these seasons are hard to explain : spring samples showed higher densities and biomass than in the winter while no juvenile recruitment was observed in the former season. During summer, smaller individuals (3-3.5mm) were sampled, the diagrams showing then a bimodal structure. In the autumn, finally, the population showed individuals from a large spectrum of sizes.

Comparison of the two years sampled showed slight differences in the population structure, as it seems that in 1997 recruitment of juveniles was higher than in 1996 . Moreover, abundances and biomass were higher during summer and autumn 1997 than in the same seasons of 1996. Variations of temperature or in primary production between these two years could explain this feature.

Fig. 3.113. Size-frequency histograms for *P. longicornis* collected seasonally in 0.1m^2 grabs at UBBC from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.



3 grabs, Win 1996 (n=33)

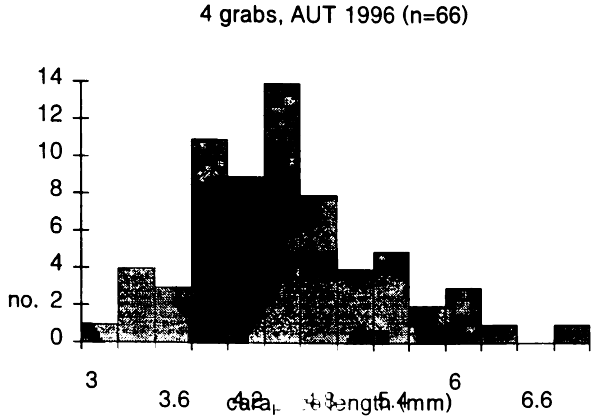
4 grabs, WIN 1997 (n=63)

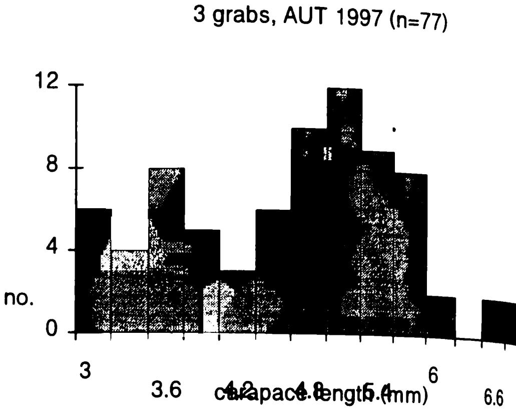
6 grabs, SPR 1996 (n=62)

3 grabs, SPR 1997 (n=63)

6 grabs, SUM 1996 (n=54)

3 grabs, SUM 1997 (n=88)

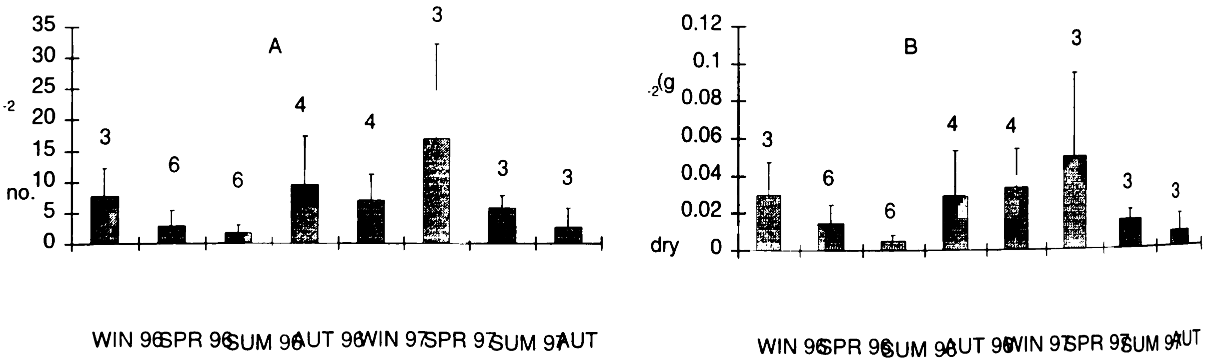

4 grabs, AUT 1996 (n=66)


3 grabs, AUT 1997 (n=77)

This species was very abundant in the living maerl layer during summer and autumn on UBBI in 1996 and 1997. It occurred in all 30 grabs analysed with means of 2 -17 and up to 34 individuals collected per 0.1 m^2 grab (Fig. 3.114A).

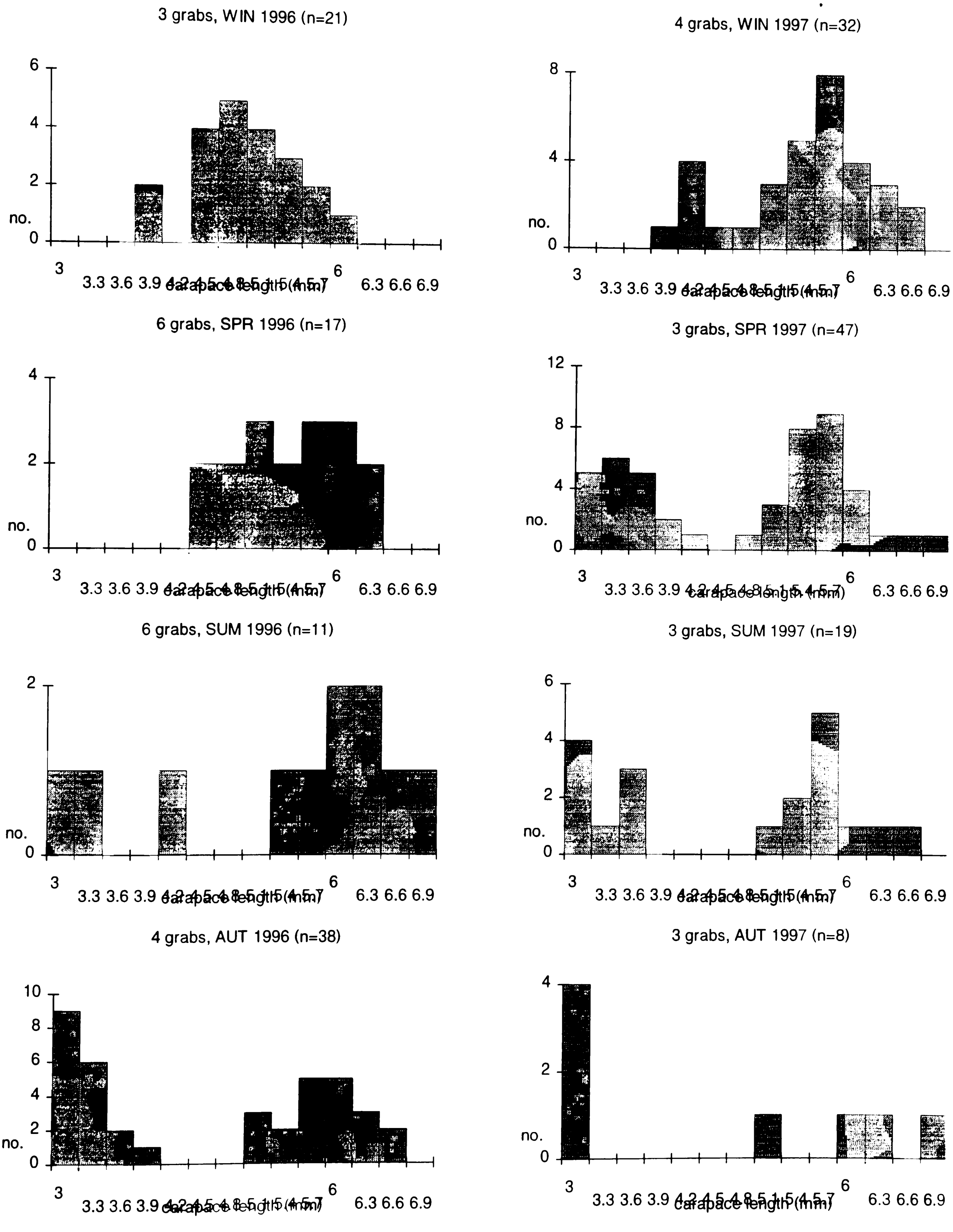
It contributed only a small part of the biomass since it made up to 0.6% of the total biomass of the grabs collected during the summer. Mean dry weight varied from 8 - 50mg per 0.1m^2 grab(Fig. 3.114B).

Fig. 3.114.A) Mean number and B) biomass (g dry weight) of *P. longicornis* per 0.1m^2 grab at UBBI. Error bars = SD, N = number of grabs analysed.



The variation in abundance, biomass and size frequency (see Fig.3.115) of *P.longicornis* show a mode of larger individuals of sizes centred on size classes from 4.8 mm in the winter to 6 mm in the summer months. Recruitment occurred from spring in 1997 but only from summer in 1996.

Fig. 3.115. Size-frequency histograms for *P. longicornis* collected seasonally in $0.1m^2$ grabs at UBBI from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.



3 grabs, WIN 1996 (n=21)

4 grabs, WIN 1997 (n=32)

6 grabs, SPR 1996 (n=17)

3 grabs, SPR 1997 (n=47)

6 grabs, SUM 1996 (n=11)

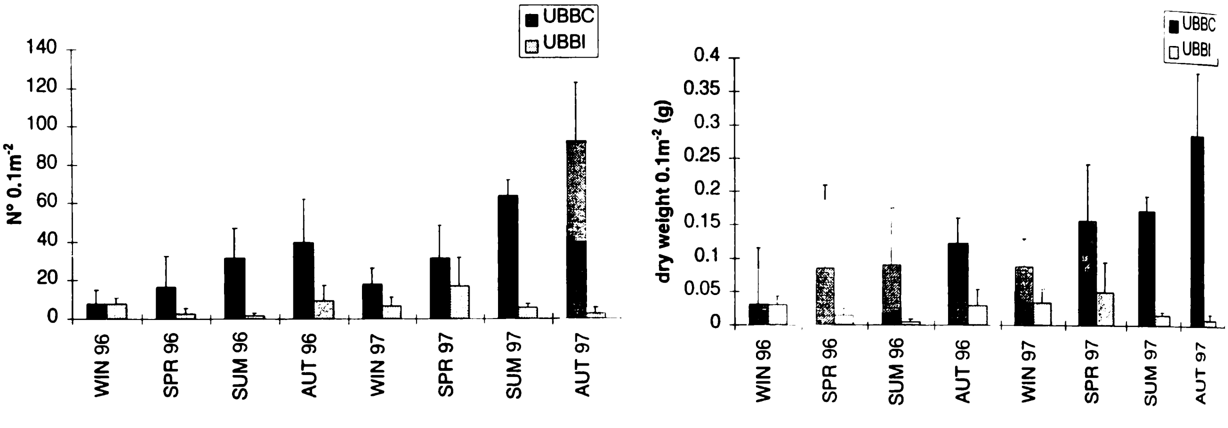
3 grabs, SUM 1997 (n=19)

4 grabs, AUT 1996 (n=38)

3 grabs, AUT 1997 (n=8)

No seasonality appears in terms of densities and abundances when comparing the two years. 1996 and 1997 seemed very similar both in terms of biomasses and abundances.

Fig. 3.116. Comparison between control and impacted sites in the Bay of Brest for 1996 and 1997 for *P. longicornis.*



Abundance and biomass were similar during the winter at UBBI, but during the following seasons, these parameters were much higher on the control than on the impacted (Fig. 3.116). Maxima were reached on UBBC in autumn while minima were reached the same season on UBBI. This suggests high mortalities on the impacted ground towards the end of the summer.

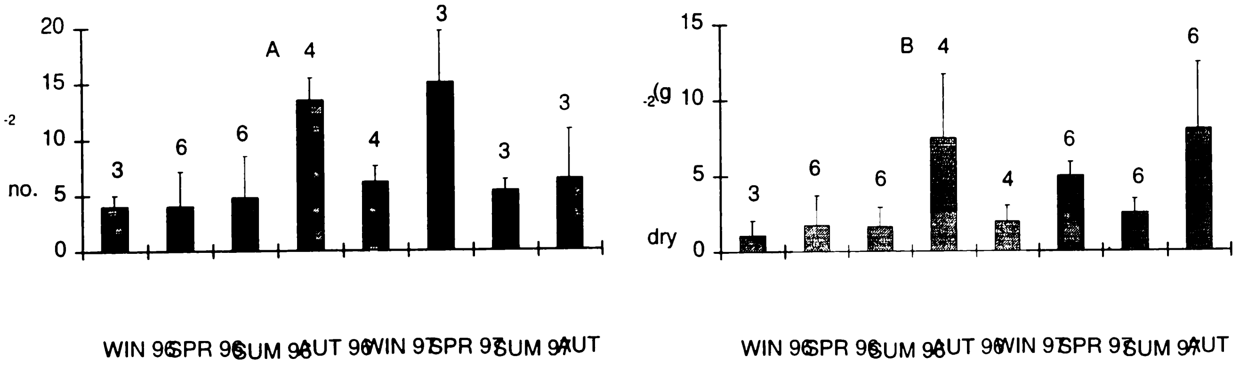
Liocarcinus arcuatus **(Leach, 1814)**

This decapod crustacean was very common on the maerl beds of the Bay of Brest. It occurred in all of the 43 samples analysed for the sampling period 1996-1997. Mean densities varied in a range of 4 to 13 individuals per m^2 with maximum of 21 per m^2 observed (Fig. 3.117A).

This crab is carnivorous, feeding on bivalves and polychaetes mainly. Divers reported that large individuals of this species walking over the surface of the sediment in search of food. It may also be able to bury into the sediment to feed or shelter. Smaller individuals move into the maerl layer, their size allowing them to move between the maerl fragments.

Being large and abundant, this species was a significant contributor to the biomass of the maerl beds for the control site. This species accounted for <10% of the total dry weight biomass in autumn 1996. Mean biomasses ranged between 1 to 8g per m^2 during the sampling period (Fig. 3.117B).

Fig. 3.117.A) Mean number and B) biomass (g dry weight) of *L.arcuatus* per 1m^2 at UBBC. Error bars = SD, N = number of AQUAREVE analysed.



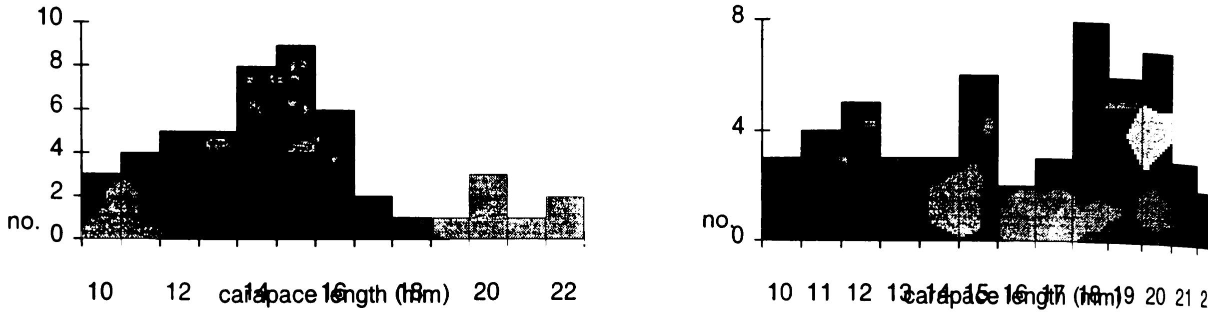
Analyses of size-frequency distributions of *L. arcuatus* (Fig. 3.118) have shown no evidence of recruitment of juveniles, except in autumn where high abundances of small animals were observed. Recruitment may occur year-round, with a maximum being reached in autumn. No growth or poor survival rates of any size classes were observed in this case.

Differences between the two sampling years appeared in spring where highest abundances of *L. arcuatus* where observed . This remains unexplained as this high abundance was not due to any recruitment. In term of biomass, the two years were very similar, maxima being reached in autumn.

Fig. 3.118. Size-frequency histograms for *Liocarcinus arcuatus* collected seasonally in AQUAREVE at UBBC from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.

3 AQUAREVE, Win 1996 (n=50)

6 AQUAREVE, WIN 1997 (n=55)

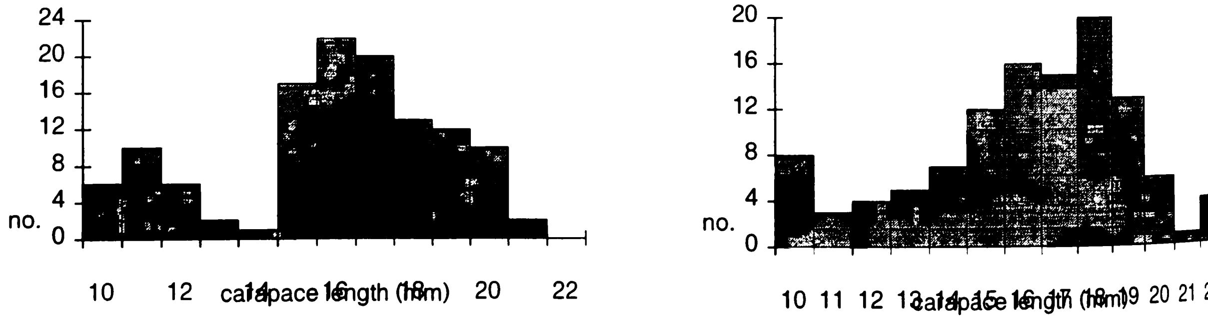


6 AQUAREVE, SPR 1996 (n=92)

6 AQUAREVE, SPR 1997 (n=87)

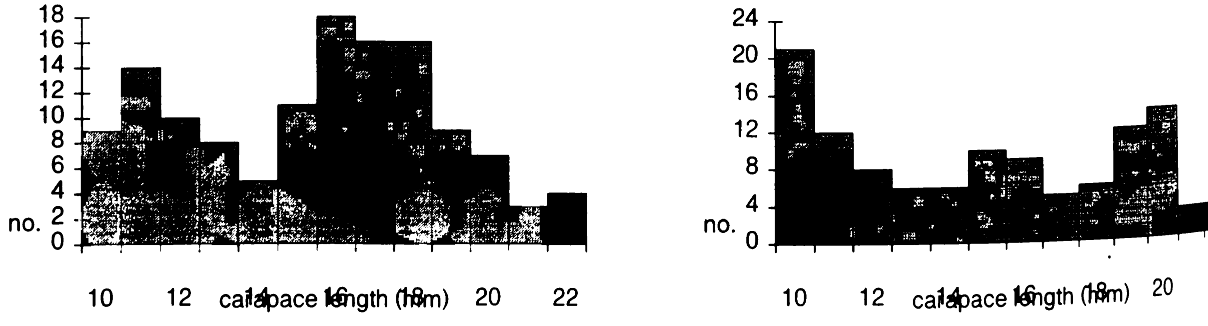
6 AQUAREVE, SUM 1996 (n=121)

3 grabs, SUM 1997 (n=114)



4 AQUAREVE, AUT 1996 (n=130)

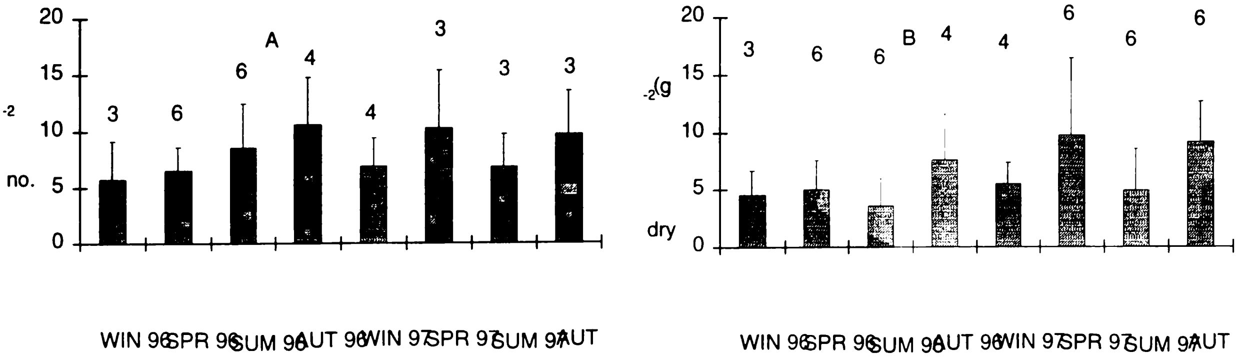
6 AQUAREVE, AUT 1997 (n=115)



This crab was also found in great densities on the impacted ground UBBI . It occurred in all the 43 samples analysed for the sampling period 1996-1997. Mean densities ranged from 5 to 11 individuals per m^2 on the grounds with a maximum of 17 per m^2 observed in an autumn 1996 sample(Fig. 3.119A).

Being large and abundant it was a significant contributor to the biomass of the impacted ground in the Bay of Brest. A maximum of 8 % of the total dry weight biomass was reached in autumn 1996. Mean biomasses ranged from 3.6 to 9.8 g per m^2 during the sampling period (Fig. 3.119B).

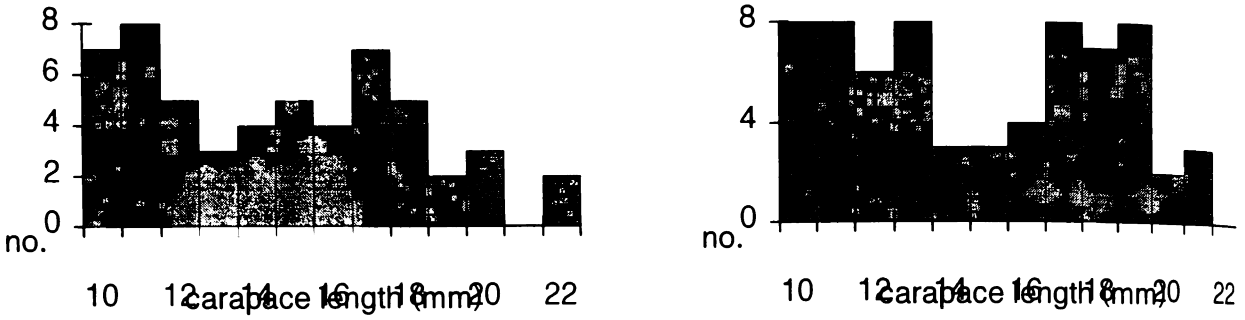
Fig. 3.119.A) Mean number and B) biomass (g dry weight) of *L. arcuatus* per 1m^2 at UBBI. Error bars = SD, N = number of AQUAREVE analysed.



Analysis of size-frequency distributions of the *L. arcuatus* data (Fig. 3.120) showed a high proportion in juveniles (centred around size classes of 10-12 mm carapace length) throughout the sampling period. No modal structure appeared, however, every size class being in similar proportion.

The two sampling years showed very similar patterns, density minima being reached during the winter months and maxima in autumn (Fig. 3.120). High biomasses observed in spring 1997 may be related to the observation of the high proportion of large individuals (size classes 20-22 mm) in these samples.

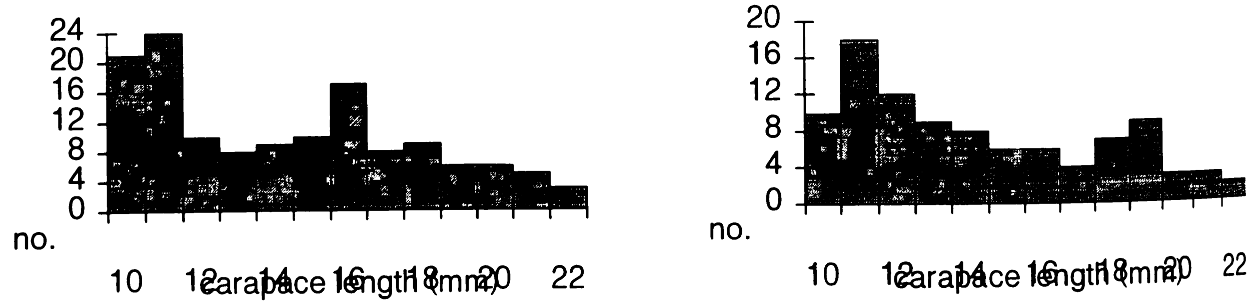
Fig. 3.120. Size-frequency histograms for *Liocarcinus arcuatus* collected seasonally in 0.1m^2 grabs at UBBI from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.


3 AQUAREVE, Win 1996 (n=55)

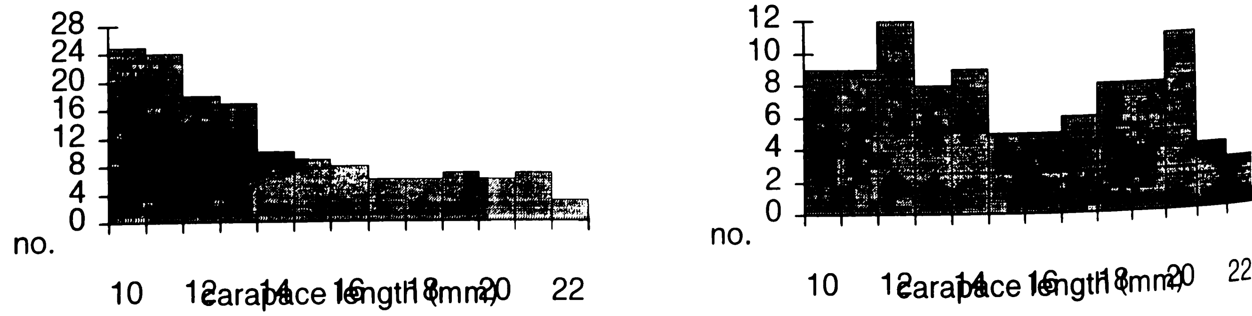
4 AQUAREVE, WIN 1997 (n=68)


6 AQUAREVE, SPR 1996 (n=70)

3 AQUAREVE, SPR 1997 (n=93)

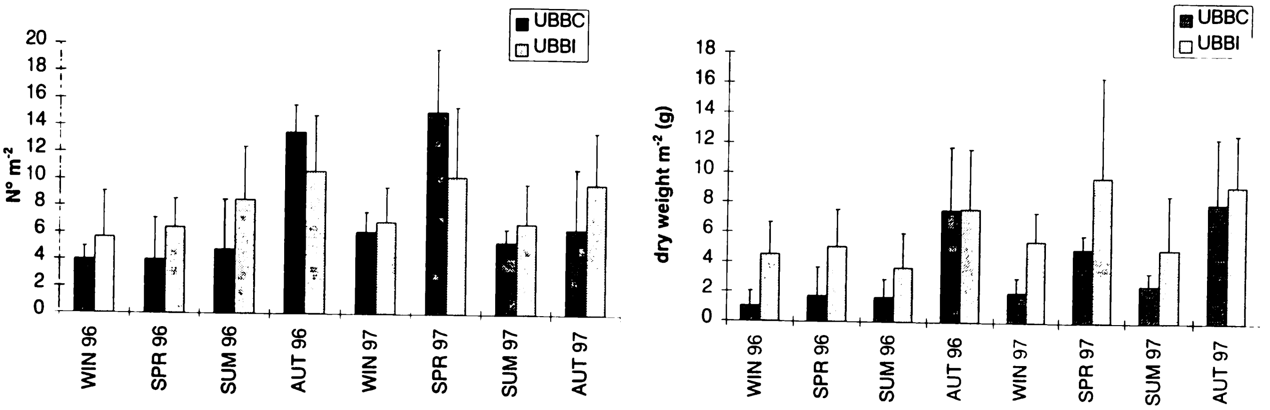

3 AQUAREVE, SUM 1996 (n=136)

3 AQUAREVE, SUM 1997 (n=97)


4 AQUAREVE, AUT 1997 (n=146)

4 AQUAREVE, AUT 1997 (n=97)

Fig. 3.121. Comparison between control and impacted sites in the Bay of Brest for 1996 and 1997 for *L. arcuatus.*



Site-to -site comparison (Fig. 3.121) showed only a very slight difference in terms of densities and a slight but obvious higher biomass on UBBI cf. UBBC.

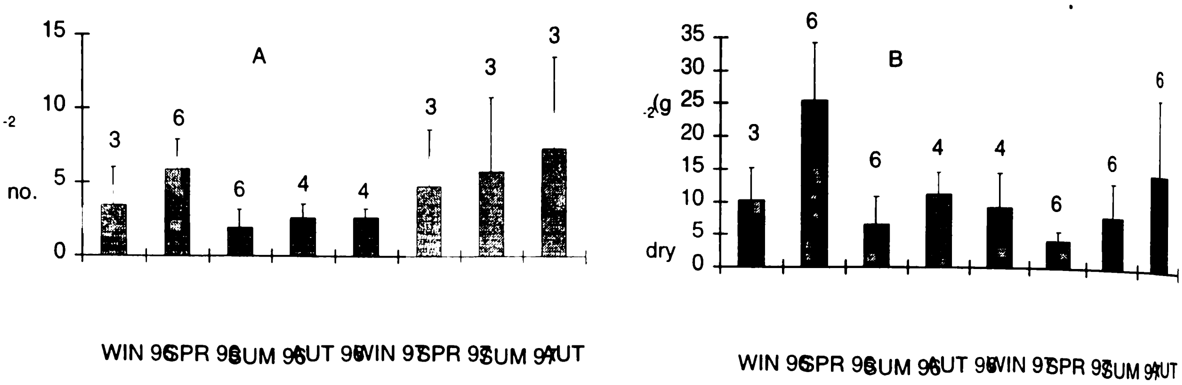
***Gibbula magus* (Leach, 1814)**

This gastropod was very common on the UBBC ground since it was sampled in all 43 samples analysed. Mean densities varied from 1.9 to 7.4 individuals per m^2, with a maximum of 18 animals sampled in autumn 1997 (Fig. 3.122A).

G. magus is a micrograzer, feeding on micro-organisms attached to hard substrata. In our maerl beds, its suspected source of food is benthic diatoms which we have observed in high densities (from SEM photography of maerl fragments taken from the Bay of Brest).

This large gastropod was a dominant contributor to the biomass of the AQUAREVE samples analysed. Its contribution reached a maximum of 30% of the total biomass of one sample in spring 1996. Mean biomasses observed varied from 4-25 g dry weight per m^2 (Fig. 3.122B).

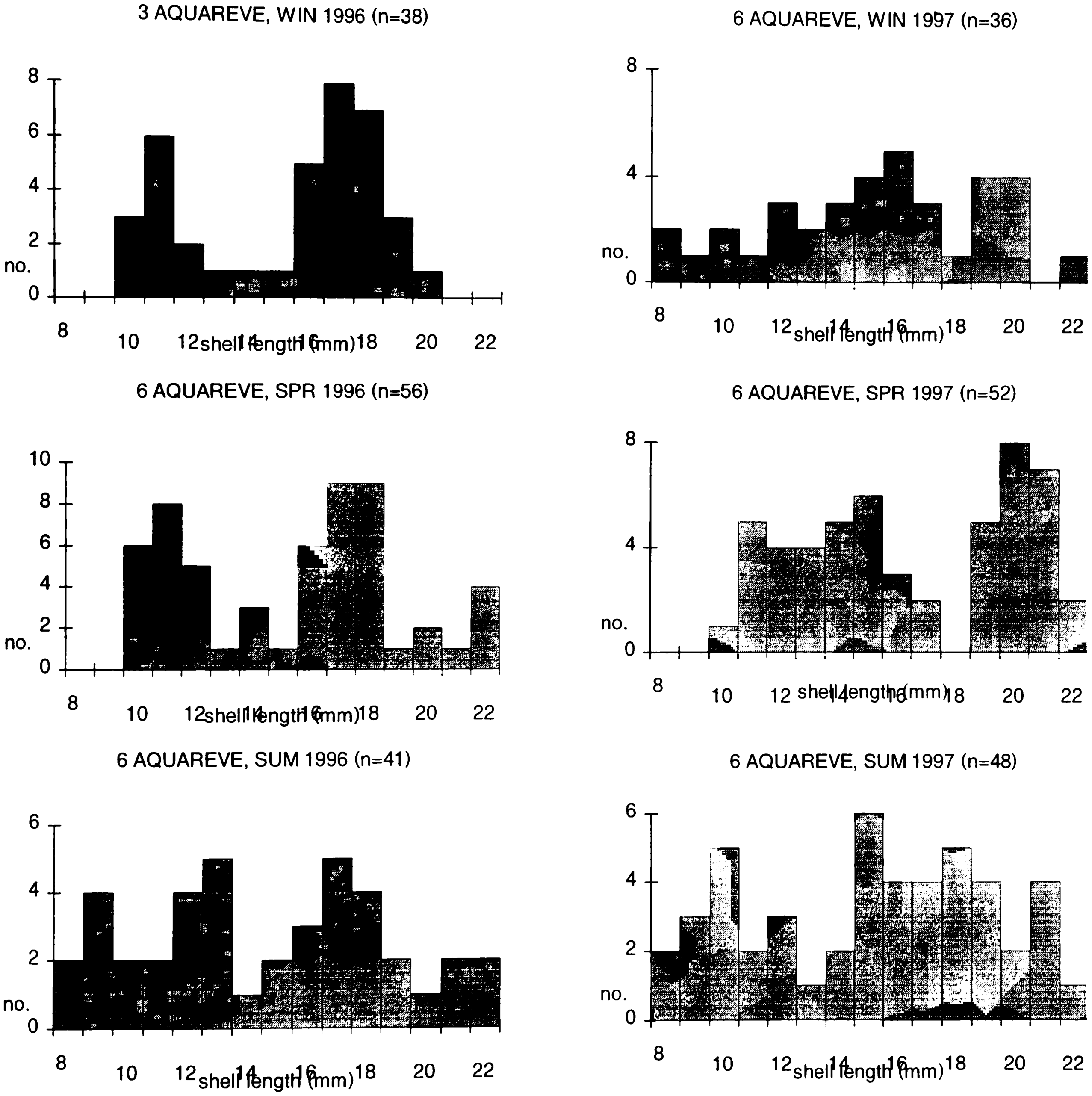
Fig. 3.122.A) Mean number and B) biomass of *G. magus* per 1m^2 at UBBC. Error bars = SD, N = number of AQUAREVE samples analysed.



From the seasonal variation in size frequency of *G. magus* sampled using the AQUAREVE, it can be seen that during the entire the sampling period, the population had a bimodal structure centred around size classes of 15-18 mm and 10-12 mm (Fig. 3.123). The only recruitment of juveniles was observed during the autumn months of 1996.

Year-to-year comparison of the densities and biomasses of *G. magus* shows that although abundance was higher in 1997 than in 1997, the difference between the two years was slight. A maximum in abundance was reached in spring 1996 but why is not clear.

Fig. 3.123. Size-frequency histograms for *Gibbula magus* collected seasonally in AQUAREVE samples at UBBC from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.



3 AQUAREVE, WIN 1996 (n=38)

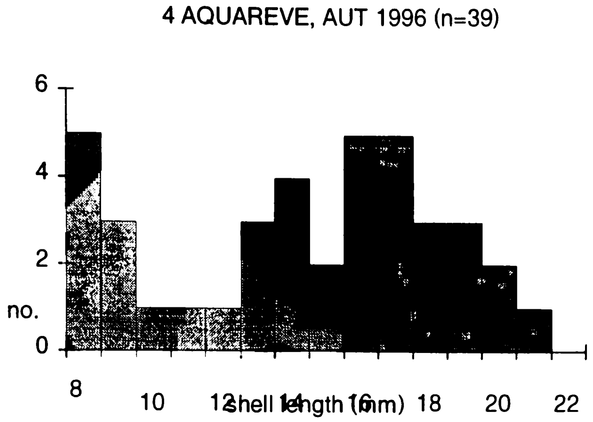
6 AQUAREVE, WIN 1997 (n=36)

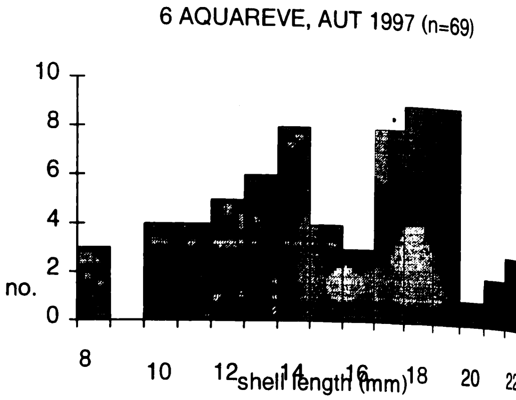
6 AQUAREVE, SPR 1996 (n=56)

6 AQUAREVE, SPR 1997 (n=52)

6 AQUAREVE, SUM 1996 (n=41)

6 AQUAREVE, SUM 1997 (n=48)

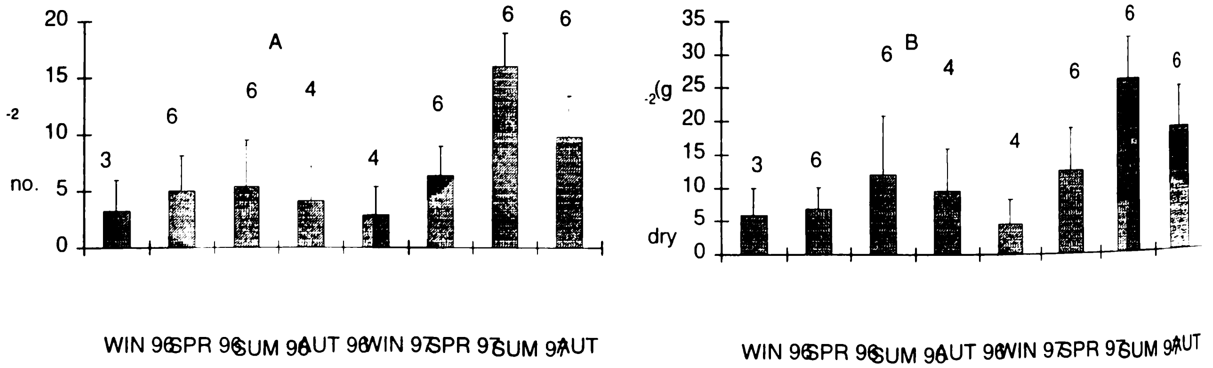




This gastropod was also very common on the impacted ground (UBBI) since it was sampled in all the 43 samples analysed. Mean densities varied from 3 to 16 individuals per m^2, with a maximum of 28 animals sampled in summer 1997 (Fig. 3.124A).

As a large gastropod, this species was one of the dominant contributors to biomass of the AQUAREVE samples analysed from the impacted ground. Its contribution reached a maximum of 50% of the total biomass of one sample in summer 1997. Mean biomasses observed varied from 4-26 g dry weight per m^2 (Fig. 3.124B).

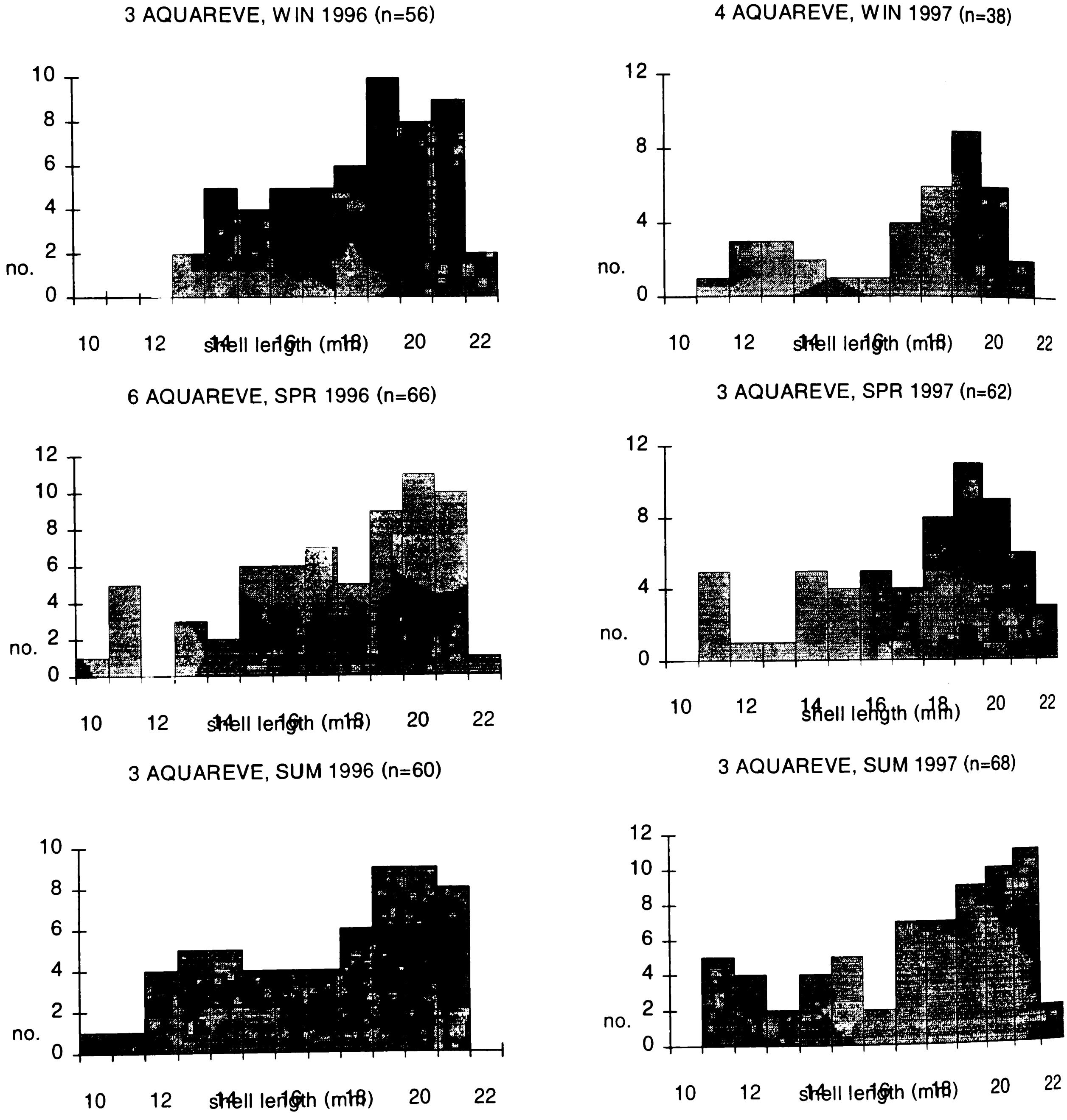
Fig. 3.124.A) Mean number and B) biomass of *G. magus* per 1m^2 at UBBI. Error bars = SD, N = number of samples analysed.



Size-frequency variations of *G. magus* can be seen in Fig. 3.125.. Throughout the sampling period there was no obvious modal structure, individuals being distributed into size classes from 11 to 22mm shell length. Bigger animals (around 20mm) seemed however to dominate the population in 1996. In 1997, a bimodal structure appeared in winter centred on size classes 12 and 19mm . The mode of larger individuals was found the following season, but no real modal structure appeared for the smaller individuals. This population structure disappeared at the end of 1997. It appears that a recruitment of smaller individuals occurred in 1997 on the impacted ground, but not in 1996,

Comparing densities and biomasses of *G. magus* between the two sampling years showed that maxima were reached during summer months while minima were reached in winter. The two years showed similar structures for these parameters, though 1997 had higher densities and biomasses than 1996.

Fig. 3.125. Size-frequency histograms for *Gibbula magus* collected seasonally in AQUAREVE samples at UBBI from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.



3 AQUAREVE, WIN 1996 (n=56)

4 AQUAREVE, WIN 1997 (n=38)

6 AQUAREVE, SPR 1996 (n=66)

3 AQUAREVE, SPR 1997 (n=62)

3 AQUAREVE, SUM 1996 (n=60)

3 AQUAREVE, SUM 1997 (n=68)

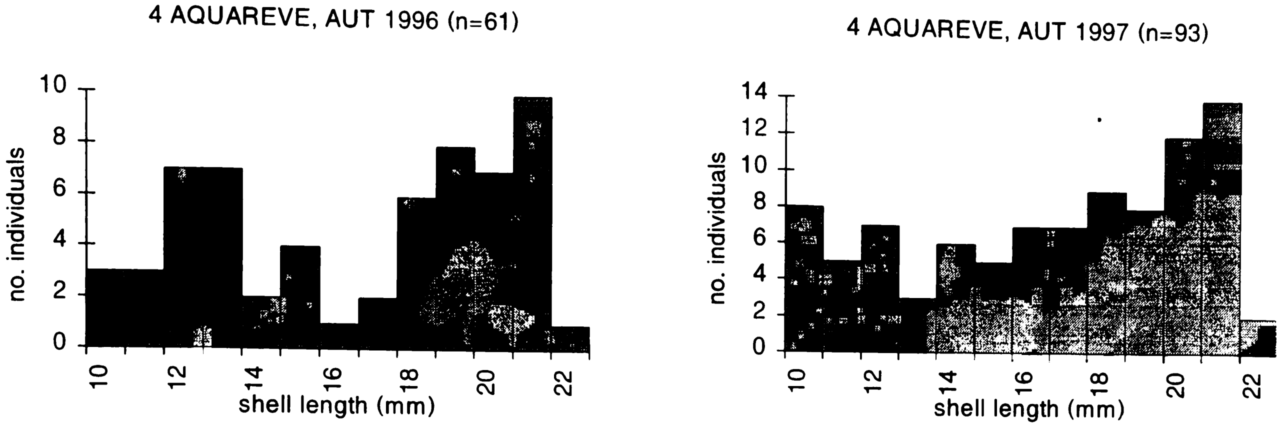
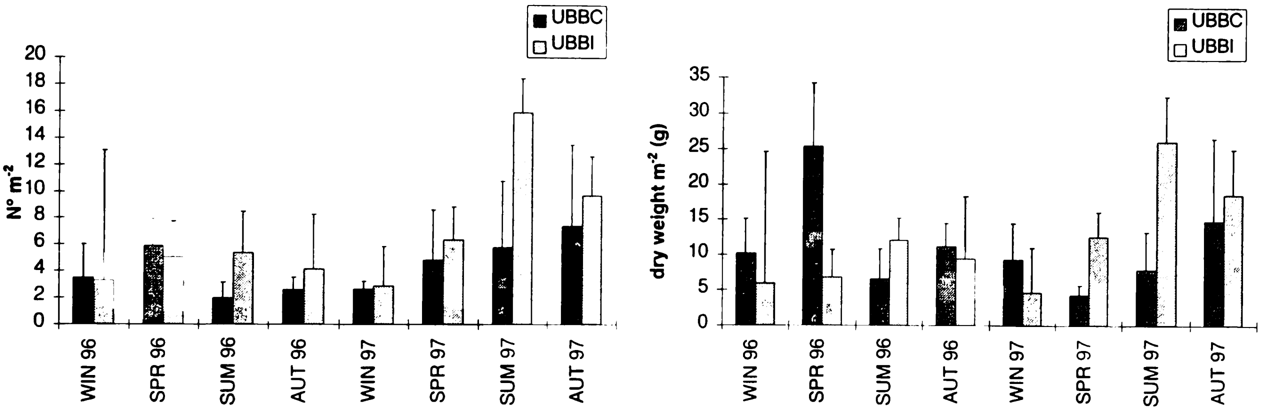


Fig. 3.126. Comparison between control and impacted sites in the Bay of Brest for 1996 and 1997 for *G. magus*.



Densities and biomasses were similar on UBBC and UBBI for the two years sampling period (Fig. 3.126). Note though that densities on the impacted ground were slightly higher than on the control during 1997.

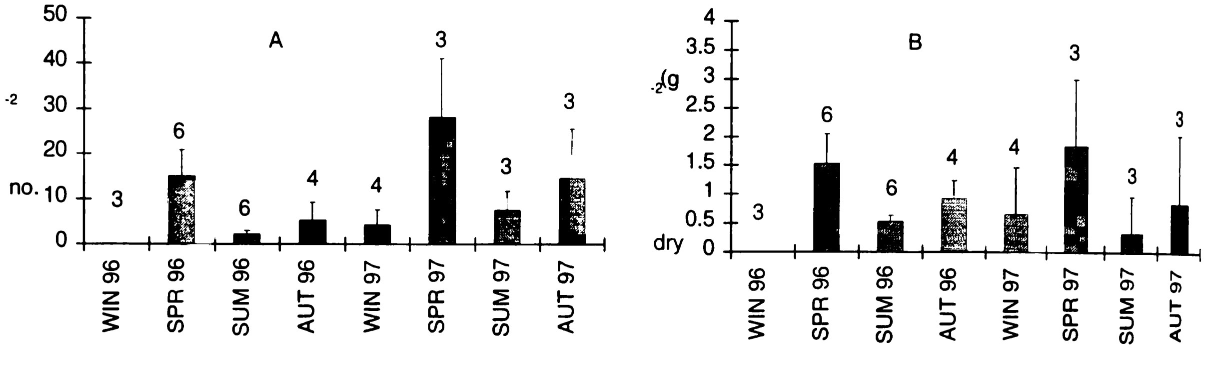
***Jujubinus striatus* (Linnaeus, 1758)**

This trochid gastropod was present at UBBC in various densities during the sampling period 1996-1997. It occurred in 24 grabs of the 30 analysed samples with mean densities of 0 to 28 individuals per 0.1m^2 grabs, with a maximum of 41 for one grab (Fig. 3.127A).

It is a micrograzer, removing micro-organisms from hard substrata. Within maerl beds, it is thought to graze on maerl fragments as SEM photography of maerl fragments from the Bay of Brest has shown high densities of benthic diatoms.

Being a shelled organism, this species made a significant contribution to the maerl bed biomass in UBBC, reaching a maximum of 40%. Mean dry weight varied from from 0 to 2 g per 0.1m^2 grab (Fig. 3.127B).

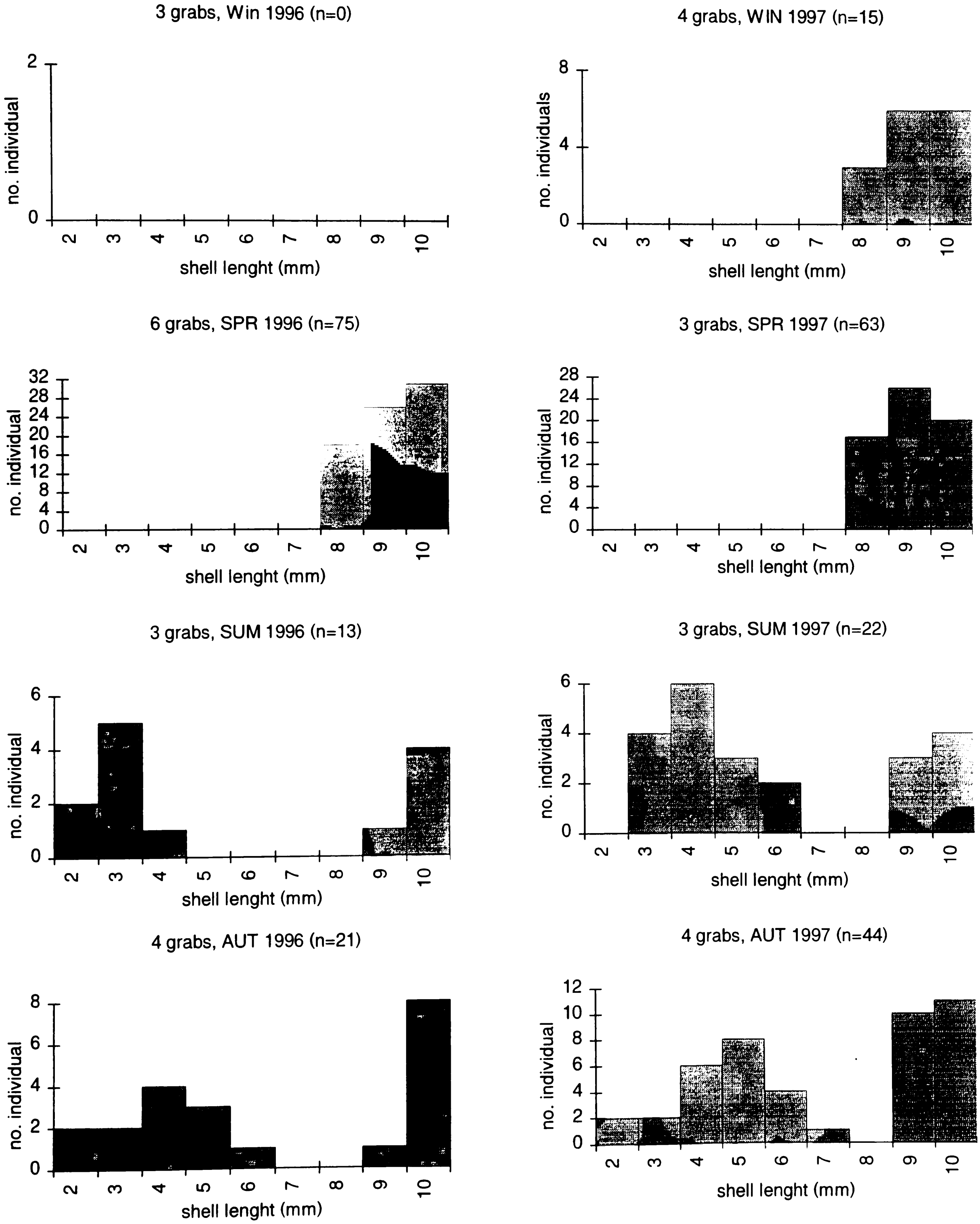
Fig. 3.127.A) Mean number and B) biomass (g dry weight) of *J. striatus* per 0.1m^2 grab at UBBC. Error bars = SD, N = number of grabs analysed.



Size-frequency analyses of *J. striatus* are shown in Fig. 3.128. The largest individuals were present at in all seasons with shell sizes ranging from 8 to 10 mm. Recruitment of juveniles was observed in summer and autumn of both years. These juveniles seem to have had a good survival rate during summer and autumn, but surprisingly disappeared during winter, as the population was not increasing.

Year-to-year comparison in biomass showed no clear pattern. Absence of the species in winter 1996 remains unexplained. Population densities were high during the spring of both years. Densities seemed to be higher in 1997, but biomasses were comparable.

Fig. 3.128. Size-frequency histograms for *J. striatus* collected seasonally in $0.1m^2$ grabs at UBBC from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.



3 grabs, Win 1996 (n=0)

4 grabs, WIN 1997 (n=15)

6 grabs, SPR 1996 (n=75)

3 grabs, SPR 1997 (n=63)

3 grabs, SUM 1996 (n=13)

3 grabs, SUM 1997 (n=22)

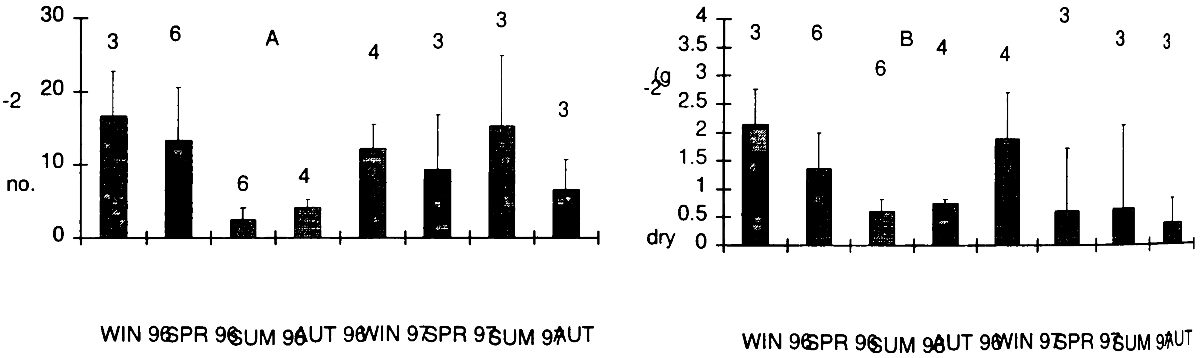
4 grabs, AUT 1996 (n=21)

4 grabs, AUT 1997 (n=44)

This trochid gastropod was regularly present on the impacted ground (UBBI) throughout the sampling period 1996-1997. It occurred in all the 30 analysed samples, with mean densities of 2.5 to 17 individuals per 0.1m^2 grabs, and a maximum of 36 for one grab (Fig. 3.129A).

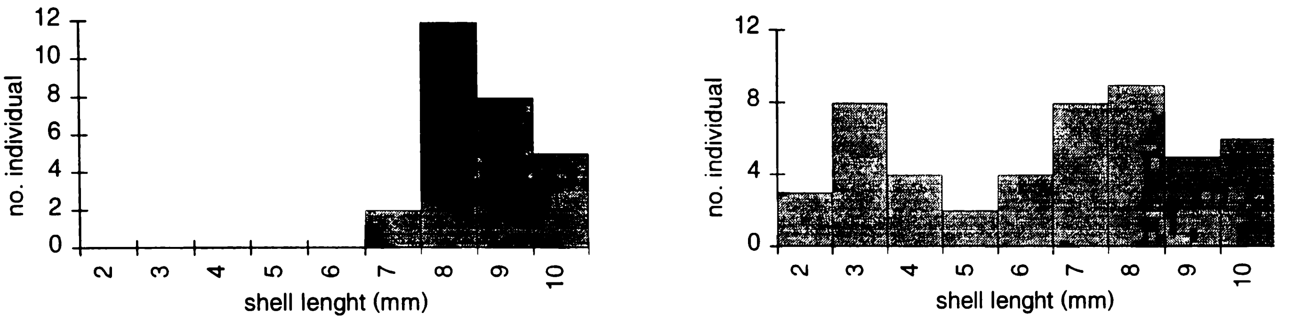
Being a shelled organism and in significant densities on the impacted ground, this species made a significant contribution to the samples biomass, reaching a maximum of 32%. Mean dry weight varied from from 0.3 to 2.13 g per 0.1m^2 grab (Fig. 3.129B).

Fig. 3.129.A) Mean number and B) biomass (g dry weight) of *J. striatus* per 0.1m^2 grab at UBBI. Error bars = SD, N = number of grabs analysed.

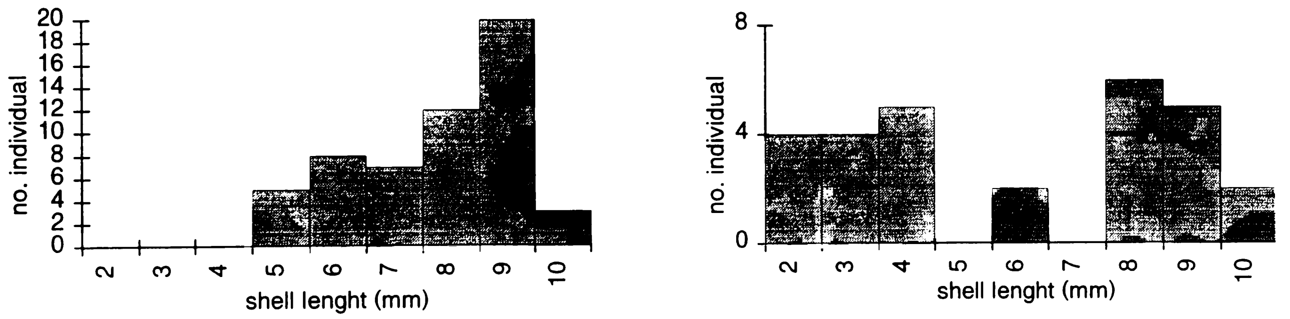


The seasonal variation in size frequency of *J. striatus* is given in Fig. 3.130. The structure of the population appeared to be unimodal, centred on shell size class of 8mm, during the sampling year 1996. In 1997, a bimodal structure appeared, centred around size classes 3 mm and 8mm. We therefore suspect a recruitment of this species during the winter months of 1997. Since the individuals of the smaller mode were found at all seasons of this year, we infer good survival rates for the individuals of these sizes.

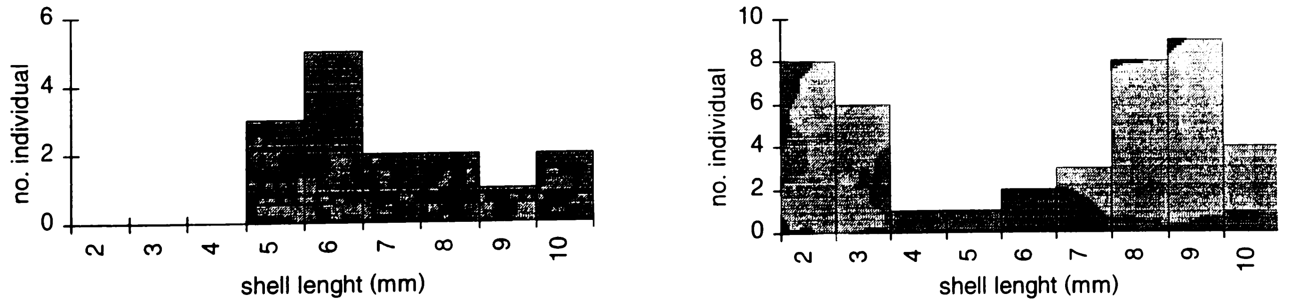
Fig. 3.130. Size-frequency histograms for *J. striatus* collected seasonally in 0.1m^2 grabs at UBBI from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.


3 grabs, WIN 1996 (n=27)

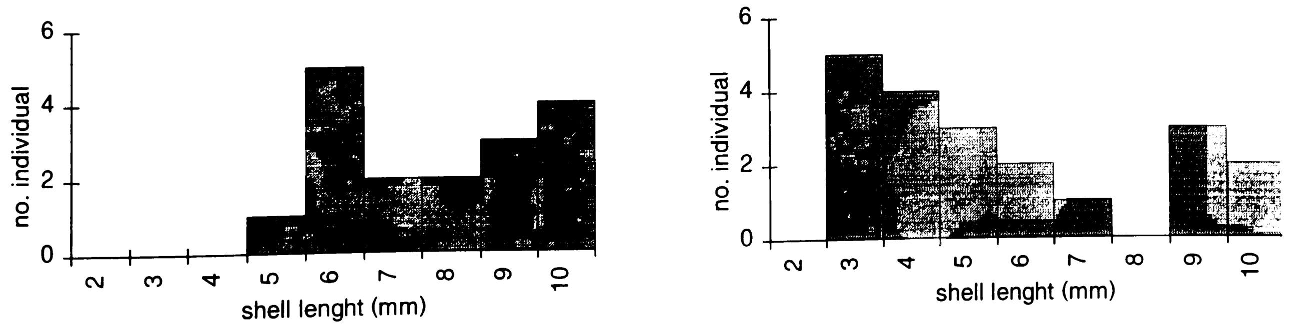
4 grabs, WIN 1997 (n=49)


6 grabs, SPR 1996 (n=55)

3 grabs, SPR 1997 (n=28)


6 grabs, SUM 1996 (n=15)

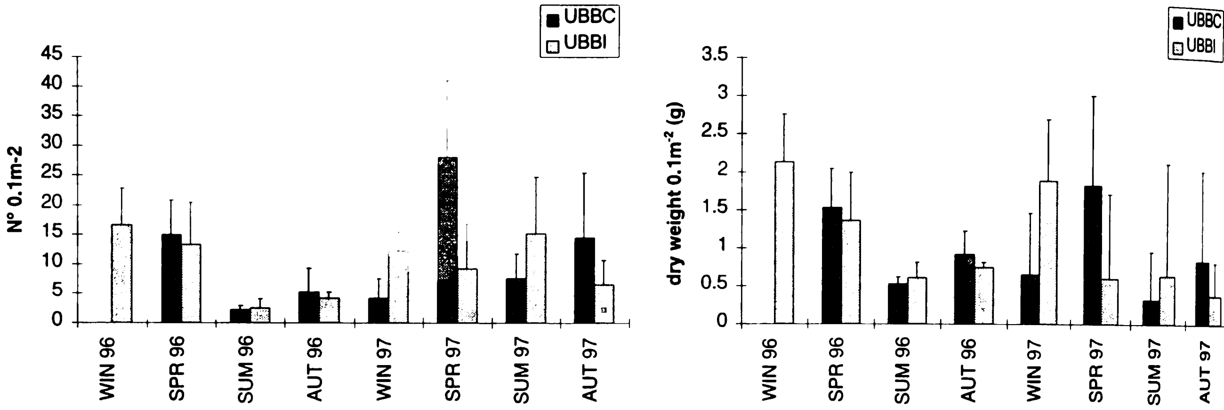
3 grabs, SUM 1997 (n=42)


4 grabs, AUT 1996 (n=17)

3 grabs, AUT 1997 (n=20)

Biomass and density data showed a drop from the summer of year 1996. Recruitment of younger individuals from winter 1997 restored densities but biomasses remained low for during the wholeof the year 1997.

Fig. 3.131. Comparison between control and impacted sites in the Bay of Brest for 1996 and 1997 for *J. striatus.*



Site-to-site comparison (Fig. 3.131) revealed that *J. straitus* occurred in similar densities and biomasses on both grounds. This species seems not to be affected by any impacts on this site.

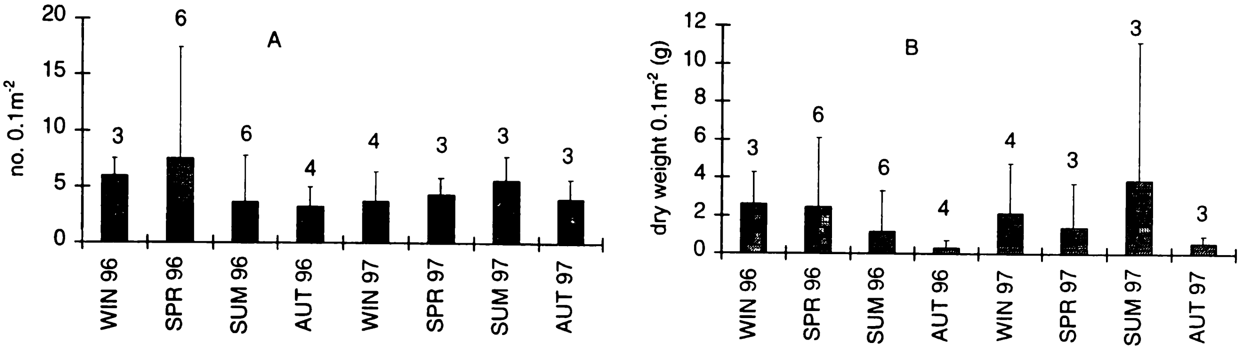
Crepidula fornicata **(Linnaeus, 1758)**

This calyptraeid gastropod was present at UBBC all through the two-year sampling period (1996-1997) in comparable densities. It occurred in 24 grabs of the 30 analysed samples with mean densities of 3 to 7.5 individuals per 0.1m^2 grab, with a maximum of 26 in one grab (Fig. 3.132A).

This species was introduced into European waters at the beginning of the century and has since spread widely. In places it can reach considerable population densities (<3000 ind.m^{-2} in the Bay of Brest), changing the sediment by increasing the fine particle ratio. *Crepidula fornicata* is a suspension-feeding gastropod and requires hard substrata for settlement.

Since it can reach 5 cm body length it was a dominant contributor to the biomass in grab samples. It reached a maximum contribution of 60 % of total biomass in one grab, and mean dry weight biomasses ranged from 0.3 to 3.8g during the sampling period (Fig. 3.132B).

Fig. 3.132.A) Mean number and B) biomass (g dry weight) of *C. fornicata* per 0.1m^2 grab at UBBC. Error bars = SD, N = number of grabs analysed.

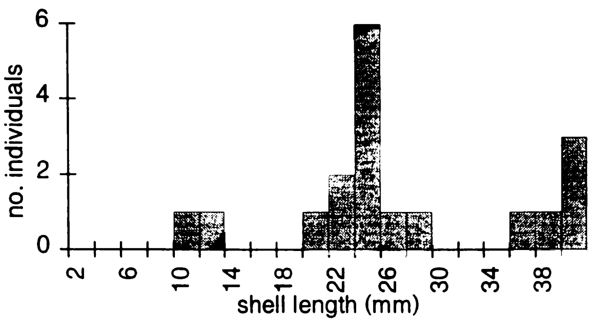


Seasonal variations in size frequency of *C. fornicata* was not easy to discern because of the low number of individuals sampled (Fig. 3.133). However, it appeared that individuals between 20 and 40 mm occurred regularly throughout the year and may constitute the basic population of *C. fornicata* on UBBC, while the proportion of smaller individuals fluctuated more. Recruitment of juveniles occurred all through the year, with varying intensities. The *C. fornicata* population was never dominated by small individuals, except during the winter of 1996. Recruitment therefore seemed to be continuous at UBBC, but with poor survival rate of juveniles as the population did not increase through time.

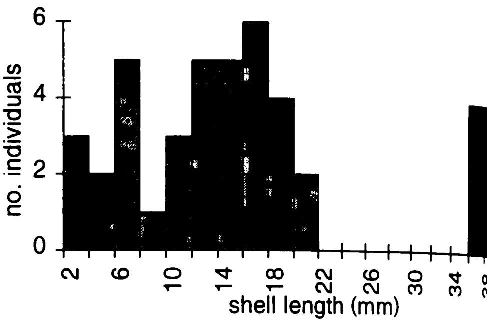
Comparison of the two sampled years showed no clear variation in abundances, but a maximum density was reached in spring 1996. This was due to massive recruitment of juveniles. Biomass showed different patterns, but was closely related to the size of the individuals sampled.

Fig. 3.133. Size-frequency histograms for *Crepidula fornicata* collected seasonally in 0.1m^2 grabs at UBBC from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.

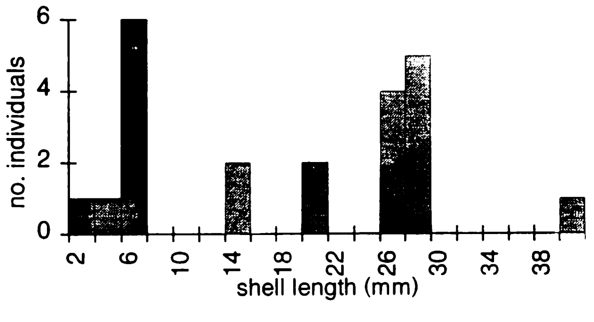
3 grabs, Win 1996 (n=18)



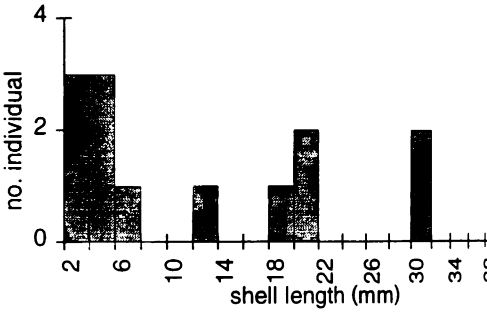
6 grabs, SPR 1996 (n=45)



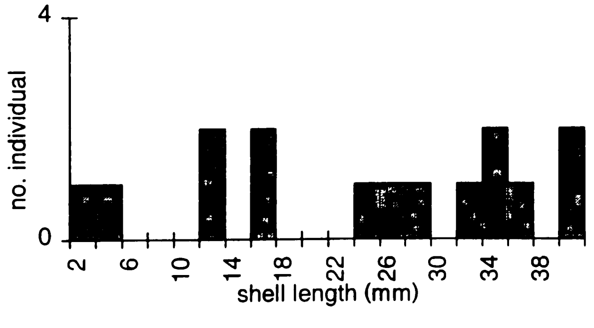
3 grabs, SUM 1996 (n=22)



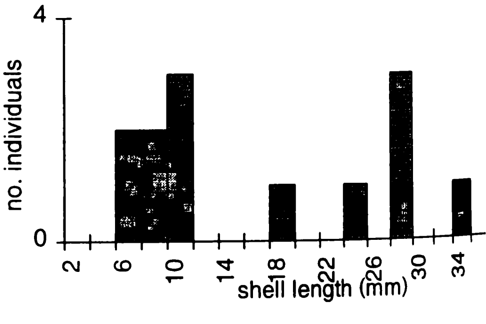
4 grabs, AUT 1996 (n=13)



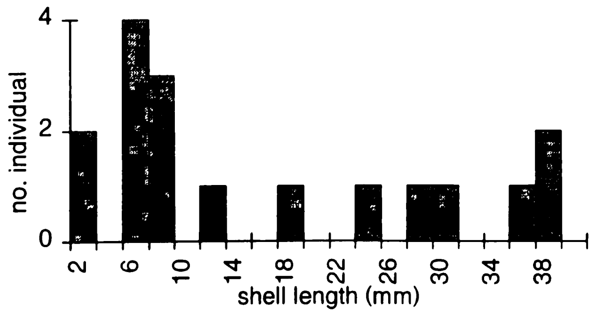
4 grabs, WIN 1997 (n=15)



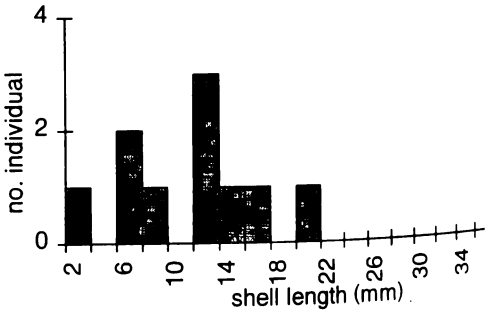
3 grabs, SPR 1997 (n=15)



3 grabs, SUM 1997 (n=17)



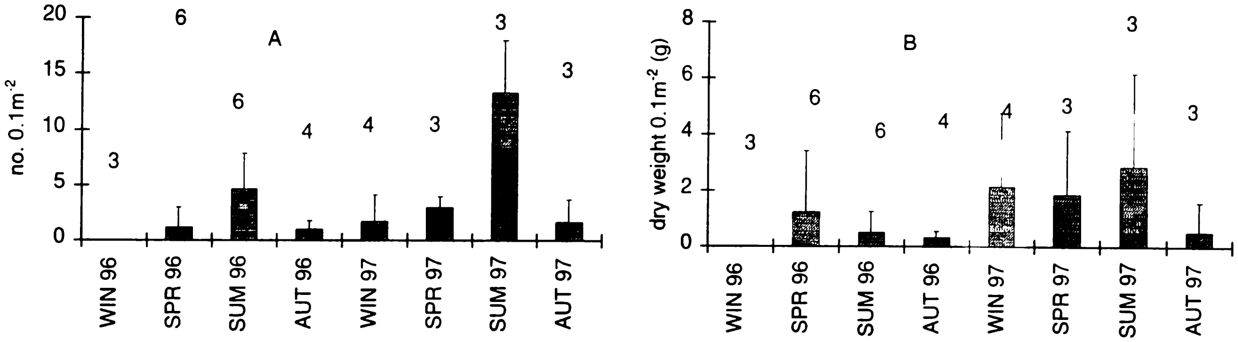
4 grabs, AUT 1997 (n=12)



This calyptraeid gastropod was also present on UBBI all through the two-year sampling period (1996-1997) in comparable densities except for summer 1997. It occurred in 20 of the 30 analysed grab samples, with mean population densities between 0 and 13 individuals per $0.1m^2$ grabs, and a maximum of 17 in one grab (Fig. 134A).

Since this species can reach 5 cm it could be a dominant contributor to the biomass of the grabs sampled here. At UBBI, its maximum contribution reached 35 % of the total biomass of one grab and mean dry weight biomasses ranged from 0 to 3.g per 0.1 m^2 grab throughout the sampling period (Fig. 3.134B).

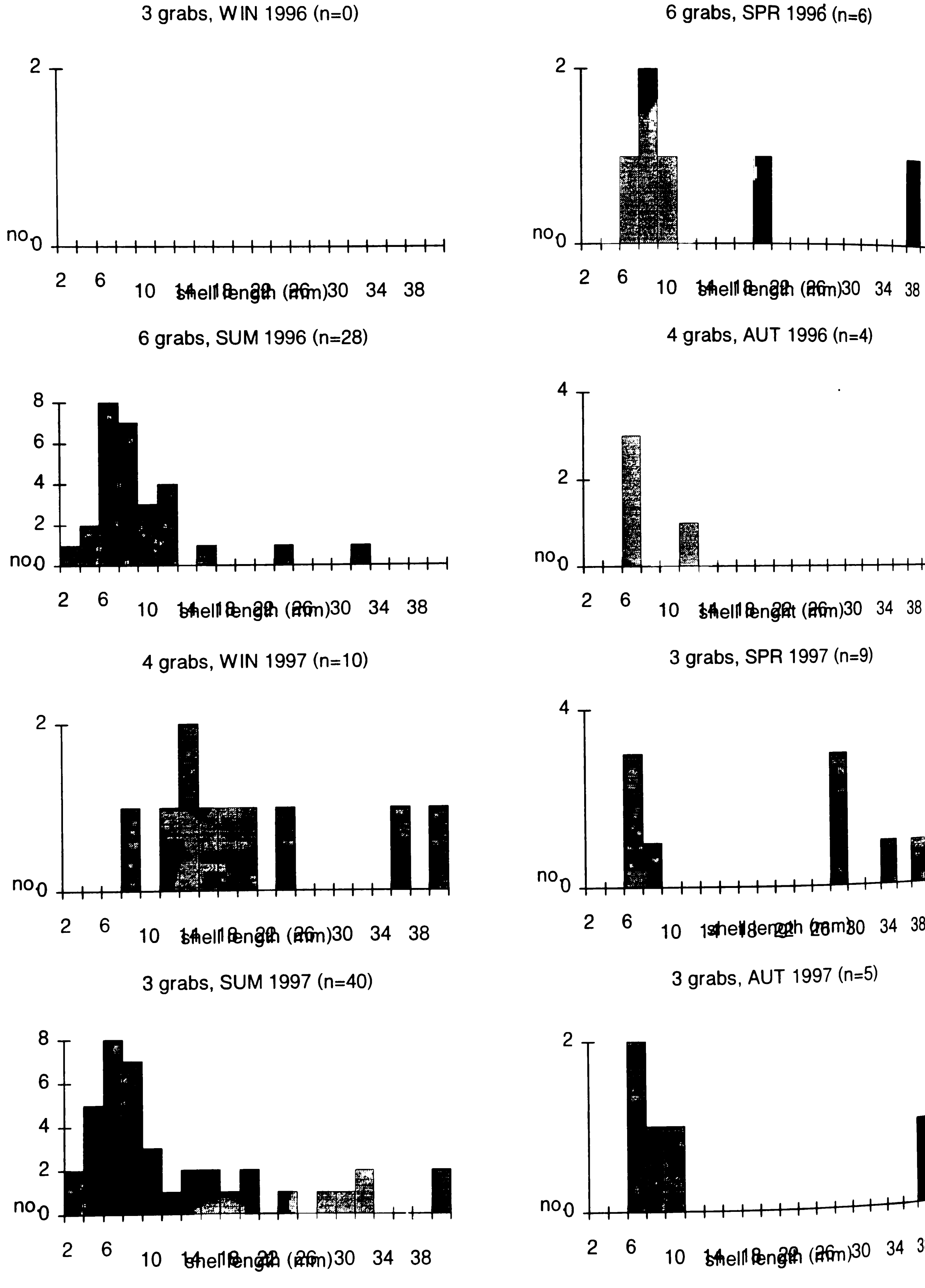
Fig. 3.134.A) Mean number and B) biomass (g dry weight) of *C. fornicata* per $0.1m^2$ grab at UBBI. Error bars = SD, N = number of grabs analysed.



Seasonal variations in size frequency of *C. fornicata* at UBBI are difficult to interpret here because of the low number of individuals sampled (Fig. 3.135). Recruitment seems obvious from spring to autumn, with smaller individuals being detected in grabs in these seasons. Maximum densities in 6-8 mm length *C. fornictata* occurred in summer but their number was much lower in autumn. It therefore seems that small individuals of this species had low survival rates on the impacted ground.

Comparison of the two sampled years showed no clear variation in abundances. The maximum in abundance observed in summer 1997 was due to a high juvenile recruitment. Biomasses were, however, higher during 1997 but no factor could be

Fig. 3.135. Size-frequency histograms for *Crepidula fornicata* collected seasonally in $0.1m^2$ grabs at UBBI from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.



3 grabs, WIN 1996 (n=0)

6 grabs, SPR 1996 (n=6)

6 grabs, SUM 1996 (n=28)

4 grabs, AUT 1996 (n=4)

4 grabs, WIN 1997 (n=10)

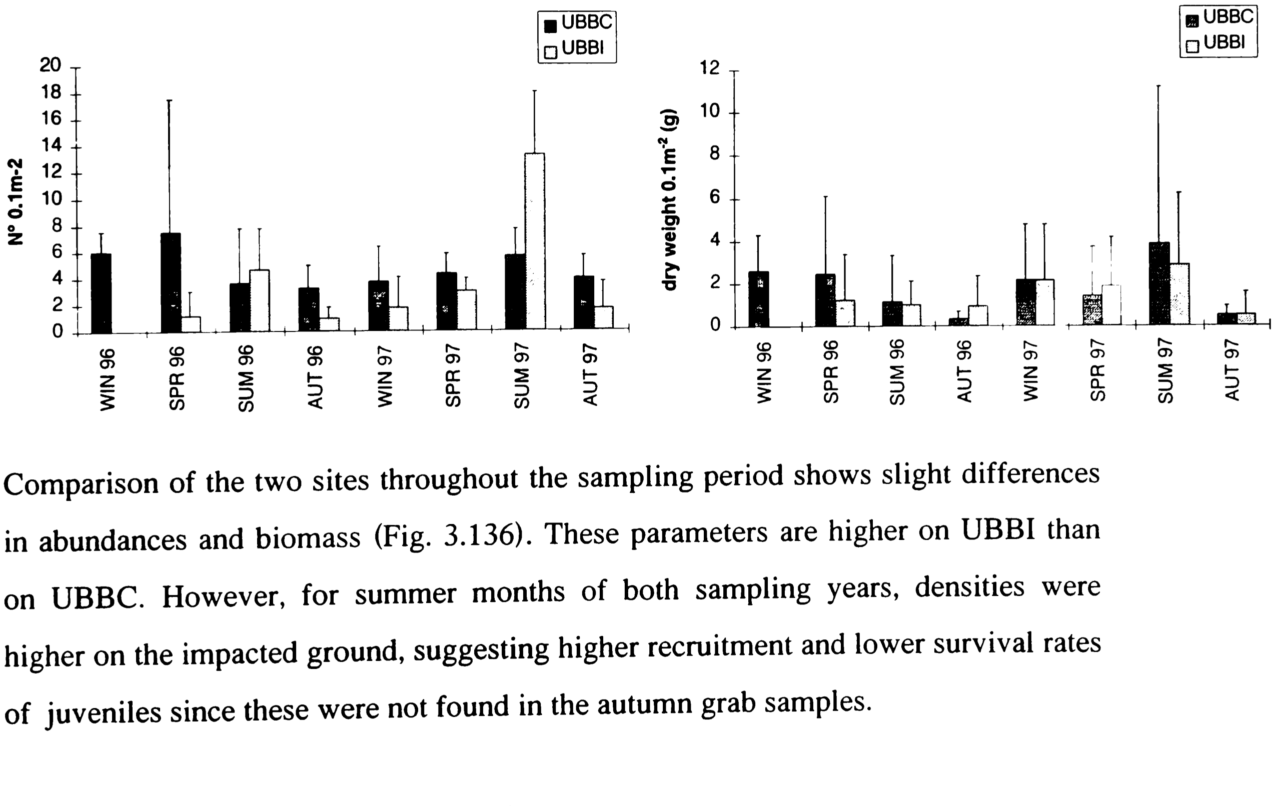
3 grabs, SPR 1997 (n=9)

3 grabs, SUM 1997 (n=40)

3 grabs, AUT 1997 (n=5)

found to explain this fact. In the case of these big scattered gastropods, a sampling area of 0.1m^2 is not sufficient to sample bigger individuals adequately. Biomasses are therefore difficult to interpret since they depend on the size of the animals sampled.

Fig. 3.136. Comparison between control and impacted sites in the Bay of Brest for 1997 and 1998 for *C.fornicata.*



Comparison of the two sites throughout the sampling period shows slight differences in abundances and biomass (Fig. 3.136). These parameters are higher on UBBI than on UBBC. However, for summer months of both sampling years, densities were higher on the impacted ground, suggesting higher recruitment and lower survival rates of juveniles since these were not found in the autumn grab samples.

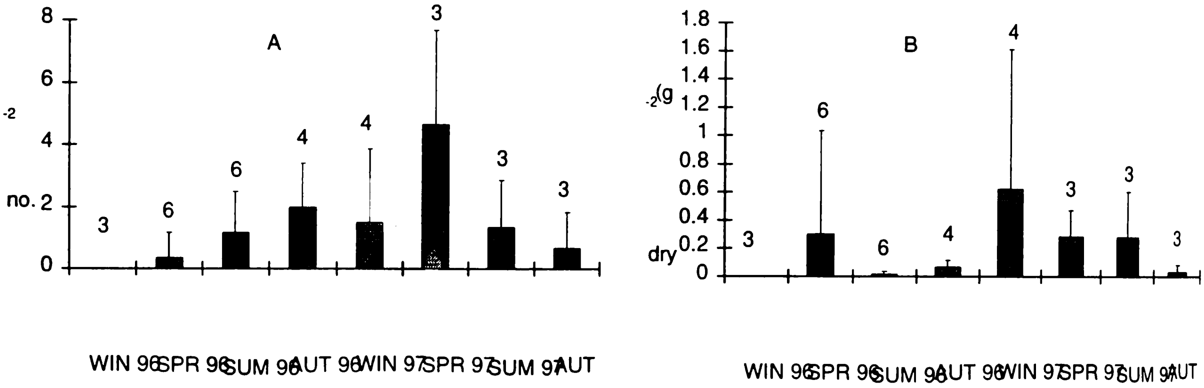
Parvicardium exiguum (Gmelin, 1791)

The bivalve *P. exiguum* was sparsely distributed on the control ground of the Bay of Brest (UBBC) during the sampling period. It occurred in 15 grabs of the total of 30 samples analysed on UBBC with means of 0-4.7, with up to 8 individuals collected per 0.1m^2 grab (Fig. 3.137A)

The cardiid *P. exiguum* is a suspension-feeding bivalve usually found living in muds or sandy muds. It seems to be a tolerant species to eutrophication and organic matter as it can be found in high densities in polluted harbour areas. In the Bay of Brest maerl beds, it can settle in the muddy sediments covered by calcareous rhodophytes.

It had a wide range of sizes in our samples (from 1 to 10 mm) and biomasses were therefore affected by the size of the individuals captured by the grabs. During the sampling period, mean dry weight biomass varied from 0 to 0.6 g per 0.m^2 grab (Fig. 3.137B). Maximum contribution of the biomass of *P. exiguum* for one grab was 2.5%.

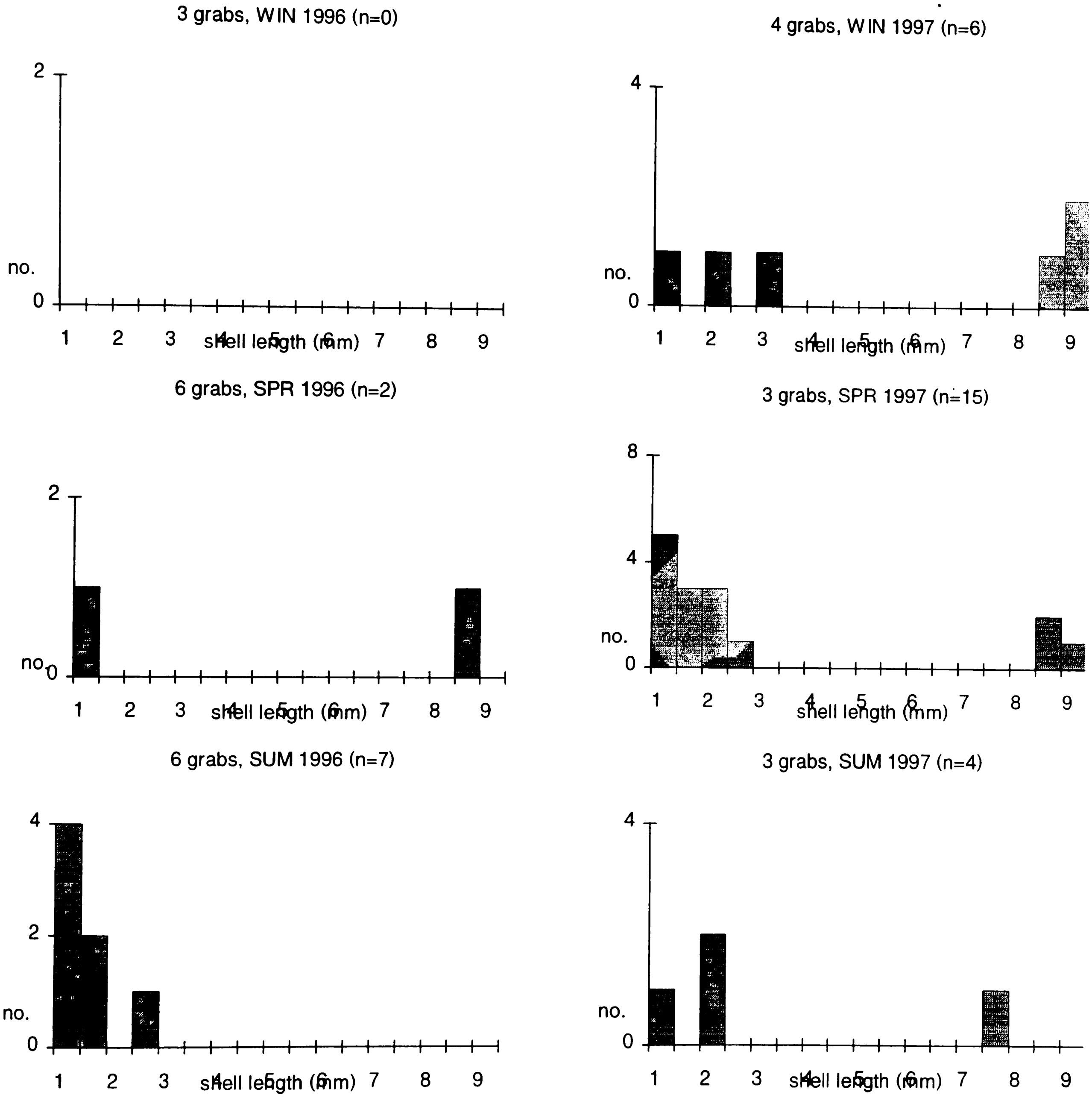
Fig. 3.137. A) Mean number and B) biomass (g dry weight) of *P. exiguum* per 0.1m^2 grab at UBBC. Error bars = SD, N = number of grabs analysed.

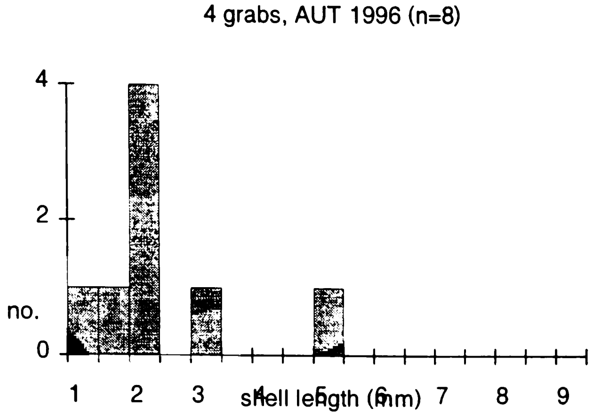


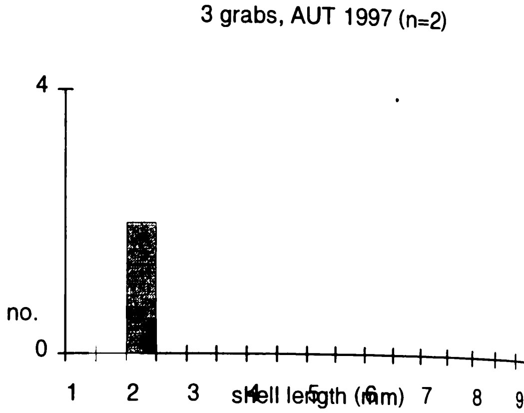
The seasonal variation in size-frequency of *P. exiguum* sampled in grabs is given in Fig.3.138. Large individuals were sparsely distributed at UBBC and no clear pattern of size distribution emerged as the number of individuals sampled was low. Individuals of 8 to 9 mm could be present in any season. On the other hand, juvenile recruitment (individuals of 1 to 3mm length) was observed during spring, summer and autumn of the two-year sampling period. Survival of the juveniles was different between the two years as small individuals recruited during spring 1997 disappeared from the samples in summer and autumn.

Year-to-year comparison showed higher population density and biomass for 1997 except for the autumn period that was equivalent for the two years. This can be explained by a recruitment at the beginning of 1997 and mortalities of juveniles in late summer on UBBC.

Fig. 3.138. Size-frequency histograms for P.. *exiguum* collected seasonally in 0.1m^2 grabs at UBBC from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.



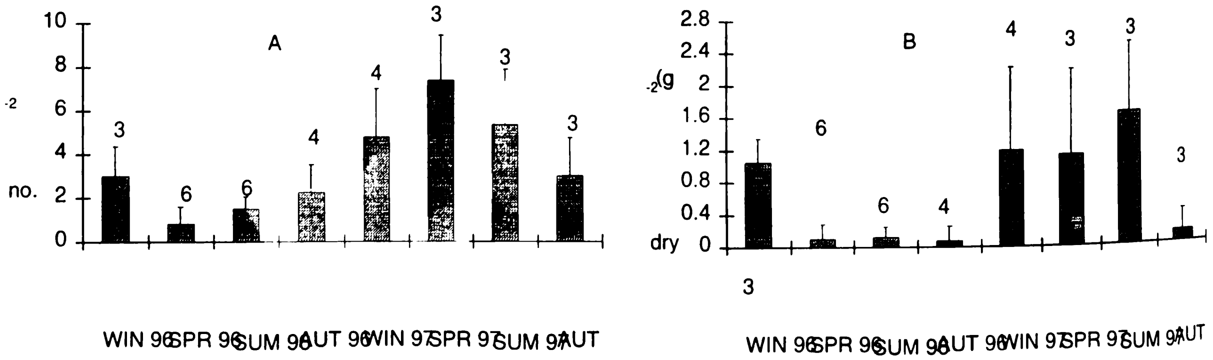




This species was sparsely distributed on the impacted ground of the Bay of Brest (UBBI) during the sampling period. It occurred in 26 grabs out of the total of 30 samples analysed from there with means of 0.8-7.3 and up to 9 individuals collected per 0.1m^2 grab (Fig . 3.139A)

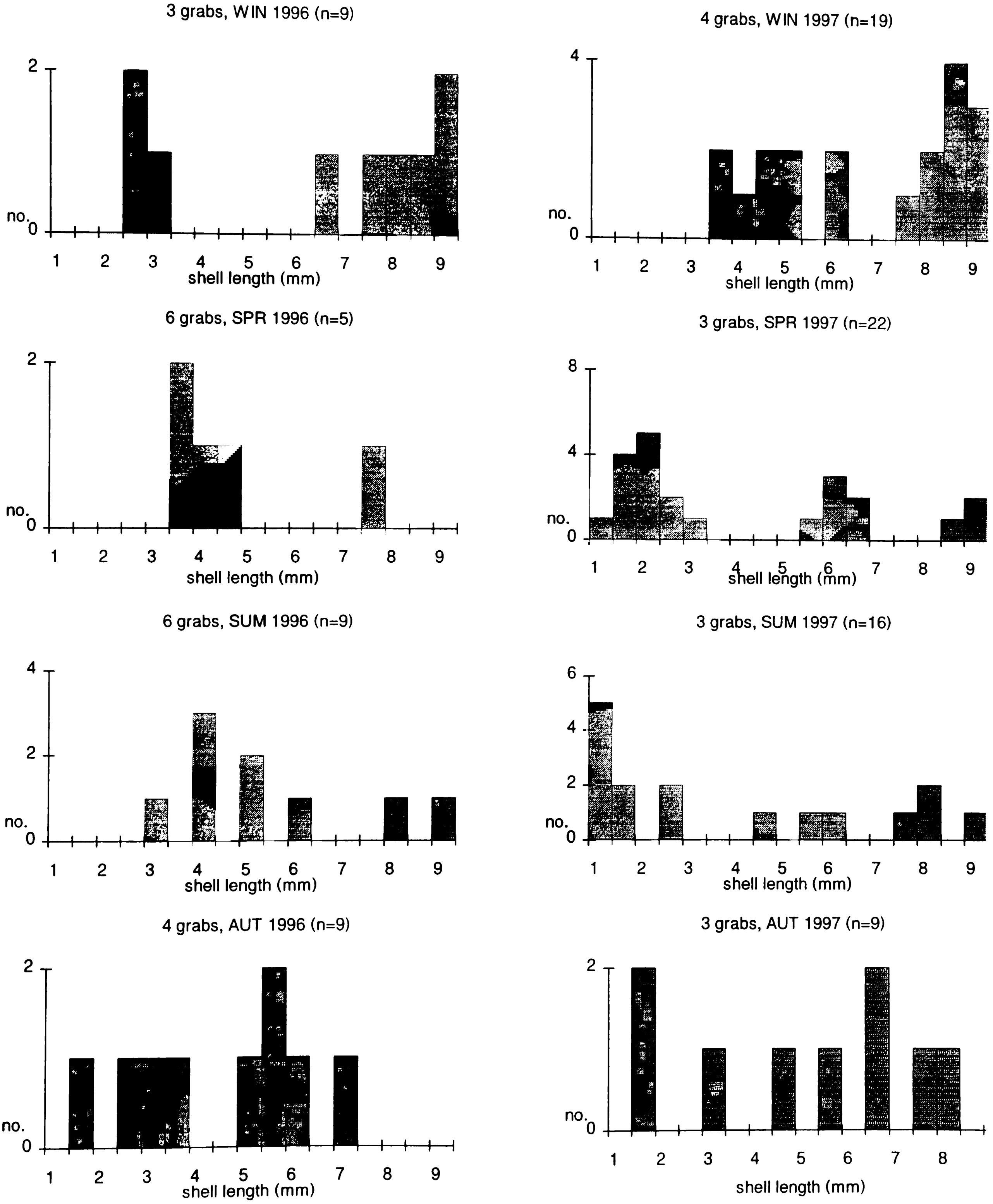
P.exiguum had a wide range of sizes in our UBBI samples (from 1 to 10 mm) and biomasses were, as before, much affected by the size of the individuals caught by the grabs. During the sampling period, mean dry weight biomass varied from 0.12 to 0.3 g per 0.m^2 grab (Fig. 3.139B). Maximum contribution of the biomass of *P. exiguum* for one grab was 2.5%.

Fig. 3.139. A) Mean number and B) biomass (g dry weight) of *P. exiguum* per 0.1m^2 grab at UBBI. Error bars = SD, N = number of grabs analysed.



The seasonal variation in size frequency of *P. exiguum* sampled in grabs at UBBI is given in Fig. 3.140. Due to low numbers of individuals sampled, no clear pattern appeared. However, a recruitment seems to have occurred in spring 1997.

Fig. 3.140. Size-frequency histograms for *P. exiguum* collected seasonally in $0.1\mathrm{m}^2$ grabs at UBBI from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.



3 grabs, WIN 1996 (n=9)

4 grabs, WIN 1997 (n=19)

6 grabs, SPR 1996 (n=5)

3 grabs, SPR 1997 (n=22)

6 grabs, SUM 1996 (n=9)

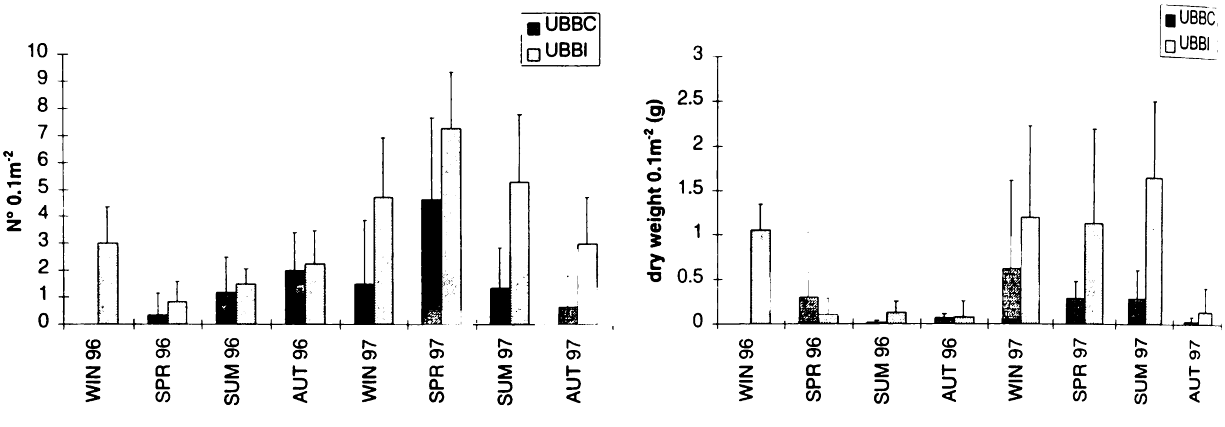
3 grabs, SUM 1997 (n=16)

4 grabs, AUT 1996 (n=9)

3 grabs, AUT 1997 (n=9)

Year-to-year comparison showed higher densities and biomass for 1997. Maximum density was reached in summer 1997, the population decreased thereafter until autumn.

Fig. 3.141. Comparison between control and impacted sites in the Bay of Brest for 1996 and 1997 for *P. exiguum.*



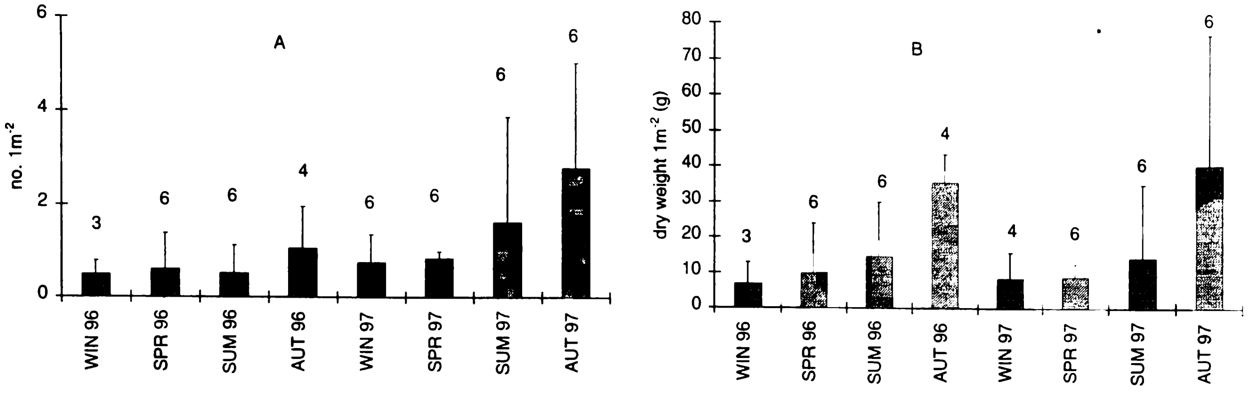
Biomass of *P. exiguum* was higher on the impacted ground while densities were similar, except for summer and autumn 1997 where abundance was higher on UBBI too (Fig. 3.141).

***Venus verrucosa* Linnaeus, 1758**

This bivalve was common on the control ground of the Bay of Brest since it was found in 34 of the 43 AQUAREVE analysed. Mean densities ranged from 0.5 to 3 individuals per m^2 (Fig. 3.142A). A maximum density of 9 individuals per m^2 was observed in autumn 1997.

Venus verrucosa is a suspension-feeding bivalve living in mud to muddy sands. Being a large, shelled species, *V. verrucosa* made a considerable contribution to the biomass in the AQUAREVE samples, reaching a maximum of 85% of a single sample during autumn 1997. Mean biomasses ranged from 6 to 40 g dry weight per m^2 throughout the sampling period (Fig. 3.142B).

Fig. 3.142.A) Mean number and B) biomass (wet weight) of *Venus verrucosa* per AQUAREVE at UBBC. Error bars = SD, N = number of AQUAREVE analysed.



Analysis of the population size structure of *V. verrucosa* (Fig. 3.143) showed no real mode appearing. Individuals were spread across all the size classes observed with no pattern appearing. Smaller individuals (size classes from 9 to 13 mm) were observed throughout the sampling period suggesting continuous recruitment to the megafauna during the year.

Maximum density of this species was reached during the autumn months for both years. However, this cannot be related to recruitment of juveniles, since densities were very similar between the other seasons: this finding remains unexplained.

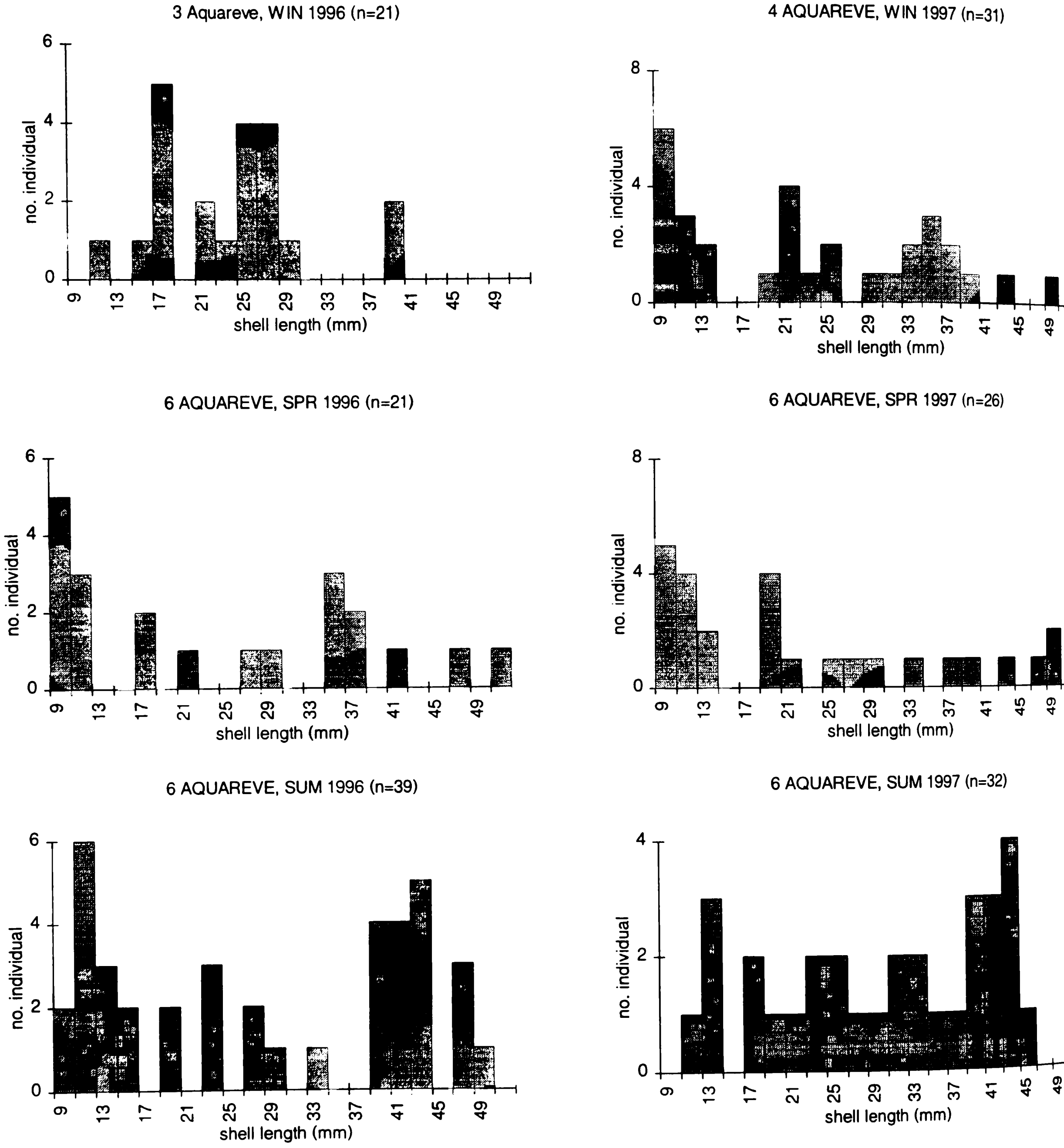


Fig. 3.143. Size-frequency histograms for *Venus verrucosa* collected seasonally in AQUAREVE at UBBC from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.

Psammechinus miliaris **(Gmelin, 1778)**

This sea urchin was present consistently on the UBBC ground. It was found in all the 43 AQUAREVE analysed A maximum of 13 individuals per m^2 was observed throughout the sampling period. Mean densities varied from 0.3 to 6 individuals per m^2(Fig. 3.144A).

Psammechinus miliaris is a common sea urchin in the Bay of Brest living on all types of sediments. It is thought to be a surface-deposit feeder, taking decaying macroalgae (Bedford & Moore, 1985b).

It was an important contributor to the biomass of the megafauna on the control ground in the Bay of Brest (UBBC). Its maximum contribution to a single AQUAREVE reached 24% during summer 1997. Biomasses ranged from to 2 to 38 g dry weight per m^2 (Fig. 3.144B).

Fig.3.144.A) Mean number and B) biomass (g dry weight) of *P. miliaris* per m^2 at UBBC. Error bars = SD, N = number of AQUAREVE analysed.

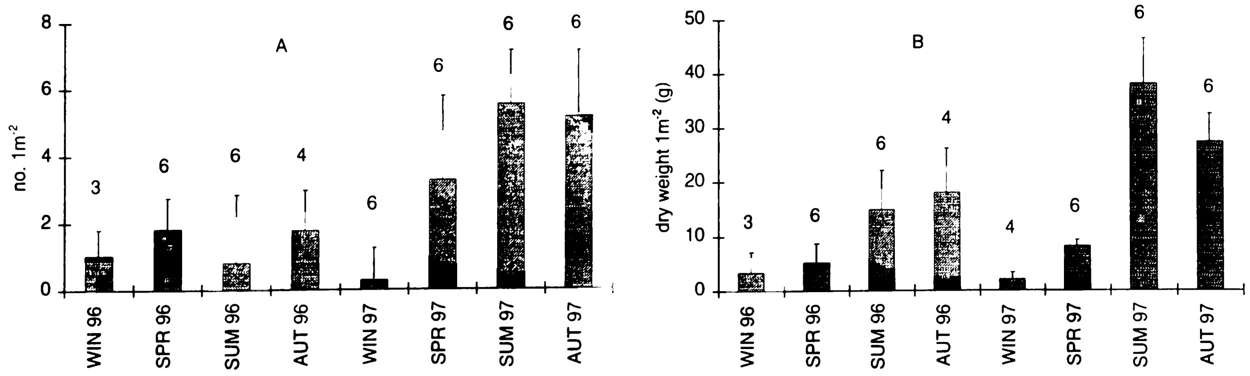
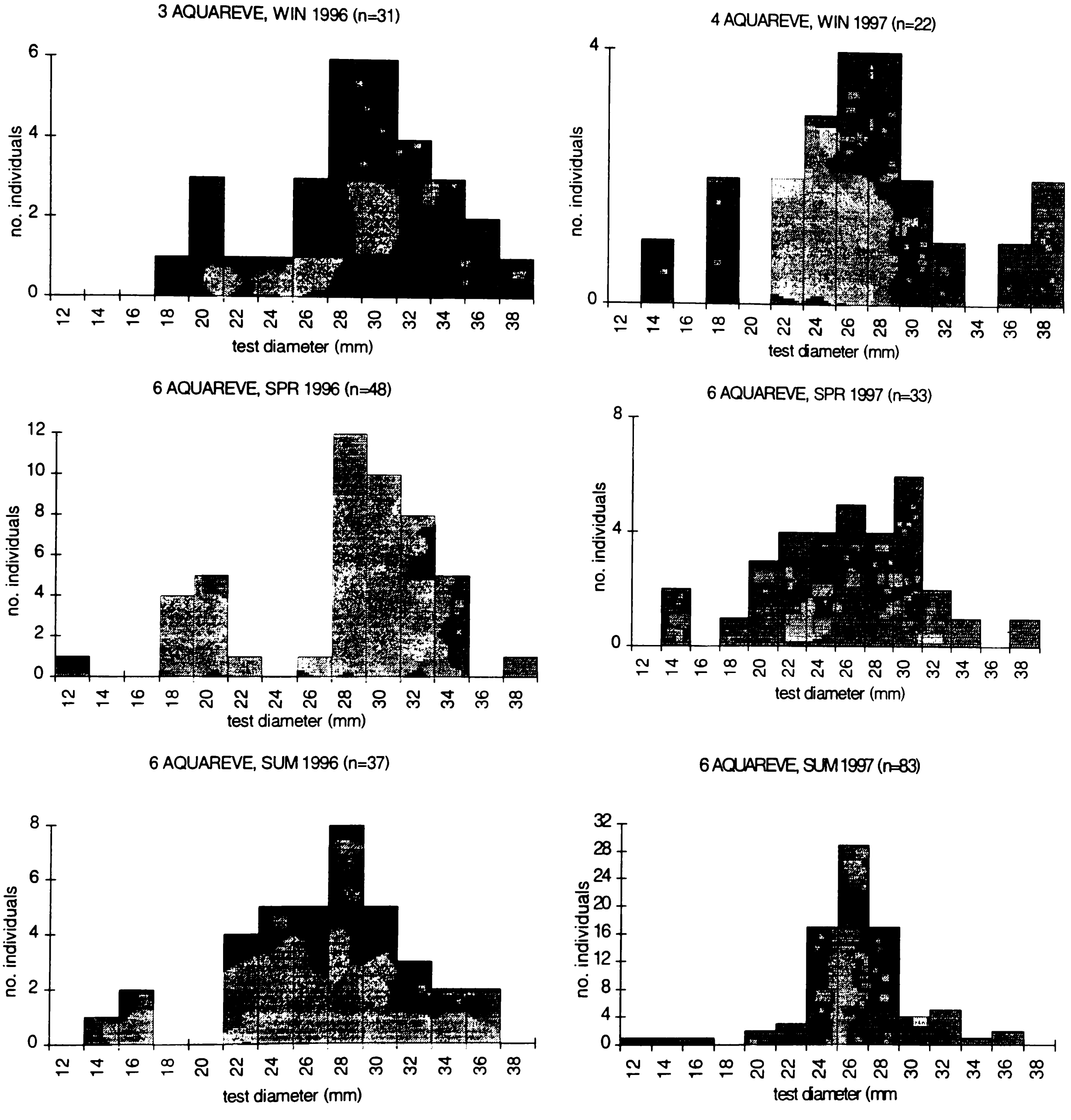


Fig. 3.145 shows the size-frequency structure of the *P. miliaris* population throughout the sampling period. Population structure was mainly unimodal during both sampling years 1996-1997, this mode being centred on a test diameter of 28 mm. However, during the summer and autumn months of 1996, smaller individuals appeared (centred on size class 11mm), suggesting juvenile recruitment. This was not observed in 1997.

The 1997 sampling year showed higher density and biomass than 1996. This cannot be related to recruitment in 1997, and may then be related to migration of this species during spring 1997. No obvious seasonal variations appeared for this species during the sampling period (Fig. 3.145).

Fig. 3.145. Size-frequency histograms for P. *miliaris* collected seasonally in 0.1m^2 AQUAREVE at UBBC from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.



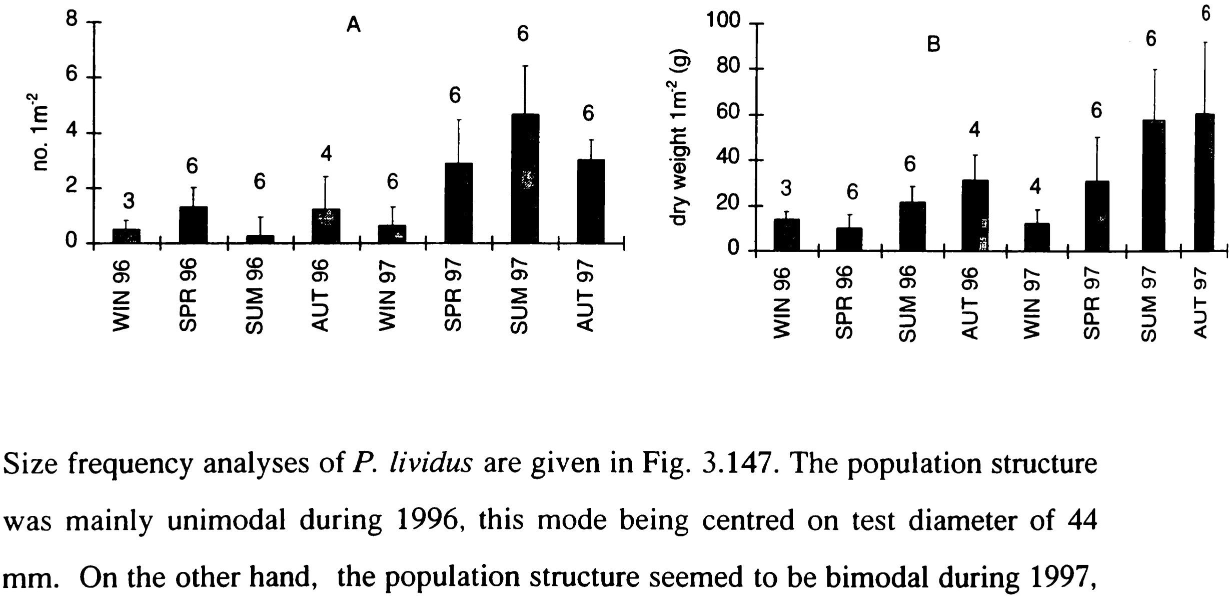
Paracentrotus lividus (Lamarck, 1816)

This sea urchin was seasonally common on the Bay of Brest maerl beds, on the UBBC ground it reached a maximum of 18 indiduals per m^2 in summer 1997. Mean densities varied from 0.3 to 4.7 individuals per m^2 (Fig. 3.146A).

P. lividus is a herbivorous species common around southern European coasts usually related to the presence of coralline algae and calcareous substrata. It feeds on macroalgae. It has also been shown to be sensitive to pollution, especially by heavy . metals.

Being a large species, *P. lividus* contributed greatly to the biomass of the maerl grounds of the Bay of Brest. Its contribution reached a maximum of 80 % of the total dry weight biomass. Mean dry weight varied from 10 to 62 g per m^2 throughout the sampling period (Fig. 3.146B).

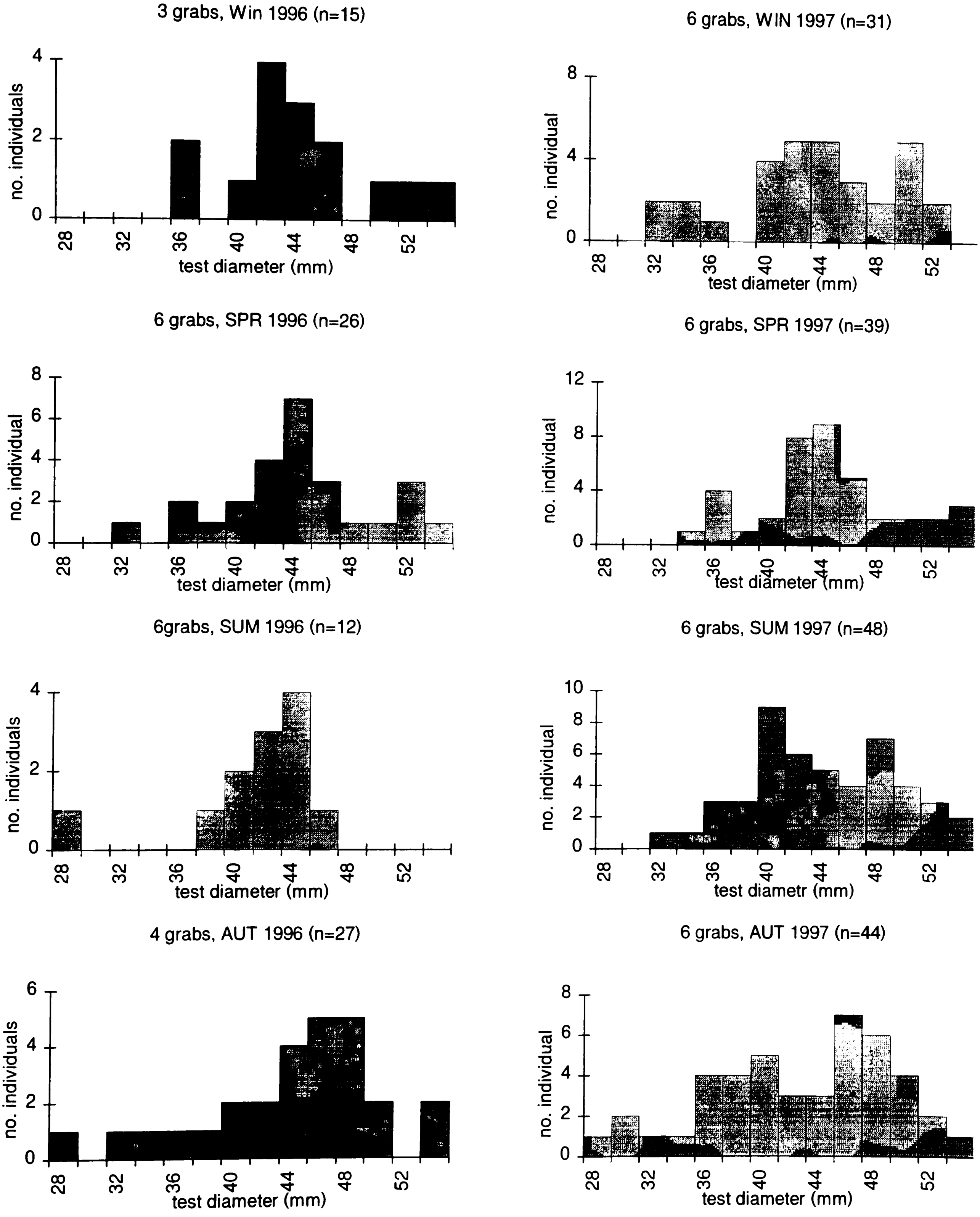
Fig. 3.146A) Mean number and B) biomass (g dry weight) of *P. lividus* per 1m^2 at UBBC. Error bars = SD, N = number of grabs analysed.



Size frequency analyses of *P. lividus* are given in Fig. 3.147. The population structure was mainly unimodal during 1996, this mode being centred on test diameter of 44 mm. On the other hand, the population structure seemed to be bimodal during 1997, centred around size classes of 38mm and 44 mm. This suggests migration of smaller individuals on the control maerl ground during winter 1997. This can be related to the increase in abundance observed in spring 1997.

Comparison of the two sampling years shows that in 1997, *P.lividus* had double the biomass and density found in 1996. Maximum abundances and biomasses were in summer and autumn 1997. These parameters were at their lowest during the winter months of both years. Since this sea urchin is a long-lived species, this facts suggest population migration during the year.

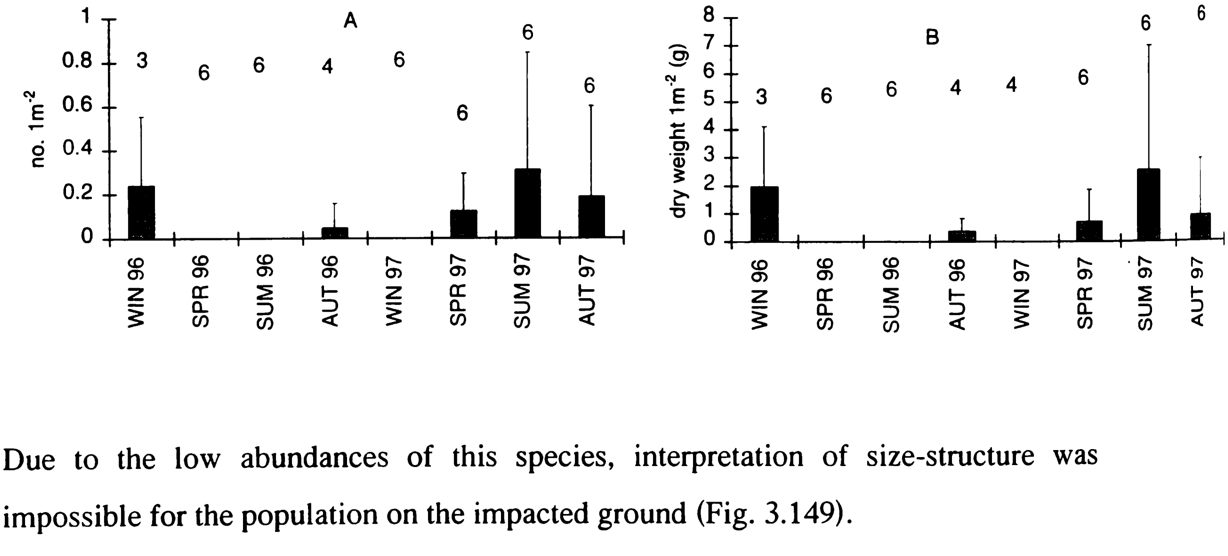
Fig. 3.147. Size-frequency histograms for *P. lividus* collected seasonally in 0.1m^2 grabs at UBBC from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.



This sea urchin was rare on the impacted maerl ground of the Bay of Brest, reaching a maximum of 4 indiduals per m^2 in summer 1997 while it occurred in only 20 of the 43 samples analysed. Mean densities varied from 0.3 to 4.7 individuals per m^2 (Fig. 3.148A).

Its contribution to biomass there reached a maximum of 80 % of the total dry weight biomass. Mean dry weight varied from 0 to 3 g per m^2 throughout the sampling period (Fig. 3.148B).

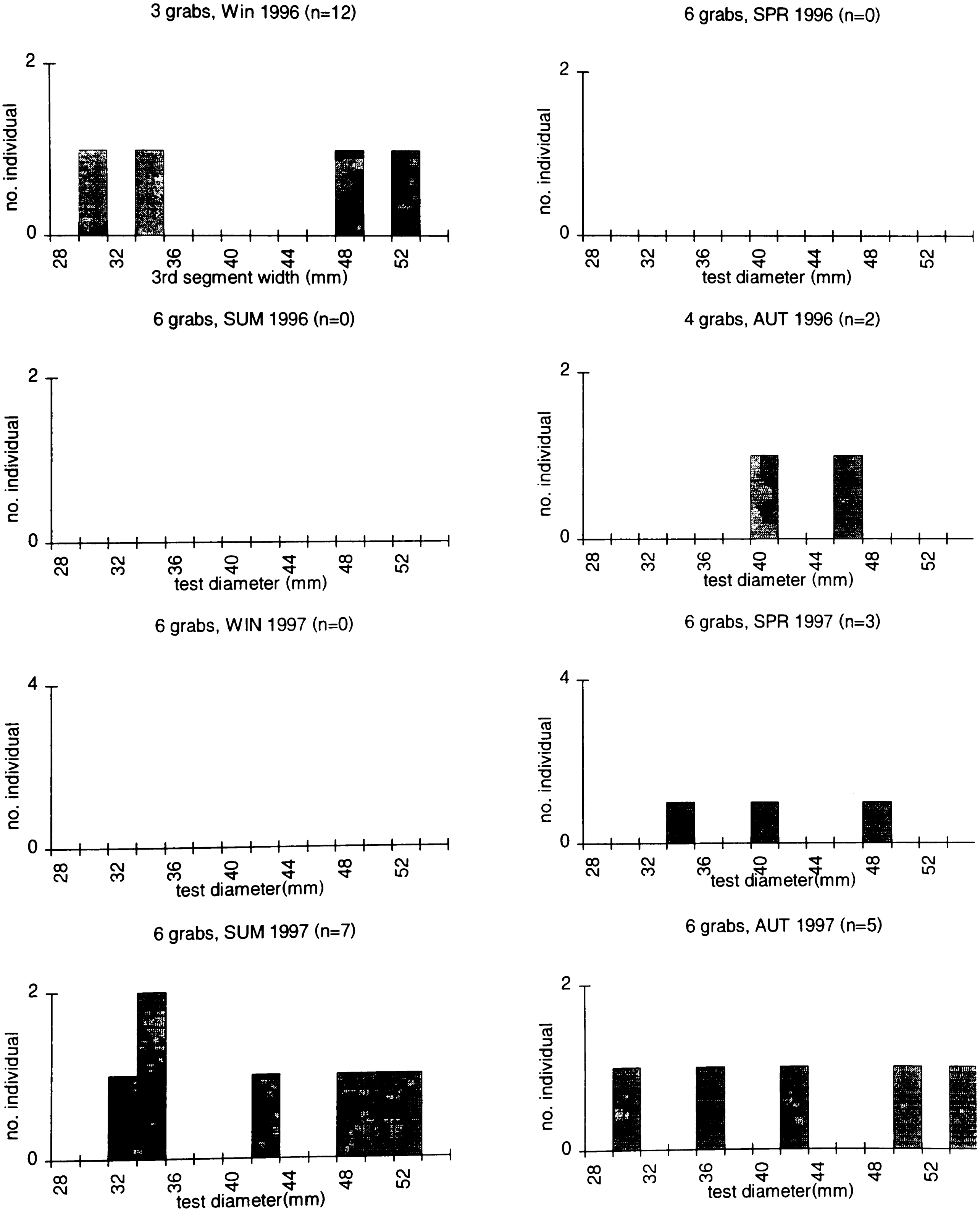
Fig. 3.148. A) Mean number and B) biomass (g dry weight) of *P. lividus* per 1m^2 at UBBI. Error bars=SD, N=number of grabs analysed.



Due to the low abundances of this species, interpretation of size-structure was impossible for the population on the impacted ground (Fig. 3.149).

Again, as for several key species, abundances and biomasses were somewhat higher in 1997 than in 1996, maximum abundance being reached in the summer for the former year (Fig. 3.150).

Fig. 3.149. Size-frequency histograms for *P.lividus* collected seasonally in 0.1m^2 grabs at UBBI from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.



3 grabs, Win 1996 (n=12)

6 grabs, SPR 1996 (n=0)

6 grabs, SUM 1996 (n=0)

4 grabs, AUT 1996 (n=2)

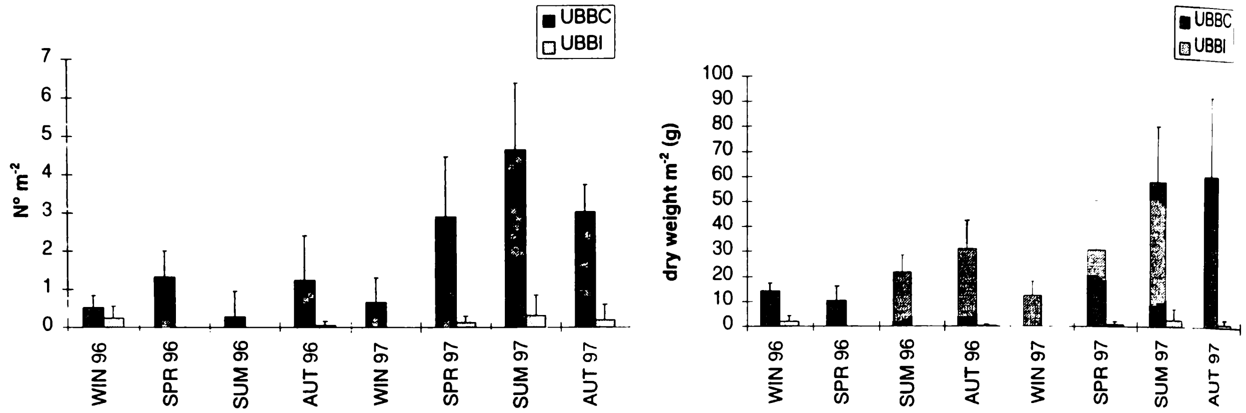
6 grabs, WIN 1997 (n=0)

6 grabs, SPR 1997 (n=3)

6 grabs, SUM 1997 (n=7)

6 grabs, AUT 1997 (n=5)

Fig. 3.150. Comparison between control and impacted sites in the Bay of Brest for 1996 and 1997 for *P. lividus.*



Abundance was much higher (from 2 to 10 times) on the control ground throughout the sampling period.

B) Glenan

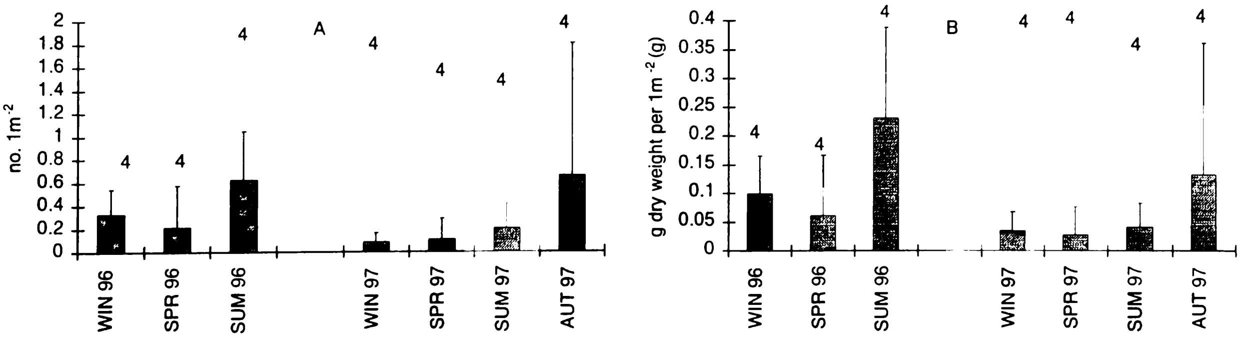
Inachus dorsettensis **(Pennant, 1777)**

This crab was sparsely distributed on the control ground at Glenan. It reached a maximum density of 2 individuals per m^2 in autumn 1997. Mean densities varied from 0.08 to 0.67 individuals per m^2.

Inachus dorsettensis is a majid crab feeding mostly on small crustaceans and hydroids. It lives on mud, sand or even rocky substrata.

Although a large species, *I. dorsettensis* made only a small contribution to the biomass of the AQUAREVE samples. Mean biomass ranged between 0.03 and 0.23 g dry weight per m^2, while the maximum contribution of this species to the dry weight of one sample was 0.2 % (Fig. 3.151).

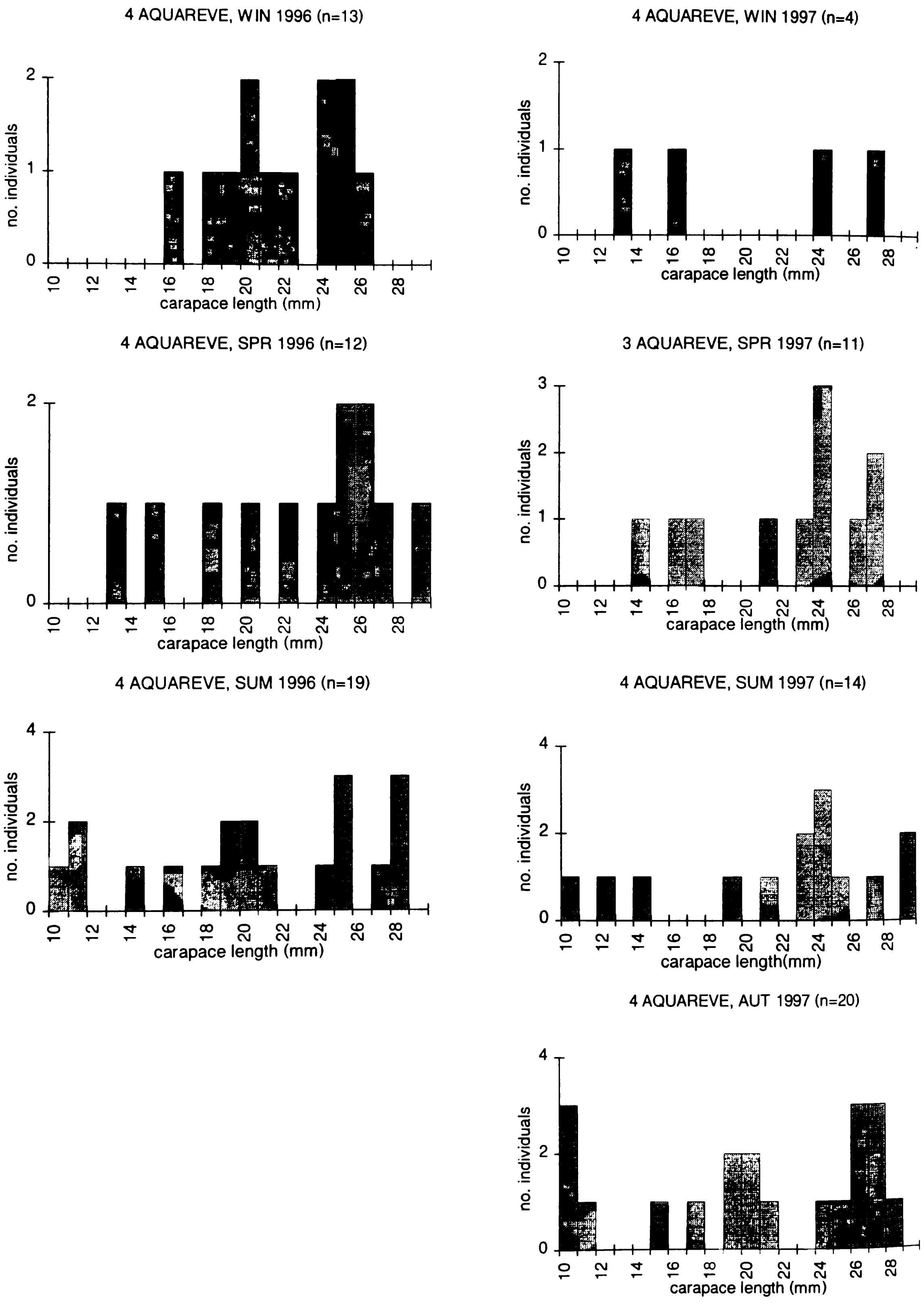
Fig. 3.151. A) Mean number and B) biomass (g dry weight) of *I. dorsettensis* per 1m^2 at UBGC. Error bars = SD, N = number of AQUAREVE samples analysed.



Recruitment of *I. dorsettensis* juveniles was observed during the summer and autumn months of both years (Fig. 3.152). No obvious size-mode was observed for larger animals, but this may be due to the small number of animals measured.

Comparison of the two sampling years shows that density and biomass were higher in 1996 than in 1997, except for autumn 1997 months when density was equivalent to that in summer 1996. High population densities observed in summer and autumn may be explained by recruitment of juveniles to the megafaunal size-category.

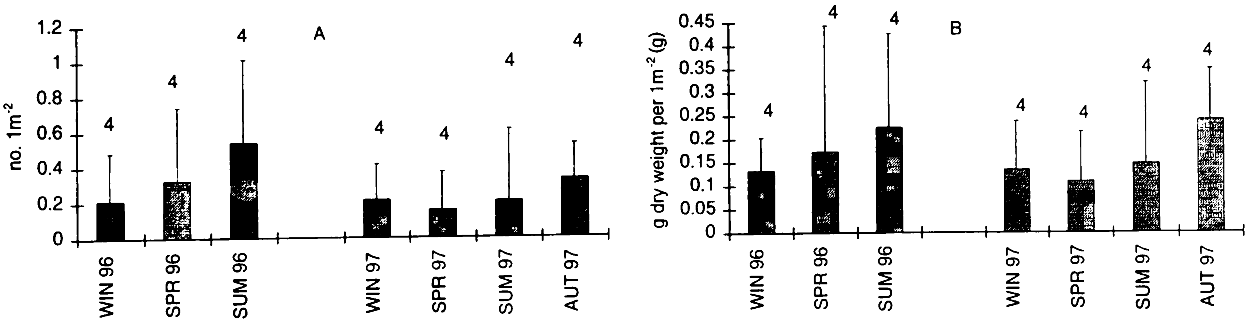
Fig. 3.152. Size-frequency histograms for *Inachus dorsettensis* collected seasonally in AQUAREVE at UBGC from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.



As at UBGC, this crab was sparsely distributed on the impacted ground of the Glenan. It reached a maximum density of 1.4 individuals per m^2 in autumn 1997. Mean densities varied from 0.2 to 0.5 individuals per m^2.

Although a large species, *I. dorsettensis* made a small contribution to the biomass of the AQUAREVE samples at UBGI. Mean biomass on the UBGI ground ranged between 0.10 and 0.24 g dry weight per m^2, while the maximum contribution of this species to the dry weight of one sample was 0.4 % (Fig. 3.153).

Fig.3.153.A) Mean number and B) biomass (g dry weight) of *I. dorsettensis* per 1m^2 at UBGI. Error bars = SD, N = number of AQUAREVE analysed.



Seasonal variation of the population size-structure of *I. dorsettensis* is shown in Fig. 3.154. In contrast to the control ground, no recruitment was observed throughout the sampling period. Only larger individuals were observed here, but no obvious mode within these was detected. Most individuals measured between 22 and 25 mm carapce length, i.e. comparable to UBGC.

Again, abundance was higher during 1996 than during 1997, but differences between the two years were lower than was the case for UBGC. Maximum density was reached in summer 1996. Concerning biomasses, no major difference was observed between the two years or even between the seasons.

Fig. 3.154. Size-frequency histograms for *Inachus dorsettensis* collected seasonally in AQUAREVE at UBGI from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.

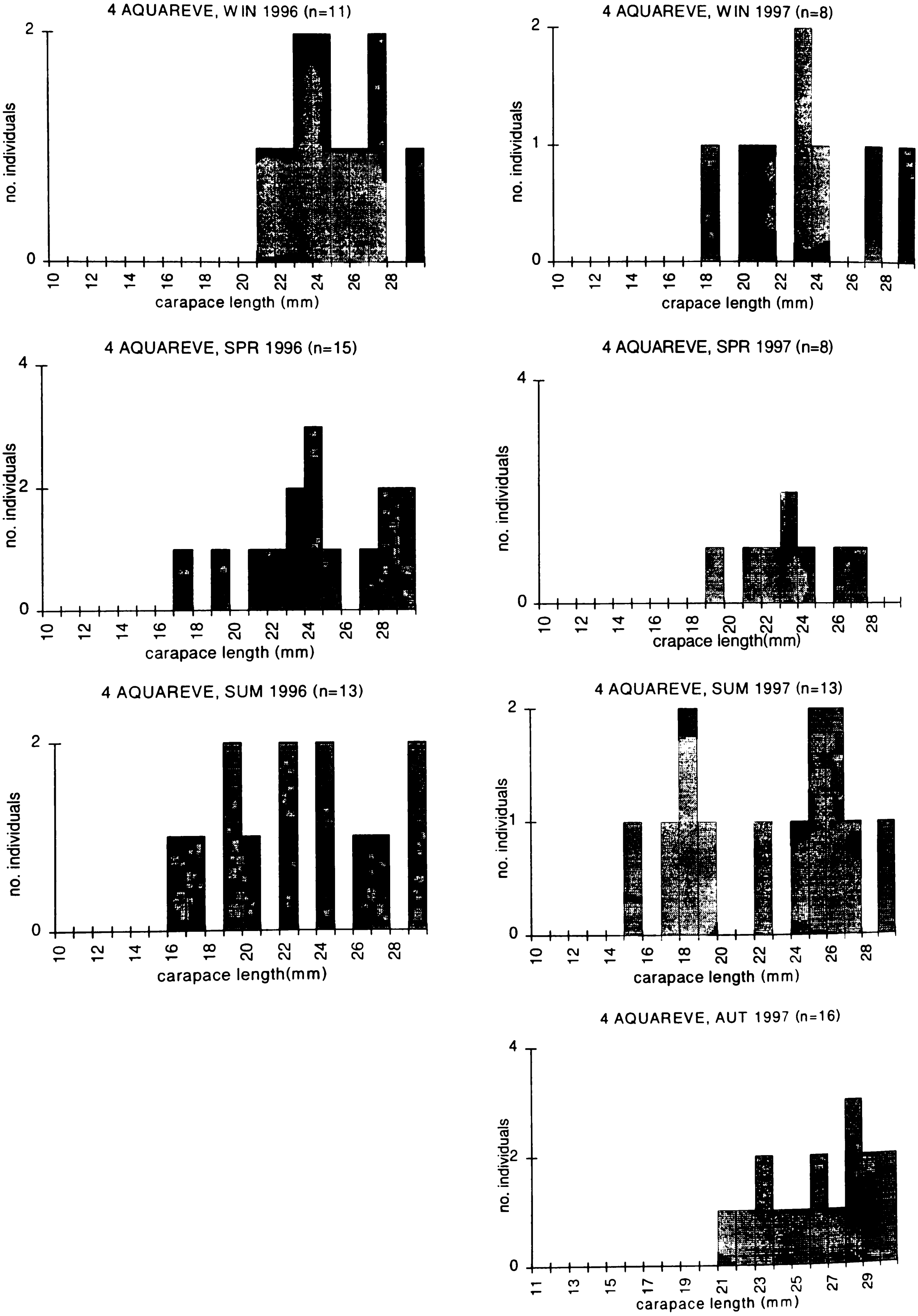
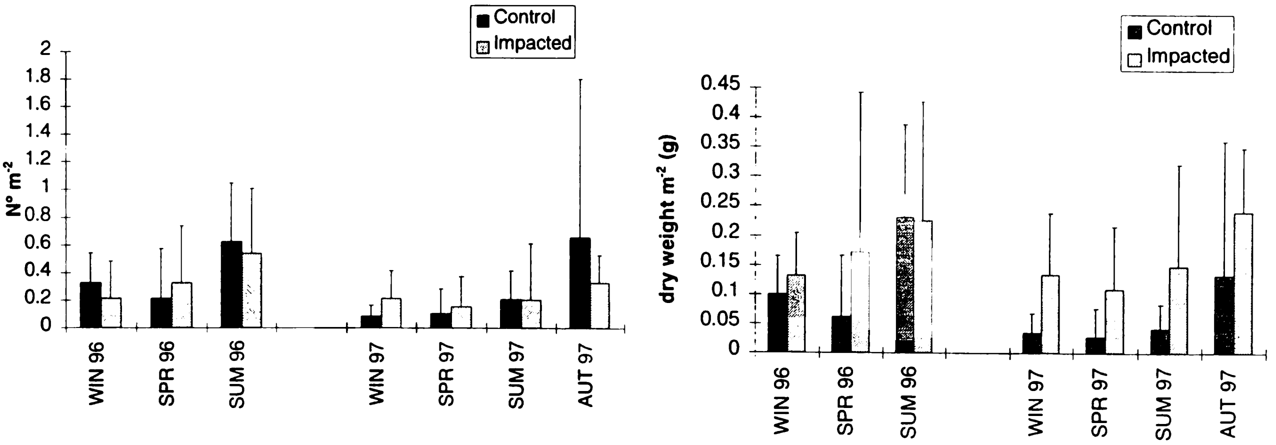


Fig. 3.155. Comparison of population density and biomass of *I. dorsettensis* between control and impacted sites in the Glenan for 1996 and 1997.



Site-to-site comparison showed that abundance and biomass were similar during year 1996 (Fig. 3.155). In 1997, population densities were similar for all seasons but mean biomasses were much on the impacted ground. This again suggests a lack of recruitment on the impacted ground, and low rates of mortality of adults of this species during the sampling period.

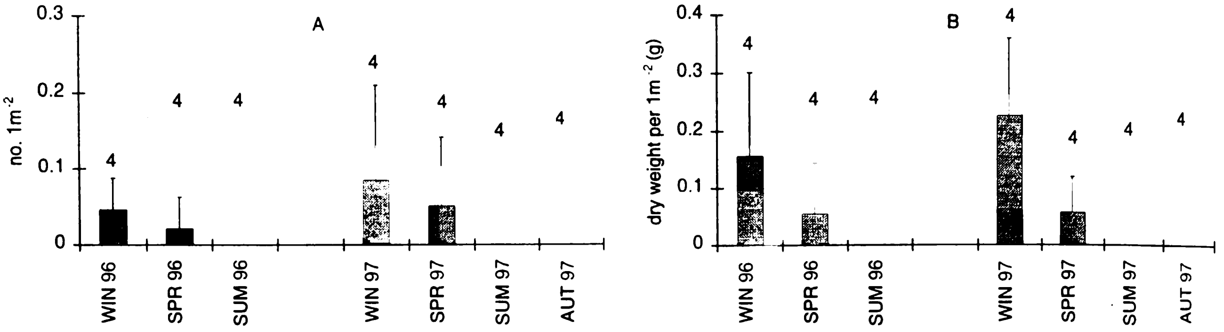
Atelecyclus rotundatus (Olivi, 1792)

This decapod crustacean was sparsely distributed on the maerl beds of Glenan. On the control ground, it only occurred in 13 of the 28 AQUAREVE analysed for the sampling period 1996-1997. Mean densities varied in the range of 0 to 0.1 individuals per m^2 on the control ground UBGC, with a maximum of 0.3 ind. per m^2 observed.

Atelecyclus rotundatus is a carnivorous crab feeding mainly on bivalves. It lives burrowed into gravels or muddy gravelly sediments

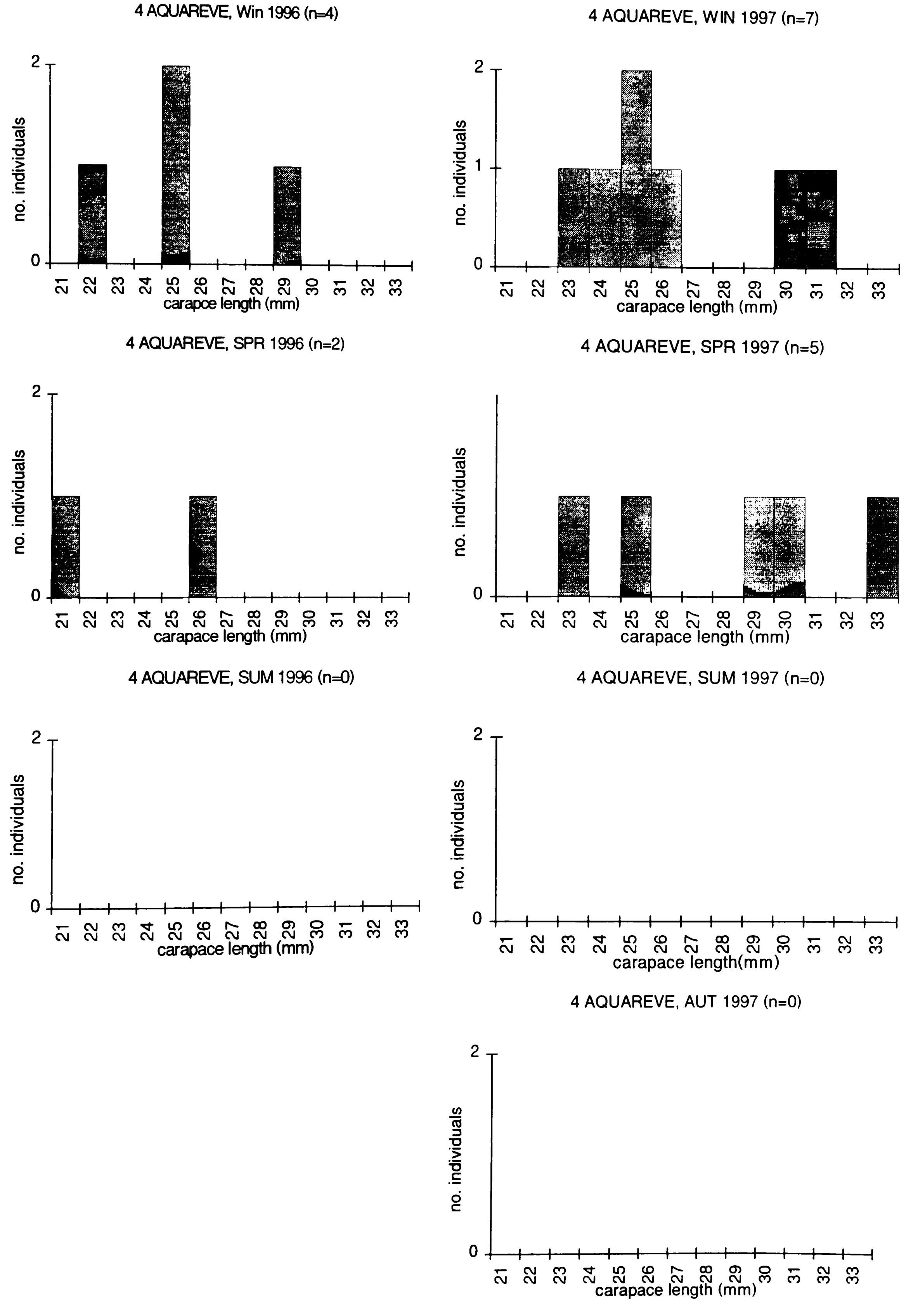
Since this species was rather rare on the control site, its contribution to the total biomass was rather low. A maximum of 6% of the total dry weight biomass was reached in winter 1997. Mean biomasses ranged between 0 to 0.2g per m² during the sampling period (Fig. 3.156).

Fig. 3.156. A) Mean number and B) biomass (g dry weight) of *A rotundatus* per 1m² at UBGC. Error bars = SD, N = number of AQUAREVE samples analysed.



Due to the low number of individuals sampled, nothing definitive can be said regarding the seasonal size structure of this species (Fig. 3.157). Year-to-year comparison shows that *A. rotundatus* was only present on the control site during winter and autumn. Densities and biomasses were higher in 1997 than in 1996. For both years, maxima were reached in winter. However, since this species was quite rare on the control ground, these facts may not be very relevant.

Fig. 3.157. Size-frequency histograms for *Atelecyclus rotundatus* collected seasonally in AQUAREVE at UBGC from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.



4 AQUAREVE, Win 1996 (n=4)

4 AQUAREVE, WIN 1997 (n=7)

4 AQUAREVE, SPR 1996 (n=2)

4 AQUAREVE, SPR 1997 (n=5)

4 AQUAREVE, SUM 1996 (n=0)

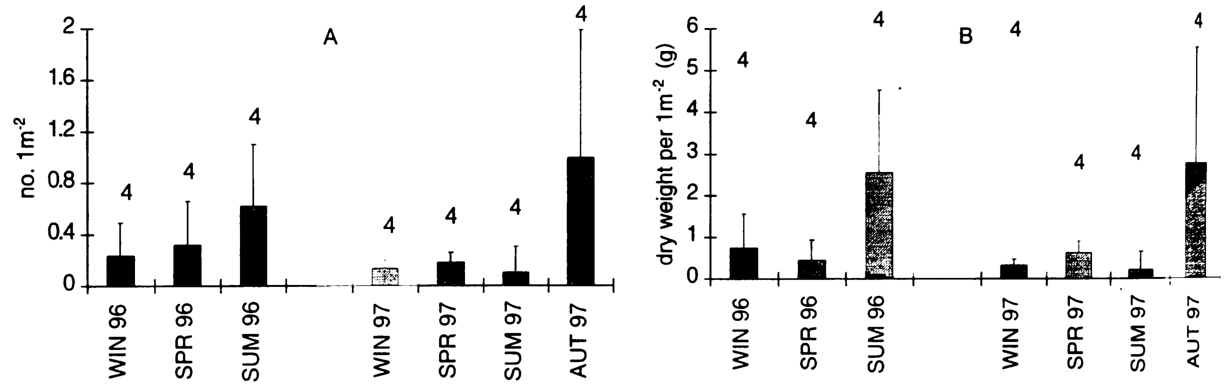
4 AQUAREVE, SUM 1997 (n=0)

4 AQUAREVE, AUT 1997 (n=0)

This decapod crustacean was commonly distributed on the impacted maerl bed of Glenan. It occurred in 22 of the 28 AQUAREVE analysed for the sampling period 1996-1997. Mean densities varied in the range from 0 to 1 individuals per m^2 on the UBGC with maximum of 3 ind. per m^2 observed in autumn 1997.

This species made a maximum contribution of 14% of the total dry weight biomass for a single AQUAREVE. Mean biomasses ranged between 0.2 to 2.8 g dry weight per m^2 during the sampling period (Fig. 3.158)

Fig. 3.158. A) Mean number and B) biomass (g dry weight) of *A rotundatus* per 1m^2 at UBGI. Error bars = SD, N = number of AQUAREVE samples analysed.

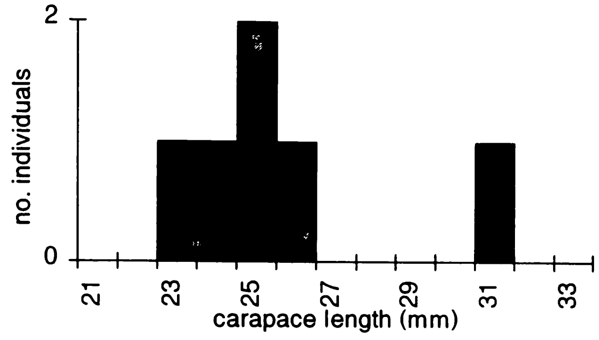


Seasonal size structural analysis of *A. rotundatus* showed that the animals were centred on the size class 25 mm carapace length throughout the sampling period (Fig. 3.159). No recruitment was observed and variation in densities may therefore be due to migration of individuals of this species to or from the Glenan impacted site.

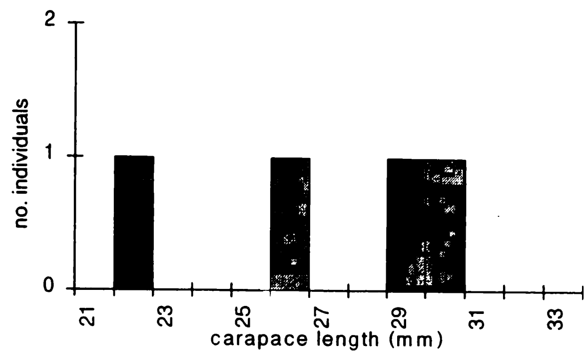
The two sampling years were quite different in terms of population density and biomass. Maxima were reached in summer for 1996 and in autumn for 1997. It seemed moreover that *A. rotundatus* was more common in 1996 than in 1997 on the impacted ground.

Fig.3.159. Size-frequency histograms for *Atelecyclus rotundatus* collected seasonally in AQUAREVE samples at UBGI from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.

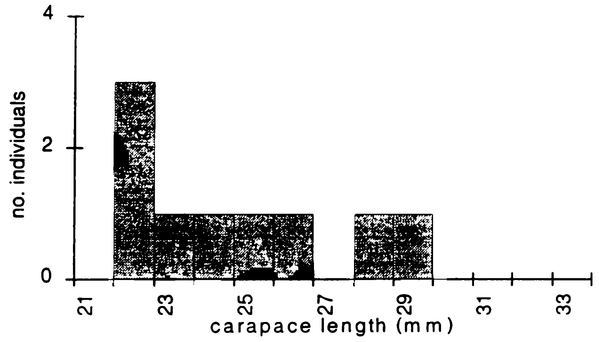
4 AQUAREVE, WIN 1996 (n=6)



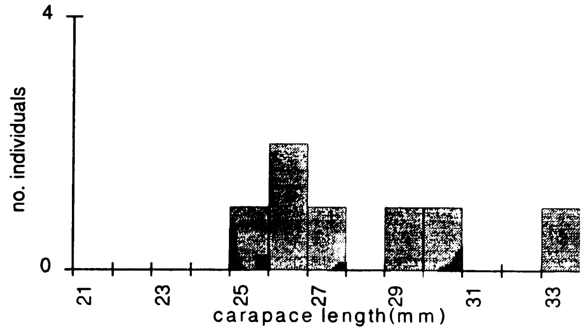
4 AQUAREVE, WIN 1997 (n=4)



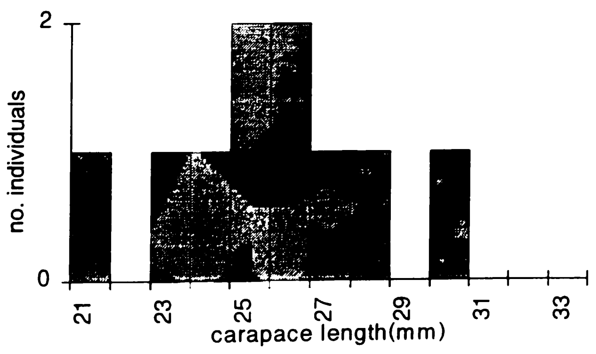
4 AQUAREVE, SPR 1996 (n=9)



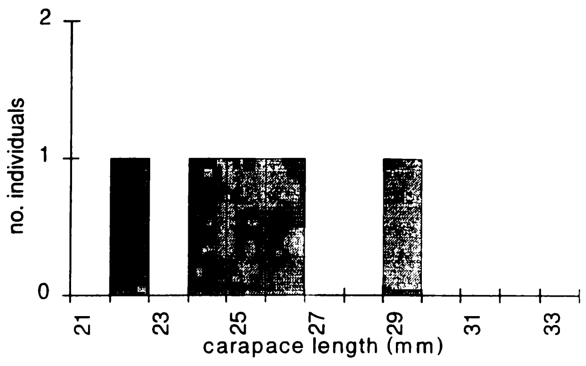
4 AQUAREVEs, SPR 1997 (n=7)



4 AQUAREVE, SUM 1996 (n=10)



4 AQUAREVE, SUM 1997 (n=5)



4 AQUAREVE, AUT 1997 (n=12)

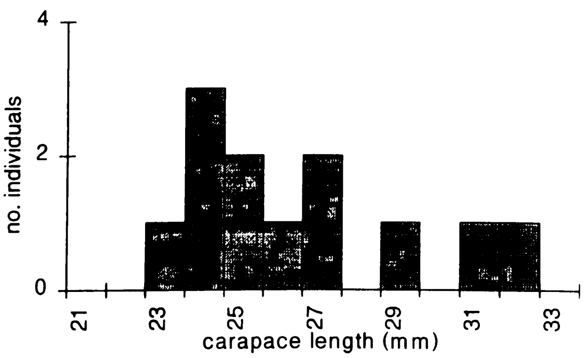
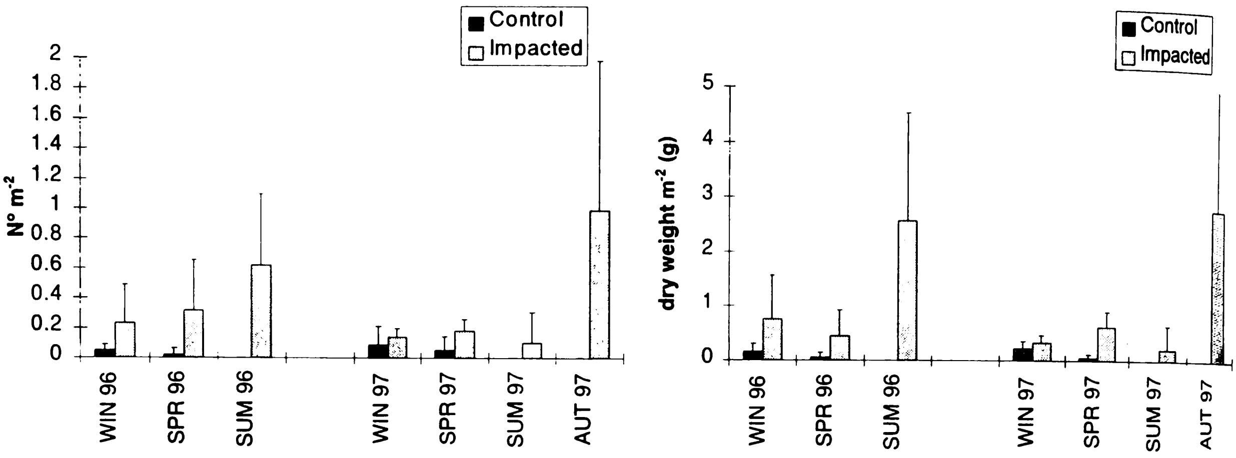


Fig. 3.160. Comparison of seasonal change in population density and biomass of *A rotundatus* at the control and impacted sites in the Glenan for 1996 and 1997.



Site-to-site comparison of the biomass and density for *A rotundatus* (Fig. 3.160) showed that this species was much commoner on the impacted than on the control ground. Maxima were reached in summer or autumn for UBGI while the species was not observed on UBGC during this period.

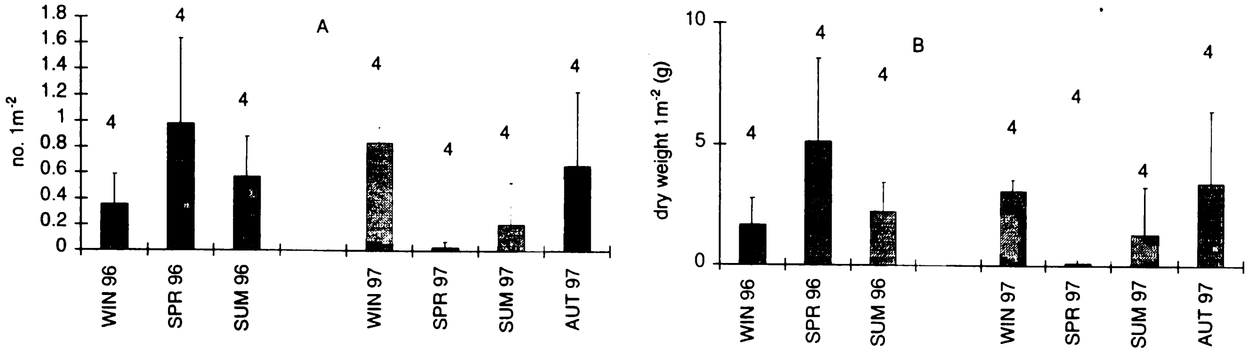
Atelecyclus undecimdentatus **(Herbst, 1783)**

This decapod crustacean was a rather common species on the UBGC maerl ground at Glenan. It occurred in 19 of the 28 AQUAREVE analysed. Mean densities ranged from 0.02 to 1 individual per m^2, with maximum of 3 per m^2 observed in spring 1996.

This crab lives in sublittoral gravel sediments into which it burrows. It is a predator, feeding mainly on polychaetes and bivalves.

It made an important contribution to the biomass of the AQUAREVE samples, its maximum contribution reaching 16% of the total biomass in a sample in spring 1996. Mean biomasses ranged between 0.1 to 5 g dry weight per m^2 on sampling period 1996-1997 (Fig. 3.161).

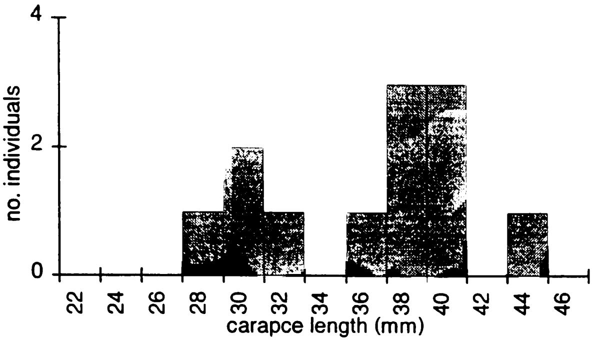
Fig. 3.161. A) Mean number and B) biomass (g dry weight) of *A undecimdentatus* per $1m^2$ at UBGC. Error bars = SD, N = number of AQUAREVE samples analysed.



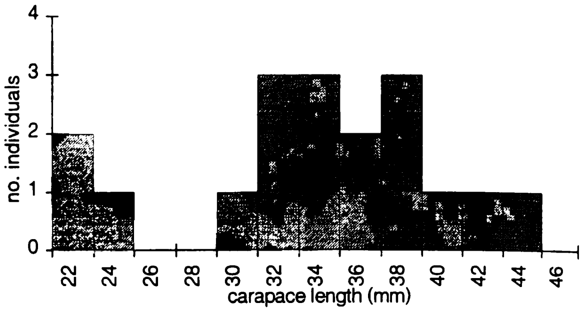
Size-frequency distribution analysis of *A. undecimdentatus* showed differences between the two sampling years 1996-1997 (Fig. 3.162). During the winter, spring and summer of 1996, the population showed a bimodal structure, the two modes being centred on size classes 30 mm and 40 mm carapace length. In 1997, the situation was different since only one mode, centred on size class 38 mm carapace length was observed. This could be due to the mortality of individuals in the larger size class in 1996 and to the growth of the smaller individuals that same year. No recruitment was definitely identifiable throughout the sampling period. Year-to-year comparison of the data for *A. undecimdentatus* shows an irregular pattern of density on the control site of the Glenan: densities varied considerably during 1997 with a minimum being reached during the spring months of that year. On the other hand, maximum density and biomass for the whole sampling period was reached in spring 1996. So 1996 was completely different from 1997 for this species. The low densities observed in spring 1997 remained unexplained.

Fig. 3.162. Size-frequency histograms for *Atelecyclus undecimdentatus* collected seasonally in AQUAREVE samples at UBGC from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.

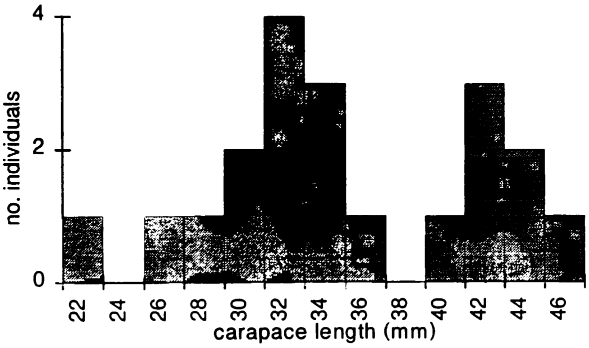
4 AQUAREVE Win 1996 (n=12)



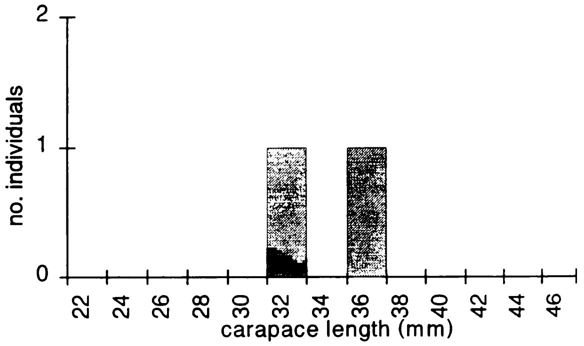
4 grabs, WIN 1997 (n=18)



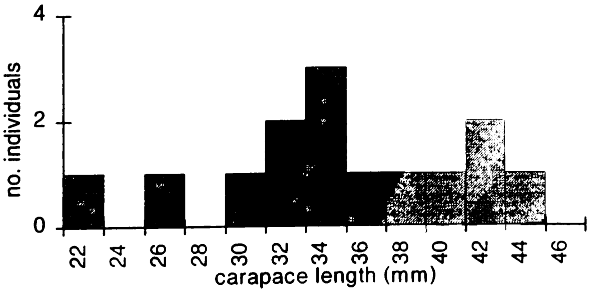
6 grabs, SPR 1996 (n=20)



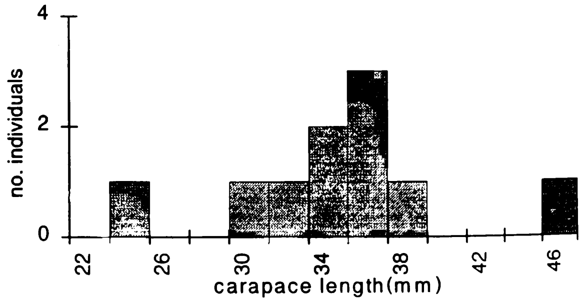
3 grabs, SPR 1997 (n=2)



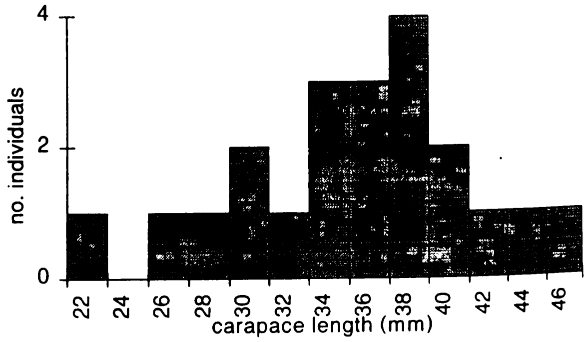
3 grabs, SUM 1996 (n=14)



3 grabs, SUM 1997 (n=0)



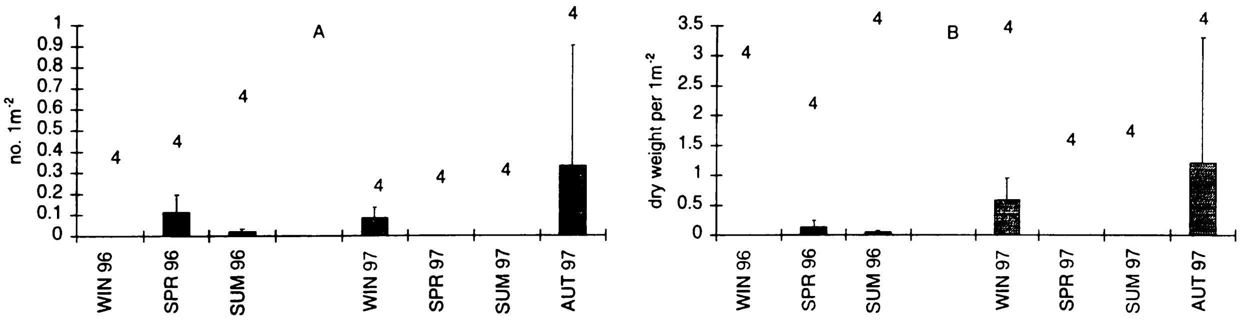
4 grabs, AUT 1997 (n=21)



This crab was rare on the UBGI ground. It only occurred in 9 of the 28 AQUAREVE . analysed. Mean densities ranged from 0 to 0.3 individual per m^2 on the impacted ground with a maximum of 0.8 per m^2 observed in autumn 1997.

Being rare on the impacted ground, it made only a minor contribution to the total biomass of the samples analysed. Its maximum contribution reached 2% of the total biomass of a single AQUAREVE sampled in autumn 1997 (Fig. 3.163). Mean biomasses ranged between 0 to 1.2 g dry weight per m^2 on sampling period 1996-1997.

Fig. 3.163.A) Mean number and B) biomass (g dry weight) of *A undecimdentatus* per 1m^2 at UBGI. Error bars = SD, N = number of AQUAREVE analysed.

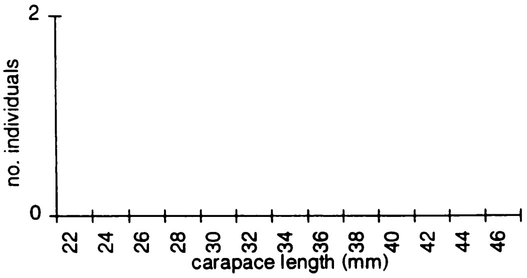


Seasonal size structure of the population of *A. undecimdentatus* on the impacted ground was hard to establish for most seasons because of the low number of individuals sampled (Fig. 3.164). However, in autumn 1997 a mode centred on size class 34 mm carapace length can be observed. This shows that smaller individuals were present on the impacted than on the control ground.

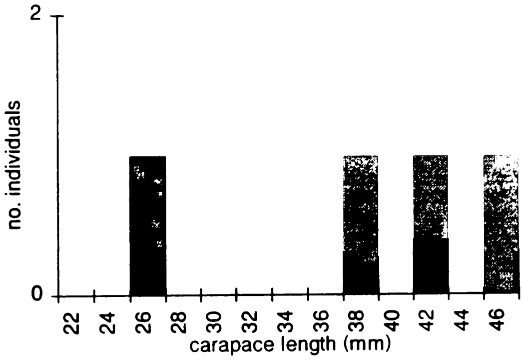
During the whole sampling period, *A. undecimdentaus* had a very low density and biomass on the impacted ground. The maximum was reached during autumn 1997 but this value remained low compared with the abundances observed on the control ground. No recruitment of juveniles was observed throughout the sampling period.

Fig. 3.164. Size-frequency histograms for *Atelecyclus undecimdentatus* collected seasonally in AQUAREVE samples at UBGI from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.

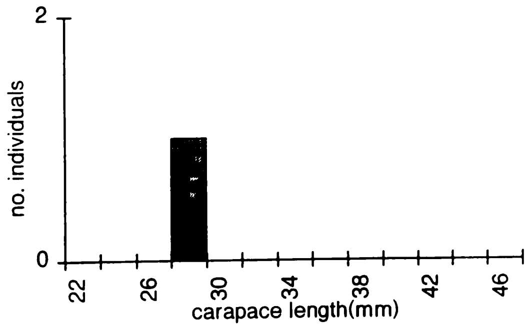
4 AQUAREVE, WIN 1996 (n=6)



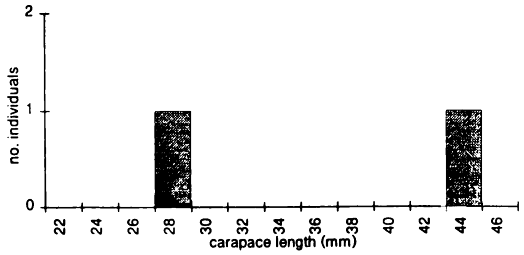
4 AQUAREVE, SPR 1996 (n=4)



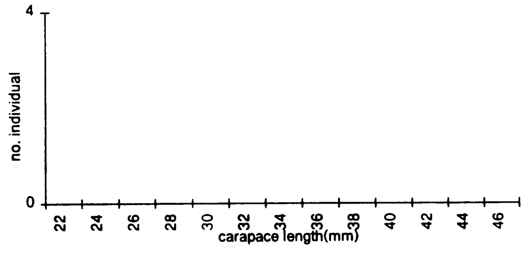
4 AQUAREVE, SUM 1996 (n=1)



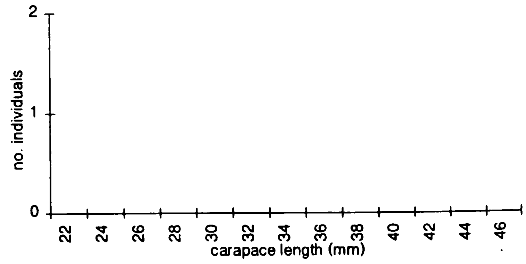
4 AQUAREVE, WIN 1997 (n=2)



4 AQUAREVE, SPR 1997 (n=0)



4 AQUAREVE, SUM 1997 (n=0)



4 AQUAREVE, AUT 1997 (n=12)

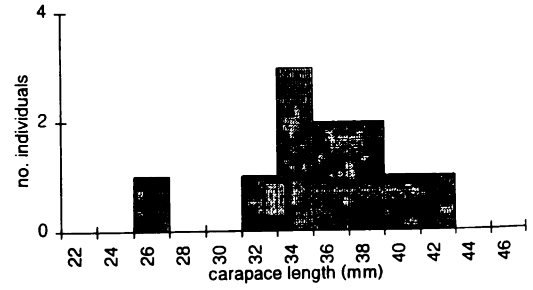
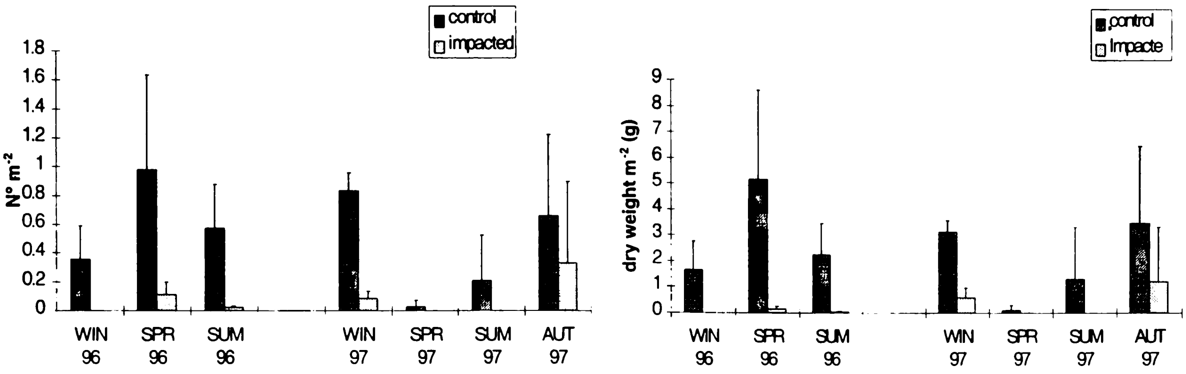


Fig. 3.165. Comparison of seasonal variation in population density and biomass for *A undecimdentatus* between control and impacted sites in the Glenan for 1996 and 1997.



A. undecimdentatus was more common on the control ground (UBGC) than on the impacted ground (UBGI) throughout the sampling period (Fig. 3.165). The variations through time of this species were also different between the two grounds, but are difficult to interpret because of low numbers on the impacted site.

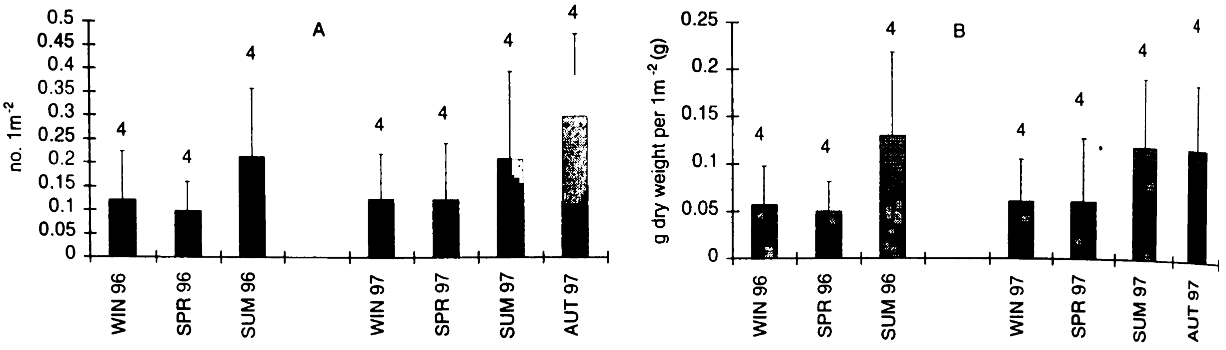
Liocarcinus depurator **(Linnaeus, 1758)**

This crab was not uncommon on the Glenan control ground (UBGC). It was found in 14 AQUAREVE samples out of the 28 analysed. Mean densities ranged from 0.1 to 0.3 individuals per m^2 with a maximum of 0.65 per m^2 observed in summer 1996.

Liocarcinus depurator lives on a wide range of sediments, from clean gravels to muddy sands. It is an active predator feeding on crustaceans and polychaetes mainly.

This species' contribution to the total biomass of the Aquareve samples on UBGC was low. It reached a maximum of 0.5% in autumn 1997, while mean biomasses varied from 0.05 to 0.12 g per m^2 (Fig. 3.166).

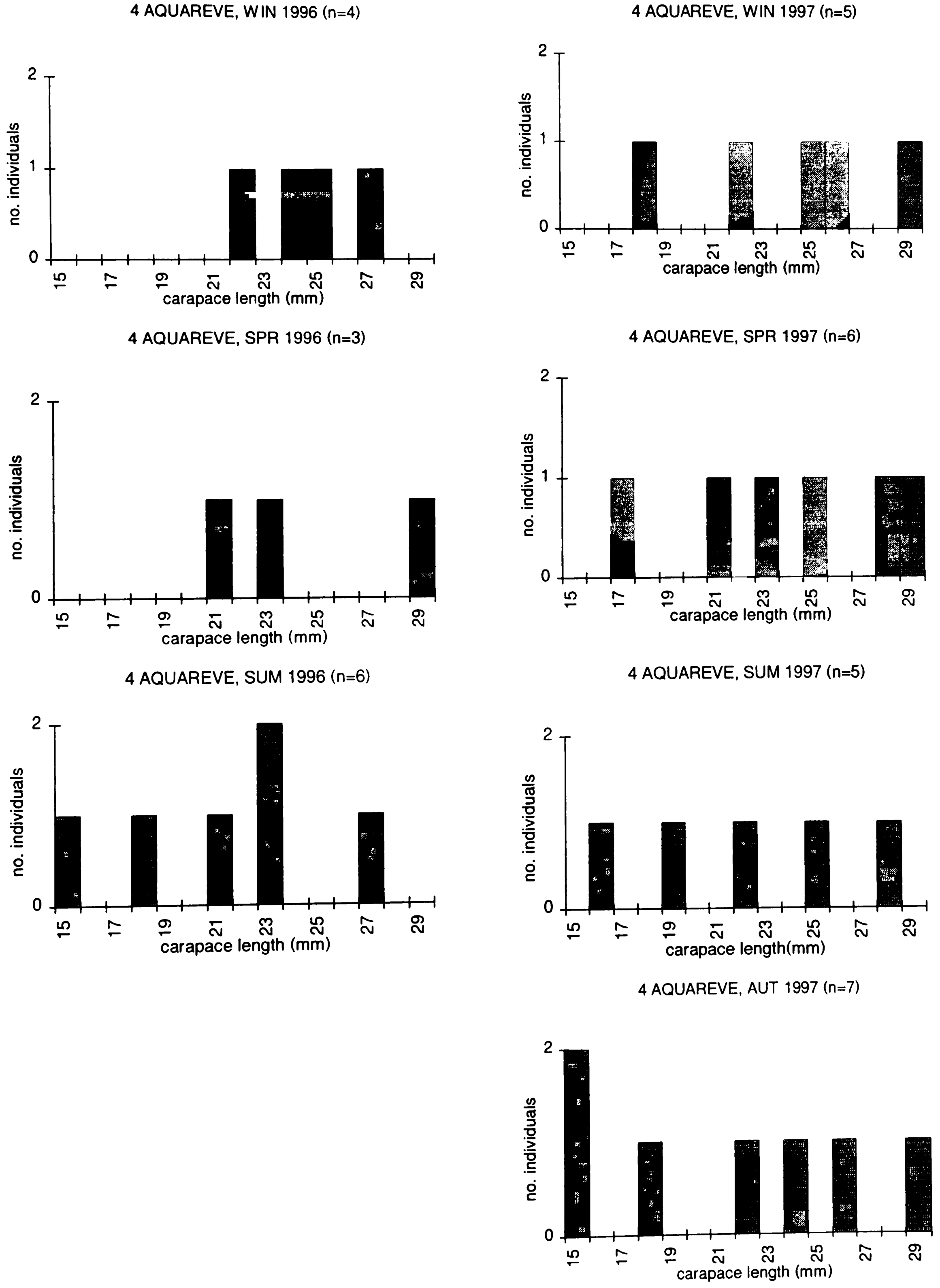
Fig. 3.166. A) Mean number and B) biomass (g dry weight) of *L. depurator* per $1m^2$ at UBGC. Error bars = SD, N = number of AQUAREVE samples analysed.



Analysis of the seasonal size-structure of the *L. depurator* population was not easy because of the small number of individuals sampled. (Fig. 3.167). Small-sized animals were only recorded during the summer and autumn months for both sampling years but this may not be reliable evidence of seasonality.

Comparison of the two sampling years showed similar patterns, with an increase in density and biomass from winter to autumn. Maximum density was reached in autumn 1997, while maximum biomass was almost equivalent during the summers of 1996 and 1997 and autumn 1997.

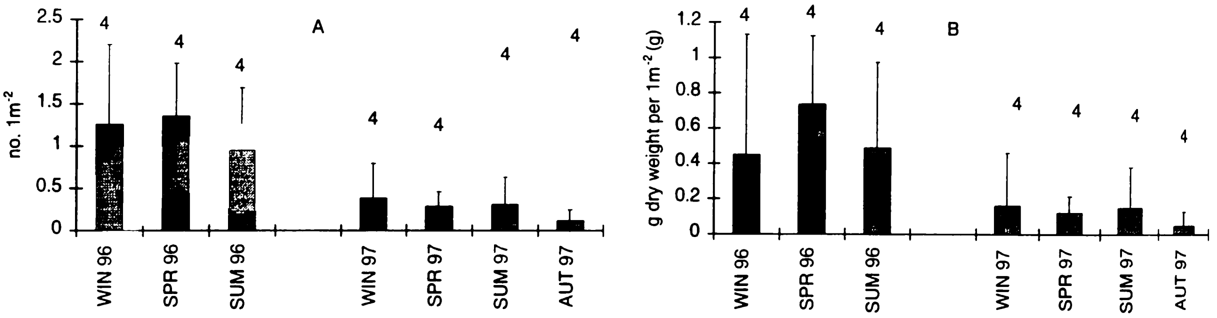
Fig. 3.167. Size-frequency histograms for *Liocarcinus depurator* collected seasonally in AQUAREVE at UBGC from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.



This crab was common on the impacted ground at Glenan (UBGI). It was found in 26 of the total of 28 AQUAREVE samples analysed. Mean densities ranged from 1 to 1.2 individuals per m², with a maximum of 2.5 per m² observed in winter 1996 (Fig. 3.168).

Its contribution to the total biomass of the AQUAREVE samples from UBGI was low. It reached a maximum of 8% in spring 1996 while mean biomasses varied from 0.05 to 0.7 g per m².

Fig. 3.168. A) Mean number and B) biomass (wet weight) of *L. depurator* per 1m² at UBGI. Error bars = SD, N = number of AQUAREVE samples analysed.



Seasonal variations in the population size-structure of *L. depurator* are shown in Fig. 3.169. Most of the individuals sampled measured between 21 and 29mm. No obvious size-mode appeared but this may be due to the low number of animals measured, except in spring 1996 where a mode centred on size class 24 mm was discernible. Few individuals smaller than 23mm were observed throughout the sampling period, suggesting low recruitment rate for this species on the impacted ground.

Density and biomass of *L. depurator* at UBGI were much higher during 1996 than during 1997. A significant reduction in the population density (of 50%) occurred between autumn 1996 and winter 1997. This could be due to high mortalities in the adult population and lack of juvenile recruitment. Maximum density was reached in spring 1996, while the minimum occurred during autumn 1997.

Fig. 3.169. Size-frequency histograms for *Liocarcinus depurator* collected seasonally in 0.1m^2 grabs at UBGI from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.

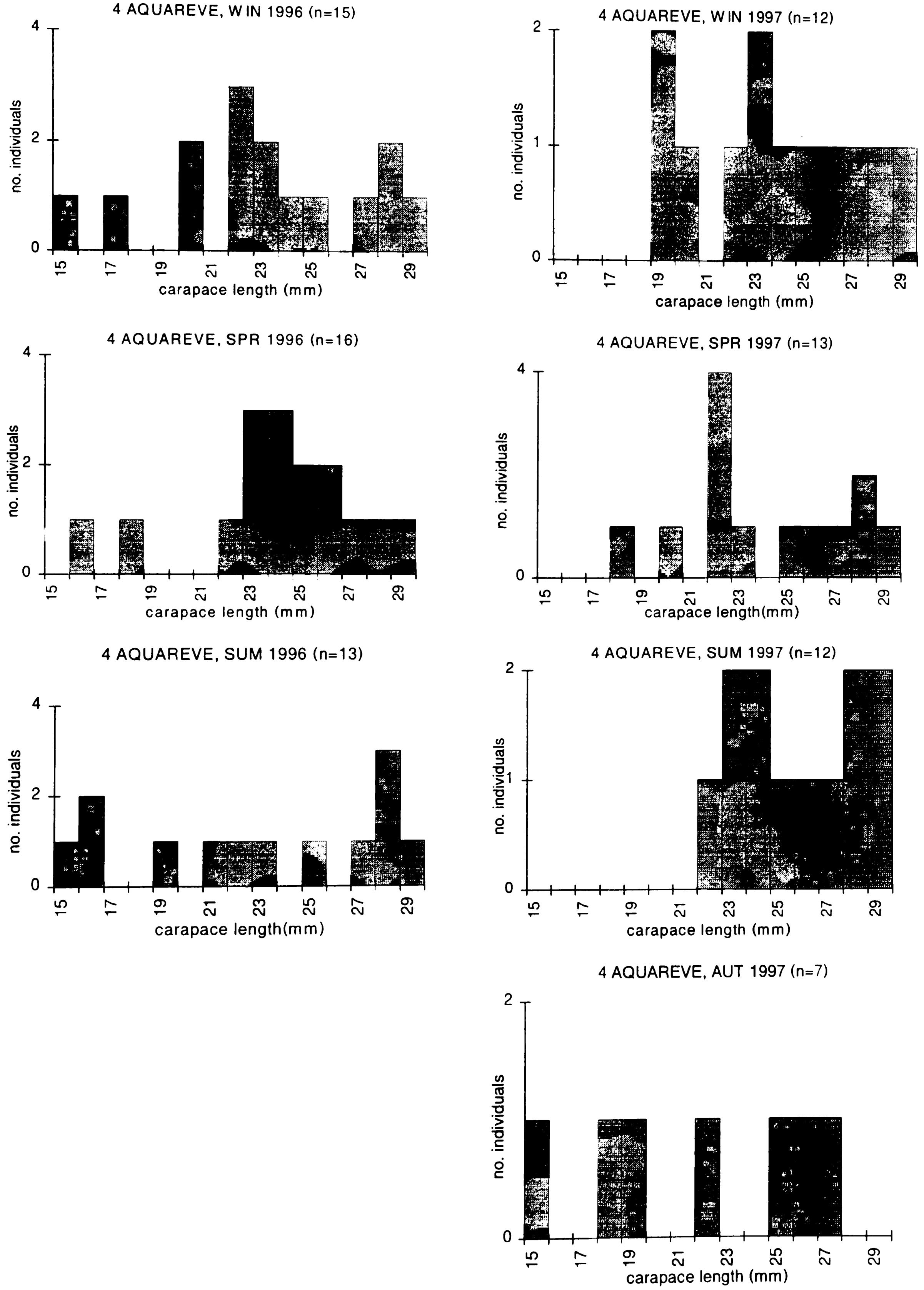
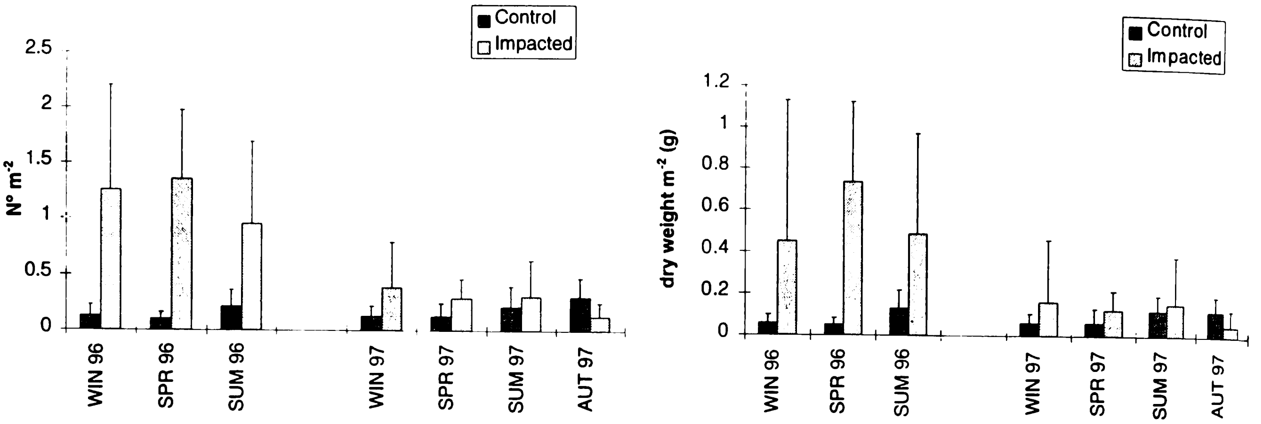


Fig. 3.170. Comparison of seasonal variation in population density and biomass of *L.depurator* between control and impacted sites in the Glenan for 1996 and 1997.



During 1996, the population of *L. depurator* showed much higher density and biomass (from 4 to 10 times higher). During 1997, the two populations were similar for these parameters (Fig. 3.170).

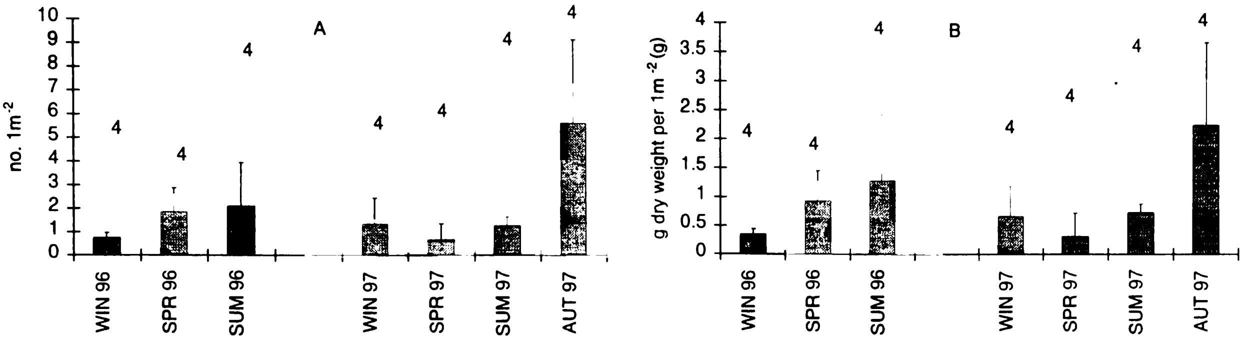
***Liocarcinus pusillus* (Leach, 1815)**

This decapod crustacean was very common on both the Glenan maerl beds (control and impacted). it occurred in all the 28 AQUAREVE samples analysed throughout the sampling period 1996-1997. Mean densities ranged from 0.6 to 5.6 individuals per m^2 on the grounds with a maximum of 11 per m^2 observed.

This crab is an active predator, feeding mainly on bivalves and polychaetes.

Being abundant, this species made a significant contribution to the biomass of the maerl beds for the control site of Glenan. A maximum of 9% of the total dry weight biomass was reached in autumn 1997. Mean biomasses ranged from 0.3 to 2.2 g per m^2 during the sampling period (Fig. 3.171).

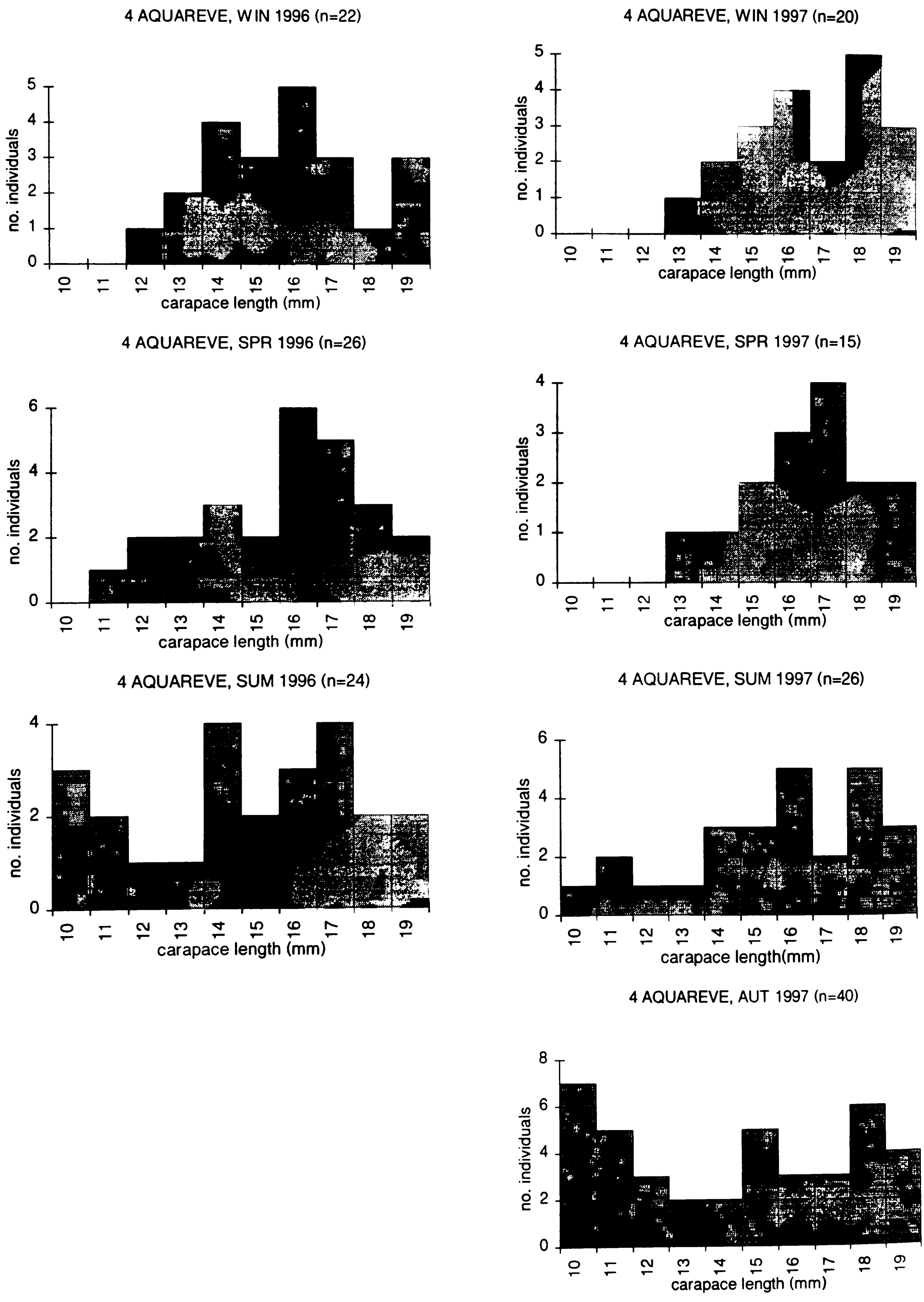
Fig. 3.171. A) Mean number and B) biomass (g dry weight) of *L. pusillus* per 1m^2 at UBGC. Error bars = SD, N = number of AQUAREVE samples analysed.



Seasonal variations in the size-structure of the population of *Liocarcinus pusillus* at the control site (UBGC) are shown in Fig. 3.172. Recruitmant of juveniles was observed during summer and autumn for both years (i.e. individuals measuring from 10 to 12 mm). For larger animals, no mode was detected, individuals of all size classes being present without any pattern appearing.

Year-to-year comparison showed that densities and biomasses of *L. pusillus* were higher during spring and summer 1996, than during spring and summer 1997. High densities were reached after high recruitment of animals to the megafauna in autumn 1997. Winter densities were similar.

Fig. 3.172. Size-frequency histograms for *Liocarcinus pusillus* collected seasonally in AQUAREVE samples at UBGC from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.



This crab was very common too on the impacted ground. On UBGI, it occurred in all the 28 AQUAREVE samples analysed throughout the sampling period 1996-1997. Mean densities ranged from 0.8 to 5 individuals per m^2, with maximum of 11 per m^2 observed (Fig. 3.173).

Being abundant, this species made a significant contribution to the biomass of the maerl beds for the impacted site of Glenan. A maximum of 9% of the total dry weight biomass was reached in autumn 1997. Mean biomasses ranged from 0.4 to 3.2 g dry weight per m^2 during the sampling period.

Fig. 3.173. A) Mean number and B) biomass (g dry weight) of *L. pusillus* per 1m^2 at UBGI. Error bars = SD, N = number of AQUAREVE analysed.

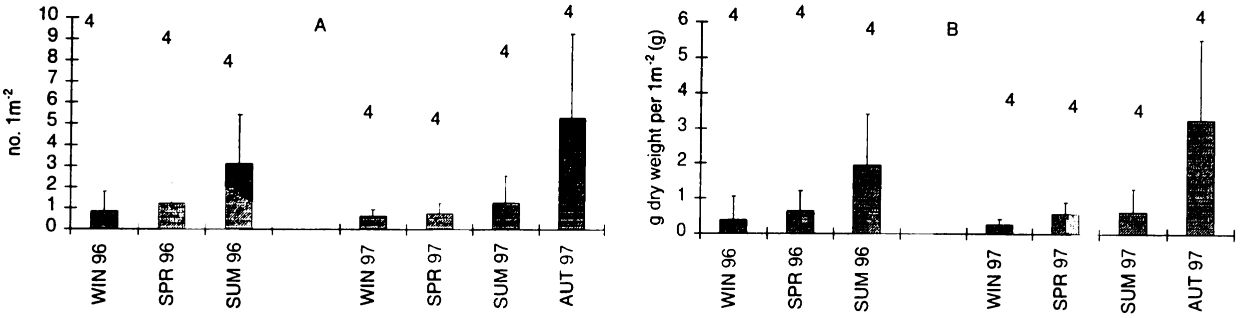
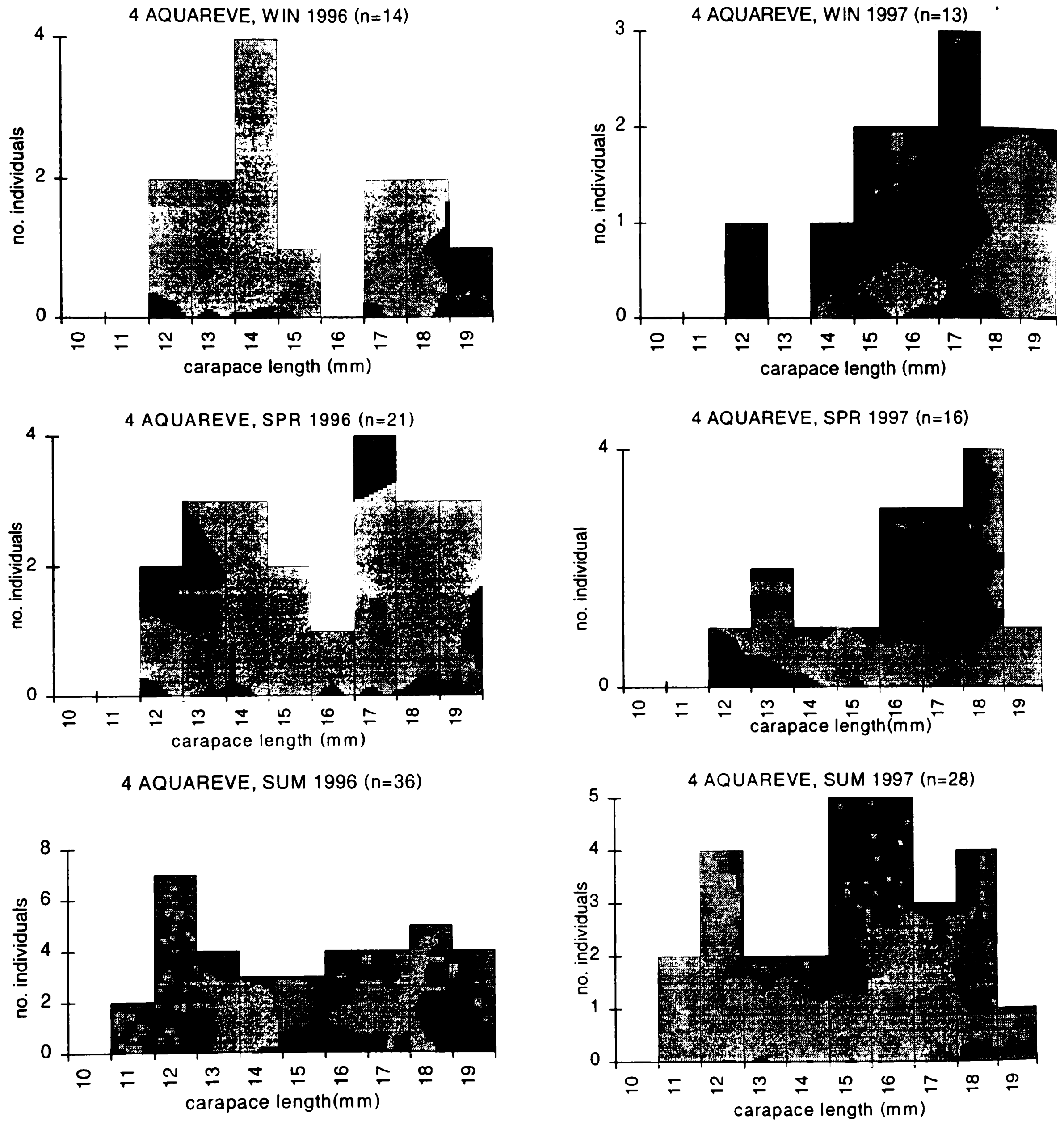


Fig. 3.174 shows seasonal variation in size structure of *L.pusillus* at the impacted ground (UBG)I. No real recruitment was observed on this site, though it was observed on the control ground. No clear size-mode appeared as animals were spread through all the size classes.

Year to year comparison shows that *L. pusillus* reached high densities during the summer and autumn on the impacted site, while lowest values occurred during winter. Since no juvenile recruitment was observed, differences between densities may be due to migration of adults onto the impacted bed during the summer months.

Fig. 3.174. Size-frequency histograms for *Liocarcinus pusillus* collected seasonally in AQUAREVE at UBGI from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.



4 AQUAREVE, WIN 1996 (n=14)

4 AQUAREVE, WIN 1997 (n=13)

4 AQUAREVE, SPR 1996 (n=21)

4 AQUAREVE, SPR 1997 (n=16)

4 AQUAREVE, SUM 1996 (n=36)

4 AQUAREVE, SUM 1997 (n=28)

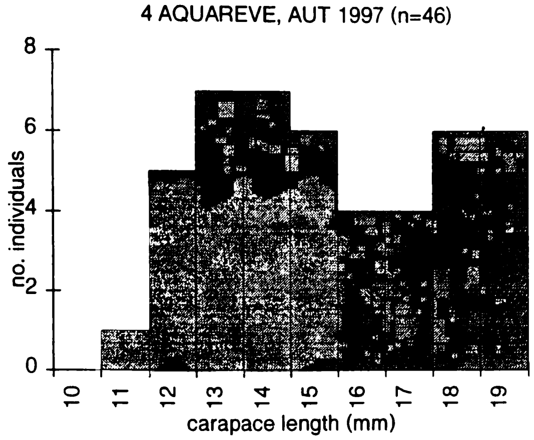
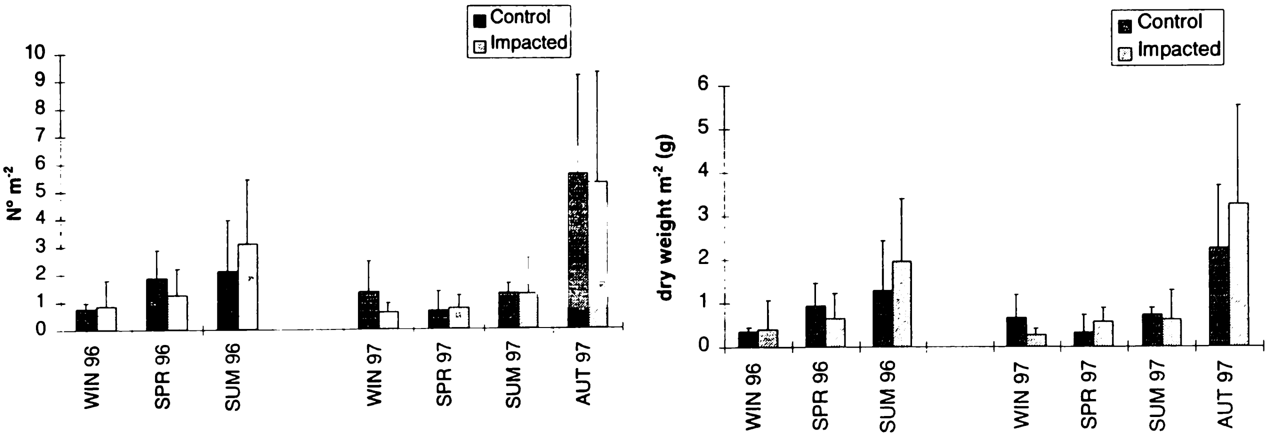


Fig. 3.175. Comparison of population density and biomass of *L.pusillus* between control and impacted sites in the Glenan for 1996 and 1997.



Site-to-site comparison (Fig. 3.175) shows that densities and biomasses of *L.pusillus*, as well as seasonal variations of these parameters, were very similar on both grounds in the Glenan during the sampling period 1996-1997.

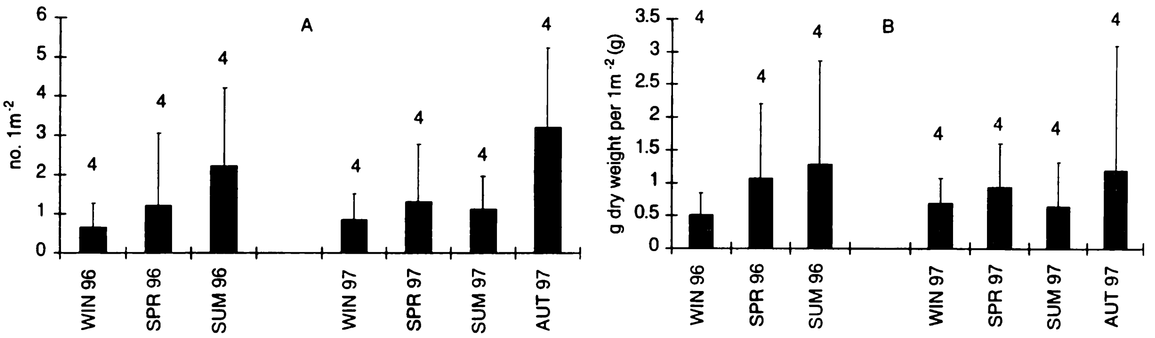
Xantho pilipes A. Milne-Edwards, 1867

This decapod crustacean was very common on the maerl beds of the Glenan. It occurred in all of the 28 AQUAREVE samples analysed from the control ground (UBGC) during the sampling period 1996-1997. Mean densities ranged from 0.65 to 3.22 individuals per m^2 with maximum of 12 per m^2 observed (Fig. 3.176A).

Xantho pilipes is an omnivorous crab feeding either on molluscs and polychaetes or on macroalgae.

Being abundant on the UBGC ground, this species made a significant contribution to the biomass of the maerl beds there. A maximum of 16% of the total dry weight biomass was reached in autumn 1997. Mean biomasses ranged between 05 to 1.20g dry weight per m^2 during the sampling period (Fig. 3.176B)

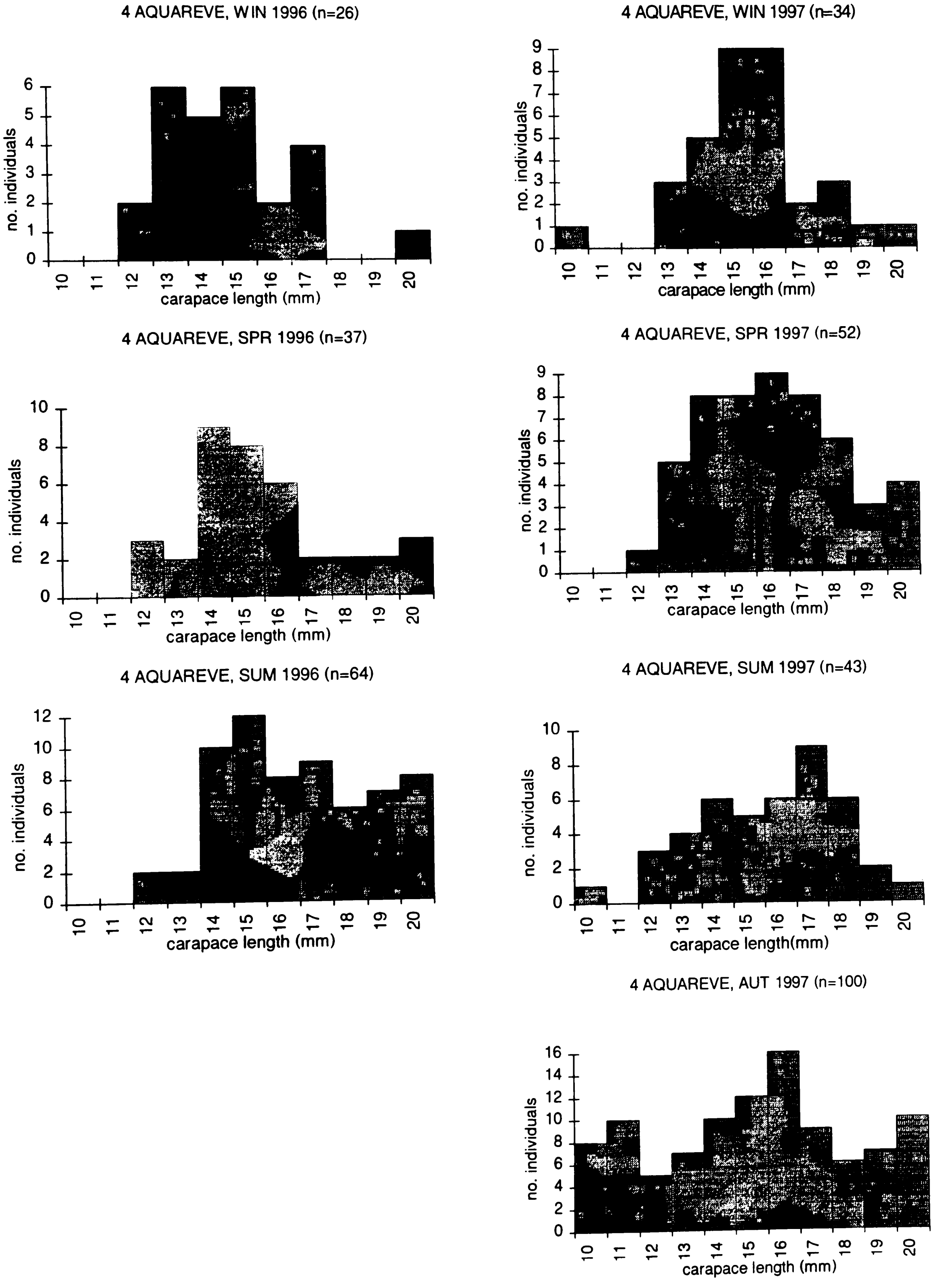
Fig3.176.A) Mean number and B) biomass (g dry weight) of *X. pilipes* per 1m^2 at UBGC. Error bars = SD, N = number of AQUAREVE analysed.



Size-frequency distribution analysis (Fig. 3.177) of the *X. pilipes* population has shown evidence of recruitment of juveniles in autumn 1997. During the other sampled seasons, small individuals were rare and were observed on only two occasions (winter and autumn 1997). No obvious size-mode was observed for this population. No evidence of growth or of poor survival rates of any size-classes were noted for this species.

Year-to-year comparison showed that in 1996, the highest density was reached during summer months, while in 1997 the abundance in summer was low. The maximum abundance for 1997 was reached during the autumn months and may be explained by juvenile recruitment. Winter months were minimal both for density and biomass.

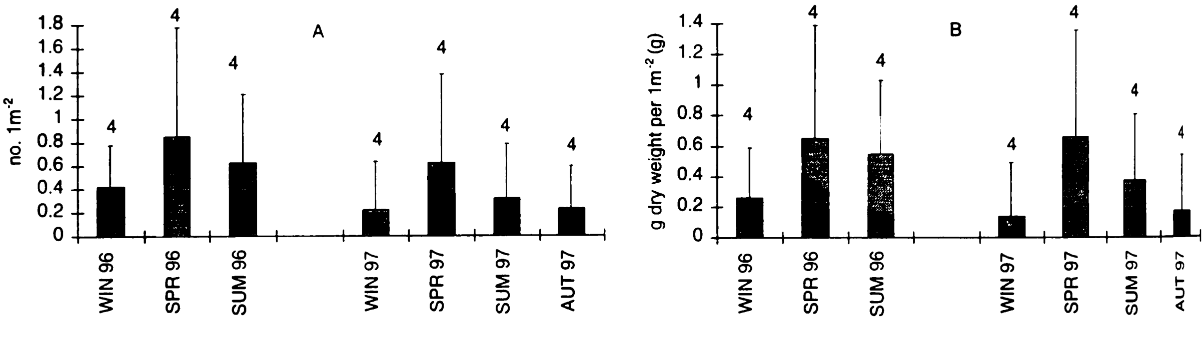
Fig. 3.177. Size-frequency histograms for *Xantho pilipes* collected seasonally in AQUAREVE samples at UBGC from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.



This crab was common on the impacted ground at Glenan (UBGI). It occurred in all the 28 samples analysed for the sampling period 1996-1997. Mean densities ranged from 0.2 to 0.8 individuals per m^2 with a maximum of 3 per m^2 observed in an autumn 1996 sample (Fig. 3.178A).

This species was a significant contributor to the biomass of the impacted ground at Glenan. A maximum of 5 % of the total dry weight biomass was reached in autumn 1996. Mean biomasses ranged from 0.13 to 0.65 g dry weight per m^2 during the sampling period (Fig. 3.178B).

Fig.3.178.A) Mean number and B) biomass (g dry weight) of *X. pilipes* per 1m^2 at UBGI. Error bars = SD, N = number of AQUAREVE analysed.



Recruitment of juveniles seems to have occurred in autumn 1997 on the impacted ground (Fig. 3.179), but it remained rather low. In spring 1996, a modal size-structure appeared centred on size class 15 mm. However, most of the individuals sampled measured between 12 and 18 mm, with no modal structure appearing through the sampling period.. This shows that large *X. pilipes* were never present on the impacted while they were present on the control. This may be due to higher mortalities of adults on UBGI or to emigration of larger individuals to surrounding areas.

The two sampling years showed similar patterns with maximum density and biomases being reached during spring months and minima reached in winter. Population densities were higher in 1996 than in 1997.

Fig. 3.179. Size-frequency histograms for *Xantho pilipes* collected seasonally in AQUAREVE samples at UBGI from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.

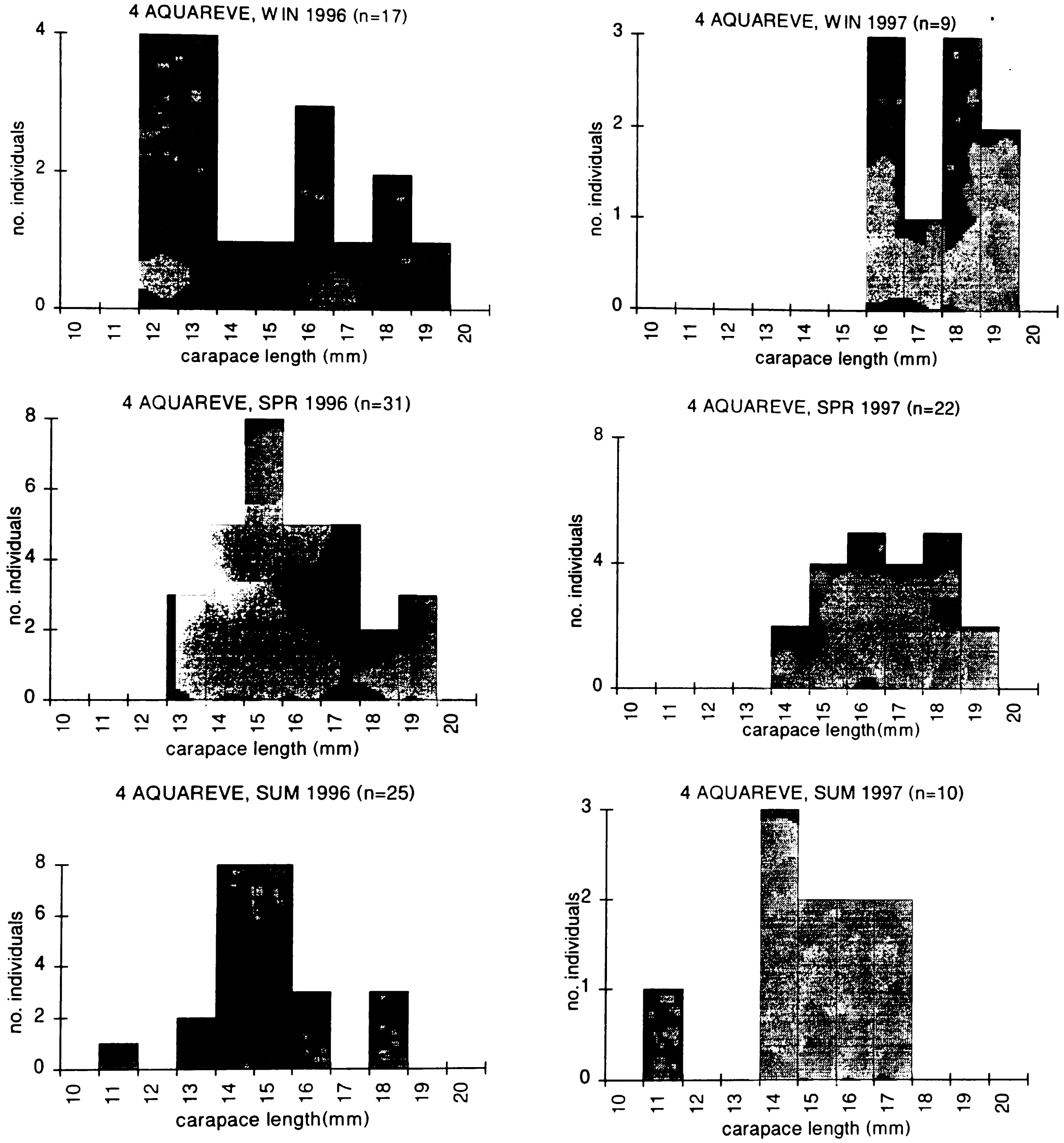
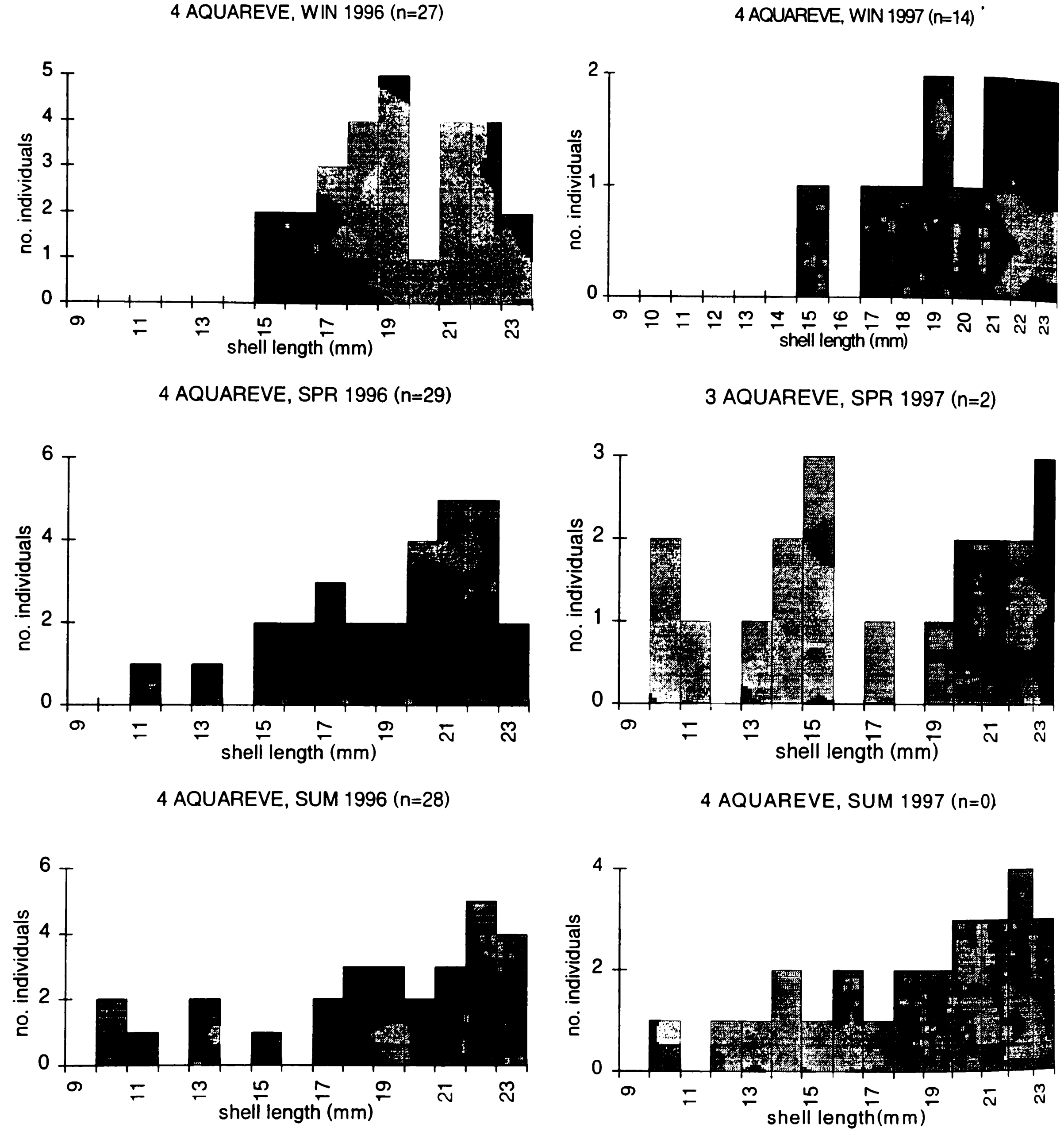


Fig. 3.182. Size-frequency histograms for *Gibbula magus* collected seasonally by AQUAREVE at UBGC from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.



4 AQUAREVE, WIN 1996 (n=27)

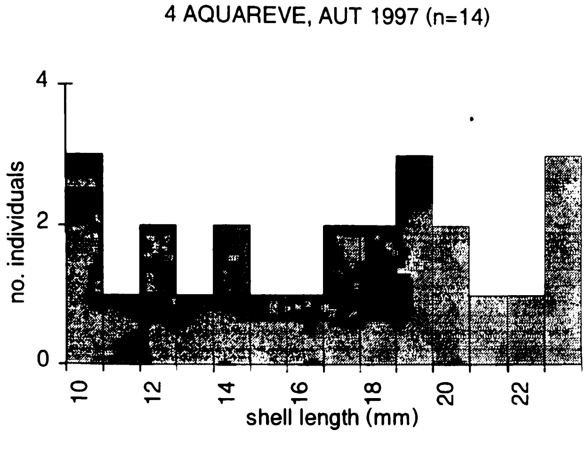
4 AQUAREVE, WIN 1997 (n=14)

4 AQUAREVE, SPR 1996 (n=29)

3 AQUAREVE, SPR 1997 (n=2)

4 AQUAREVE, SUM 1996 (n=28)

4 AQUAREVE, SUM 1997 (n=0)

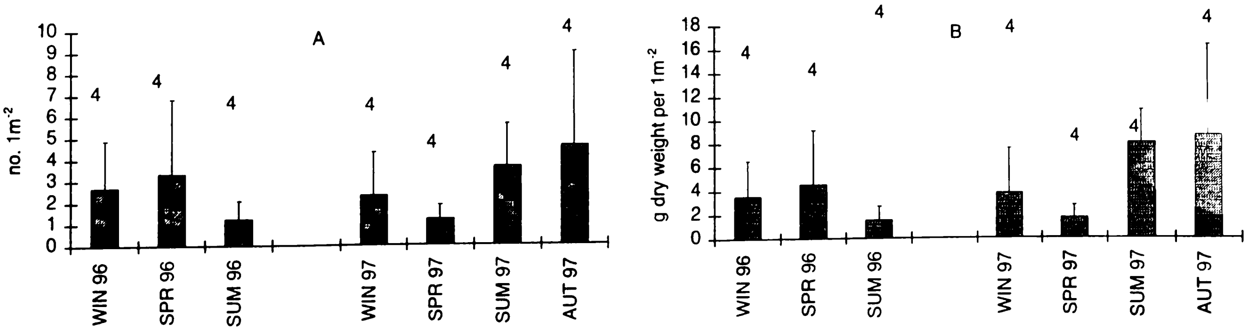


Both sampling years appeared to be very similar in terms of abundance and biomass. Maxima were reached during summer months for both species while minima were observed either during the winter (1997) or spring months (1996).

This gastropod was common on the impacted Glenan maerl bed. It was found in all the 28 AQUAREVE samples analysed for 1996 and 1997. The maximum density observed for this species in a single sample was 18 individuals per m^2. Mean densities varied in a range of 1.2 to 4.7 individuals per m^2 (Fig. 3.183).

Being large and abundant, this species, was significant contributor to the biomass of the maerl beds for the control site. A maximum of 44 % of the total dry weight biomass was reached in autumn 1996. Mean biomasses were ranging between 1.5 to 8.7 g dry weight per m^2 during the sampling period

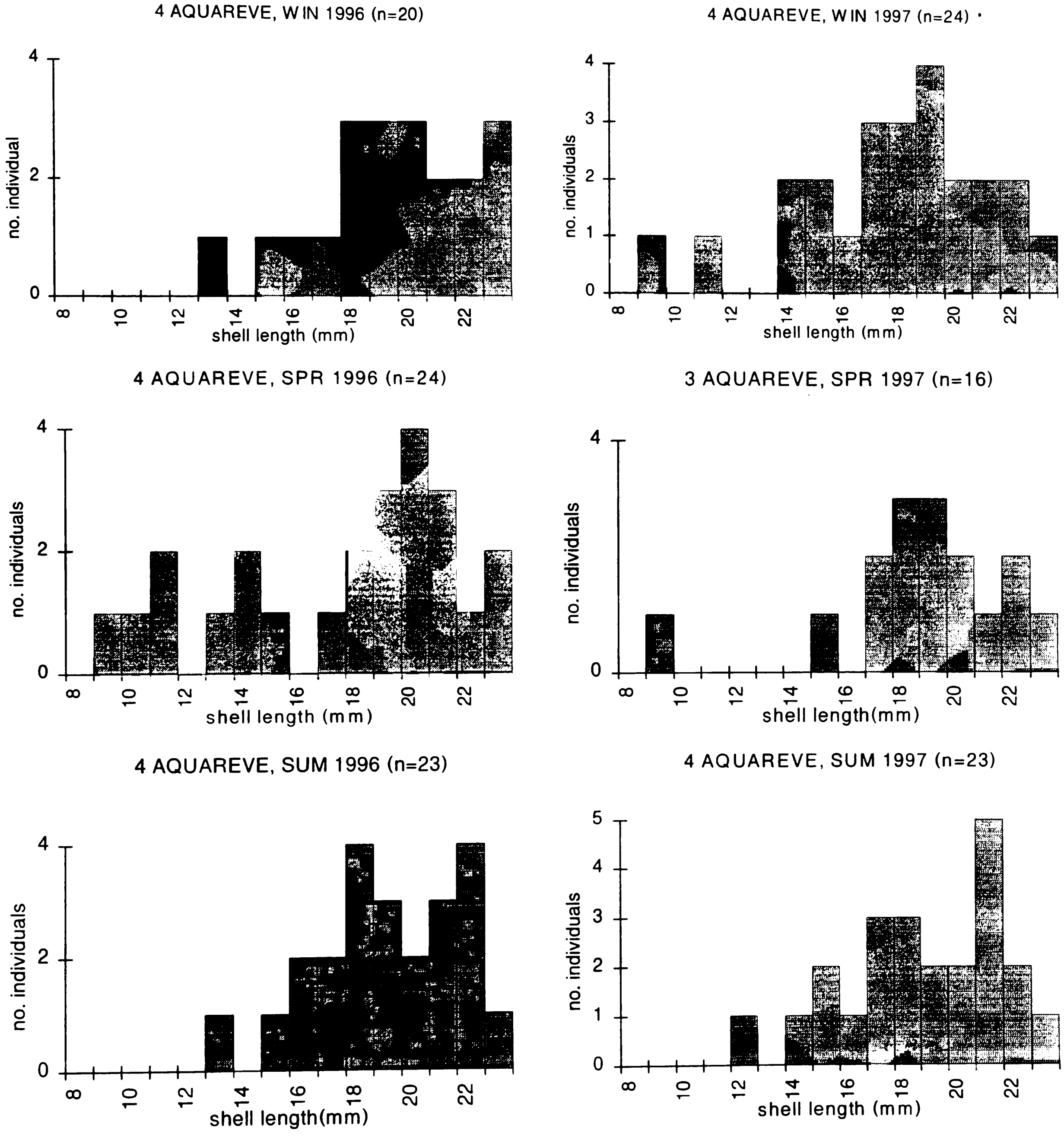
Fig. 3.183.A) Mean number and B) biomass (g dry weight) of *G. magus* per 1m^2 at UBGI. Error bars = SD, N = number of AQUAREVE samples analysed.



Analysis of the seasonal population structure of *G. magus* from the impacted ground is shown in Fig. 3.184. A mode of larger individuals, centred on size class 19 mm shell length, was observed for most seasons. This mode was usually dominant in the population (representing < 90% of animals). Juvenile recruitment occurred during several seasons (spring 1996, winter and autumn 1997), but remained very low.

The two sampling years were completely different in terms of abundance and biomass: maximum denity was reached during the spring months in 1996 while it occurred in autumn for 1997. However, the years showed similar densities and biomass, even if 1997 seemed to be a year with slightly higher biomass than 1996.

Fig. 3.184. Size-frequency histograms for *Gibbula magus* collected seasonally in AQUAREVE samples at UBGI from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.



4 AQUAREVE, WIN 1996 (n=20)

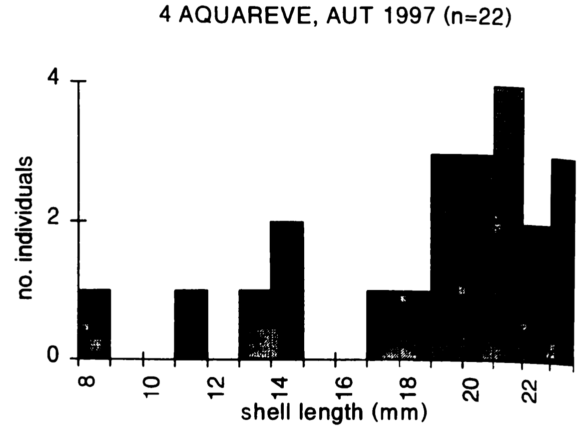
4 AQUAREVE, WIN 1997 (n=24)

4 AQUAREVE, SPR 1996 (n=24)

3 AQUAREVE, SPR 1997 (n=16)

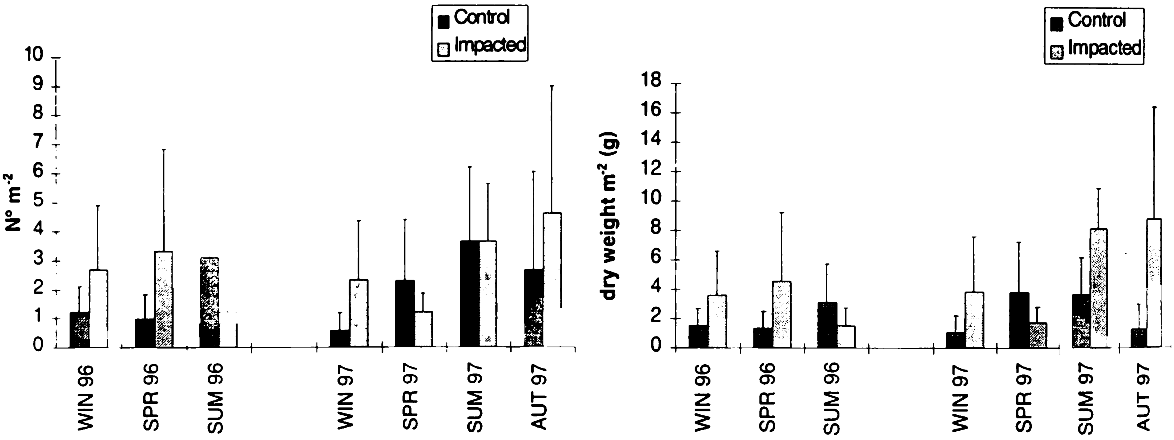
4 AQUAREVE, SUM 1996 (n=23)

4 AQUAREVE, SUM 1997 (n=23)



4 AQUAREVE, AUT 1997 (n=22)

Fig. 3.185. Comparison of seasonal variation in population density and biomass for *G.magus* between control and impacted sites in the Glenan for 1996 and 1997.



Site-to-site comparison (Fig. 3.185) shows completely different patterns for this species for both sampling years. In 1996, maximum density was reached during the spring months at UBGI, while the minimum density was reached the same season for UBGC. In 1997, the dynamics of density and biomass were more similar, high values being reached in summer or autumn. It should be noted that if recruitment of juveniles was high on the control ground in autumn 1997, this was not so for the impacted ground.

Turritella communis **Risso, 1826**

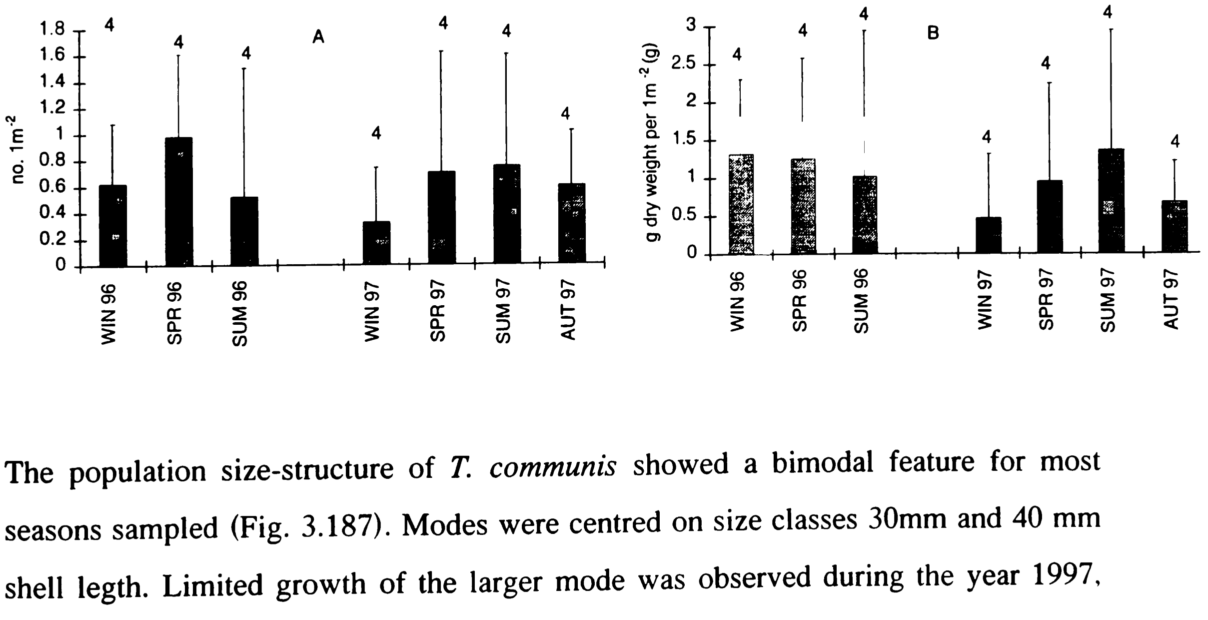
This gastropod was present on UBGC all through the sampling period 1996-1997. It occurred in 24 of the 28 AQUAREVE samples analysed with mean densities of 0.3 to

1 individuals per m^2 with a maximum of 2 per m^2 observed in spring 1996 (Fig. 3.186).

Turritella communis is a gastropod living partly buried in muddy bottoms. Unusually for a gastropod, it is a suspension feeder, removing particles from the water by way of a ciliary current maintained through the mantle cavity.

This species was one of the dominant contributors to biomass in the AQUAREVE samples on the control ground of the Glenan. Its maximum contribution to one sample reached 38% and mean dry weight biomasses ranged from 0.46 to 1.36 g per m^2 during the sampling period (Fig. 3.186).

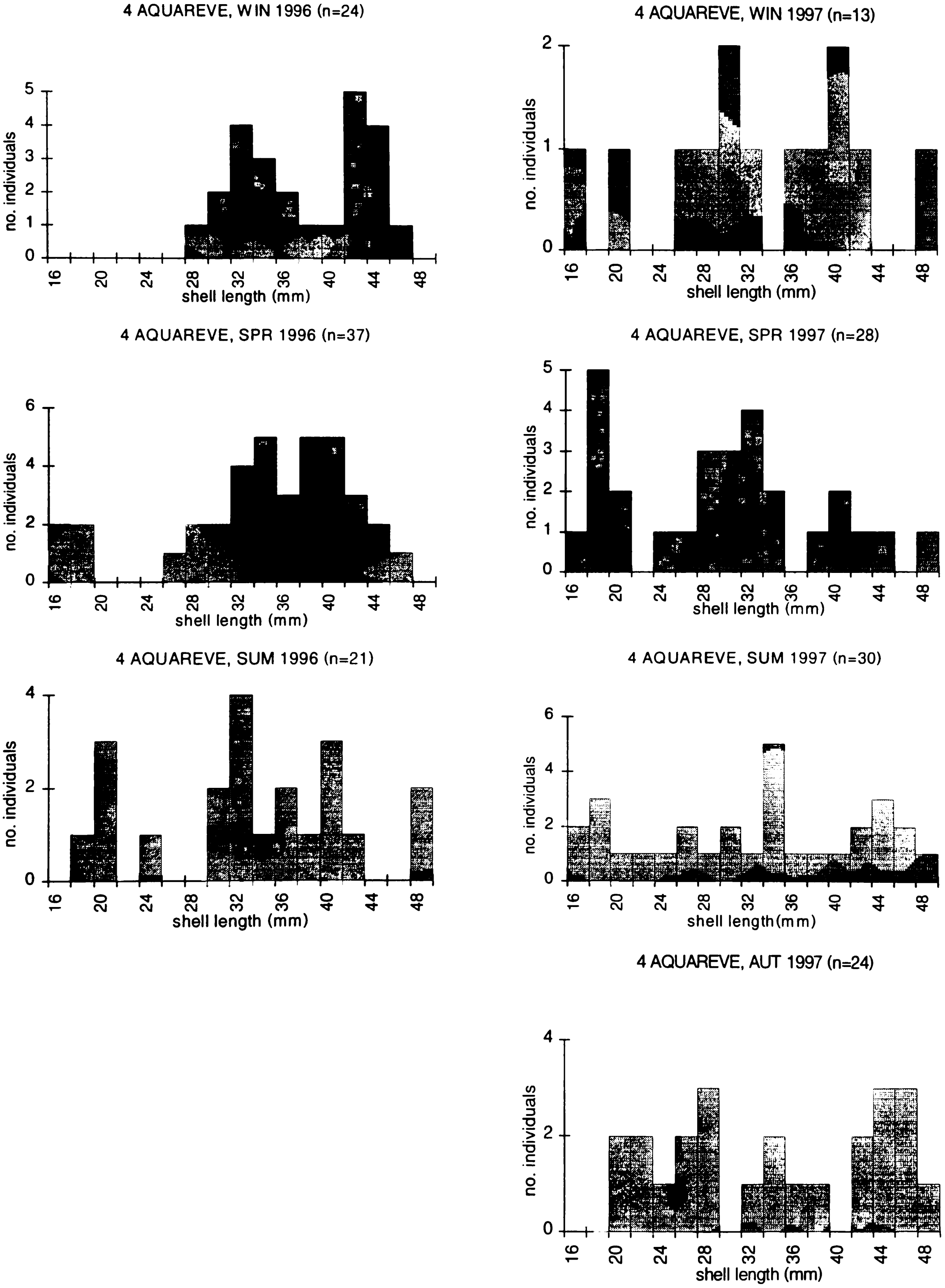
Fig.3.186. A) Mean number and B) biomass (g dry weight) of *T. communis* per 1m^2 at UBGC. Error bars=SD, N=number of AQUAREVE analysed.



The population size-structure of *T. communis* showed a bimodal feature for most seasons sampled (Fig. 3.187). Modes were centred on size classes 30mm and 40 mm shell legth. Limited growth of the larger mode was observed during the year 1997, since this mode was centred on size class 44-46 mm in the autumn of this year. Recruitment of juveniles to the megafauna was observed for this species during spring and summer.

The two years were similar in term of density and biomass, maxima being reached in spring and summer, after juvenile recruitment.

Fig. 3.187. Size-frequency histograms for *Turritella communis* collected seasonally in AQUAREVE at UBGC from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.



4 AQUAREVE, WIN 1996 (n=24)

4 AQUAREVE, WIN 1997 (n=13)

4 AQUAREVE, SPR 1996 (n=37)

4 AQUAREVE, SPR 1997 (n=28)

4 AQUAREVE, SUM 1996 (n=21)

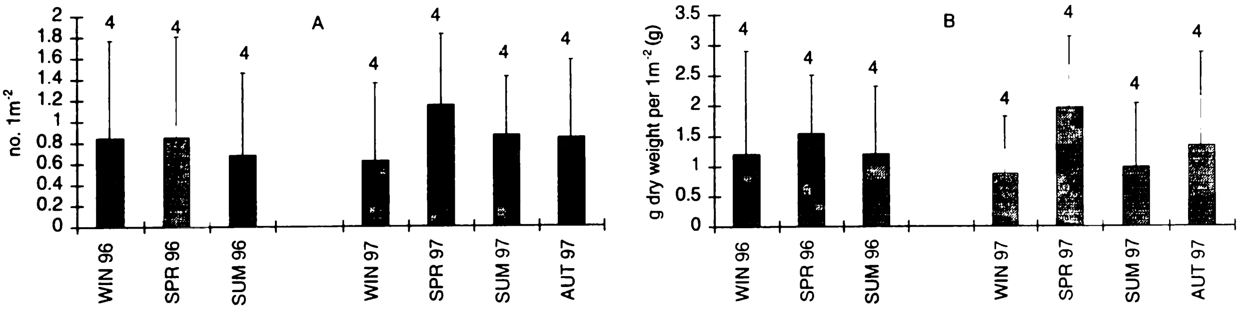
4 AQUAREVE, SUM 1997 (n=30)

4 AQUAREVE, AUT 1997 (n=24)

This gastropod was common on the impacted ground at Glenan (UBGI) all through the sampling period 1996-1997. It occurred in 21 of the 28 AQUAREVE samples analysed, with mean densities of 0.6 to 1.1 individuals per m^2 and a maximum of 3.5 per m^2 observed in spring 1996 (Fig. 3.188).

This species was one of the dominant contributors to biomass in AQUAREVE samples from UBGI. Its maximum contribution to one sample reached 61% and mean dry weight biomasses ranged from 0.8 to 2 g per m^2 during the sampling period.

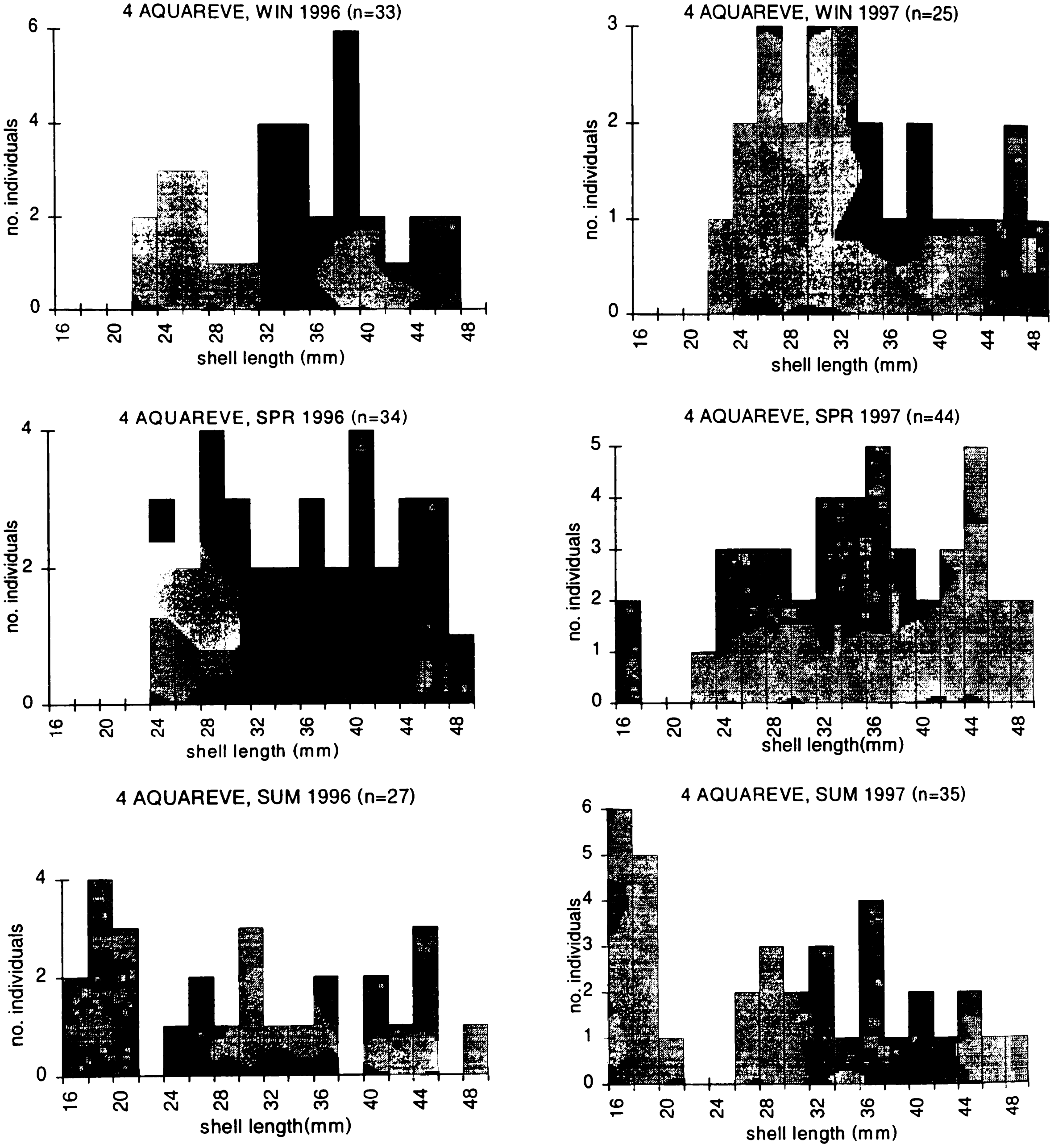
Fig. 3.188.A) Mean number and B) biomass (dry weight) of *T. communis* per 1m^2 at UBGI. Error bars = SD, N = number of AQUAREVE samples analysed.



Interpretation of the seasonal variation in size-structure of *T. communis* on the impacted ground (Fig. 3. 189) was difficult since no size-mode appeared throughout the sampling period. However, juvenile recruitment to the megafauna was obvious during the summer months of the two sampling years. Juveniles made up to the third of the population then. During autumn 1997, these juveniles were still making up one third of the population, suggesting low mortality rates for this species on the impacted ground.

Density and biomass were very consistent on the impacted ground throughout the sampling period. Even when recruitment was observed, abundance did not increase, and an explanation for this fact remains elusive (presumably mortality was in balance with recruitment).

Fig. 3.189. Size-frequency histograms for *Turritella communis* collected seasonally in AQUAREVE at UBGI from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.



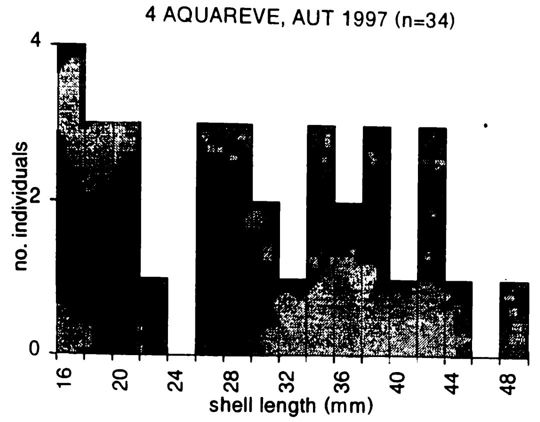
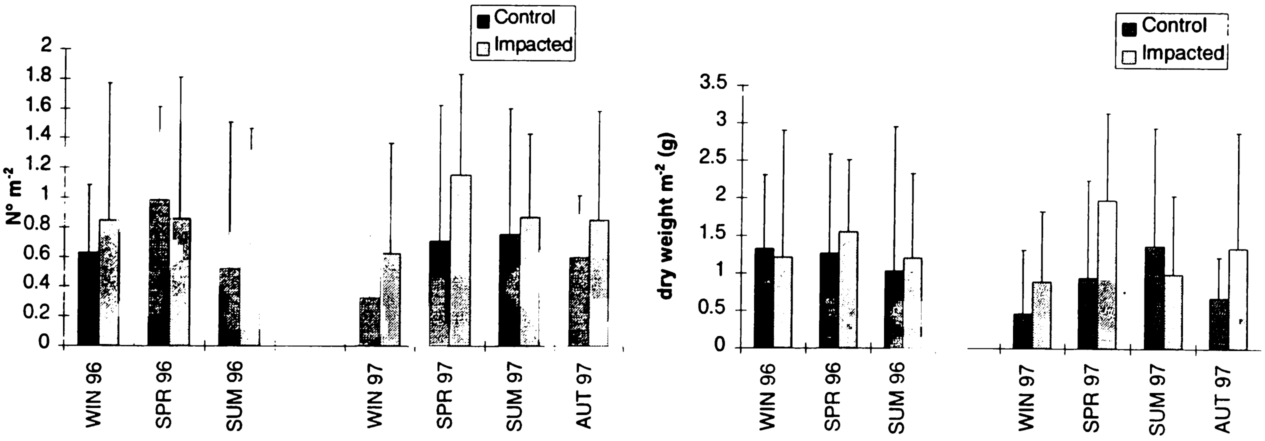


Fig. 3.190. Comparison of seasonal variation in abundance and biomass of *T.communis* between control and impacted sites in the Glenan for 1996 and 1997.



Population densities and biomasses of *T. communis* were similar on both sampling sites in the Glenan (Fig. 3.190). Biomass was higher on the impacted ground during 1997, however, suggesting that 'impacted site' animals were bigger than those on the control ground.

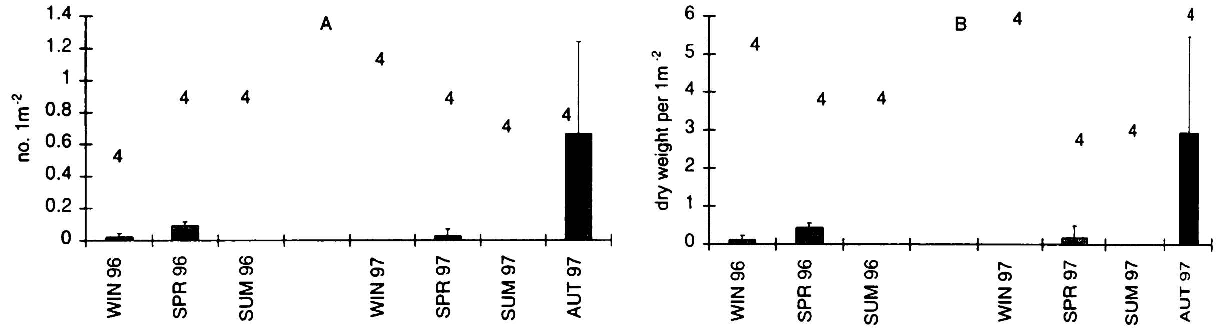
Buccinum undatum **Linnaeus, 1758**

This buccinid gastropod was uncommon on the control ground of the Glenan maerl beds. It was sampled in only 9 of the total of 28 AQUAREVE analysed. Densities varied in the range 0 to 0.7 individuals per m^2, with maximum of 4 per m^2 observed.

Buccinum undatum is a large gastropod living on sandy and muddy sediments. It is a predator feeding on polychaetes or bivalves, but it is a scavenger eating carrion .

This species is a large shelled gastropod. Even being quite rare on the control UBGC, it still made a consistent contribution to the total biomass of the samples analysed. Maximum contribution reached 17 % of the total dry weight of one sample in autumn 1997. Mean biomasses ranged between 0 to 3g per m^2 throughout the sampling period (Fig. 3.191).

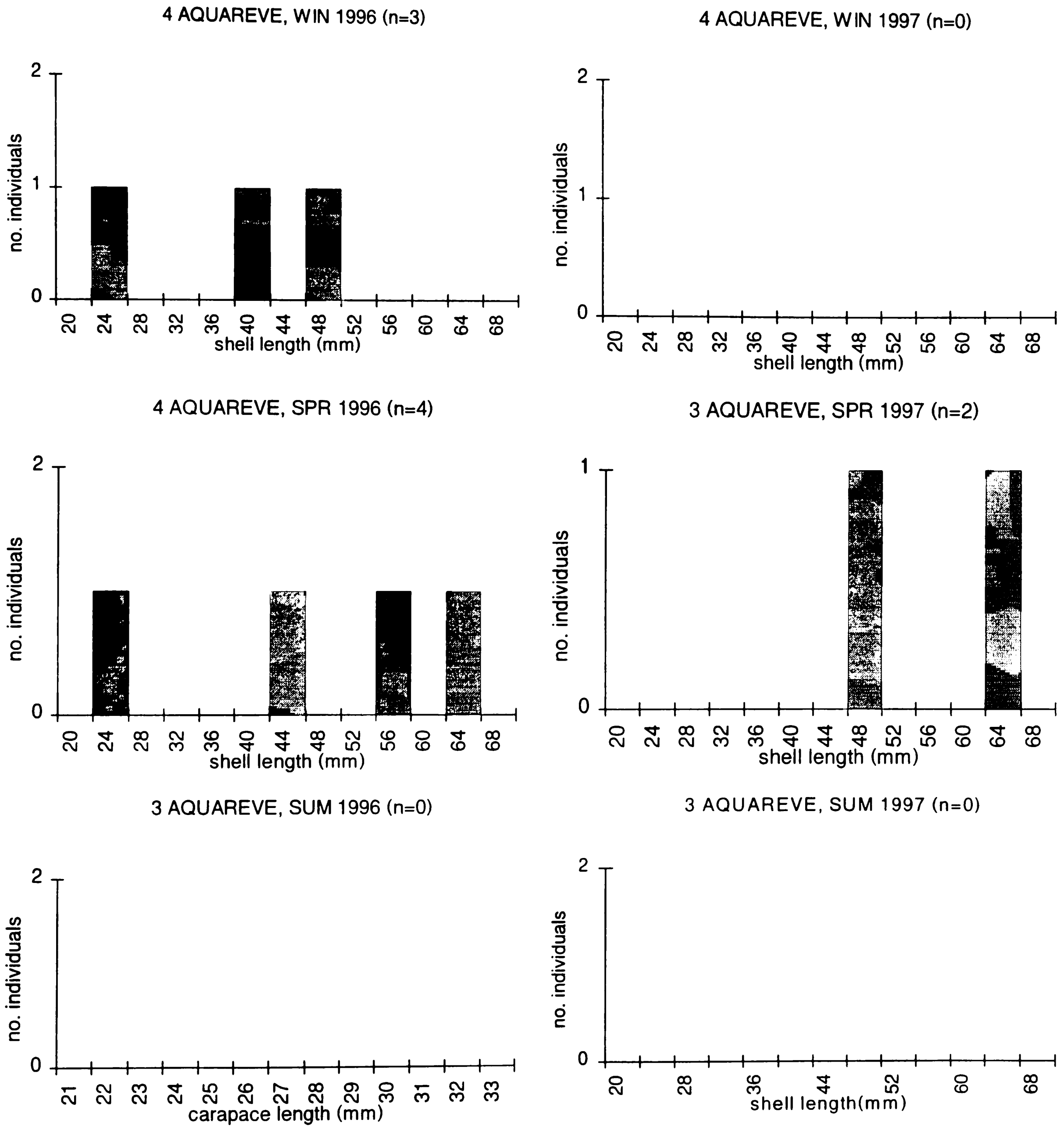
Fig. 3.191.A) Mean number and B) biomass (g dry weight) of *B. undatum* per 1m^2 at UBGC. Error bars = SD, N = number of AQUAREVE analysed.

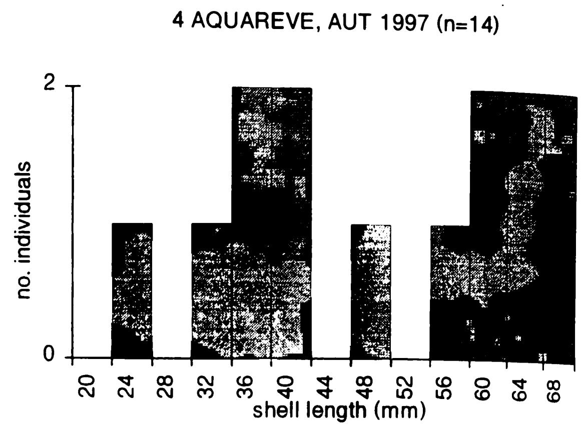


Interpretation of size-frequencies distribution of *B. undatum* was difficult due to the low numbers of individuals measured. However, in autumn 1997, when 14 animals were sampled, no real mode appeared, individuals being spread over all size classes (Fig. 3.192).

No seasonal pattern was observed for this species throughout the sampling period. The maximum density was reached in autumn 1997, this was ten times higher than any other density observed throughout the sampling period. This fact remain unexplained.

Fig. 3.192. Size-frequency histograms for *Buccinum undatum* collected seasonally in AQUAREVE at UBGC from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.

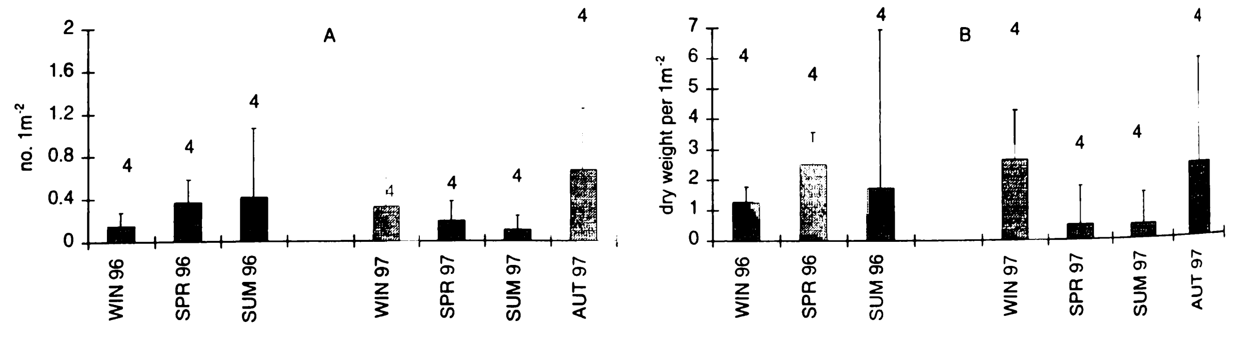




This buccinid gastropod was common on the impacted maerl ground at Glenan (UBGI). It was observed in 24 of the total of 28 AQUAREVE sampled in 1996 and 1997. Densities varied in the range 0.4 to 0.7 individuals per m^2, with maximum of 6 per m^2 observed.

Being a large shelled gastropod, this species made an important and consistent contribution to the total biomass of the samples analysed. Maximum contribution reached 22 % of the total dry weight of one sample in summer 1996. Mean biomasses ranged between 0.5 to 2.7 g dry weight per m^2 throughout the sampling period (Fig. 3.193).

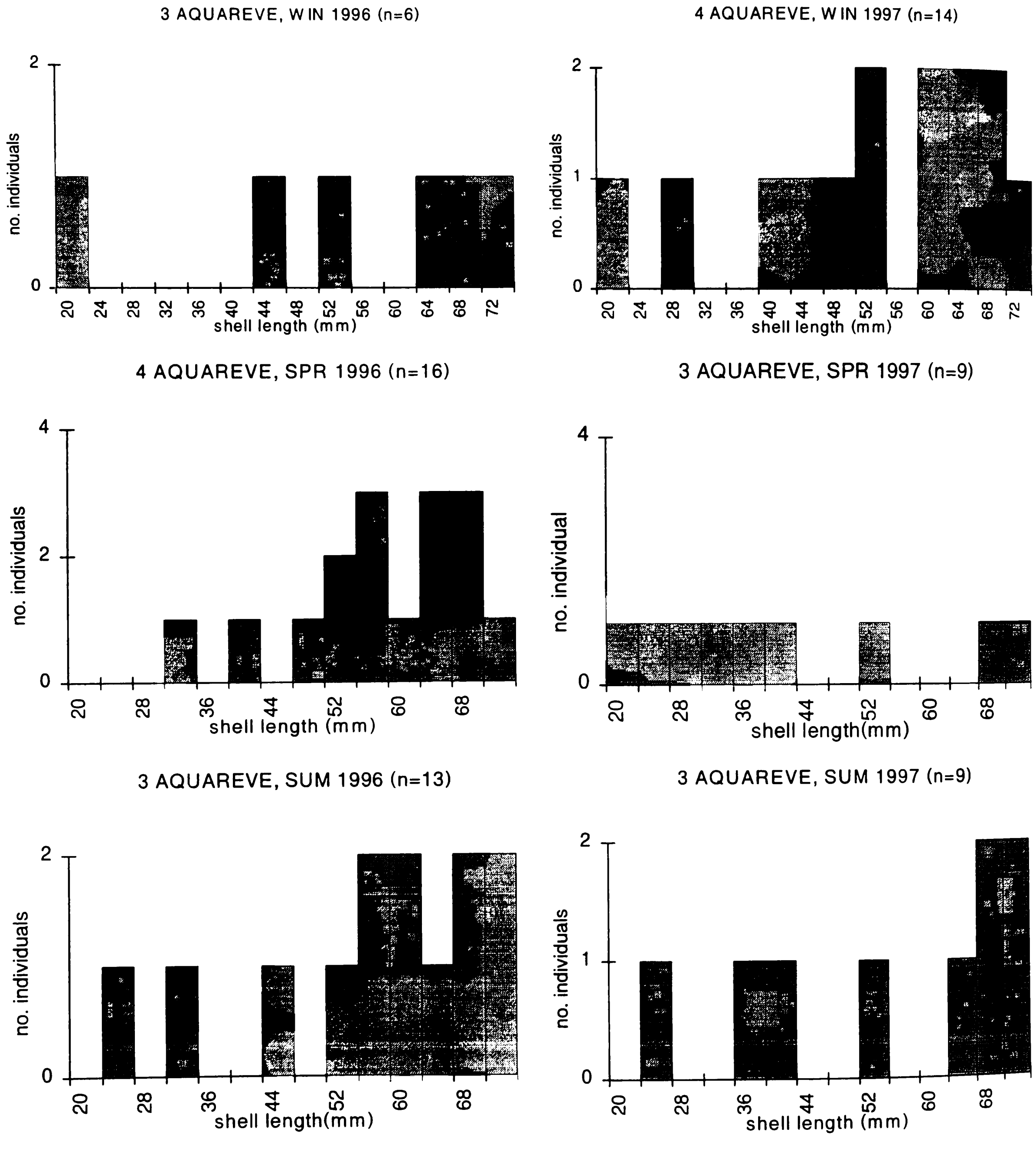
Fig. 3.193. A) Mean number and B) biomass (g dry weight) of *B. undatum* per 1m^2 at UBGI. Error bars = SD, N = number of AQUAREVE samples analysed.



Analysis of the size frequencies of *B. undatum* throughout the sampling period (Fig. 3.194) showed no modal structure: individuals of all size classes were encountered at any season. However, individuals between 52 to 68 mm shell length were perhaps more numerous than others.

The two sampling years showed very different patterns. Maximum density was reached in summer for 1996 while this season was the minimum for 1997. Densities and biomasses were comparable for both years.

Fig. 3.194. Size-frequency histograms for *Buccinum undatum* collected seasonally in AQUAREVE samples at UBGC from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.



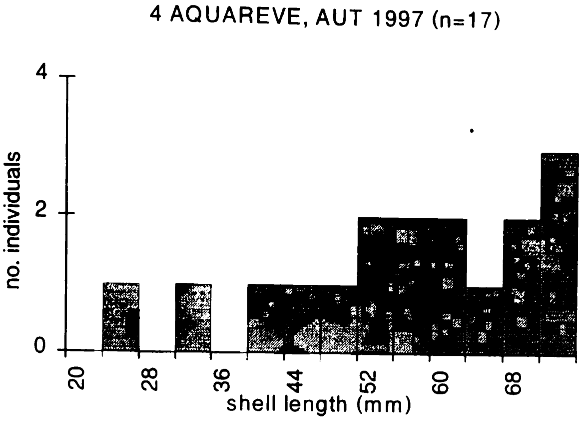
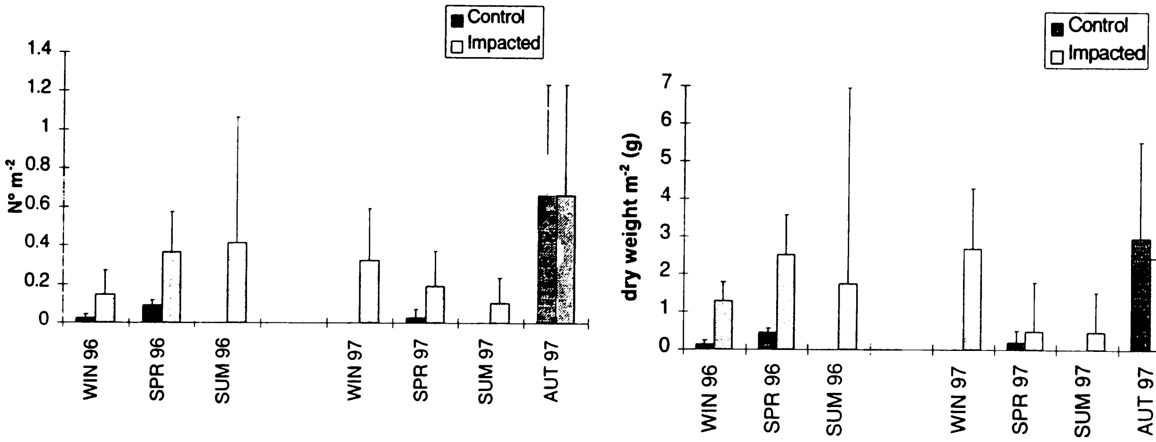


Fig. 3.195. Comparison of seasonal variation of population density and biomass of *B.undatum* between control and impacted sites in the Glenan for 1996 and 1997.



The population density of ***Buccinum undatum*** was greater on the impacted ground than on the control throughout the sampling period 1996-1997. In autumn 1997 however, mean density and biomass were very similar (Fig. 3.195), a fact that remains unexplained.

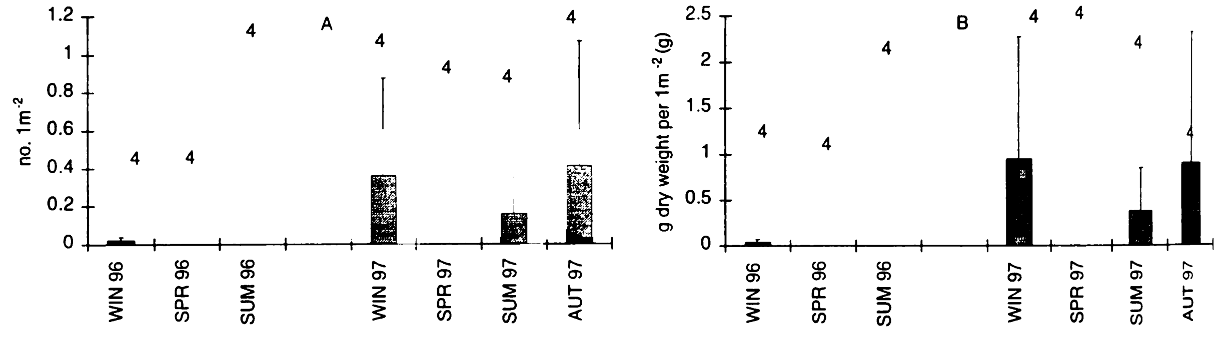
Hinia reticulata **(Linnaeus, 1758)**

This gastropod was not common on the control maerl ground of the Glenan. It only occurred in half (14) of the 28 AQUAREVE samples analysed throughout the sampling period. Mean densities ranged from 0 to 0.4 individuals per m^2 with a maximum of 3 individuals per m^2 reached in summer 1997.

Hinia reticulata is a nassariid gastropod occurring mainly in muddy or sandy sediments. It is a scavenger and carrion feeder.

This species was a low contributor to the biomass of the maerl beds at the control site. Mean biomasses ranged between 0 to 0.4 g dry weight per m^2 during the sampling period, with a maximum contribution of 2 % reached during winter 1997 (Fig. 3.196).

Fig. 3.196. A) Mean number and B) biomass (g dry weight) of *H. reticulata* per 1m^2 at UBGC. Error bars = SD, N = number of AQUAREVE samples analysed.



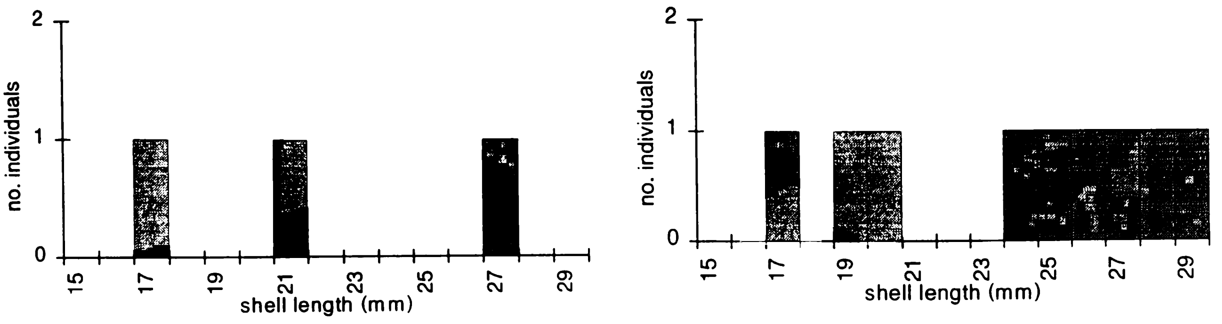
Interpretation of seasonal size-structural changes in the population of *H. reticulata* was not possible since only a few animals of this species were sampled on the control ground (Fig. 3.197). No recruitment or growth was therefore identifiable through the sampling period.

Year-to-year comparison showed that densities and biomasses of *H. reticulata* were higher during 1997 than during 1997. However, these parameters remained low throughout the sampling period and variations recorded may therefore not be very reliable.

Fig. 3.197. Size-frequency histograms for *Hinia reticulata* collected seasonally in AQUAREVE samples at UBGC from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.

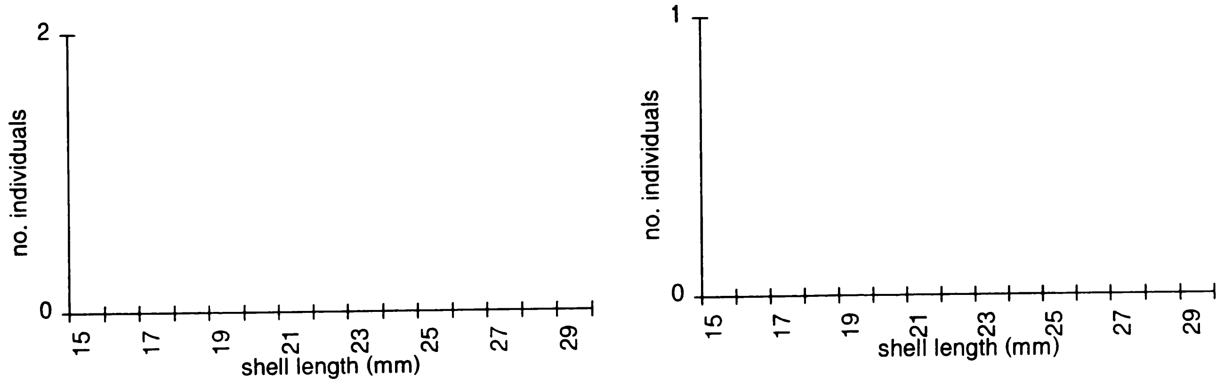
4 AQUAREVE, WIN 1996 (n=3)

4 AQUAREVE, WIN 1997 (n=9)



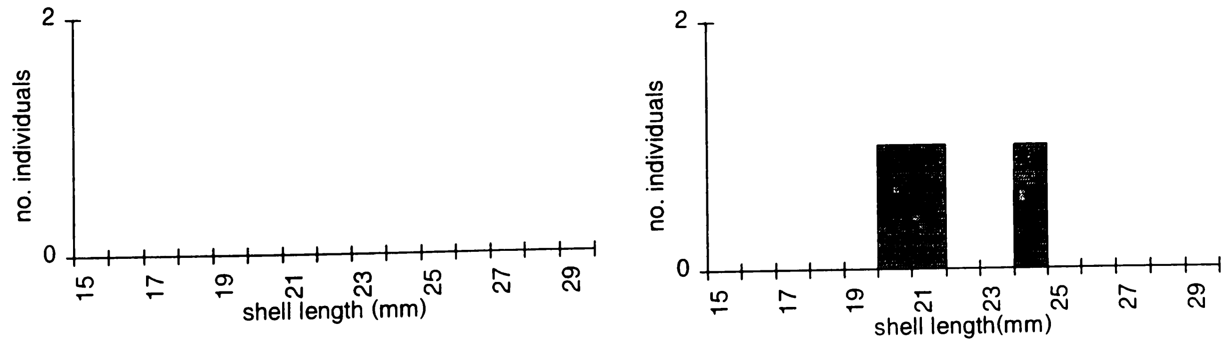
4 AQUAREVE, SPR 1996 (n=0)

3 AQUAREVE, SPR 1997 (n=0)

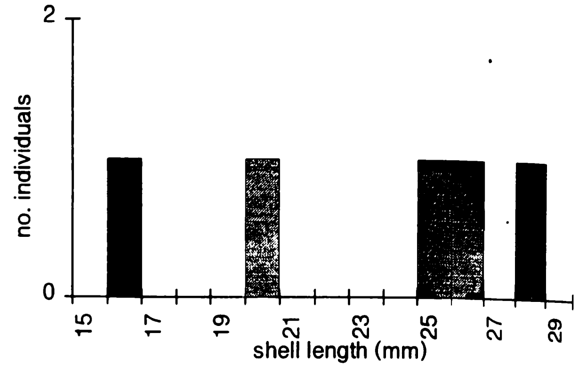


4 AQUAREVE, SUM 1996 (n=0)

4 AQUAREVE, SUM 1997 (n=3)



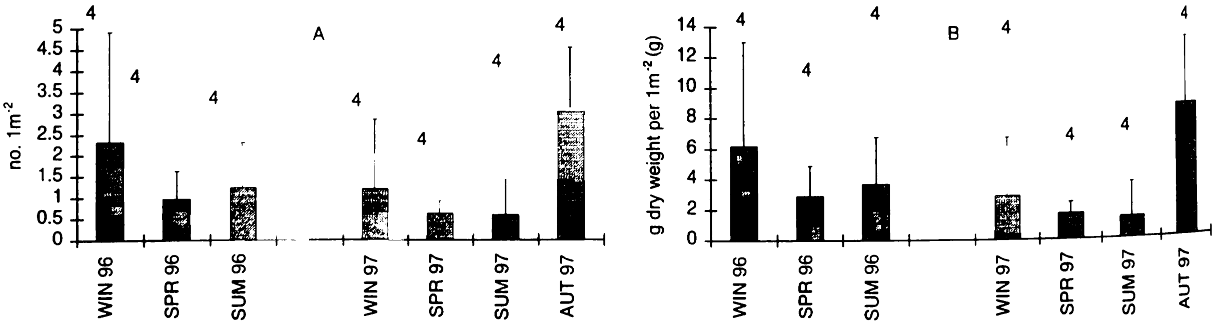
4 AQUAREVE, AUT 1997 (n=5)



This gastropod was common on the impacted ground UBGI. It occurred in all the 28 AQUAREVE samples analysed throughout the sampling period. Mean densities ranged from 0.6 to 3 individuals per m^2 with a maximum of 8 individuals per m^2 reached in summer 1997 (Fig. 3.198).

This species, was a significant contributor to the biomass of the maerl bed at UBGI. Mean biomasses ranged from 1.4 to 8.7 g dry weight per m^2 during the sampling period, with a maximum contribution of 16 % to the total biomass in a single AQUAREVE sample reached during winter 1997.

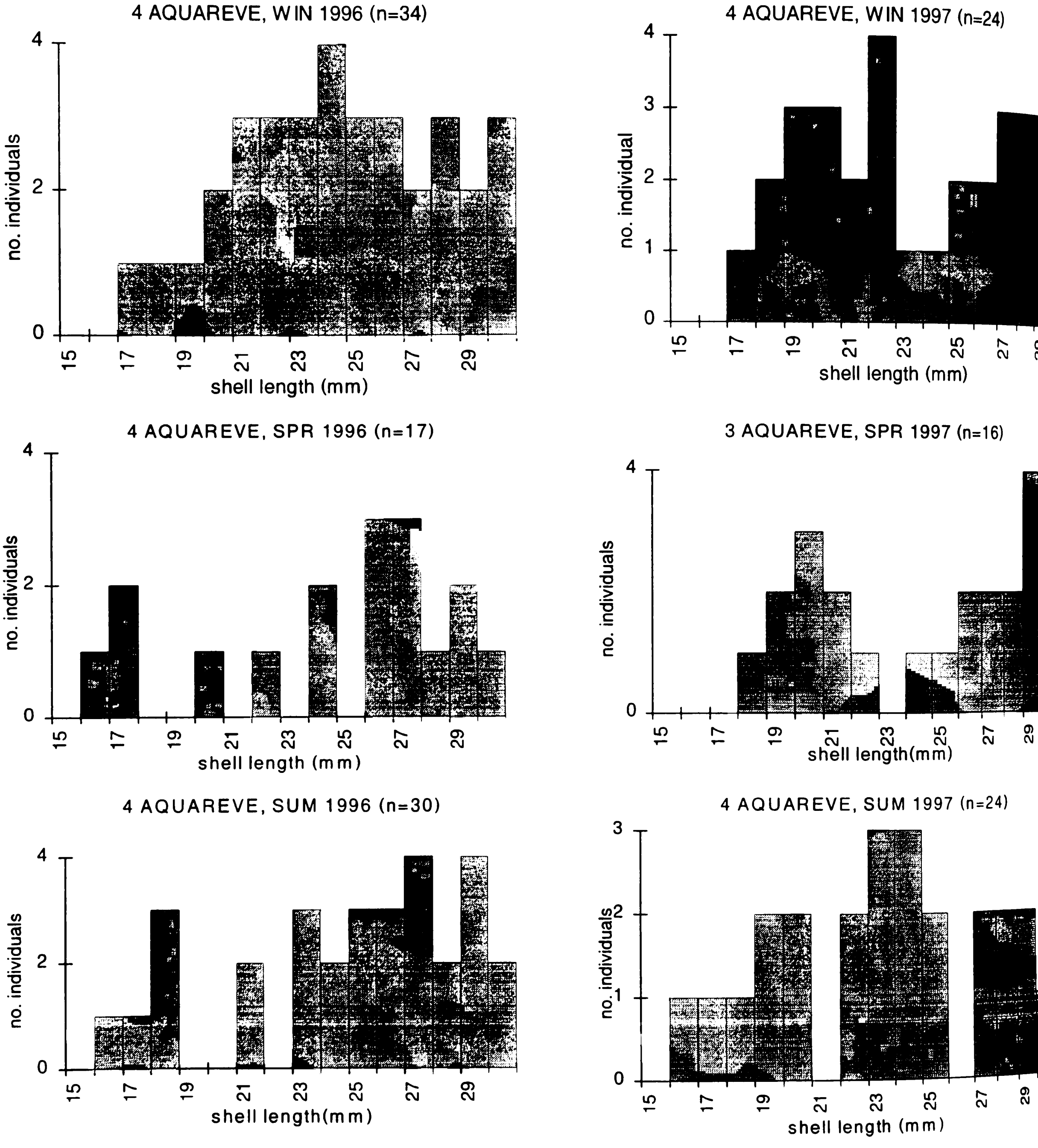
Fig. 3.198. A) Mean number and B) biomass (g dry weight) of *H. reticulata* per 1m^2 at UBGI. Error bars = SD, N = number of AQUAREVE samples analysed.



Seasonal variations of the size structure of *H. reticulata* are shown in Fig. 3.199. Individuals were distributed between all size classes without any modes appearing. Recruitment of juveniles to the megafauna seemed therefore to be rather constant during the sampling period, except during winter months when no individuals of size classes 15 to 17 mm were observed.

Year-to-year comparison of density and biomass showed similar patterns for this species, with high densities being observed in winter for both years and autumn for 1997, while the minimum density occurred in spring for both years. However, seasonal variations remained slight for this species.

Fig. 3.199. Size-frequency histograms for *Hinia reticulata* collected seasonally in AQUAREVE samples at UBGI from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.



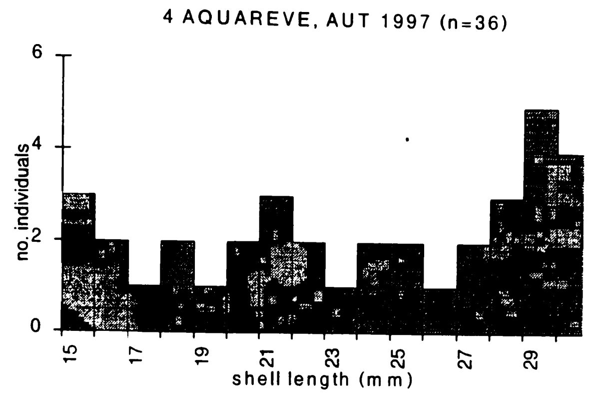
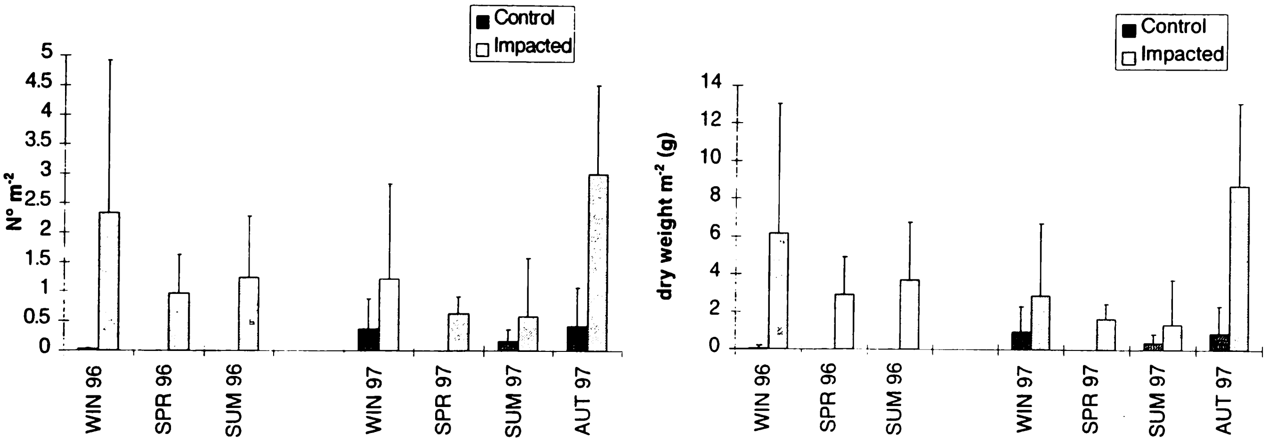


Fig. 3.200. Comparison of seasonal variation of population density and biomass of *H.reticulata* between control and impacted sites in the Glenan for 1996 and 1997.



Site-to-site comparison (Fig. 3.200) showed that, during the few seasons when it was present on the control ground, *H. reticulata* was found at a higher density and biomass (from 3 to 6 times greater) on the impacted ground than on the control.

Pecten maximus **(Linnaeus, 1758)**

This bivalve was sparsely distributed on the Glenan maerl beds. Its abundance was low on the control ground, but it was regularly sampled there since it was present in 22 out of the 28 AQUAREVE samples analysed throughout the sampling period 1996-1997. Mean densities ranged from 0.1 to 0.7 individuals per m^2, with a maximum of 1.2 per m^2 sampled in autumn 1997 (Fig. 3.201).

Pecten maximus is a suspension-feeding bivalve of commercial importance living on gravels and sandy bottoms, from the sublittoral to 100m deep.

This species was a large contributor to the biomass of the control maerl bed in Glenan. Mean biomasses ranged between 5 to 26 g dry weight per m^2 during the sampling period, with a maximum contribution of 80 % reached during autumn 1997.

Fig. 3.201.A) Mean number and B) biomass (g dry weight) of *P. maximus* per 1m^2 at UBGC. Error bars = SD, N = number of AQUAREVE samples analysed.

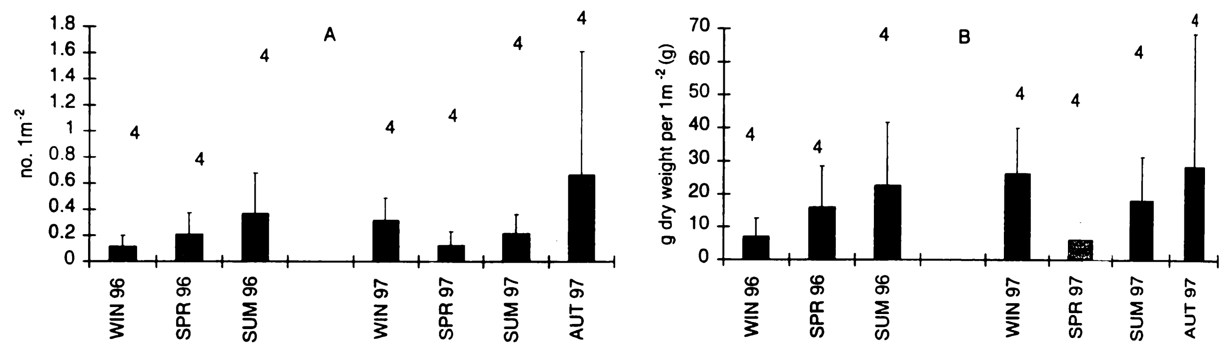
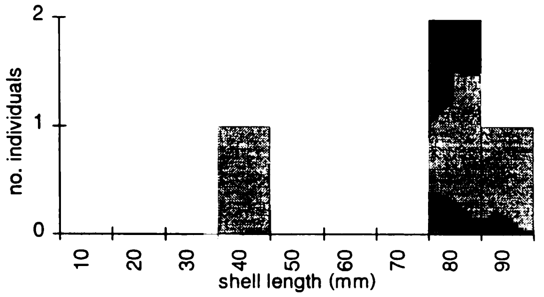


Fig. 3.202 shows the seasonal variations in size-structure for *P. maximus*. Most of the population was made up of larger individuals (mode centred on size class 90 mm). This mode may include individuals of several age-classes (of 3 and more years old). However, obvious recruitment of juveniles was observed in autumn 1997 when very small individuals (around 10mm shell length) were sampled.

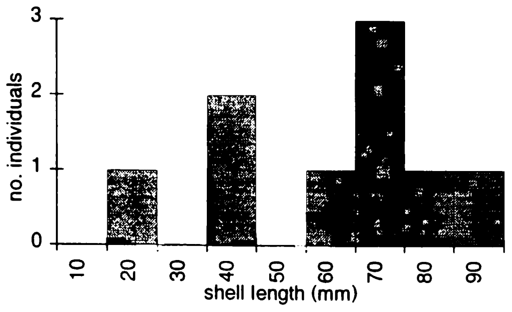
The population density of this species was consistent during the sampling period. Scallops were more numerous in summer 1996 and autumn 1997, but abundance variations remained slight and differences in densities between seasons may not be significant.

Fig. 3.202. Size-frequency histograms for *Pecten maximus* collected seasonally in AQUAREVE at UBGC from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.

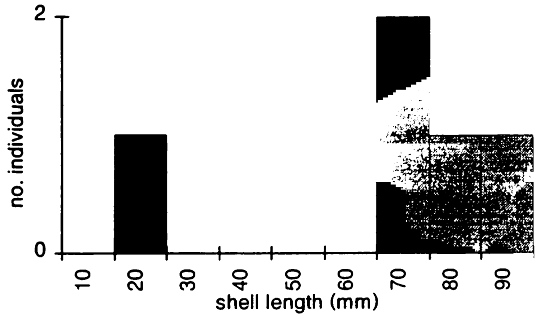
4 AQUAREVE, WIN 1996 (n=4)



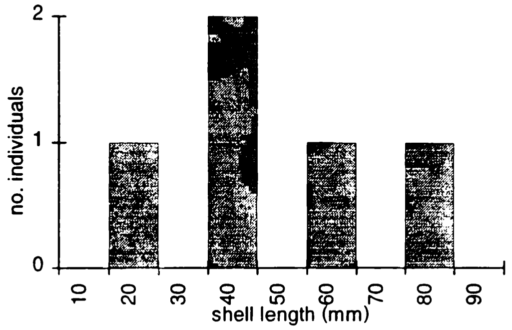
4 AQUAREVE, WIN 1997 (n=9)



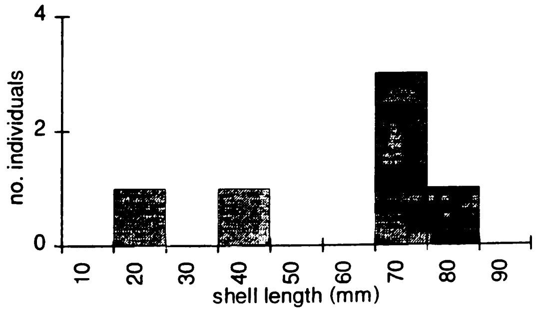
4 AQUAREVE, SPR 1996 (n=5)



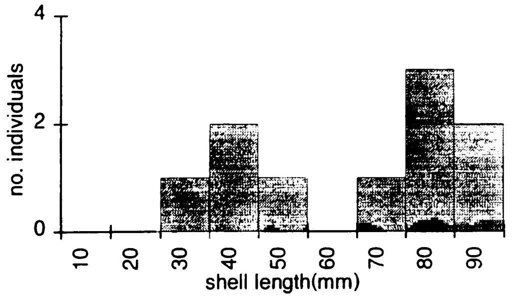
4 AQUAREVE, SPR 1997 (n=5)



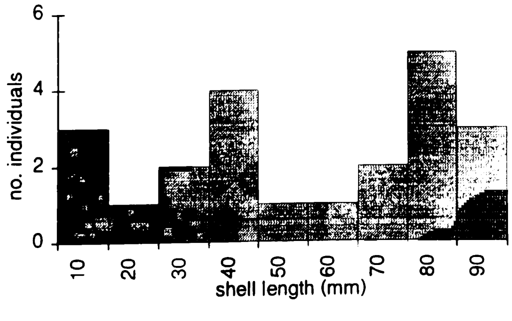
4 AQUAREVE, SUM 1996 (n=6)



4 AQUAREVE, SUM 1997 (n=10)



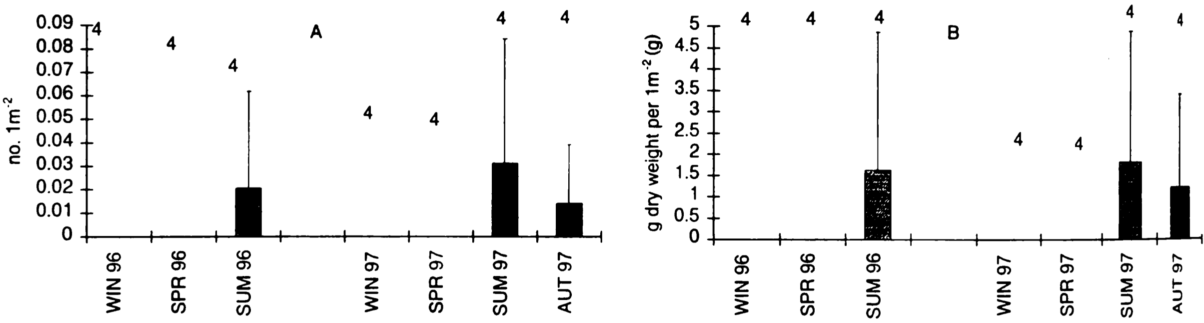
4 AQUAREVE, AUT 1997 (n=22)



This bivalve was found in very low abundance on the impacted ground (UBGI). It was observed in only 3 AQUAREVE samples out of the 28 analysed. Mean densities ranged from 0 to 0.03 individuals per m^2, with a maximum of 0.6 per m^2 sampled in summer 1997 (Fig. 3.203).

When present on the impacted ground, it was an important contributor to the biomass of the samples. Mean biomasses ranged between 1 to 4 g dry weight per m^2 during the sampling period, with a maximum contribution of 60 % reached during autumn 1997.

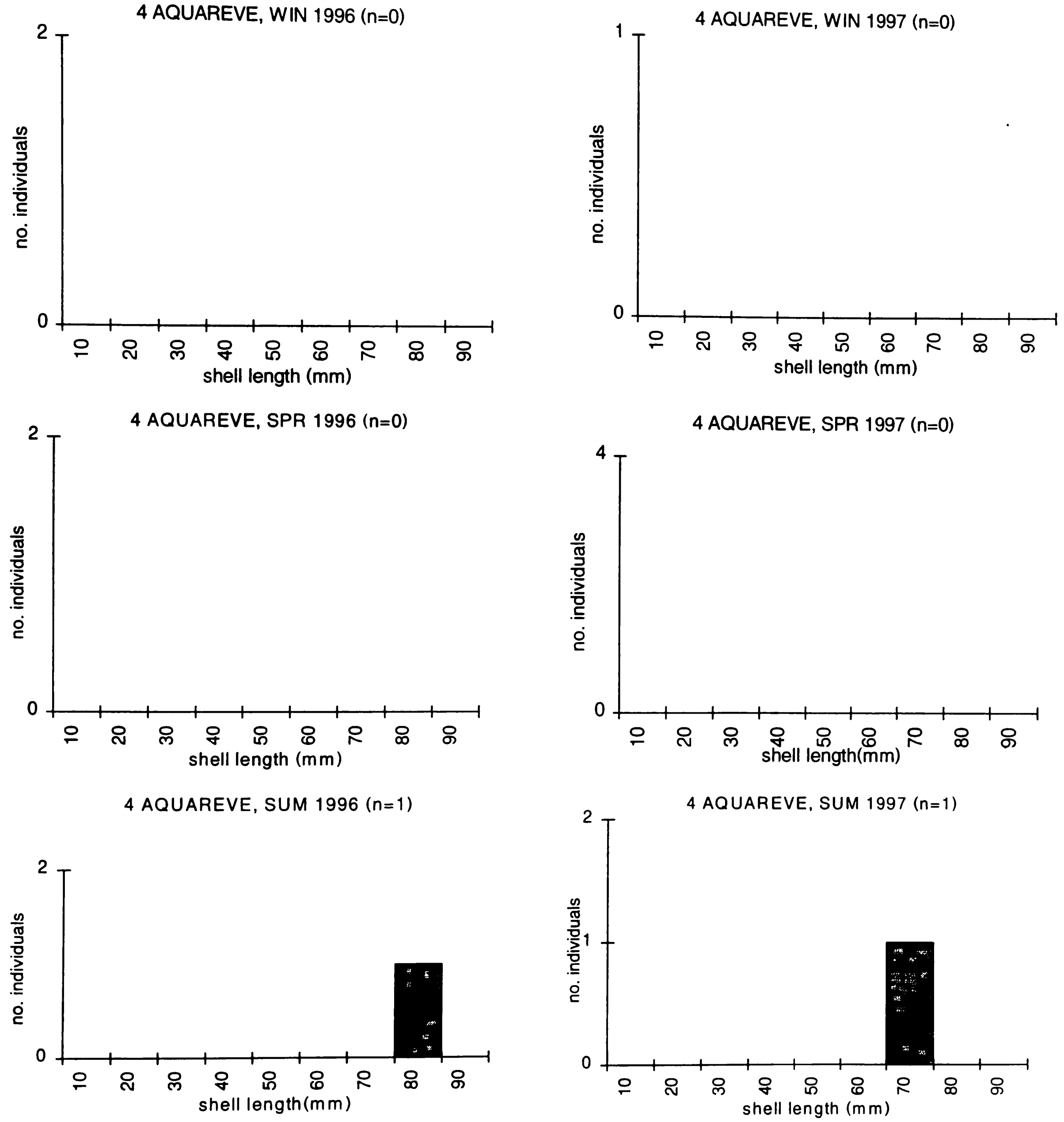
Fig. 3.203.A) Mean number and B) biomass (g dry weight) of *P. maximus* per 1m^2 at UBGI. Error bars = SD, N = number of AQUAREVE samples analysed.



Population densities of *Pecten maximus* on the impacted ground were too low for satisfactory interpretation of changes in size structure (Fig. 3.204). No small individuals (presumably juveniles recruits) were observed there during the sampling period.

Pecten maximus, when observed on the impacted ground was only found during the summer and autumn months.

Fig. 3.204. Size-frequency histograms for *Pecten maximus* collected seasonally in AQUAREVE at UBGI from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.



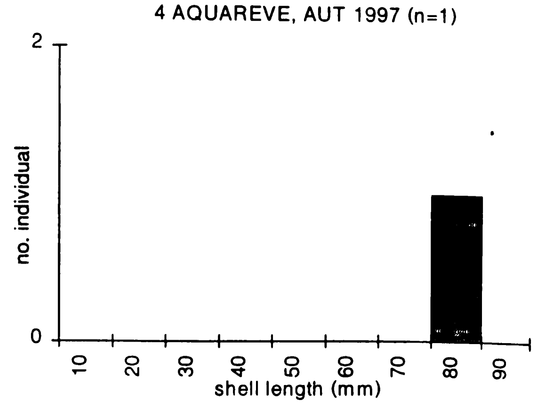
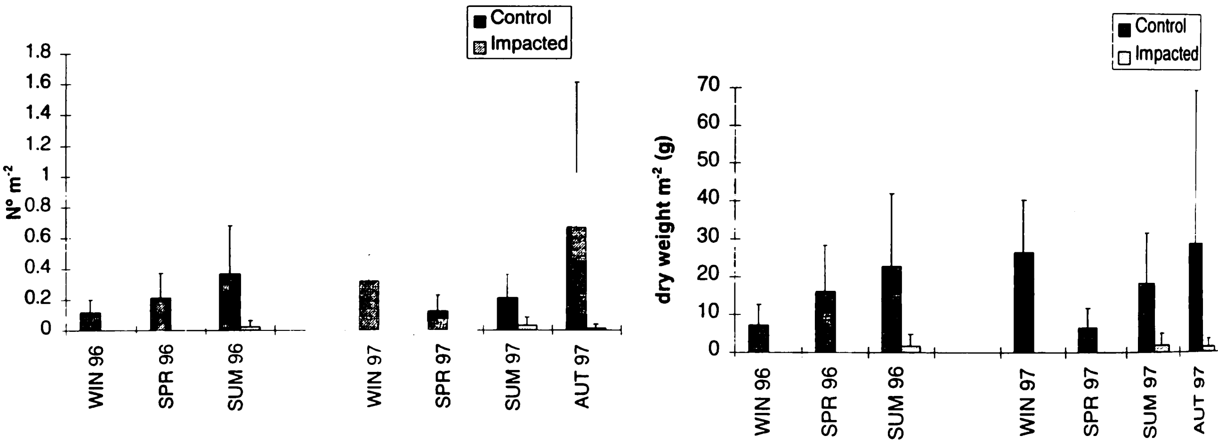


Fig. 3.205. Comparison of abundance and biomass of *P.maximus* between control and impacted sites in the Glenan for 1996 and 1997.



This species was mostly absent from the impacted bed UBGI (Fig. 3.205). It may therefore be a good indicator of the anthropogenic impacts at Glenan.

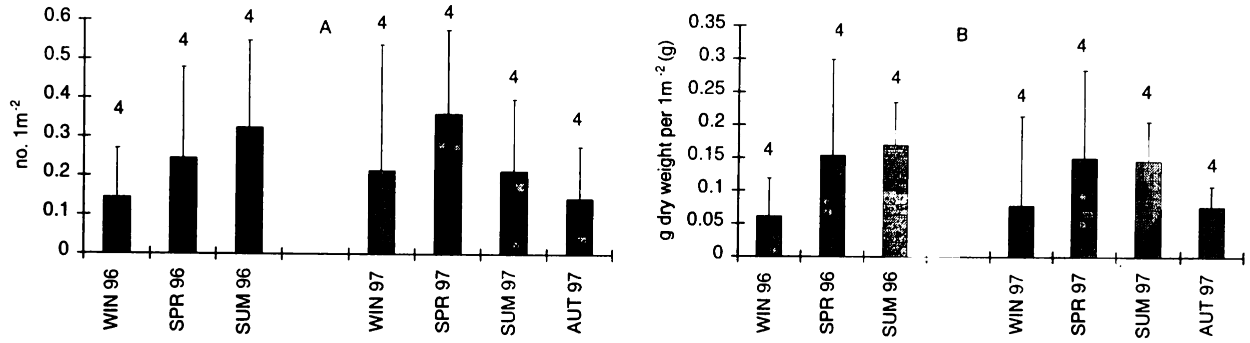
***Timoclea ovata* (Pennant, 1777)**

The bivalve *T. ovata* was sparsely distributed on the control ground of the Glenan (UBGC) during the sampling period. It occurred in 23 of the total of 28 AQUAREVE samples analysed on UBGC with means of 0.14-0.36 individuals per m^2, and up to 1 individual per m^2 for a single AQUAREVE in summer 1996 (Fig . 3.206A)

The venerid *T. ovata* is a suspension-feeding bivalve living in muds or sandy-muds.

It made a rather low contribution to abundance in the Glenan AQUAREVE samples. During the sampling period, mean dry weight biomass varied from 0.06 to 0.17 g per m^2 (Fig. 3.206B). Maximum contribution of the biomass of *T. ovata* for one grab was 0.2%.

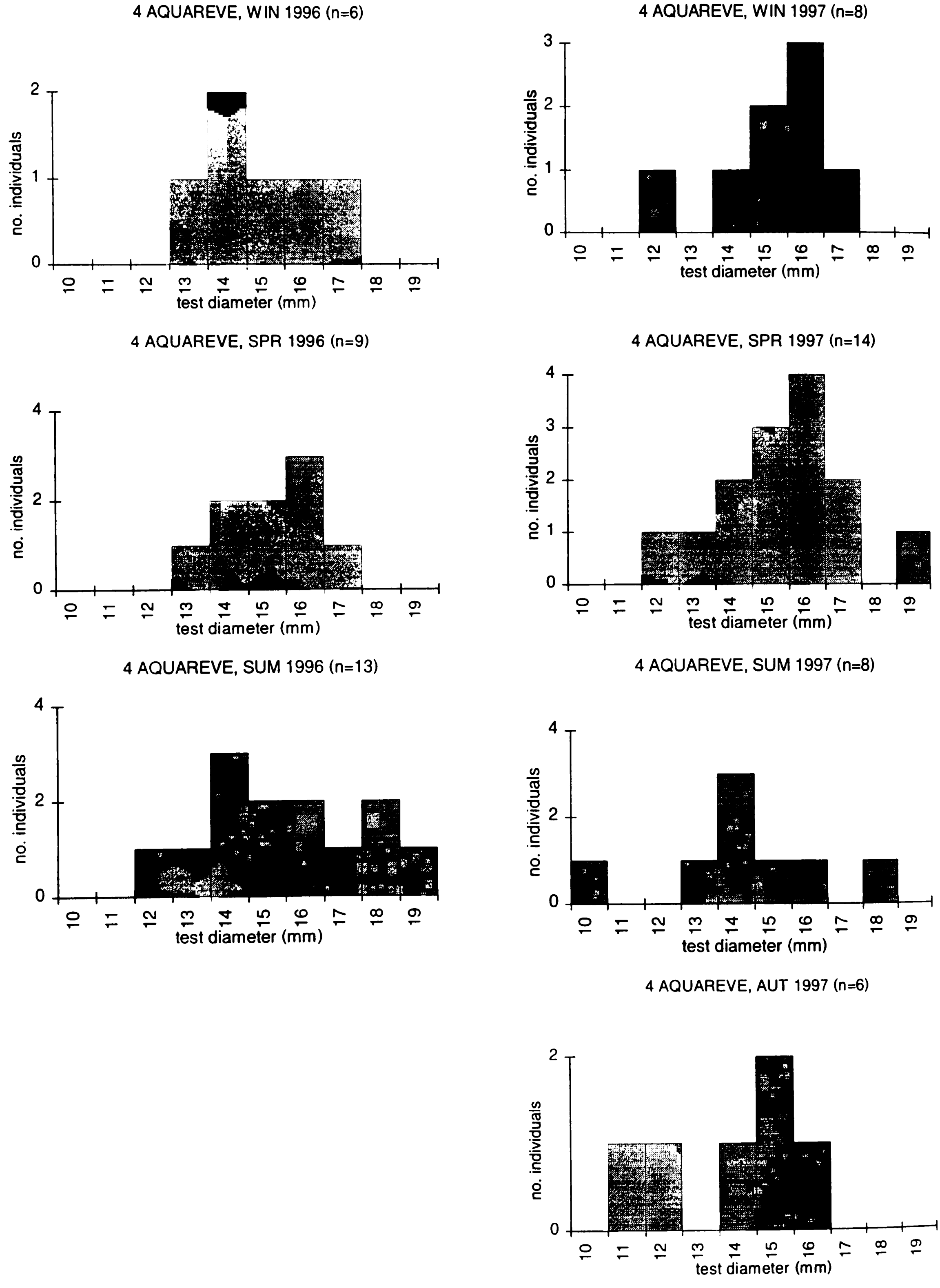
Fig. 3.206.A) Mean number and B) biomass (g dry weight) of *T. ovata* per 1m^2 at UBGC. Error bars = SD, N = number of AQUAREVE analysed.



The seasonal variation in size-frequency of the *T. ovata* population sampled in grabs is given in Fig. 3.207. Almost all *T. ovata* sampled on the control ground belonged to the same mode, centred on size classes 15-16mm. No growth of these animals was observed throughout the sampling period, and no recruitment of small individuals to the megafauna was detected during the same period (except maybe for the 10mm individual sampled in summer 1997).

Differences were observed between the two sampling years in terms of density and biomass. These parameters increased during the year in 1996 and decreased during year in 1997. Maximm density was observed during spring 1997.

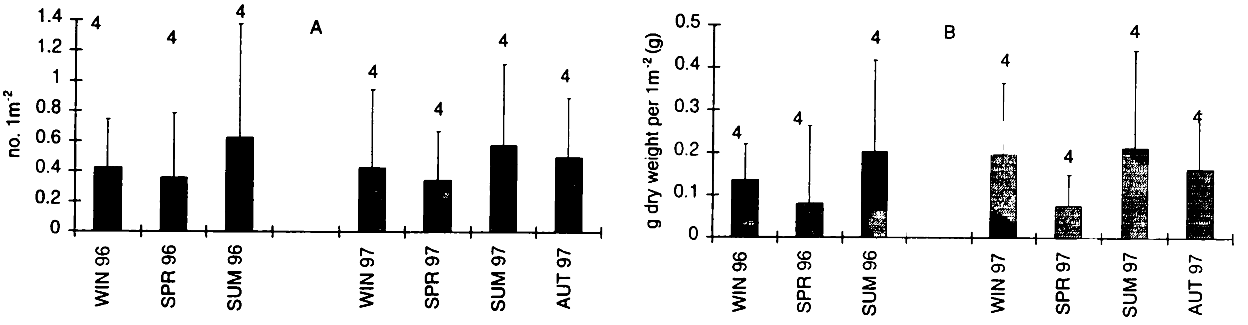
Fig.3.207. Size-frequency histograms for *Timoclea ovata* collected seasonally in AQUAREVE samples at UBGC from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.



The bivalve *T. ovata* was sparsely distributed on the impacted ground at Glenan (UBGI). It occurred in 24 of the total of 28 AQUAREVE samples analysed from there with means of 0.34-0.57 individuals per m^2, and up to 1.6 individuals per m^2 for a single AQUAREVE in summer 1996 (Fig. 3.208A)

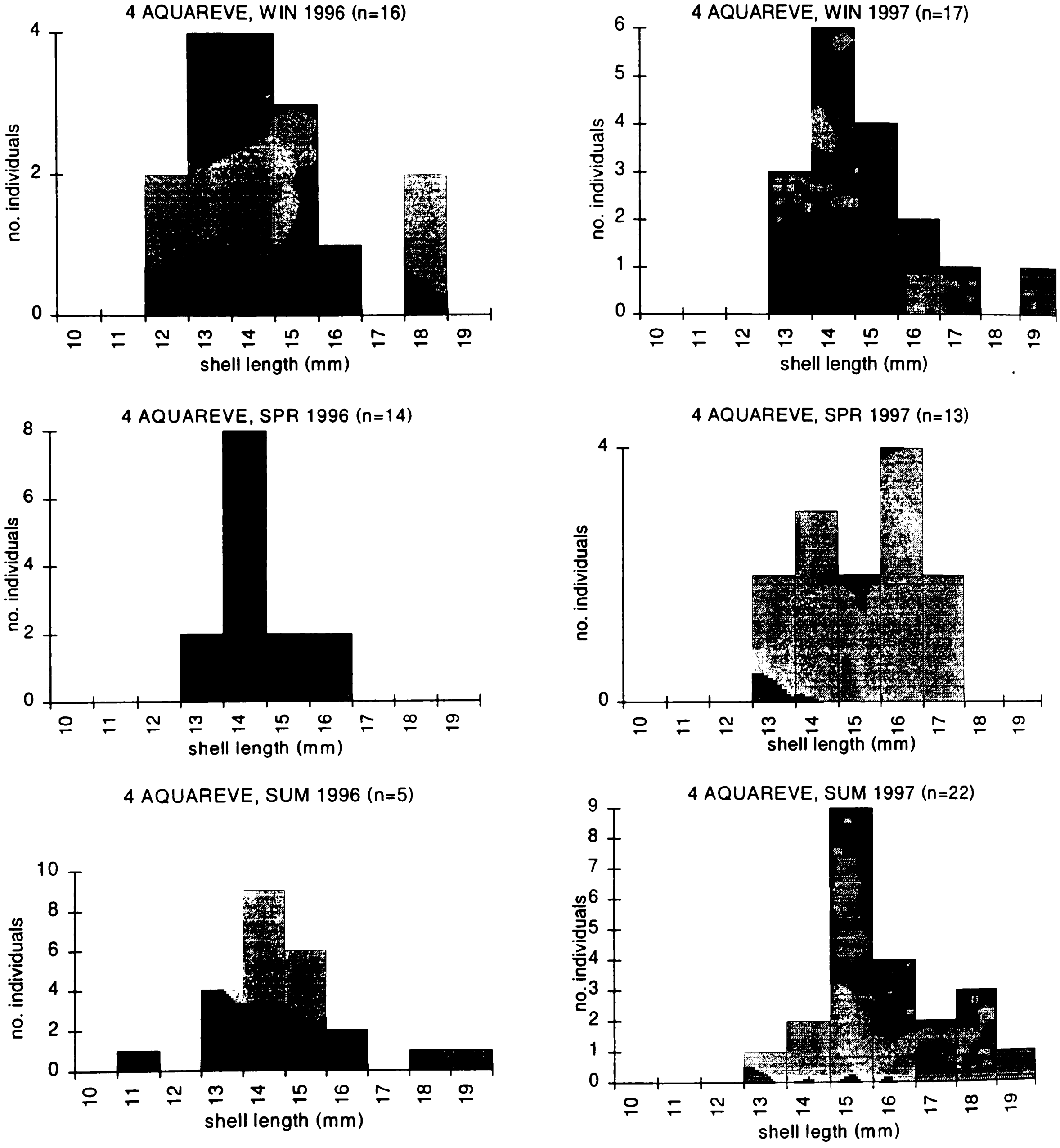
This species had a low contribution to the AQUAREVE samples on the impacted ground. During the sampling period, mean dry weight biomass varied from 0.13 to 0.21 g per m^2 (Fig. 3.208B). Maximum contribution of the biomass of *T. ovata* for one grab was 0.35 %.

Fig. 3.208.A) Mean number and B) biomass (g dry weight) of *T. ovata* per $1m^2$ at UBGI. Error bars = SD, N = number of AQUAREVE analysed.



As for UBGC, the majority of *T. ovata* sampled on the impacted ground belonged to the same size-mode (Fig. 3.209). There they were centred on size classes 13-14mm. No growth of these animals was observed throughout the sampling period. Recruitment seems to have occurred in autumn 1997, but only two small individuals were observed, suggesting that this recruitment was low. The two sampling years were very similar in terms of biomass and density. No seasonal pattern appeared for either sampling year on this impacted ground.

Fig. 3.209. Size-frequency histograms for *Timoclea ovata* collected seasonally in AQUAREVE at UBGI from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.



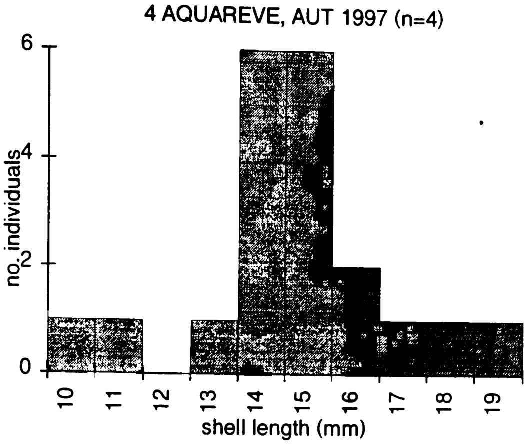
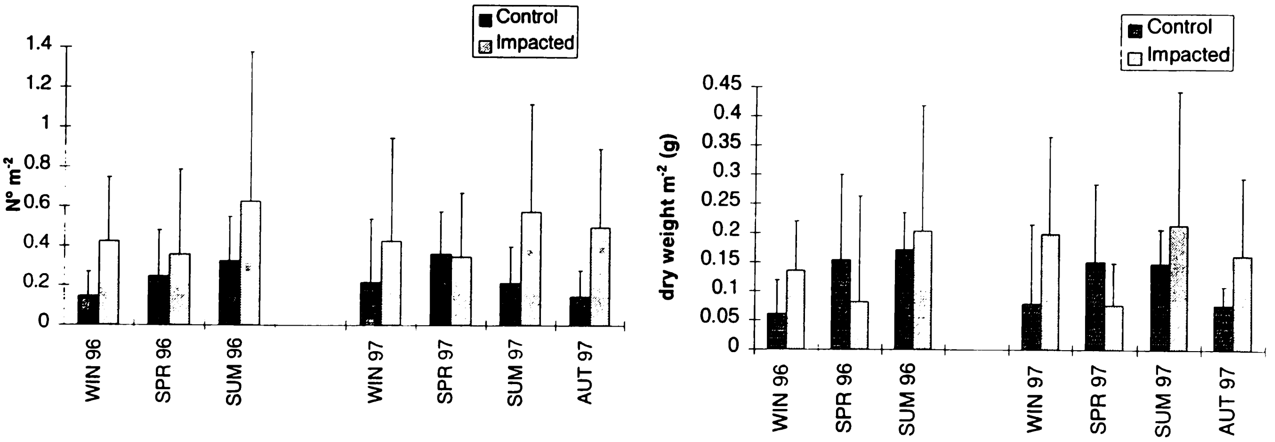


Fig.3.210. Comparison of seasonal variation in abundance and biomass of *T.ovata* between control and impacted sites in the Glenan for 1996 and 1997.



Population densities and biomasses of *T. ovata* were higher on the impacted ground than on the control ground throughout the sampling period 1996-1997 (Fig. 3.210). This species, being more of a mud-dweller, could be an indicator of inputs of fine particles to the maerl beds.

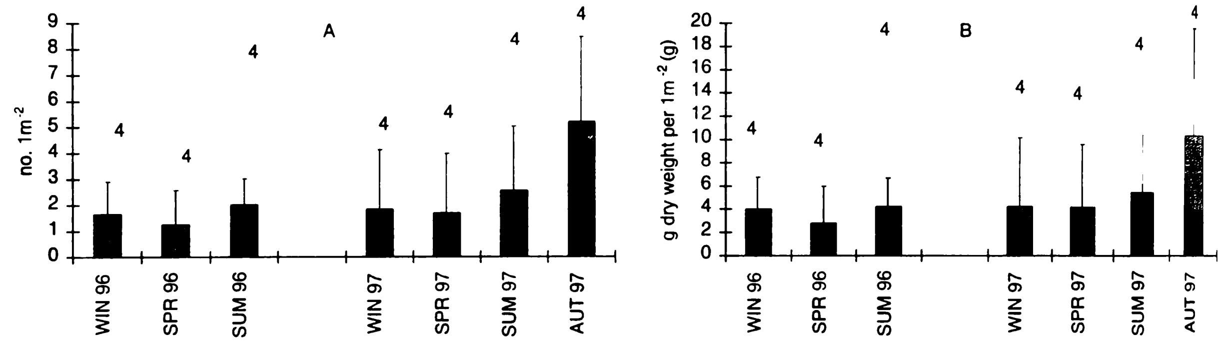
Tapes rhomboides (Pennant, 1777)

This bivalve was very dense on the control ground of the Glenan since it occurred in the all of the 28 AQUAREVE samples taken. Its maximum abundance was reached in autumn 1997 with 17 individuals per m^2. Mean densities ranged from 1.2 to 5.2 individuals per m^2 throughput the sampling period (Fig. 3.211A).

Tapes rhomboides is a suspension-feeding bivalve living in clean gravels and usually in areas with strong currents.

It was a dominant contributor to the biomass of the AQUAREVE samples of UBGC. Its maximum contribution to a single sample was of 61%. Mean biomasses ranged from 3 to 10 g per m^2 (Fig. 3.211B).

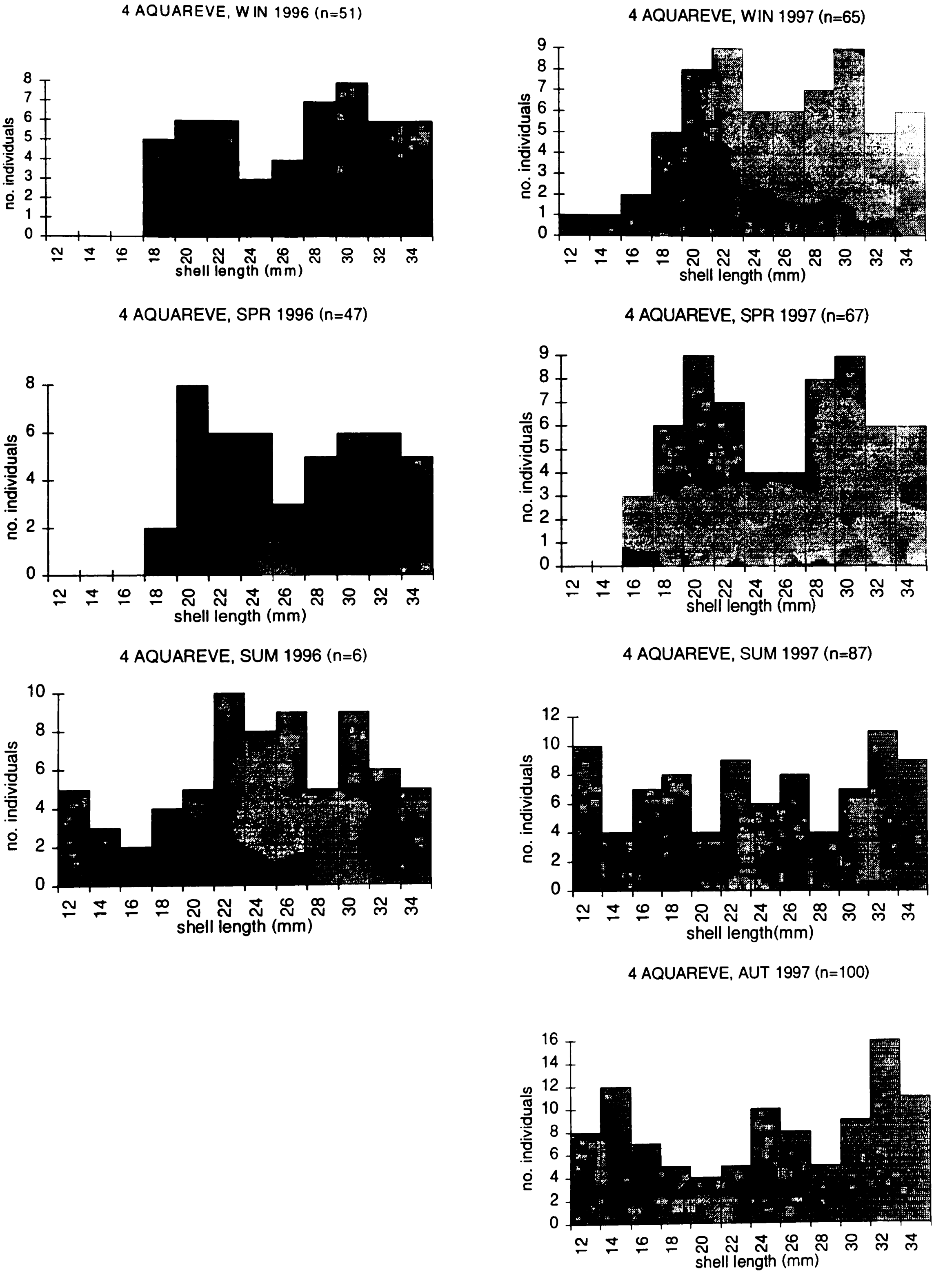
Fig. 3.211.A) Mean number and B) biomass (g dry weight) of *T. rhomboides* per 1m^2 at UBGC. Error bars = SD, N = number of AQUAREVE samples analysed.



The seasonal variation in size-structure of the UBGC population of *Tapes rhomboides* is shown in Fig.3.212. Two size-modes of larger individuals appear centred on size classes 22 mm and 30 mm shell length. No obvious growth of these was apparent during the sampling period though. Recruitment of juveniles to the megafauna occurred in summer for both sampling years. In autumn 1997, the juvenile mode was still important suggesting low mortalities of these individuals during summer 1997. When present, juveniles did not dominate the population, their proportion remaining relatively low (<1/3 of the population in autumn 1997).

The maximum population density was observed in autumn 1997, after recruitment of juveniles to the megafauna. Otherwise, densities remained similar throughout the sampling period in winter and spring. Summer densities were somewhat higher than these because of the onset of recruitment then.

Fig. 3.212. Size-frequency histograms for *Tapes rhomboides* collected seasonally in AQUAREVE samples at UBGC from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.



4 AQUAREVE, WIN 1996 (n=51)

4 AQUAREVE, WIN 1997 (n=65)

4 AQUAREVE, SPR 1996 (n=47)

4 AQUAREVE, SPR 1997 (n=67)

4 AQUAREVE, SUM 1996 (n=6)

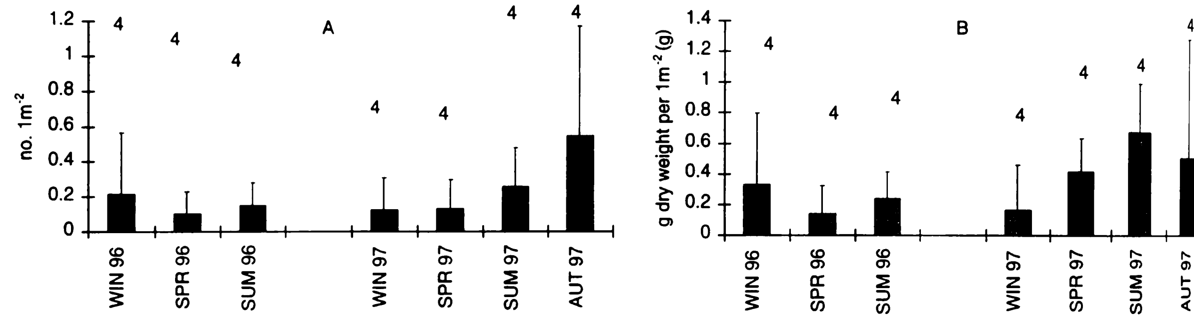
4 AQUAREVE, SUM 1997 (n=87)

4 AQUAREVE, AUT 1997 (n=100)

This bivalve very sparsely distributed on the impacted site at Glenan (UBGI). It occurred in 16 of the 28 AQUAREVE samples taken. Its maximum abundance was 4 individuals per m^2 in autumn 1997. Mean densities ranged from 0.14 to 0.68 individuals per m^2 throughout the sampling period (Fig. 3.213).

Because of its low abundance, this species was a low contributor to the biomass of the AQUAREVE samples of UBGI. Its maximum contribution to a single sample was 0.8%. Mean biomasses ranged from 0.14 to 0.68 g per m^2.

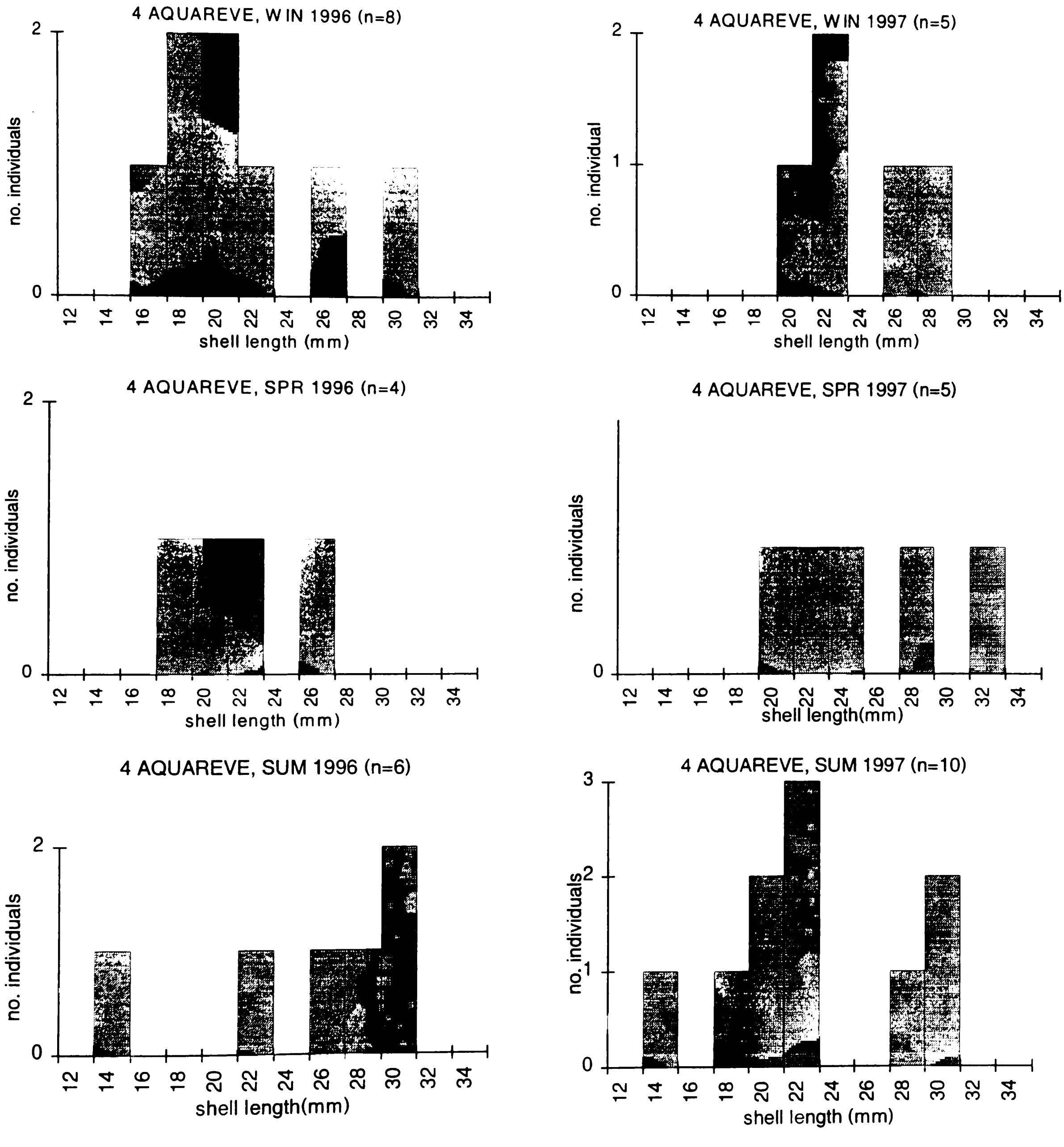
Fig. 3.213.A) Mean number and B) biomass (g dry weight) of *T. rhomboides* per 1m^2 at UBGI. Error bars=SD, N=number of AQUAREVE analysed.



Since population densities of *Tapes rhomboides* on the impacted ground were low, interpretation of seasonal changes in population size-frequency (Fig. 3.214) were difficult. It seems that no recruitment to the megafaunal size category occurred on this ground throughout the sampling period. Most of the individuals observed were between 16 and 30mm shell length. Bigger individuals, like those sampled on the control ground were not observed here. This suggests that *T. rhomboides* individuals observed on the control ground came from a single recruitment, and that recruitment on the UBGI is only occasional.

Both sampling years showed similar population densities, except in autumn 1997 when density reached its maximum. For biomass, the maximum was reached during the summer months (1997) and mean densities were higher in 1997 than in 1996.

Fig. 3.214. Size-frequency histograms for *Tapes rhomboides* collected seasonally in AQUAREVE at UBGI from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.



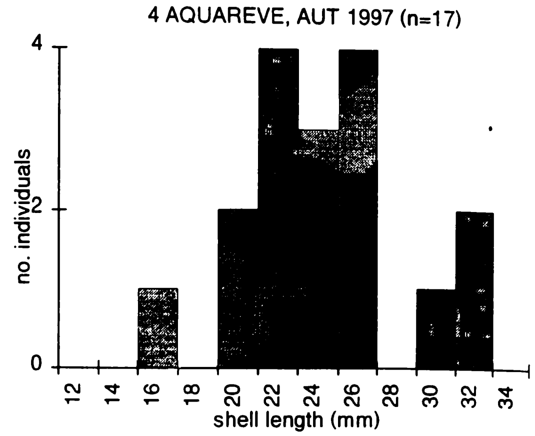
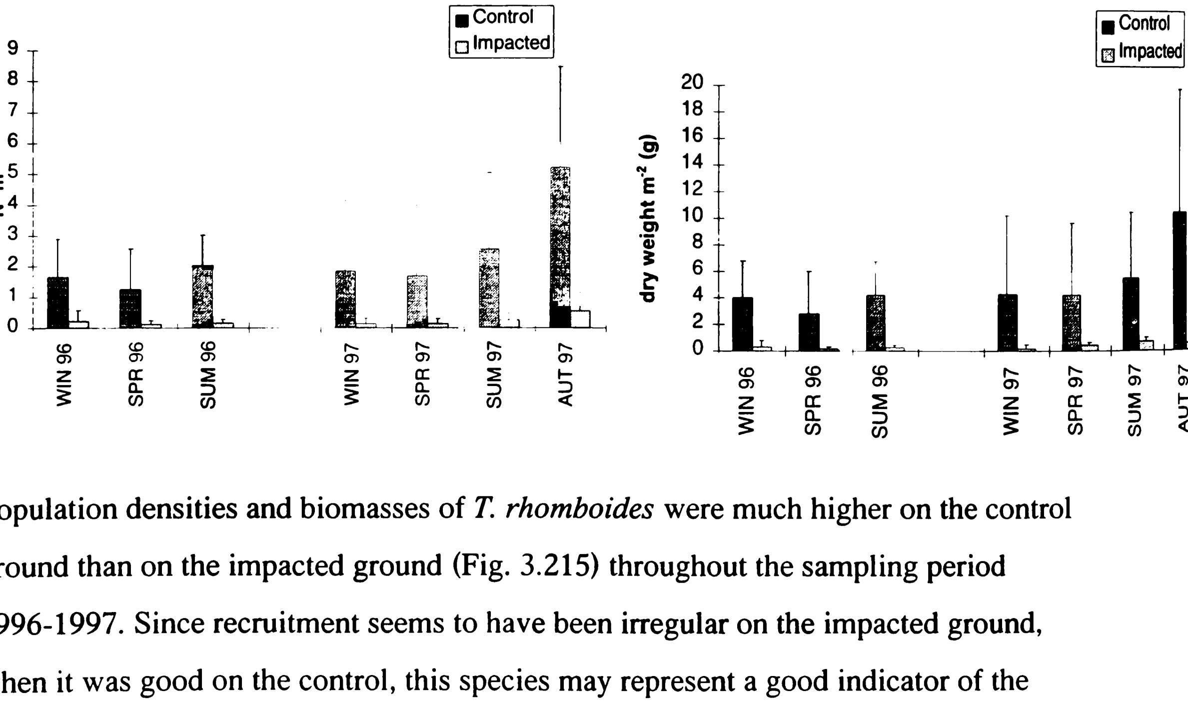


Fig. 3.215. Comparison of population density and biomass of *T.rhomboides* between control and impacted sites in the Glenan for 1996 and 1997.



Population densities and biomasses of *T. rhomboides* were much higher on the control ground than on the impacted ground (Fig. 3.215) throughout the sampling period 1996-1997. Since recruitment seems to have been irregular on the impacted ground, when it was good on the control, this species may represent a good indicator of the impact of maerl extraction on maerl beds.

Psammechinus miliaris **(Gmelin, 1778)**

This sea urchin was common on the Glenan control ground (UBGC). It was found in 26 of the 28 AQUAREVE samples analysed from there. A maximum of 6 individuals per m^2 was observed throughout the sampling period. Mean densities varied from 0.2 to 0.6 individuals per m^2 (Fig. 3.216).

Psammechinus miliaris is a common sea urchin on maerl beds in Brittany. It lives on all types of sediments from clean sands and gravels to muddy sands. It feeds on decaying macrophytic detritus (Bedford & Moore, 1985b).

Psammechinus miliaris was an poor contributor to the biomass of the megafauna on the UBGC ground. Its maximum contribution to a single AQUAREVE sample reached 5% during winter 1996. Biomasses ranged from 0.5 to 1.5 g dry weight per m^2.

Fig. 3.216. A) Mean number and B) biomass (g dry weight) of *P. miliaris* per 1m^2 at UBGC. Error bars = SD, N = number of AQUAREVE samples analysed.

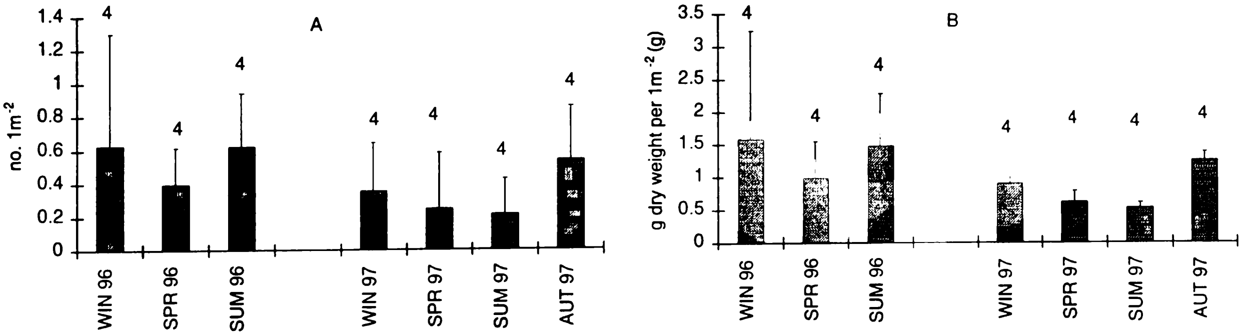
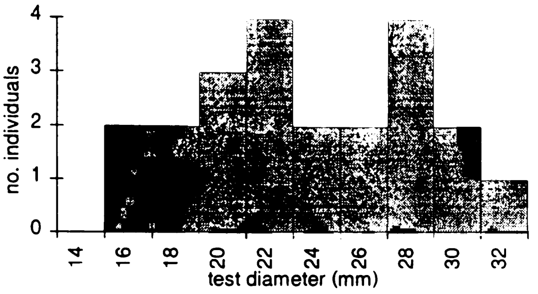


Fig. 3.217 shows the population size-frequency structure of *P. miliaris* throughout the sampling period. No clear modal sizes could be discerned for most of the period sampled (1996-1997). However, recruitment of juveniles seems to have occurred in autumn 1997 and summer 1996 and 1997.

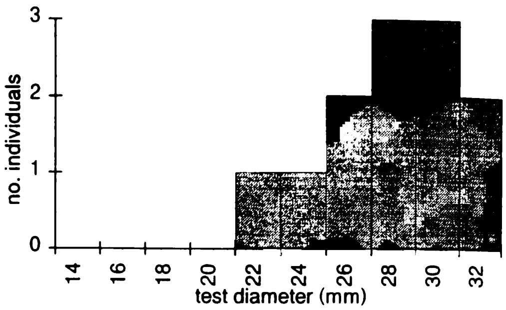
Year-to-year comparison showed that densities and biomasses of *P. miliaris* were comparable between the two years. Maximum density, however, was reached in summer for 1996, while this season was the minimum for 1997. Maximum density for the latter year was reached in autumn, after juvenile recruitment.

Fig. 3.217. Size-frequency histograms for *Psammechinus miliaris* collected seasonally in AQUAREVE at UBGC from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.

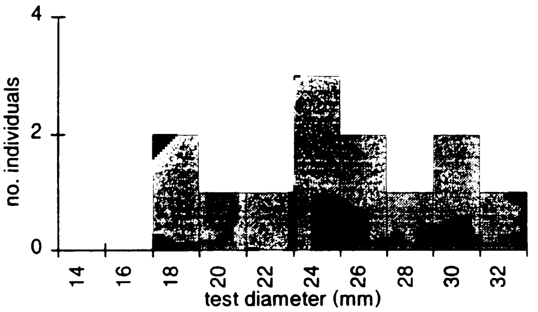
4 AQUAREVE, WIN 1996 (n=22)



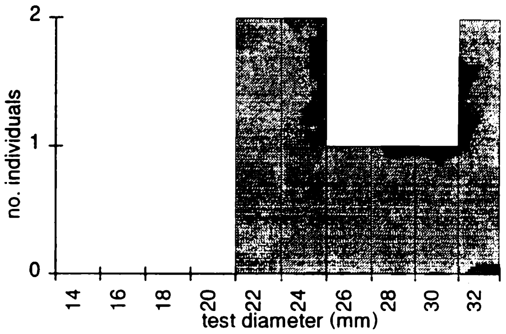
4 AQUAREVE, WIN 1997 (n=12)



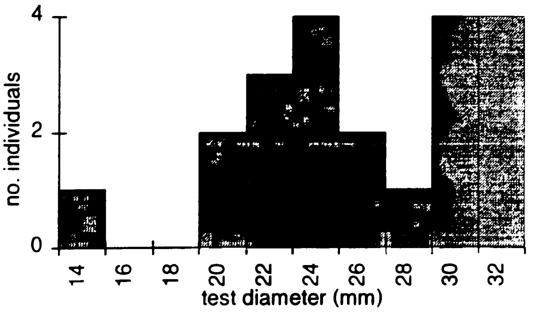
4 AQUAREVE, SPR 1996 (n=13)



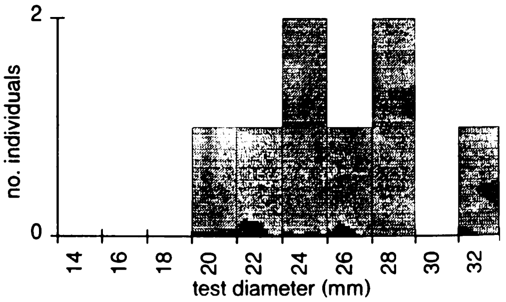
4 AQUAREVE, SPR 1997 (n=9)



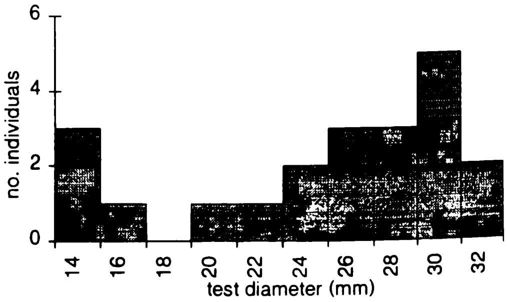
4 AQUAREVE, SUM 1996 (n=21)



4 AQUAREVE, SUM 1997 (n=8)



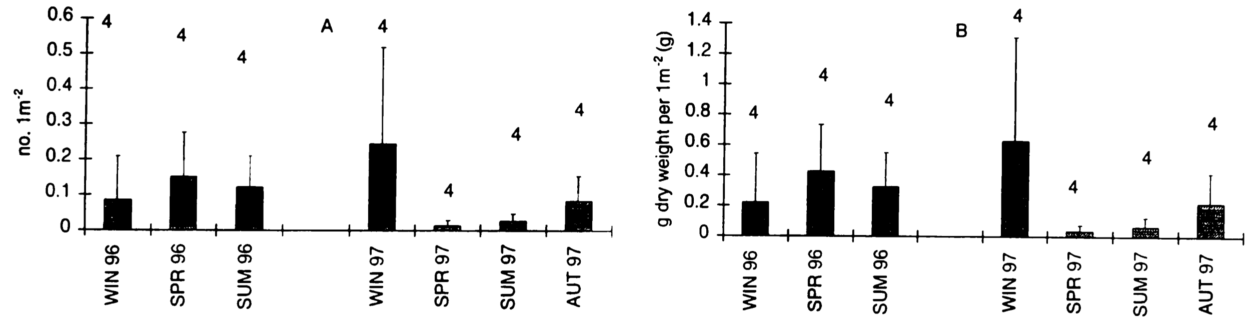
4 AQUAREVE, AUT 1997 (n=22)



This sea urchin was less common on the impacted maerl bed of the Glenan It was observed in 15 of the 28 AQUAREVE samples analysed A maximum of 0.8 individuals per m^2 was observed throughout the sampling period. Mean densities varied from 0.01 to 0.25 individuals per m^2(Fig. 3.218).

Being present only at a low density on the UBGI ground, *Psammechinus miliaris* made a low contribution to the biomass of the AQUAREVE samples. Its maximum contribution to a single AQUAREVE reached 1% during winter 1997. Biomasses ranged from 0.03 to 0.6 g dry weight per m^2.

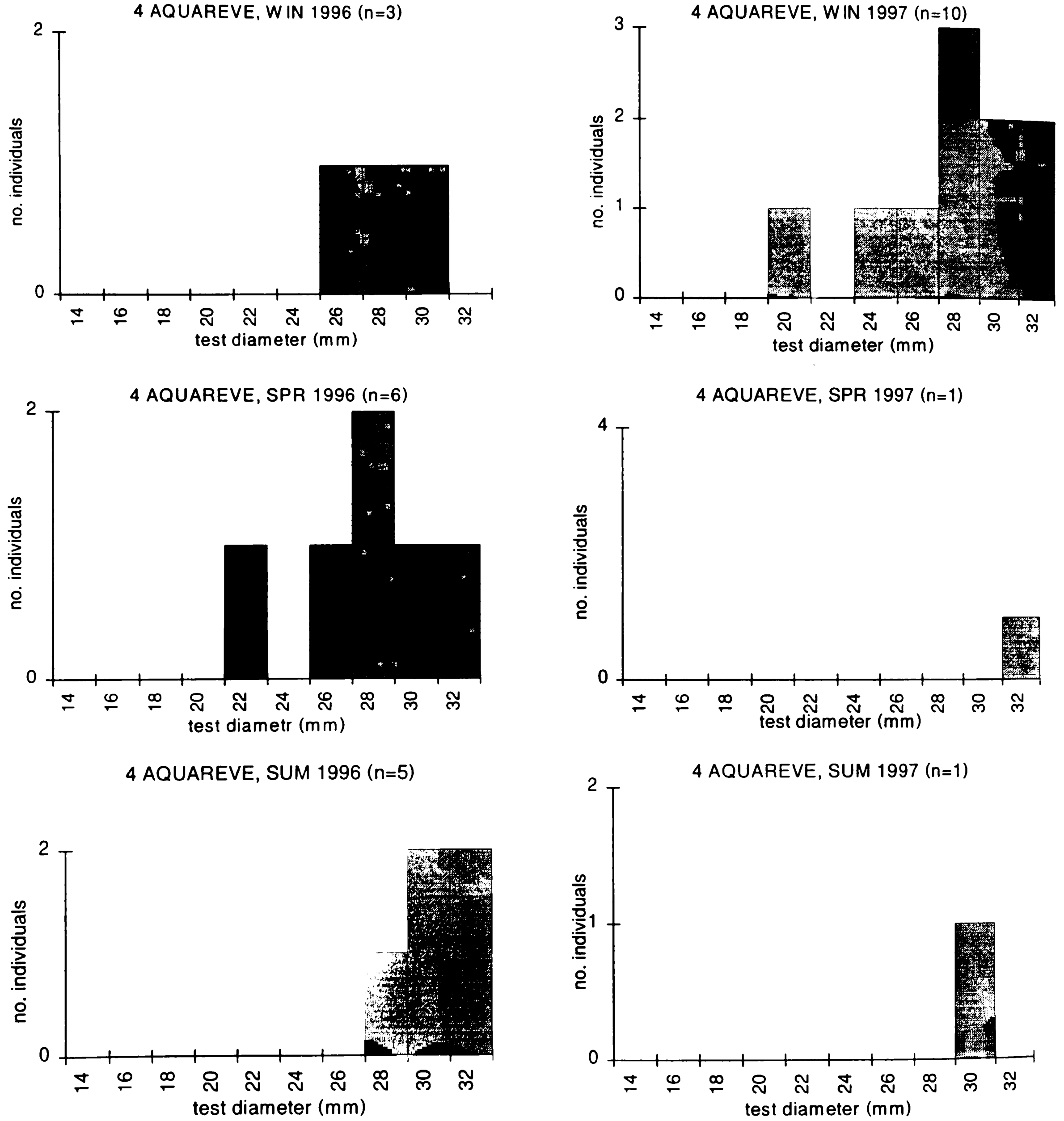
Fig. 3.218. A) Mean number and B) biomass (g dry weight) of *P. miliaris* per 1m^2 at UBGI. Error bars = SD, N = number of AQUAREVE samples analysed.



Variation of the population size-structure of *P.miliaris* was not easy to interpret because of the small number of individuals of this species sampled on the impacted ground (Fig. 3.219). During the entire sampling period, the sea urchins encountered measured between 20 and 30mm and no recruitment of juveniles was detected.

The two sampling years were different in term of biomass and abundance seasonality. In 1996, the maximum for these two parameters was reached in spring, yet this season was the minimum for 1997. The highest values in these two sampling years was reached during winter 1997 months.

Fig. 3.219. Size-frequency histograms for *Psammechinus miliaris* collected seasonally in AQUAREVE at UBGI from 1996–1998. WIN = winter, SPR = spring, SUM = summer, AUT = autumn.



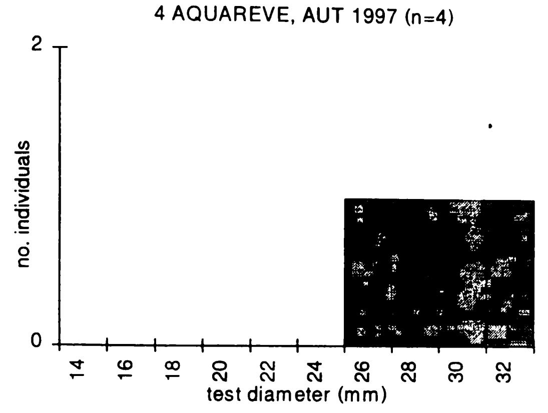
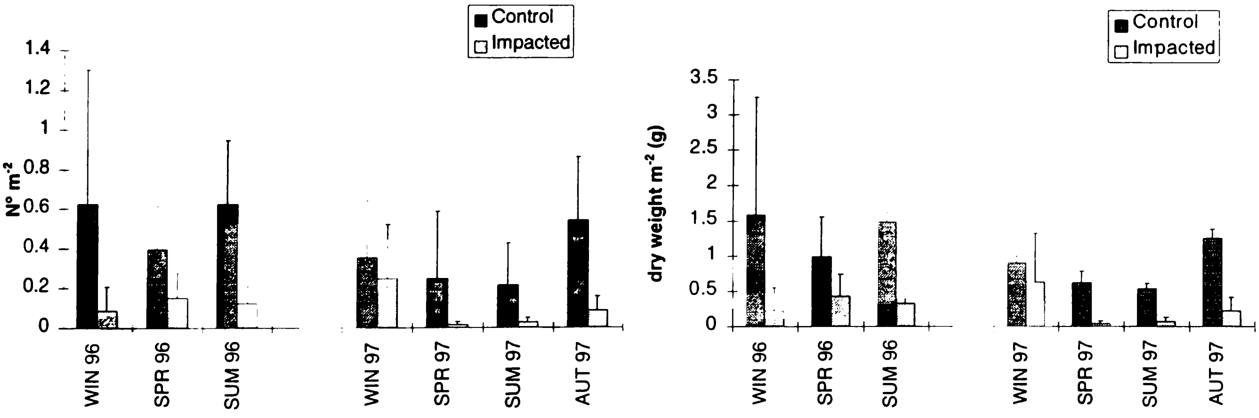


Fig. 3.220. Comparison of seasonal variation in population density and biomass of *P.miliaris* between the control and impacted sites in the Glenan for 1996 and 1997.



P. miliaris was more abundant on the control ground than on the impacted throughout the sampling period (Fig. 3.220). It should be noted that seasonal variations were similar on both grounds for the two years.

3) Galicia

Polygordius lacteus **Schneider, 1868.**

This archiannelid lives in infralittoral sediments ("Amphioxus sand") or, less often, in the intertidal zone (Jouin, 1971).

It is <10 cm long and 1.5 mm in diameter. Its colour is whitish (male) or reddish (ripe female).(Orensanz, 1987).

Fig. 3.221: A) Mean number and B) biomass (g wet weight) of *Polygordius lacteus* per 0.1 m^2 grab at USC. Error bars = SD, N = six grabs analysed

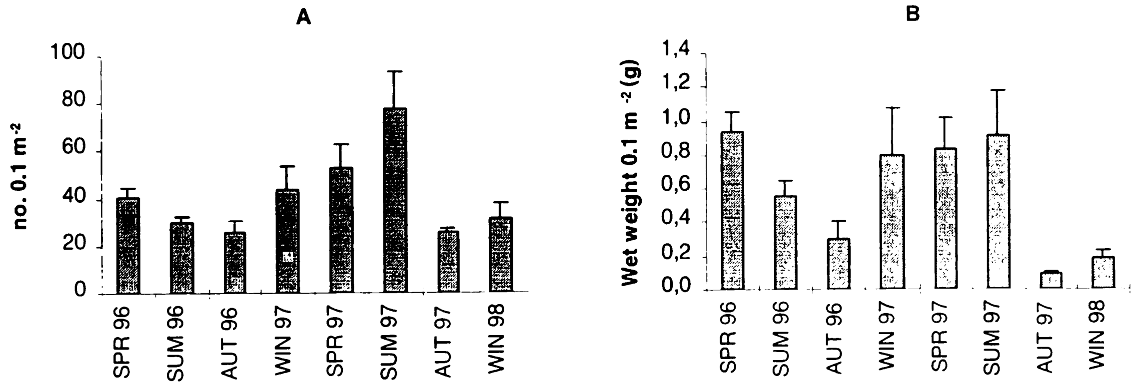


Figure 3.221 shows the seasonal variation in abundance and biomass at the control sites (USC). The size-frequency distribution of this species over the period sampled (1996-1998) at USC is shown in Figure 3.222.

Fig. 3.222. Size-frequency histograms for *Polygordius lacteus* collected seasonally in 0.1 m^2 at USC from 1996-1998. AP = April, JL = July, OC = October, JAN = January

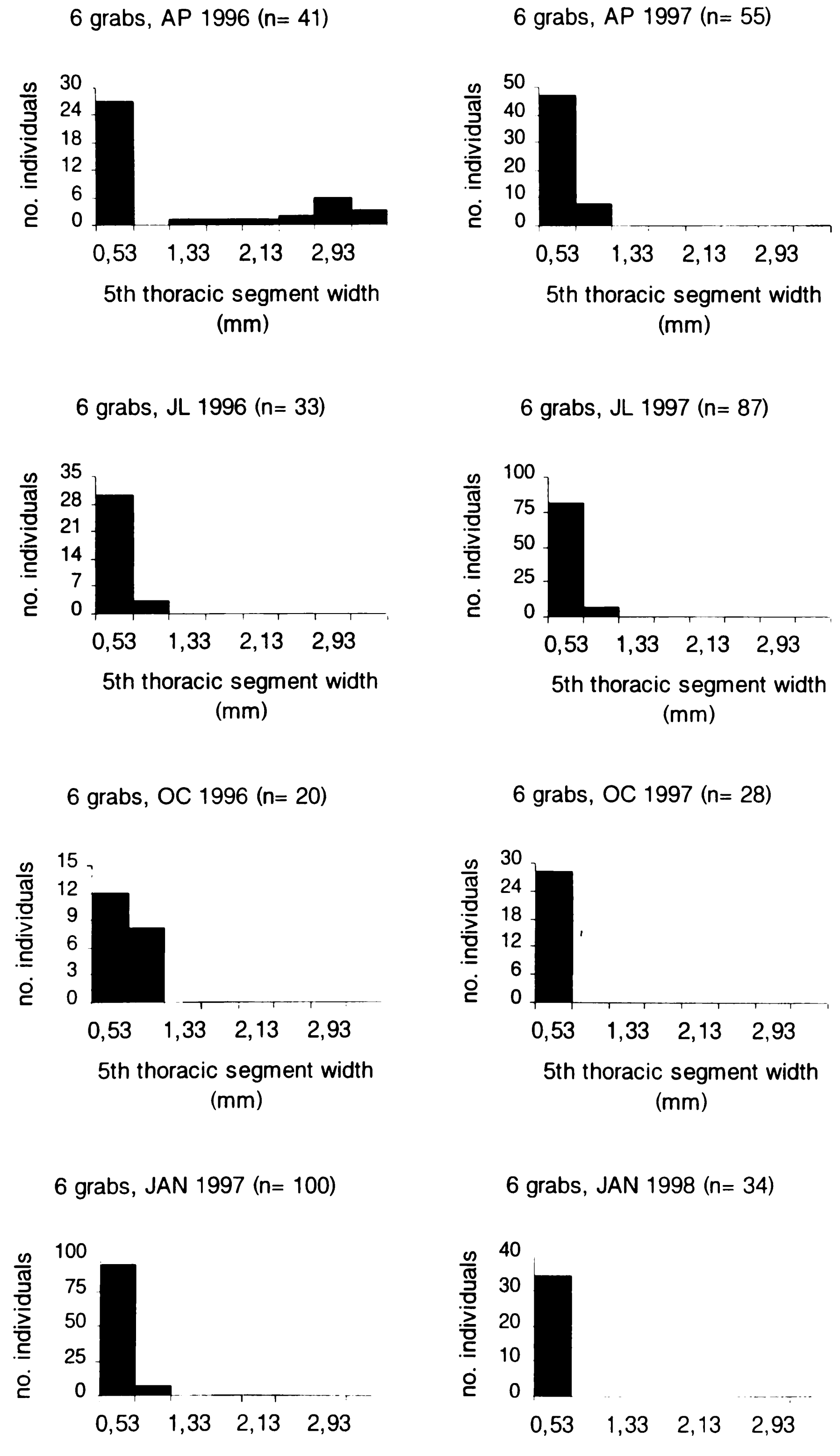
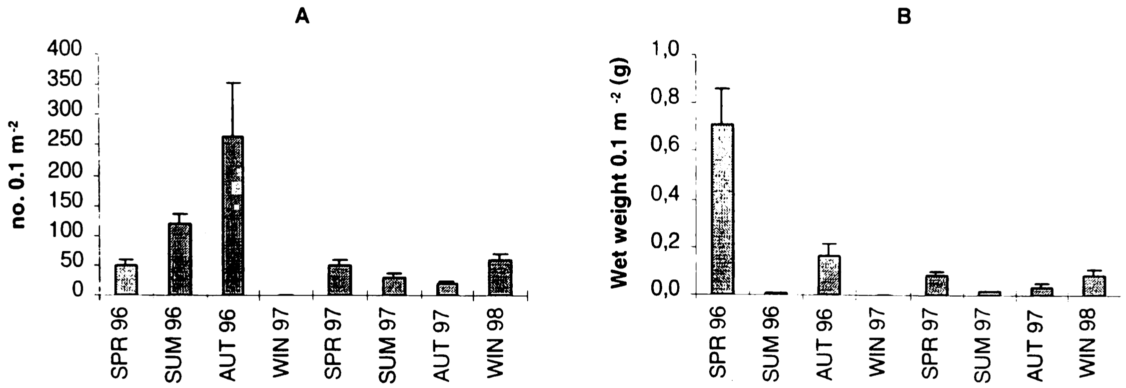
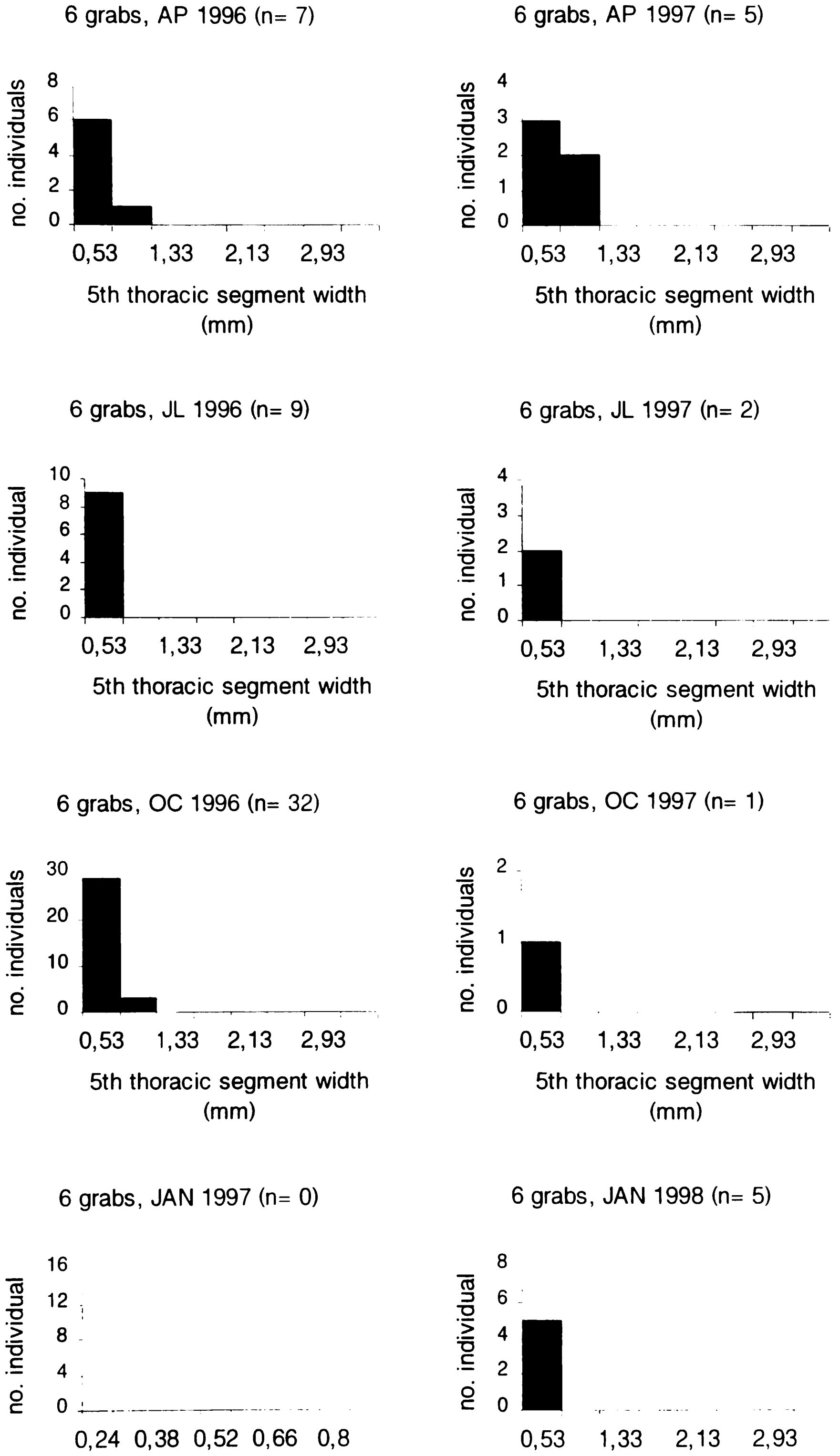


Fig. 3.223. A) Mean number and B) biomass (g wet weight) of *Polygordius lacteus* per 0.1 m^2 grab at USI. Error bars = SD, N = six grabs analysed



Figures 3.223 and 3.224 show the data for the impacted site (USI).

Fig. 3.224. Size-frequency histograms for *Polygordius lacteus* collected seasonally in 0.1 m^2 at USI from 1996-1998. AP = April, JL = July, OC = October, JAN = January



6 grabs, AP 1996 (n= 7)

6 grabs, AP 1997 (n= 5)

6 grabs, JL 1996 (n= 9)

6 grabs, JL 1997 (n= 2)

6 grabs, OC 1996 (n= 32)

6 grabs, OC 1997 (n= 1)

6 grabs, JAN 1997 (n= 0)

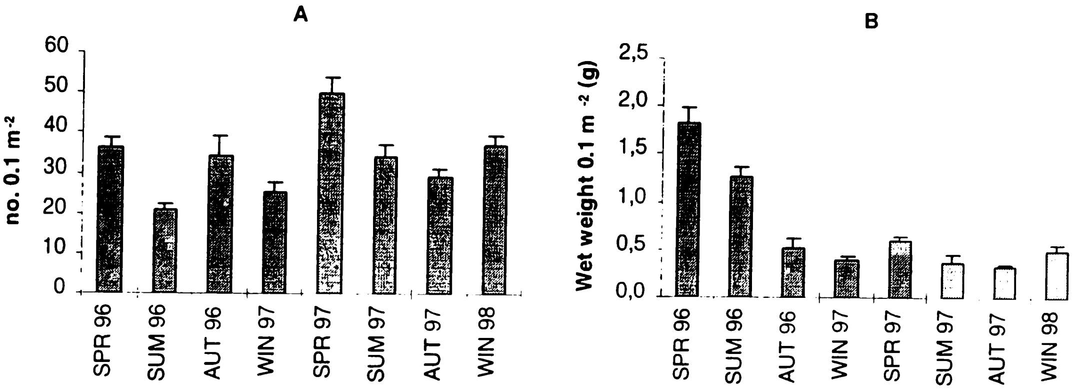
6 grabs, JAN 1998 (n= 5)

Notomastus latericeus M Sars 1851

This species is considered to be a selective deposit-feeder. The list of gut contents, however, nearly always includes algal fragments with sand and silt. Less opportunistic species, such as *Notomastus latericeus,* prove to be more selective.

This capitellid is tube-forming as a juvenile but becomes free-living as adult. Adult *Notomastus* spp. build partially spiralled burrows that maintain integrity for some time after construction, but which lack a distinct wall structure.

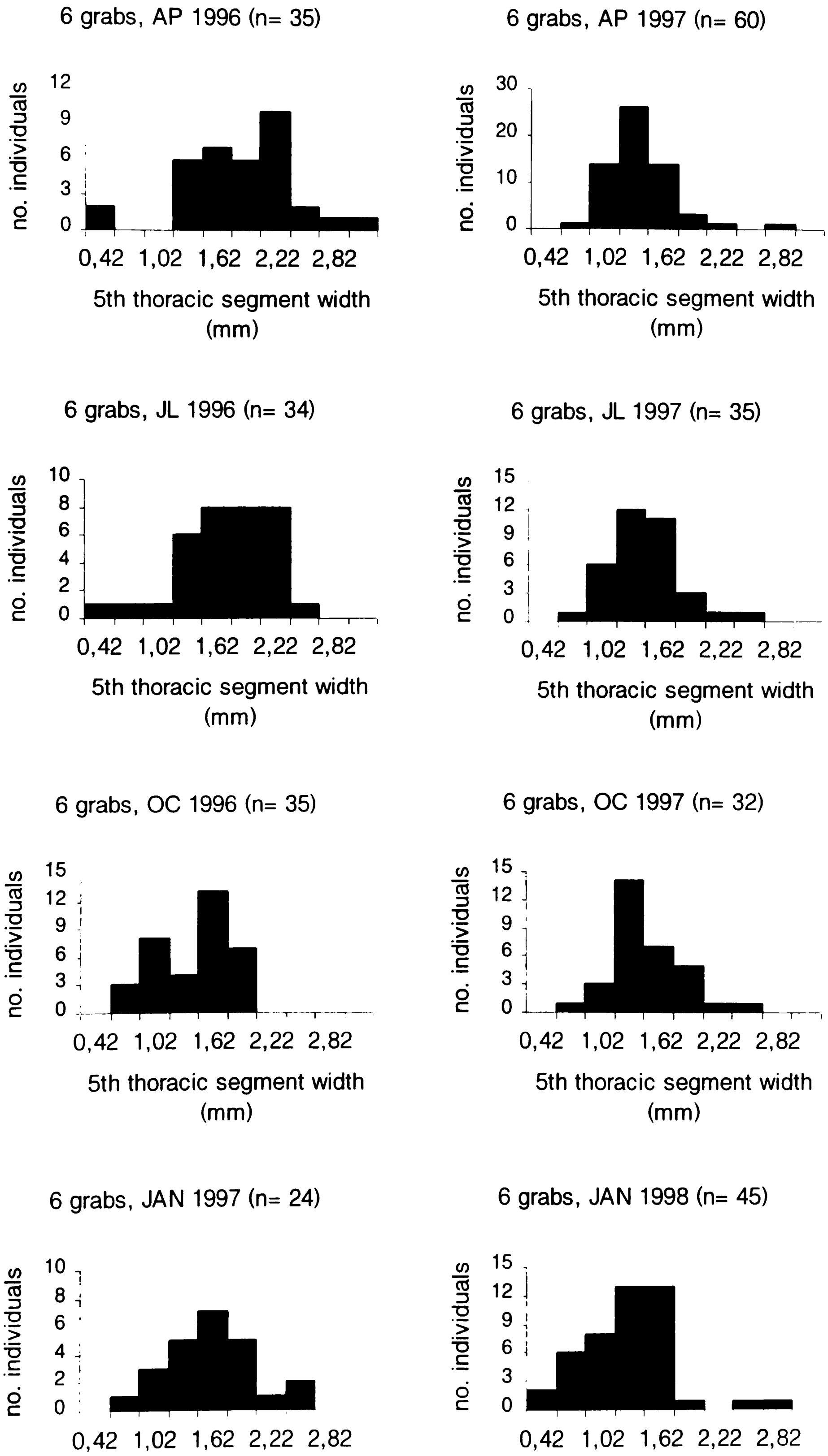
Fig. 3.225 A) Mean number and B) biomass (g wet weight) of *Notomastus latericeus* per 0.1 m^2 grab at USC. Error bars = SD, N = six grabs analysed



Notomastus latericeus was one of the most important of the key species, both in terms of abundance and biomass at the control site. It was consistently present in all seasons, reaching the highest values in spring (1997 and 1996) (Fig. 3.225 A). Abundances were not very high (maximum of 50 ind. /0.1m^2) compared with other more opportunistic species as *Mediomastus fragilis*. Biomass was highest in spring 1996, and decreased slowly in summer, autumn and winter, increasing again slightly in spring 1997 (Fig. 3.225 B).

Figure 3.226 shows *N. latericeus* size-frequency distribution. The maximum number of small individuals was collected in spring 1997 (60 ind./0.1 m^2).

Fig. 3.226. Size-frequency histograms for *Notomastus latericeus* per 0.1 m^2 grab at USC from 1996-1998. AP= April, JL= July, OC= October, JAN= January.



6 grabs, AP 1996 (n= 35)

6 grabs, AP 1997 (n= 60)

6 grabs, JL 1996 (n= 34)

6 grabs, JL 1997 (n= 35)

6 grabs, OC 1996 (n= 35)

6 grabs, OC 1997 (n= 32)

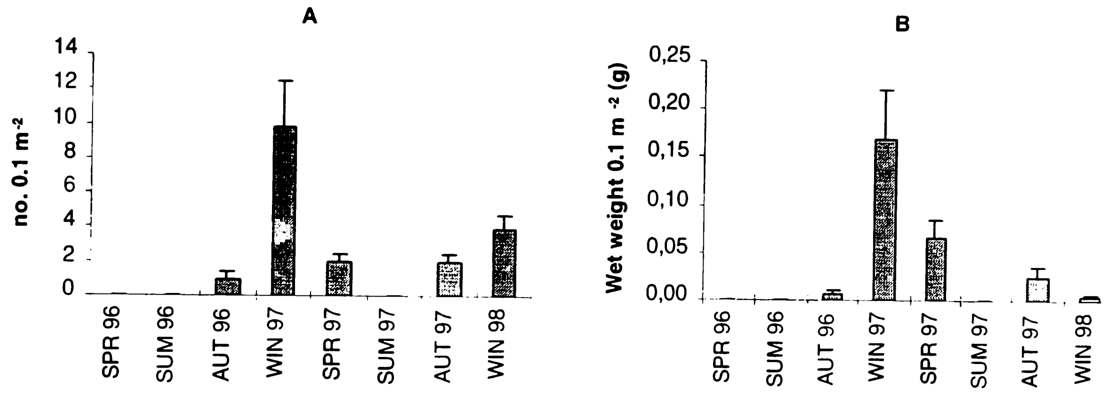
6 grabs, JAN 1997 (n= 24)

6 grabs, JAN 1998 (n= 45)

Eunice vittata (Chiaje, 1828)

This eunicid is mostly free-living as a juvenile, becoming tubicolous as it gets older. Eunicids are not exclusively carnivores, but free-living or tubicolous species of *Eunice* are primarily carnivores, feeding on all kinds of small invertebrates. This species inhabits sand, mud, gravel and rocky areas, and is found also among algae, sponges, and corals.

Fig. 3.227. A) Mean number and B) biomass (g wet weight) of *Eunice vittata* per 0.1 m^2 grab at USC. Error bars = SD, N = six grabs analysed



Eunice vittata has been found occasionally, in fluctuating abundances, through the two-year period, reaching its maximum in the winter of both years and being absent in summer (1996 and 1997).

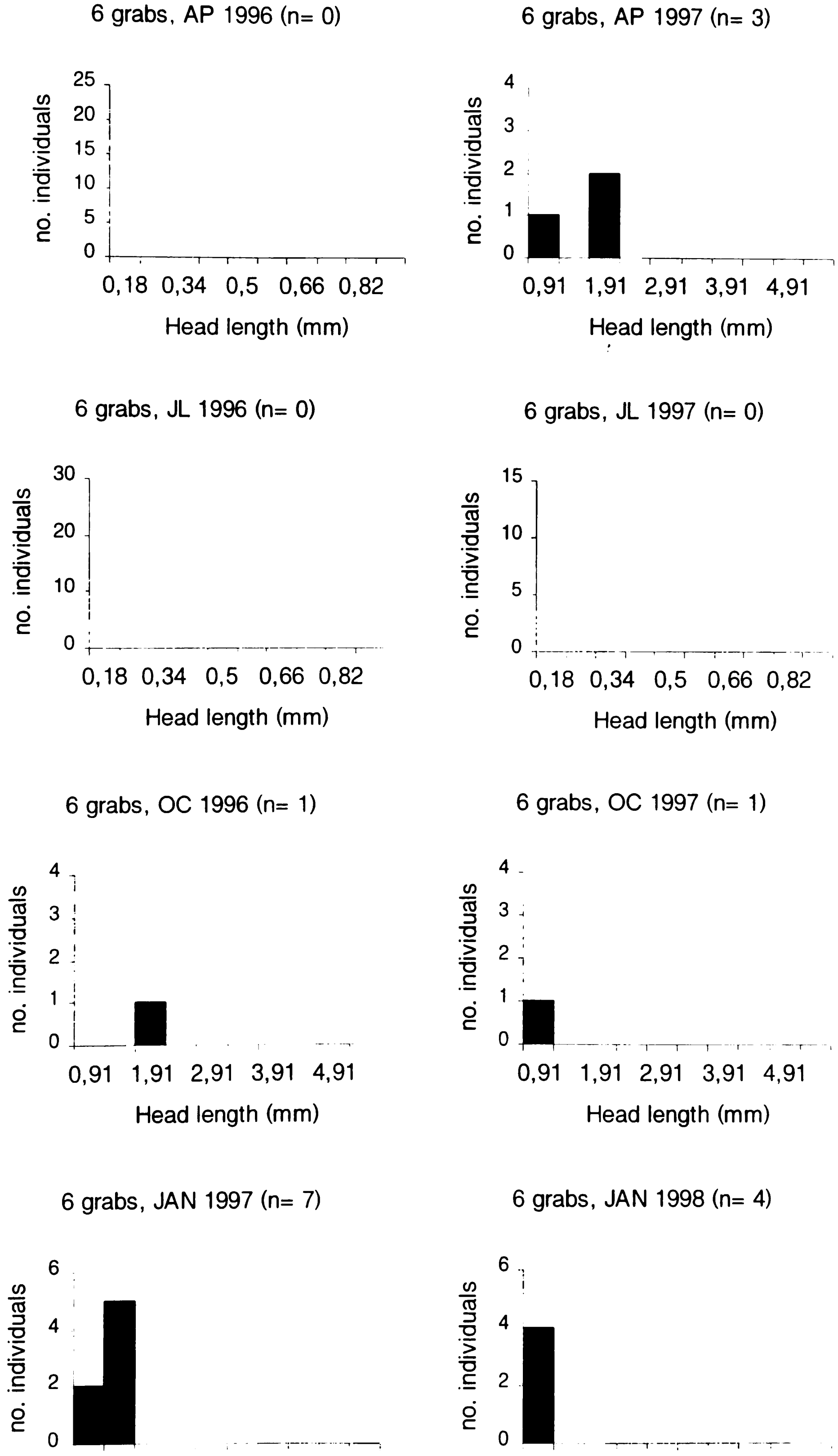
It was not a very abundant species (Fig. 3.227 A) and was only present at the control site (as a consequence of its trophic habits, preferentially based on predation?).

Adult specimens of higher biomass were found in winter 1996/7, which is illustrated in Fig. 3.227 B, where biomass over this period was the highest recorded for this species.

The seasonal variation of size-frequency of the *Eunice vittata* population at the control station USC is shown in Fig. 3.228. Mostly small individuals (up to 1.91 mm head length) were found in the two years of study.

No seasonal pattern could be detected from the size-frequency measures because of its scarcity and the small size of individuals present in all seasons.

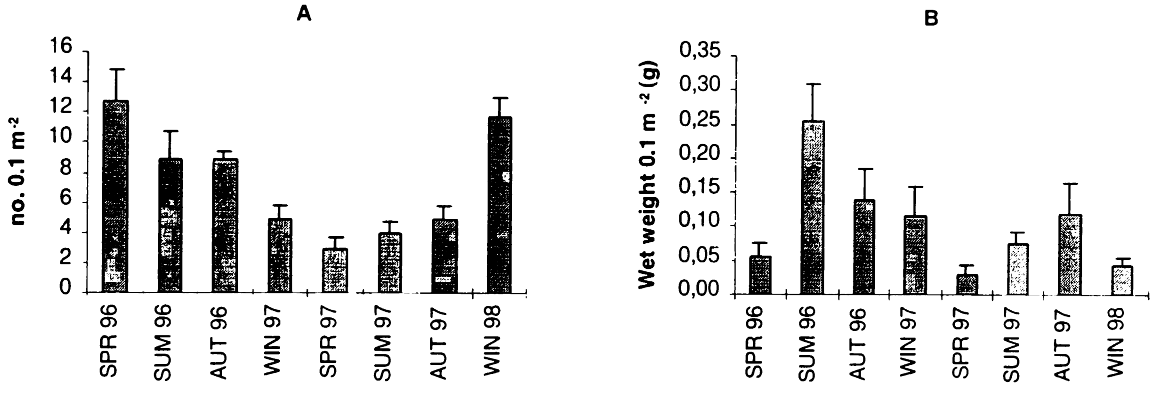
Fig. 3.228. Size-frequency histograms for *Eunice vittata* per 0.1 m^2 grab at USC from 1996-1998. AP= April, JL= July, OC= October, JAN= January.



Glycera lapidum Quatrefages, 1866

Glycera lapidum is a slender, long-bodied polychaete which, on morphological grounds is presumed to have a carnivorous habit, this being the primary feeding mode among the glycerids (but an unknown, probably small, number of species are thought to have become detritivores).

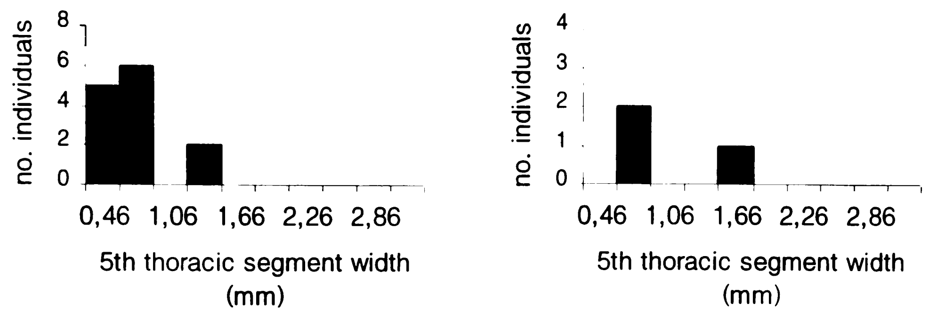
Fig. 3.229. A) Mean number and B) biomass (g wet weight) of *Glycera lapidum* per 0.1 m^2 grab at USC. Error bars = SD, N = six grabs analysed



Glycera lapidum was one of the scarcer species consistently present at the control site. Its seasonal pattern through the first year of study showed highest numbers in spring 1996, decreasing towards the winter period of the same year (Fig. 3.229 A). The pattern is reversed during the second year (1997), with lowest numbers in spring and maximum values in winter. This may be interpreted as the recovery of the *Glycera lapidum* population over more than one year. The biomass data (Fig. 3.229 B) support this interpretation, since recruits were maximum in spring 1996 and were not high again until winter 1998 (in both seasons biomass values were very low).

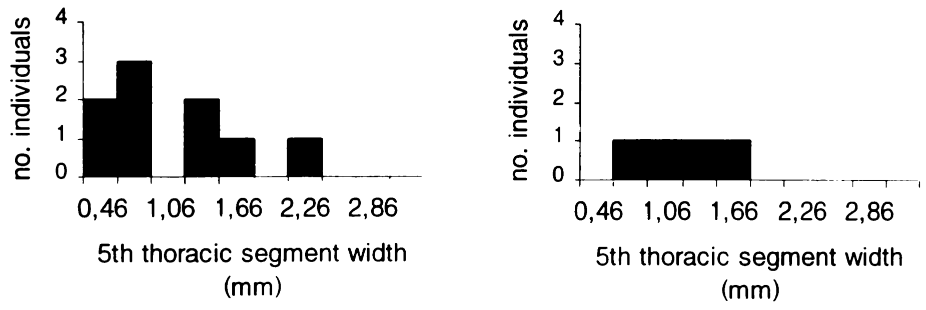
The size-frequency seasonal variation of *Glycera lapidum* population at the control station USC is shown in Fig. 3.230. Small individuals (up to 2.46 mm width at the 5th thoracic segment) were mostly found in the two years of study, with the exception of spring 1996.

Fig. 3.230. Size-frequency histograms for *Glycera lapidum* per 0.1 m^2 grab at USC from 1996-1998. AP= April, JL= July, OC= october, JAN= January.



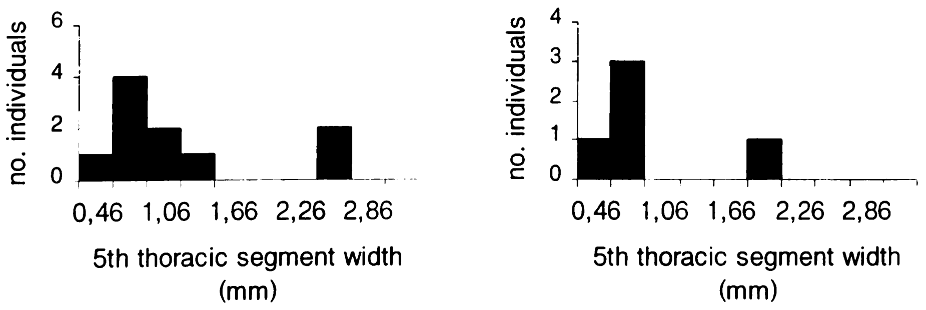
6 grabs, AP 1996 (n= 13)

6 grabs, AP 1997 (n= 3)



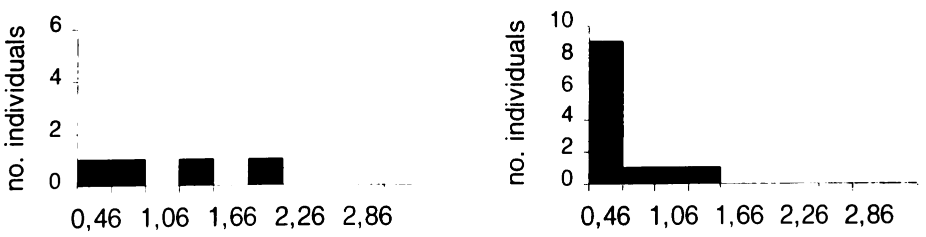
6 grabs, JL 1996 (n= 9)

6 grabs, JL 1997 (n= 4)



6 grabs, OC 1996 (n= 10)

6 grabs, OC 1997 (n=5)



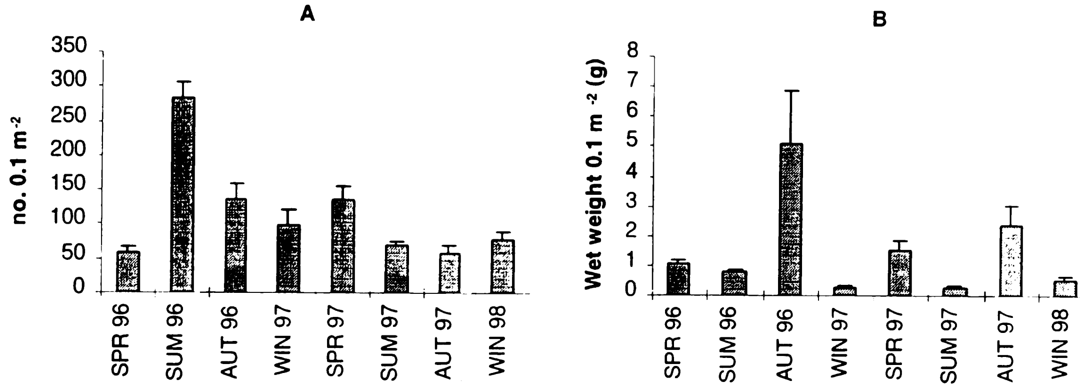
6 grabs, JAN 1997 (n= 4)

6 grabs, JAN 1998 (n= 12)

No seasonal pattern could be detected from the size-frequency distributions in spite of its abundance because only small individuals were present.

This species was also present at the impacted site (USI) with significantly higher numbers than at the control (USI: 280 ind/0.1 m^2; USC: 12 ind/0.1 m^2) (Fig. 3.231 A). The highest numbers occurred in summer 1996. For the rest of the year it was relatively constant and below 140 ind/0.1 m^2. Biomass reached its highest in autumn 1996, repeating maximum values in the second year of study (1997) (Fig. 3.231 B).

Fig. 3.231. A) Mean number and B) biomass (g wet weight) of *Glycera lapidum* per 0.1 m^2 grab at USI. Error bars = SD, N = six grabs analysed



The seasonal variation in size-frequency of *Glycera lapidum* at the impacted site USI is shown in Fig. 3.232. Here, two size-classes can be separated: a juvenile stage (individuals between 0.46 and 1.36 mm width at the 5th thoracic segment) and another more mature stage (individuals between 1.36 and 3.46 mm width); the latter was found in summer and autumn 1996 and 1997.

Fig. 3.232. Size-frequency histograms for *Glycera lapidum* per 0.1 m^2 grab at USC from 1996-1998. AP= April, JL= July, OC= October, JAN= January.

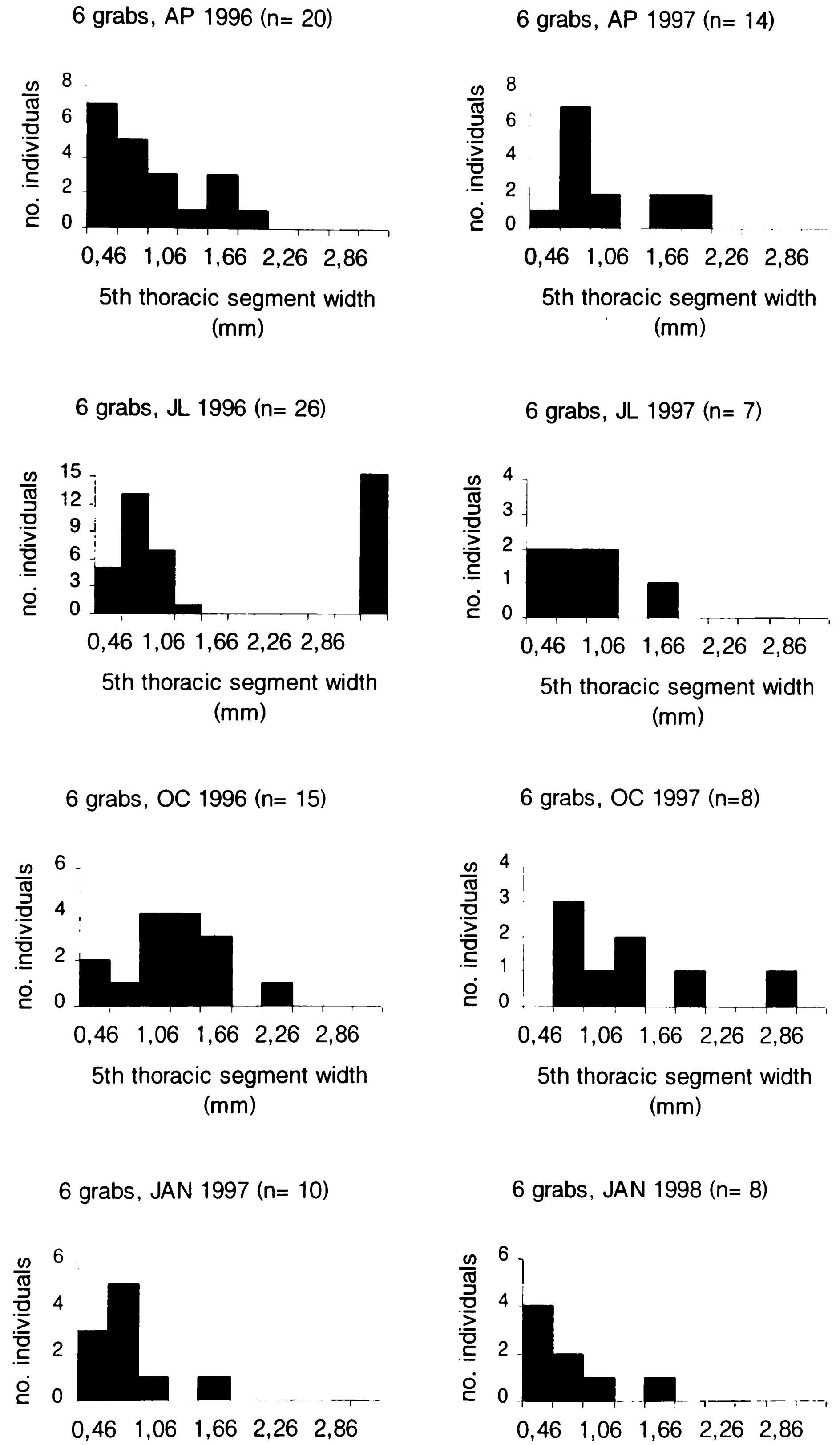
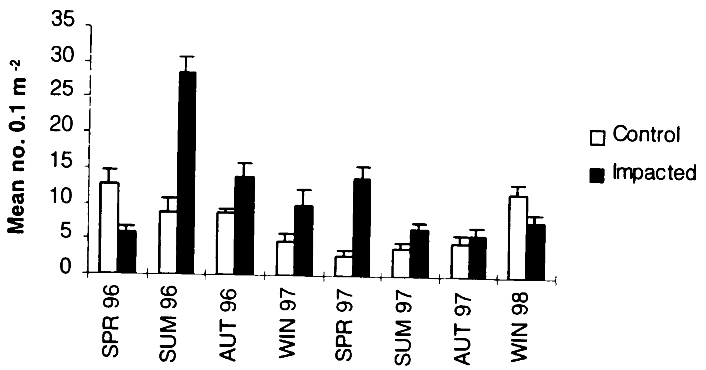
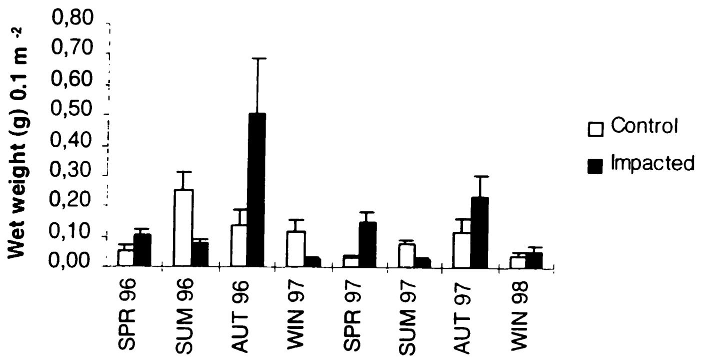


Fig. 3.233.

Seasonal variation in abundance of *Glycera lapidum* on control and impacted grounds in Ría de Vigo



Seasonal variation in biomass of *Glycera lapidum* on control and impacted grounds in



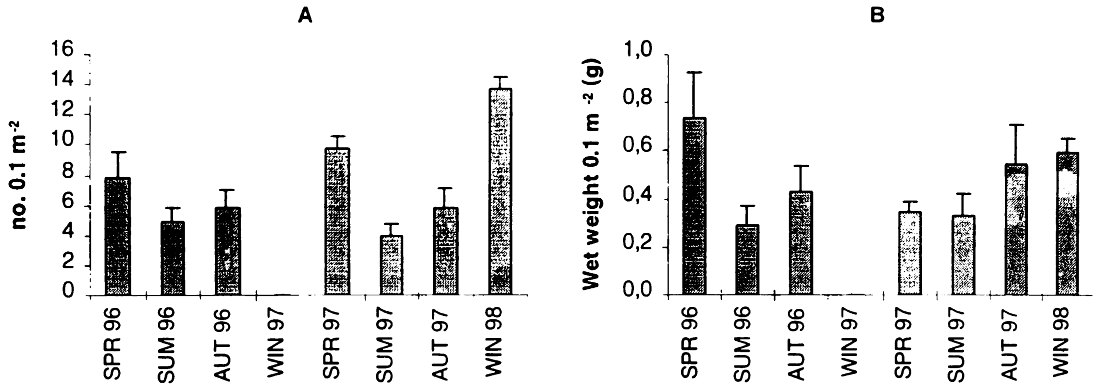
Ría de Vigo

Figure 3.233 compares the abundance and biomass of *Glycera lapidum* on the control and the impacted sites. This species was much more abundant on the impacted ground, both in terms of abundance and biomass, except in winter and spring 1996. The greatest numbers of this species were collected in summer 1996 whereas highest biomass was recorded in autumn of the same year.

Pista cristata (O F Müller, 1976)

This rather large terebellid polychate is usually tubicolous Its food is detritus, usually including diatoms, other unicellular algae, and various small invertebrates.

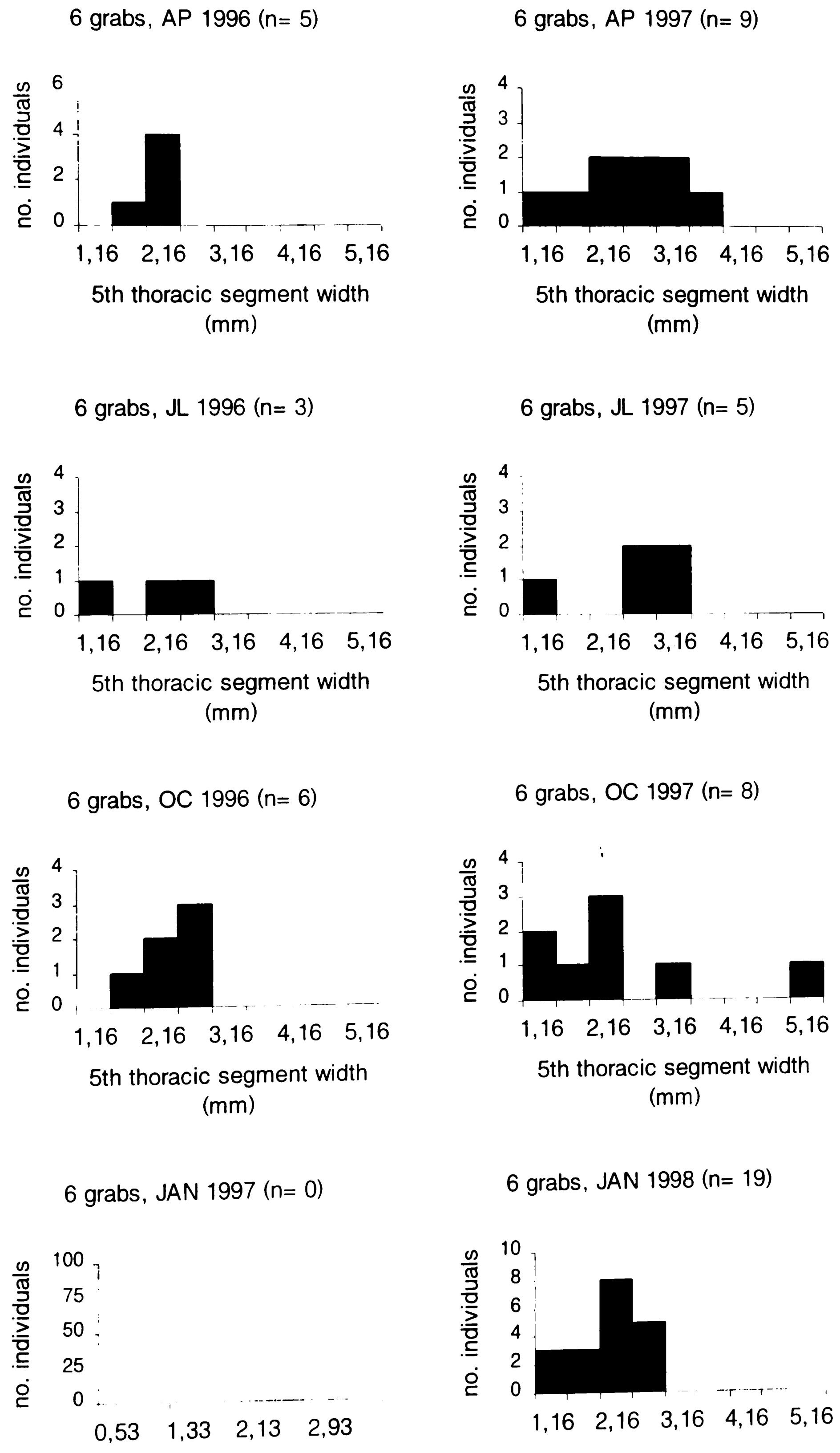
Fig. 3.234. A) Mean number and B) biomass (g wet weight) of *Pista cristata* per 0.1 m^2 grab at USC. Error bars = SD, N = six grabs analysed



Pista cristata was, together with *Notomastus latericeus,* a consistent species at the control site though never very abundant. It was not found in winter 1997, though it had maximum densities in winter 1998 (Fig. 3.234 A). The biomass data (Fig. 3.234 B) showed a constant trend ranging between 0.3 and 0.7g/0.1 m^2 (the last maximum observed in spring 1996).

The size-frequency distribution for *Pista cristata* is shown for the control ground in Fig. 3.235. Small individuals were collected during the first year of study while bigger ones appeared from spring to autumn 1997.

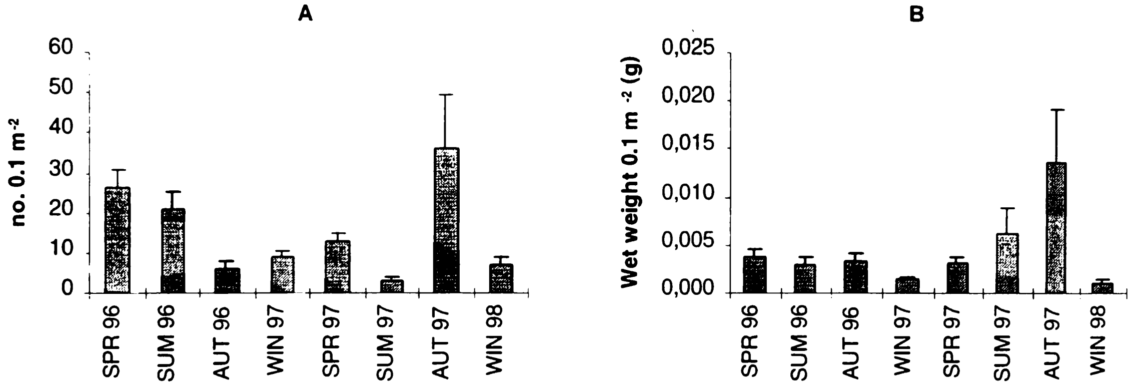
Fig. 3.235. Size-frequency histograms for *Pista cristata* per 0.1 m^2 grab at USC from 1996-1998. AP= April, JL= July, OC= October, JAN= January.



Leptocheirus tricristatus (Chevreux, 1887)

This tube-dwelling amphipod has a depth range about 0-20 metres amongst algae on coarse bottom sediments like maerl. *L. tricristatus* was not a very abundant species but it was recorded in all seasons at the control site. It showed no clear seasonality between 1996-1997 and 1997-1998.

Fig. 3.236. A) Mean number and B) biomass (wet weight) of *Leptocheirus tricristatus* per 0.1 m^2 grab at USC. Error bars = SD, N = six grabs analysed

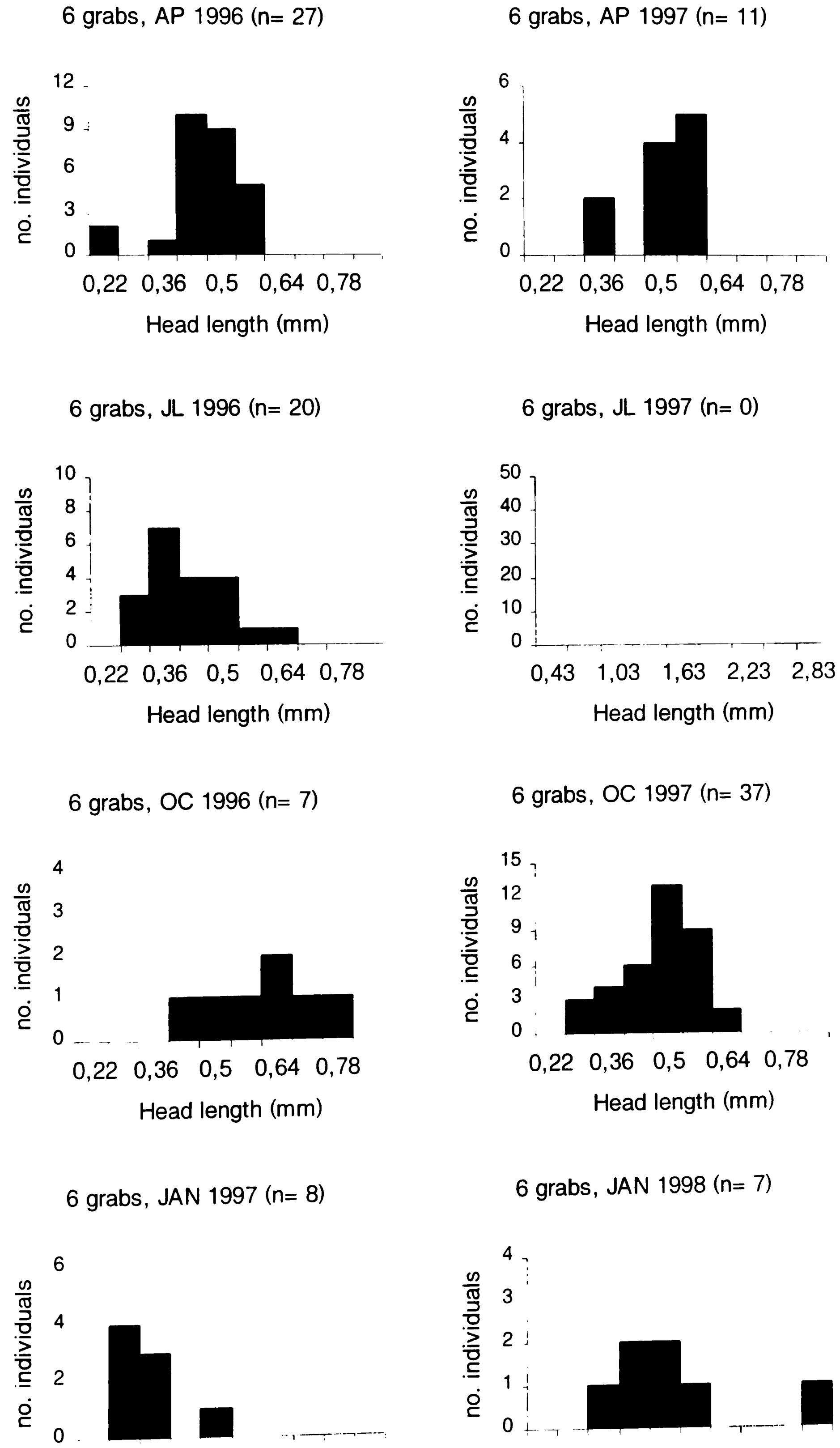


For *Leptocheirus tricristatus* maximum values were recorded in autumn 1997 (for numbers and biomass) with a minimum abundance in summer of the same year (Fig. 3.236 A & B).

The temporal variation of size-frequency of *Leptocheirus tricristatus* (based on head length) on the control site is shown in Fig. 3.237. It was collected in all the seasonal samples except in summer 1997; small individuals appeared all through the two year period and no seasonal replacement of cohorts could be discerned between 1996 and 1998.

Juvenile individuals were dominant in the spring and summer months whereas adults were found in higher numbers in autumn and winter.

Fig. 3.237. Size-frequency histograms for *Leptocheirus tricristatus* per 0.1 m^2 grab at USC from 1996-1998. AP= April, JL= July, OC= October, JAN= January.



6 grabs, AP 1996 (n= 27)

6 grabs, AP 1997 (n= 11)

6 grabs, JL 1996 (n= 20)

6 grabs, JL 1997 (n= 0)

6 grabs, OC 1996 (n= 7)

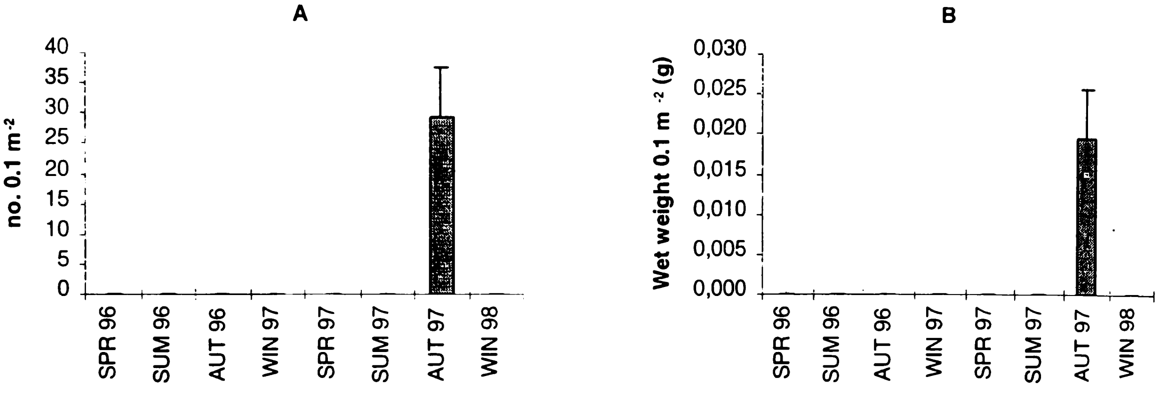
6 grabs, OC 1997 (n= 37)

6 grabs, JAN 1997 (n= 8)

6 grabs, JAN 1998 (n= 7)

At the impacted site *Leptocheirus tricristatus* was a very rare species only found in autumn 1997, but then with similar abundance as at the control site (30 individuals/0.1 m^2) (Fig. 3.238).

Fig. 3.238. A) Mean number and B) biomass (wet weight) of *Leptocheirus tricristatus* per 0.1 m^2 grab at USI. Error bars = SD, N = six grabs analysed



In Figure 3.239 the seasonal variation in size-frequency of *L. tricristatus* at the impacted site is shown.

Fig. 3.239. Size-frequency histograms for *Leptocheirus tricristatus* per 0.1 m^2 grab at USI from 1996-1998. AP= April, JL= July, OC= October, JAN= January.

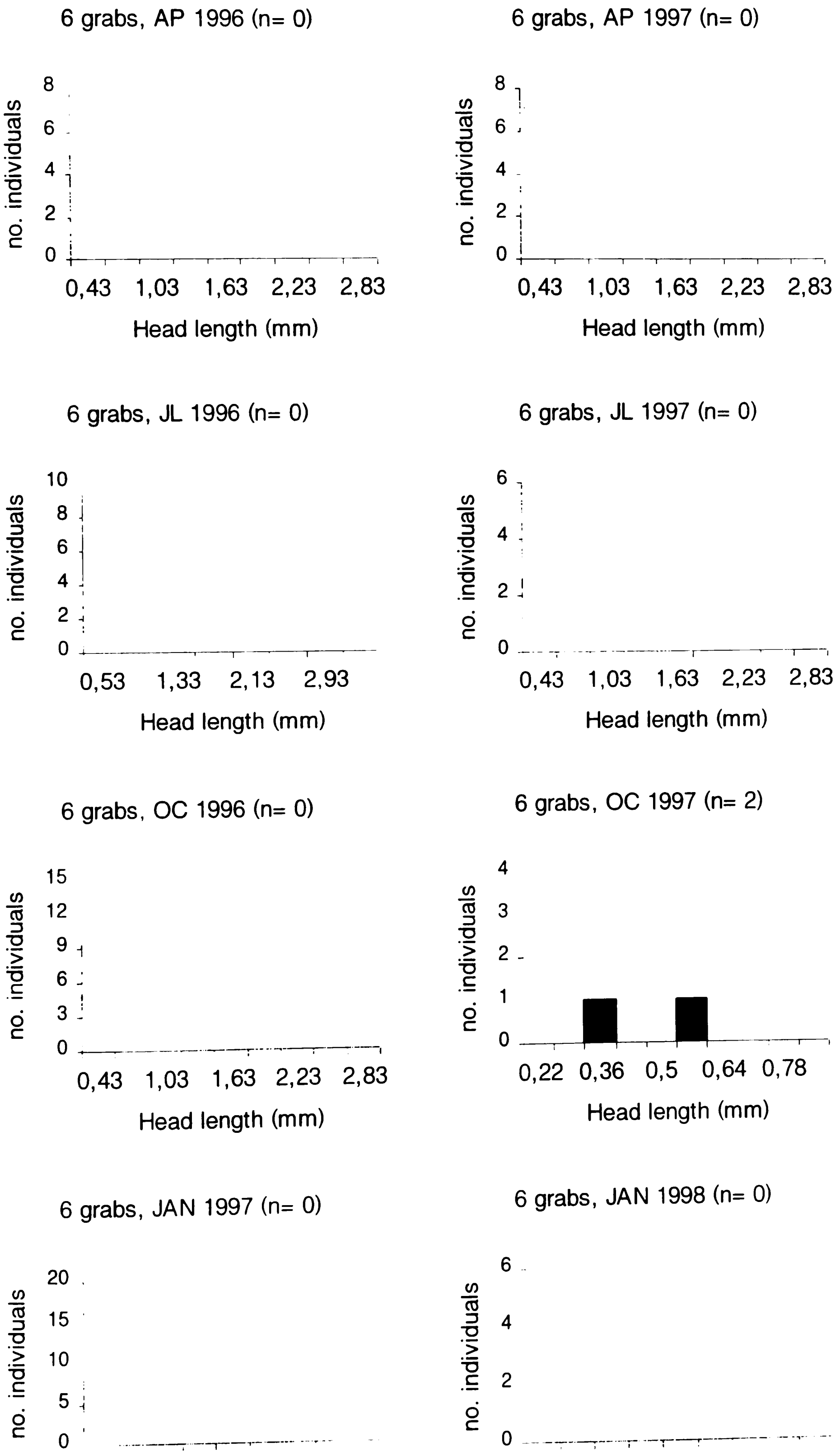
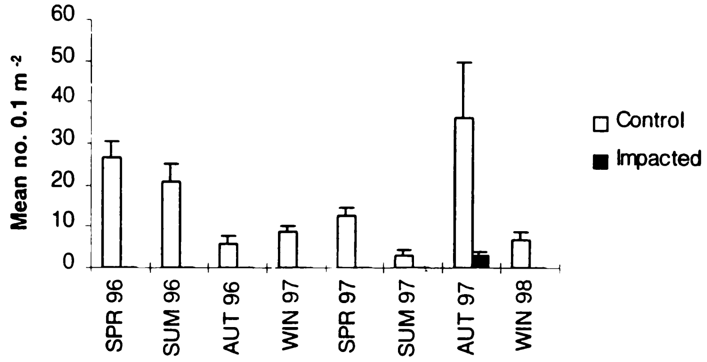
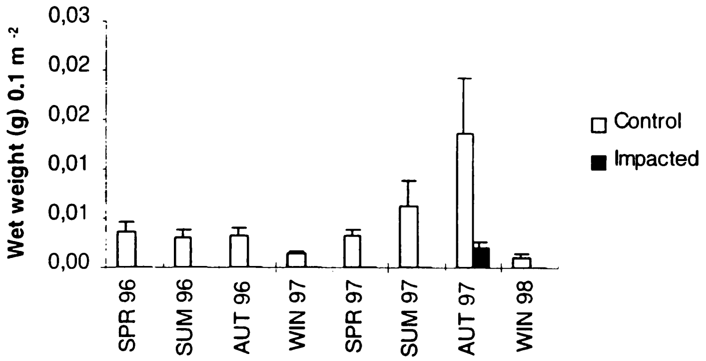


Fig. 3.240.

Seasonal variation in abundance of *Leptocheirus tricristatus* on control and impacted grounds in Ría de Vigo



Seasonal variation in biomass of *Leptocheirus tricristatus* on control and impacted grounds in Ría de Vigo

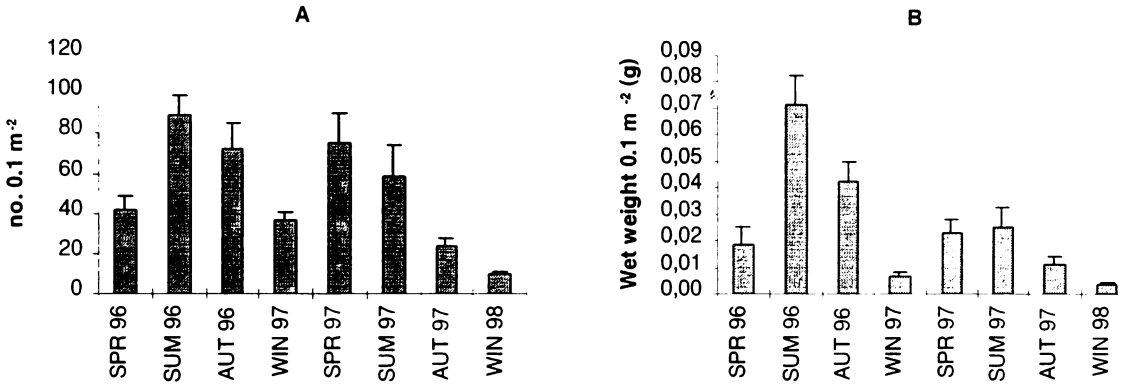


As can be observed from the comparison of the control and the impacted grounds through two seasonal cycles (Fig. 3.240) *Leptocheirus tricristatus* was only constantly present and abundant at the control site whereas at the impacted site is almost non-existent For the control site no seasonal pattern can be observed for this species.

***Socarnes erythrophthalmus* (Robertson, 1892).**

This amphipod normally inhabits the depth range 0-50 metres. It can be locally quite common (Chevreux & Fage, 1925) and occasionally intertidal (Lincoln, 1979).

Fig. 3.241. A) Mean number and B) biomass (g wet weight) of *Socarnes erythrophthalmus* per 0.1 m^2 grab at USC. Error bars = SD, N = six grabs analysed



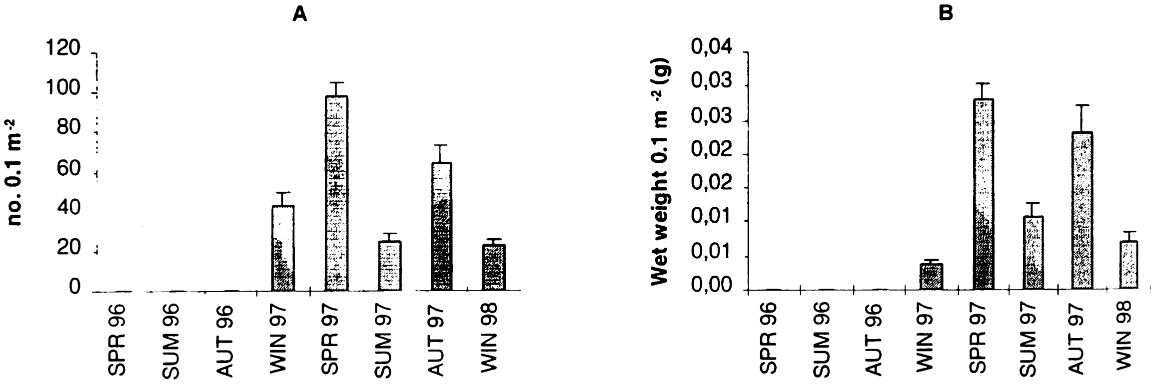
S. erythrophthalmus was one of the key species that was important both on the control and the impacted grounds. It was, together with *G. fucicola* the most abundant on Ria de Vigo maerl grounds. High values for both abundance and biomass were obtained in summer and autumn 1996 with low values in autumn and winter 1997 (Fig. 3.241 A & B).

A seasonal and inter-annual pattern can be observed from Fig. 3.241 A & B with highest values in summer and autumn 1996 and minimum in spring 1996 and winter 1997 and the same pattern though somewhat advanced appearing in spring, reaching the maximum values in spring and summer 1997 and minimum in autumn 1997and winter 1998. The seasonal variation in size frequency of *S. erythropthalmus* at the control site is seen in Fig. 3.242.

The pattern of distribution of *Socarnes erythrophthalmus* on the impacted site did not follow the same scheme as on the control site. The abundances of this species at the impacted site were much higher (up to 1000 ind./0.1m^2) against the fewer 100 ind./0.1m^2 found on the control site. At the impacted ground this amphipod was not distributed constantly along the two year period; in fact, it was only sampled during the second year of study (from winter 1997 to winter 1998).

The highest abundances and biomass for this period were found in spring and autumn 1997, with minimum values being observed in summer and winter. (Fig. 3.243 A & B).

Fig. 3.243. A) Mean number and B) biomass (g wet weight) of *Socarnes erythrophthalmus* per 0.1 m^2 grab at USI. Error bars = SD, N = six grabs analysed



The seasonal variation in size-frequency of *Socarnes erythrophthalmus* at the impacted site USI is shown in Fig. 3.244. Individuals (smaller than 1 mm head length) were found throughout the second year of study. A certain seasonal pattern can be observed from the size-frequency diagram through the year 1997-1998 where small individuals are replaced by the bigger ones from January to July 1997.

Fig. 3.244. Size-frequency histograms for *Socarnes erythrophthalmus* per 0.1 m^2 grab at USI from 1996-1998. AP= April, JL= July, OC= October, JAN= January.

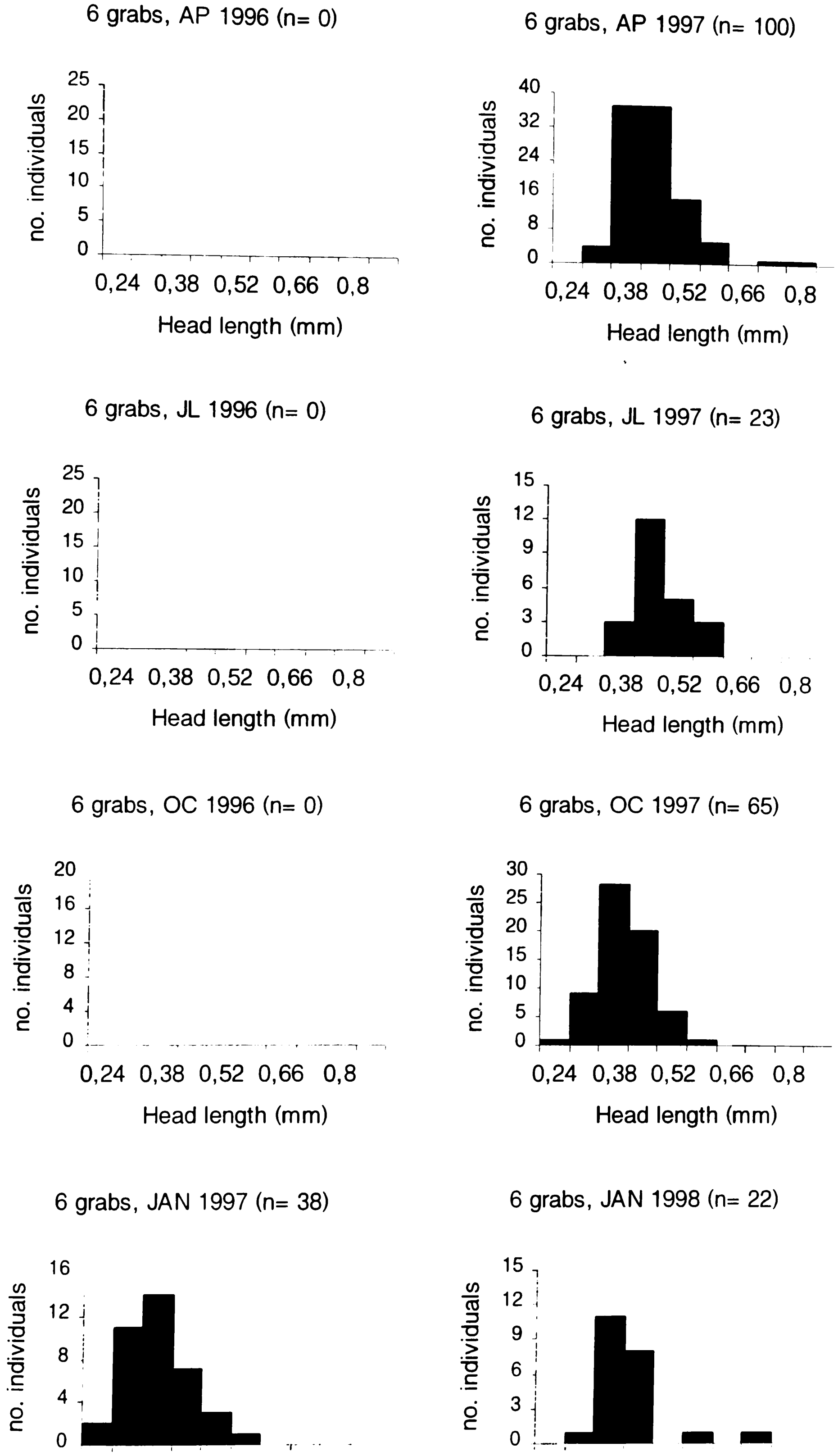
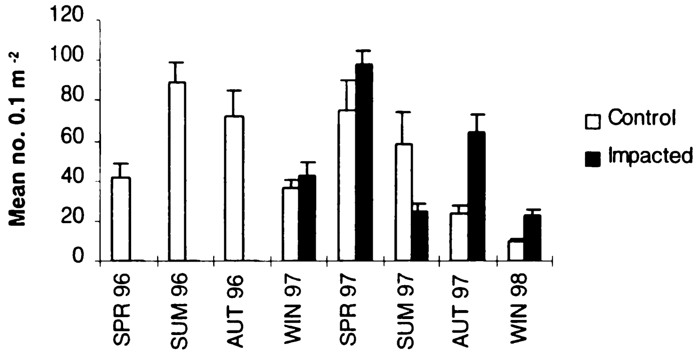
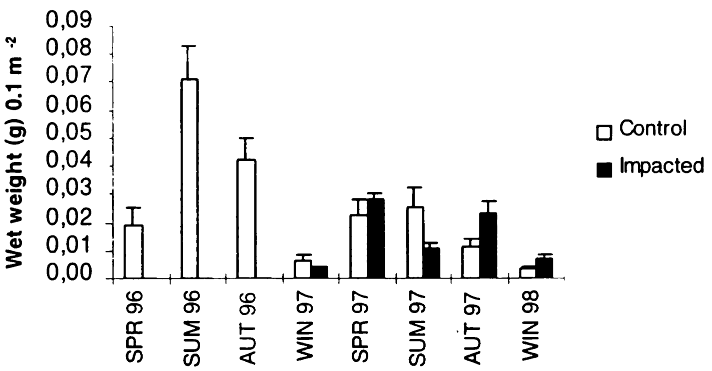


Fig. 3.245.

Seasonal variation in abundance of *Socarnes erythrophthalmus* on control and impacted grounds in Ría de Vigo



Seasonal variation in biomass of *Socarnes erythrophthalmus* on control and impacted grounds in Ría de Vigo



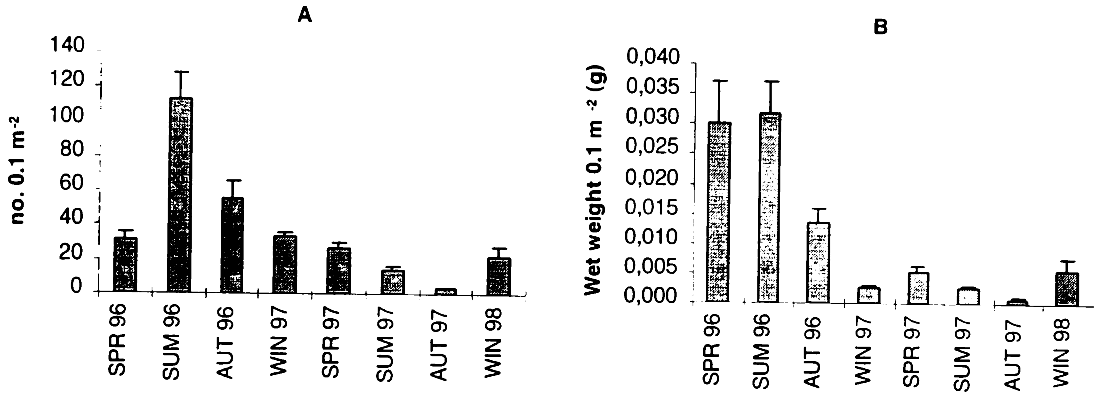
The comparison of abundance and biomass of *Socarnes erythrophthalmus* on the control and the impacted sites is shown at the Fig. 3.245 above. From these figures it is evident that this species was much more consistently abundant at the control site, both in terms of abundance and biomass, except in spring 1997. The greatest numbers and biomass for this species were collected in summer 1996.

At the impacted site it had an almost insignificant biomass during spring, summer and autumn 1996.

Ceradocus semiserratus (Bate, 1862)

The amphipod *C. semiserratus* usually lives among algae (*Peyssonnelia, Lithothamnium*), and from 9 to 45 m deep offshore.

Fig. 3.246. A) Mean number and B) biomass (g wet weight) of *Ceradocus semiserratus* per 0.1 m^2 grab at USC. Error bars = SD, N = six grabs analysed

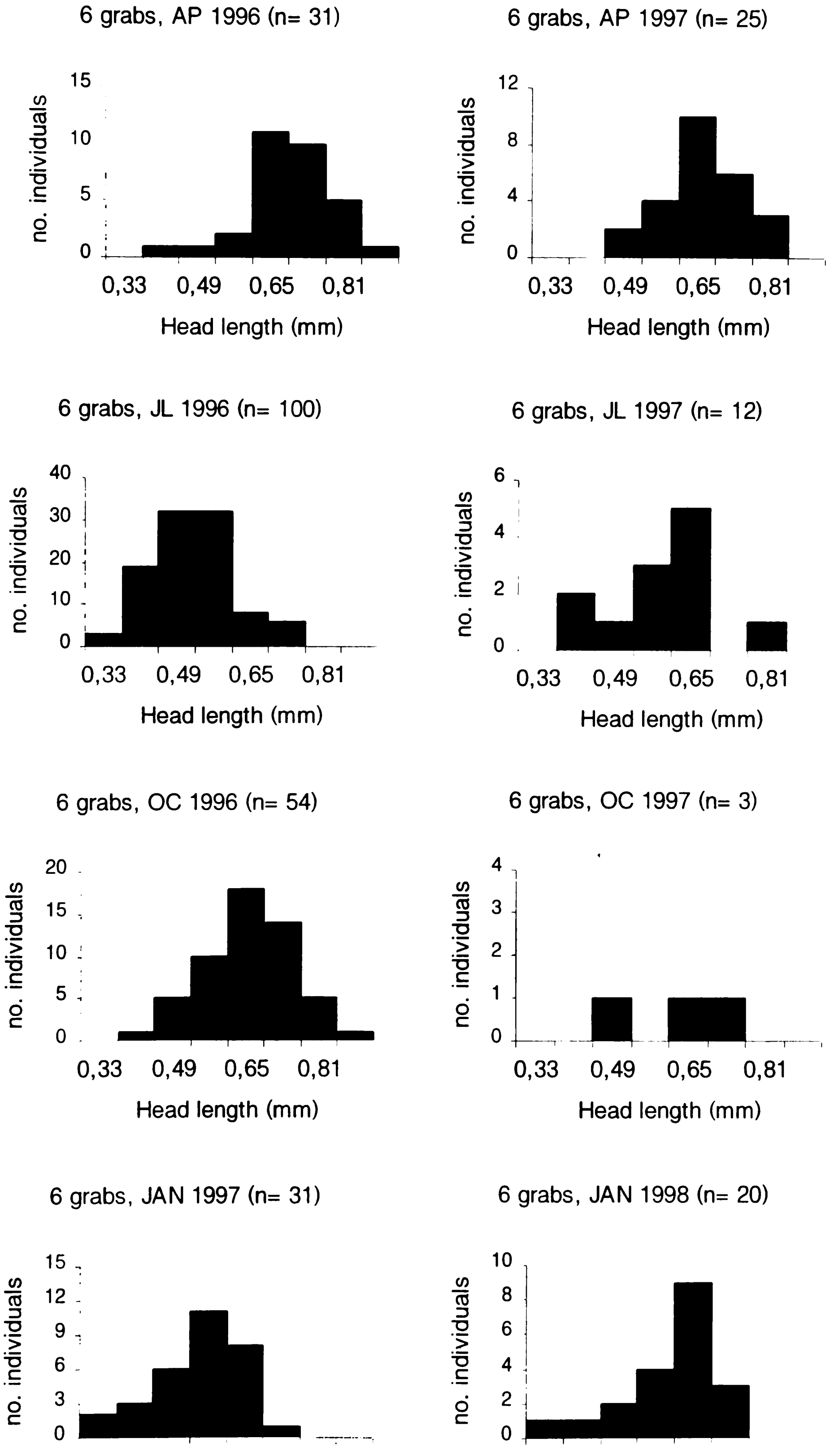


Ceradocus semiserratus is one of the key species found only at the control site. It is thought to be a non selective deposit-feeder. Its maximum numbers were found in summer 1996 (115 ind./0.1 m^2) and minimum in autumn 1997 with 4 ind./0.1 m^2 (Fig. 3.246 A).

The recruitment of this species took place during the autumn and winter seasons and adults were detected in spring and summer. This fact can be deduced from the differences found between abundance and biomass values from the Fig. 3.246 A & B above, but only for the first year of study (1996).

Juvenile individuals were dominant in the spring and summer months whereas adults are found in higher numbers in autumn 1996 (Fig. 3.247).

Fig. 3.247. Size-frequency histograms for *Ceradocus semiserratus* per 0.1 m^2 grab at USC from 1996-1998. AP= April, JL= July, OC= October, JAN= January.



6 grabs, AP 1996 (n= 31)

6 grabs, AP 1997 (n= 25)

6 grabs, JL 1996 (n= 100)

6 grabs, JL 1997 (n= 12)

6 grabs, OC 1996 (n= 54)

6 grabs, OC 1997 (n= 3)

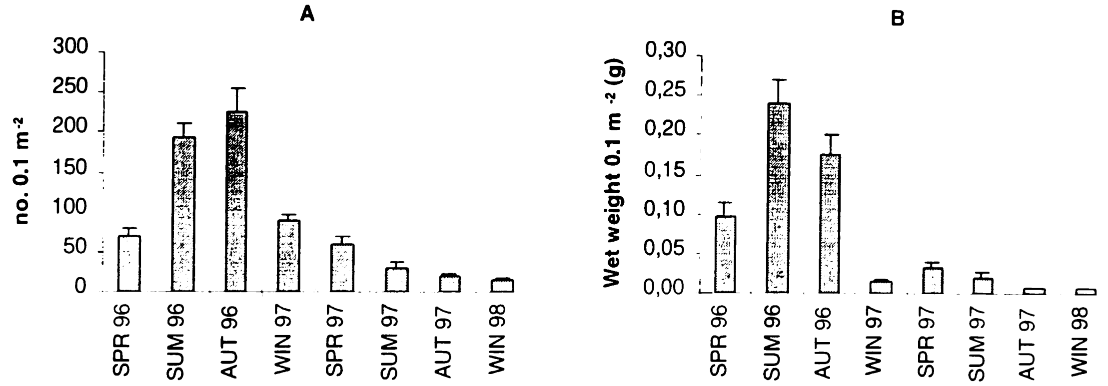
6 grabs, JAN 1997 (n= 31)

6 grabs, JAN 1998 (n= 20)

Gammarella fucicola (Leach 1814)

The amphipod *G. fucicola* usually lives among algae (*Ectocarpus, Lithophyllum*, etc.), and seagrass (*Zostera, Posidonia*) in shallow coastal waters, from 0 to 55 m deep. It is not more abundant in exposed zones. It lives under stones, or in crevices in the substratum. It is a detritivore. In soft substrata it is best represented in gravel bottoms (*Amphioxus* sands) and muddy bottoms.

Fig. 3.248. A) Mean number and B) biomass (g wet weight) of *Gammarella fucicola* per 0.1 m^2 grab at USC. Error bars = SD, N = six grabs analysed

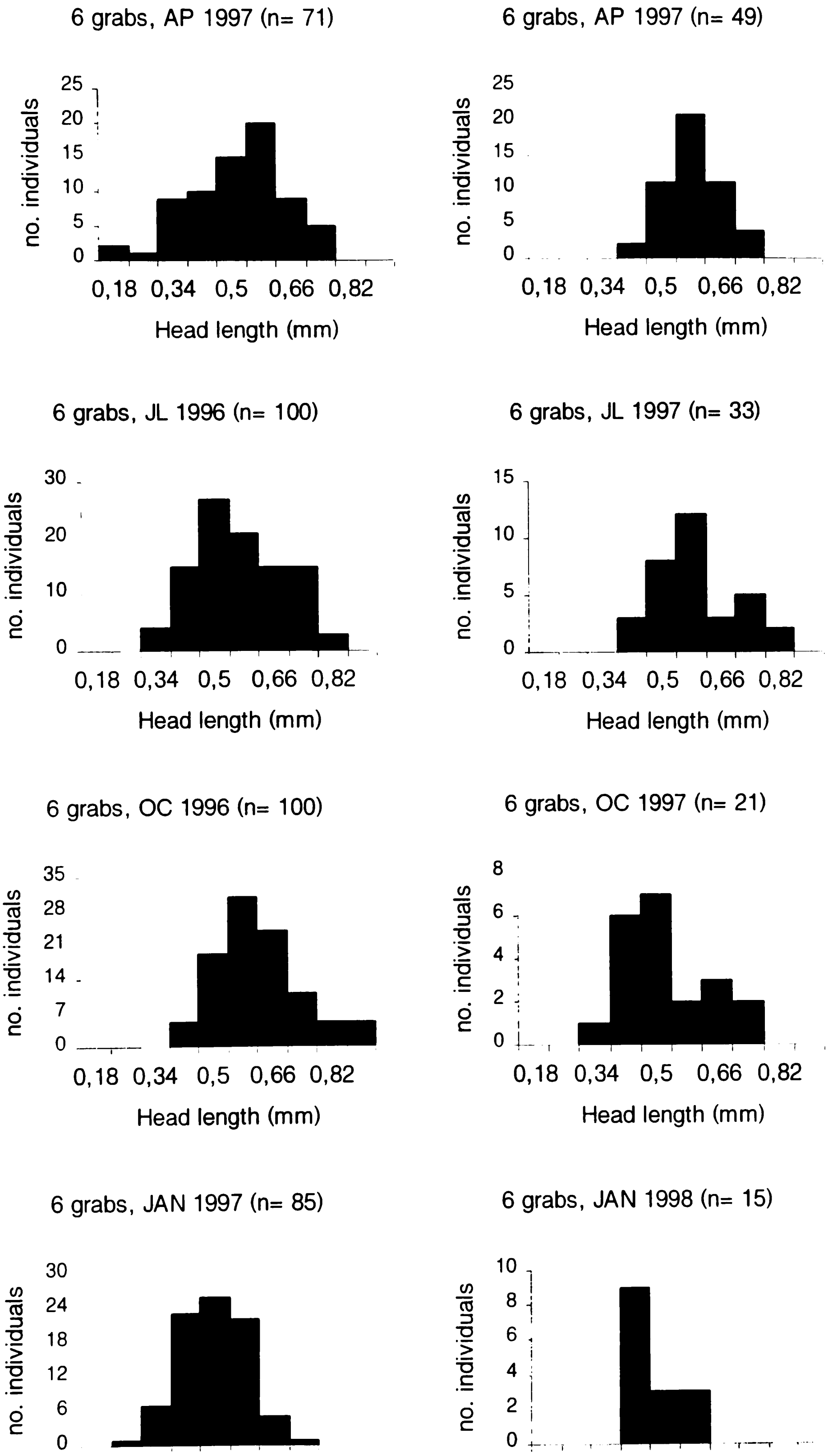


Gammarella fucicola was consistently present at the control site. Its seasonal cycle for the first year of study showed highest abundances in summer and autumn (1996), decreasing then to 20 ind./0,1 m^2 in winter 1997 (Fig. 3.248 A).

The biomass trend corresponds to the abundance pattern (Fig. 3.248 B), with highest weights in summer and autumn 1996 and low values for autumn and winter 1997-1998).

The size-frequency diagrams of Fig. 3.249 show a population composed of individuals of the same size through the two year period.

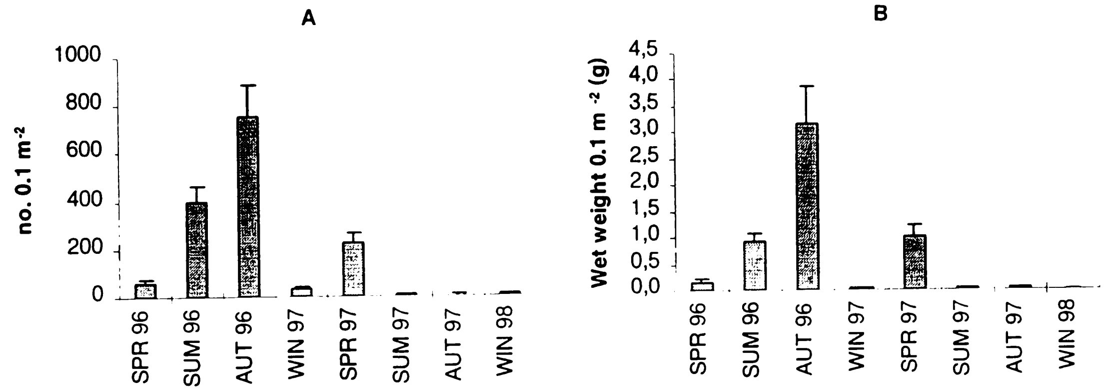
Fig. 3.249. Size-frequency histograms for *Socarnes erythrophthalmus* per 0.1 m^2 grab at USC from 1996-1998. AP= April, JL= July, OC= October, JAN= January.



***Pisidia longicornis* (Linnaeus, 1767)**

This anomuran decapod lives on rock or gravel substrata, also among the bryozoan *Pentapora fascialis*, and amongst other colonial forms; intertidal to 100 m.
It was locally very abundant on maerl grounds. Its abundance was four times higher on the impacted ground than on the control, related to the presence of mussel rafts at the impacted site, perhaps due to the the generation of shell debris for shelter.

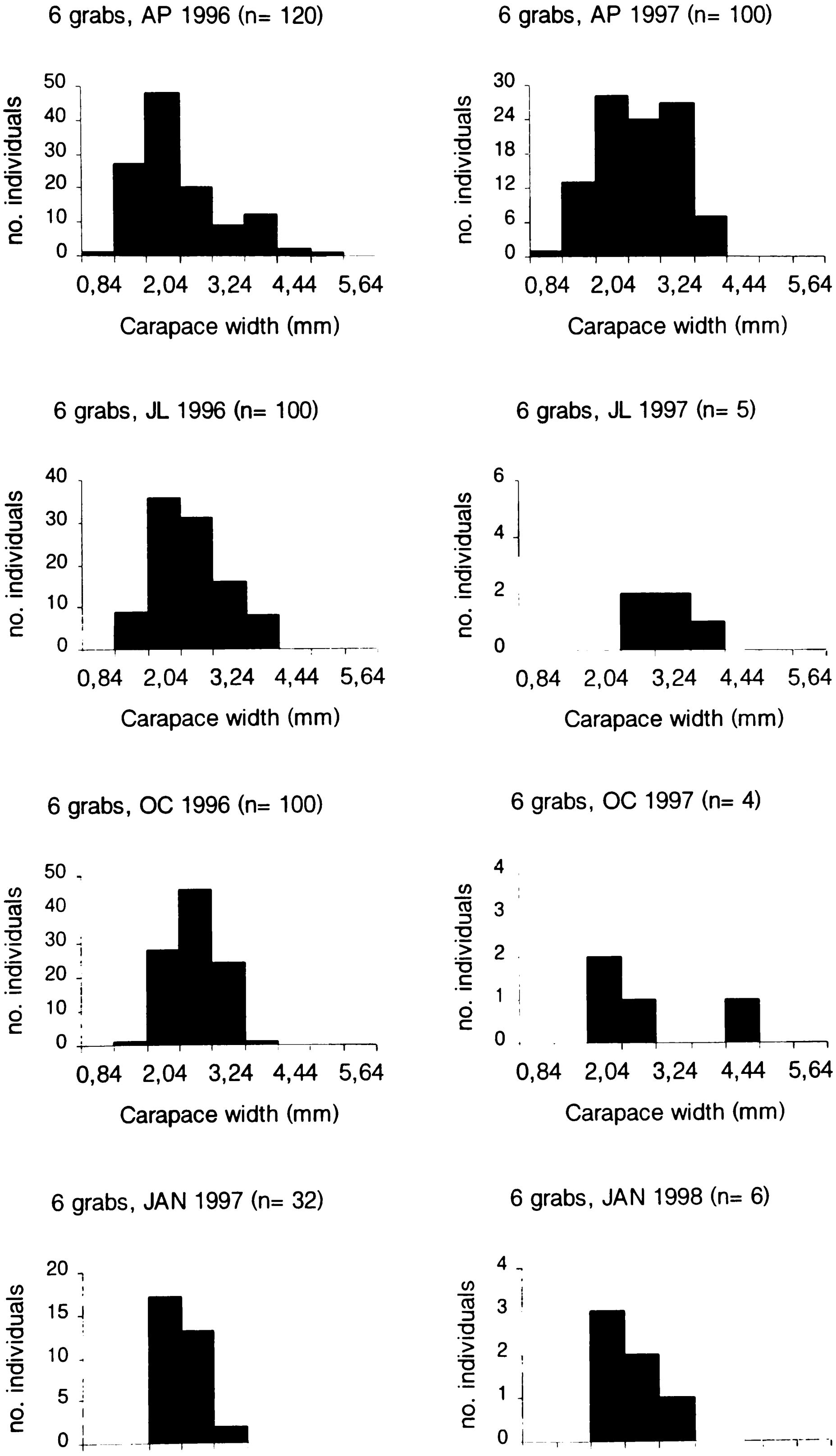
Fig. 3.250. A) Mean number and B) biomass (g wet weight) of *Pisidia longicornis* per 0.1 m^2 grab at USC. Error bars = SD, N = six grabs analysed



Maximum values in terms of abundance and biomass were found in autumn 1996 but this seasonal pattern did not repeat again the following year (Fig. 3.250 A & B).

The seasonal change in size frequency (based on carapace width) of *Pisidia longicornis* on the control site is shown in Fig. 3.251. It was collected in all the seasonal samples; however, small individuals appeared all through the two-year sampling period and no seasonal replacement of cohorts was observed between 1996 and 1998.

Fig. 3.251. Size-frequency histograms for *Pisidia longicornis* per 0.1 m^2 grab at USC from 1996-1998. AP= April, JL= July, OC= October, JAN= January.



6 grabs, AP 1996 (n= 120)

6 grabs, AP 1997 (n= 100)

6 grabs, JL 1996 (n= 100)

6 grabs, JL 1997 (n= 5)

6 grabs, OC 1996 (n= 100)

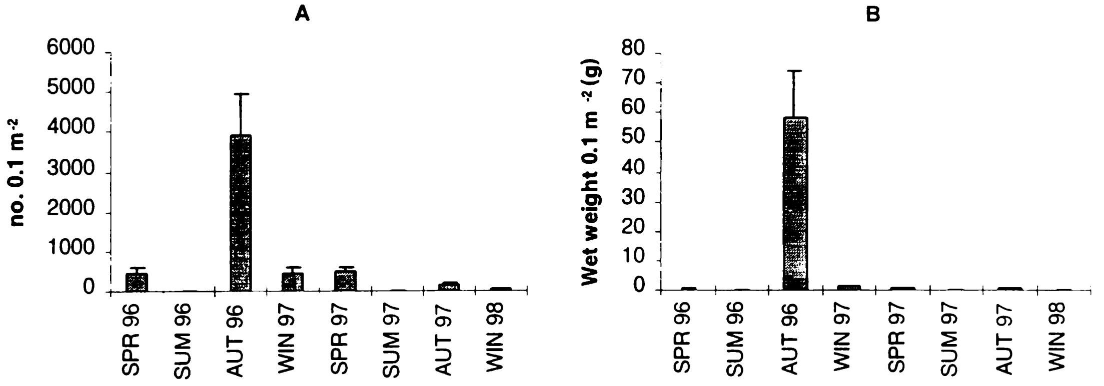
6 grabs, OC 1997 (n= 4)

6 grabs, JAN 1997 (n= 32)

6 grabs, JAN 1998 (n= 6)

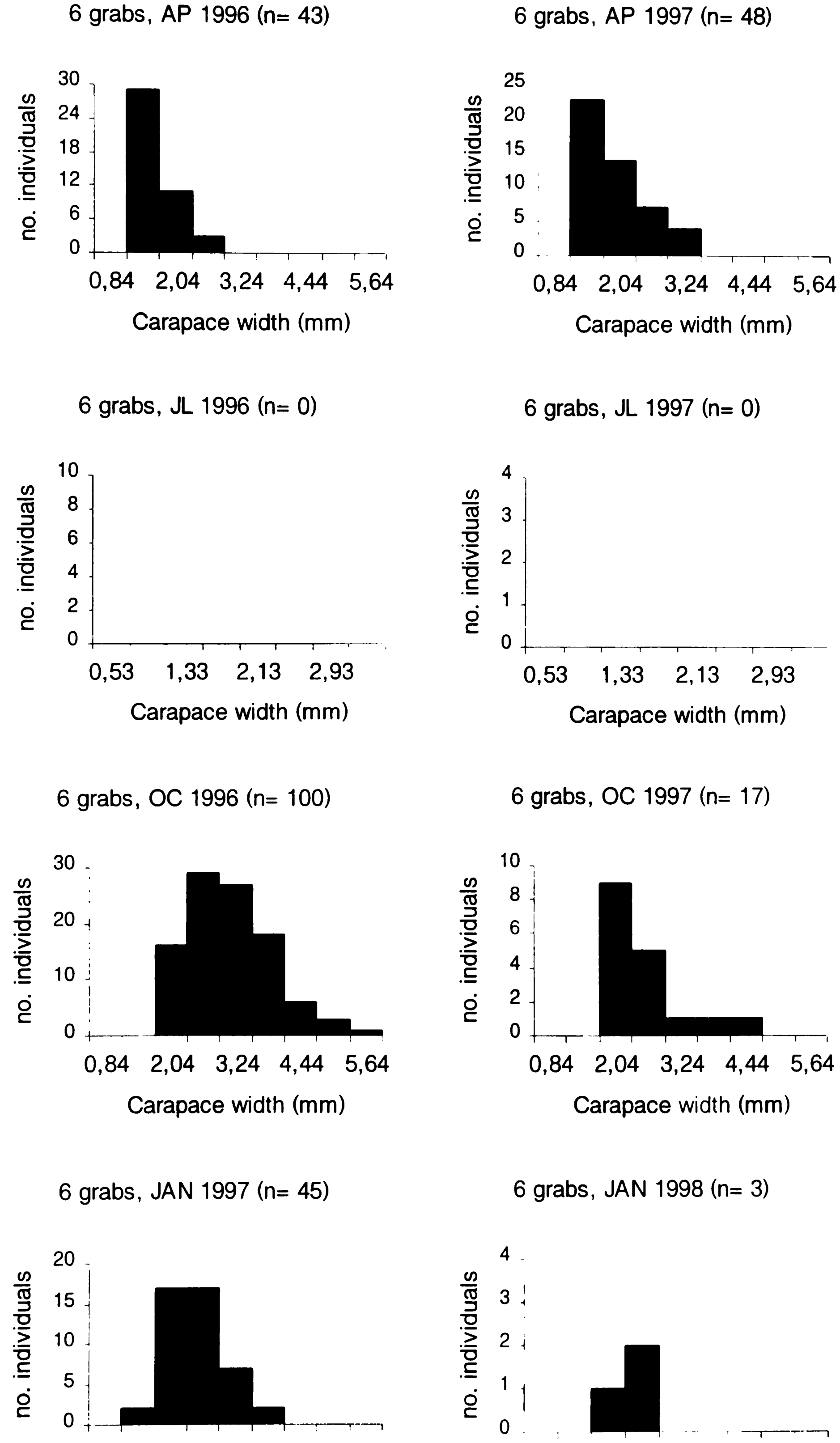
At the impacted ground *Pisidia longicornis* was not a constant species being absent from the samples of summer 1996 and 1997. In spite of its high abundance and biomass (maximum of 4000 ind/0.1 m^2 and 58 g/0.1 m^2 in autumn 1996) no clear seasonal or interannual periodicity was observed (Fig. 3.252 A & B).

Fig. 3.252. A) Mean number and B) biomass (g wet weight) of *Pisidia longicornis* per 0.1 m^2 grab at USI. Error bars = SD, N = six grabs analysed



The seasonal variation of size-frequency of *P. longicornis* at the impacted site is shown in Fig. 3.253. Mostly small individuals were collected between 1996 and 1998. Of these, the mean size of the carapace length was 3.5 mm while this species has been known to reach up to 10 mm. That sampling revealed just juveniles under the rafts (impacted site) suggest that this site is a good settlement place for this species. It was not found in summer 1996 and 1997, this season coinciding with the harvesting of adult mussels.

Fig. 3.253. A) Size-frequency histograms for *Pisidia longicornis* per 0.1 m^2 grab at USI from 1996-1998. AP= April, JL= July, OC= October, JAN= January.



6 grabs, AP 1996 (n= 43)

6 grabs, AP 1997 (n= 48)

6 grabs, JL 1996 (n= 0)

6 grabs, JL 1997 (n= 0)

6 grabs, OC 1996 (n= 100)

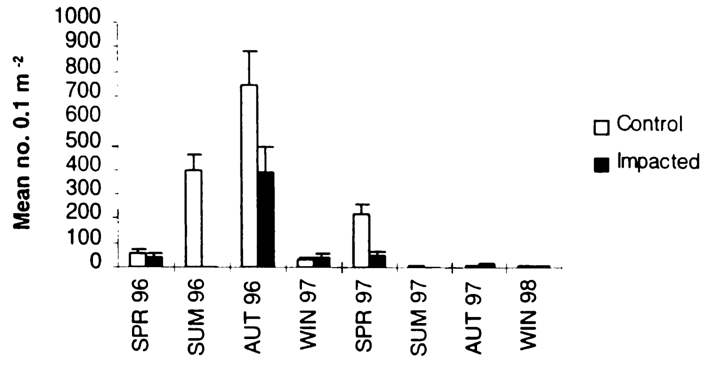
6 grabs, OC 1997 (n= 17)

6 grabs, JAN 1997 (n= 45)

6 grabs, JAN 1998 (n= 3)

Fig. 3.254.

Seasonal variation in abundance of *Pisidia longicornis* on control and impacted grounds in Ría de Vigo



Seasonal variation in biomass of *Pisidia longicornis* on control and impacted grounds in Ría de Vigo

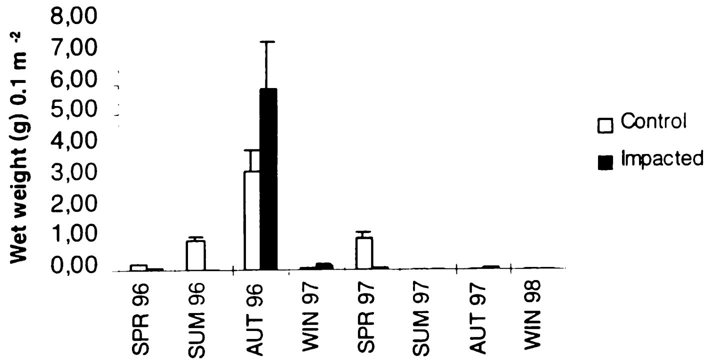


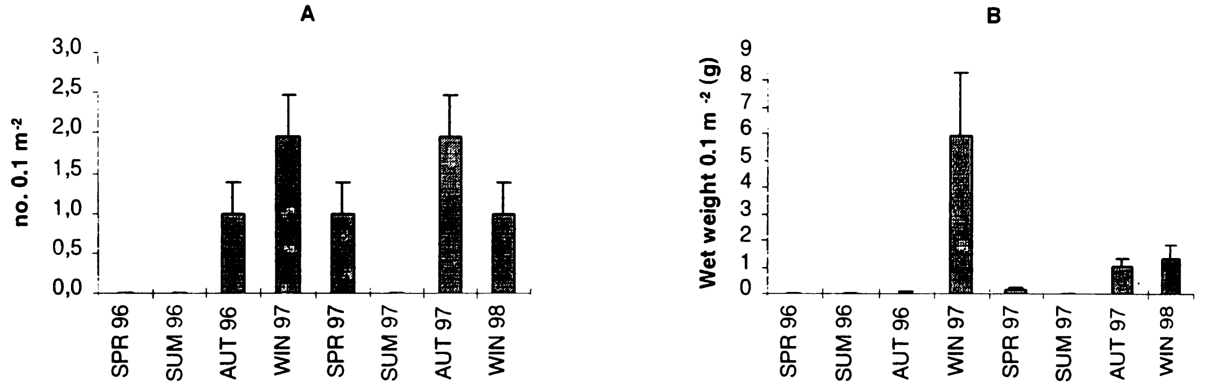
Fig. 3.254 summarises the differences between the control and the impacted grounds in terms of abundance and biomass for *P. longicornis*.

This was one of the most abundant key species; its temporal distribution, though, revealed an irregular pattern both for abundance and biomass. *P. longicornis* is a species linked to the mussel rafts in the Galician rías. It lives on the deposits and faecal pellets produced by the mussels. Its suspension-feeding is then conditioned by the organic matter supplies from the rafts above. On the impacted area. the suspended organic matter was disturbed very often by the action of currents and storms which could affect *P. longicornis* distribution.

Liocarcinus corrugatus (Pennant, 1777)

The decapod *Liocarcinus corrugatus* is found on stoney and gravelly substrata, from the intertidal to 100 m. It is more abundant in "rías" with better influence of oceanic water like Ría de Vigo.

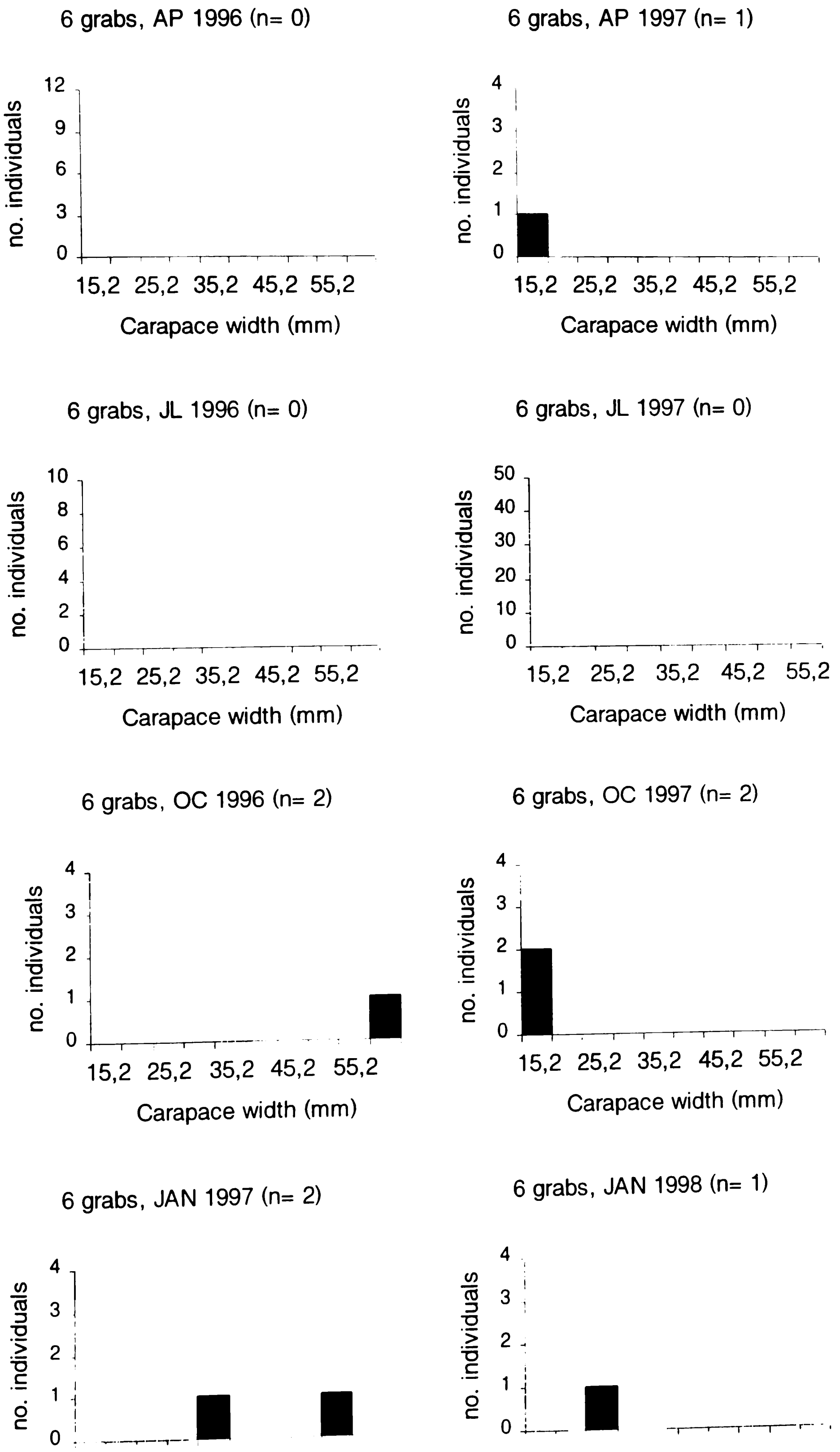
Fig. 3.255. A) Mean number and B) biomass (g wet weight) of *Liocarcinus corrugatus* per 0.1 m^2 grab at USC. Error bars = SD, N = six grabs analysed



This is one of the species most typical of maerl bottoms. However, it was not constant at either of the sites studied, but was occasional (Fig. 3.255 A & B).

The seasonal variation in size-frequency (based on carapace width) of *Liocarcinus corrugatus* on the control site is shown in Fig. 3.256. It was not collected in all the seasonal samples, just in those of autumn, winter and spring, disappearing in summer. Small individuals appeared on those occasions when the species was recorded (Fig. 3.256) and no seasonal replacement of cohorts could be observed between 1996 and 1998.

Fig. 3.256. Size-frequency histograms for *Liocarcinus corrugatus* per 0.1 m^2 grab at USC from 1996-1998. AP= April, JL= July, OC= October, JAN= January.



6 grabs, AP 1996 (n= 0)

6 grabs, AP 1997 (n= 1)

6 grabs, JL 1996 (n= 0)

6 grabs, JL 1997 (n= 0)

6 grabs, OC 1996 (n= 2)

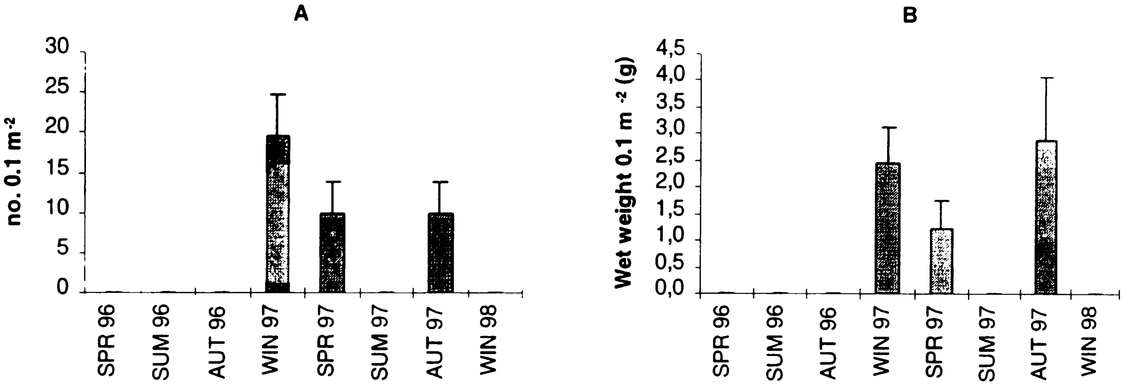
6 grabs, OC 1997 (n= 2)

6 grabs, JAN 1997 (n= 2)

6 grabs, JAN 1998 (n= 1)

Liocarcinus corrugatus was rare at the impacted site (USI) having only been recorded during spring, autumn and winter 1997 and always in very low numbers. The abundance of this crab was quite similar for the two sites, though it was slightly more important at the control site.

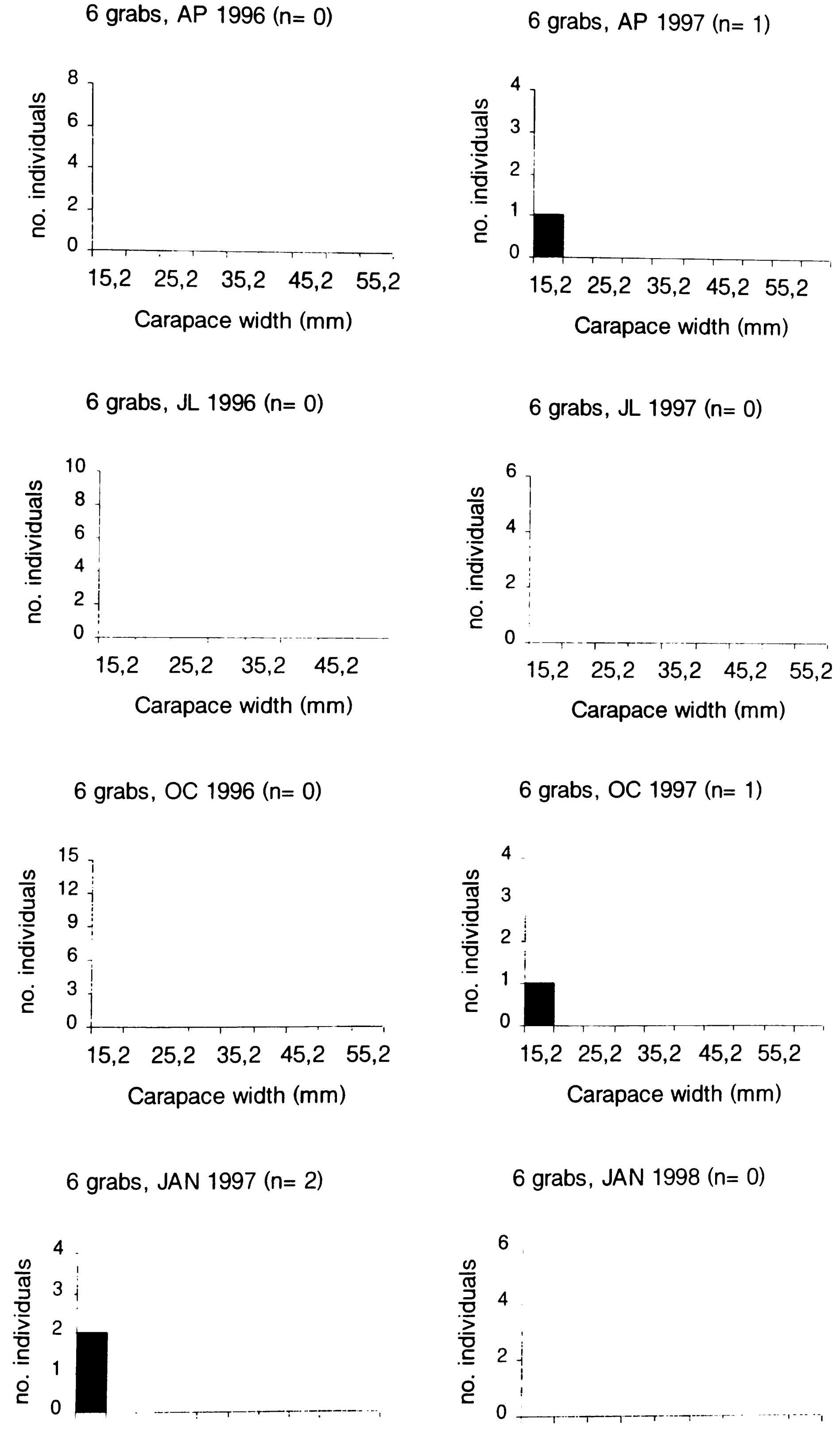
Fig. 3.257. A) Mean number and B) biomass (wet weight) of *Liocarcinus corrugatus* per 0.1 m^2 grab at USI. Error bars = SD, N = six grabs analysed



The seasonal variation in abundance and biomass of *Liocarcinus corrugatus* at the impacted site is shown in Fig. 3.257 A & B.

Fig. 3.258 shows the size-frequency histograms for this species during the two-year period studied. A small number of individuals were collected (and only in 1997). Of these, the mean size of the carapace length was 15.2 mm while this species has been recorded to measure up to 100 mm.

Fig. 3.258. Size-frequency histograms for *Liocarcinus corrugatus* per 0.1 m^2 grab at USI from 1996-1998. AP= April, JL= July, OC= October, JAN= January.



6 grabs, AP 1996 (n= 0)

6 grabs, AP 1997 (n= 1)

6 grabs, JL 1996 (n= 0)

6 grabs, JL 1997 (n= 0)

6 grabs, OC 1996 (n= 0)

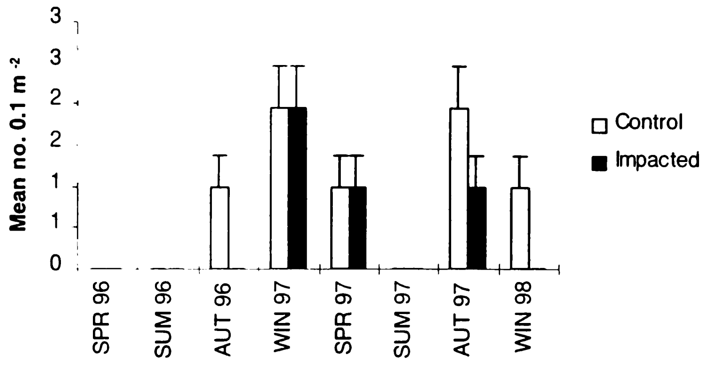
6 grabs, OC 1997 (n= 1)

6 grabs, JAN 1997 (n= 2)

6 grabs, JAN 1998 (n= 0)

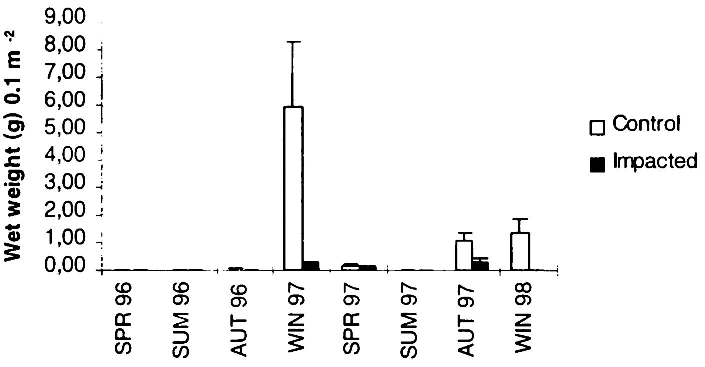
Fig. 3.259.

Seasonal variation in abundance of *Liocarcinus corrugatus* on control and impacted



grounds in Ría de Vigo

Seasonal variation in biomass of *Liocarcinus corrugatus* on control and impacted grounds in Ría de Vigo



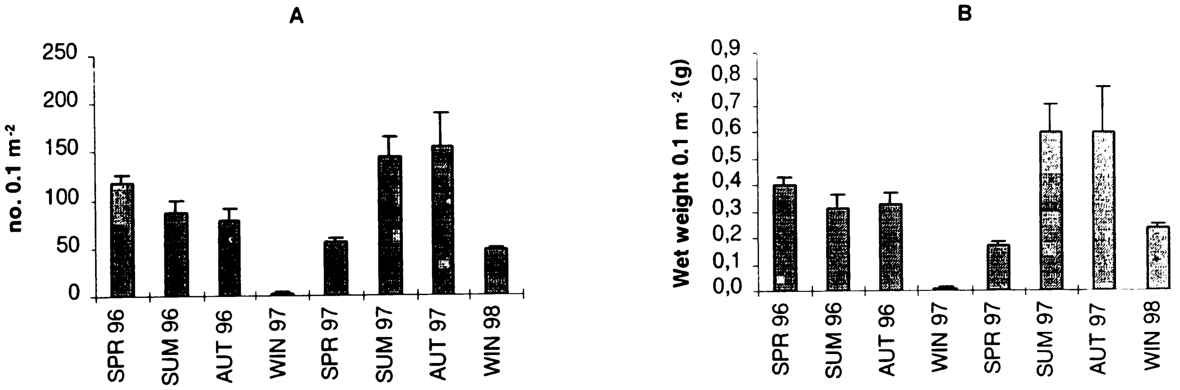
From the comparison of the abundance of *L. corrugatus* on the control and the impacted sites no seasonal pattern is discernible neither any interannual variability (Fig. 3.259). Only a slight dominance of this species is revealed at the control site together with a more consistent presence than at the impacted site.

Biomass comparison at the control and impacted grounds shows a clear dominance of *L. corrugatus* at the control site reaching a maximum of wet weight in winter 1997 (5.8 g/0.1 m^2).

Leptochiton cancellatus (G B Sowerby II, 1840)

L. cancellatus is a herbivore and lives on hard substrata. This species lives on stony and gravelly bottoms among shells and *Lithothamnia*, from the infralittoral zone to depths in excess of 900 m.

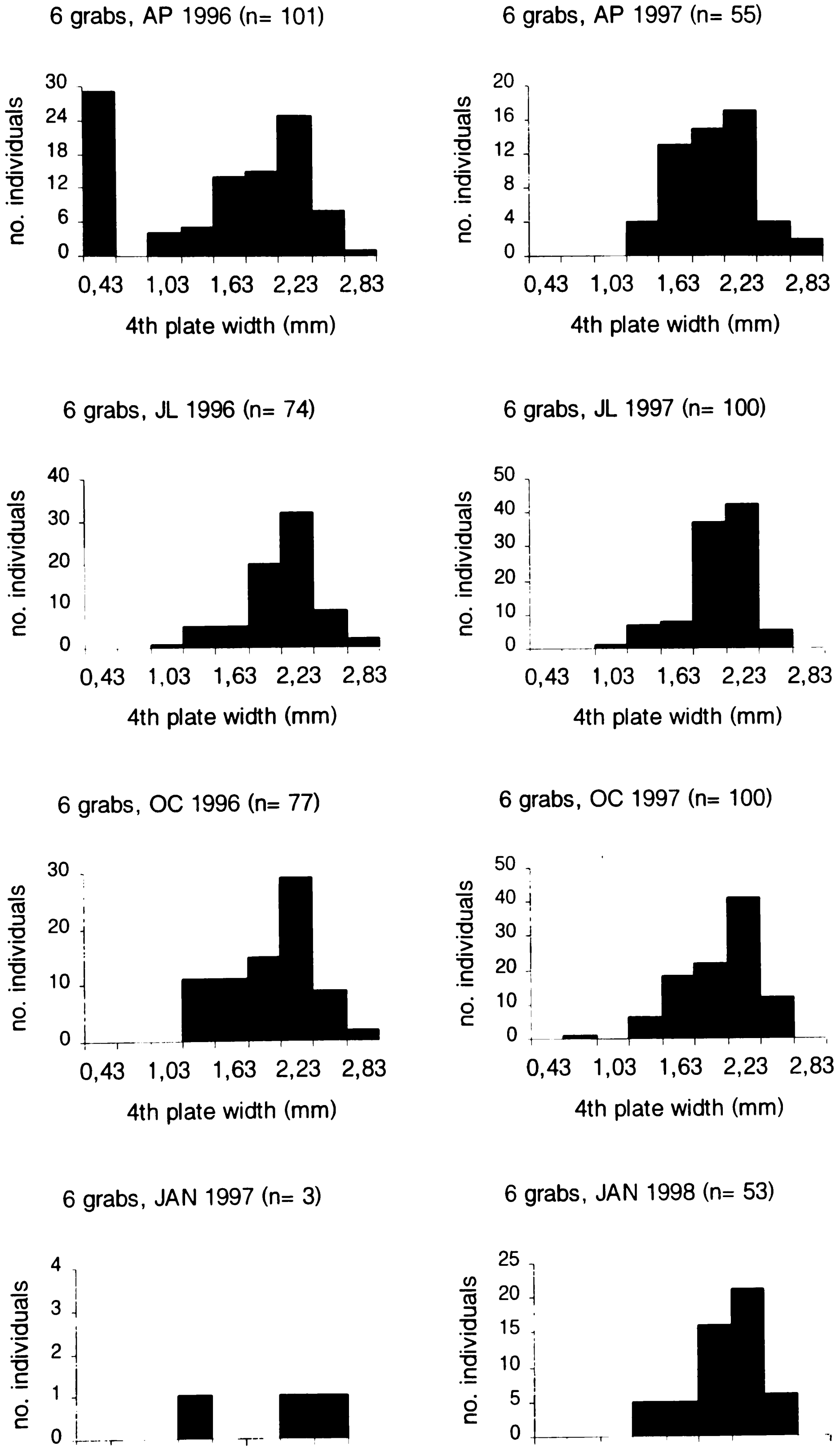
Fig. 3.260 A) Mean number and B) biomass (g wet weight) of *Leptochiton cancellatus* per 0.1 m^2 grab at USC. Error bars = SD, N = six grabs analysed



The highest abundance and biomass of *L. cancellatus* at USC was found in summer and autumn 1997 (more than 140 ind./0.1 m^2 and 0.6 g/0.1 m^2). It was present in all seasons, but these parameters were lowest in winter 1998 (Fig. 3.260 A & B).

The maximum width of the fourth plate was measured for this species and variations and differences in size-frequency distribution are shown in Fig. 3.261 for the control site.

Fig. 3.261. Size-frequency histograms for *Leptochiton cancellatus* per 0.1 m^2 grab at USC from 1996-1998. AP= April, JL= July, OC= October, JAN= January.



6 grabs, AP 1996 (n= 101)

6 grabs, AP 1997 (n= 55)

6 grabs, JL 1996 (n= 74)

6 grabs, JL 1997 (n= 100)

6 grabs, OC 1996 (n= 77)

6 grabs, OC 1997 (n= 100)

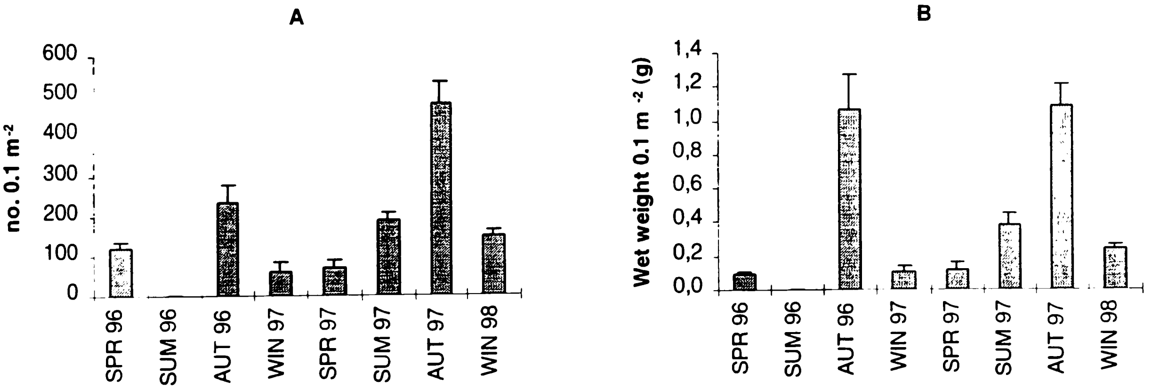
6 grabs, JAN 1997 (n= 3)

6 grabs, JAN 1998 (n= 53)

L. cancellatus was one of the most abundant key-species at the control site. Juveniles recruited in spring 1996, and all during that year (from summer to autumn) juveniles grew into adults. In winter 1996 there was a reduction of the population which recovered again in spring 1997. During the second year of study, the *L. cancellatus* population was bigger than in 1996.

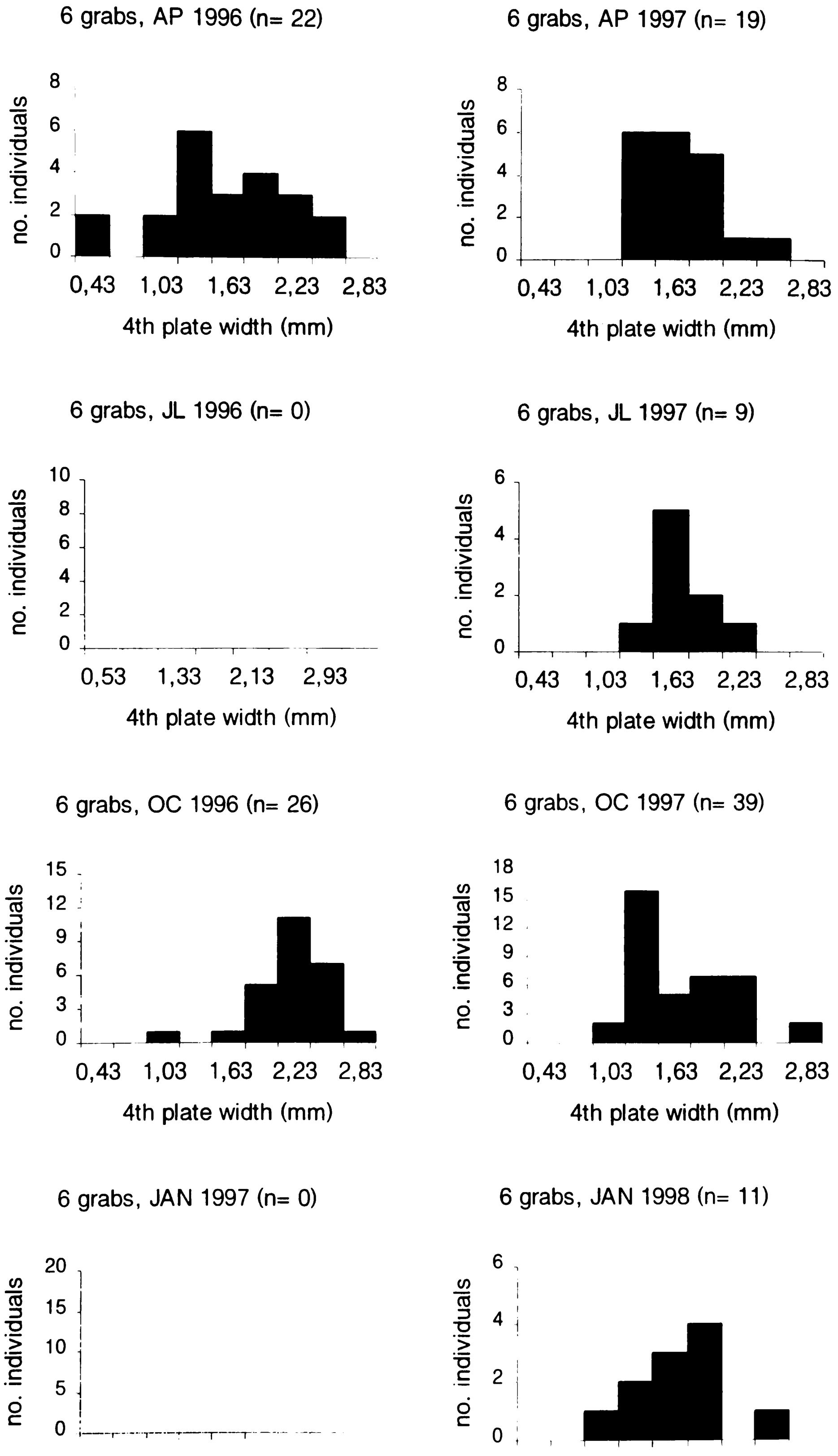
At the impacted site (USI), *L. cancellatus* was less constantly present nor consistently abundant. It was not found in summer 1996. Maximum abundance and biomass for this species was recorded in autumn 1996 and 1997 with more than 250 ind./0.1 m^2 and 1 g/0.1 m^2. Some seasonality was observed with maxima in autumn and minima in spring and winter (Fig. 3.262 A & B).

Fig. 3.262. A) Mean number and B) biomass (g wet weight) of *Leptochiton cancellatus* per 0.1 m^2 grab at USI. Error bars = SD, N = six grabs analysed



In Fig. 3.263, the size-frequency histograms for two seasonal cycles (1996-1998) are recorded for this species at the impacted site. The adult individuals appeared in autumn (October 1996 and 1997) and the juveniles in spring (April 1996 and 1997).

Fig. 3.263. Size-frequency histograms for *Leptochiton cancellatus* per 0.1 m^2 grab at USI from 1996-1998. AP= April, JL= July, OC= October, JAN= January.



6 grabs, AP 1996 (n= 22)

6 grabs, AP 1997 (n= 19)

6 grabs, JL 1996 (n= 0)

6 grabs, JL 1997 (n= 9)

6 grabs, OC 1996 (n= 26)

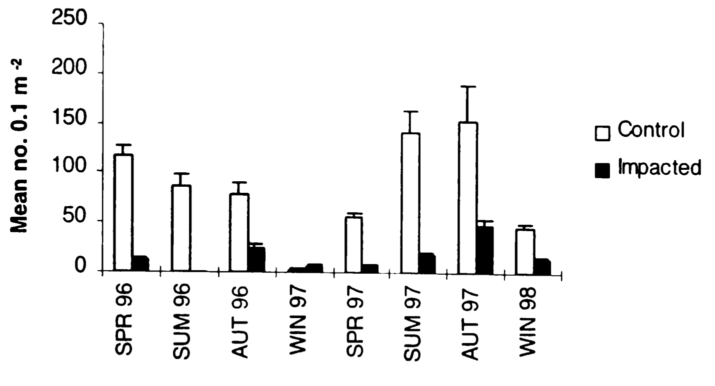
6 grabs, OC 1997 (n= 39)

6 grabs, JAN 1997 (n= 0)

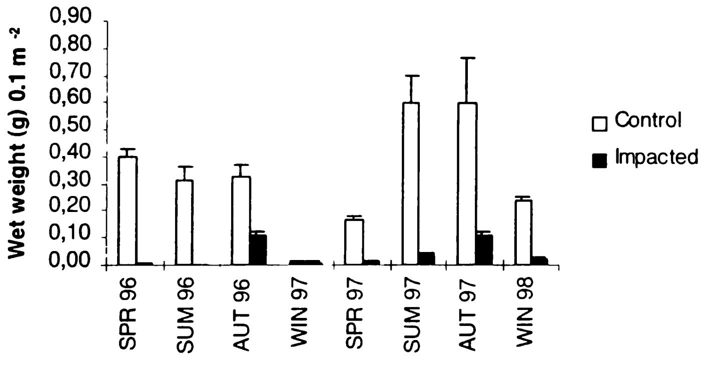
6 grabs, JAN 1998 (n= 11)

Fig. 3.264.

Seasonal variation in abundance of *Leptochiton cancellatus* on control and impacted grounds in Ría de Vigo



Seasonal variation in biomass of *Leptochiton cancellatus* on control and impacted grounds in Ría de Vigo



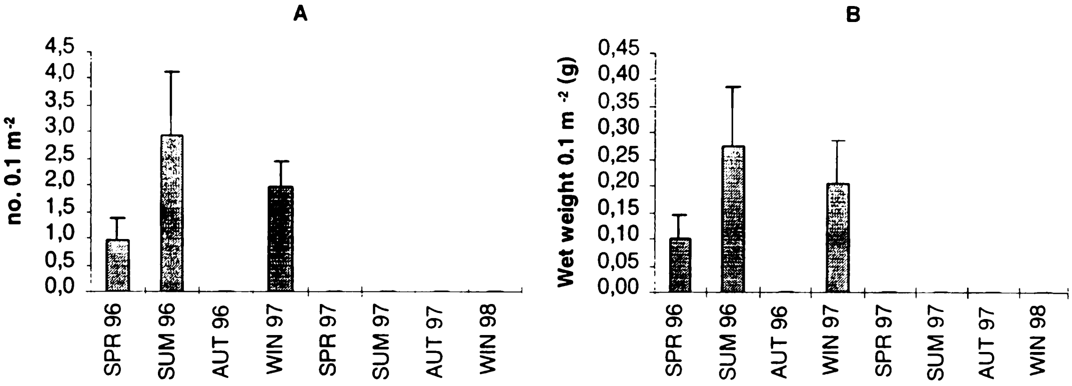
Comparing the seasonal abundance and biomass both at the control and the impacted grounds (Fig. 3.264) a clear dominance of *L. cancellatus* can be seen at the control ground (always more than 50 ind./0.1 m^2 and 0.2 g/0.1 m^2 whereas at the impacted site the maximum of abundance was 50 ind./0.1 m^2 in autumn 1997 and the maximum of biomass was 0.1 g/0.1 m^2 in autumn 1996 and 1997.

No strong seasonality was observed for this species when comparing the two annual cycles studied.

Gibbula magus (Linnaeus, 1758)

This gastropod usually lives below the tidemarks, on shells and stones in sandy, muddy bottoms as well as among seaweeds.

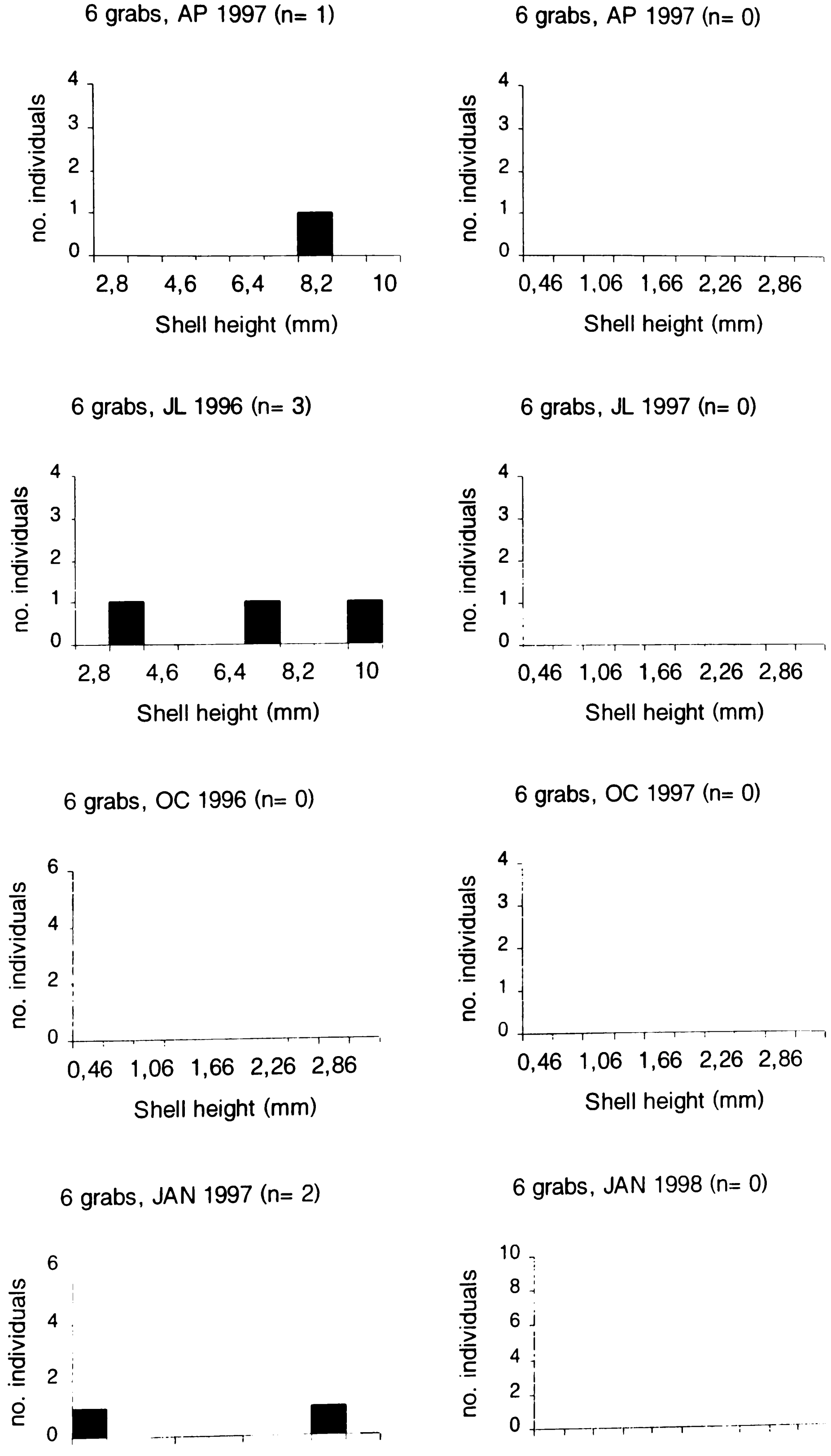
Fig. 3.265. A) Mean number and B) biomass (g wet weight) of *Gibbula magus* per 0.1 m^2 grab at USC. Error bars = SD, N = six grabs analysed



Gibbula magus was an occasional species, only found in very low numbers during the first year of study in spring, summer and winter 1996 at USC (Fig. 3.265). Its feeding behaviour as micrograzer may have been something to do with the limited (sometimes completely absent) seaweed cover at the control site. At USC, seaweeds were only abundant during the summer period 1996. The strong hydrodynamics of the area did not allow most seaweed species to settle and cover the maerl grounds.

The shell height was measured for this species and seasonal differences in size are shown in Fig. 3.266 for the control site. The species reached a maximum size of 10 mm in summer.

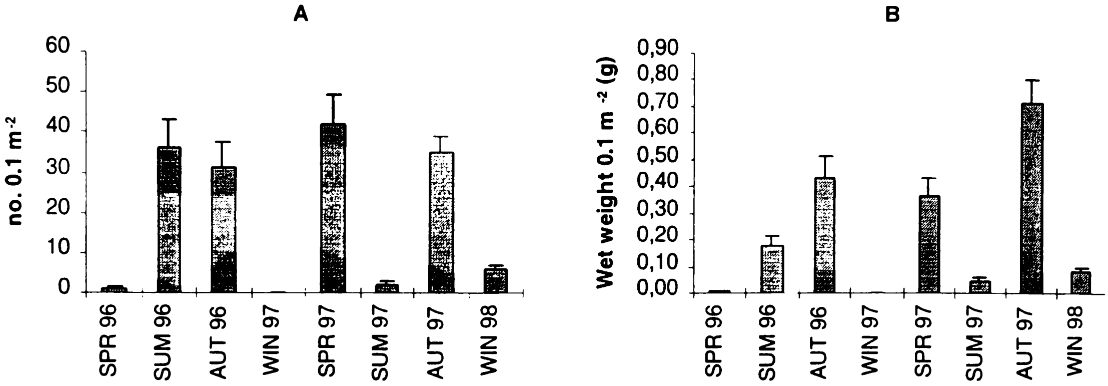
Fig. 3.266. Size-frequency histograms for *Gibbula magus* per 0.1 m^2 grab at USC from 1996-1998. AP= April, JL= July, OC= October, JAN= January.



Jujubinus miliaris (Brocchi, 1814)

J. miliaris is always sublittoral, living on stony and gravelly bottoms (35-800 m deep) with shells or *Lithothamnion* (Graham, 1988).

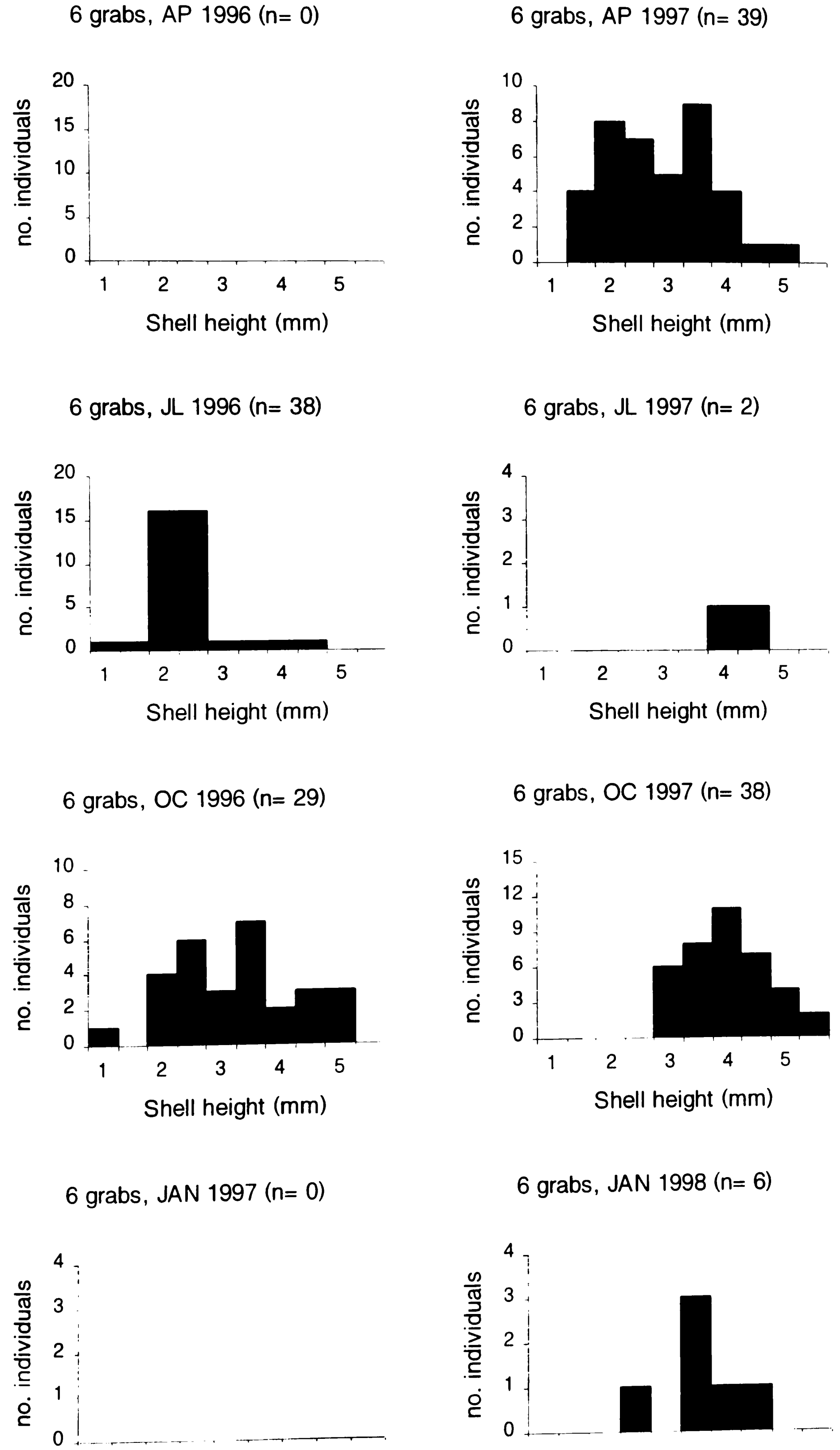
Fig. 3.267. A) Mean number and B) biomass (g wet weight) of *Jujubinus miliaris* per 0.1 m^2 grab at USC. Error bars = SD, N = six grabs analysed



Jujubinus miliaris, together with *Jujubinus exasperatus,* was one of the gastropod species typical of maerl grounds. Unexpectedly, it reached higher abundances (Fig. 3.267) than *Jujubinus exasperatus*, though neither were as rich in numbers as was expected at the beginning of this study.

Its micrograzer capabilities may have been compromised by winter and summer storms which may have induced the erratic pattern of distribution recorded (Fig. #). Shell height was measured for this species and seasonal differences in size are shown in Fig. 3.268 for the control site. This species reached a maximum of 5.5 mm in autumn.

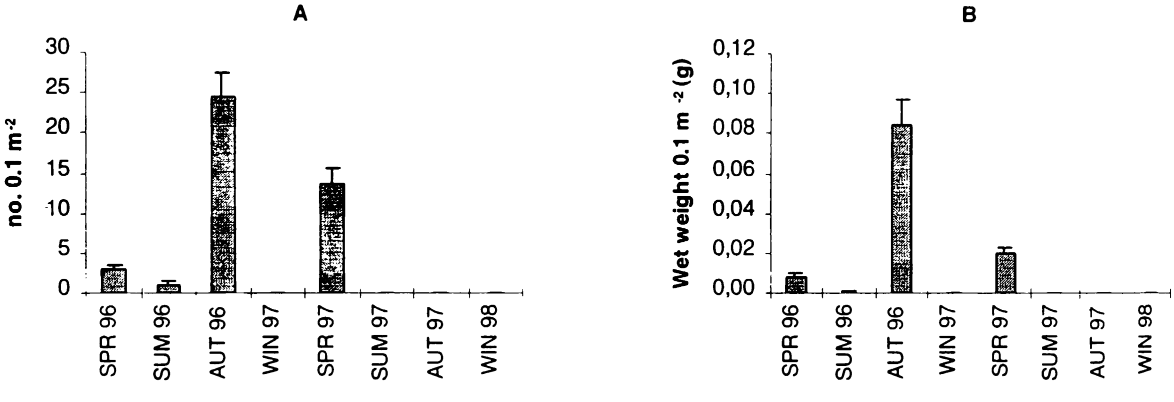
Fig. 3.268. Size-frequency histograms for *Jujubinus miliaris* per 0.1 m^2 grab at USC from 1996-1998. AP= April, JL= July, OC= October, JAN= January.



Tectura virginea (O F Müller, 1776)

This limpet is common in and out of rock pools, attached to the underside of smooth, fixed stones with a growth of red weeds, especially *Lithothamnion*, on which it feeds. It breeds in spring.

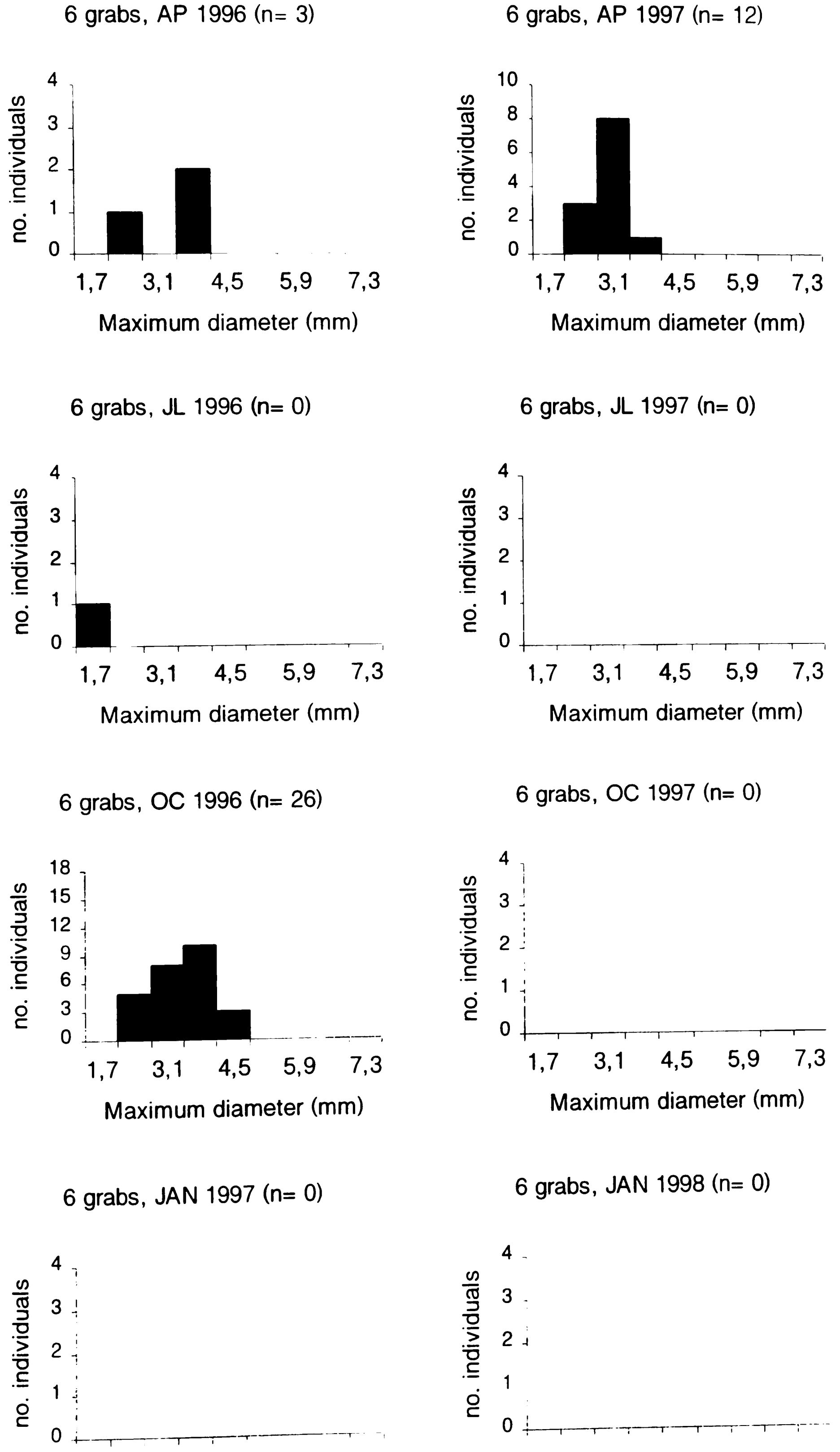
Fig. 3.269. A) Mean number and B) biomass (wet weight) of *Tectura virginea* per 0.1 m^2 grab at USC. Error bars = SD, N = six grabs analysed



At the control site (USC), *Tectura virginea* was not an abundant species, with the exception of autumn 1996 where it reached 24 ind/0.1 m^2 (Fig. 3.269 A). Generally it was a rare species and it was not even sampled in winter, summer and autumn 1997 and winter 1998. Consequently it was not important in terms of biomass on the control ground (Fig. 3.269 B). This, however, was not the case on the impacted ground.

The seasonal variation in size frequency of T. virginea at USC is shown in Fig. 3.270. On the impacted ground (USI), *Tectura virginea* showed highest values both for abundance and biomass with presences in all seasons during the two years of study. Also, a seasonal pattern was observed with maximum values in autumn (1996 and 1997) both for abundance an biomass and minimum for summer 1996 and 1997 (Fig. 3.271).

Fig. 3.270. Size-frequency histograms for *Tectura virginea* per 0.1 m^2 grab at USC from 1996-1998. AP= April, JL= July, OC= October, JAN= January.



6 grabs, AP 1996 (n= 3)

6 grabs, AP 1997 (n= 12)

6 grabs, JL 1996 (n= 0)

6 grabs, JL 1997 (n= 0)

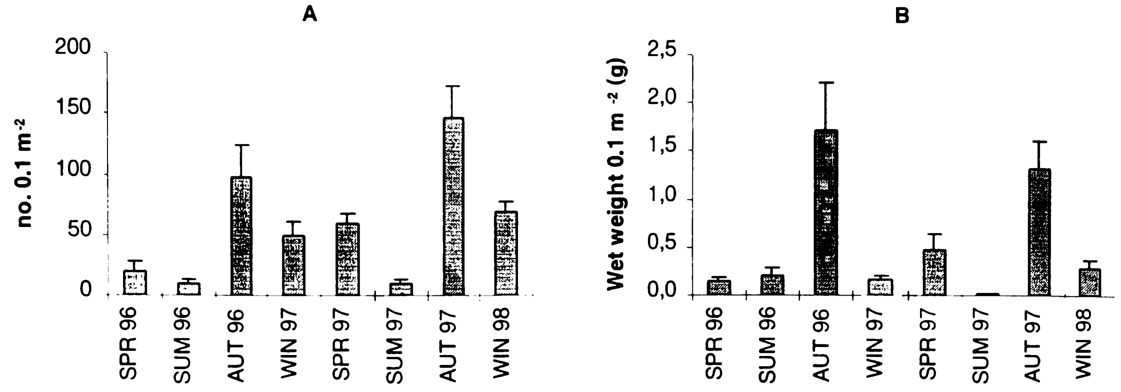
6 grabs, OC 1996 (n= 26)

6 grabs, OC 1997 (n= 0)

6 grabs, JAN 1997 (n= 0)

6 grabs, JAN 1998 (n= 0)

Fig. 3.271. A) Mean number and B) biomass (wet weight) of *Tectura virginea* per 0.1 m^2 grab at USI. Error bars = SD, N = six grabs analysed



The seasonal variation in size-frequency of *Tectura virginea* at the impacted ground is shown in Fig. 3.272. Between October and April (1996-1997 and 1997-1998) the individuals of this species are well represented with all sizes from the smallest not measuring more than 1 mm to the biggest sampled which reached 7.3 mm. During the rest of the year, this species was not very abundant and so its size distribution greatly diminished.

Fig. 3.272. Size-frequency histograms for *Tectura virginea* per 0.1 m^2 grab at USI from 1996-1998. AP= April, JL= July, OC= October, JAN= January.

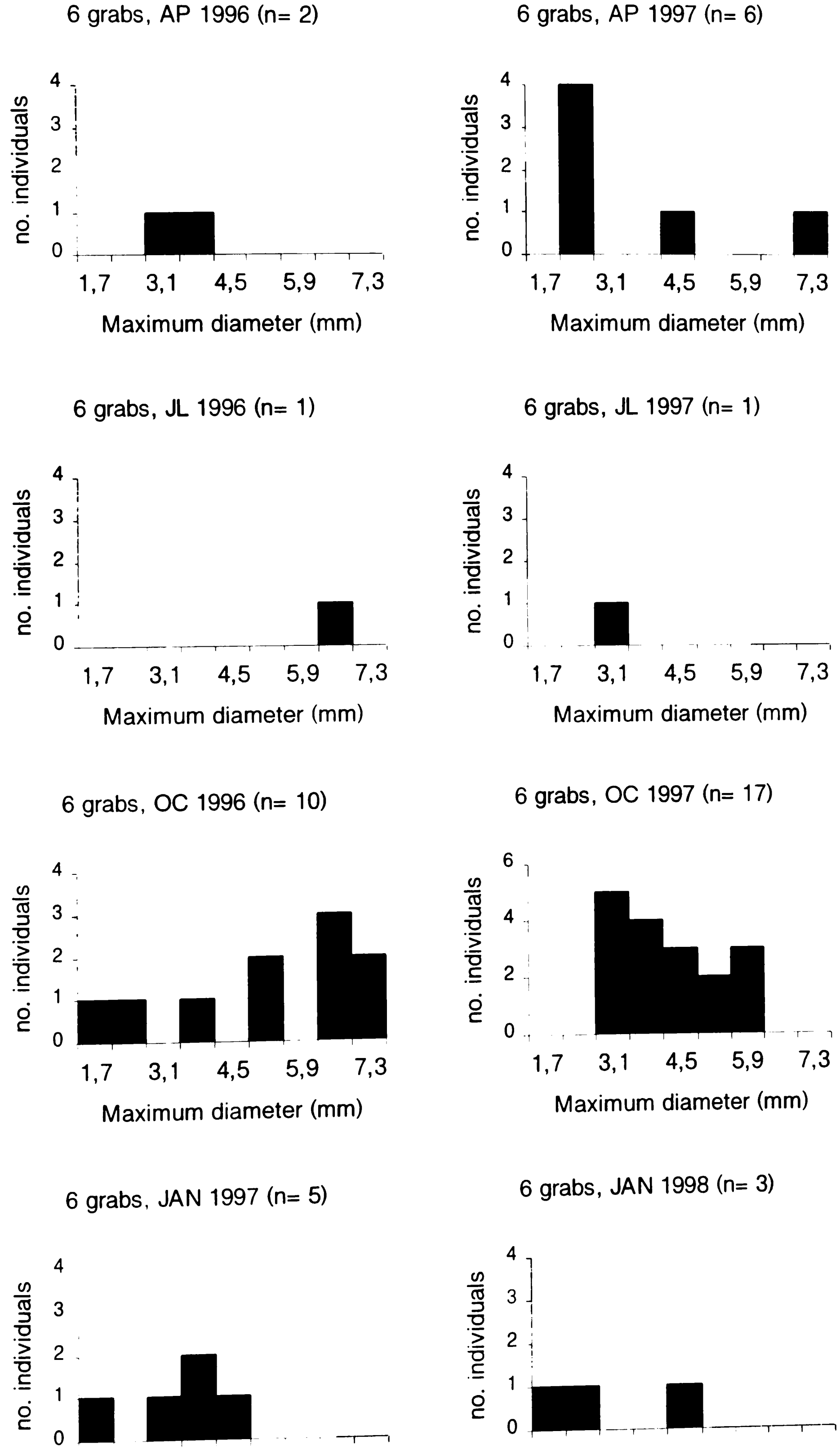
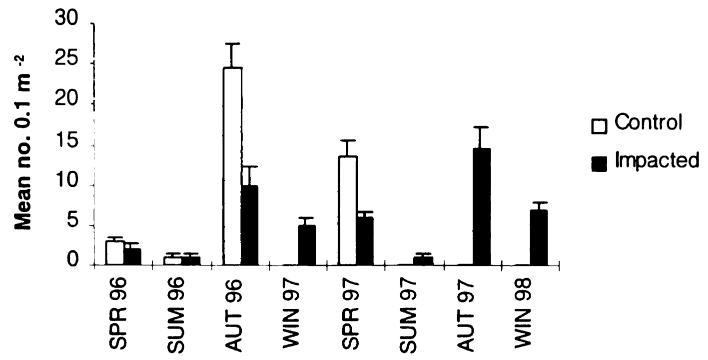


Fig.3.273.

Seasonal variation in abundance of *Tectura virginea* on control and impacted grounds in Ría de Vigo



Seasonal variation in biomass of *Tectura virginea* on control and impacted grounds in Ría de Vigo

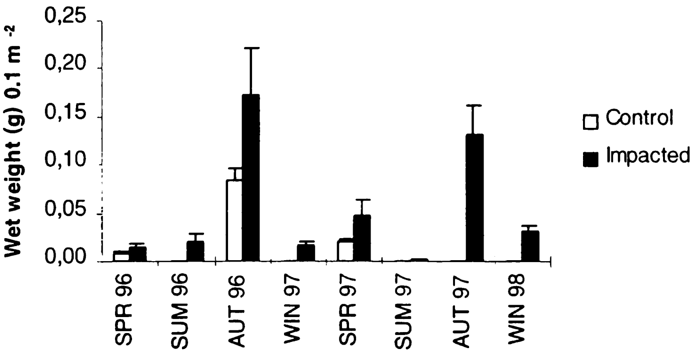
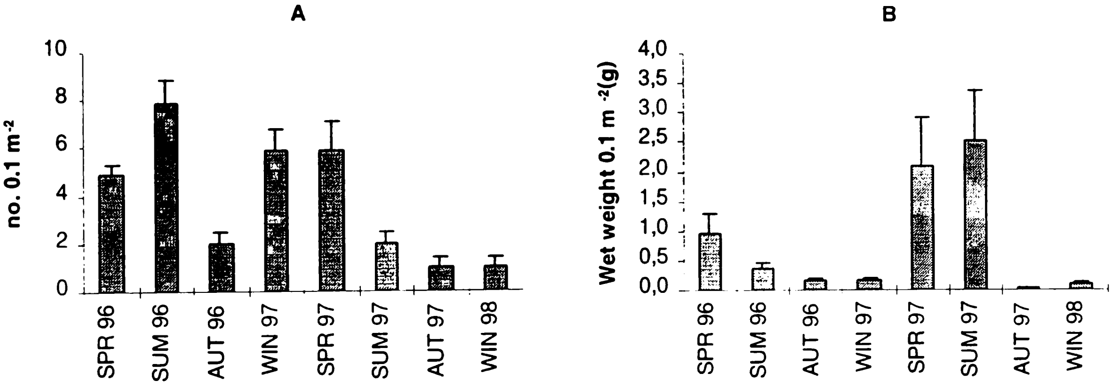


Fig. 3.273 shows the comparison between abundance and biomass of *Tectura virginea* on the control and impacted sites. Note the seasonal and interannual pattern shown by this species on the impacted site with highest abundances and biomass in autumn 1996 and 1997 and lowest in summer 1996 and 1997.

Clausinella fasciata (da Costa, 1778)

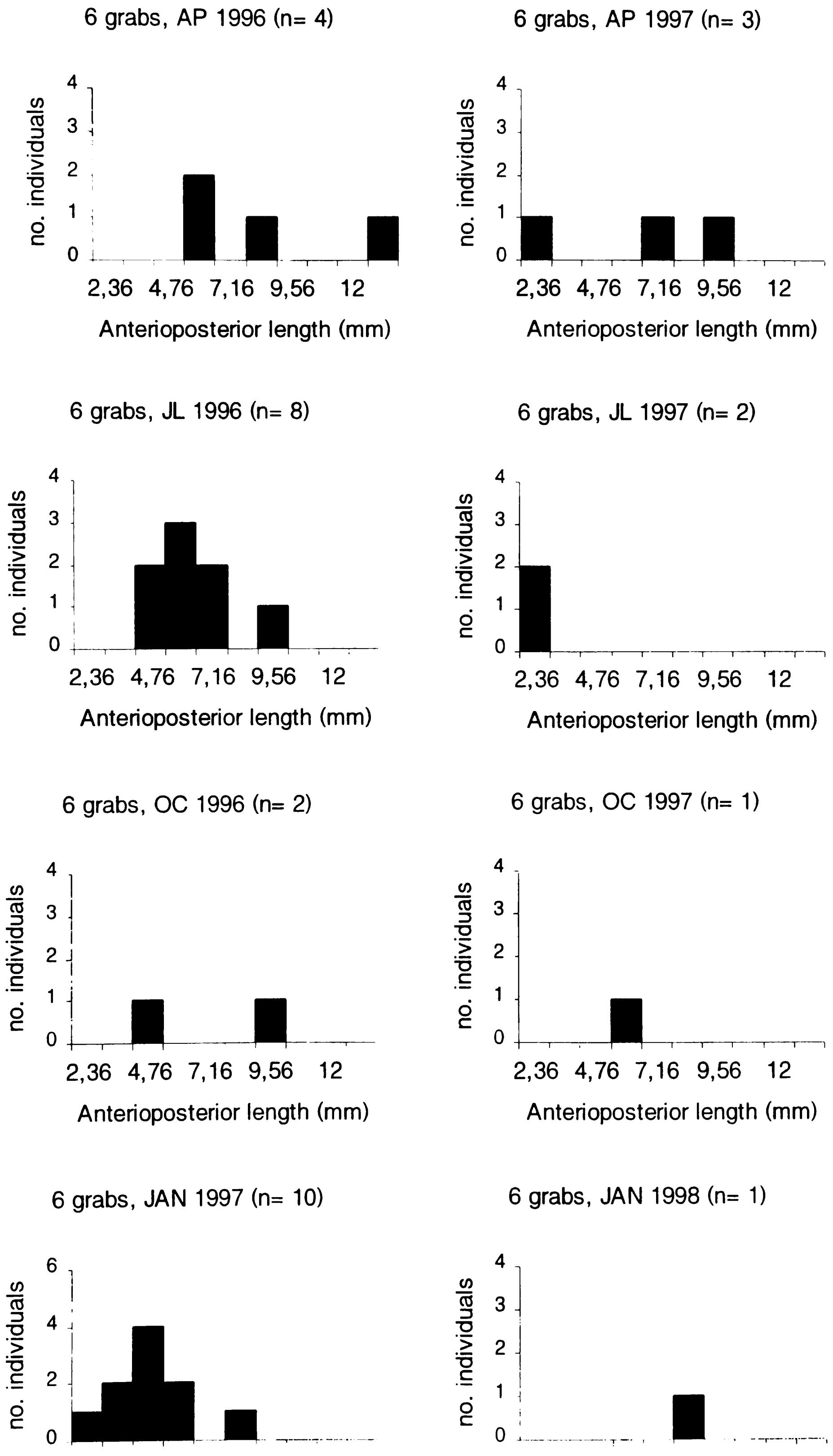
This bivalve is a shallow-burrowing species preferring bottoms of coarse gravel, shell-gravel and muddy or sandy gravel. It has also been regarded as a key species in our control maerl ground. As a suspension-feeder it is very habitat-selective needing clean, well oxygenated grounds.

Fig. 3.274. A) Mean number and B) biomass (g wet weight) of *Clausinella fasciata* per 0.1 m^2 grab at USC. Error bars = SD, N = six grabs analysed



No consistent seasonal patterns for *C. fasciata* from the first year to the second can be deduced from Fig. 3.274 A. Being a most conspicuous animal, their numbers are lower than the ones registered for other key taxa. A different pattern in the population dynamics of this species was found when comparing the two years of study (Fig. 3.274 A & B). The highest abundances do not correspond in time with the highest biomass, implying that we may be dealing with recruitment. This could be deduced from the very low numbers (2 ind./0.1 m^2) and quite high biomass values (2.5 g/0.1 m^2) in summer 1997 (Fig. 3.274 A & B, see also Fig. 3.275).

Fig. 3.275. Size-frequency histograms for *Clausinella fasciata* per 0.1 m^2 grab at USC from 1996-1998. AP= April, JL= July, OC= October, JAN= January.



6 grabs, AP 1996 (n= 4)

6 grabs, AP 1997 (n= 3)

6 grabs, JL 1996 (n= 8)

6 grabs, JL 1997 (n= 2)

6 grabs, OC 1996 (n= 2)

6 grabs, OC 1997 (n= 1)

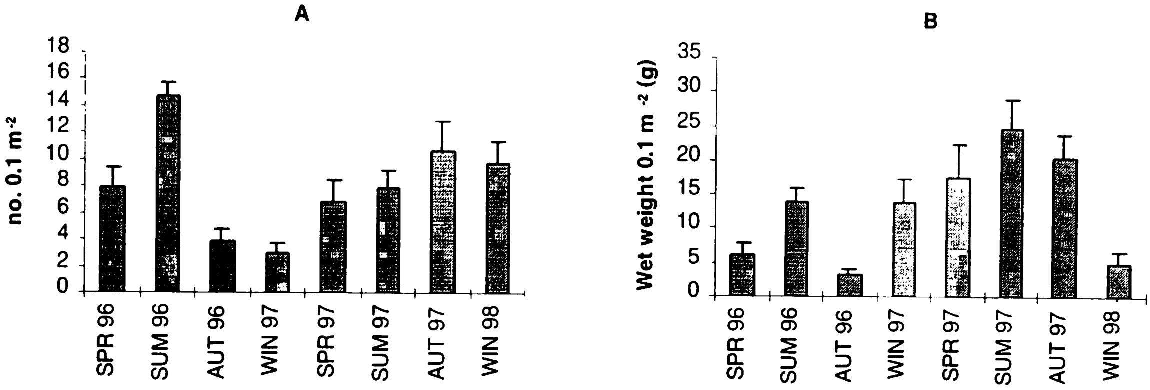
6 grabs, JAN 1997 (n= 10)

6 grabs, JAN 1998 (n= 1)

Dosinia exoleta (Linnaeus, 1758)

Dosinia exoleta burrows rather deeply into shelly or muddy gravel, from low in the intertidal zone to about 73 metres depth offshore.

Fig. 3.276. A) Mean number and B) biomass (g wet weight) of *Dosinia exoleta* per 0.1 m^2 grab at USC. Error bars = SD, N = six grabs analysed

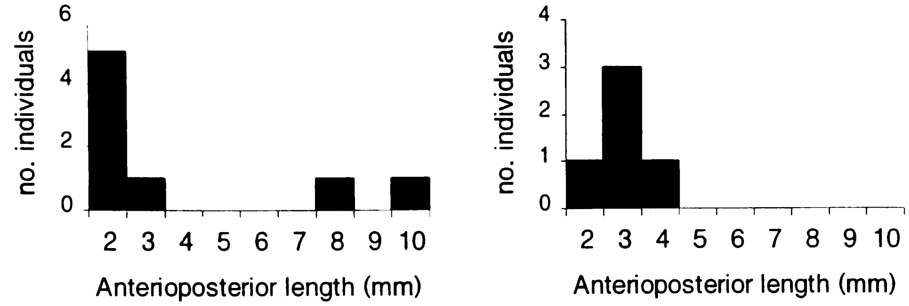


This is one of the few species in which a seasonal pattern can be discerned. It is less evident for the second year of study (1997) than for the first (1996), but it follows the same trend nevertheless. The main difference in seasonality is a deplacement of the maximum numbers from summer 1997 to autumn 1997, compared with the values found for 1996 (maximum numbers in summer and not in autumn) (Fig. 3.276 A). Apart from this, the biomass data also showed that recruitment of this species was taking place during the first year of study (high numbers, low biomass) while throughout the second year adult cohorts were already in existence (mean numbers and highest biomass) (Fig. 3.276 B).

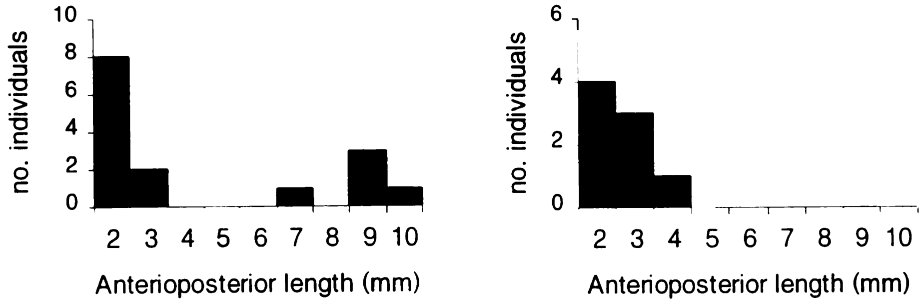
There is a possible seasonal pattern with highest abundance values in summer 1996 for the first year of study being shifted to autumn in the second year.

Fig. 3.277 shows the seasonal variation in size-frequency of the *Dosinia exoleta* population at the control site.

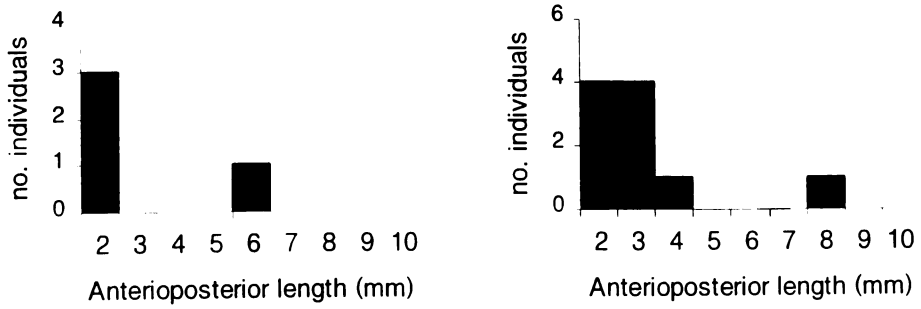
Fig. 3.277. Size-frequency histograms for *Dosinia exoleta* per 0.1 m^2 grab at USC from 1996-1998. AP= April, JL= July, OC= October, JAN= January.


6 grabs, AP 1996 (n= 8)

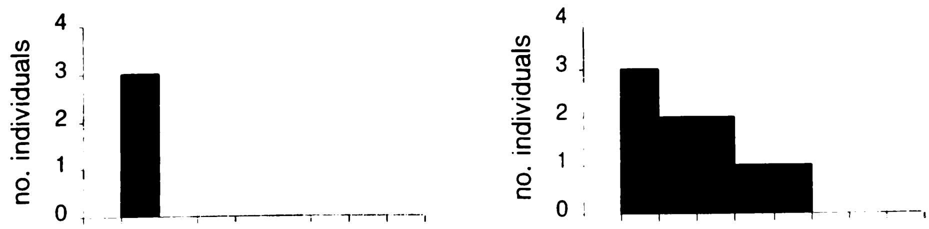
6 grabs, AP 1997 (n= 5)


6 grabs, JL 1996 (n= 15)

6 grabs, JL 1997 (n= 8)


6 grabs, OC 1996 (n= 4)

6 grabs, OC 1997 (n= 10)

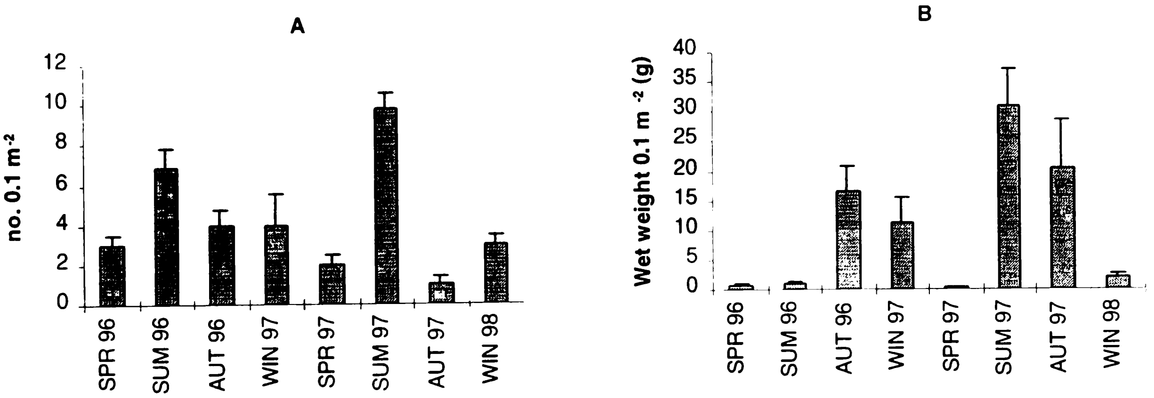

6 grabs, JAN 1997 (n= 3)

6 grabs, JAN 1998 (n= 9)

Tapes rhomboides (Pennant, 1777).

The bivalve mollusc *Tapes rhomboides* burrows in bottoms of gravel, shell-gravel, sandy gravel, muddy gravel or coarse sand, from low tide-mark to 182 m (Tebble, 1966).

Fig. 3.278. A) Mean number and B) biomass (g wet weight) of *Tapes rhomboides* per 0.1 m^2 grab at USC. Error bars = SD, N = six grabs analysed

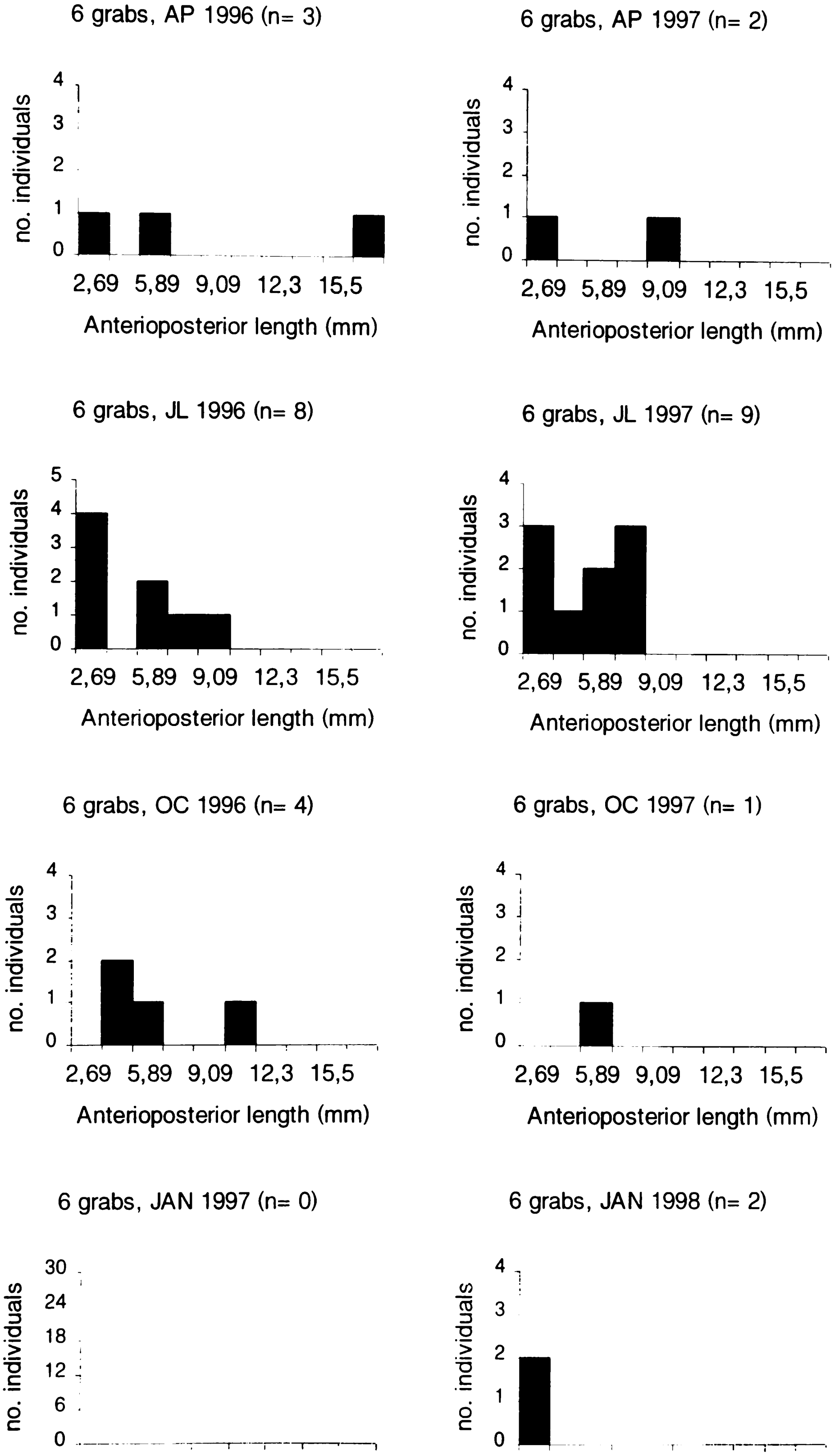


T. rhomboides was one of the key species that was only present at the control maerl ground (USC). It was present throughout the two-year period of study though numbers were not high.

Maximum values were found in summer 1996 and 1997 (Fig. 3.278 A), though it was only in summer 1997 where adult cohorts were detected (Fig. 3.278 B).

There was a possible seasonal pattern with highest abundance values in summer 1996 and 1997 and much lower ones in autumn and winter. Though this pattern was less evident from the biomass data, Fig. 3.279 shows the seasonal variation in size-frequency of the *T. rhomboides* population at the control site.

Fig. 3.279. Size-frequency histograms for *Tapes rhomboides* per 0.1 m^2 grab at USC from 1996-1998. AP= April, JL= July, OC= October, JAN= January.


6 grabs, AP 1996 (n= 3)

6 grabs, AP 1997 (n= 2)

6 grabs, JL 1996 (n= 8)

6 grabs, JL 1997 (n= 9)

6 grabs, OC 1996 (n= 4)

6 grabs, OC 1997 (n= 1)

6 grabs, JAN 1997 (n= 0)

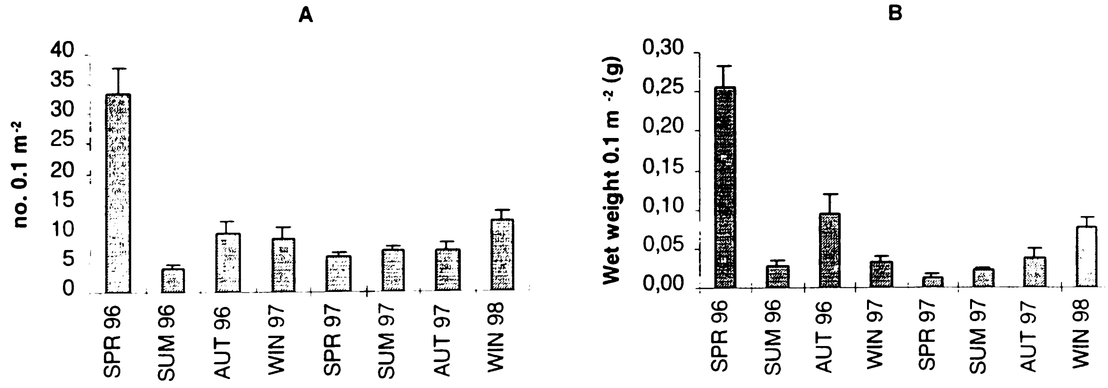
6 grabs, JAN 1998 (n= 2)

Echinocyamus pusillus (O F Müller, 1776).

The sea urchin *Echinocyamus pusillus* reaches up to 15 mm diameter. It prefers a bottom of coarse sand or gravel. Its food consists of small benthic organisms, especially Foraminifera, remains of plants, and general bottom detritus. It is consumed by fishes, especially by dab and haddock.

The breeding season of *E. pusillus* is in the summer months, and it is probably common everywhere on appropriate coarse sandy or gravelly bottoms in shallow depths.

Fig. 3.280. A) Mean number and B) biomass (g wet weight) of *Echinocyamus pusillus* per 0.1 m^2 grab at USC. Error bars = SD, N = six grabs analysed

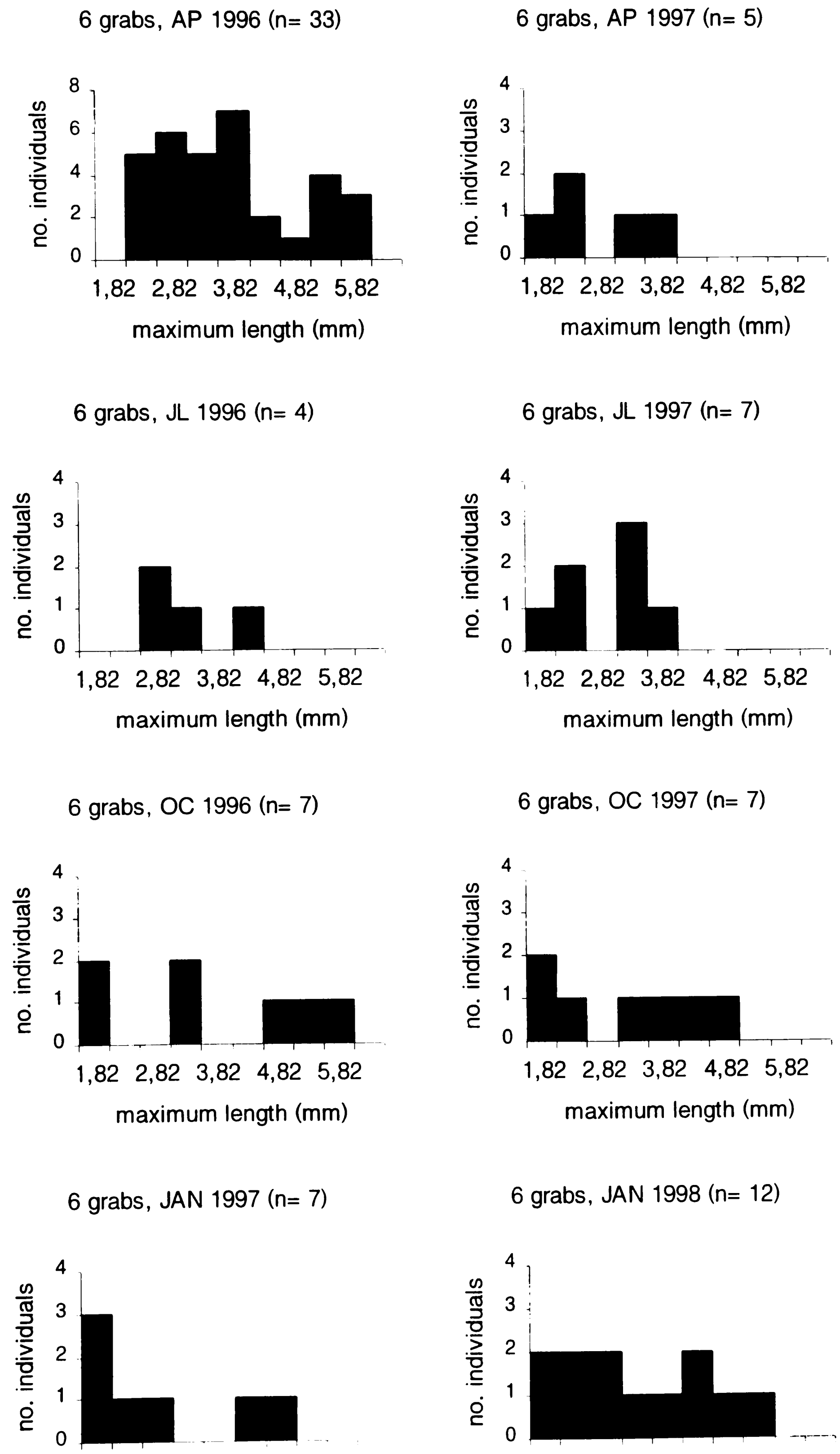


This species was found all through the two-year period with relatively constant abundances except for spring 1996 when the maximum values were registered (Fig. 3.280 A). This pattern was also repeated in the biomass data (Fig. 3.280 B).

The sseasonal variation in size-frequency of the *Echinocyamus pusillus* population at the control station USC is shown in Fig. 3.281. Mostly small individuals, *i.e.* smaller than the 6 mm length, were found during the two years of study.

No seasonality was observed for this species in which abundances decreased from spring 1996, then remained constant until winter 1998.

Fig. 3.281. Size-frequency histograms for *Echinocyamus pusillus* per 0.1 m^2 grab at USC from 1996-1998. AP= April, JL= July, OC= October, JAN= January.

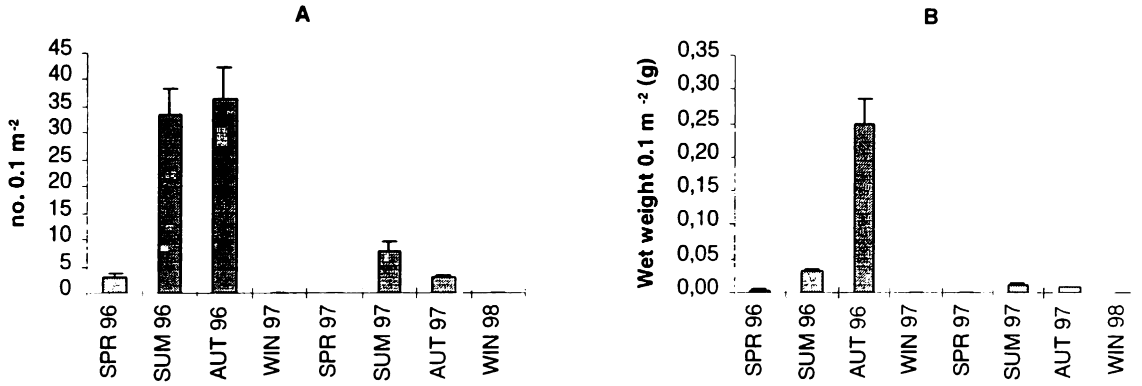


***Psammechinus miliaris* (Gmelin, 1778)**

The breeding season of this sea urchin is essentially in the early summer months. It is hought to form hybrids with *Echinus esculentus*.

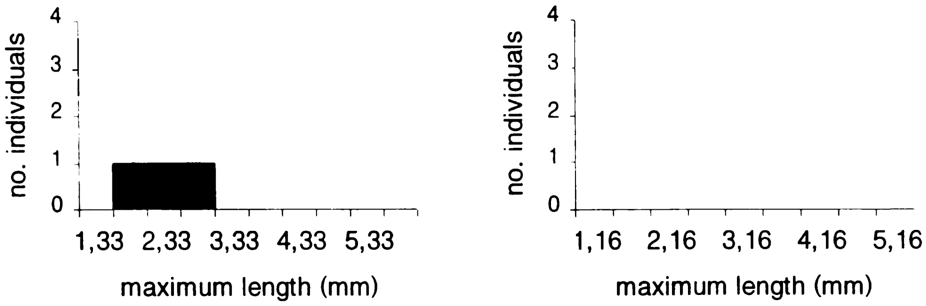
It is omnivorous, its diet varying according to the bottom on which it lives. Typically its food consists of *Zostera*, algae, or all sorts of bottom organisms. It is essentially a littoral form, living among sea-grass, algae, often to be found under stones and on rocks within the tide limits.

Fig. 3.282. A) Mean number and B) biomass (g wet weight) of *Psammechinus miliaris* per 0.1 m^2 grab at USC. Error bars = SD, N = six grabs analysed

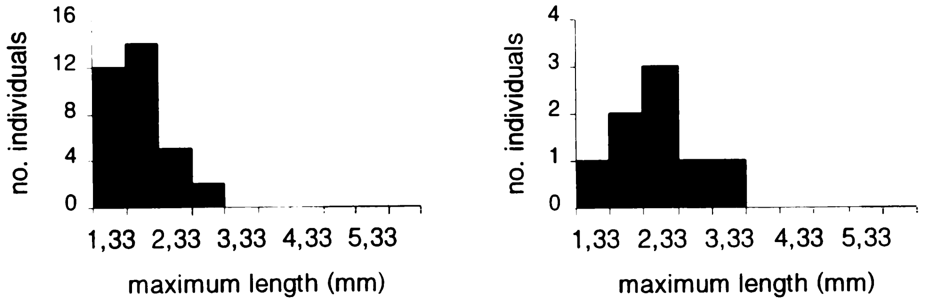


This species was only present at the control site where it showed highest abundances in summer and autumn 1996 and much lower values in the same seasons of year 1997 (Fig. 3.282 A). Highest values for biomass were also observed in autumn 1996 (Fig. 3.282 B). The size-frequency distribution for *Psammechinus miliaris* is shown for the control ground in Fig. 3.283. Small individuals were collected during the first year of study while bigger ones appeared from spring to autumn 1997.

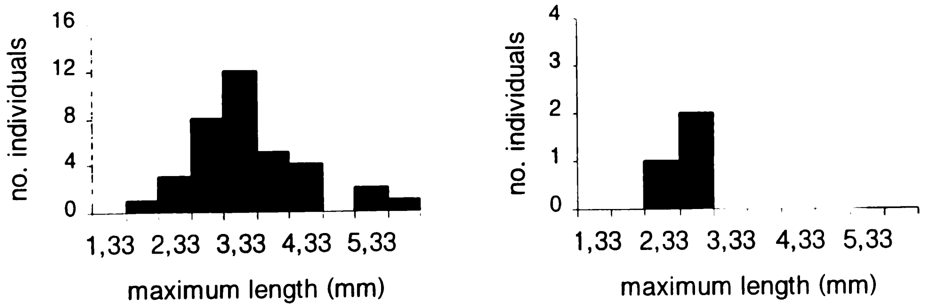
Fig. 3.283. Size-frequency histograms for *Psammechinus miliaris* per 0.1 m^2 grab at USC from 1996-1998. AP= April, JL= July, OC= October, JAN= January.


6 grabs, AP 1996 (n= 3)

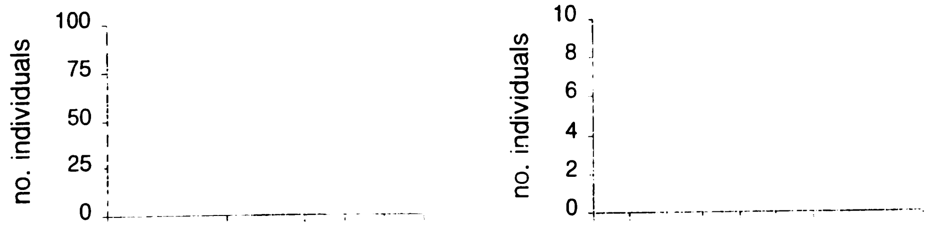
6 grabs, AP 1997 (n= 0)


6 grabs, JL 1996 (n= 33)

6 grabs, JL 1997 (n= 8)


6 grabs, OC 1996 (n= 36)

6 grabs, OC 1997 (n= 3)

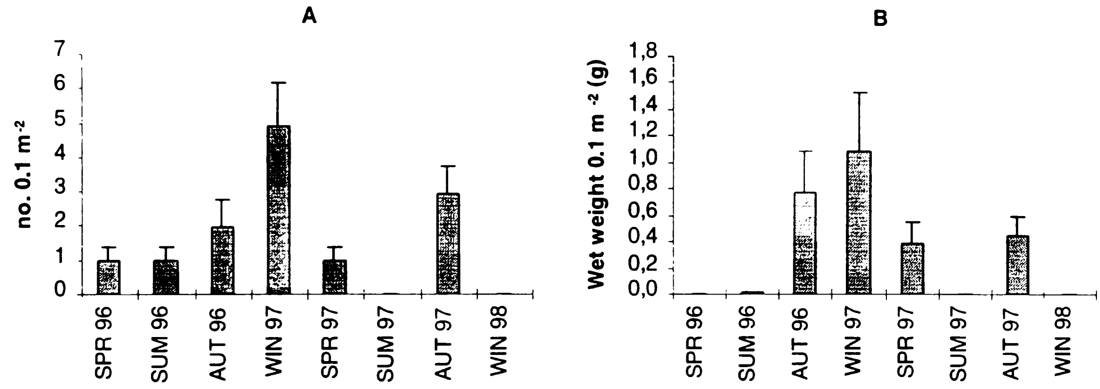

6 grabs, JAN 1997 (n= 0)

6 grabs, JAN 1998 (n= 0)

Branchiostoma lanceolatum (Pallas, 1778)

The lancelet *Branchiostoma lanceolatum* has been recorded as a species forming its own biocoenosis in fine oxygenated sands (Sânchez-Mata, 1996) named *Amphioxus* sands. It is fed upon by various crustaceans, sea anemones and fishes.

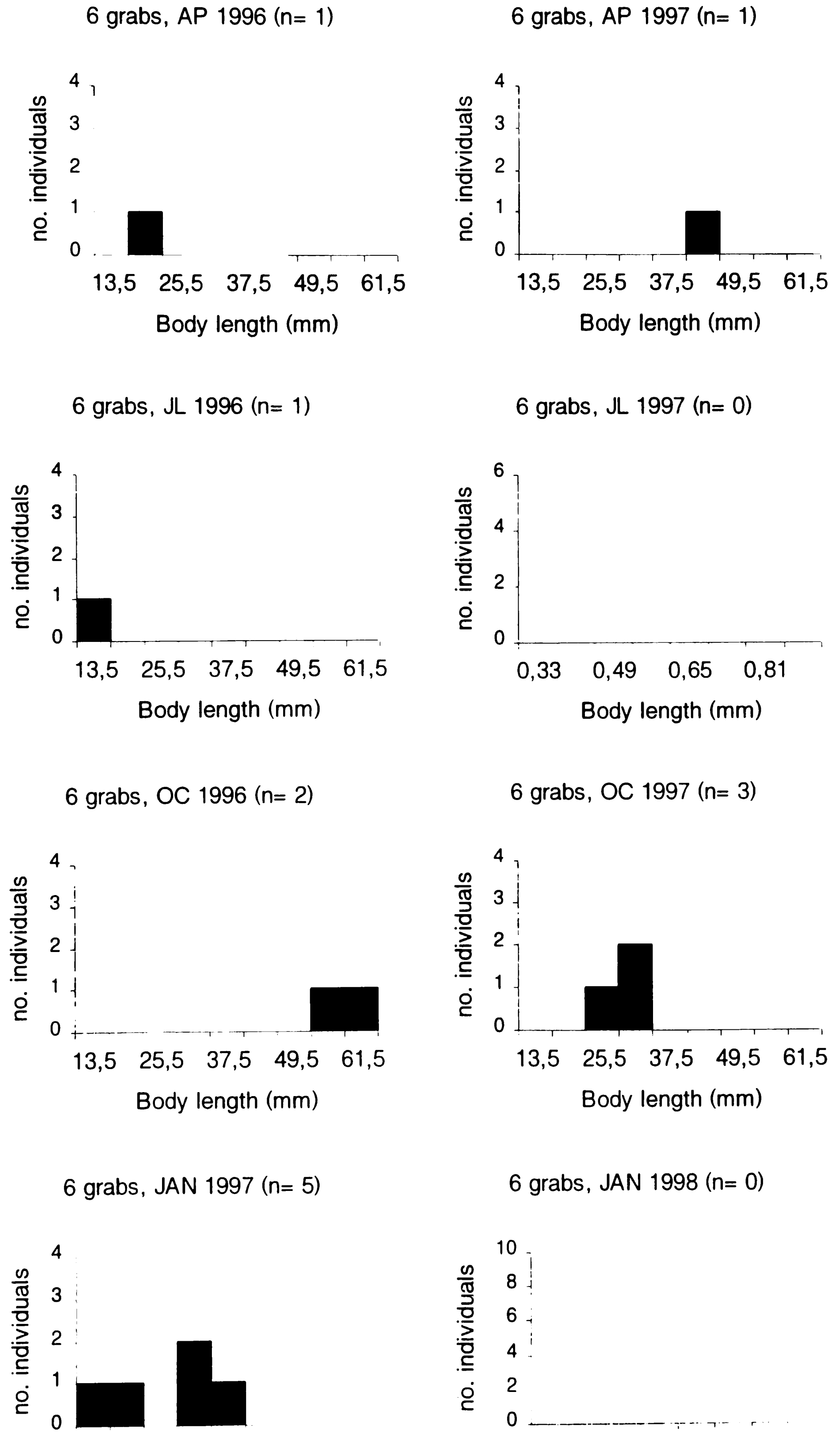
Fig. 3.284. A) Mean number and B) biomass (g wet weight) of *Branchiostoma lanceolatum* per 0.1 m^2 grab at USC. Error bars = SD, N = six grabs analysed



Highest abundances of *B. lanceolatum* were recorded in winter with lower numbers in spring and summer during the first year of study (Fig. 3.284). For the second year, no seasonality can be detected as *B. lanceolatum* was scarcely found (present only in spring and autumn). Such unpredictability is very typical of this species due to the fact that it is a very sensitive animal, which lives by suspension feeding and responds quickly to any fluctuations in the ecosystem where it dwells. That is why it was only found at the control site where it was not disturbed by the detritus inputs to the ground from mytiliculture rafts.

Another point to highlight, however, is that its low numbers may have to do with the sampling technique employed (these are very fast-swimming animals and some may have escaped from the grab before it closed). Low numbers make interpretation of size-frequency distribution (Fig. 3.285) difficult.

Fig. 3.285. Size-frequency histograms for *Branchiostoma lanceolatum* per 0.1 m^2 grab at USC from 1996-1998. AP= April, JL= July, OC= October, JAN= January.


6 grabs, AP 1996 (n= 1)

6 grabs, AP 1997 (n= 1)

6 grabs, JL 1996 (n= 1)

6 grabs, JL 1997 (n= 0)

6 grabs, OC 1996 (n= 2)

6 grabs, OC 1997 (n= 3)

6 grabs, JAN 1997 (n= 5)

6 grabs, JAN 1998 (n= 0)

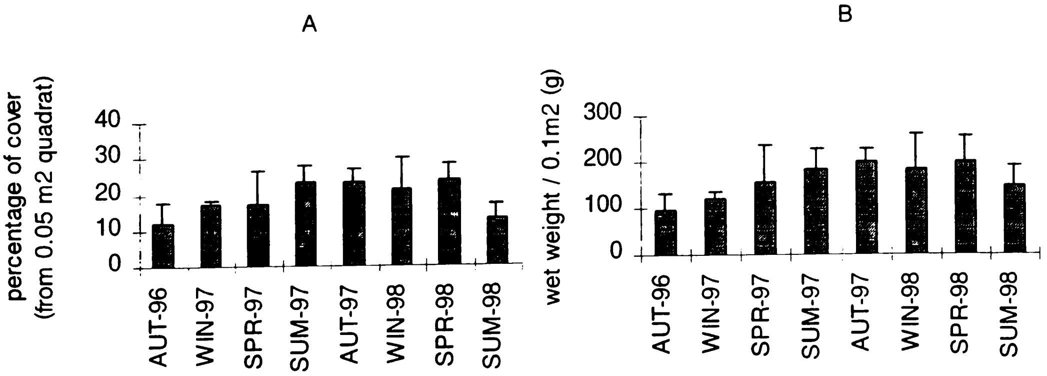
4) Alicante

Lithothamnion minervae **Basso**

This was one of the commonest calcareous algae at the control site and one of the main maerl-forming species. It was not detected at the impacted site. It has a characteristic massive round to oval shape, with an irregular disposition of short branches, creating rhodoliths with a high sphericity value.

Although some small peaks in both percentage cover and biomass were detected in autumn 1997 and spring 1998, no major seasonal patterns could be detected (Fig. 3.286 A & B). The variability encountered is probably due to environmental patchiness, rather than to any real change in the population since this alga is a long-lived species.

Fig. 3.286. A) Mean cover and B) Biomass (g wet weight) of *L. minervae* per 0.1m^2 (data from 0.05m^2 quadrat) at UAC. Error bars = S.D., N = 3 in all cases.



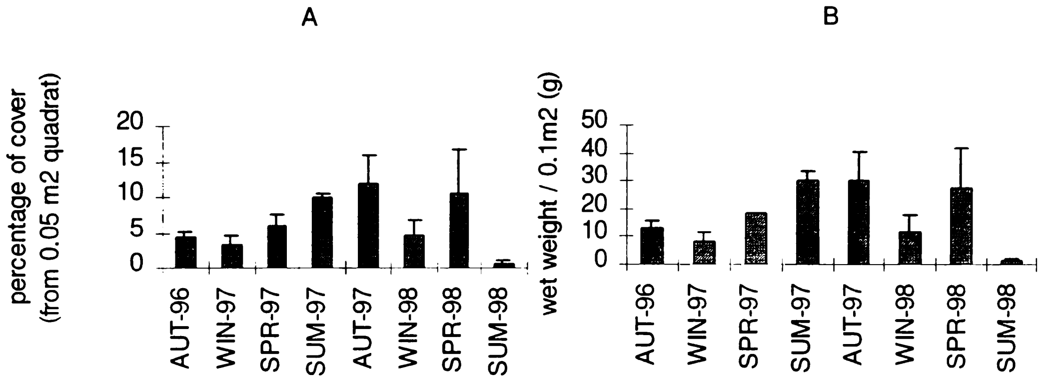
This species was not found at the impacted site, so no comparisons can be made.

Phymatolithon calcareum **(Pallas) Adey & McKibbin**

This calcareous species forms open-branched rhodoliths. Its branches are harder and thicker than those of *Lithothamnion corallioides* which was present on the impacted gound. *P. calcareum*, with *L. minervae,* were the most important maerl-forming species at the control site (UAI). Although a peak in both cover and biomass occurred in autumn 1997, no seasonal patterns could be discerned (Fig. 3.287 A & B). This is probably due to spatial heterogeneity, this alga being a long-lived species.

Live *P. calcareum* was not found on the impacted grounds (only dead pieces of calcareous thalli), perhaps due to the different sedimentological conditions (higher mud fraction) and the mechanical impact of trawling.

Fig. 3.287. A) Mean cover and B) Biomass (g wet weight) of *Phymatolithon calcareum* per 0.1 m^2 (data from $0.05m^2$ quadrats) at UAC. Errors bars = SD, N = 3 in all cases.



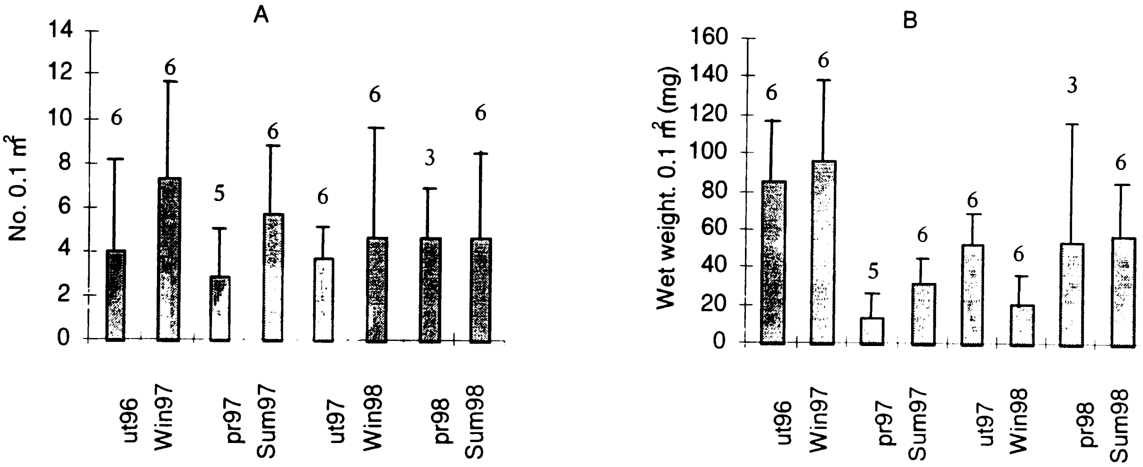
P. calcareum was not present at the impacted site, so no comparisons can be made.

Eunice vittata delle Chiaje, 1828

Eunice vittata was one of the commonest polychaetes on the Alicante maërl beds. It was abundant in both control and impacted sites. Abundances were quite similar at the two sites, but the biomass was higher at the control site, due to the larger size of worms there cf. the impacted ground. This is a species with wide ecological distribution (Picard, 1965), and the feeding habits are omnivorous (carnivore/scavenger). Compared with the other UA key-species polychaete, we would consider *E. vittata* as more opportunistic than *Lysidice ninetta*.

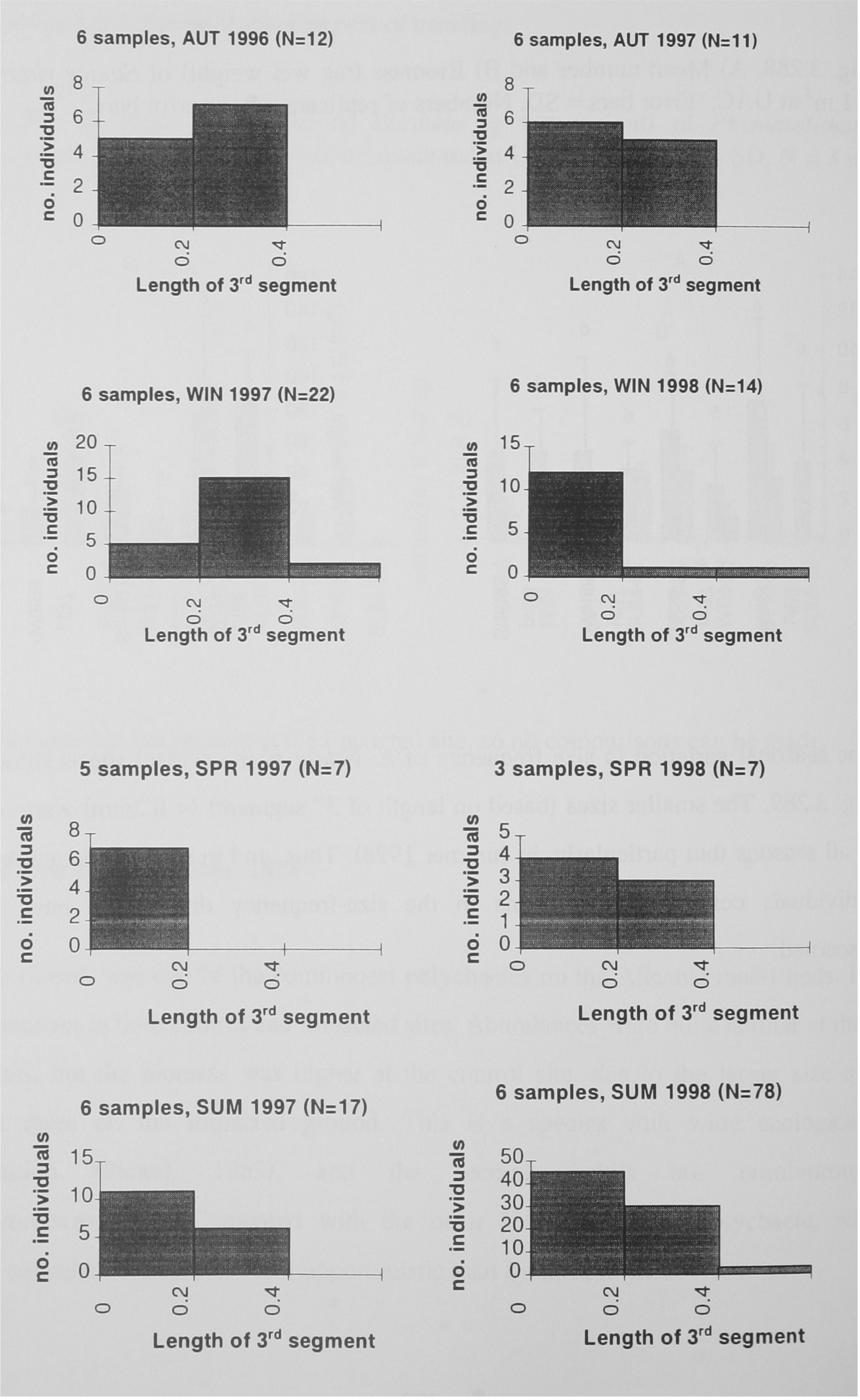
No particular seasonal pattern was observed in either abundance or biomass of this species at the control area (Fig. 3.288). However, the highest values of abundance during the two years were obtained in winter. The highest value for biomass was also in winter 1997.

Fig. 3.288. A) Mean number and B) Biomass (mg wet weight) of *Eunice vittata* per 0.1 m^2 at UAC. Error bars = SD. Numbers of replicates above error bars.



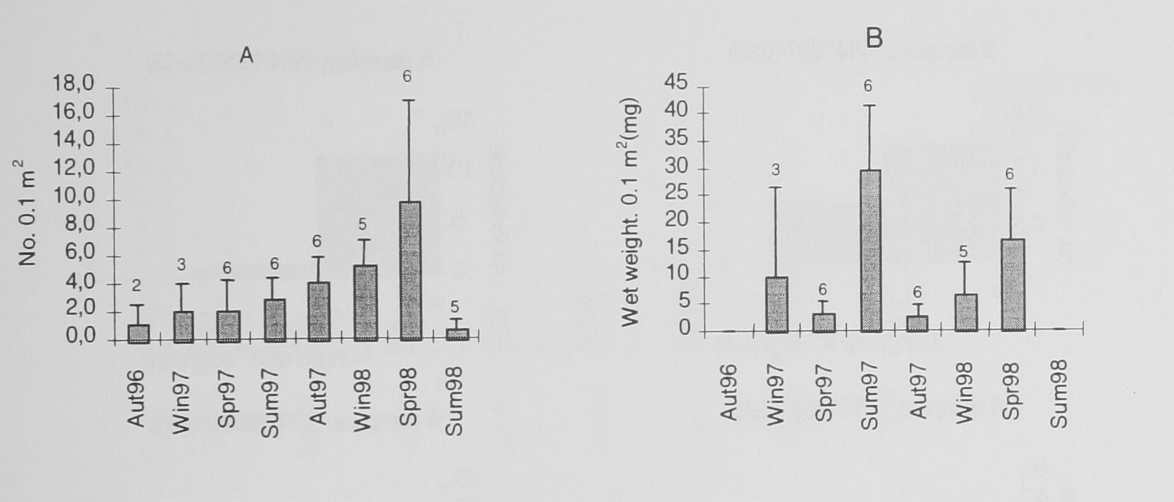
The seasonal variation in size frequency of *E. vittata* at the control site is shown in Fig. 3.289. The smaller sizes (based on length of 3rd segment) (< 0.2mm) were found in all seasons (but particularly, in summer 1998). Thus, and in spite of the number of individuals collected, no patterns in the size-frequency distribution have been discerned.

Fig. 3.289. Size-frequency histograms for *Eunice vittata* collected seasonally per 0.1 m^2 at UAC from 1996-1998. SUM = summer, AUT = autumn, WIN = winter, SPR = spring.



The abundance of this species at the impacted site was greater than at the control site in the second year (except in summer1998). However, the biomass was much lower than control ground (more small individuals). The highest value for abundance was in spring 1998, and for biomass in summer 1997. No seasonal pattern could be detected (Fig. 3.290).

Fig. 3.290. A) Mean number and B) Biomass (mg wet weight) of *Eunice vittata* per 0.1 m^2 at UAI. Error bars = SD. Numbers of replicates above error bars.



The seasonal variation in size frequency of *E. vittata* at the impacted site is shown in Fig. 3.291. The smaller sizes (lengh of 3rd segment < 0.2mm) are found throughout the year. Thus, no seasonal patterns in size-frequency distribution can be discerned.

Fig. 3.291. Size-frequency histograms for *Eunice vittata* collected seasonally per 0.1 m^2 quadrat at UAI from 1996-1998. SUM = summer, WIN = winter, AUT = autumn, SPR = spring.

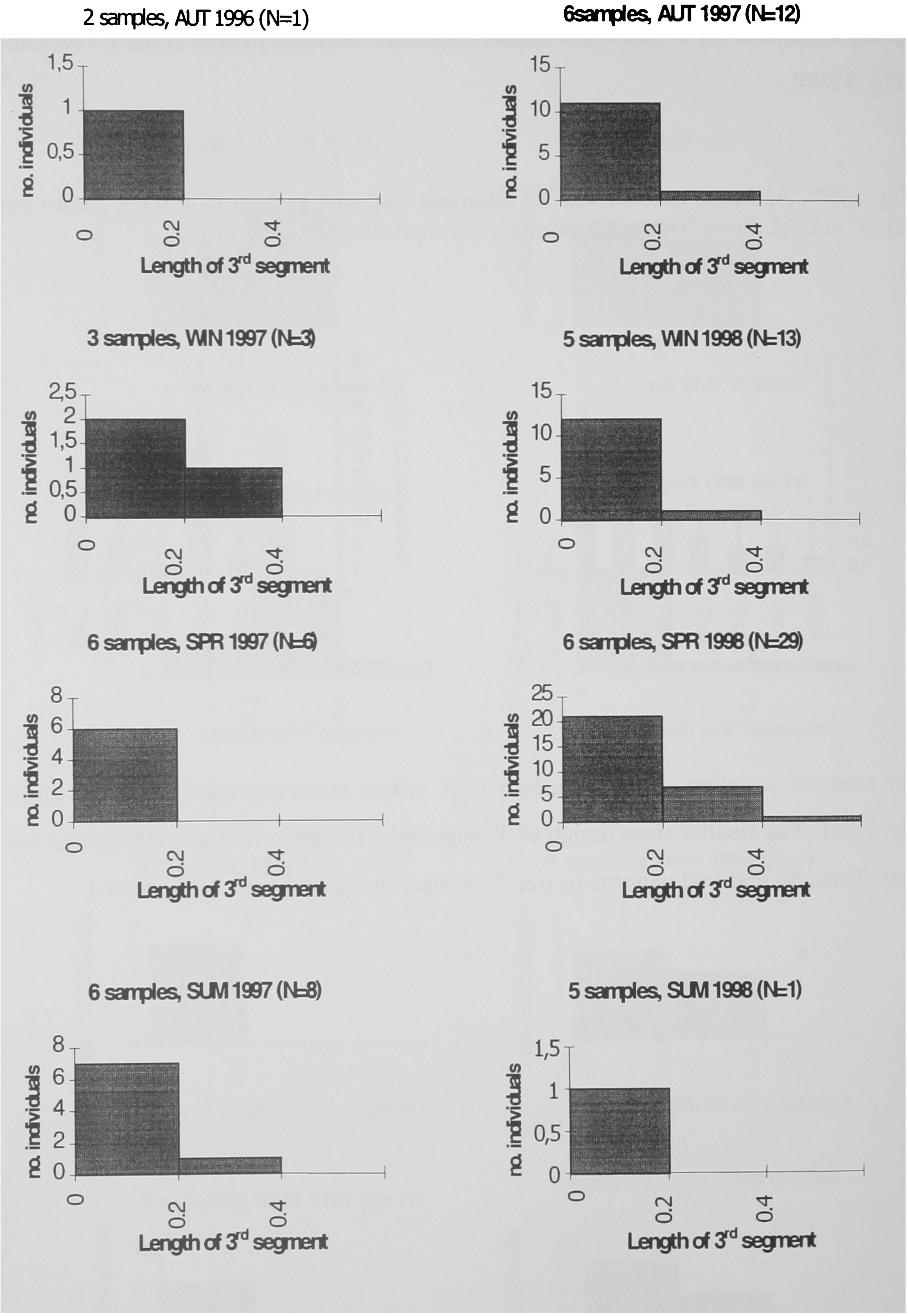
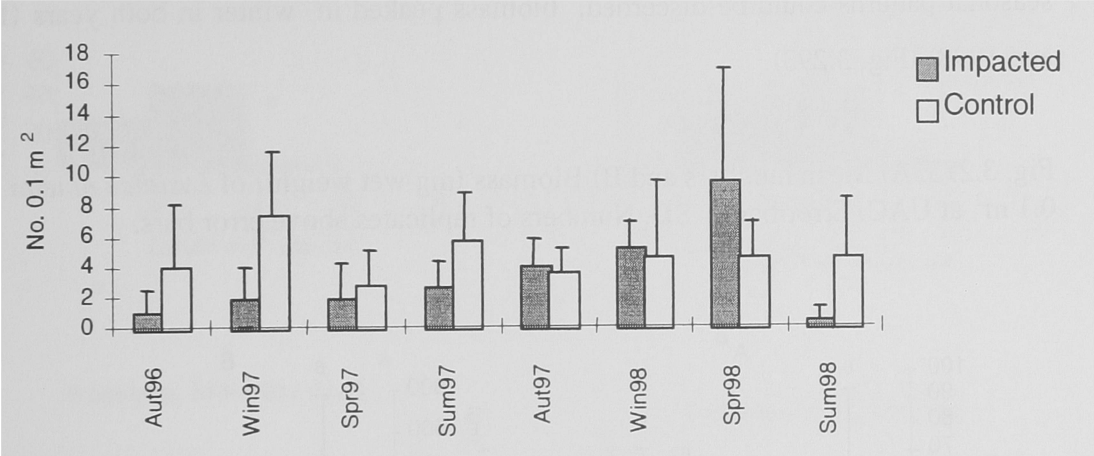


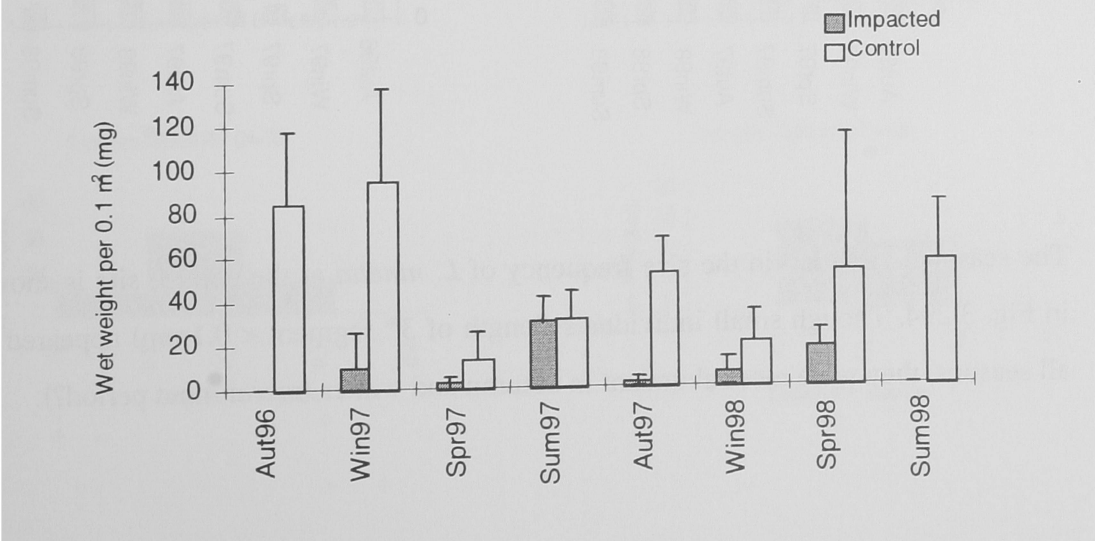
Fig. 3.292 compares the abundance and biomass of *Eunice vittata* on the control and impacted sites. With regard to the abundance, there were some differences between years, this species was more abundant in the first year at the control site. However, . densities at the control site were higher than at the impacted site in all seasonal samples.

Fig. 3.292.

Seasonal variation in abundance (±sd) of *Eunice vittata* on impacted and control grounds



Seasonal variation in mean biomass (±sd) of *Eunice vittata* on impacted and control grounds

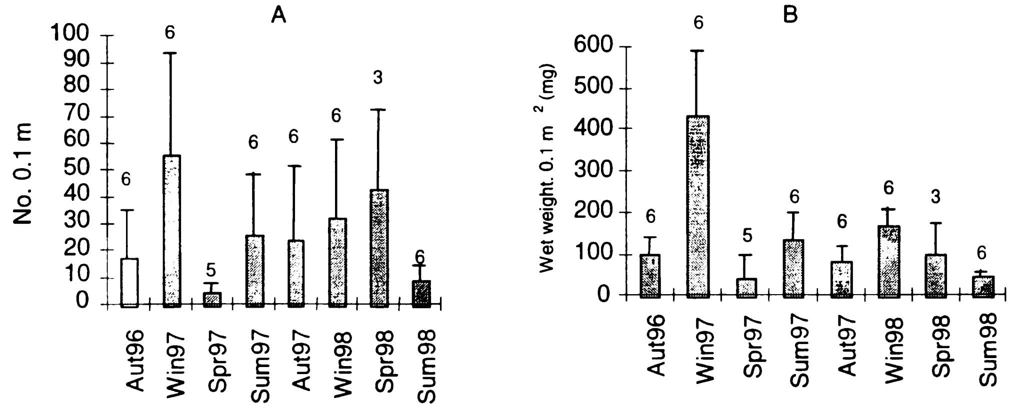


Lysidice ninetta Audouin & Milne Edwards, 1833

L. ninetta was the most common polychaete on the Alicante maerl grounds. Although it was found both at the control and impacted sites, only a few individuals were collected at the impacted site. This species' detailed ecological significance is unknown (Picard, 1965), but it has a carnivorous/scavenging feeding habit.

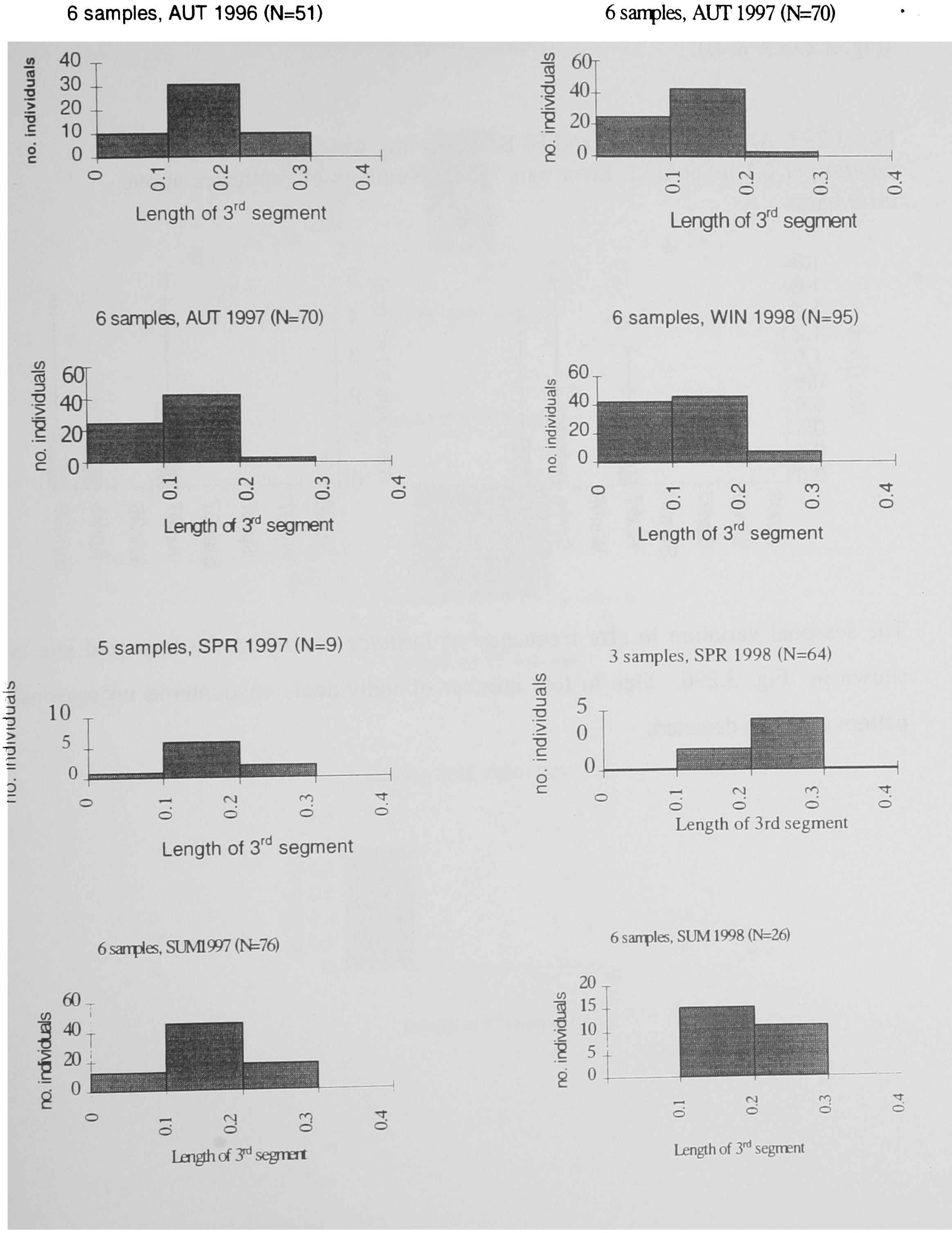
It was more abundant at the control site in all seasonal samples. The highest values, both in terms of abundance and biomass, were in winter 1997. Although few general seasonal patterns could be discerned, biomass peaked in winter in both years (1997 and 1998) (Fig. 3.293).

Fig. 3.293. A) Mean numbers and B) Biomass (mg wet weight) of *Lysidice ninetta* per 0.1 m^2 at UAC. Error bars = SD. Numbers of replicates above error bars.



The seasonal variation in the size frequency of *L. ninetta* at the control site is shown in Fig. 3.294. Though small individuals (length of 3rd segment < 0.1mm) appeared in all seasons, they were more abundant in autumn and winter (recruitment period?).

Fig. 3.294. Size-frequency histograms for *Lysidice ninetta* collected seasonally in 0.1 m^2 at UAC from 1996-1998. SUM = summer, AUT = autumn, WIN = winter, SPR = spring.


6 samples, AUT 1996 (N=51)

6 samples, AUT 1997 (N=70)

6 samples, AUT 1997 (N=70)

6 samples, WIN 1998 (N=95)

5 samples, SPR 1997 (N=9)

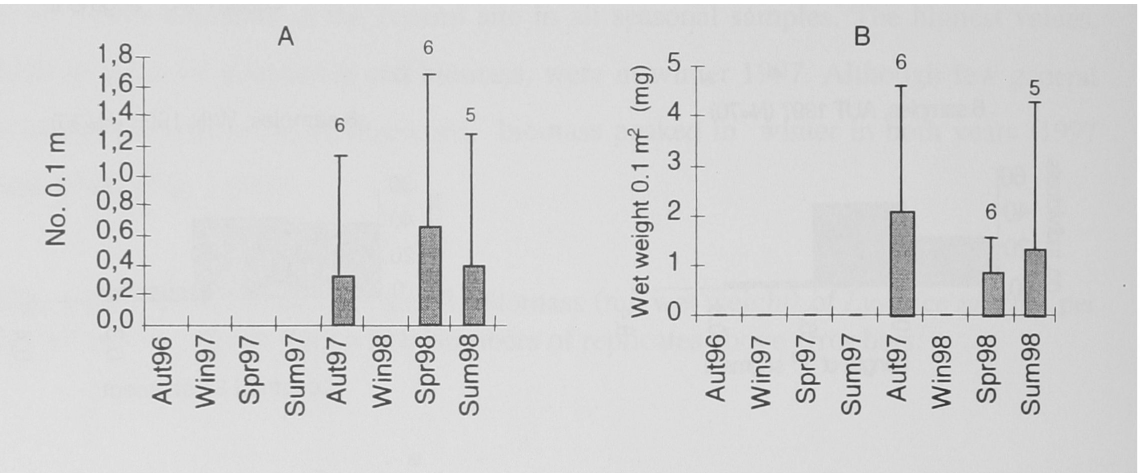
3 samples, SPR 1998 (N=64)

6 samples, SUM1997 (N=76)

6 samples, SUM 1998 (N=26)

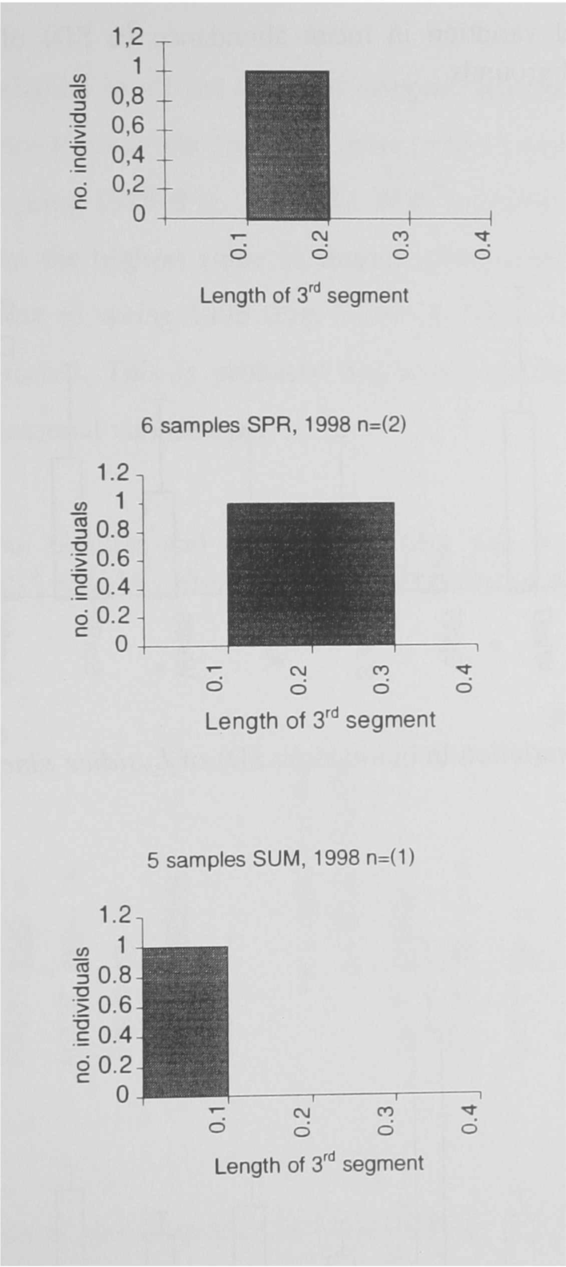
L. ninetta was very rare at the impacted site, and was only collected in the second year of sampling (autumn 1997, spring and summer 1998), and then with only a low number of specimens. Due to these limitations no seasonal pattern can be discerned . (Fig. 3.295 A & B).

Fig. 3.295. A) Mean number and B) Biomass (mg wet weight) of *Lysidice ninetta* per 0.1 m^2 at UAI. Error bars = SD. Numbers of replicates above error bars.



The seasonal variation in size frequency of *Lysidice ninetta* at the impacted site is shown in Fig. 3.296. Due to low number of individuals encountered no seasonal pattern could be detected.

Fig.3.296. Size-frequency histograms for *Lysidice ninetta* collected seasonally in 0.1 m^2 quadrats at UAI from 1996-1998. SUM = summer, AUT = autumn, WIN = winter, SPR = spring.



6 samples, AUT 1997 (n=1)

6 samples SPR, 1998 n=(2)

5 samples SUM, 1998 n=(1)

Figures 3.297 & 3.298 compare the abundance and biomass of *Lysidice ninetta* on the control and impacted sites. This polychaete was much more abundant at the control site, where it is very common and very rare at the impacted site.

Fig. 3.297. Seasonal variation in mean abundance (± SD) of *Lysidice ninetta* on impacted and control grounds.

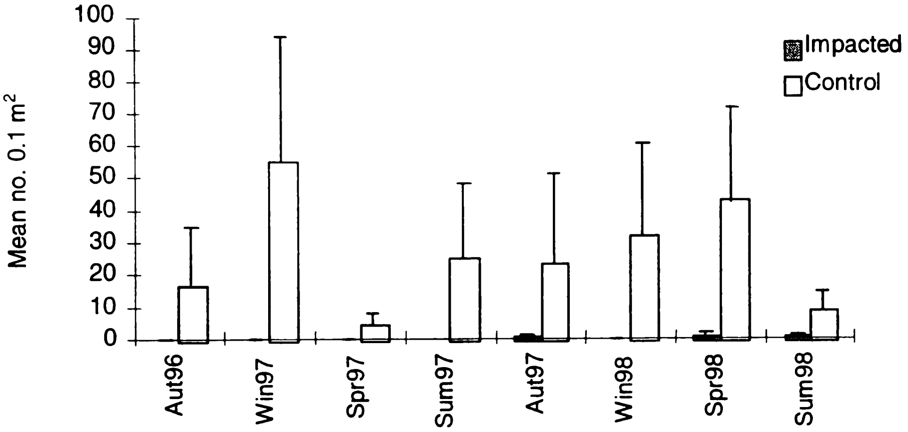
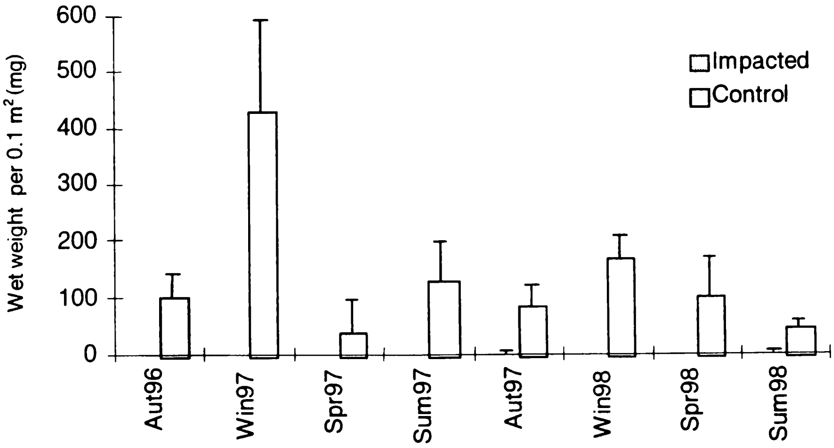


Fig. 3.298. Seasonal variation in biomass (± SD) of *Lysidice ninetta* on impacted and control grounds.

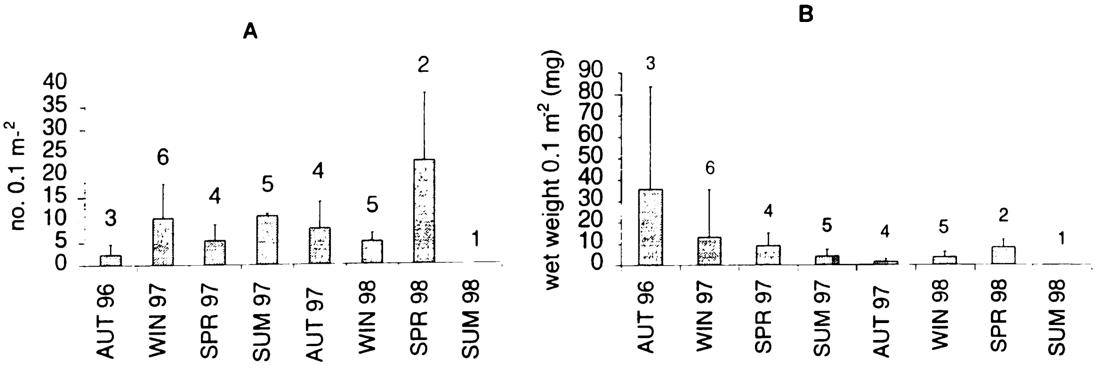


***Leptochiton cancellatus* (Sowerby, 1840)**

Leptochiton cancellatus was one of the commonest molluscs on the Alicante control maerl ground. It was not found on the impacted site. This polyplacophoran is a micrograzer (herbivore), feeding upon epiphytic microalgae growing on maerl thalli.

This species was collected in all the seasonal samples, excepting in summer 1998. Although its abundance through the year was more or less constant, there was a peak in the abundance in spring 1998 (Fig. 3.299 A). With regard to biomass, there was a gradual decrease from the highest value in autumn 1996 to autumn 1997, and after that a gradual increase to spring 1998 (Fig. 3.299 B). Thus, no consistent seasonal pattern could be detected. This is probably due to the patchy distribution of this species, rather than seasonal variation *per se*.

Fig. 3.299. A) Mean number and B) Biomass (mg wet weight) of *Leptochiton cancellatus* per 0.1 m^{-2} at UAC. Error bars = SD. Number of replicates given above error bars.



The seasonal variation in size frequency of *L. cancellatus* at the control site is shown in Fig. 3.300. The smaller sizes (length ≤ 1mm) were present in all of the seasonal samples. Although, no clear seasonal pattern in size-frequency distribution could be observed, in winter and spring the individuals reached the 2-3mm size class, while in summer and autumn the majority of individuals were 1-2 mm. That may be interpreted as a possible recruitment period.

Fig. 3.300. Size-frequency histograms for *Leptochiton cancellatus* collected seasonally in 0.1 m^2 at UAC from 1996-1998. SUM = summer, AUT = autumn, WIN = winter, SPR = spring.

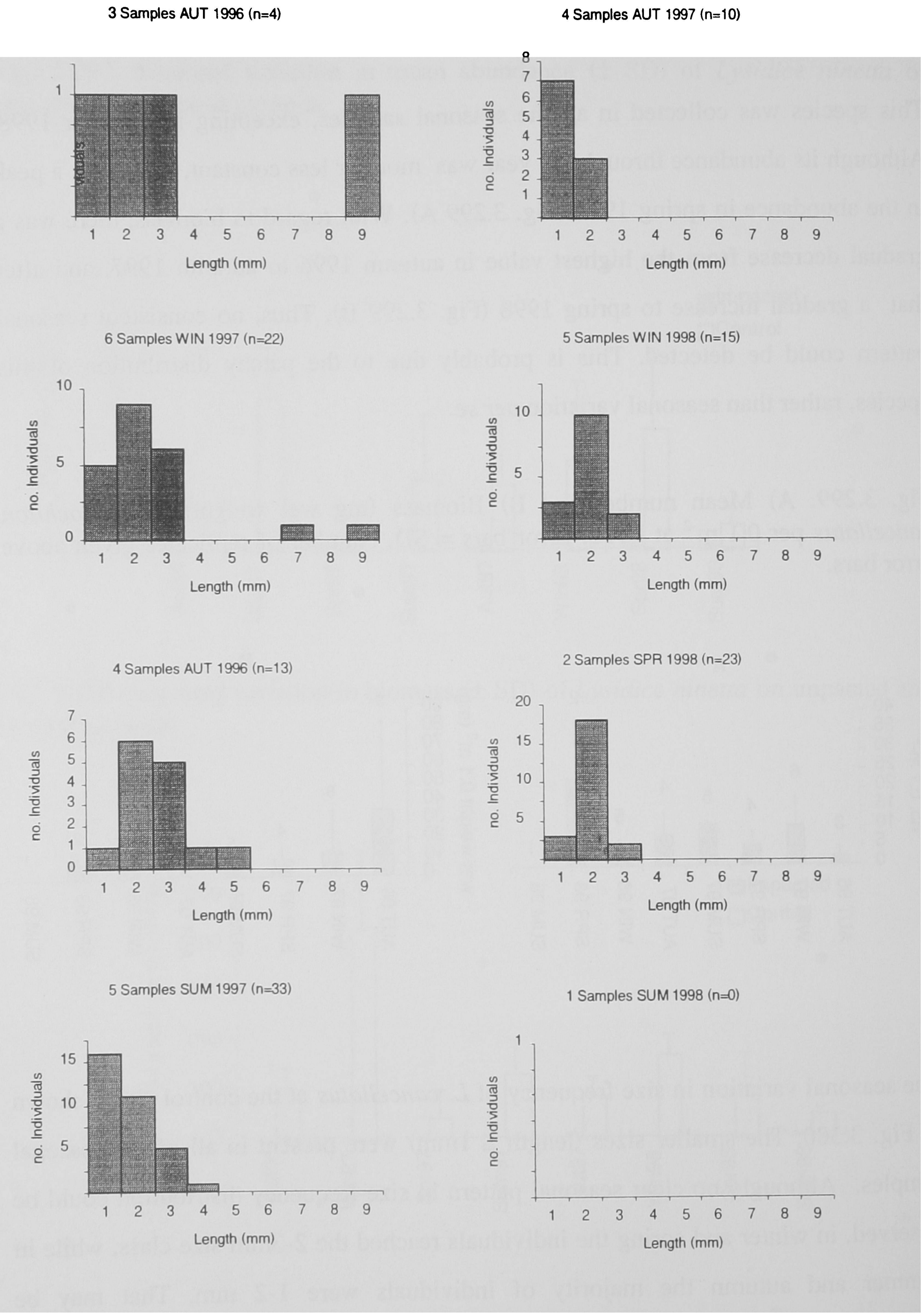
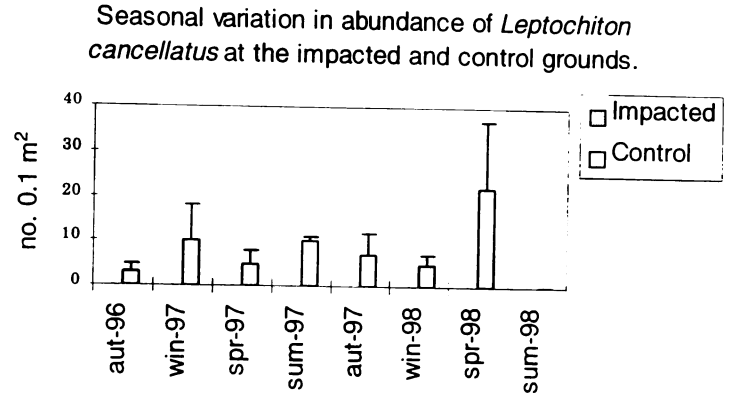
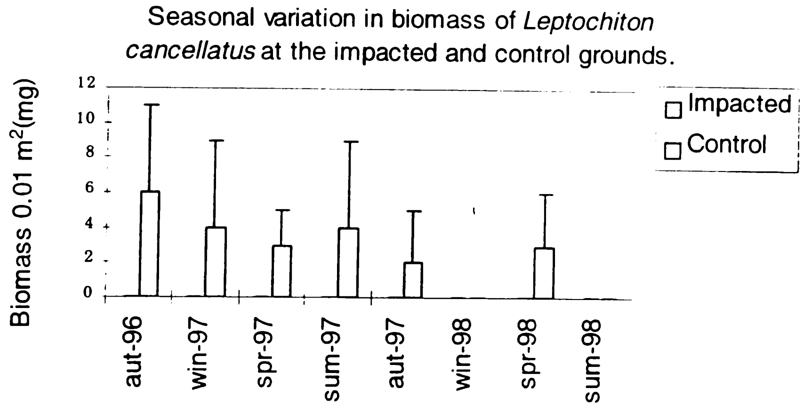


Figure 3.301 compares the abundance and biomass of *Leptochiton cancellatus* at the impacted and control sites. *Leptochiton cancellatus* was found exclusively on the control site. It was present in nearly all the seasonal samples. The lack of suitable food and substrata (soft Peyssonneliaceae) could be the reason of the absence from the samples from the impacted site.

Fig. 3.301.



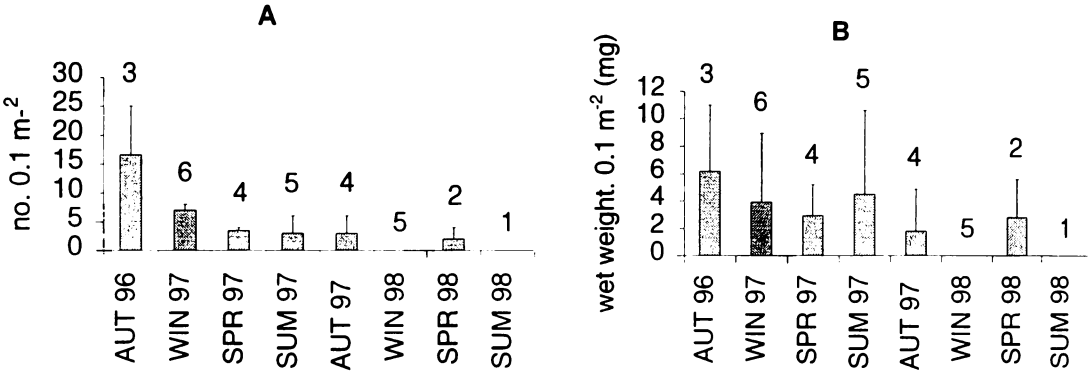


Caecum trachea (Montagu, 1803)

Caecum trachea was one of the commonest molluscs on Alicante maerl grounds, but it was only sampled by quantitative quadrats at the control site. It was collected by dredge at the impacted site, but only in very low numbers. The feeding habits of this gastropod are not know with certainly but it is considered to be a deposit feeder eating macroalgae debris and/or micrograzer on epiphytic diatoms.

C. trachea was collected in almost all the seasonal samples at UAC, excepting in winter and summer 1998. This fact, could be due to the spatial arrangement of individuals, which probably aggregate in patches. The highest values both in terms of abundance and biomass were in autumn 1996, and it was more abundant in the first year of sampling (Fig. 3.302 A & B). Due to this, no seasonal pattern could be observed.

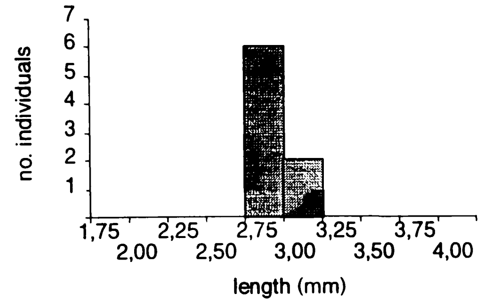
Fig. 3.302. A) Mean number and B) Biomass (mg wet weight) of *Caecum trachea* per 0.1 m^{-2} at UAC. Error bars = SD. Numbers of replicates above error bars.



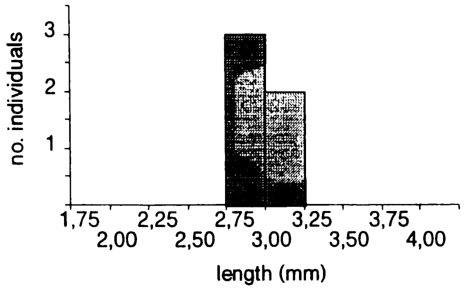
The seasonal variation in size frequency of *C. trachea* at the control site is shown in Fig. 3.303. The smallest individuals (shell length ≤ 2.25mm) were present in winter 1997. Although this species was not collected in all seasonal samples during year two, a possible seasonal pattern in size-frequency distribution could be detected. The smaller individuals (shell length ≤ 2.75mm) were not detected in summer and autumn, but these sizes were present in spring 1997. Probably, this means that recruitment to the sampled size occurs during the winter.

Fig. 3.303. Size-frequency histograms for *C. trachea* collected seasonally per 0.1 m^2 at UAC. Error bars = SD. SUM = summer, AUT = autum, WIN = winter, SPR = spring.

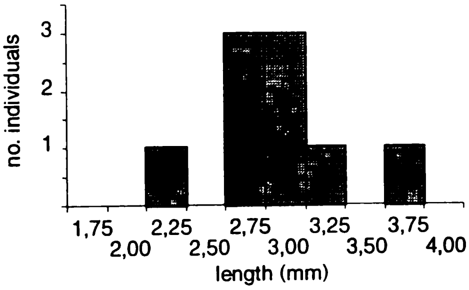
3 Samples, AUT 1997 (n=8)



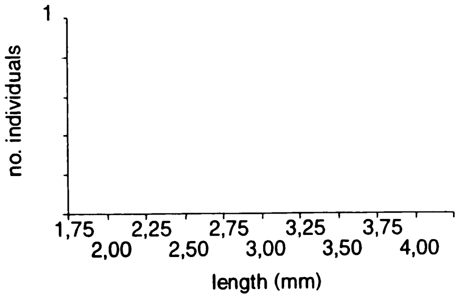
4 Samples, AUT 1997 (n=5)



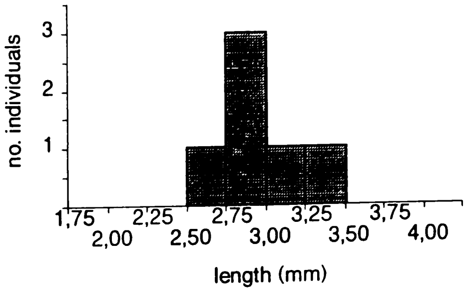
6 Samples, WIN 1997 (n=9)



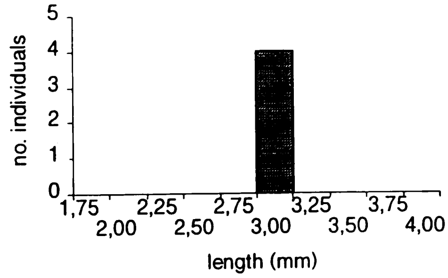
5 Samples, WIN 1998 (n=0)



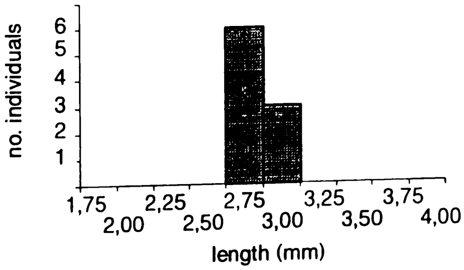
4 Samples, SPR 1997 (n=6)



2 Samples, SPR 1998 (n=4)



5 Samples, SUM 1997 (n=9)



1 Samples, SUM 1998 (n=0)

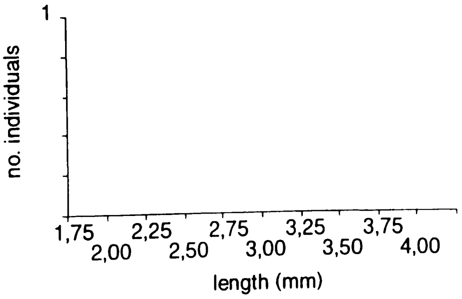
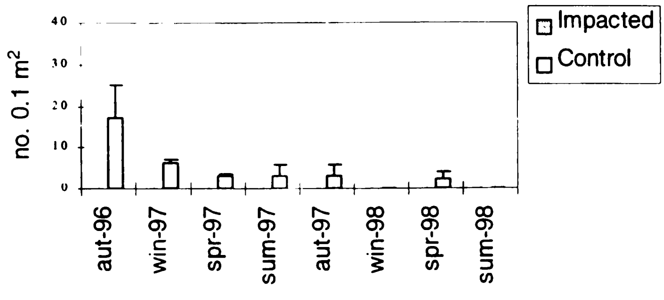


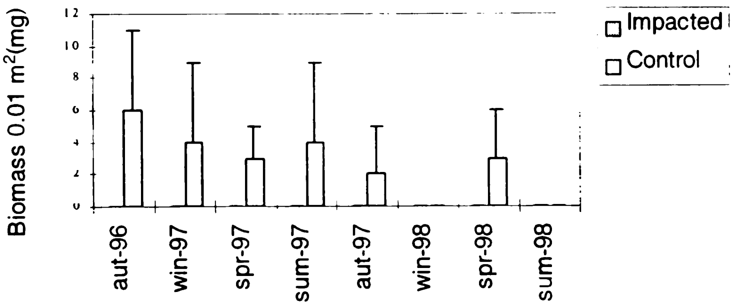
Fig. 3.304 compares the abundance and biomass of *Caecum trachea* on the impacted and control sites. Although *Caecum trachea* was observed at the impacted site, it was not sampled in the quantitative quadrats. Its relative abundance on the control site suggests, like *Lepidochiton cancellatus*, that it found an adequate habitat in calcareous free algae, probably due to the presence of epiphytic diatoms and/or suitable macroalgae debris. At the impacted site, such sources of food are less abundant.

Fig. 3.304

Seasonal variation in abundance of *Caecum trachea* at the impacted and control grounds.



Seasonal variation in biomass of *Caecum trachea* at the impacted and control grounds.

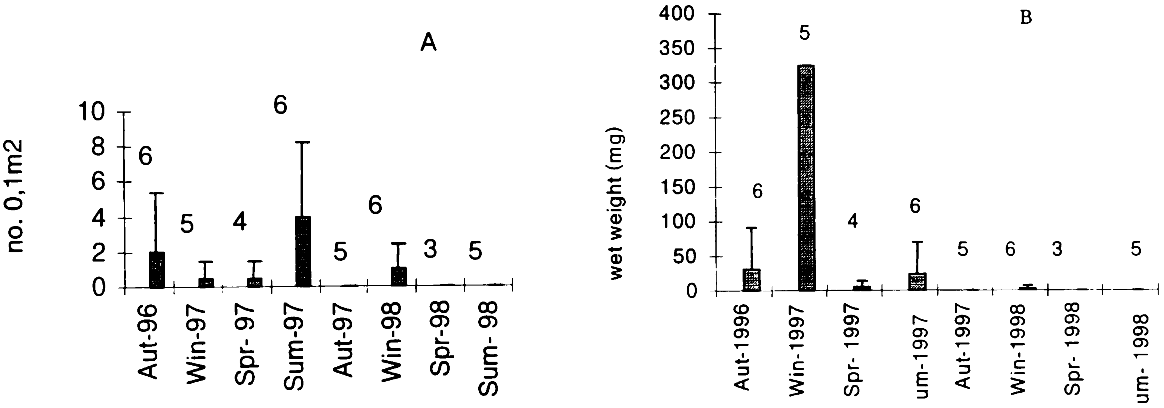


Cymodoce truncata (Omer-Cooper & Rawson, 1934)

Cymodoce truncata was one of the commonest isopods on the Alicante maërl grounds. Although not rare at the control site, it was very rare at the impacted site, being present there in only one seasonal sample and then in very low numbers. This isopod is a surface-dweller that inhabits the spaces amongst the maerl thalli and gravel. Its feeding habits are not known with certainly but is possibly a detritus-feeder. Analysis of gut contents have showed that *Cymodoce* spp. consumes a large percentage of animal and vegetal detritus.

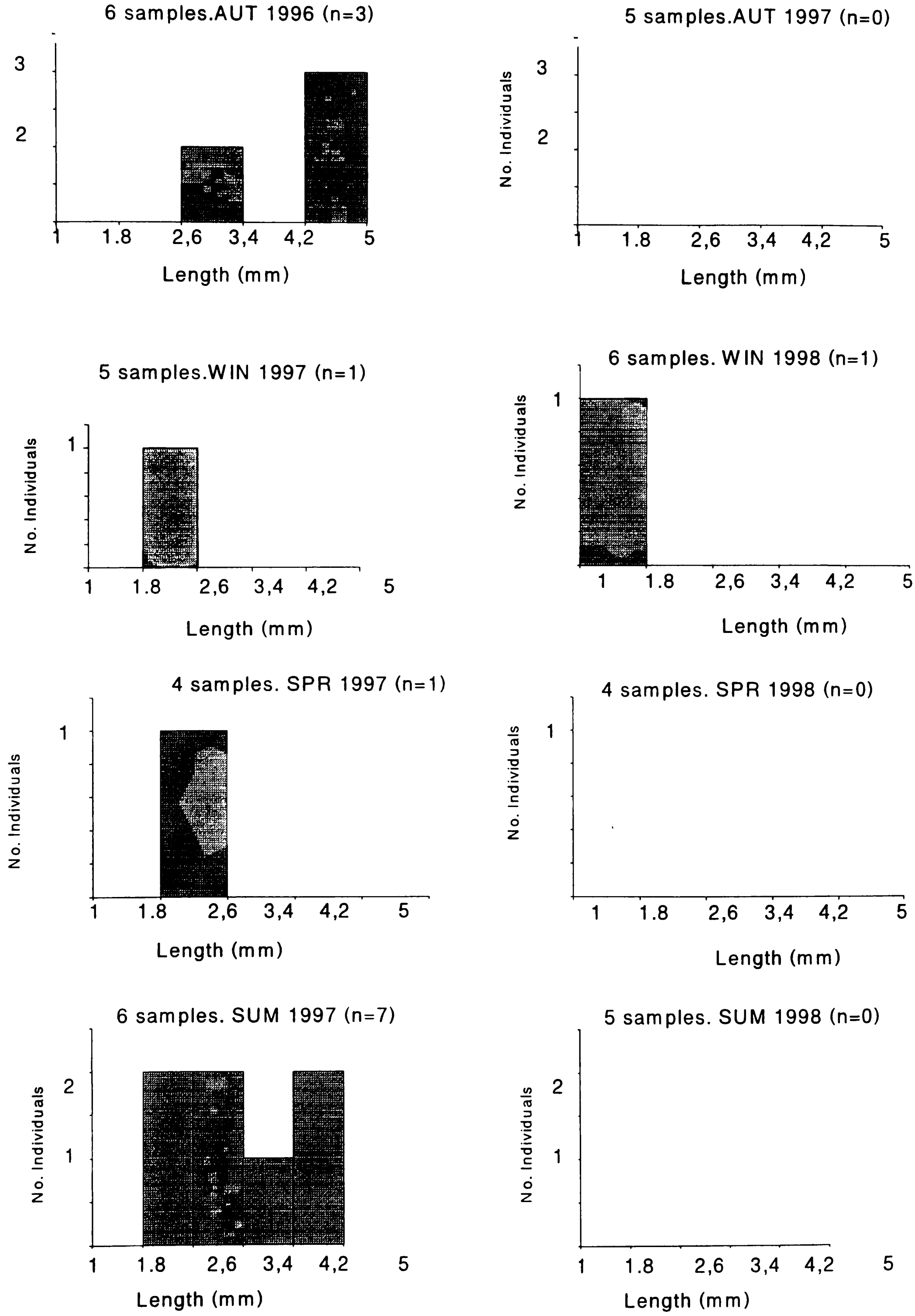
Cymodoce truncata was fairly common at the control site and was more frequently collected during the first year of sampling there. No particular seasonal pattern could be discerned in the abundance and biomass data (Fig. 3.305 A & B). However, in the first year a peak was observed in summer 1997, with low values in winter and spring 1997. It was only collected in one seasonal sample (winter 1998) in the second year.

Fig. 3.305. A) Mean number and B) Biomass (mg wet weight) of *Cymodoce truncata* per 0.1 m^{-2} sample at UAC. Error bars = SD. Numbers of replicates above error bars.



The seasonal variation in size-frequency of *Cymodoce truncata* at the control site is shown in Fig. 3.306. Small animals (length ≤ 1.8mm) were present in winter 1998. Although no seasonal pattern in size-frequency distribution could be discerned, due to the small numbers of individuals collected, the bigger sizes were present in summer and autumn whereas the smaller ones were obtained in winter and spring.

Fig. 3.306. Size-frequency histograms of *Cymodoce truncata* collected seasonally in 0.05m^2 quadrats at UAC from 1996-1998. SUM = Summer, AUT = Autumn, WIN = Winter, SPR = Spring



This species was very rare at the impacted site and was represented from only one seasonal sample (winter 1998) by one individual (Fig. 3.307).

The seasonal variation in size-frequency of *Cymodoce truncata* at the impacted site is shown in Fig. 3.308. As the control site, small animals (length ≤ 1.8mm) were present in winter 1998. This could suppose a possible recruitment period in winter season. No seasonal pattern in size-frequency distribution could be discerned at the impacted site, since only one individual was collected.

Fig. 3.307. A) Mean number and B) Biomass (mg wet weight) of *Cymodoce truncata* per 0.1 m^2 sample at UAI. Error bars= SD.

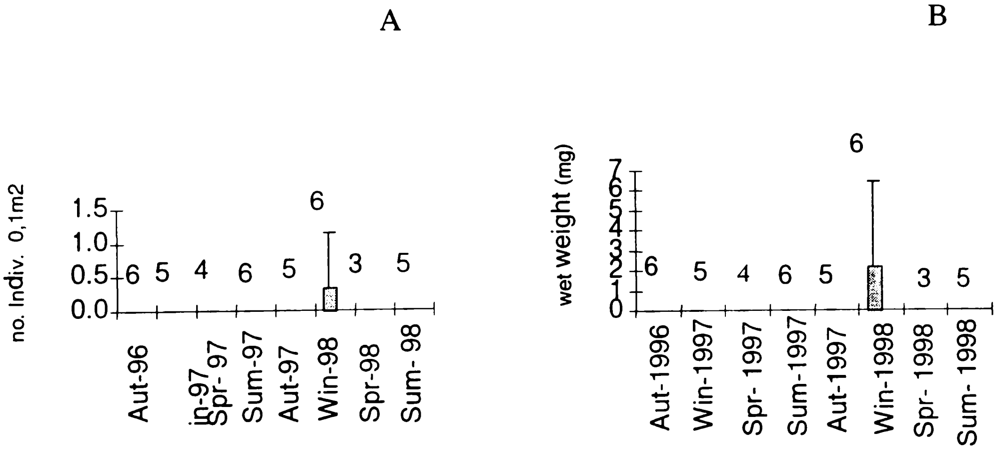
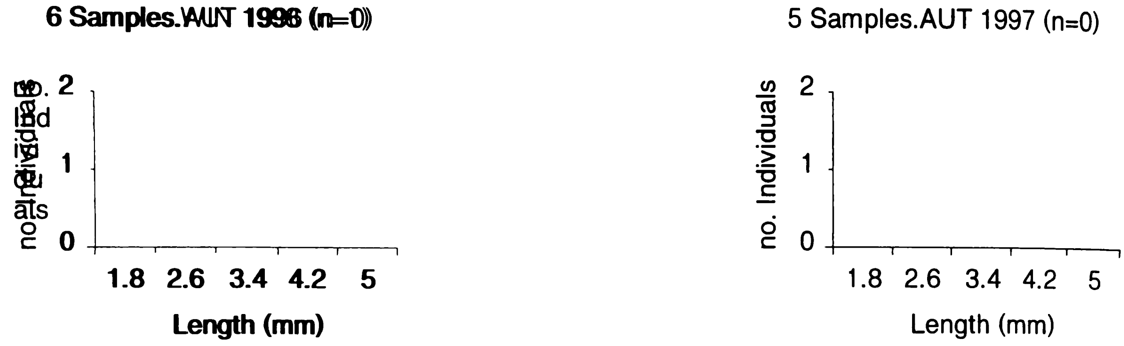
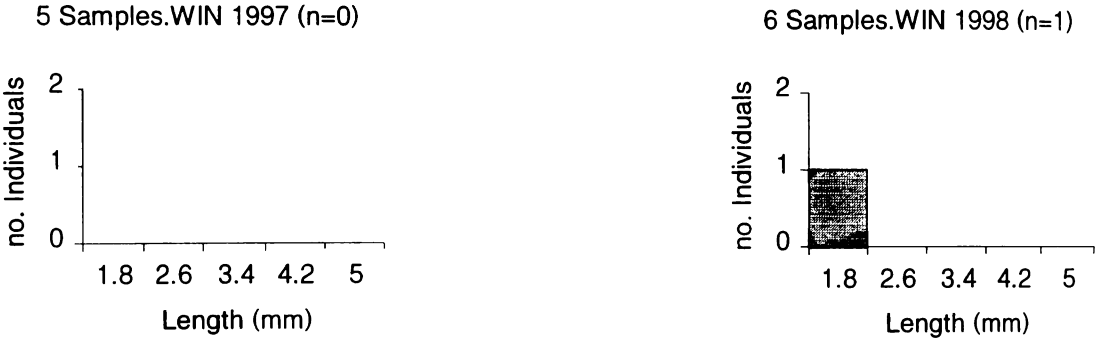
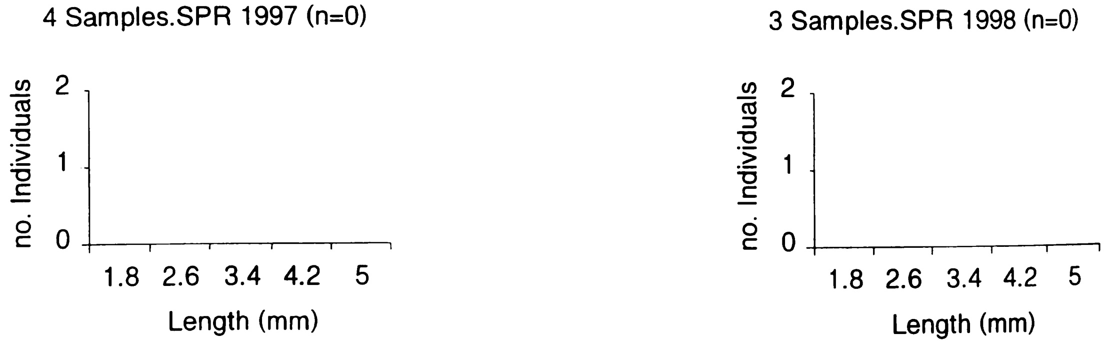


Fig. 3.308. Size-frequency histograms for *Cymodoce truncata* collected seasonally in 0.05 m^2 quadrats at UAI from 1996-1998. SUM= summer, AUT= autumn; WIN= winter, SPR= spring.







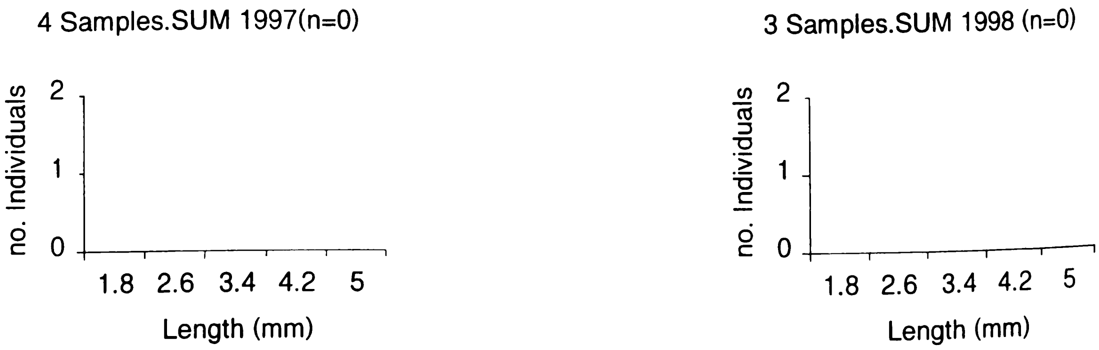
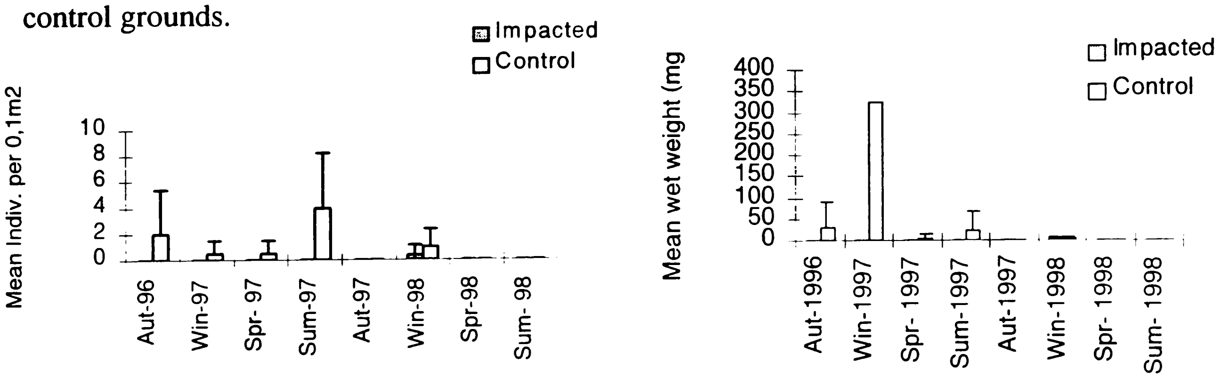


Fig. 3.309 compares the abundance and biomass of *Cymodoce truncata* on the control and impacted sites. This isopod was much more abundant at the control site, where is fairly common, and very rare at the impacted site. It was more abundant during the first year of sampling. The smaller sized animals appeared in winter (recruitment season?) and bigger ones in summer and autumn.

The differences in abundance and frequency between the control and impacted sites could be due to the greater structural complexity of the maerl at the control site. This provides shelter to the isopods. At the impacted site, by contrast, shelter is destroyed due to perturbation of the maerl by trawling.

Fig. 3.309. Seasonal variation in abundance and biomass of C. truncata at the impacted and control grounds.



Synisoma carinata (Rezig, 1989)

Synisoma carinata is a characteristic infra-circalittoral deposit-feeding isopod. It was more abundant at the control site (Fig. 3.310) than the impacted one, where it was only sampled on in winter periods. No significant differences have been observed in inter- and intra-annual abundance comparisons, but the results suggest an increase of the populations during the spring and winter periods. The possible explanation may be sought in the species' recruitment-mortality cycles (Fig. 3.311).

Fig. 3.310. A) Mean number and B) Biomass (mg wet weight) of *S. carinata* per 0.1 m^2 grab at UAC. Error bars=SD; number of replicate grabs above error bars.

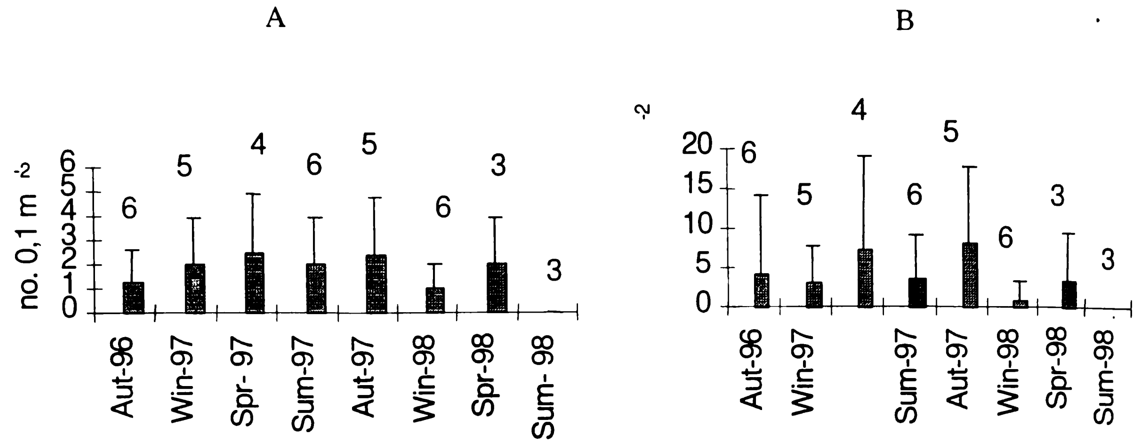
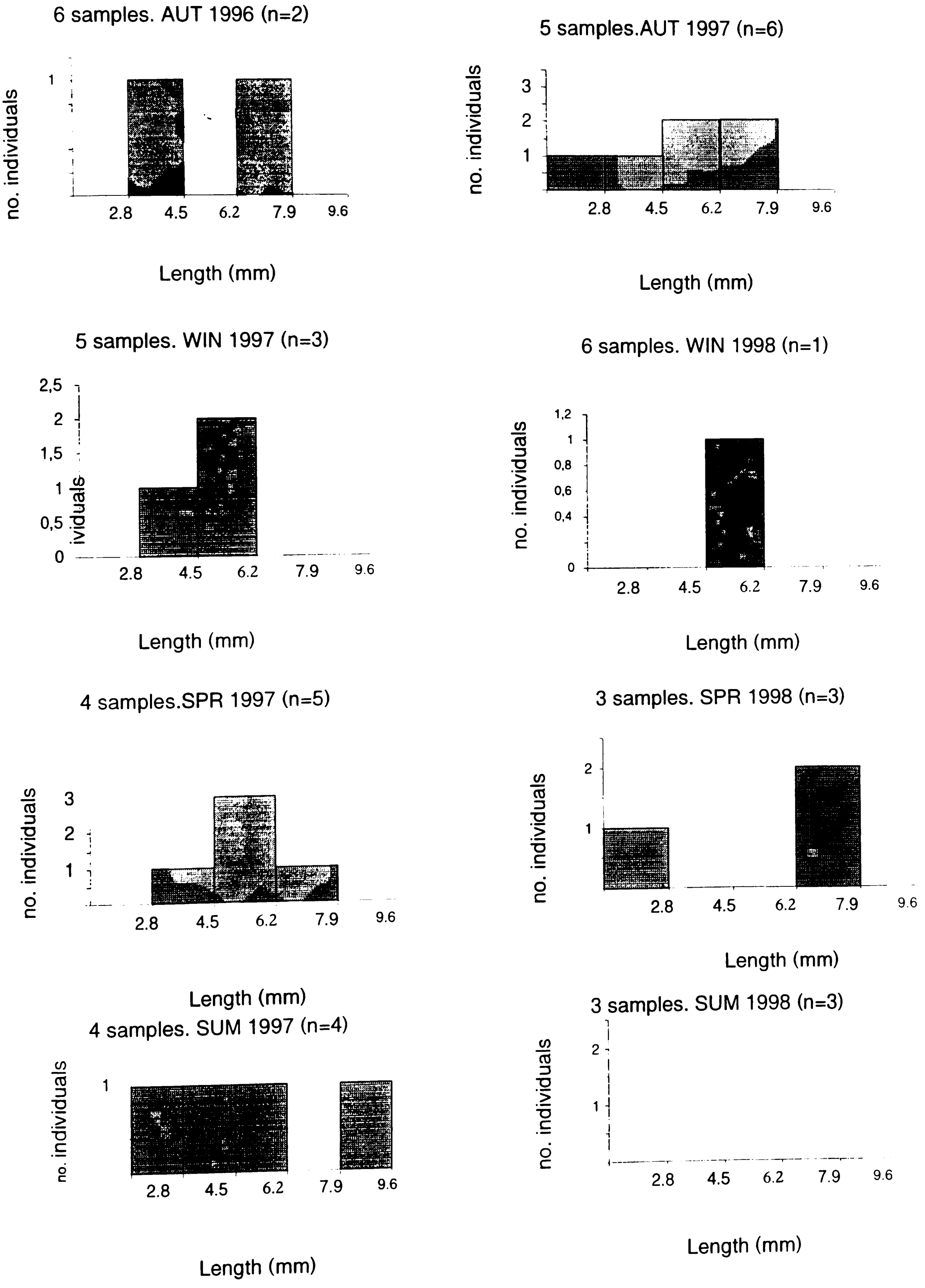


Fig. 3.311. Size-frequency distribution of *Synisoma carinata* at UAC (Control area) collected seasonally in 0.1 m^2 from Autumn 1996- Autumn 1998; and total number of animals (n) are given. SUM= Summer, AUT= Autumn, WIN= Winter; SPR= Spring. .


6 samples. AUT 1996 (n=2)

5 samples.AUT 1997 (n=6)

5 samples. WIN 1997 (n=3)

6 samples. WIN 1998 (n=1)

4 samples.SPR 1997 (n=5)

3 samples. SPR 1998 (n=3)

4 samples. SUM 1997 (n=4)

3 samples. SUM 1998 (n=3)

Synisoma carinata was significantly less abundant at the impacted site (Figs. 3.312 & 3.313). It was only collected on the maërl beds there in one season (winter 1998) and with a lower density (0.5 ind./0.1m^2) cf. the control site (with a mean of about 2.0 ind./ 0.1m^2). These differences suggest that the species (the prey of some fishes) has a better refuge in the more complex maerl structure at the control site.

Fig. 3.312. A) Mean number and B) Biomass (mg wet weight) of *S. carinata* per 0.1 m^2 grab at UAI. Error bars = SD; number of replicate grabs above error bars.

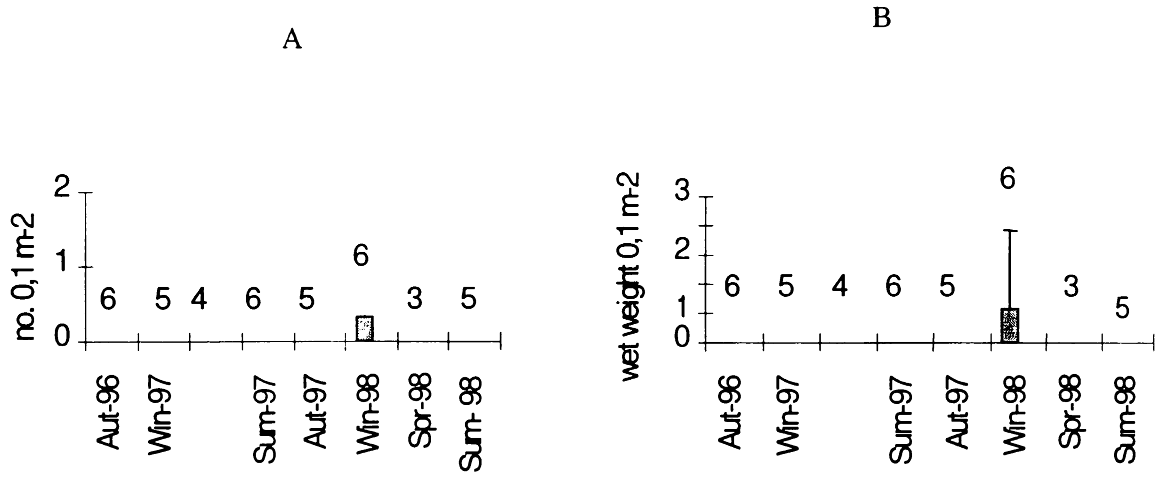
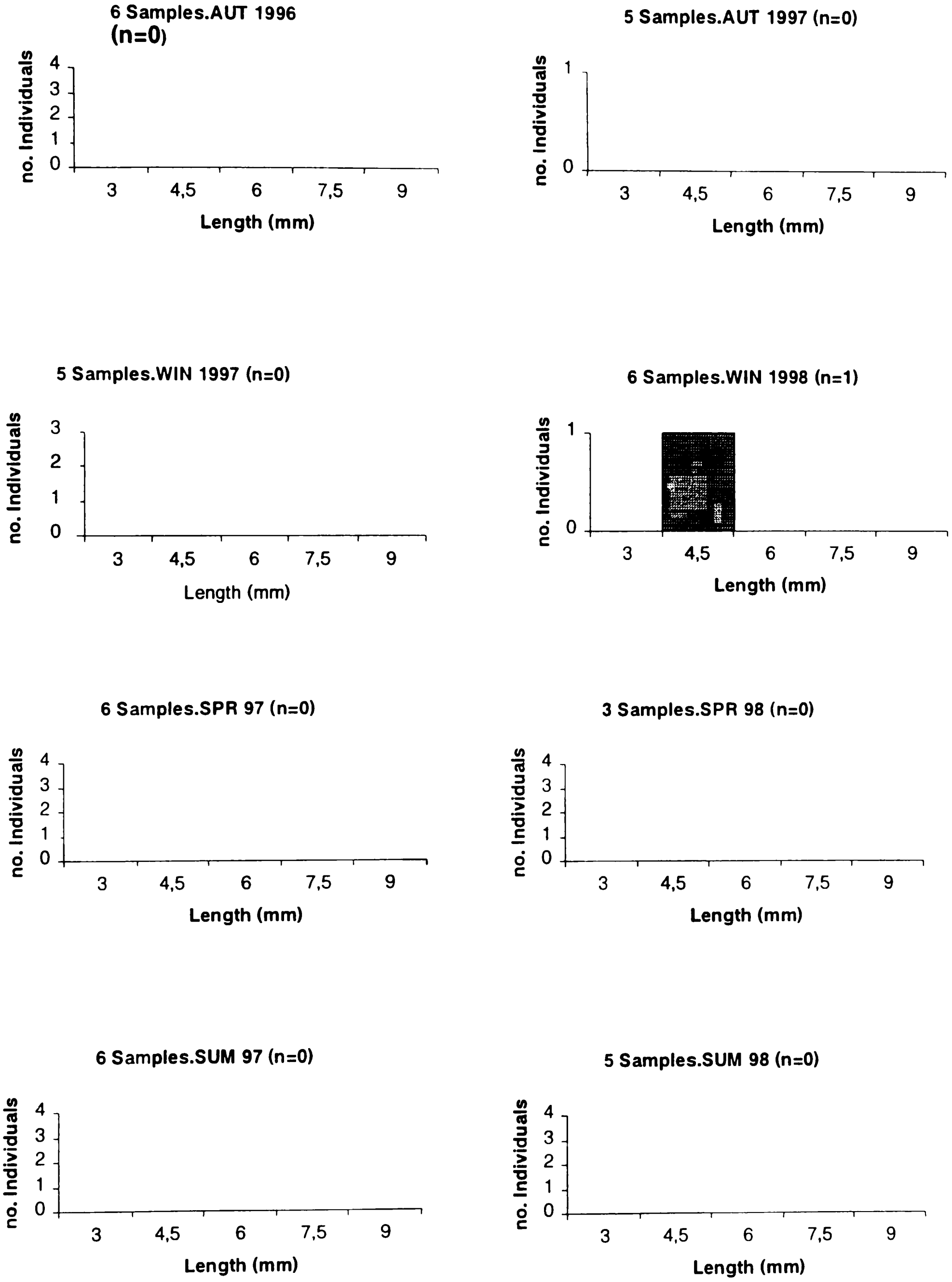


Fig.3.313. Size-frequency histograms for *Synisoma carinata* at UAI (impacted area) collected seasonally in 0.1 m^2 quadrats from Autumn 1996- Autumn 1998; and total number of animals (n) are given. SUM= Summer, AUT= Autumn, WIN= Winter; SPR= Spring.



Figs. 3.314 & 3.315 compare the abundance and biomass of *Synisoma carinata* on the control and impacted sites. This species was much more abundant at the control site.

Fig. 3.314. Seasonal variation in the abundance of *Synisoma carinata* on control and impacted grounds

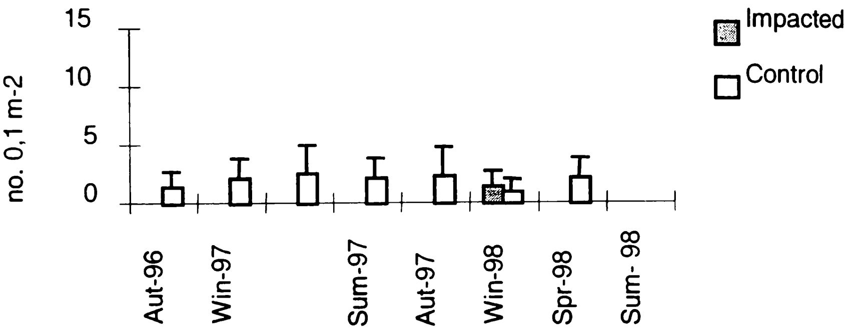
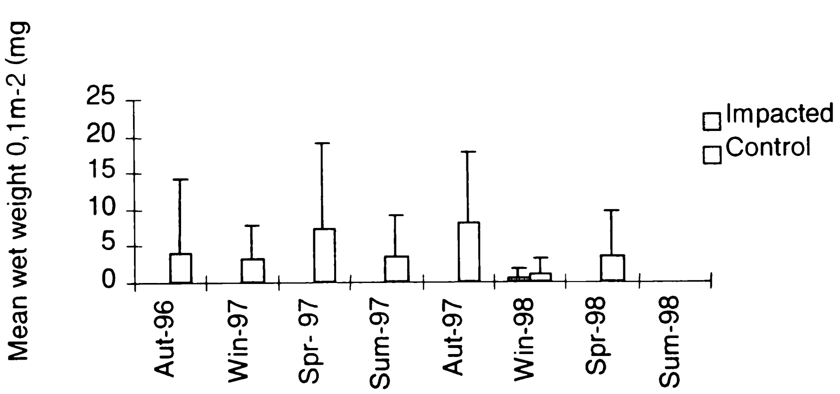


Fig. 3.315. Seasonal variation in biomass (mg wet weight) of *Synisoma carinata* at the control and impacted sites.

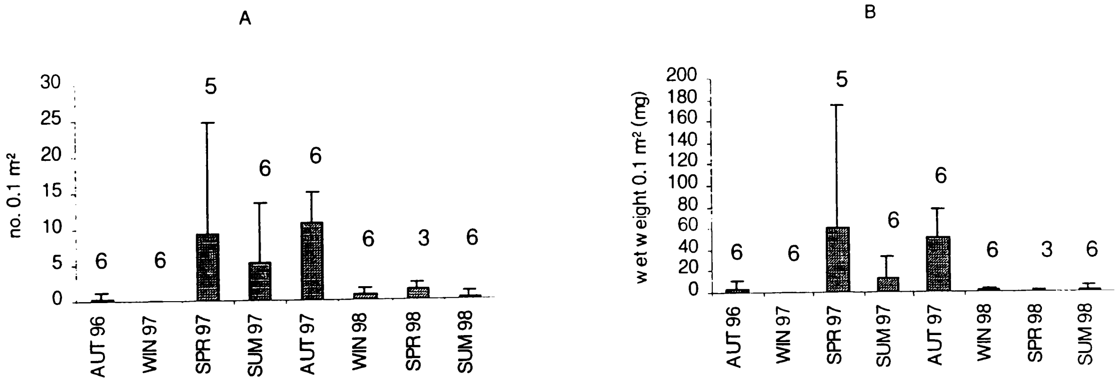


Apseudes latreillii (Milne Edwards, 1828)

A. latreillii was the most common tanaidacean on Alicante maerl beds in both the control and impacted sites. It was collected in most of the seasonal samples (excepting those from winter 1997 and summer 1998 at the control and impacted sites, respectively). Its feeds by deposit/suspension feeding, and lives in tubes mainly on muddy bottoms.

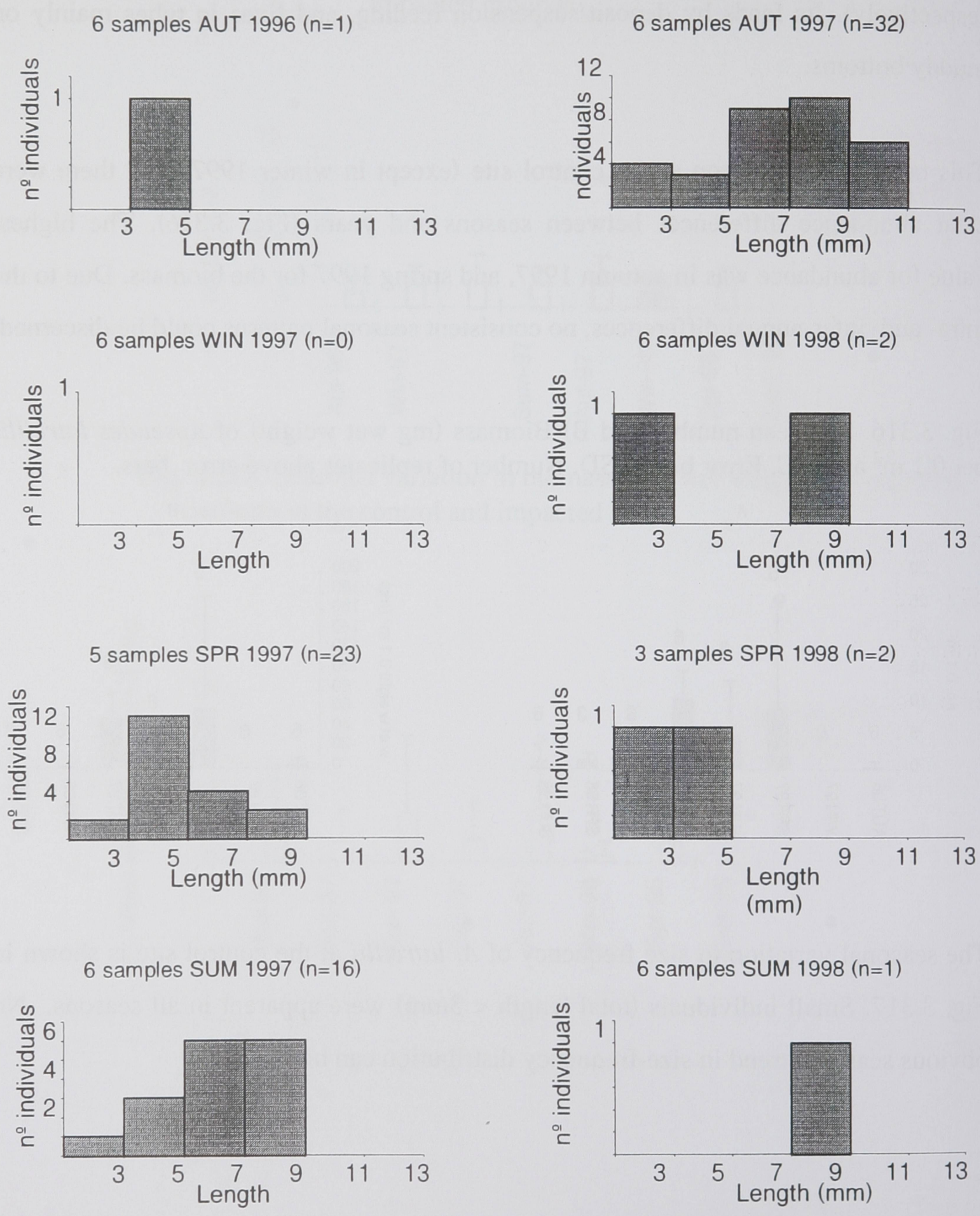
This tanaid was common at the control site (except in winter 1997), but there were clear abundance differences between seasons and years (Fig. 3.316). The highest value for abundance was in autumn 1997, and spring 1997 for the biomass. Due to the intra- and inter-annual differences, no consistent seasonal patterns could be discerned.

Fig. 3.316. A) Mean number and B) Biomass (mg wet weight) of *Apseudes latreillii* per 0.1 m^2 at UAC. Error bars = SD. Number of replicates above error bars.



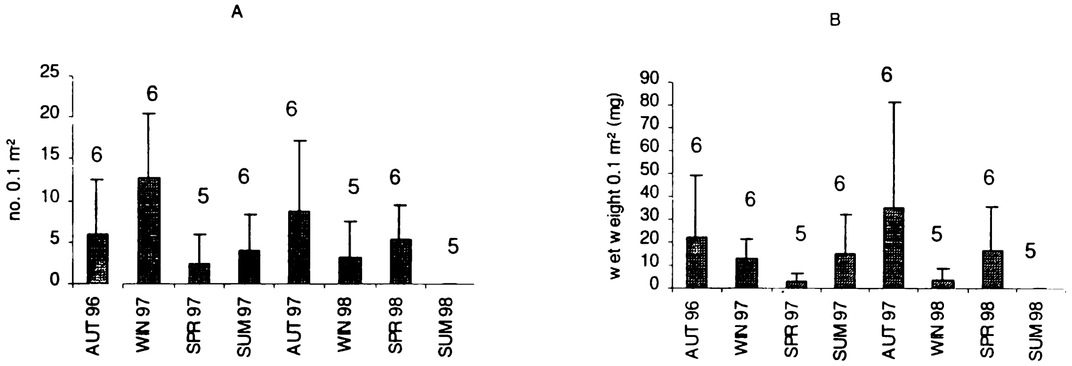
The seasonal variation in size frequency of *A. latreillii* at the control site is shown in Fig. 3.317. Small individuals (total length < 3mm) were apparent in all seasons. No obvious seasonal trend in size-frequency distribution can be observed.

Fig. 3.317. Size-frequency histograms for *Apseudes latreillei* collected seasonally in 0.05 m^2 quadrats at UAC from 1996 to 1998. SUM= summer, AUT= autumn, WIN= winter, SPR= spring.



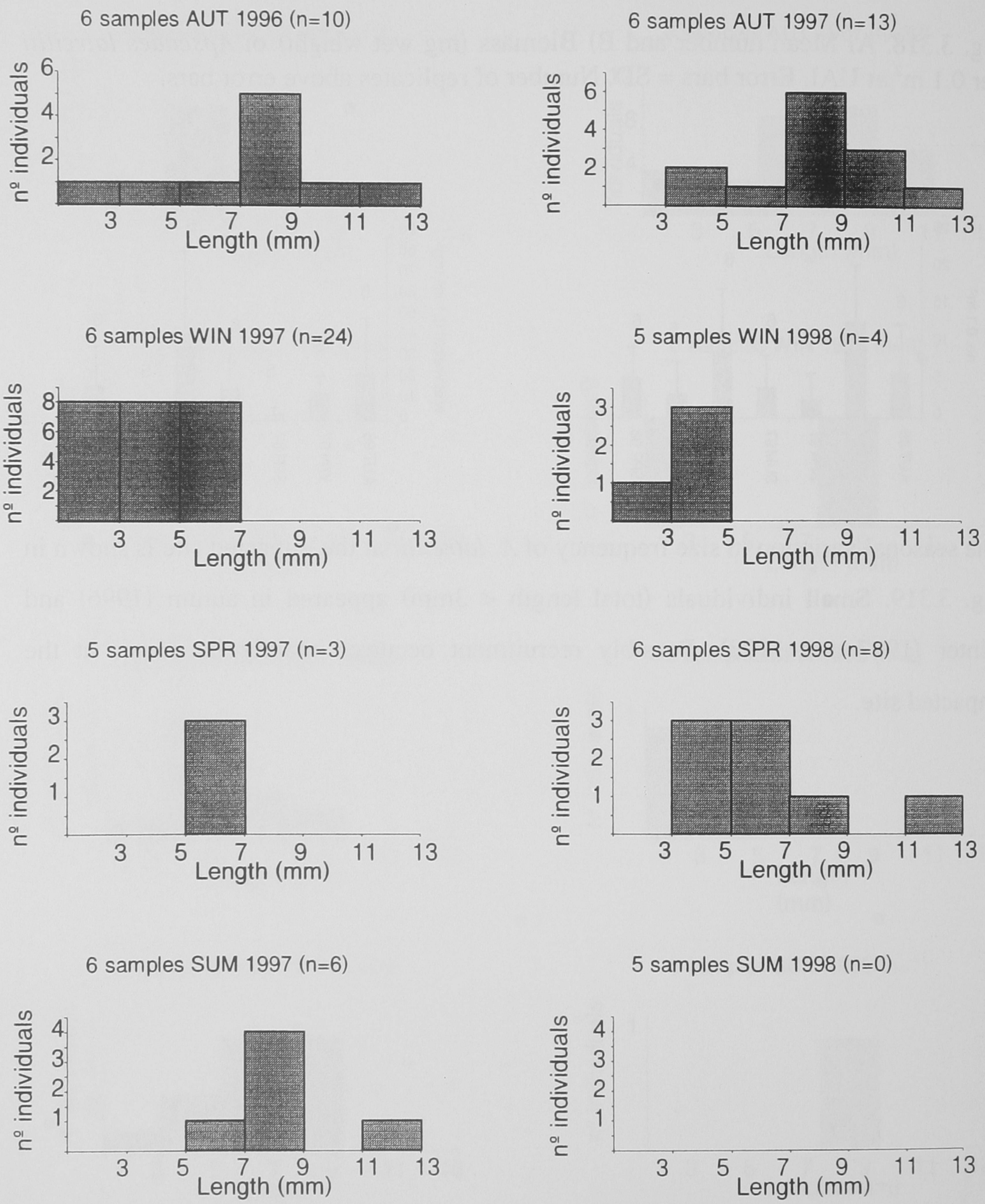
This species was also common at the impacted site. It was collected in most of the seasonal samples (except in summer 1998). Its highest abundance was in winter in 1997, and autumn in 1998 (Fig. 3.318). In spite of their abundance, no seasonal patterns could be detected.

Fig. 3.318. A) Mean number and B) Biomass (mg wet weight) of *Apseudes latreillii* per 0.1 m^2 at UAI. Error bars = SD. Number of replicates above error bars.



The seasonal variation in size frequency of *A. latreillii* at the impacted site is shown in Fig. 3.319. Small individuals (total length < 3mm) appeared in autum (1996) and winter (1997 and 1998). Possibly recruitment occurred mainly in winter at the impacted site.

Fig. 3.319. Size-frequency histograms for *Apseudes latreillii* collected seasonally in 0.05 m^2 quadrats at UAI from 1996 to 1998. SUM= summer, AUT= autumn, WIN= winter, SPR= spring.



6 samples AUT 1996 (n=10)

6 samples AUT 1997 (n=13)

6 samples WIN 1997 (n=24)

5 samples WIN 1998 (n=4)

5 samples SPR 1997 (n=3)

6 samples SPR 1998 (n=8)

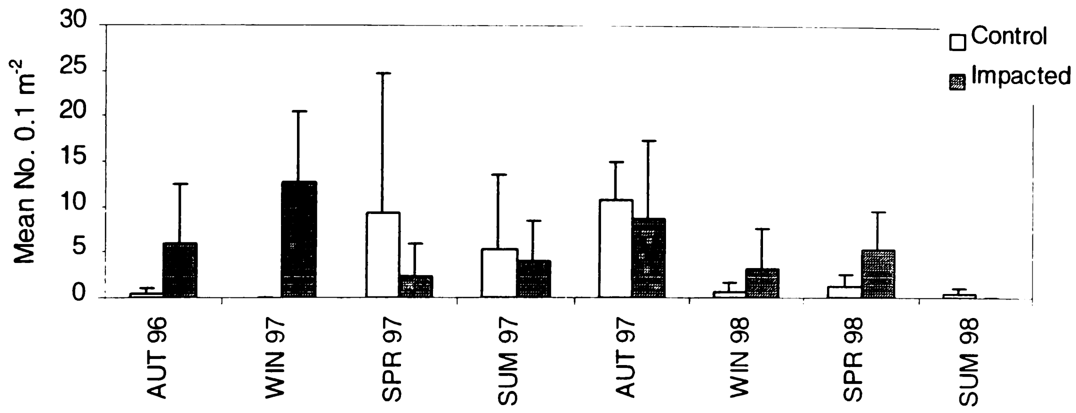
6 samples SUM 1997 (n=6)

5 samples SUM 1998 (n=0)

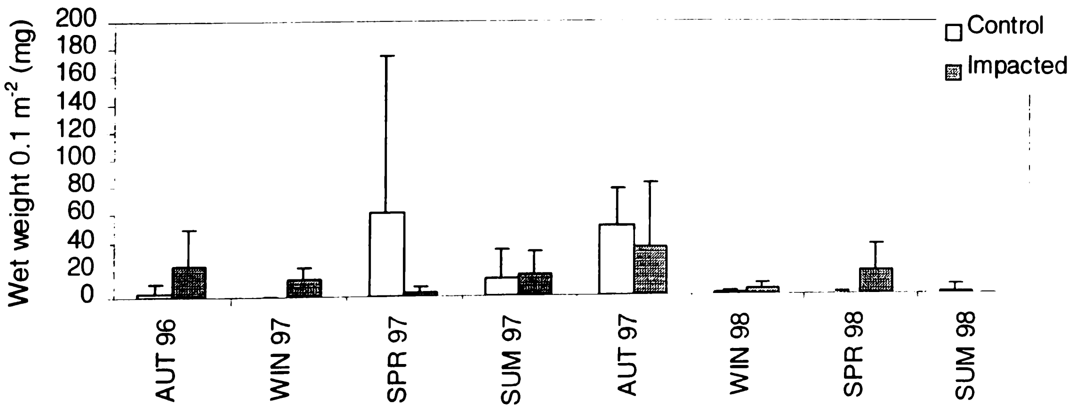
Fig. 3.320 compares the abundance and biomass of *Apseudes latreillei* on the control and impacted sites. This species is one of the more constant between seasons at the both sites, its prominence, both in terms of abundance or biomass being quite similar at both sites. However, it was more abundant in the winter of both years (1997 and 1998) at the impacted site.

Fig. 3.320.

Seasonal variation in mean abundance (± s.d.) of *Apseudes latreillei* on impacted and control grounds.



Seasonal variation in mean biomass (± s.d.) of *Apseudes latreillei* on impacted and control grounds.

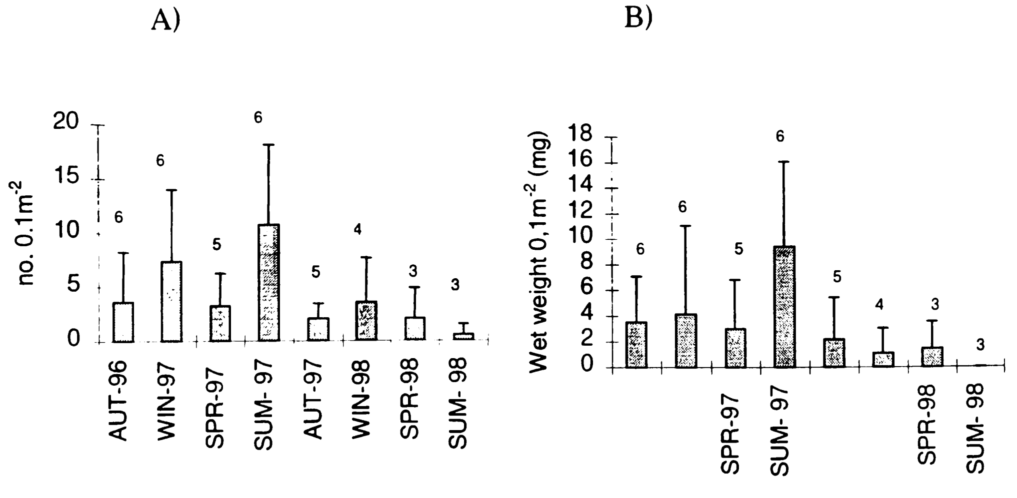


***Leptocheirus hirsutimanus* (Bate, 1862)**

This amphipod was frequent at both the control and impacted sites, but it was not present in all of the seasonal samples. It was much more abundant both in abundance and biomass at the control site (excepting during summer 1998). This species is a suspension feeder.

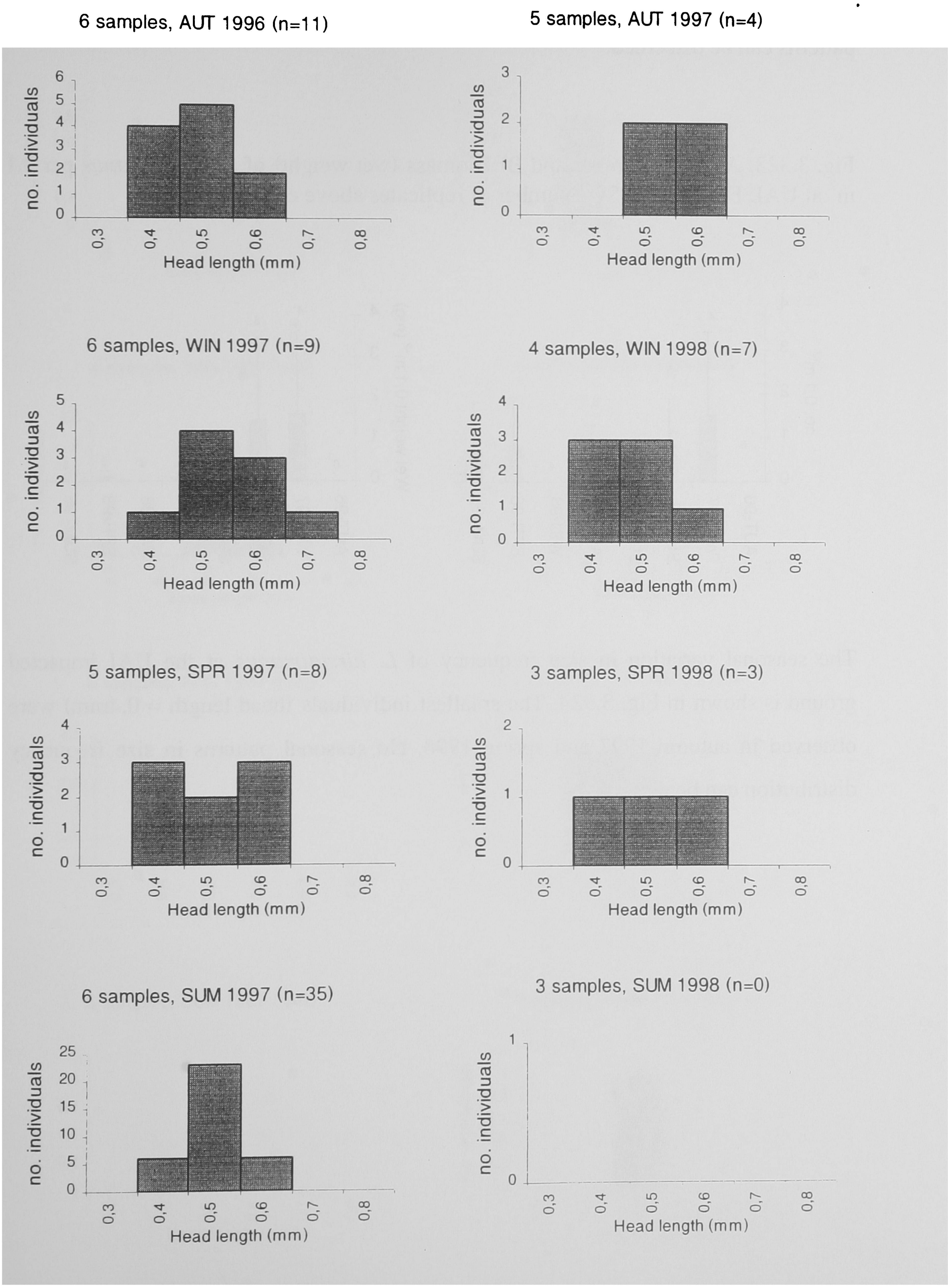
Although *Leptocheirus hirsutimanus* was collected in all seasonal samples (excepting summer 1998), it was most prominent both in terms of numbers and biomass during the first year of sampling. The highest value both in abundance and biomass was in summer 1997. A seasonal pattern in abundance emerged with peaks in winter (1996 and 1997) and summer 1997 (excepting summer 1998) and low values in spring and autumn (Fig. 3.321).

Fig.3.321. A) Mean number and B) Biomass (mg wet weight) of *L. hirsutimanus* per 0.1 m^2 at UAC. Error bars = SD. Number of replicates above error bars.



The seasonal variation in size frequency of *L. hirsutimanus* at the control ground is shown in Fig.3.322. Small individuals (head length = 0.4mm) appeared in all of seasons. Due to this, no seasonal patterns in size-frequency distribution were discernible.

Fig. 3.322. Size-frequency histograms for *L. hirsutimanus* collected seasonally in 0.1 m^2 at UAC from 1996-1998. SUM = summer, AUT = autumn, WIN = winter, SPR = spring.



6 samples, AUT 1996 (n=11)

5 samples, AUT 1997 (n=4)

6 samples, WIN 1997 (n=9)

4 samples, WIN 1998 (n=7)

5 samples, SPR 1997 (n=8)

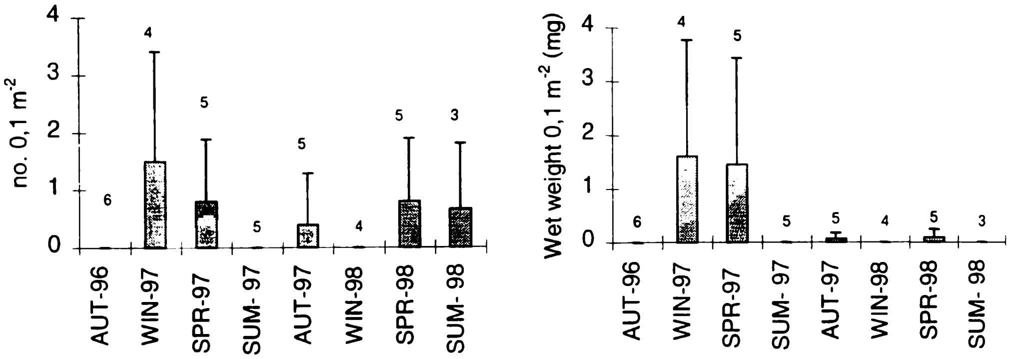
3 samples, SPR 1998 (n=3)

6 samples, SUM 1997 (n=35)

3 samples, SUM 1998 (n=0)

This species was collected in low numbers from five seasonal samples at the impacted site (Fig. 3.323). The highest value in both abundance and biomass was in winter 1996. As before, due to the low numbers of specimens of this species no seasonal patterns can be discerned.

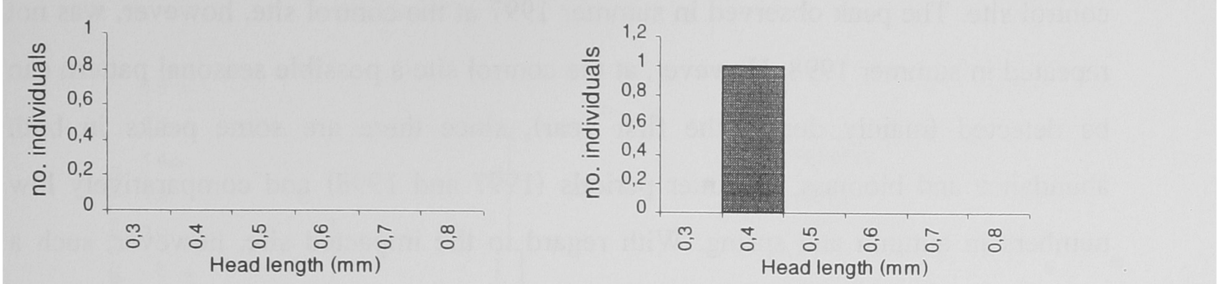
Fig. 3.323. A) Mean number and B) Biomass (wet weight) of *L. hirsutimanus* per 0.1 m^2 at UAI. Error bars = SD, Number of replicates above error bars.



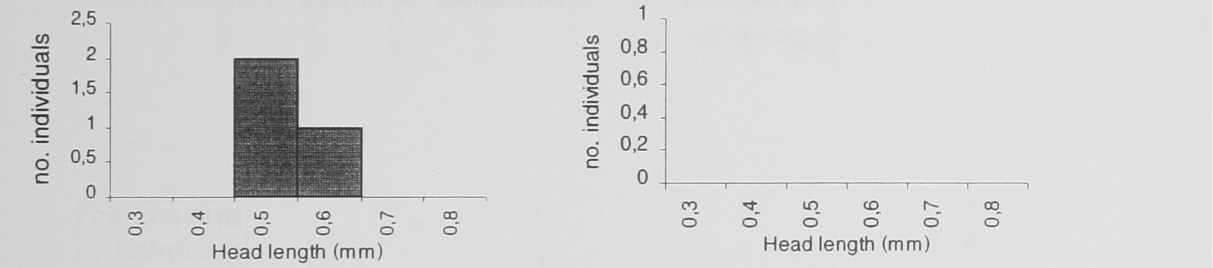
The seasonal variation in size frequency of *L. hirsutimanus* at the UAI impacted ground is shown in Fig. 3.324. The smallest individuals (head length = 0.4mm) were observed in autumn 1997 and spring 1998. No seasonal patterns in size frequency distribution can be discerned.

Fig. 3.324. Size-frequency histograms for *L. hirsutimanus* collected seasonally in 0.1 m^2 at UAI from 1996-1998. SUM = summer, AUT = autumn, WIN = winter, SPR = spring.

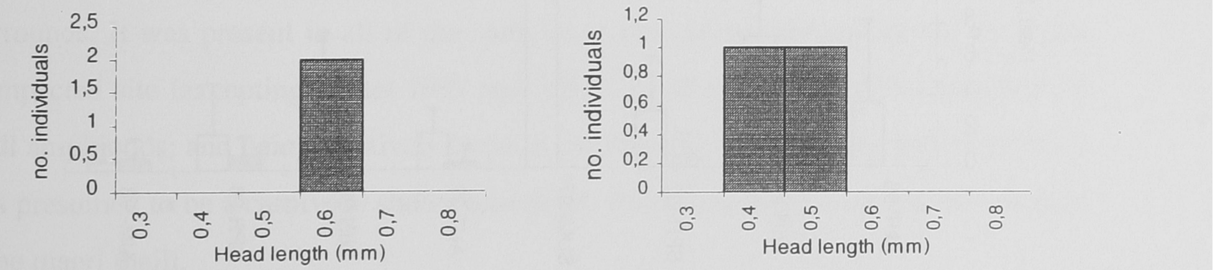
6 samples, AUT 1996 (n=0) 5 samples, AUT 1997 (n=1)



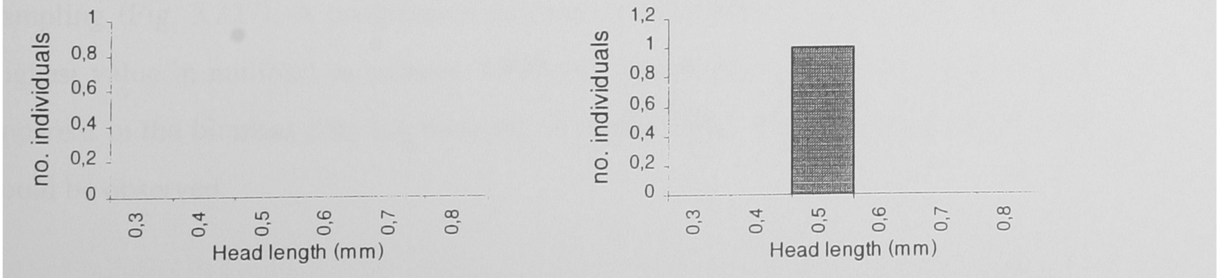
4 samples, WIN 1997 (n=3) 4 samples, WIN 1998 (n=0)



5 samples, SPR 1997 (n=2) 5 samples, SPR 1998 (n=2)



5 samples, SUM 1997 (n=0) 3 samples, SUM 1998 (n=1)



Figures 3.325 and 3.326 respectively compare the abundance and biomass of *Leptocheirus hirsutimanus* on the control and impacted sites. This amphipod was much more abundant both in abundance and biomass (excepting summer 1998) at the control site. The peak observed in summer 1997 at the control site, however, was not repeated in summer 1998. However, at the control site a possible seasonal pattern can be detected (mainly during the first year), since there are some peaks in both abundance and biomass in winter periods (1997 and 1998) and comparatively low numbers in autumn and spring. With regard to the impacted site, however, such a pattern was not observed.

Fig. 3.325. Seasonal variation in mean abundance (± s.d.) of *Leptocheirus hirsutimanus* on impacted and control grounds.

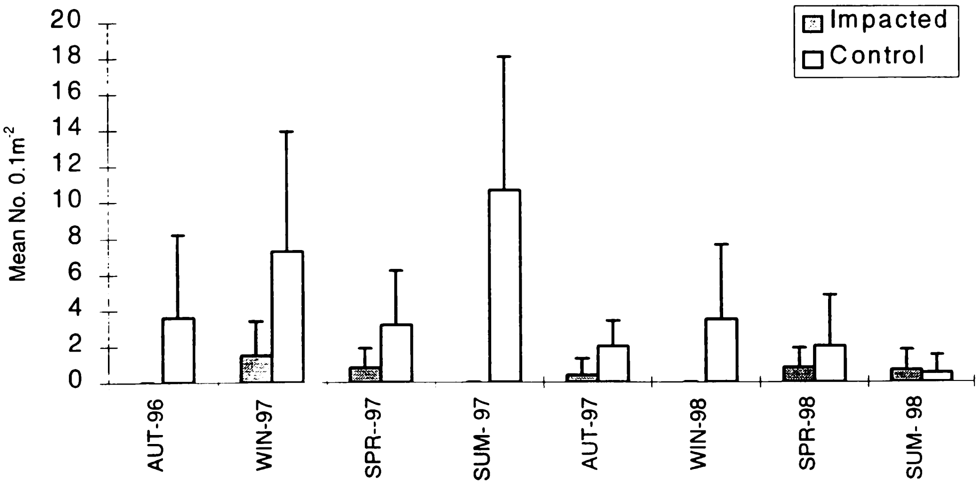
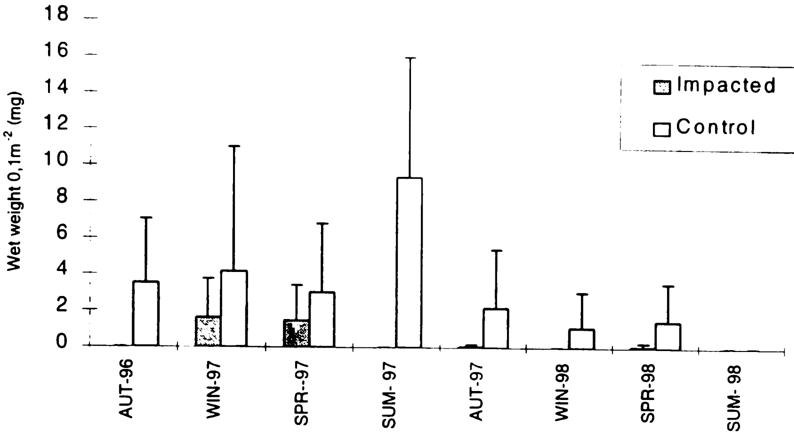


Fig. 3.326. Seasonal variation in mean biomass (± s.d.) of *Leptocheirus hirsutimanus* on impacted and control grounds.

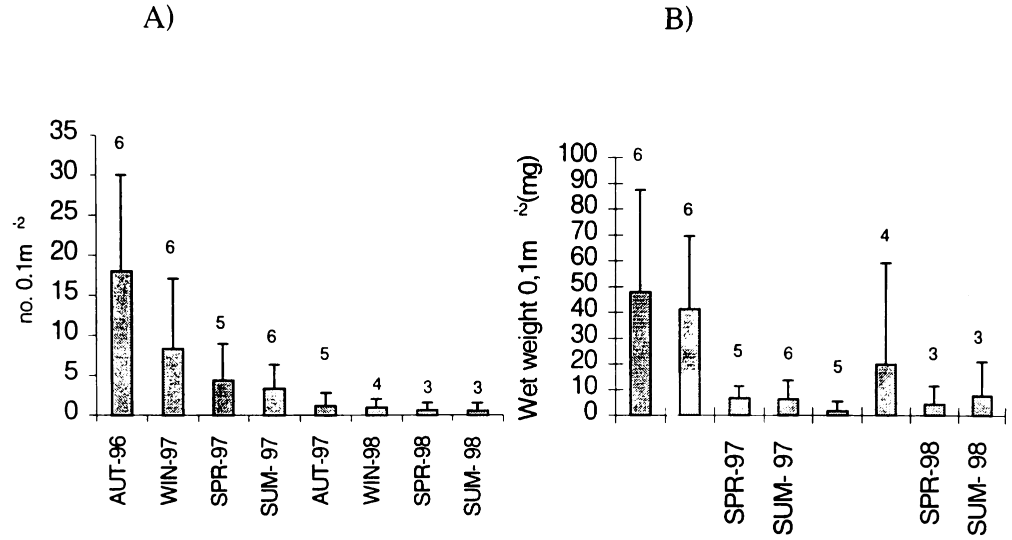


Lysianassa longicornis Lucas, 1849

Lysianassa longicornis was the most common amphipod on the Alicante maërl grounds. It was present in all of the samples at the control site and nearly all at the impacted site (excepting winter 1997 and 1998). Its abundance often reached 40% of all amphipods; and being relatively large, it contributed most to amphipod biomass. It is presumed to be a carnivore and/or scavenger, inhabiting the narrow spaces amongst the maerl thalli.

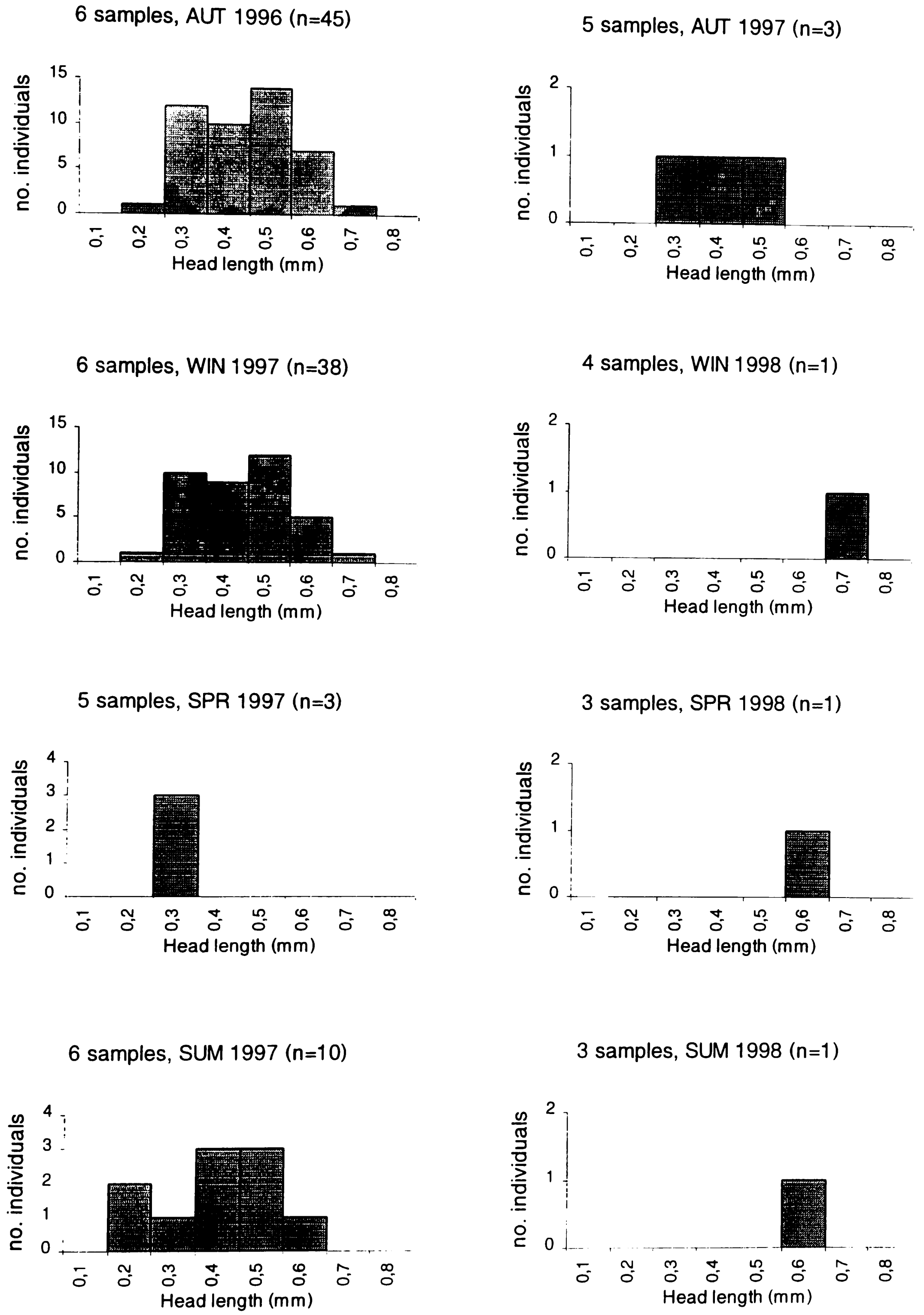
L. longicornis was very common at the control site, particularly in the first year of sampling (Fig. 3.327). A progressive decrease in abundance from autumn 1996 (the highest value in number) to summer 1998 was noticeable, but this decrease was not apparent in the biomass data (an increase in winter 1998). Thus, no seasonal patterns could be observed.

Fig. 3. 327. A) Mean number and B) Biomass (mg wet weight) of *L. longicornis* per 0.1 m^2 at UAC. Error bars = SD. Number of replicates above error bars.



The seasonal variation in size frequency of *L. longicornis* at the control ground is shown in Fig. 3.328. The differences of abundance between years mean that no seasonal pattern of size-frequency distribution could be discerned. The smallest sizes (head length = 0.2mm) were found in autumn 1996, winter 1997 and summer 1997.

Fig.3.328. Size-frequency histograms for *L. longicornis* collected seasonally in 0.1 m^2 at UAC from 1996-1998. SUM = summer, AUT = autumn, WIN = winter, SPR = spring.



6 samples, AUT 1996 (n=45)

5 samples, AUT 1997 (n=3)

6 samples, WIN 1997 (n=38)

4 samples, WIN 1998 (n=1)

5 samples, SPR 1997 (n=3)

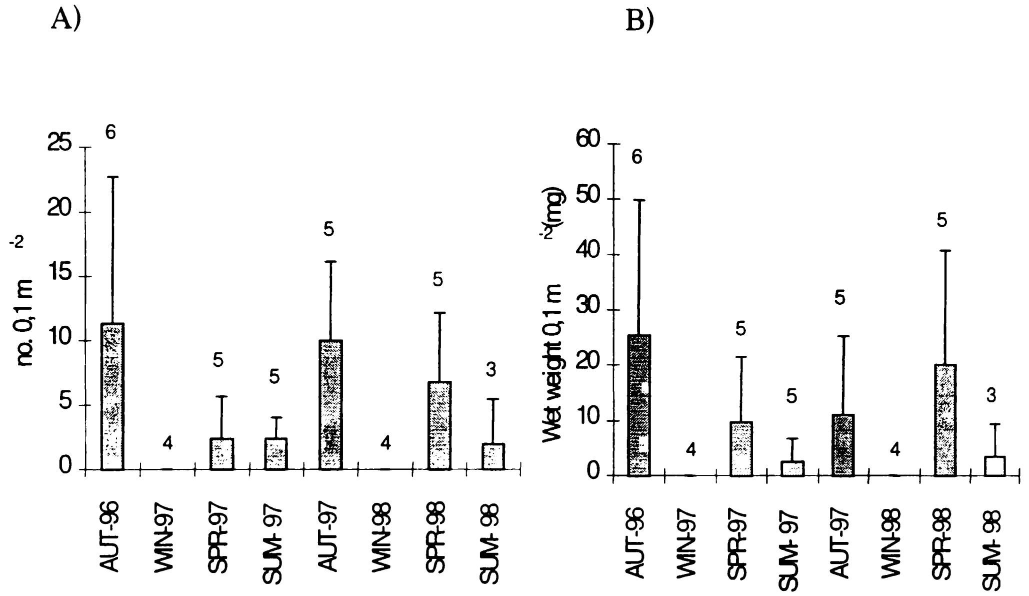
3 samples, SPR 1998 (n=1)

6 samples, SUM 1997 (n=10)

3 samples, SUM 1998 (n=1)

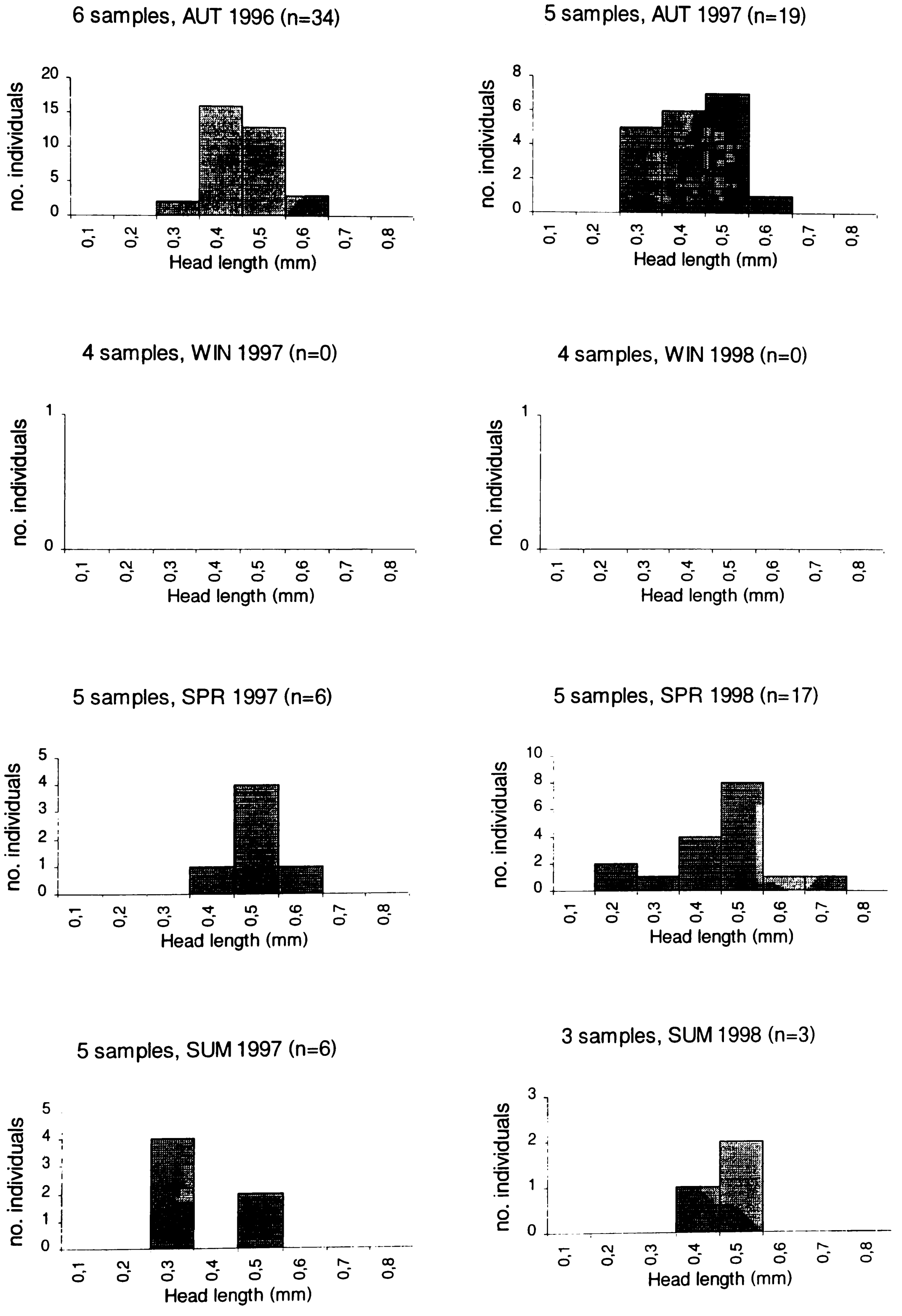
Lysianassa longicornis, though common at the impacted site (UAI), was less so than at the control site, and was not collected during the winter periods (1997 and 1998) (Fig. 3.329). However, it was more prominent (excepting winter 1998) both in terms of numbers and biomass at the impacted site in the second year of sampling. It is notable that the peak of abundance was in autumn in both years (1996 and 1997).

Fig.3.329. A) Mean number and B) Biomass (mg wet weight) of *L. longicornis* per 0.1 m^2 at UAI. Error bars = SD. Number of replicates above error bars.



The seasonal variation in size frequency of *L. longicornis* at the impacted ground is shown in Fig. 3.330. Due to the differences between years and its not having been collected in winter, it is not possible to detect any consistent patterns in the size frequency distribution. However, the smallest individuals (head length = 0.2) were detected in spring 1998 (which presumably represents the onset of recruitment).

Fig. 3.330. Size-frequency histograms for *L. longicornis* collected seasonally in 0.1 m^2 at UAI from 1996-1998. SUM = summer, AUT = autumn, WIN = winter, SPR = spring.



Figures 3.331 and 3.332 respectively compare the abundance and biomass of *Lysianassa longicornis* on the control and impacted grounds. Generally, this species was more abundant at the control site than at the impacted ground. However, it was more abundant at the impacted site in the second year (excepting winter 1998). With regard to biomass both sites were similar in the second year.

Fig.3.331. Seasonal variations in mean abundance (± s.d.) of *Lysianassa longicornis* on the impacted and control grounds.

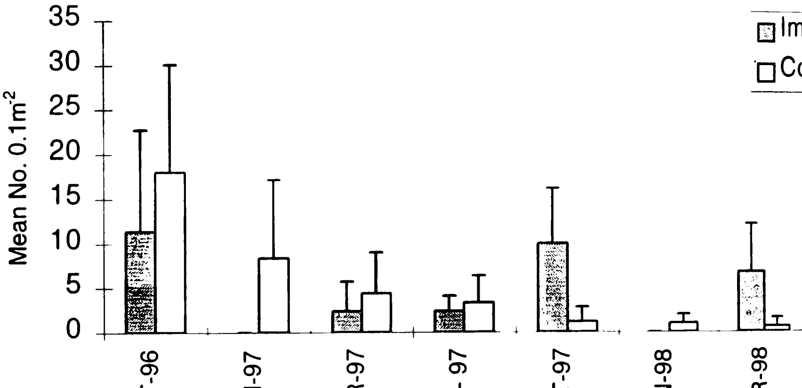
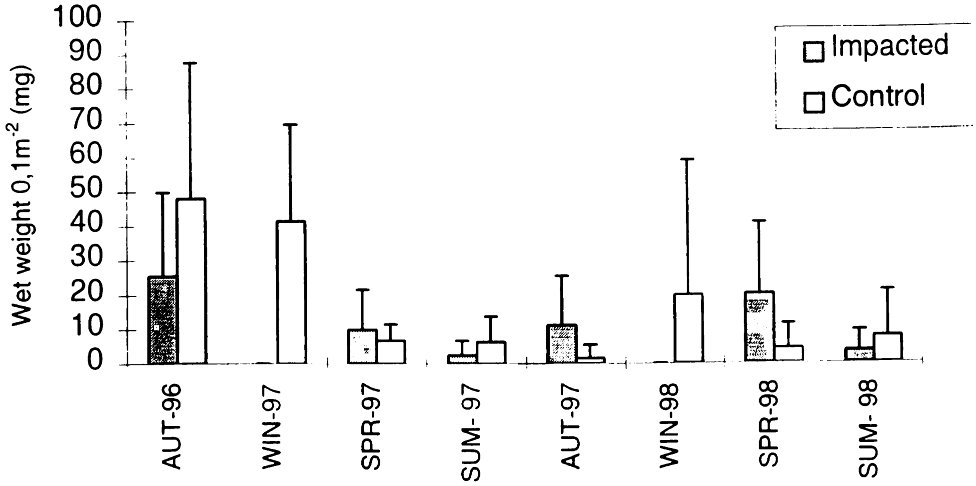


Fig.3.332. Seasonal variations in mean biomass (± s.d.) of *Lysianassa longicornis* on the impacted and control grounds.

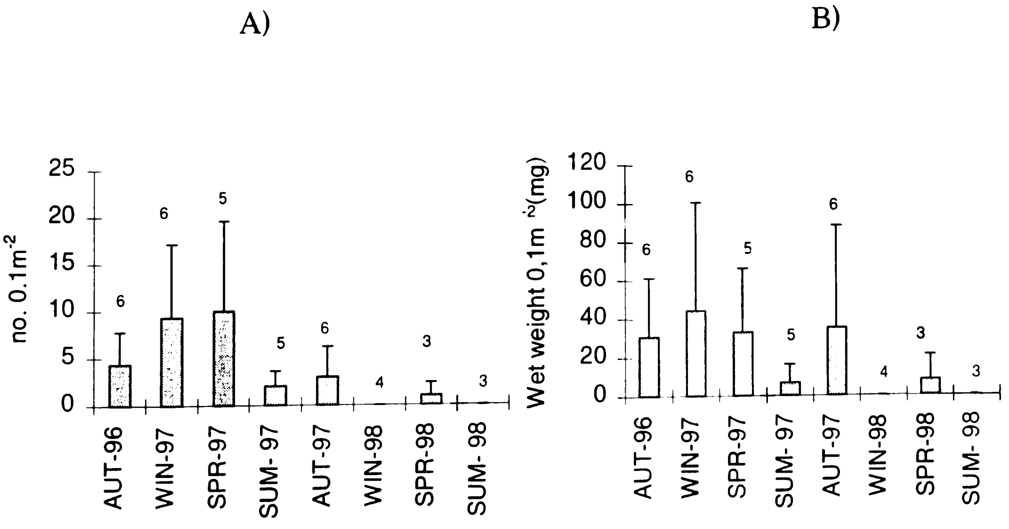


Maera knudseni Reid, 1951

This species was one of the commonest amphipods on the Alicante maerl grounds, representing about 10% of the amphipod abundance and biomass. It was especially abundant (in density and biomass) at the control site, though it was also fairly common at the impacted site. It is assumed to be a deposit feeder (based on knowledge of its cogener *M.loveni*) and it lives between the maerl thalli.

Maera knudseni was always very common at the control site, but it was more abundant in the first year of sampling (Fig. 3.333). It was not collected in winter 1998 and summer 1998. The highest population density was in spring 1997, the highest biomass in winter 1997. No consistent seasonal patterns were found, due to the differences between years. However, for the first year a seasonal pattern in abundance was observed, with a maximum in spring and a minimum in summer. This pattern was not repeated though in the second year (in winter and summer 1997 it was not collected).

Fig.3.333. A) Mean numbers and B) Biomass (wet weight) of *M. knudseni* per 0.1 m^2 at UAC. Error bars = SD. Number of replicates above error bars.

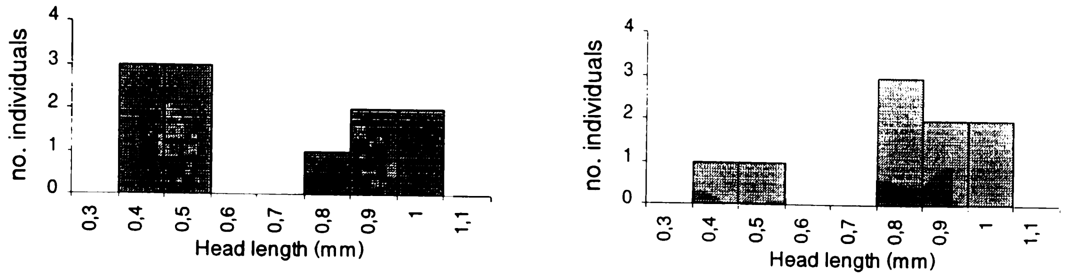


The seasonal variation in size frequency of *M. knudseni* at the control ground is shown in Fig. 3.334. Small individuals (head length = 0.4mm) were present in autumn (1996 and 1997), winter 1997 and summer 1997. No particular seasonal patterns could be detected in size-frequency distribution.

Fig. 3.334.Size-frequency histograms for *Maera knudseni* collected seasonally in 0.1 m^2 at UAC from 1996-1998. SUM = summer, AUT = autumn, WIN = winter, SPR = spring.

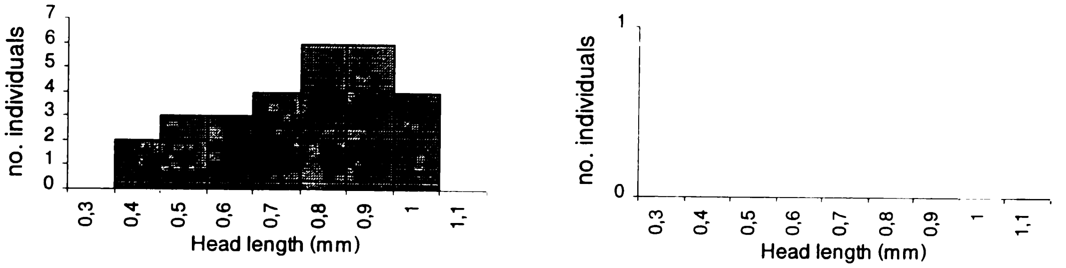
6 samples, AUT 1996 (n=11)

5 samples, AUT 1997 (n=9)



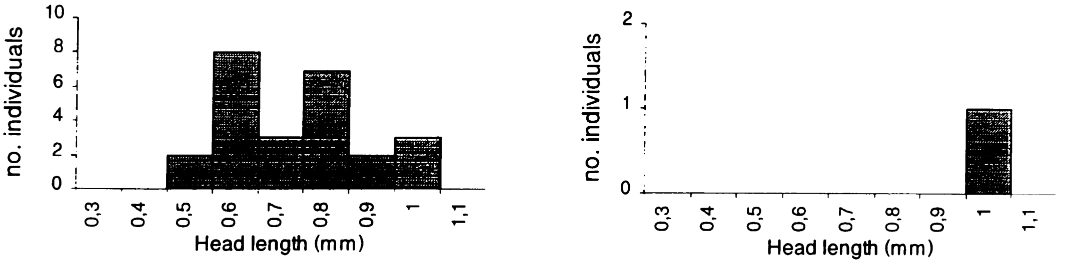
6 samples, WIN 1997 (n=28)

4 samples, WIN 1998 (n=0)



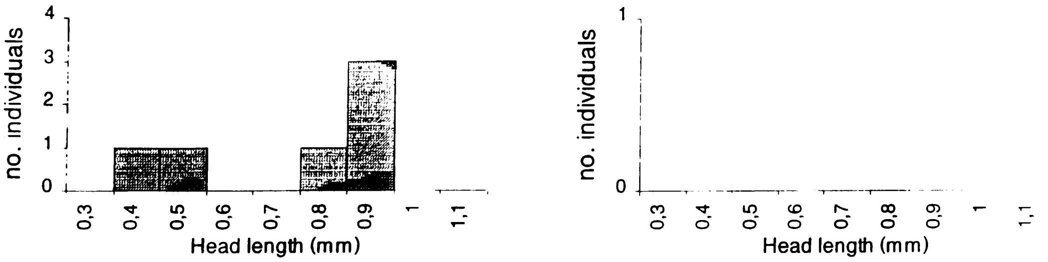
6 samples, SPR 1997 (n=25)

3 samples, SPR 1998 (n=1)



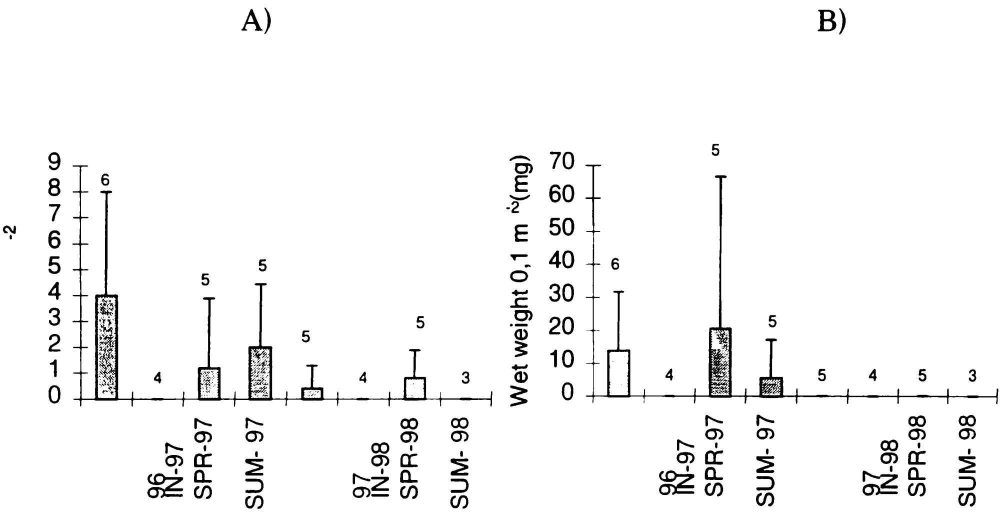
6 samples, SUM 1997 (n=6)

3 samples, SUM 1998 (n=0)



At the impacted site (UAI), this amphipod was not collected in winter (1997 and 1998) or summer 1998 (Fig. 3.335). The highest abundance was obtained in autumn 1996; the highest biomass in spring 1997. No seasonal patterns were observed, but it seems to decrease in the winter.

Fig. 3.335.A) Mean number and B) Biomass (mg wet weight) of *M. knudseni* per 0.1 m^2 at UAI. Error bars = SD. Number of replicates above error bars.



The seasonal variations in size frequency of *M. knudseni* at the impacted ground is shown in the Fig. 3.336. No size-frequency distribution patterns were found, but it is worth pointing out some bimodal distributions (in spring 1996 and 1997, and summer 1997). Such a bimodal disribution was also observed at the control site (autumn 1996 and 1997, and summer 1997). Small individuals (head length = 0.4) were collected in summer 1997, which is presumably the breeding season.

Fig.3.336.Size-frequency histograms for *M. knudseni* collected seasonally in 0.1 m^2 at UAI from 1996-1998. SUM = summer, AUT = autumn, WIN = winter, SPR = spring.

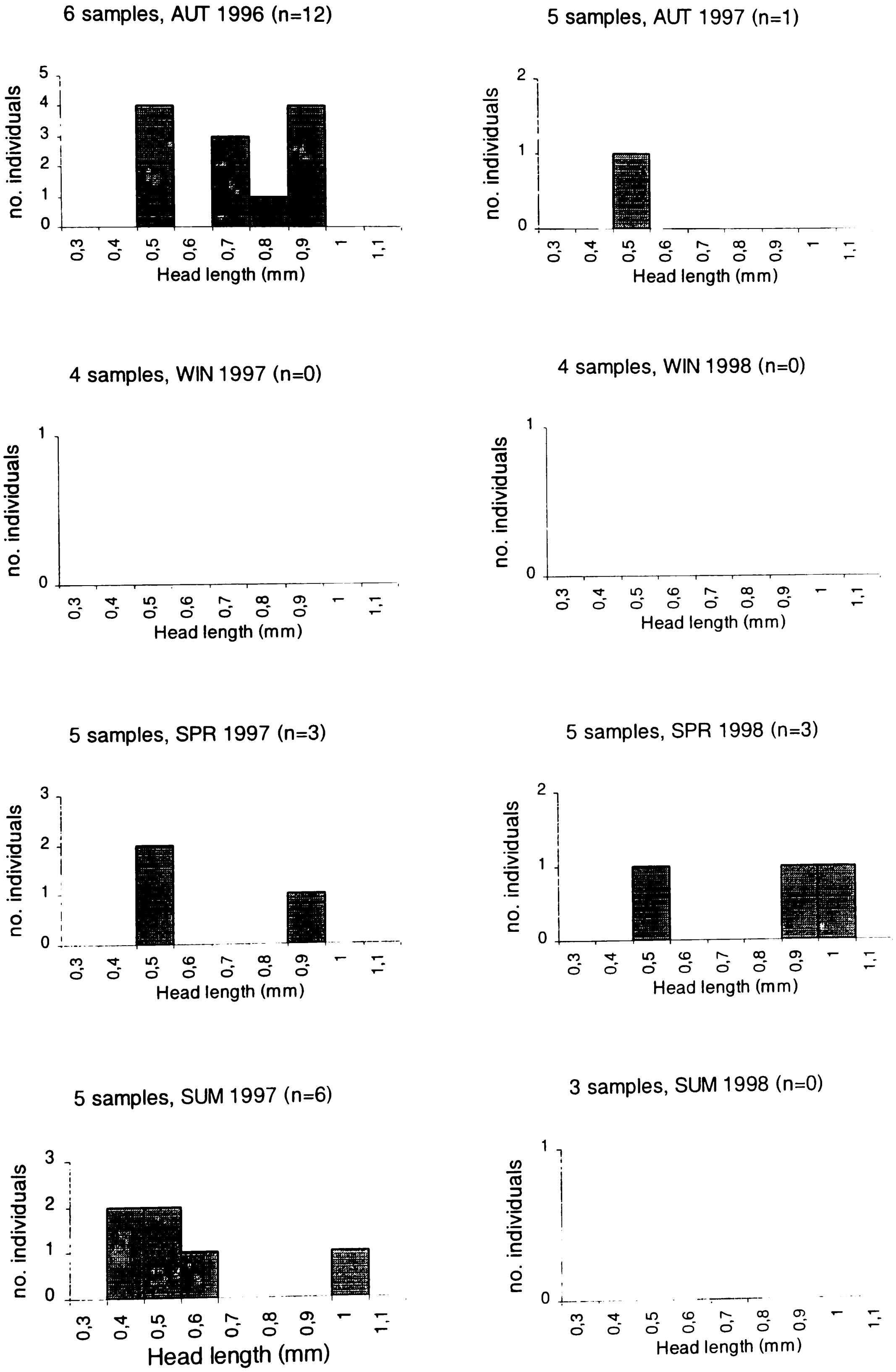


Figure 3.337 and 3.338 respectively compare the abundance and biomass of *Maera knudseni* on the control and impacted sites. This species was more abundant, bothin terms of abundance or biomass, at the control site than at the impacted, but a marked inter-annual variability was observed in both population parameters.

Fig. 3.337. Seasonal variation in mean abundance (± s.d.) of *Maera knudseni* on the impacted and control ground.

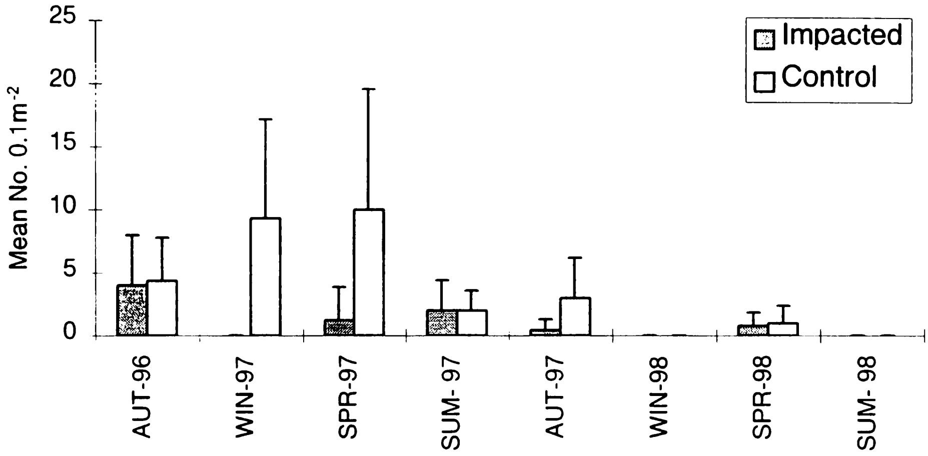
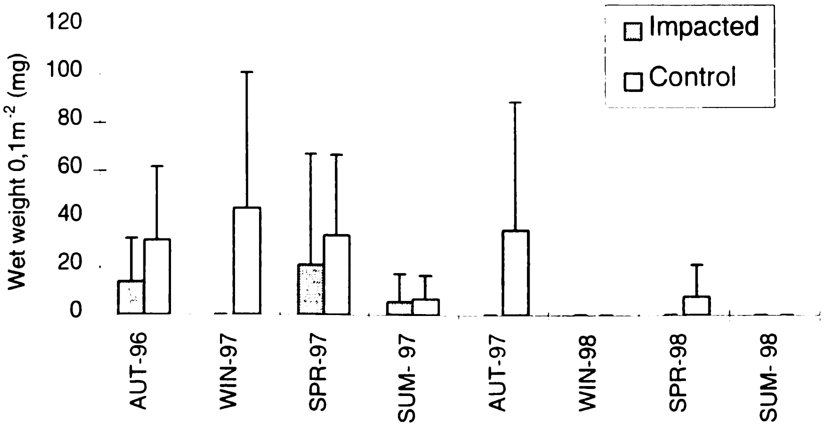


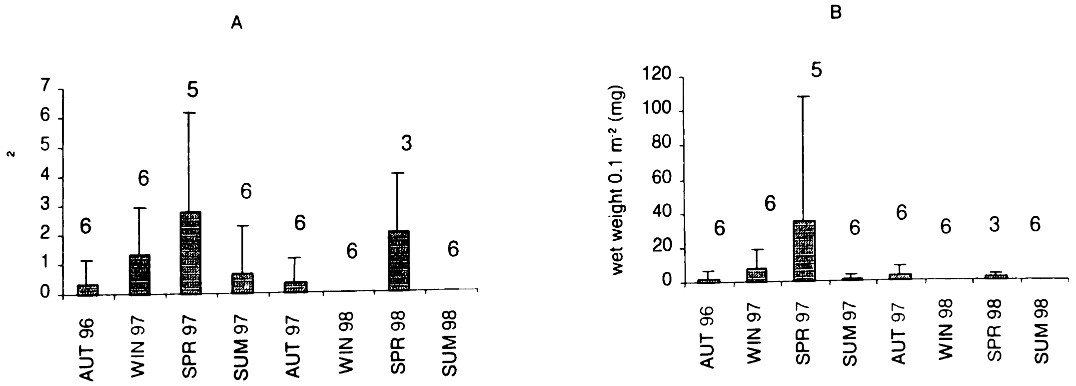
Fig. 3. 338. Seasonal variation in mean biomass (± s.d.) of *Maera knudseni* on the impacted and control ground.



Thoralus cranchii (Leach, 1817)

Thoralus cranchii was relatively common on Alicante maerl beds. It was found both at the control and impacted sites, but with marked differences between years (Fig. 3.339). It was more abundant in the first year of sampling at the control site, and it was rare at the impacted site where it was only collected by dredges); and more abundant in the second year at the impacted site. This decapod is a surface-dwelling omnivorous (carnivorous/scavenger) that lives on and amongst the maerl thalli. It is a species with a broad ecological distribution, as it is also present on *Posidonia* beds and infralittoral soft algae.

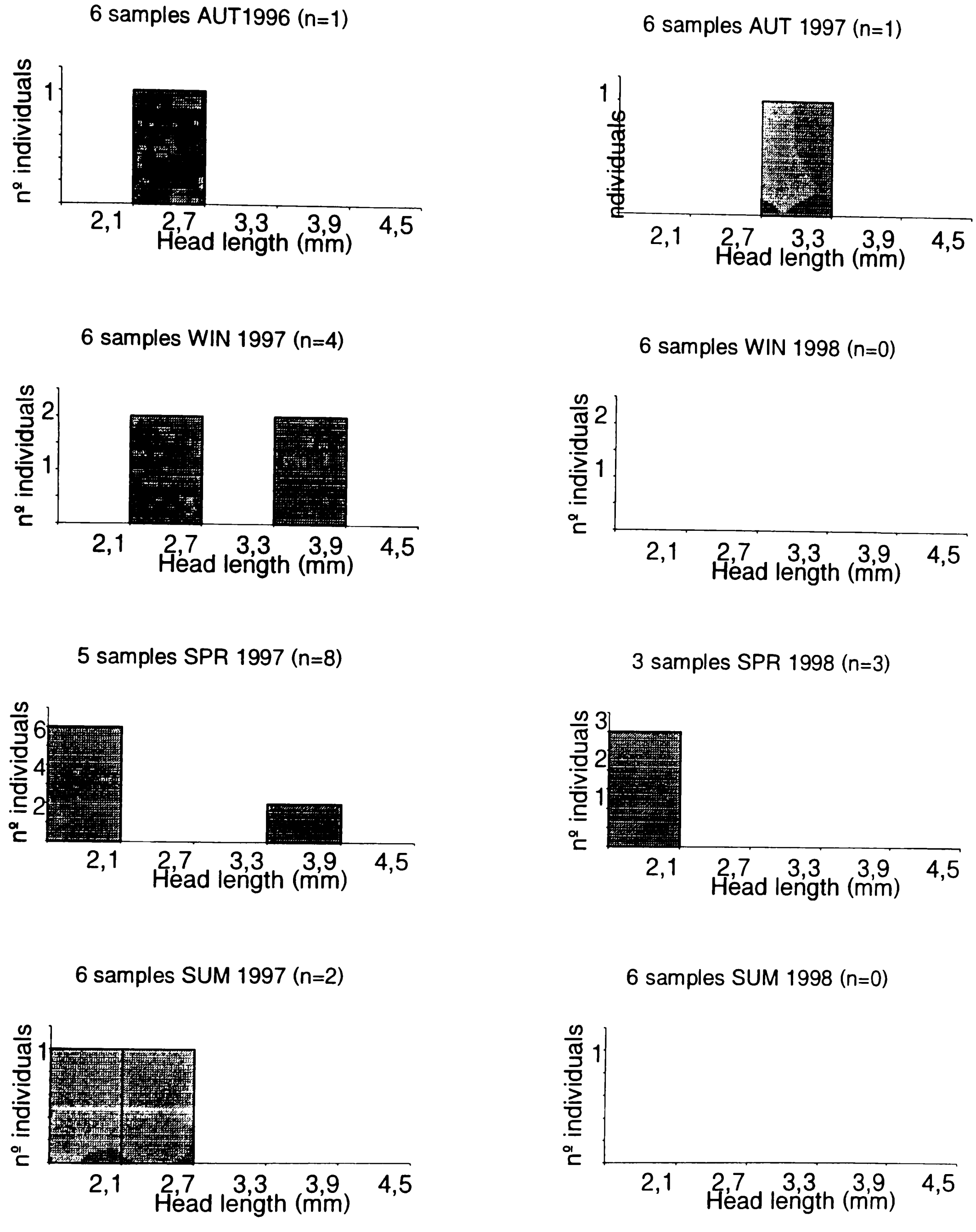
Fig. 3.339. A) Mean number and B) Biomass (mg wet weight) of *Thoralus cranchii* per 0.1 m^2 at UAC. Error bars = SD. Number of replicates above error bars.



Due to these inter-annual differences, no clear seasonal patterns could be discerned. However, two peaks in abundance were detected, i.e. in spring (1997 and 1998) with lower values in autumn (1996 and 1997).

The seasonal variation in size frequency of *T. cranchii* on the control ground is shown in Fig. 3.340. The smallest individuals (head length < 2.1mm) were present in spring (1997, 1998) and summer 1997. Probably then, recruitment occurred in spring, since the highest value for abundance was recorded then. However, due the low number of individuals taken, no seasonal pattern in size-frequency distribution could be detected.

Fig. 3.340. Size-frequency histograms for *Thoralus cranchii* collected seasonally in 0.05 m^2 quadrats at UAC from 1996 to 1998. SUM= summer, AUT= autumn, WIN= winter, SPR= spring.



6 samples AUT1996 (n=1)

6 samples AUT 1997 (n=1)

6 samples WIN 1997 (n=4)

6 samples WIN 1998 (n=0)

5 samples SPR 1997 (n=8)

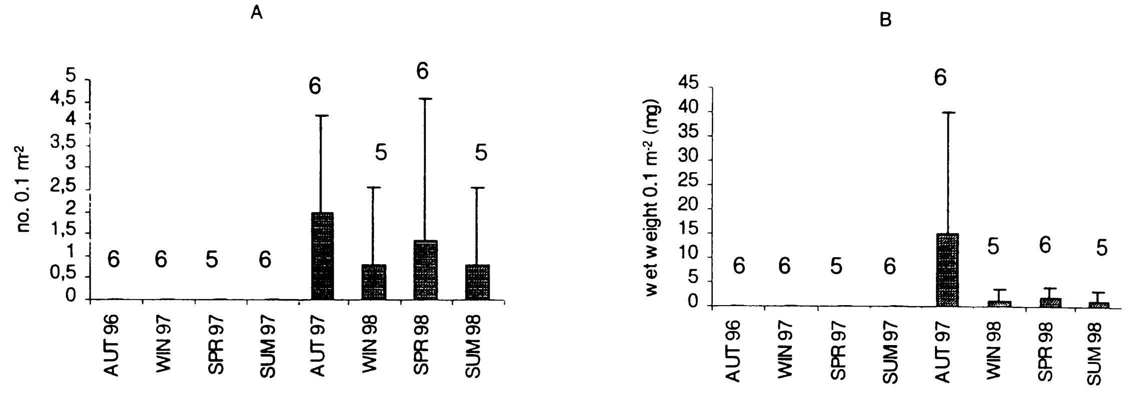
3 samples SPR 1998 (n=3)

6 samples SUM 1997 (n=2)

6 samples SUM 1998 (n=0)

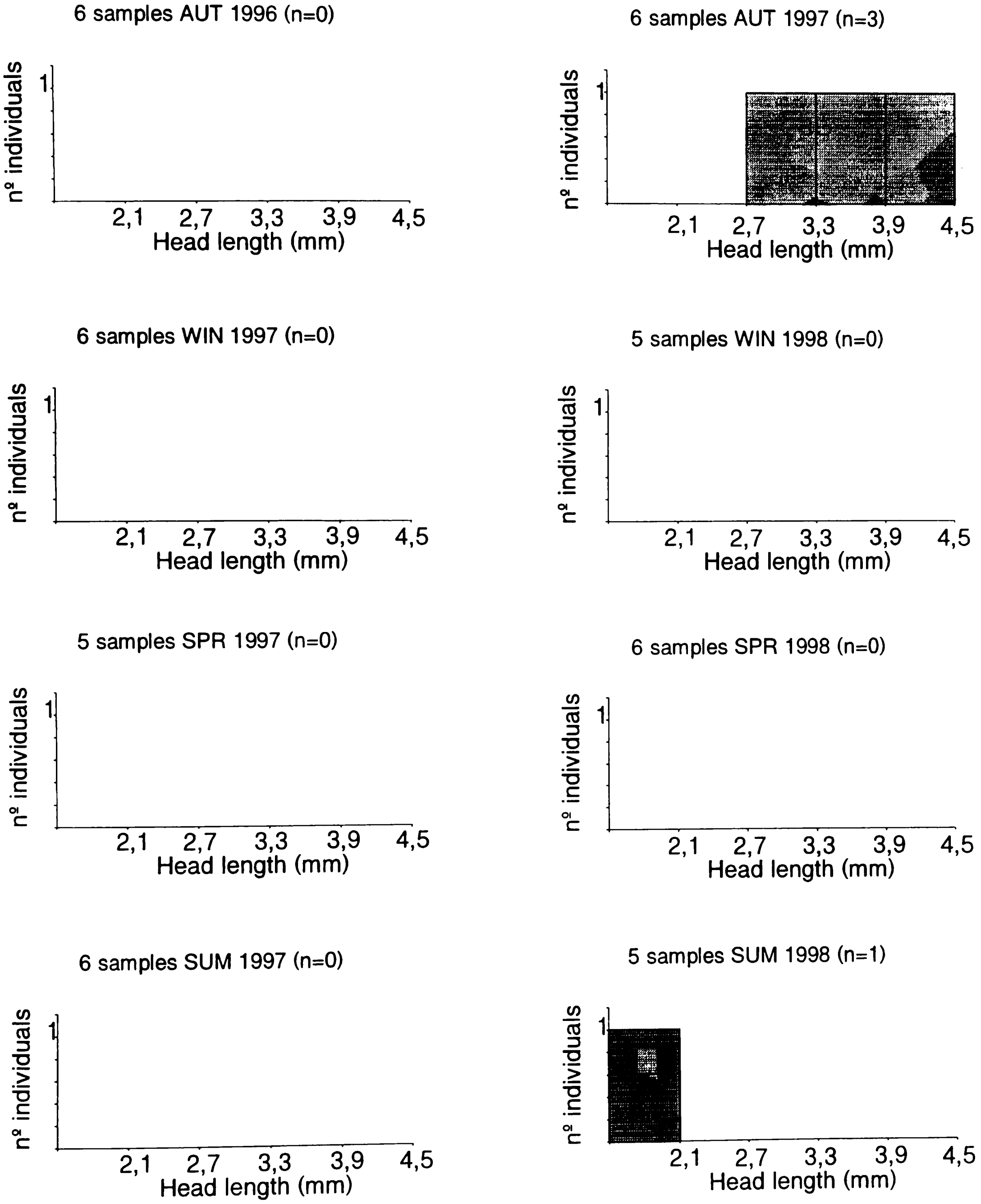
Although *T. cranchii* was not collected by quantitative quadrats in the first year of sampling at the impacted site, it appeared in dredge samples, though always in low numbers. It was more abundant than on the control ground during the second year (excepting spring 1998) (Fig. 3.341). The highest value in abundance and biomass was in autumn 1997 cf. the control site. Due to interannual differences, no seasonal pattern could be detected.

Fig. 3.341. A) Mean number and B) Biomass (mg wet weight) of *Thoralus cranchii* per 0.1 m^2 at UAI. Error bars = SD. Number of replicates above error bars.



The seasonal variation in size frequency of *T. cranchii* at the impacted ground is shown in Fig. 3.342. The smallest individuals (head length < 2.1mm) were present in summer. But due to the low numbers, no seasonal pattern in size-frequency distribution could be detected.

Fig. 3.342. Size-frequency histograms for *Thoralus cranchii* collected seasonally in 0.05 m^2 quadrats at UAI from 1996 to 1998. SUM= summer, AUT= autumn, WIN= winter, SPR= spring.


6 samples AUT 1996 (n=0)

6 samples AUT 1997 (n=3)

6 samples WIN 1997 (n=0)

5 samples WIN 1998 (n=0)

5 samples SPR 1997 (n=0)

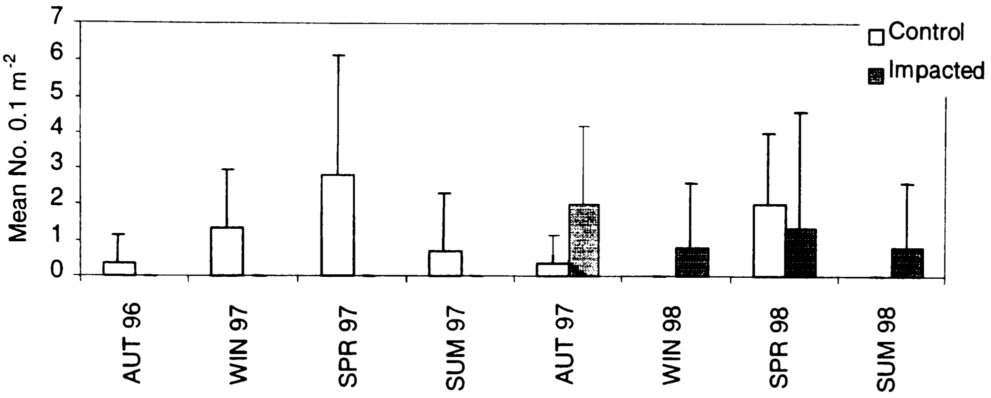
6 samples SPR 1998 (n=0)

6 samples SUM 1997 (n=0)

5 samples SUM 1998 (n=1)

Fig. 3.343.

Seasonal variation in mean abundance (± s.d.) of *Thoralus cranchii* on impacted and control grounds.



Seasonal variation in mean biomass (± s.d.) of *Thoralus cranchii* on impacted and control grounds.

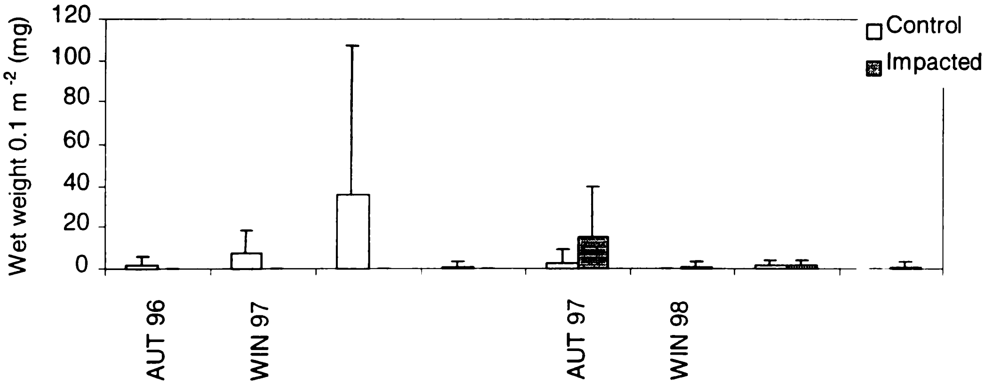


Figure 3.343 compares the abundance and biomass of *Thoralus cranchii* on the control and impacted sites. Although, it was more abundant at the control site both in terms of numbers or biomass, in the second year it was less evident cf the impacted site (excepting spring 1998).

Athanas nitescens (Leach, 1814)

The decapod *Athanas nitescens* was fairly common on the Alicante maerl beds and it was present on both control and impacted sites. It was collected in nearly all the samples at the control site, but it was very rare at the impacted site (only collected in two seasonal samples). It is a surface-dwelling decapod with a broad ecological distribution (also found on *Posidonia* beds and among infralittoral soft algae). Its feeding habit is probably omnivorous (scavenger/carnivore).

This species was common at the control site and present in all the seasonal samples (excepting in winter 1998), but it was more abundant in the first year of sampling (Fig. 3.344). The highest value for abundance was in winter 1997. In contrast, it was not collected in winter 1998. Spring 1998 was the highest value for biomass. Due to this differences in abundance, no seasonal pattern could be detected.

Fig. 3.344. A) Mean number and B) Biomass (mg wet weight) of *Athanas nitescens* per 0.1m2 at the UAC. Error bars = SD. Number of replicates above error bars.

The seasonal variation in size frequency of *A. nitescens* at the control ground is shown in Fig. 3.345. The smaller individuals (carapace length ≤ 1.5mm) were present in summer and autumn 1997, which is probably the recruitment period (a feature also observed at the impacted site). Due to low numbers of individuals in the second year, no seasonal patterns in the size frequency distribution could be discerned. However, in the first year an increase of size classes from autumn 1996 to spring 1997 is noted, and a possible recruitment in summer 1997.

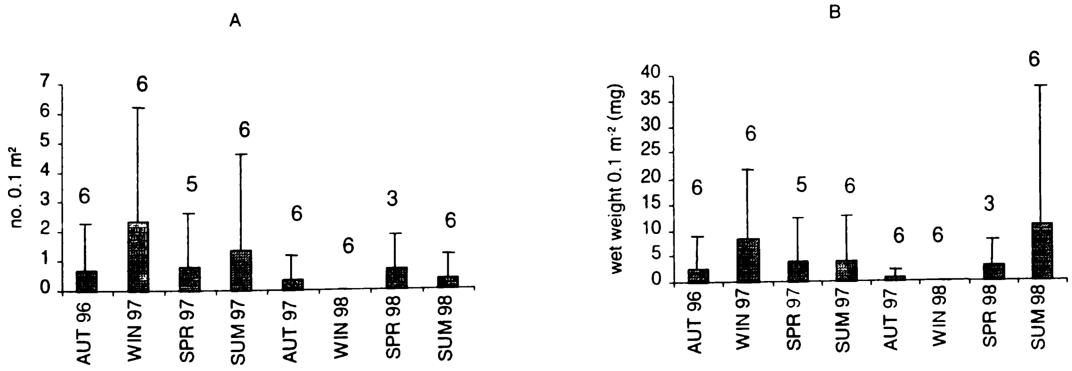


Fig. 3.345. Size-frequency histograms for *Athanas nitescens* collected seasonally in 0.05 m^2 quadrats at UAC from 1996 to 1998. SUM= summer, AUT= autumn, WIN= winter, SPR= spring.

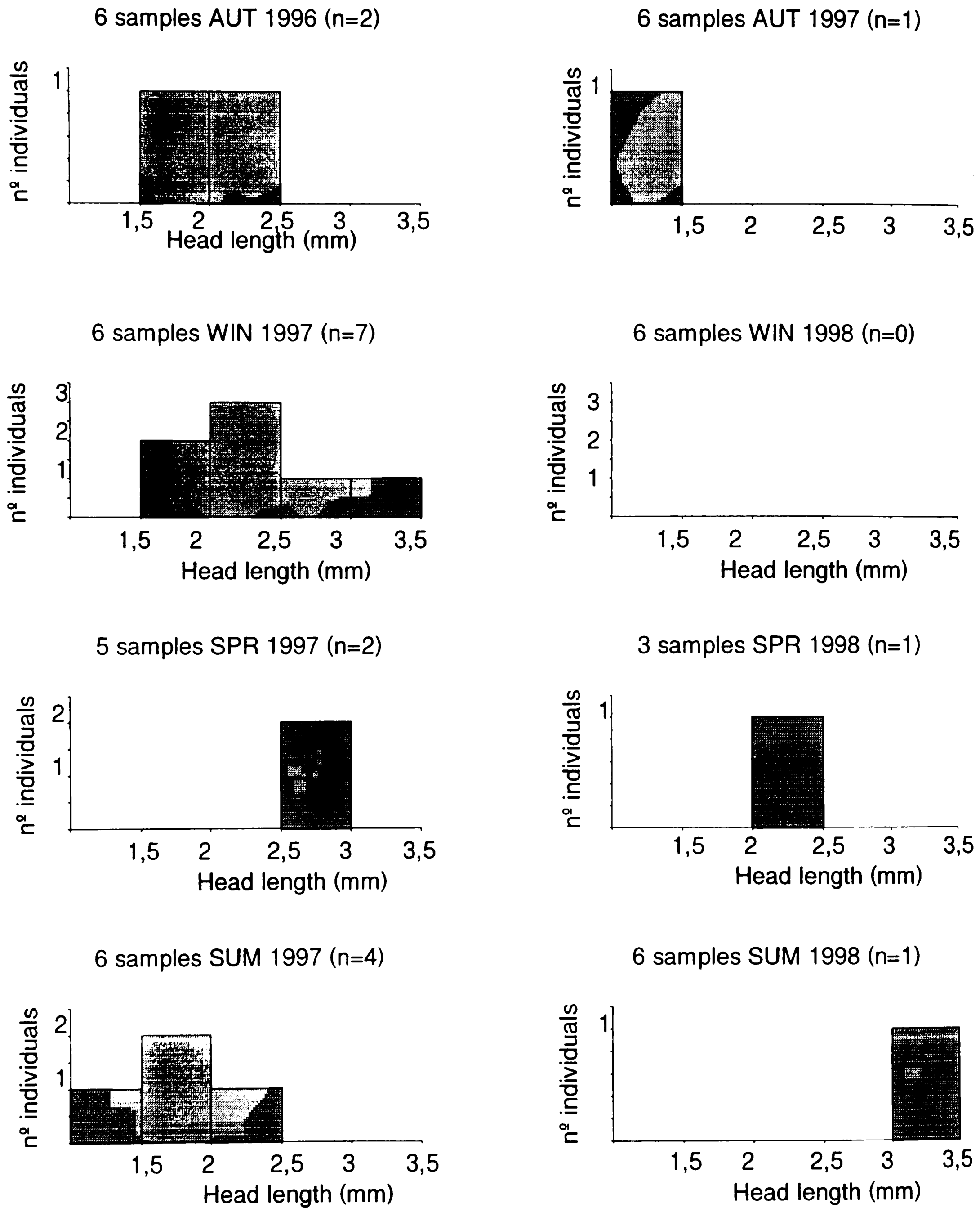
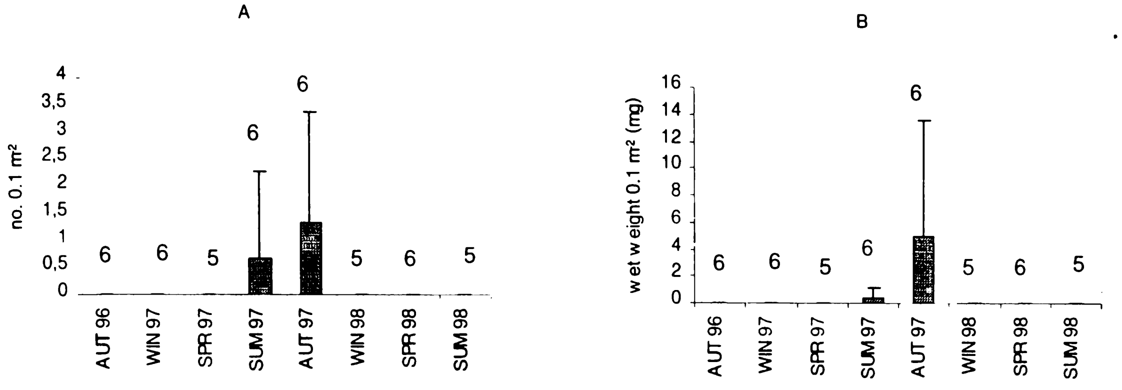


Fig. 3.346. A) Mean number and B) Biomass (mg wet weight) of *Athanas nitescens* per 0.1 m^2 at UAI. Error bars = SD. Number of replicates above error bars.



A. nitescens was very rare at the impacted site (Fig. 3.346). It was only present in two seasonal samples and then only in low numbers. The highest values, both in abundance and biomass, was observed in autumn 1997. No seasonal pattern can be discerned.

The seasonal variation in size frequency of *A. nitescens* at the impacted ground is shown in Fig. 3.347. The smaller individuals (carapace length ≤ 1.5mm) were present in summer and autumn 1997, the same seasons that in the control site. That means a possible recruitment period in later summer and early autumn.

Fig. 3.347. Size-frequency histograms for *Athanas nitescens* collected seasonally in 0.05 m^2 quadrats at UAI from 1996 to 1998. SUM= summer, AUT= autumn, WIN= winter, SPR= spring

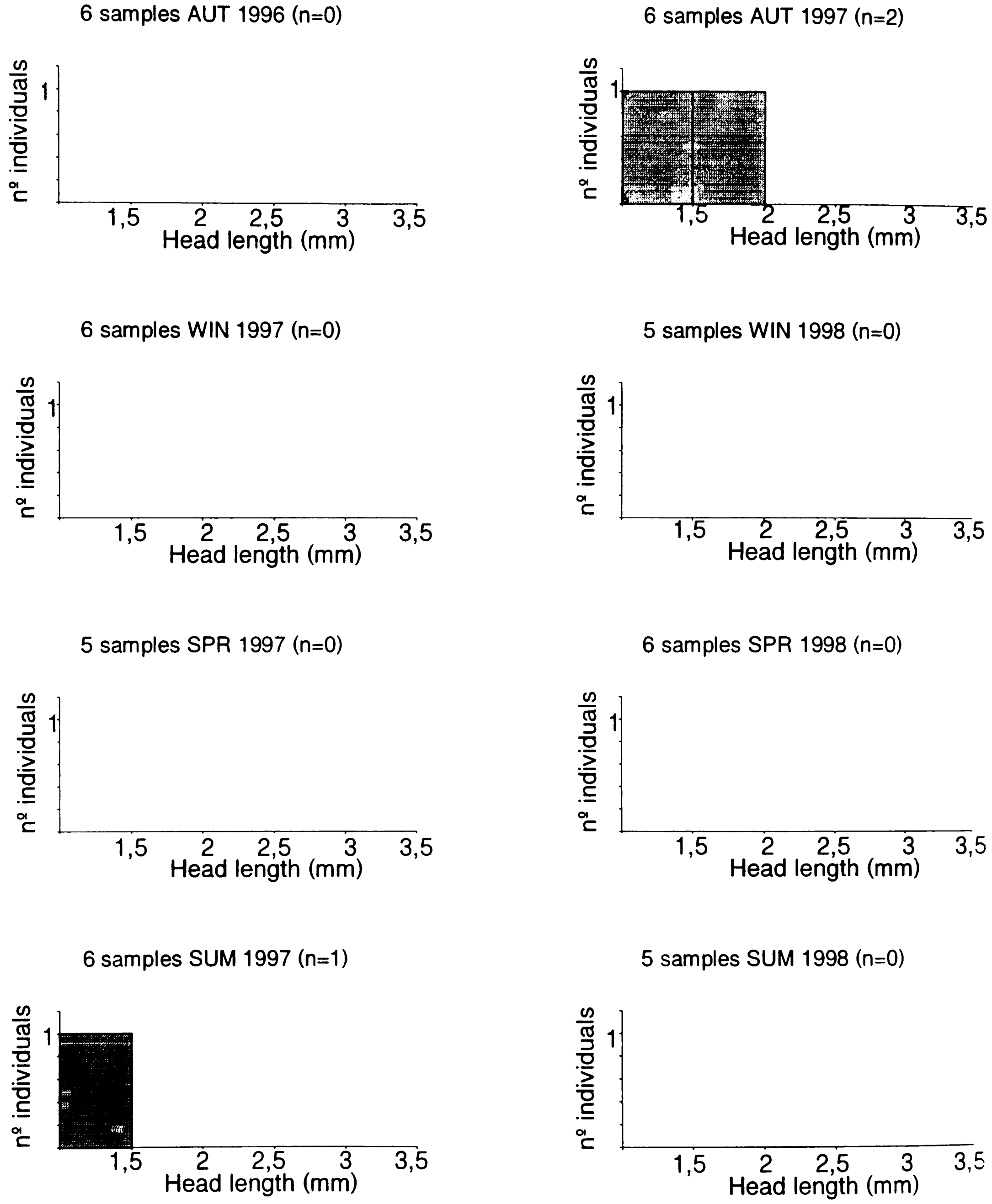
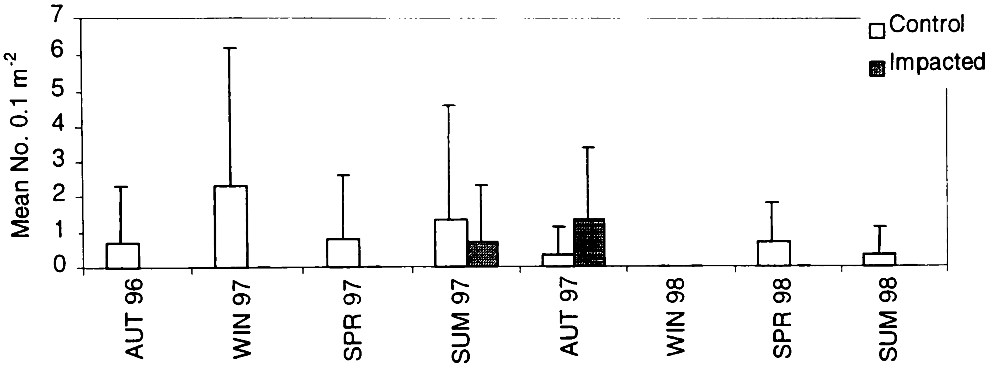
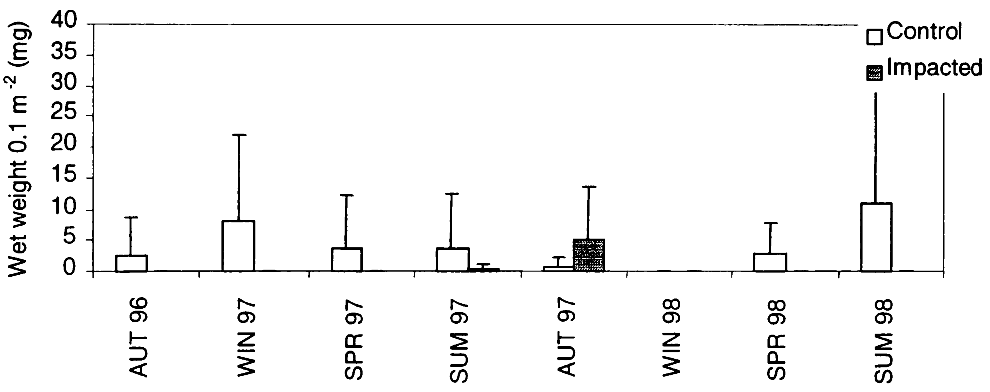


Fig. 3.348. Seasonal variation in abundance of *Athanas nitescens* at the impacted and control grounds.



Figures 3.348 & 3.349 respectively compare the abundance and biomass of *Athanas nitescens* on the control and impacted sites. This species was clearly more abundant at the control site than the impacted site in both abundance and biomass, excepting in autumn 1997. No seasonal patterns in abundance could be detected, due to the differences between years and seasons, e.g. the highest value of the abundance was in winter 1997, yet none was collected in winter 1998. Like *Thoralus cranchii,* another natantian decapod, *A. nitescens* may be a good indicator of the algal cover (refuge availability). Because of this propensity, these species may have been more abundant at the control site where the algal cover is higher than at the impacted site.

Fig. 3.349. Seasonal variation in biomass of *Athanas nitescens* at the impacted and control grounds.

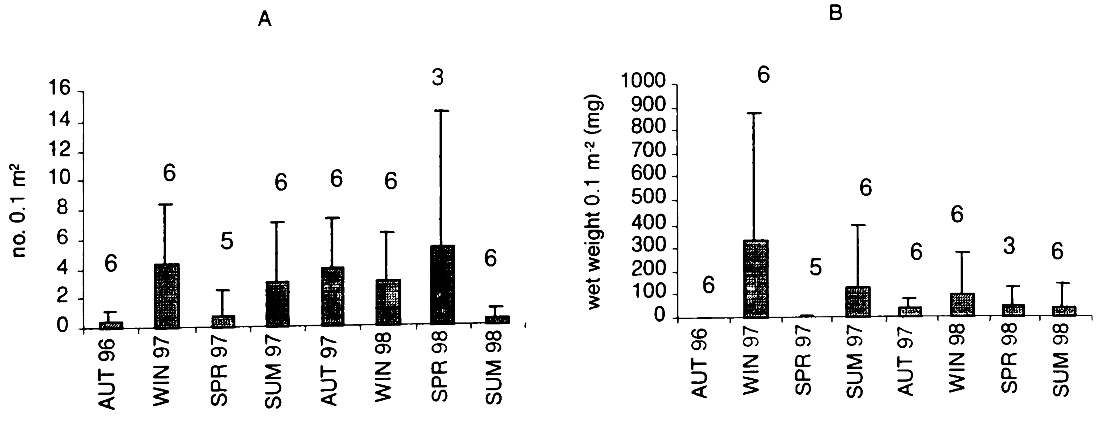


Ebalia edwardsi **Costa, 1838**

This species was one of the most common decapods on Alicante maerl grounds. It was collected from both the control and impacted sites in nearly all the seasonal samples (excepting autumn 1997 and summer 1998 at the impacted site). Its feeding habit is not known with certainly but it is possiby an omnivorous (scavenger/carnivore) animal. It is considered to be a characteristic species of the circalittoral coastal detritic biocenoses in Mediterranean waters (Picard, 1965).

This species was very common on the control ground, being present in all the seasonal samples (Fig. 3.350). The highest values for abundance were in spring 1998 and winter 1997, but only in winter 1997 for biomass. In spite of its abundance, no particular seasonal patterns was observed.

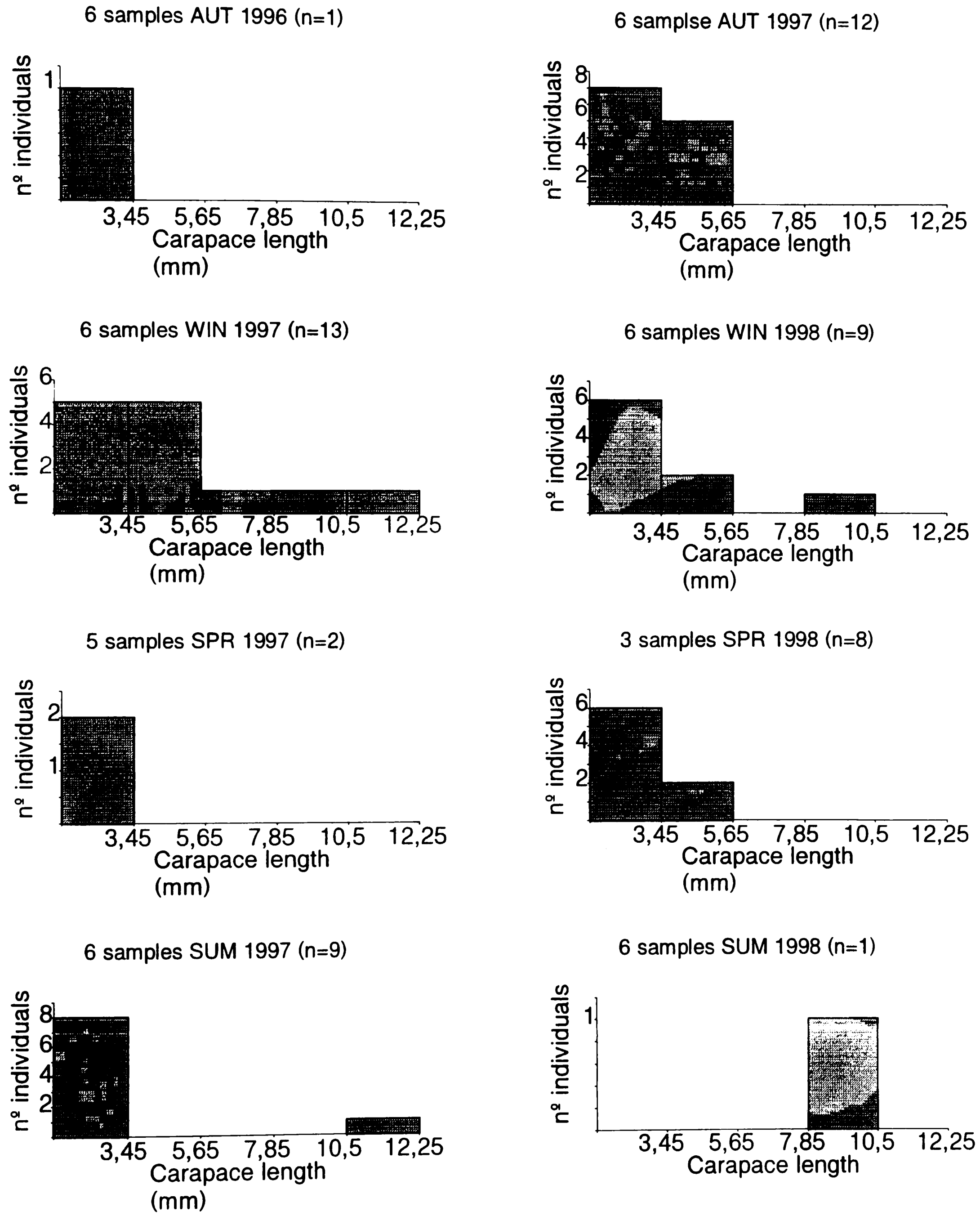
Fig. 3.350. A) Mean number and B) Biomass (mg wet weight) of *Ebalia edwardsi* per $0.1m^2$ at UAC. Error bars = SD. Number of replicates above error bars.



The seasonal variation in size frequency of *E. edwardsi* at the control ground is shown in Fig. 3.351. The smaller sizes (carapace length < 3.5mm) were collected in all of the seasonal samples. However, the bigger sizes (carapace length > 10mm) were only sampled in winter and summer from both years. Although the number of individuals was not low, no patterns in size frequency distribution could be observed.

This species was more abundant in the samples collected during the first year of sampling: it was very rare in the second year. The highest values in both abundance and biomass were obtained in autumn 1996 and spring 1997. No particular seasonal pattern could be observed in the abundance and biomass of this species at the impacted site. However, maximum values in abundance from the two years were obtained in spring, and minimum in summer.

Fig. 3.351. Size-frequency histograms for *Ebalia edwardsi* collected seasonally in 0.05m^2 quadrats at UAC from 1996 to 1998. SUM= summer, AUT= autumn, WIN= winter, SPR= spring.



6 samples AUT 1996 (n=1)

6 samplse AUT 1997 (n=12)

6 samples WIN 1997 (n=13)

6 samples WIN 1998 (n=9)

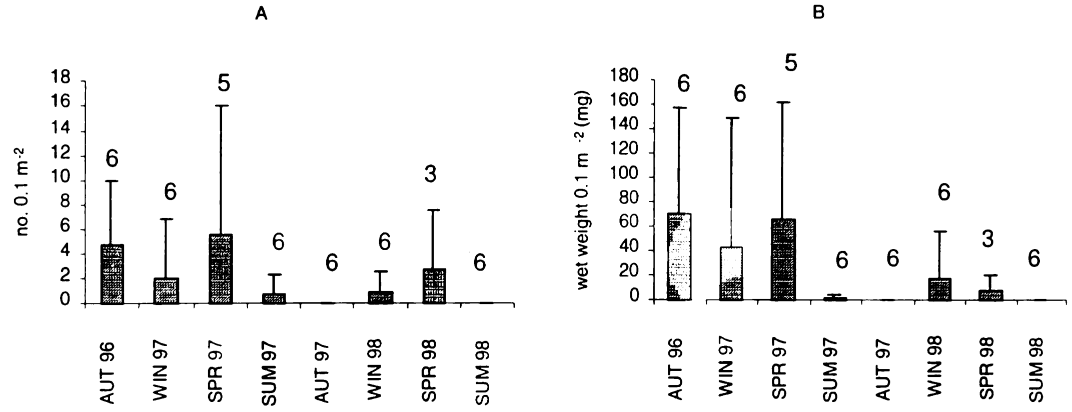
5 samples SPR 1997 (n=2)

3 samples SPR 1998 (n=8)

6 samples SUM 1997 (n=9)

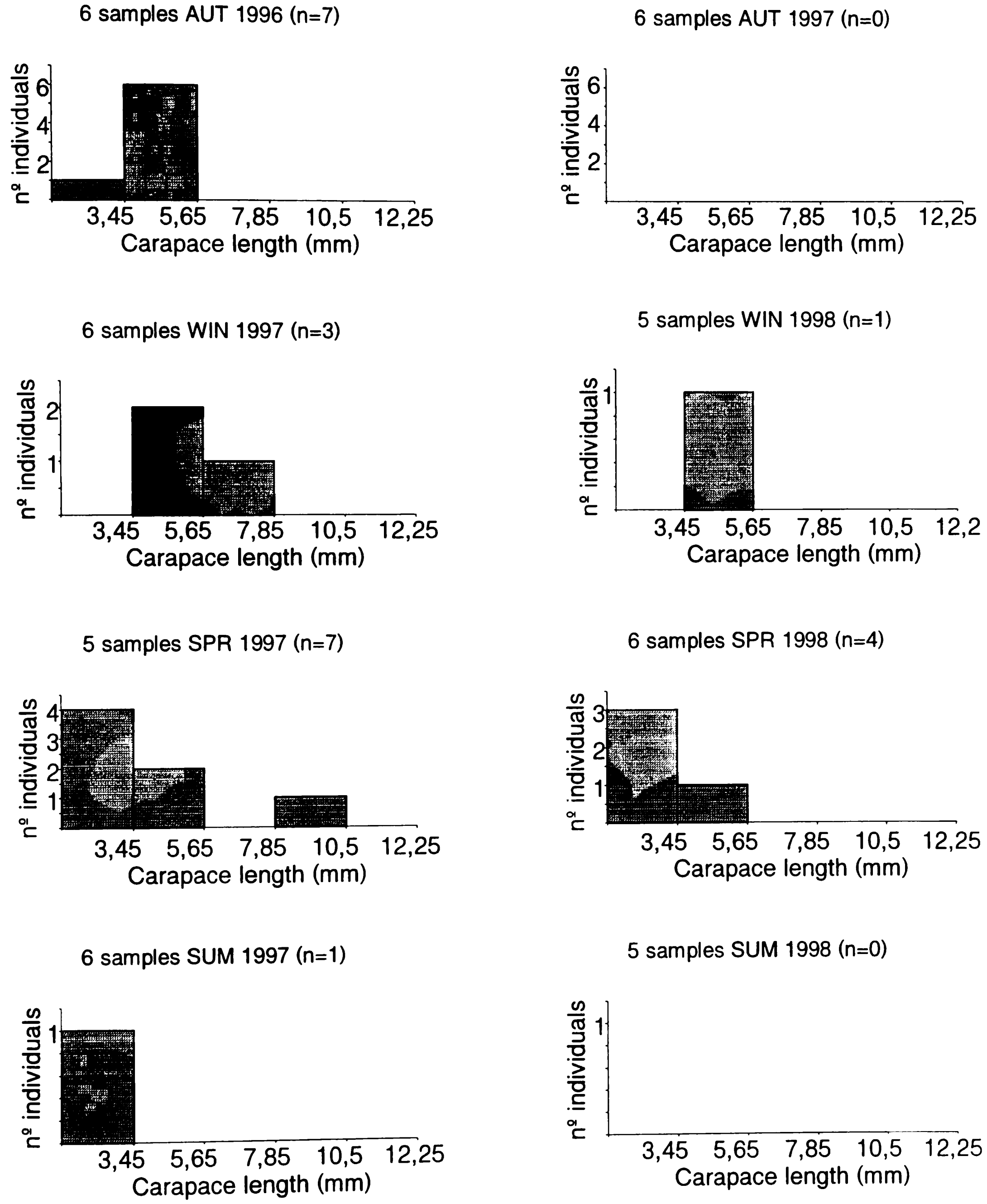
6 samples SUM 1998 (n=1)

Fig.3. 352. A) Mean number and B) Biomass (mg wet weight) of *Ebalia edwardsi* per 0.1 m^2 at UAI. Error bars= SD. Number of replicates above error bars.



The seasonal variation in size frequency of *E. edwardsi* at the impacted ground is shown in Fig. 3.353. The smaller sizes (carapace length < 3.5mm) were collected in nearly all of the seasonal (excepting in winter). This species was important in spring, which probably is the recruitment season. The bigger sizes (carapace length > 10.5mm) were very rare, cf. the control site where they were more frequent. Since this species was mostly collected during the first year of sampling and was rare in the second year, no patterns in size-frequency distribution could be observed.

Fig.3. 353. Size-frequency histograms for *Ebalia edwardsi* collected seasonally in 0.05 m^2 quadrats at UAI from 1996 to 1998. SUM= summer, AUT= autumn, WIN= winter, SPR= spring.



6 samples AUT 1996 (n=7)

6 samples AUT 1997 (n=0)

6 samples WIN 1997 (n=3)

5 samples WIN 1998 (n=1)

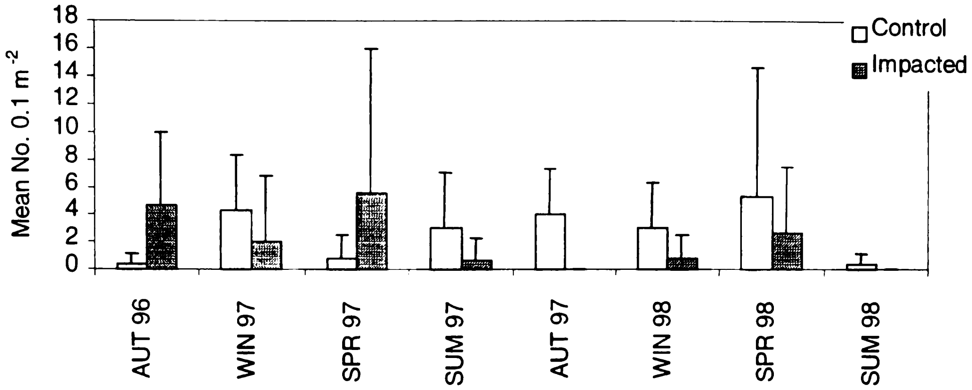
5 samples SPR 1997 (n=7)

6 samples SPR 1998 (n=4)

6 samples SUM 1997 (n=1)

5 samples SUM 1998 (n=0)

Seasonal variation in mean abundance (± s.d.) of *Ebalia edwarsi* on impacted and control grounds.



Seasonal variation in mean biomass (± s.d.) of *Ebalia edwarsi* on impacted and control grounds.

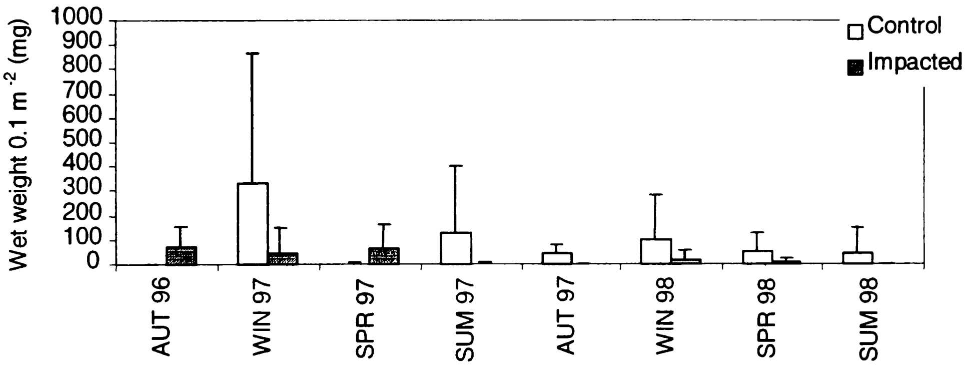


Fig. 3.354.

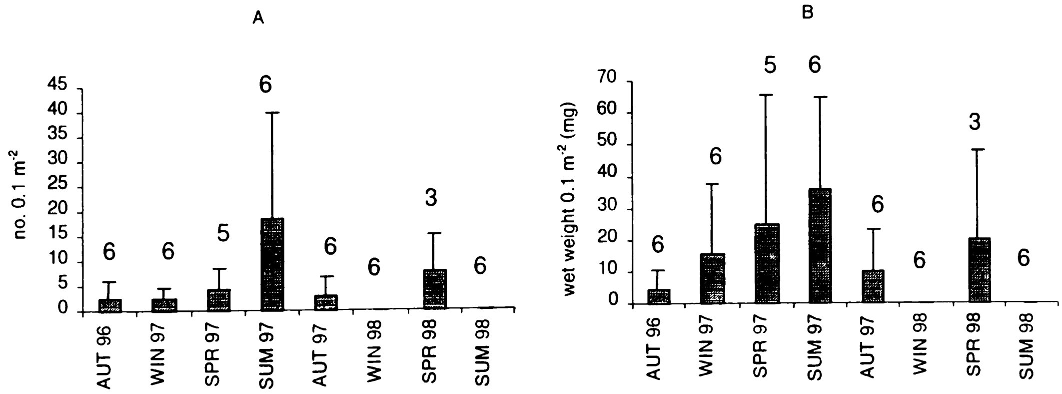
E. edwardsi represents a good indicator of the impact of trawling activity, both in relation to its frequency and size-structure (biomass). Present on both control and impacted sites, it showed marked differences between sites. It was present in all of the seasonal samples at the control site, with no great seasonal changes. By contrast, at the impacted site, there were marked intra- and interannual variations (not collected in autumn 1997 and summer 1998) (Fig. 3.354). Also, biomass was consistently higher at the control site in all of the seasonal samples (except in autumn 1996). The bigger size classes were more frequent at the control site.

Galathea intermedia Lilljeborg, 1851

Galathea intermedia was the most abundant decapod in Alicante maerl grounds. Although it was sampled in both control and impacted sites, only a few individuals were collected from the impacted ground. It is a deposit/suspension feeder and inhabits the spaces amongst gravel and maerl thalli. This decapod presents a broad ecological distribution (Picard, 1965).

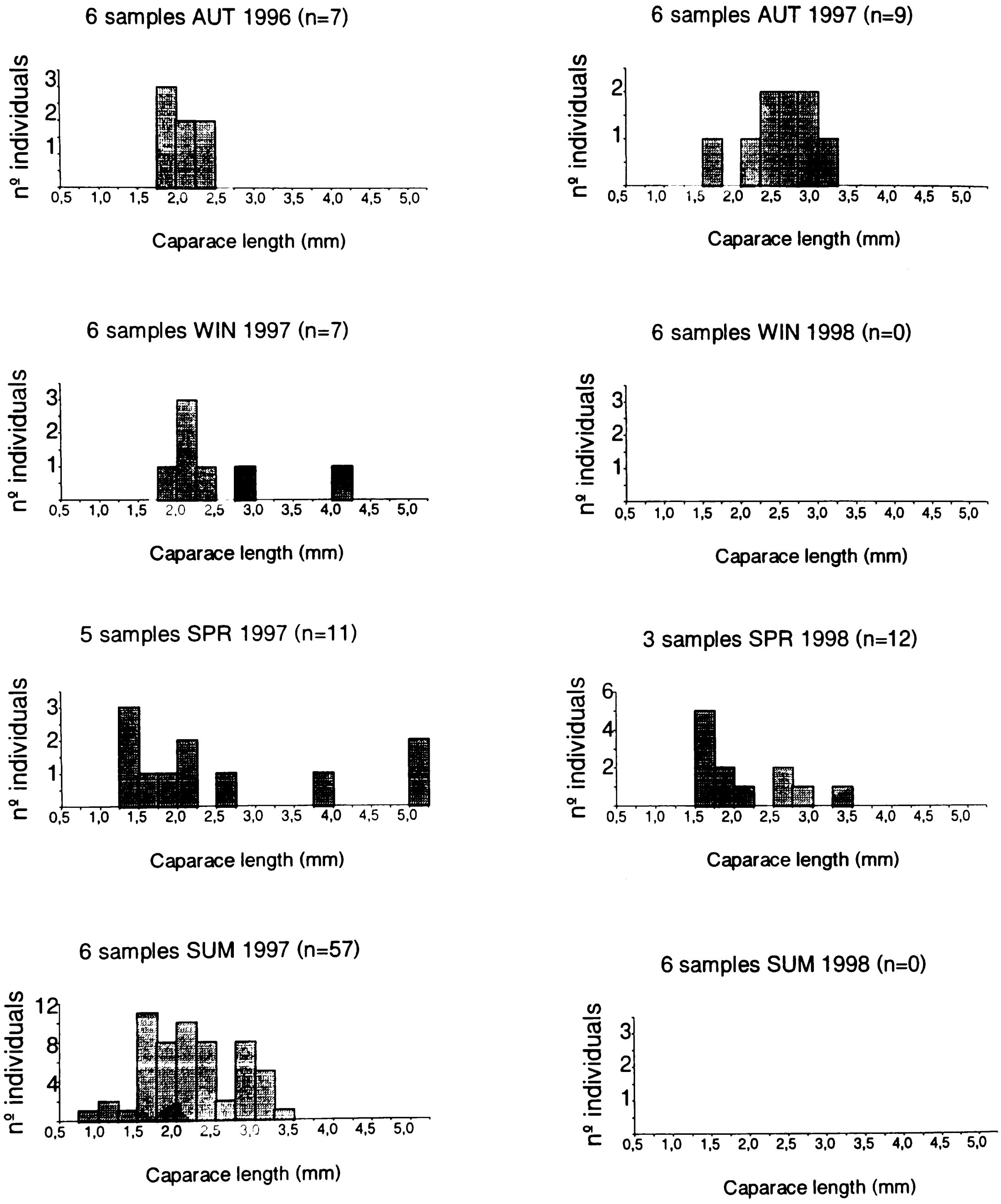
G. intermedia was more abundant on the control ground. However, there were some differences between the first and second year of sampling (none collected in winter and summer 1998) (Fig. 3.355). The highest values, both in abundance and biomass, were in summer 1997, cf. summer 1998 where it was not collected. On the other hand, it seems abundant in spring. The differences between years and seasonal samples mean that no seasonal patterns could be discerned.

Fig. 3.355. A) Mean number and B) Biomass (mg wet weight) of *Galathea intermedia* per 0.1 m^2 at UAC. Error bars = SD. Number of replicates above error bars.



The seasonal variation in size frequency of *G. intermedia* at the control ground is shown in Fig.3.355. The smaller individuals (carapace length < 1.0mm) were collected in summer 1997, also some individuals with the caparace length < 1.5mm, which were not observed in the rest of the seasonal samples. This may mean a recruitment period in summer. But no seasonal pattern in size-frequency distribution could be detected.

Fig. 3.355. Size-frequency histograms for *Galathea intermedia* collected seasonally in 0.05 m^2 quadrats at UAC from 1996 to 1998. SUM= summer, AUT= autumn, WIN= winter, SPR= spring.



6 samples AUT 1996 (n=7)

6 samples AUT 1997 (n=9)

6 samples WIN 1997 (n=7)

6 samples WIN 1998 (n=0)

5 samples SPR 1997 (n=11)

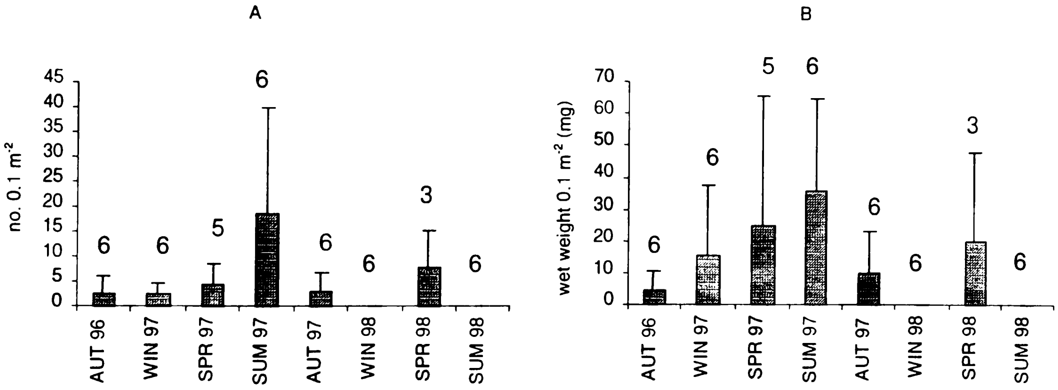
3 samples SPR 1998 (n=12)

6 samples SUM 1997 (n=57)

6 samples SUM 1998 (n=0)

With regard to the impacted site, only a few individuals were collected from four seasonal samples (Fig. 3.356). The highest values, both in abundance and biomass, were obtained in winter 1998, but still only in very low numbers. Due to this, no seasonal pattern could be detected.

Fig. 3.356.A) Mean number and B) Biomass (mg wet weight) of *Galathea intermedia* per 0.1 m^2 at UAI. Error bars = SD. Number of replicates above error bars.



The seasonal variation in size frequency of *G. intermedia* at the impacted ground is shown in Fig.3.357. The smaller individuals (carapace length < 1.5mm) were collected in winter 1997. Due to the low numbers, no seasonal pattern in size-frequency can be discerned.

Fig. 3.357. Size-frequency histograms for *Galathea intermedia* collected seasonally in 0.05 m^2 quadrats at UAI from 1996 to 1998. SUM= summer, AUT= autumn, WIN= winter, SPR= spring.

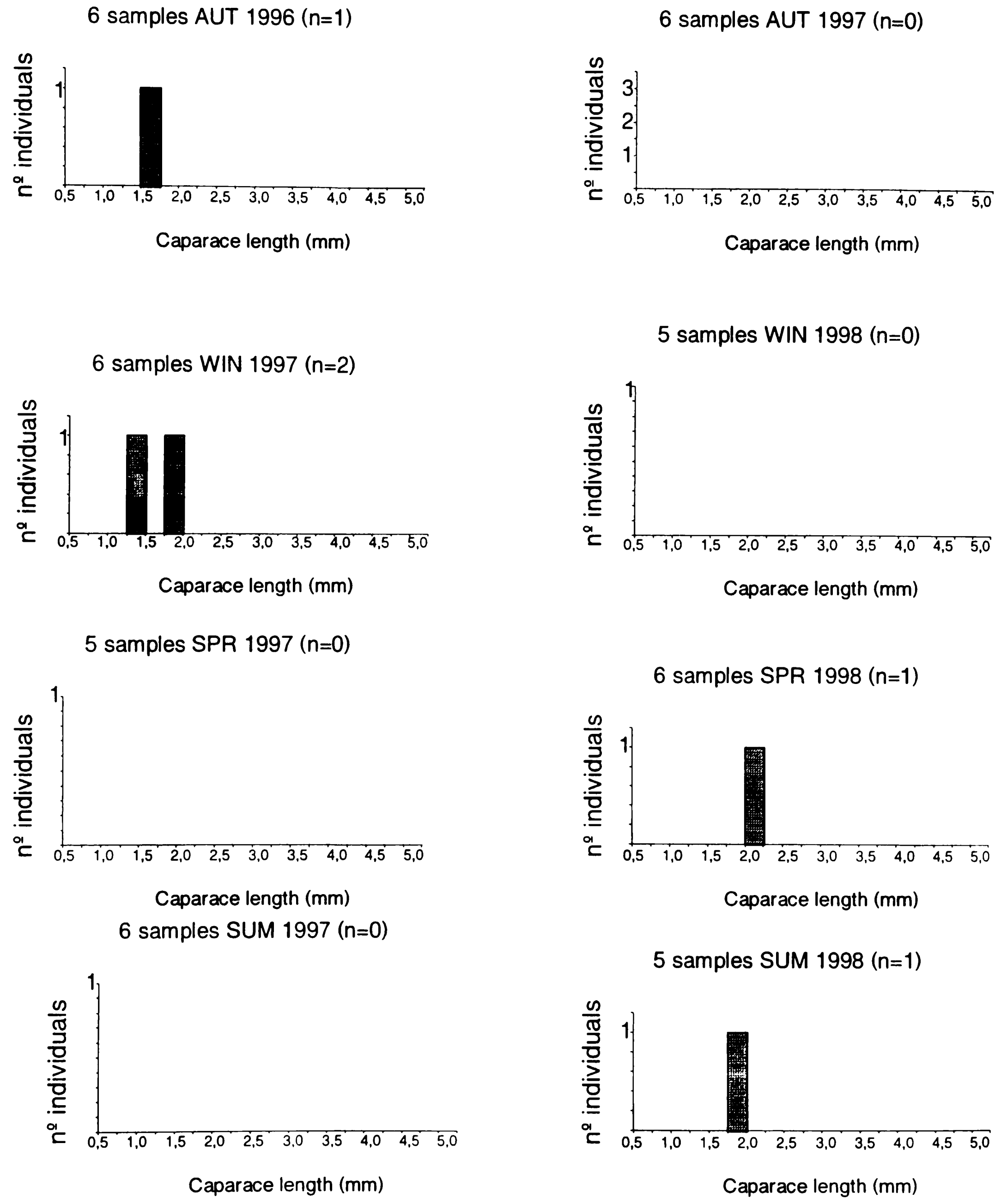
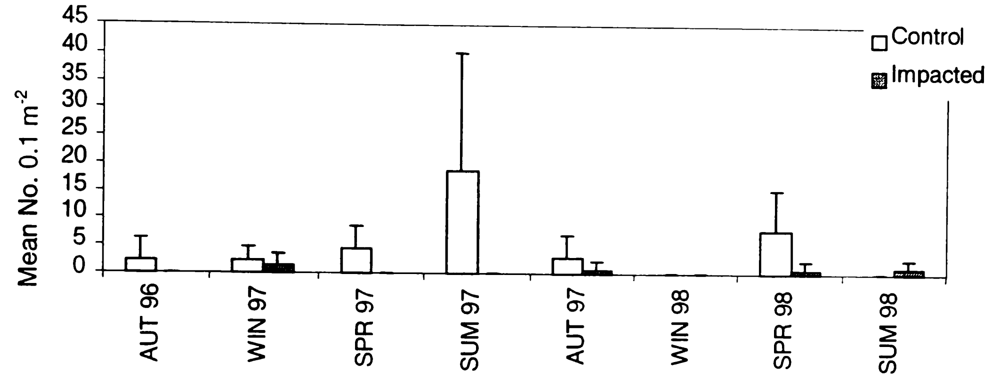


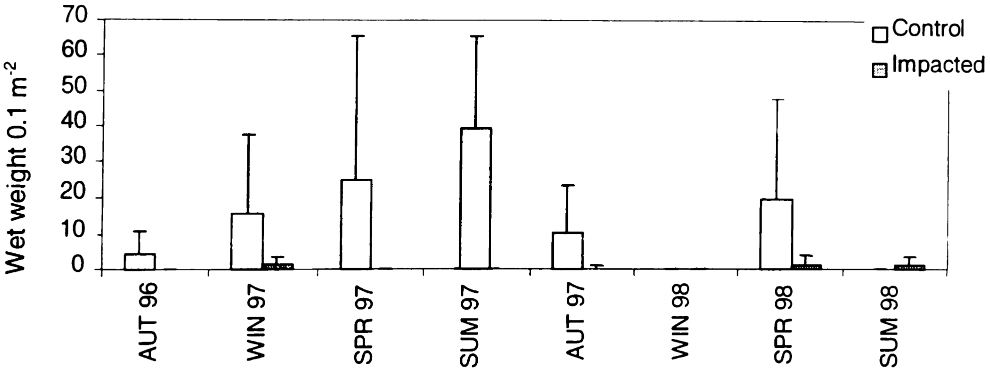
Figure 3.358 compares the abundance and biomass of *Galathea intermedia* on the control and impacted sites. This decapod was much more abundant at the control site, and only very rare at the impacted site. The highest value was obtained in summer 1997, but it was not collected in summer 1998 at the control site. Also, two peaks can be observed in spring (1997 and 1998).

Fig. 3.358.

Seasonal variation in mean abundance (± s.d.) of *Galathea intermedia* on impacted and control grounds.



Seasonal variation in mean biomass (± s.d.) of *Galathea intermedia* on impacted and control grounds.

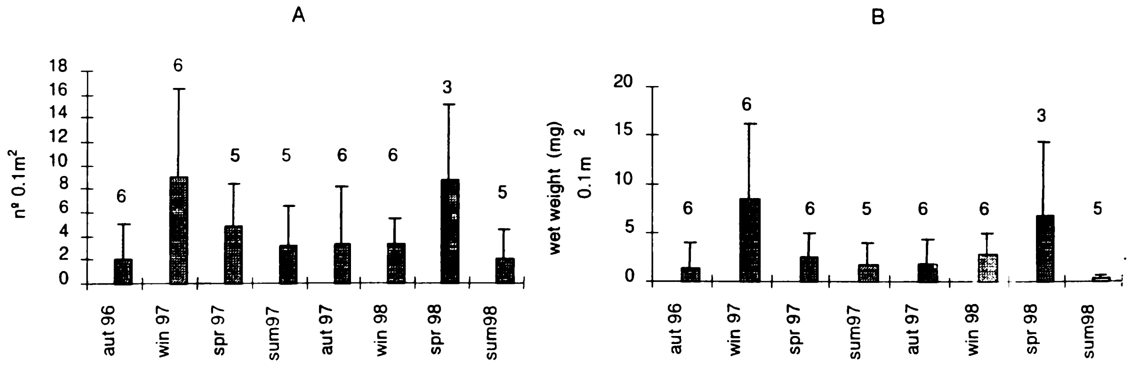


Amphipholis squamata (Delle Chiaje, 1828)

Amphipholis squamata was the most abundant ophiuroid both in terms of numbers and biomass on Alicante maerl grounds. It was present both on the control and impacted sites, and in almost all the seasonal samples (excepting spring 1997 at the impacted site). The feeding habits of this ophiuroid are not known with certainty but it is probably either a scavenger or a carnivore. It has a broad euryhaline ecological distribution (Picard, 1965).

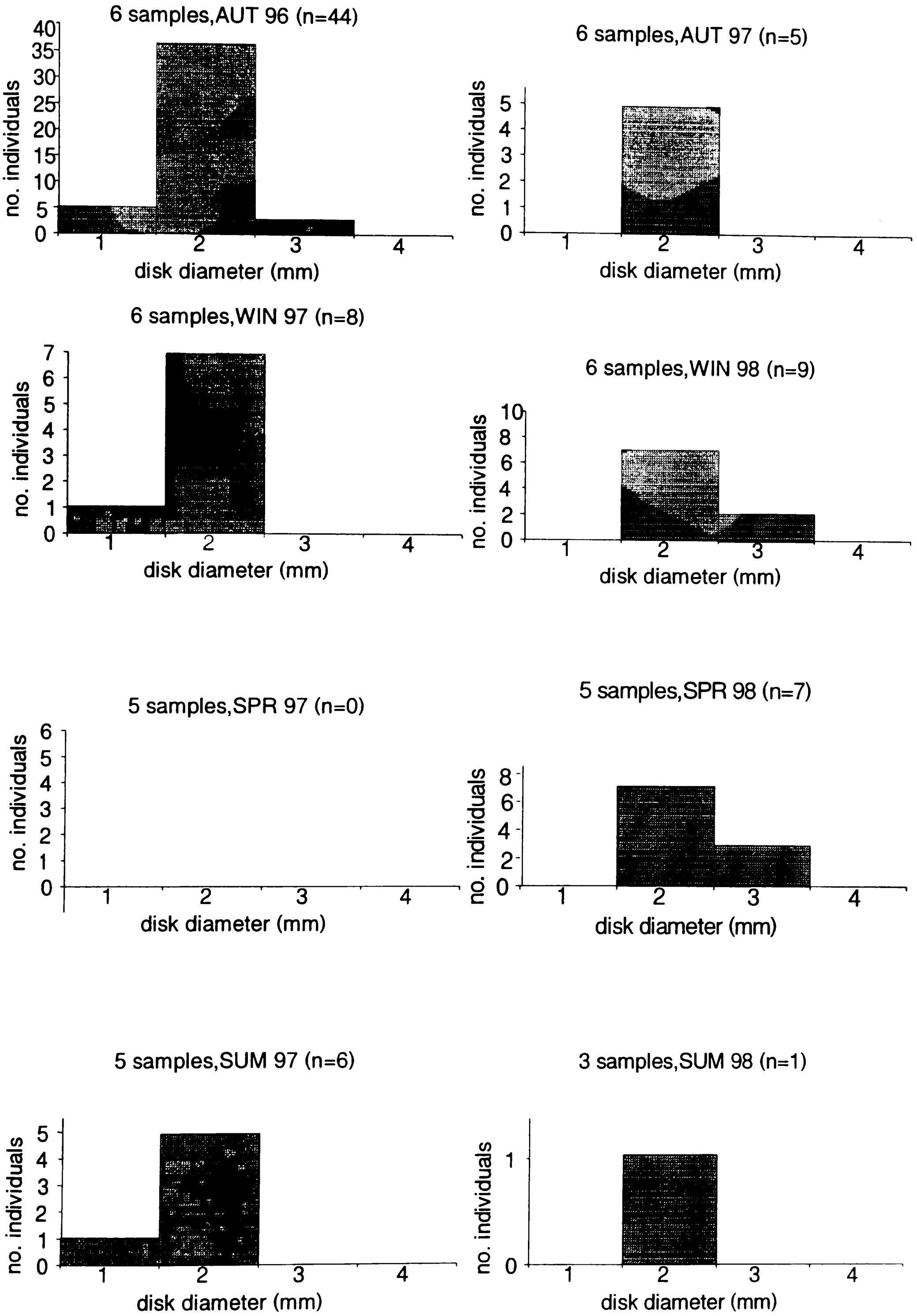
This species was abundant at the control site and was collected in all seasonal samples. High values for both abundance and biomass were obtained in winter 1997 and spring 1998, with low values in autumn 1996 and summer 1998 (Fig. 3.359). A possible seasonal pattern both in abundance and biomass could be detected: it was more abundant in winter and spring and less so in summer and autumn.

Fig.3.359. A) Mean number and B) Biomass (mg wet weight) of *Amphipholis squamata* per 0.1m^2 at UAC. Error bars = SD. Numbers of replicates above error bars.



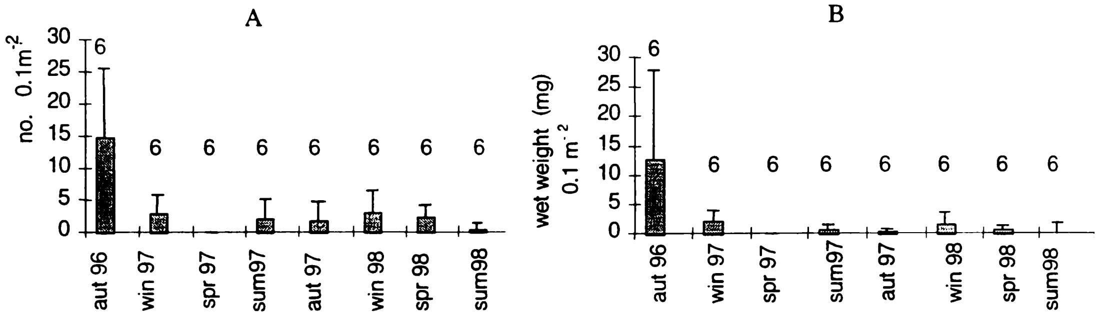
The seasonal variation in size frequency of the *Amphipholis squamata* population at the control site is shown in Fig.3.360. Small individuals (disc diameter ≤ 1.0mm) appeared at all seasons. In spite of its abundance, no seasonal pattern in size-frequency distribution could be detected.

Fig.3.360.Size-frequency histograms for *Amphipholis squamata* collected seasonally in 0.1m^2 at UAC from 1996-1998. SUM=summer, AUT=autumn, WIN=winter, SPR=spring.



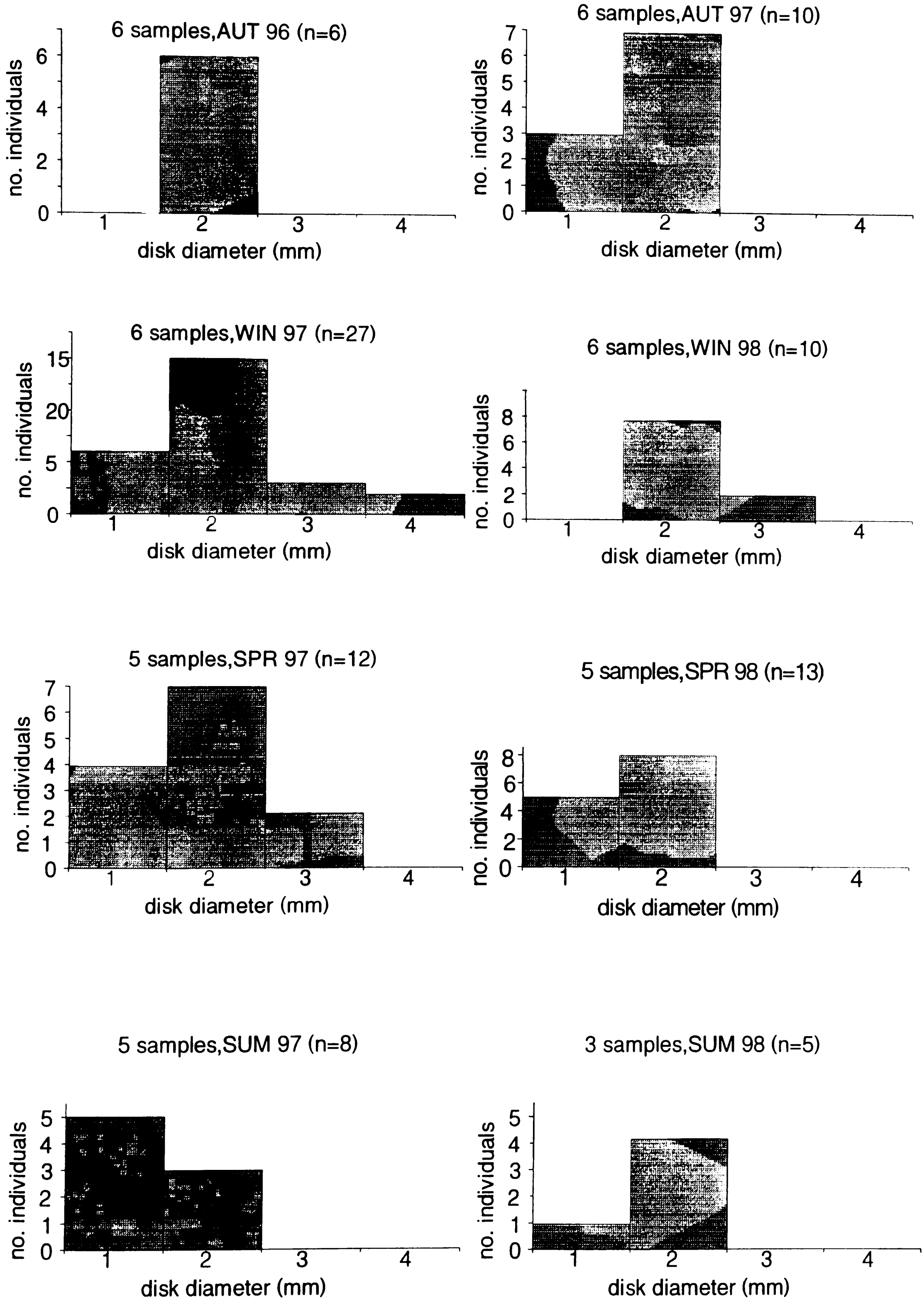
Although *A. squamata* was collected in nearly all seasonal samples at the impacted site, it was not abundant (Fig. 3.361). In autumn 1996, it reached its highest value in both abundance and biomass, in contrast it was not collected in spring 1997. The remaining values both in biomass and abundance were lower than at the control site. Due to this, no seasonal pattern could be detected.

Fig.3.361. A) Mean number and B) Biomass (mg wet weight) of *Amphipholis squamata* per $0.1m^2$ at UAI. Error bars = SD. Number of replicates above error bars.



The seasonal variation in size frequency of *Amphipholis squamata* at the impacted site is shown in Fig.3.362. Small individuals (disc diameter ≤ 1.0mm) were collected particularly in autumn 1996, and also in winter and summer 1997. The sizes at the impacted site were smaller than at the control site. No seasonal pattern in size-frequency distribution could be detected.

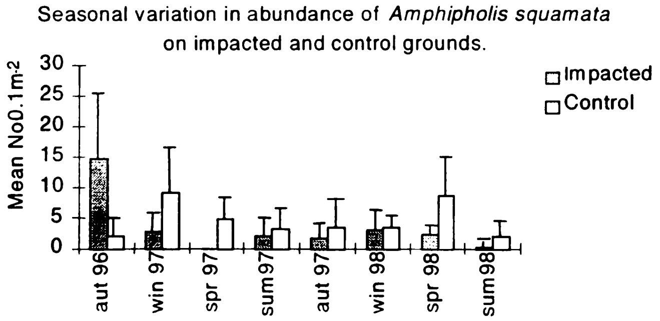
Fig. 3.362. Size-frequency histograms for *Amphipholis squamata* collected seasonally in 0.05m^2 quadrats at UAI from 1996-1998. SUM=summer, AUT=autumn, WIN=winter, SPR=spring.

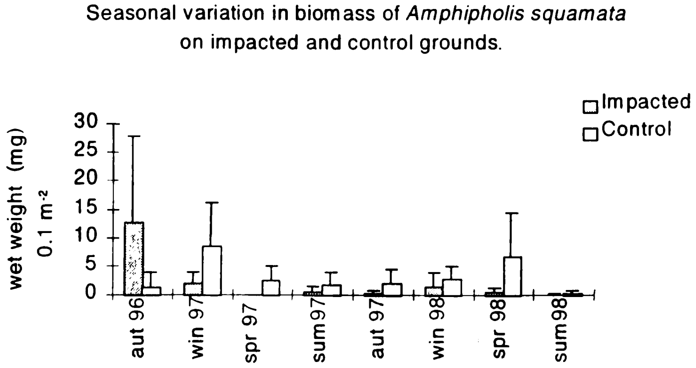


Except for the values (both for abundance and biomass) in autumn 1996 at the impacted site, *A. squamata* was more abundant and constant at the control site. The relative constancy of this species and the presence of larger animals on the control site (cf. the impacted site) could be related to the greater stability of the former, contrasting with the disturbance caused by trawling in the latter. There is a possible seasonal pattern at the control site with high values in winter and spring and low ones in summer and autumn. *Amphipholis squamata* may thus be a good species to characterize the mechanical disturbance caused by trawling.

Figure 3.363 compares the abundance and biomass of *Amphipholis squamata* on the control and impacted sites. No consistent seasonal and/or inter-annual patterns were discernible at either site. *A. squamata* was more abundant (in numbers and biomass) at the control site, except in autumn 1996. At the impacted site it had a more irregular distribution. It was collected in the greatest numbers in autumn 1996 (18 ind./0.05m^2) but none was sampled in spring 1997.

Fig. 3.363.


Seasonal variation in abundance of *Amphipholis squamata* on impacted and control grounds.

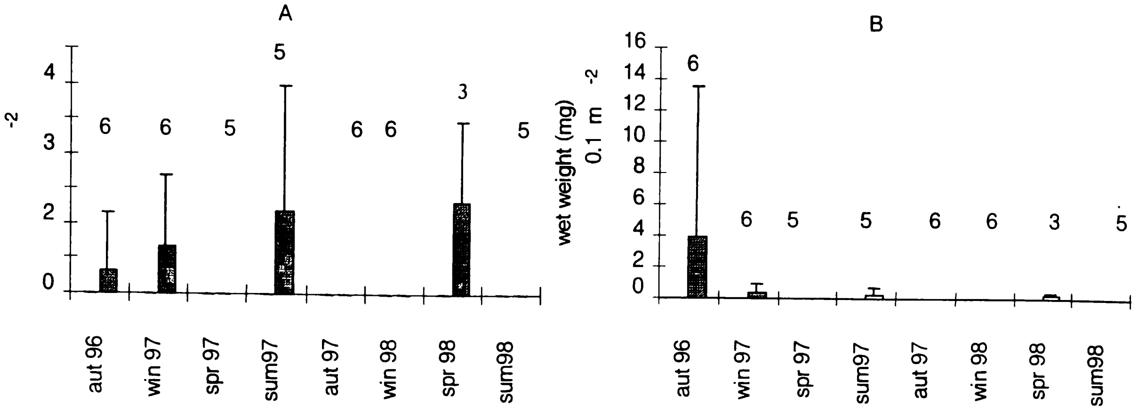

Seasonal variation in biomass of *Amphipholis squamata* on impacted and control grounds.

Ophiothrix fragilis (Abildgaard, 1789)

Ophiothrix fragilis was not abundant on Alicante maerl grounds. It was only collected at the control site. This species is a suspension feeder with a broad ecological distribution (Picard, 1965), mainly on hard bottoms. It lives amongst the maerl thalli and sessile animals. It is the characterizing species of the *Ophiothrix fragilis* facies of coastal detritic bottoms with calcareous Squamariaceae (Pérès & Picard, 1964).

Collected exclusively at the control site (Fig. 3.364), this ophiuroid was only found in low numbers in four seasonal samples (autumn 1996, winter 1997, spring and summer 1998). The higher values for abundance were obtained in summer 1997 and spring 1998 (and autumn 1996 for biomass). Due to the low numbers and sampled occurrence, no seasonal pattern could be detected.

Fig. 3.364. A) Mean number and B) Biomass (mg wet weight) of *Ophiothrix fragilis* per 0.1 m^2 at UAC. Error bars = SD. Number of replicates above error bars.



The seasonal variation in size frequency of *O. fragilis* at the control ground is shown in Fig. 3.365. Small individuals (disc diameter ≤ 1.0mm) were obtained in spring and summer. However, the number of individuals collected is too low to detect any patterns in the size-frequency distribution of the species.

Ophiothrix fragilis was only found on the control ground. Its irregular presence in the samples could be due to a patchy distribution. Frequently, this species is associated with sessile animals (sponges, ascidians, bryozoans, cnidarians), and amongst the maerl thalli, where it can find some refuge. That might explain its absence from the impacted site, i.e. due to the loss of the maerl spatial complexity and mechanical attrition of sessile animals caused by bottom trawling. Therefore, we could consider *Ophiothrix fragilis* as a good indicator species of impact.

Fig. 3.365. Size-frequency histograms for *Ophiothrix fragilis* collected seasonally in $0.1m^2$ quadrats at UAC from 1996-1998. SUM=summer, AUT=autumn, WIN=winter, SPR=spring.

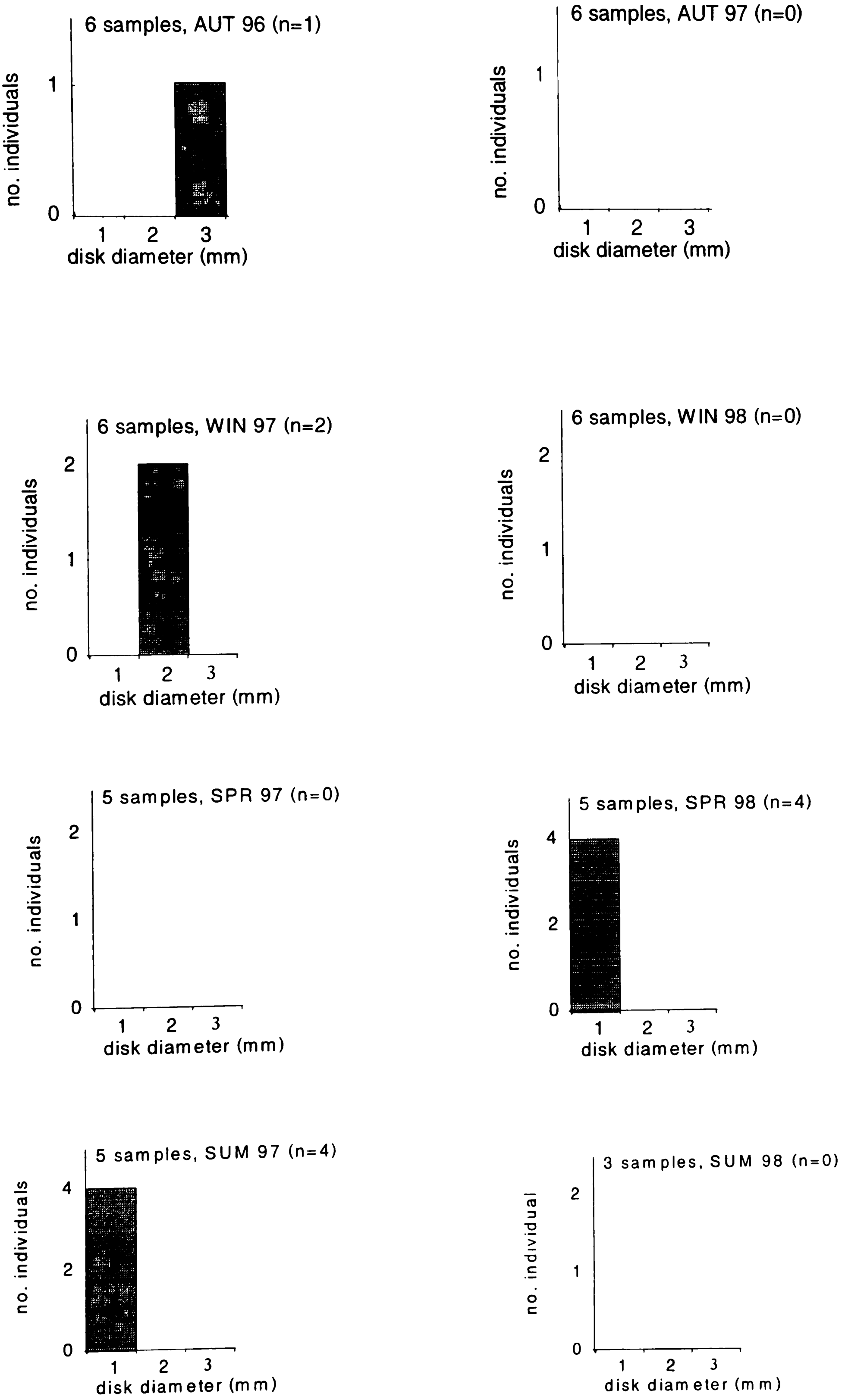
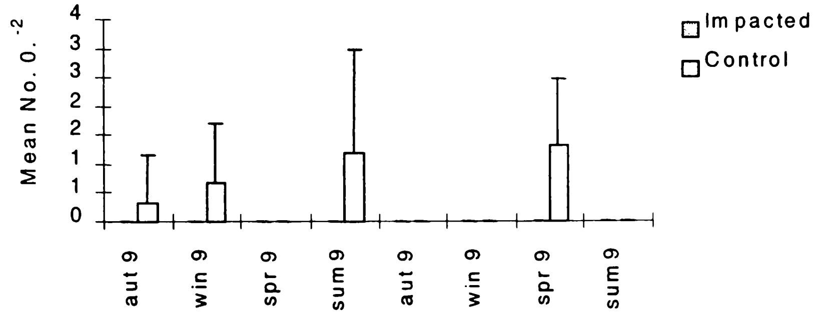


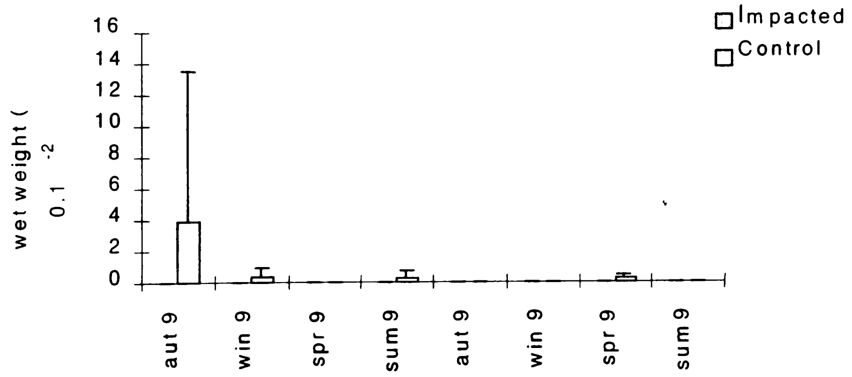
Figure 3.366 compares the abundance and biomass of *Ophiothrix fragilis* on the control and impacted sites. This species was only apparent on the control site.

Fig. 3.366.

Seasonal variation in abundance of *Ophiothrix fragilis* on the impacted and control grounds.



Seasonal variation in biomass of *Ophiothrix fragilis* on the Impacted and Control grounds.

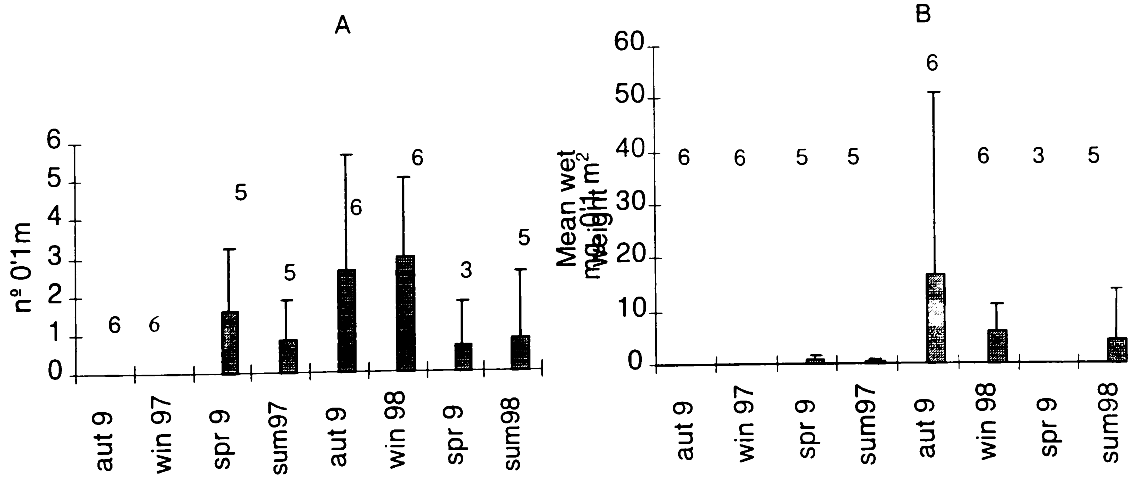


Echinocyamus pusillus (O.F. Müller, 1776)

Echinocyamus pusillus was the most abundant echinoid on Alicante maerl bottoms, in both control and impacted sites. However, its biomass was less than that of the larger species *Genocidaris maculata* at the impacted site. It is a deposit feeder and a characteristic species of gravel bottoms (Picard, 1965).

Common at the control site, it was more abundant in the second year (Fig. 3.367). It was not collected in autumn 1996 and winter 1997. Its abundance presented two peaks in winter 1998 and autumn 1997, which seasonal sample also represented the highest value for biomass. No seasonal patterns could be detected.

Fig. 3.367. A) Mean number and B) Biomass (mg wet weight) of *Echinocyamus pusillus* per $0.1m^2$ at UAC. Error bars = SD. Numbers of replicates above error bars.



The seasonal variation in size frequency of *Echinocyamus pusillus* at the control site is shown in Fig. 3.368. The smallest sized animals (test length = 1.0mm) were only obtained in autumn 1997 (which may indicate the recruitment period). Due the differences between seasons and years, no consistent seasonal patterns in size-frequency distribution were discerned.

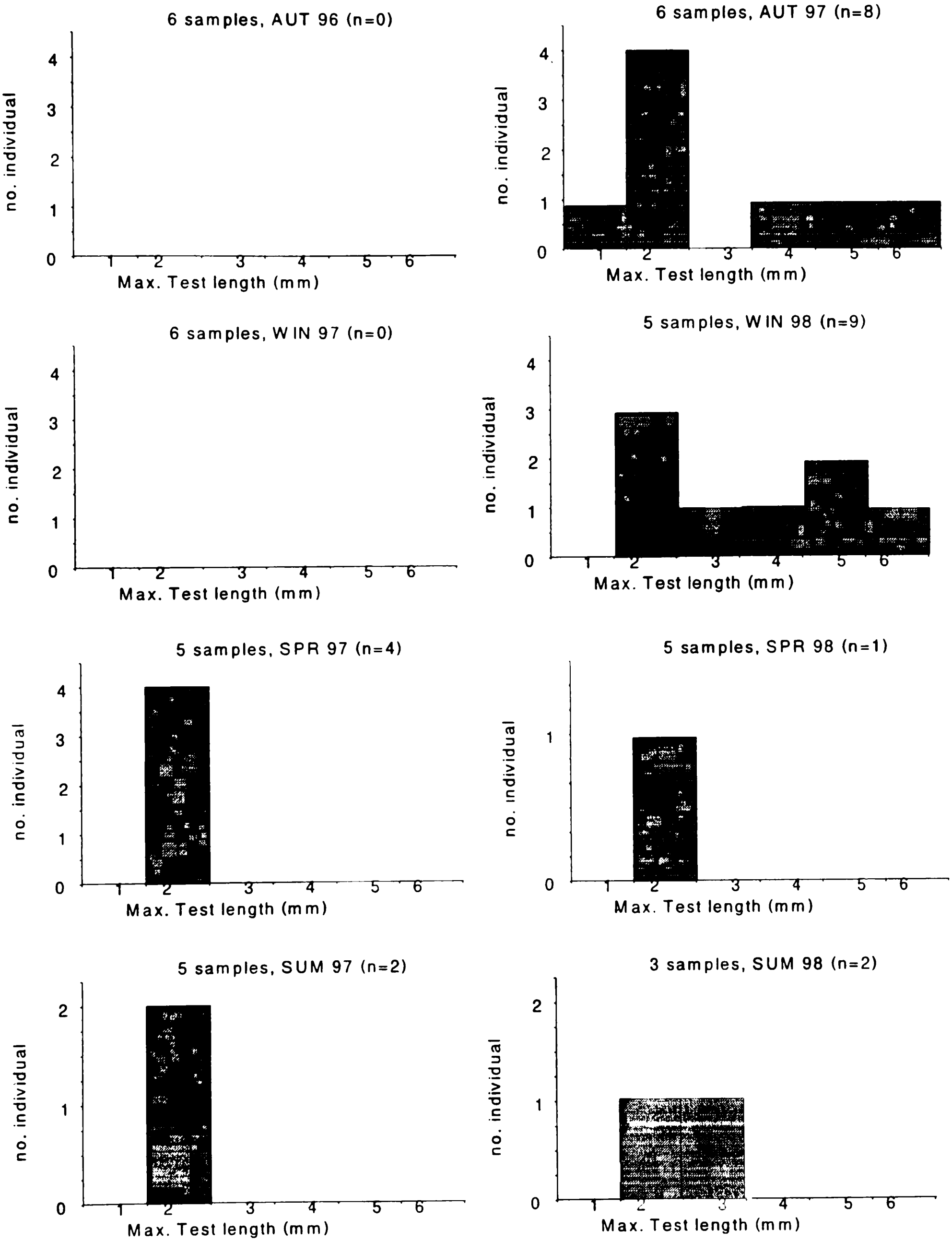


Fig. 3.368. Size-frequency histograms for *Echinocyamus pusillus* collected seasonally in $0.1m^2$ at UAC from 1996-1998. SUM= summer, AUT= autumn, WIN= winter, SPR= spring.

E. pusillus was more prominent, both in terms of abundance and biomass (Fig. 3.369), at the impacted site, excepting in winter 1998 (density) and autumn 1997 (biomass). It was sampled in all seasonal samples, and the highest value for the abundance was obtained in autumn 1996. No clear seasonal pattern was observed. However, there was a peak in biomass in both summers (1997 and 1998)

Fig. 3.369.A) Mean number and B) Biomass (mg wet weight) of *Echinocyamus pusillus* per $0.1m^2$ at UAI. Error bars = SD. Number of replicates above error bars.

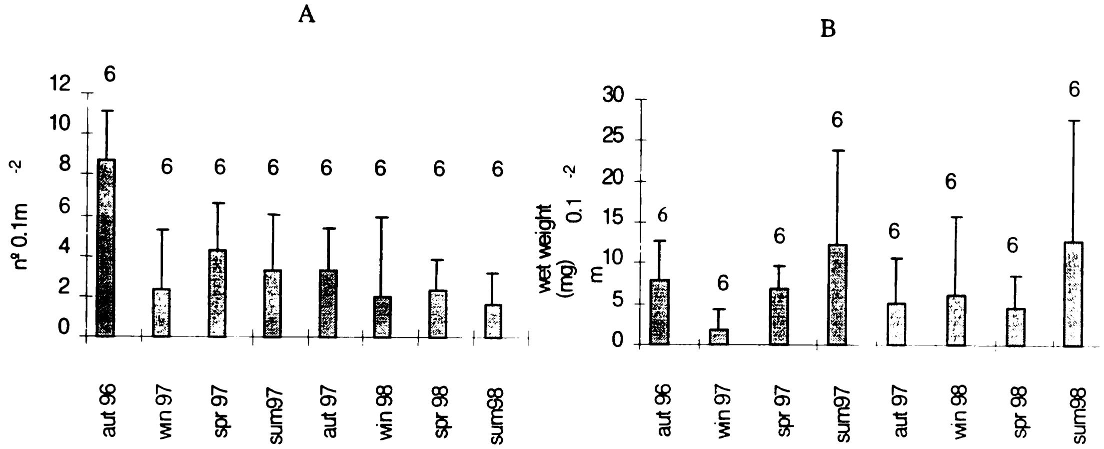
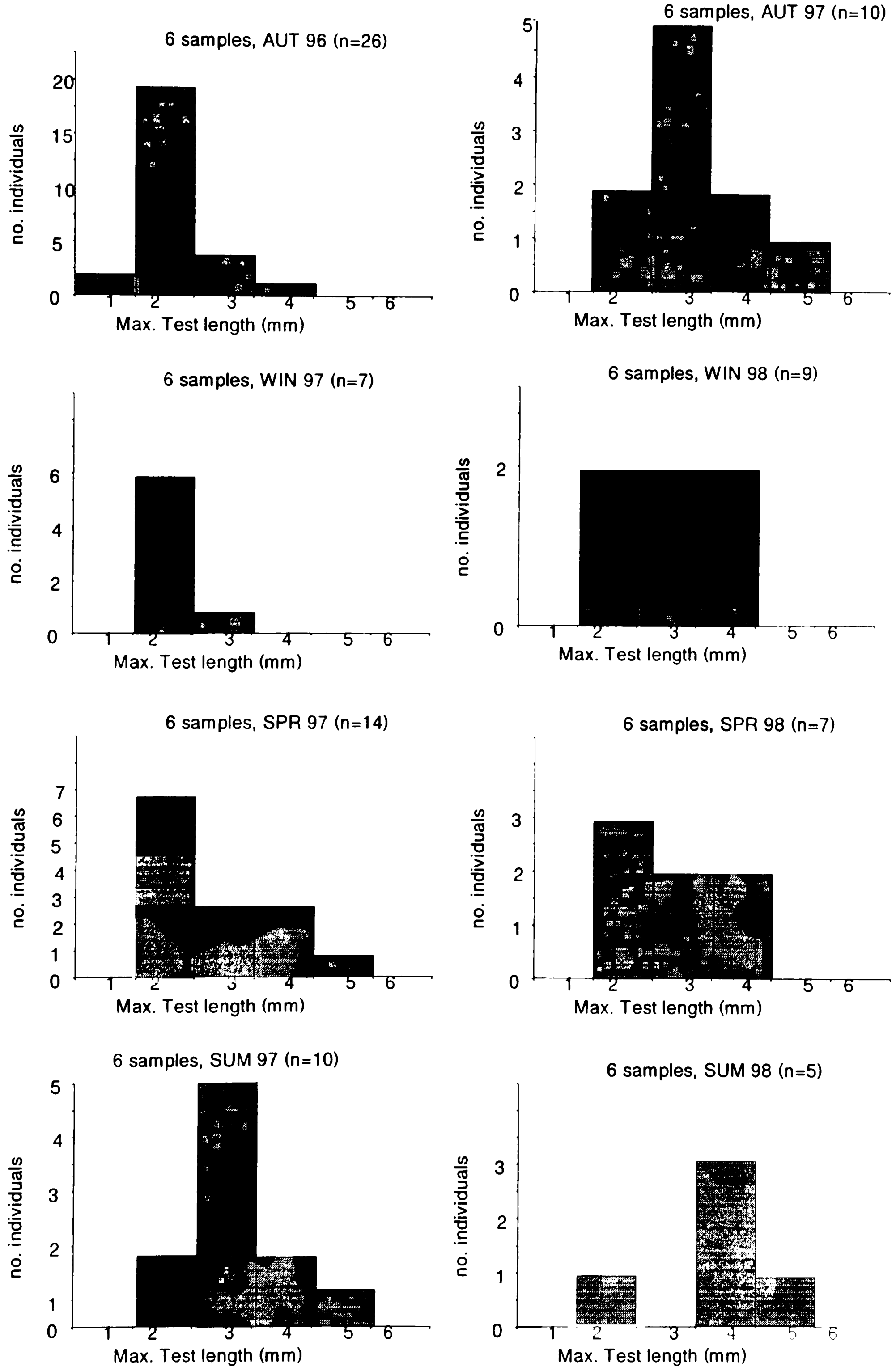


Figure 3.370 shows the size-frequency distribution of *E. pusillus* at UAI. Fig. 3.371 compares the abundance and biomass of *E. pusillus* on the control and impacted sites. As is shown in this figure, this species was more abundant and had a higher biomass at the impacted site (excepting in winter 1998 for abundance and autumn 1997 for biomass) where it was present in all seasonal samples. Although, no seasonal patterns could be detected, there are two biomass peaks in summer (1997 and 1998) at the impacted site.

Fig. 3.370. Size-frequency histograms for *Echinocyamus pusillus* collected seasonally in 0.1m^2 at UAI from 1996-1998. SUM= summer, AUT= autumn, WIN= winter, SPR= spring.



6 samples, AUT 96 (n=26)

6 samples, AUT 97 (n=10)

6 samples, WIN 97 (n=7)

6 samples, WIN 98 (n=9)

6 samples, SPR 97 (n=14)

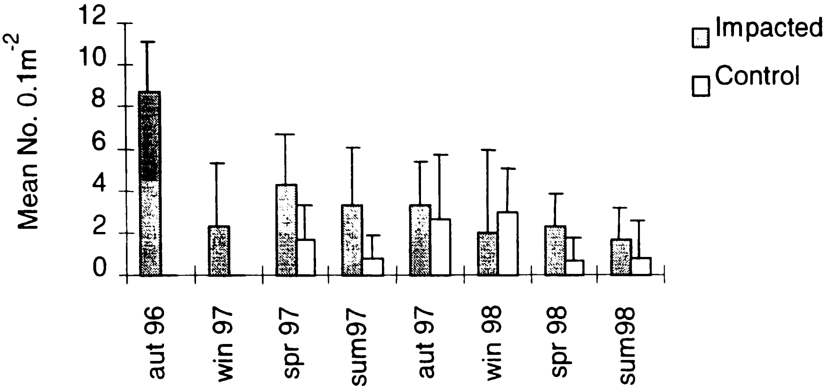
6 samples, SPR 98 (n=7)

6 samples, SUM 97 (n=10)

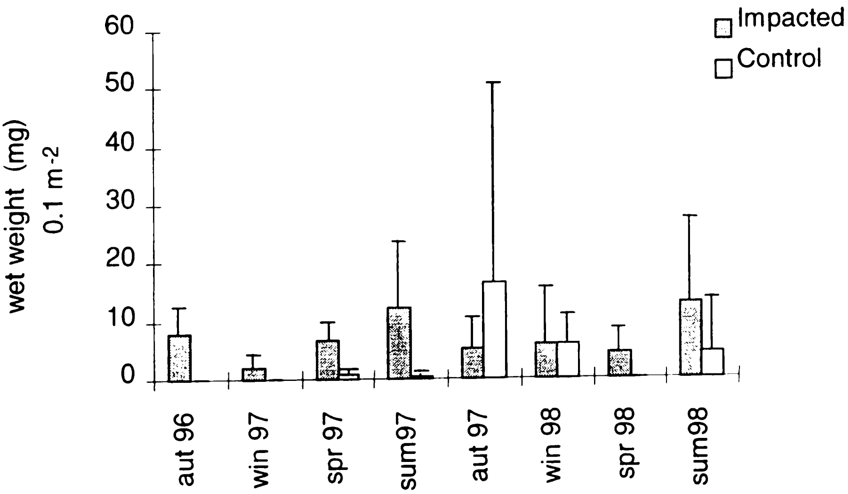
6 samples, SUM 98 (n=5)

Fig. 3.371.

Seasonal variation in abundance of *Echinocyamus pusillus* on impacted and control grounds.



Seasonal variation in biomass of *Echinocyamus pusillus* on Impacted and Control grounds.

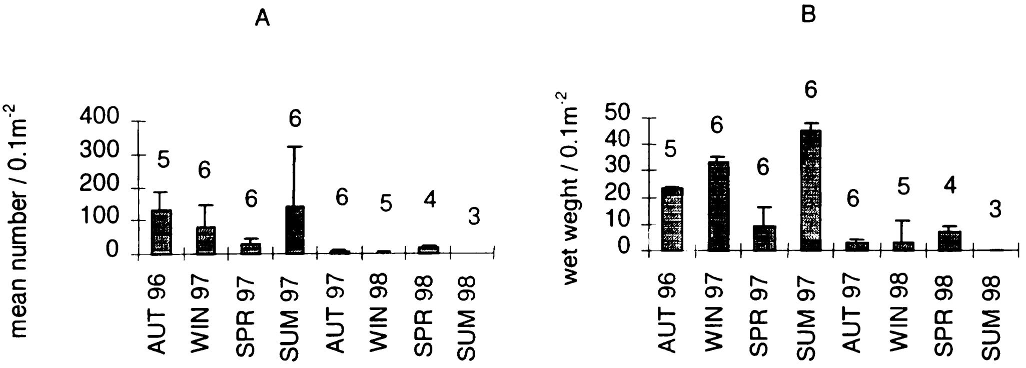


Didemnum coriaceum (Von Drasche, 1883)

Colonial species of the genus *Didemnum* have appeared in almost all the samples. The population density of colonies in control samples was rather higher than in those from the impacted ground. This may be explicable in terms of differences in sedimentology and granulometry between sites.

The majority (nearly 100 %) of the colonies were tiny and immature, so there have been many problems in trying to determine them to species. The mature colonies were all *D. coriaceum*, so a comparison was done of zooid morphology and spiculae with the smaller specimens. Fifty percent congruity resulted. The remainder of the colonies could be *D. maculosum*, or even *D. coriaceum*, but we cannot yet be certain.

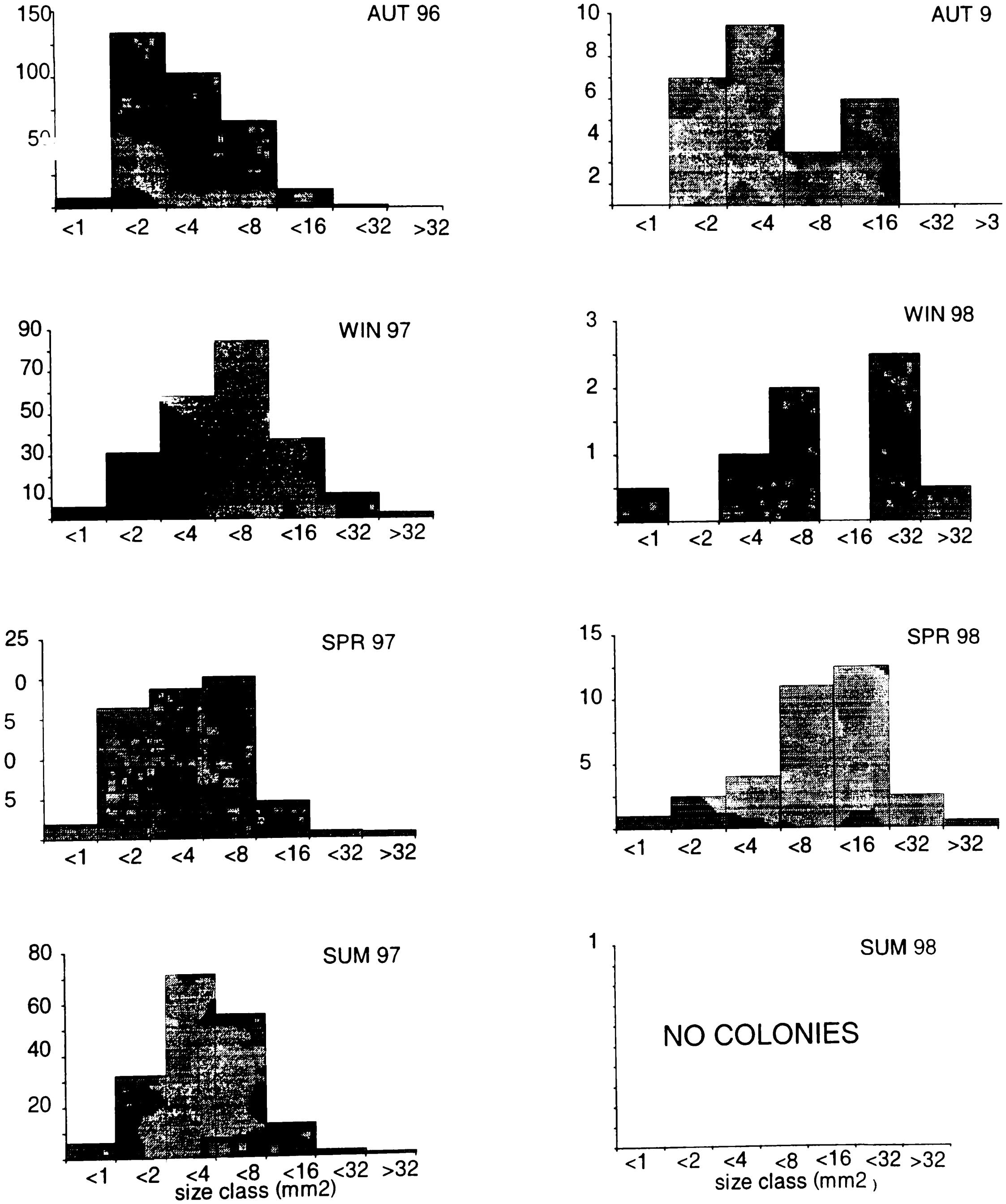
Fig. 3.372. A) Mean number of colonies and B) Biomass (mg wet weight) of *Didemnum coriaceum* per 0.1 m^2 (data from $0.05m^2$ quadrats) at UAC. Errors bars = SD. Number of replicates above error bars.



The abundance of colonies in the first year of sampling was greater than in the second year (Fig. 3.372). The differences among seasons are not exclusively due to any biological cycle, however, since the influence of spatial heterogeneity has a big effect on the data.

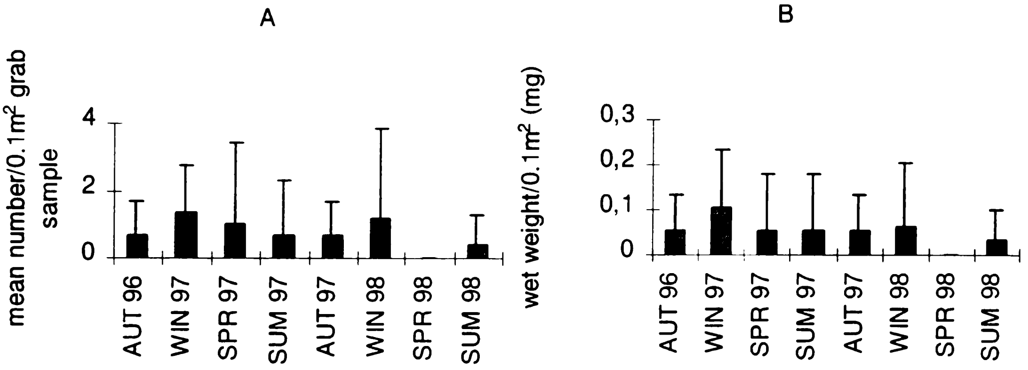
Biomass data were less variable due to the relatively homogeneous size of the colonies, a large proportion of which was very small, at about 20 mm^2. This small size indicates that the settlement is great but the recruitment is very low due to the mortality of young colonies.

Fig. 3.373. Size frequency histograms for *Didemnum coriaceum* collected seasonally at UAC in 0.05 m^2 quadrats. Data are standardized per 0.1 m^2. Size classes measured by colony area in mm^2.



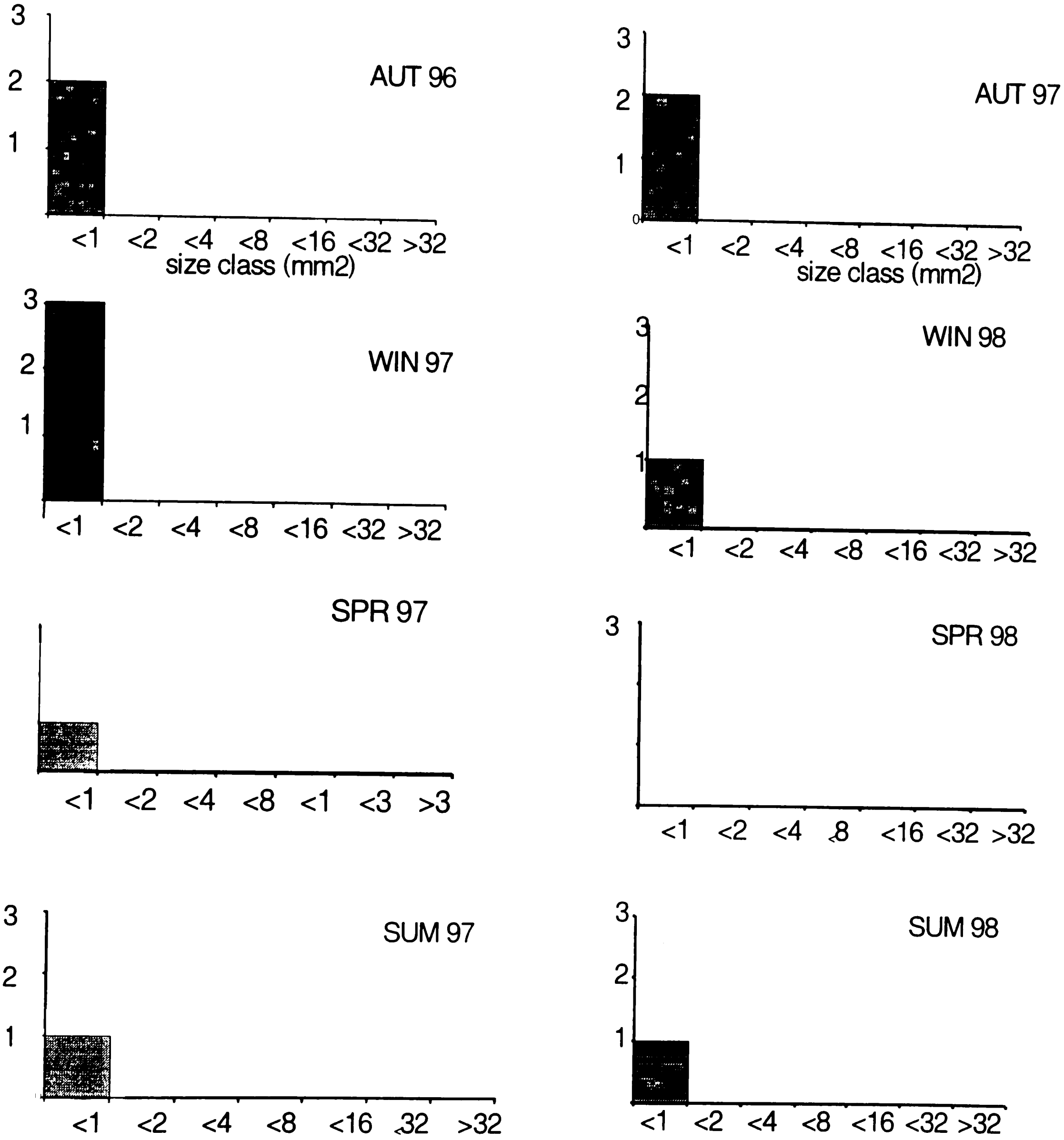
Small colonies were commoner in autumn (1996 and 1997) and spring 1997 (Fig. 3.373). The difference in size between the smallest colonies and largest size class (32 mm^2) is very small and not thought to represent yearly cohorts. In summer 1998 no colonies were recorded, perhaps due to the different nature of the substrata in that sample.

Fig. 3.374. A) Mean number and B) Biomass (mg wet weight) of *Didemnum coriaceum* at UAI. Data were taken by 0.05 m^2 quadrats, but standardized per 0.1 m^2.



As can be seen in the figure above (Fig. 3.374), the density of colonies at UAI was very low. Perhaps, the lack of stable rhodoliths does not allow the establishment of mature colonies, so larvae supply may be very low.

Fig. 3.375. Size frequency histograms for *Didemnum coriaceum* collected seasonally in 0.05 m^2 quadrats at UAI . Data were standardized to 0.1 m^2.



Very few colonies were present at UAI; all of them very small (Fig. 3.375). As at the control site, the lack of hard substrata and bottom instability (e.g. rhodoliths, stones) was responsible for their poor development and rapid elimination of those colonies that were able to settle.

There was no significant cycle in the temporal change of the size classes. Even the biggest animals (>32 mm^2) are still very small, so these didemnids are rather poorly developed on this maërl bottom. The lack of a stable substratum may be the feature responsible of the small size and the low density of these colonies.

The lack of large colonies (e.g. >2mm^2) in either sampling sites shows that the environment is not generally suitable for the development of Ascidiacea. A negative interaction between ascidians and other taxa is unlikely, so abiotic environmental factors such as instability of the substratum and the turbidity of the water due to small particles in suspension could account for the unsuitability of these bottoms.

The Figures below (Figs 3.376 & 3.377) show the difference of abundance and biomass between the control and impacted grounds. The abundance of this entity at the control site was significantly greater than at the impacted site.

Fig. 3.376. Seasonal variation in mean abundance (± SD) of *Didemnum coriaceum* on control and impacted grounds

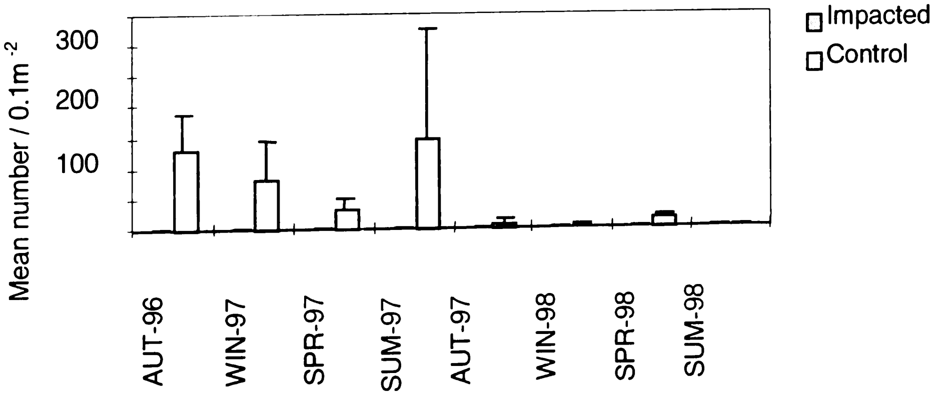
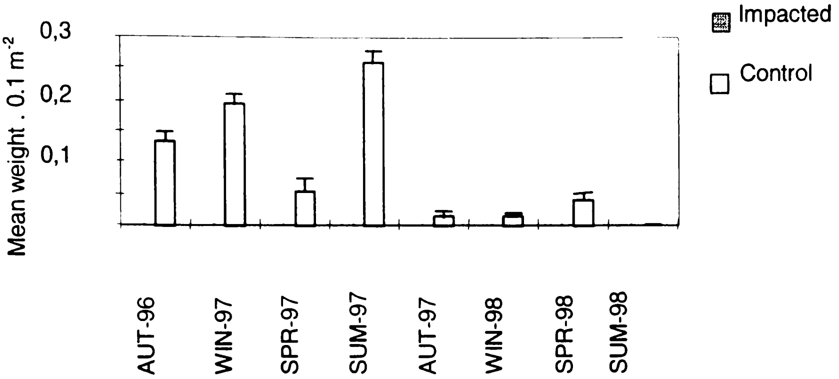


Fig. 3.377. Seasonal variation in mean biomass (± SD) of *Didemnum coriaceum* on control and impacted grounds. Data in mg per colony.



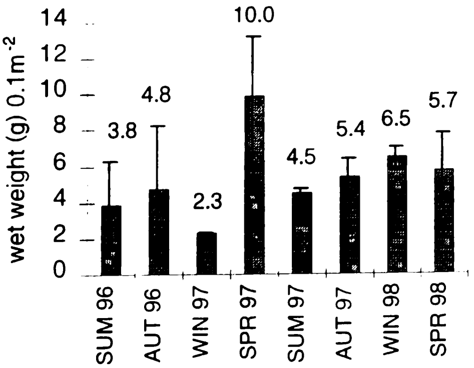
5) Malta

Flabellia petiolata (Turra) Nizamuddin

Flabellia petiolata was very common on Maltese maerl grounds where this alga is a very important binder of maerl sediment. Its fine filamentous rhizoids arise from horizontal axes ('stolons') and penetrate and ramify amongst sediment grains binding them together into a hard compact crust over the underlying loose sediment. Where the sediment is gravely, this crust immobilizes the surface layer to such as extent that a pseudo-hard bottom forms on which macroscopic algae can attach.

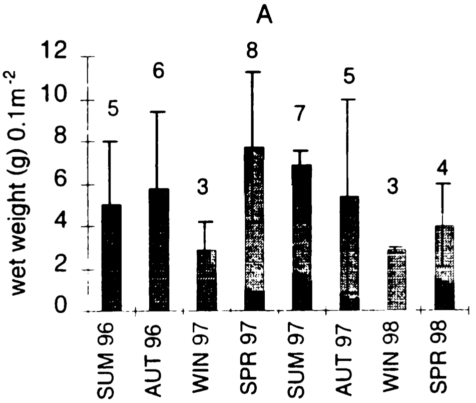
Flabellia petiolata was assessed quantitatively by taking wet weight. It was very common on the control ground and the highest value was obtained in spring 1997 (Fig. 3.378). No particular seasonal pattern can be observed, since the peak in spring 1997 is not repeated in spring 1998, and the low value in winter 1997 was not repeated in winter 1998.

Fig. 3.378. Biomass (g wet weight) of *F. petiolata* per $0.1m^2$ grab at UMC. Error bars = SD. Numbers above each column are mean values (n = 3 replicates).



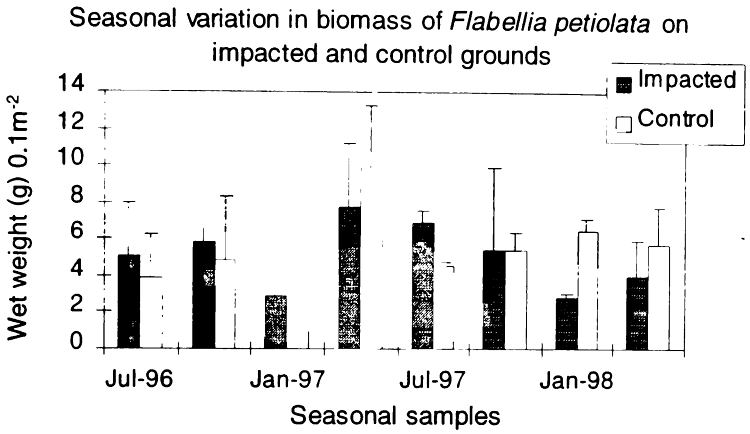
Flabellia petiolata was also very common at the impacted site. In this case a seasonal pattern can be observed (Fig. 3.379). The biomass of the alga decreases between autumn and winter to reach a minimum value in winter 1997 and 1998. Then it increases again in spring, to give the highest value (spring 1997) and decreases again in summer. The highest value obtained at the impacted site in spring 1997 corresponds to the highest value obtained in the control site.

Fig. 3.379. Biomass (g wet weight) of *F. petiolata* per 0.1m^2 grab at UMI. Error bars = SD. Numbers above each column are mean values (n = 3 replicates).



A comparison of the biomass of *Flabellia petiolata* at the impacted and control sites (Fig. 3.380) reveals no particular trend. In some seasonal samples, *Flabellia petiolata* was more abundant at the impacted site, while in others it was more abundant at the control site.

Fig.3.380.

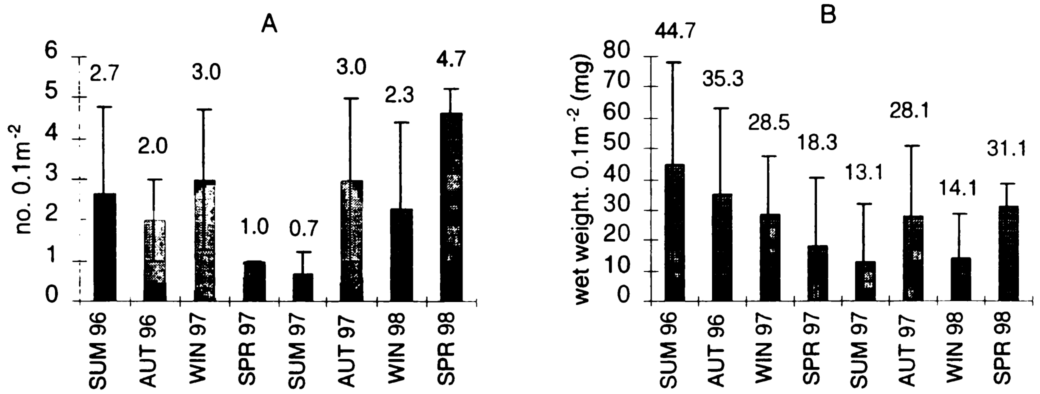


Eunice vittata (Delle Chiaje, 1828)

Eunice vittata was a relatively common species on Maltese maerl grounds and it was one of the few polychaetes which attained a large size cf. the other species encountered. The feeding habit of this species is not known with certainty but it is either a carnivore or an omnivore.

No particular seasonal pattern in either abundance or biomass can be discerned for *Eunice vittata* at the control site (Fig. 3.381). The highest value for abundance was obtained in spring 1998, but the abundance in spring 1997 was very low.

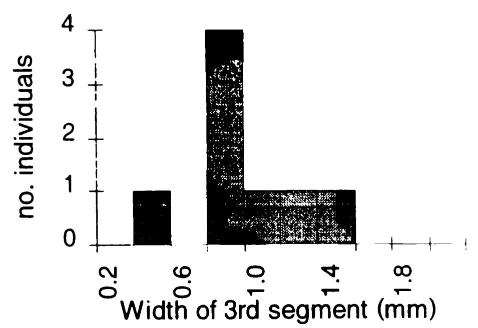
Fig. 3.381.A) Mean number and B) Biomass (mg wet weight) of *E. vittata* per 0.1m^2 grab at UMC. Error bars = SD.



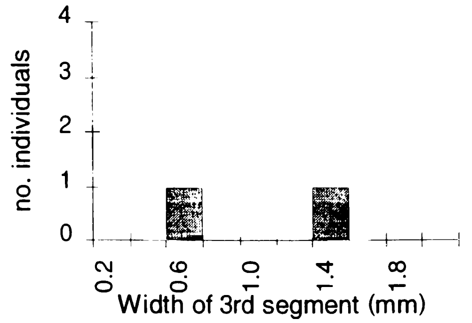
The seasonal variation in size frequency of *Eunice vittata* in the control ground is shown in Fig. 3.382. Although this species was not very rare, no patterns in the size-frequency distribution could be detected. Small specimens (width of 3rd segment behind head = 0.4-0.6mm) seem to occur through all seasons (summer 1996; autumn 1997; winter 1998 and spring 1998)

Fig. 3.382. Size-frequency histograms for *Eunice vittata* collected seasonally in $0.1m^2$ grabs at UMC from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring.

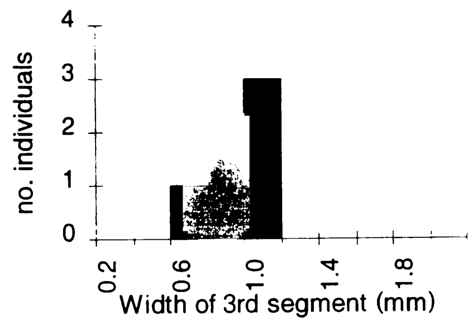
3 grabs, SUM 1996 (n=8)



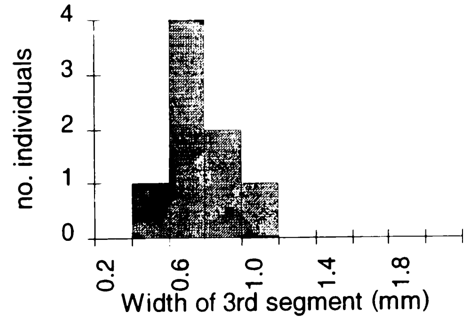
3 grabs, SUM 1997 (n=2)



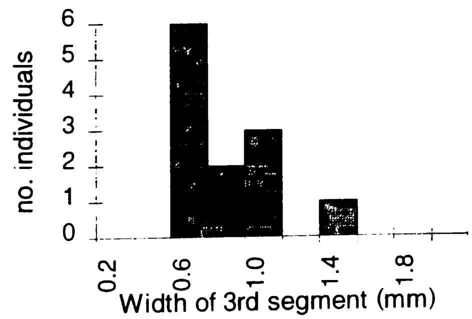
3 grabs, AUT 1996 (n=6)



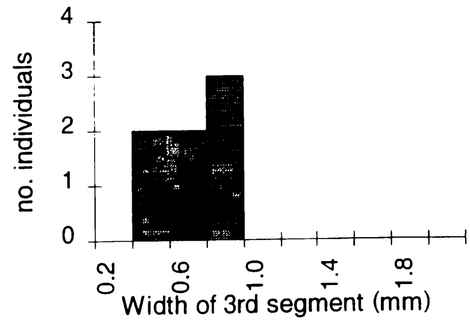
3 grabs, AUT 1997 (n=8)



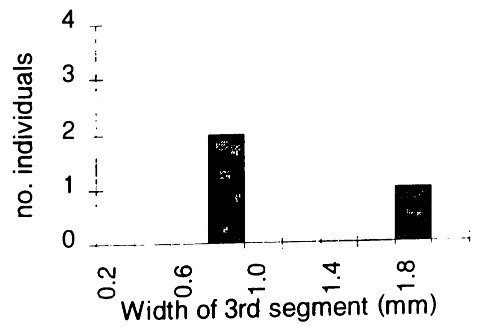
6 grabs, WIN 1997 (n=12)



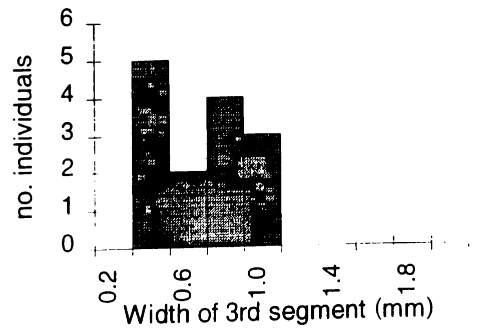
3 grabs, WIN 1998 (n=7)



3 grabs, SPR 1997 (n=3)

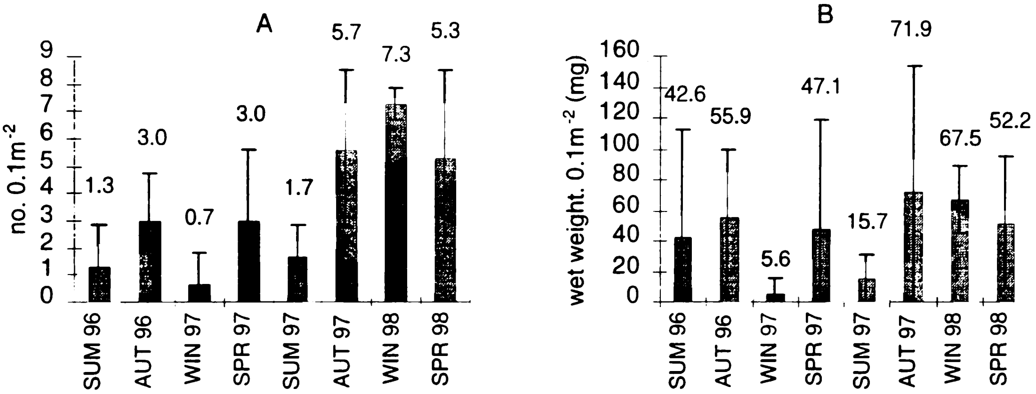


3 grabs, SPR 1998 (n=14)



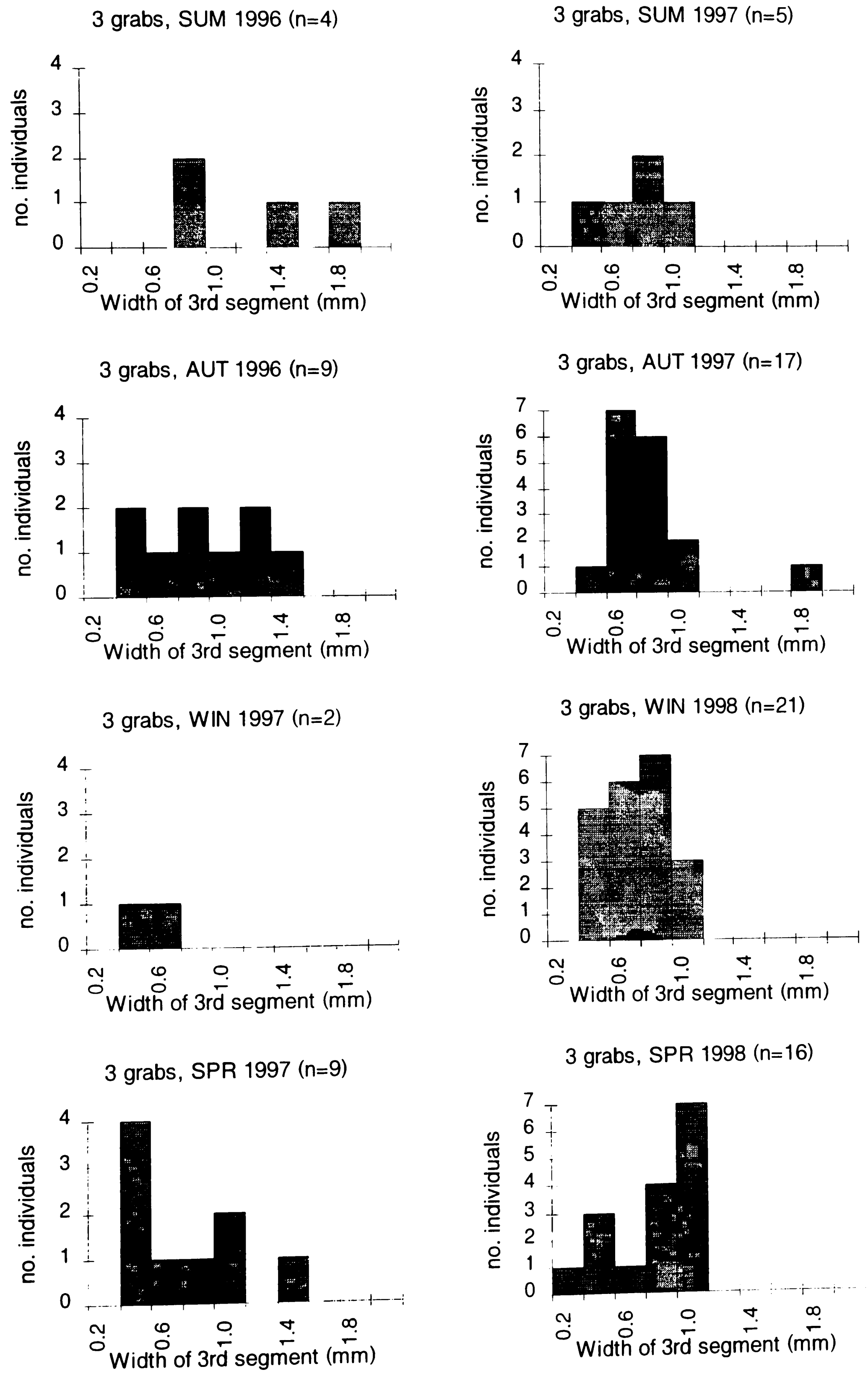
Eunice vittata was also very common at the impacted site but again, no particular seasonal pattern in either abundance or biomass could be detected (Fig. 3.383). The highest value for abundance was obtained in winter 1998 and the lowest value was obtained in winter 1997.

Fig. 3.383.A) Mean number and B) Biomass (mg wet weight) of *E. vittata* per 0.1m^2 grab at UMI. Error bars = SD.



The seasonal variation in size frequency of *Eunice vittata* is shown in Fig. 3.384. This species was more abundant in the second year of sampling, during which the number of larger specimens seems to increase from autumn 1997 to spring 1998. On the other hand small specimens (width of 3rd segment behind head = 0.2-0.4mm) were collected in spring 1998.

Fig. 3.384. Size-frequency histograms for *Eunice vittata* collected seasonally in 0.1m^2 grabs at UMI from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring.



3 grabs, SUM 1996 (n=4)

3 grabs, SUM 1997 (n=5)

3 grabs, AUT 1996 (n=9)

3 grabs, AUT 1997 (n=17)

3 grabs, WIN 1997 (n=2)

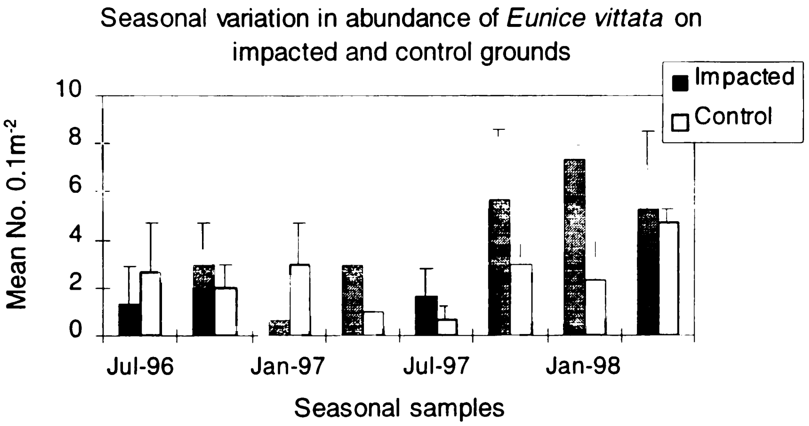
3 grabs, WIN 1998 (n=21)

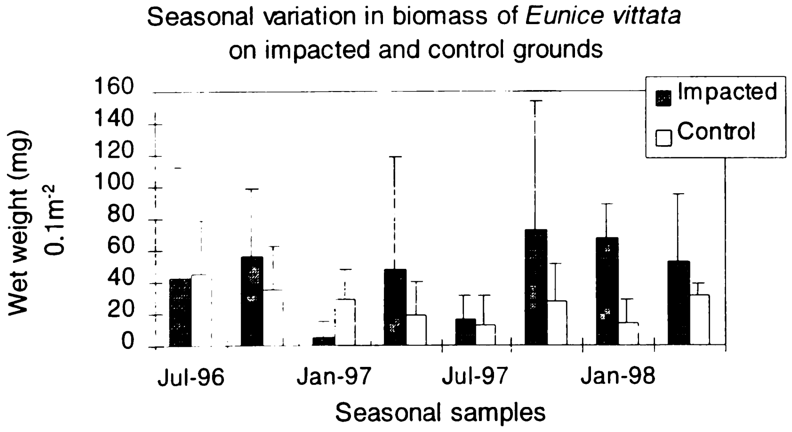
3 grabs, SPR 1997 (n=9)

3 grabs, SPR 1998 (n=16)

Figure 3.385 compares the abundance and biomass of *Eunice vittata* on the control and impacted sites. Overall, this species was more abundant at the impacted site, although in July 1996 and in January 1997 it was more abundant at the control site. Biomass followed the same trend.

Fig. 3.385.



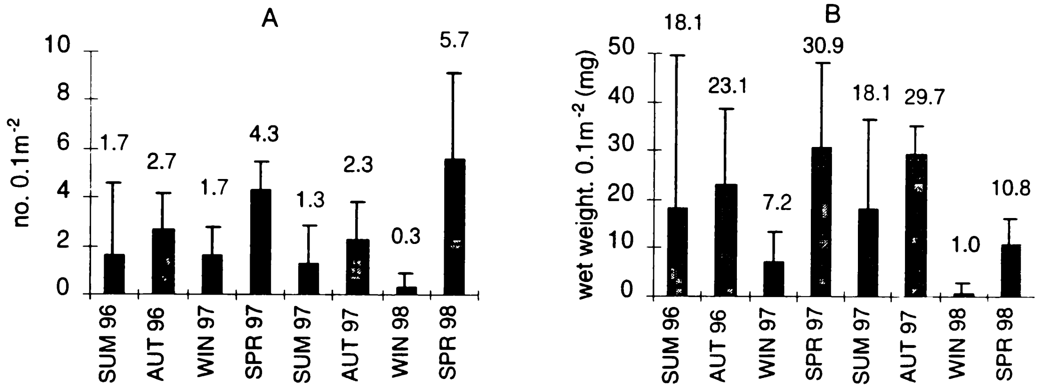


Lysidice ninetta Audouin & Milne Edwards, 1834

Lysidice ninetta was very common on Maltese maerl grounds and occurred at both the impacted and control sites. The feeding habits of this polychaete are not known with certainty but it is either a carnivore or an omnivore.

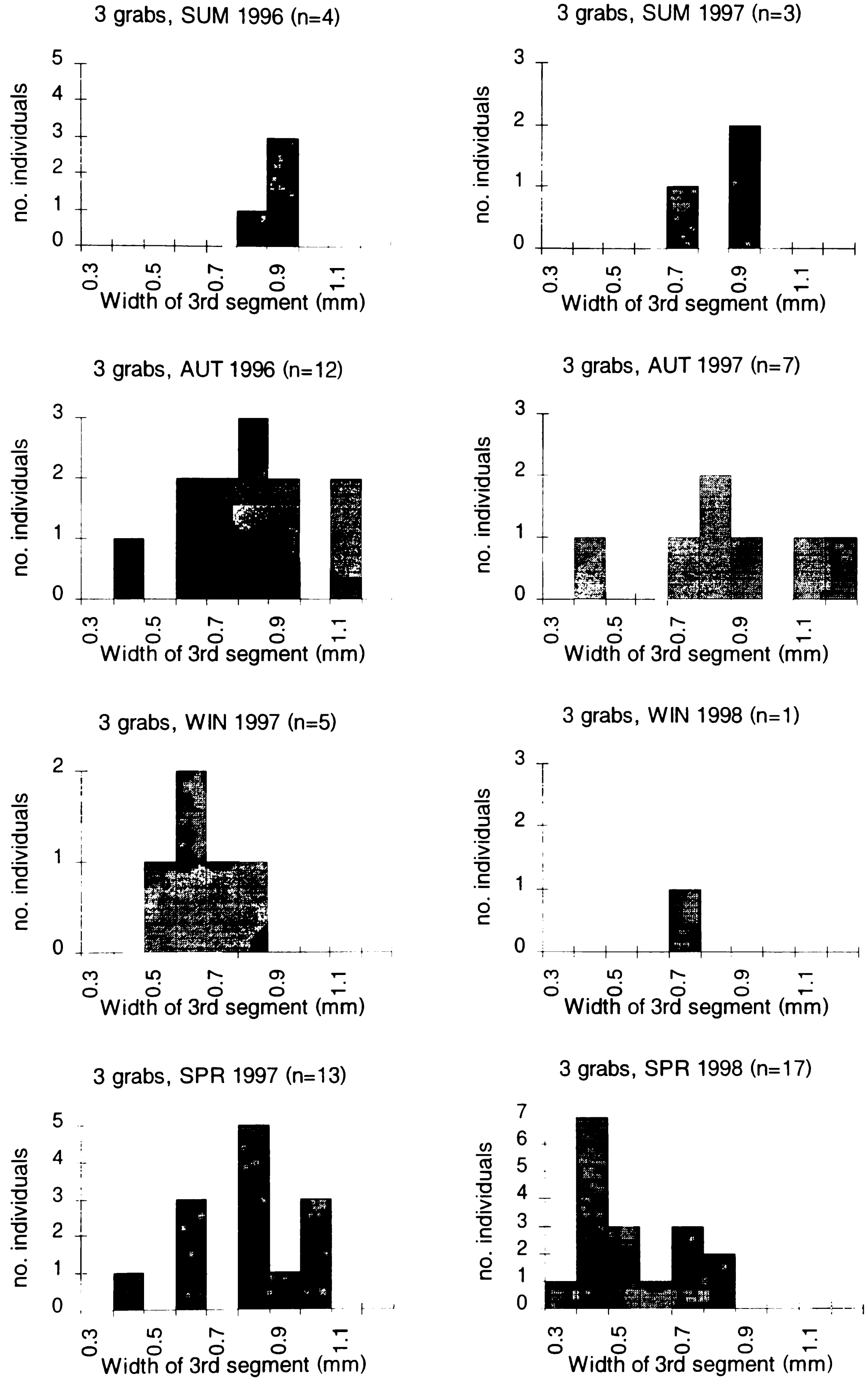
A seasonal pattern in the abundance and biomass of *Lysidice ninetta* at the control site can be detected (Fig. 3.386). Abundance increased from summer to autumn, decreased from autumn to reach a minimum in winter, and then increased again to reach a maximum in spring. Biomass followed the same pattern.

Fig. 3.386.A) Mean number and B) Biomass (mg wet weight) of *L. ninetta* per 0.1m^2 grab at UMC. Error bars = SD.



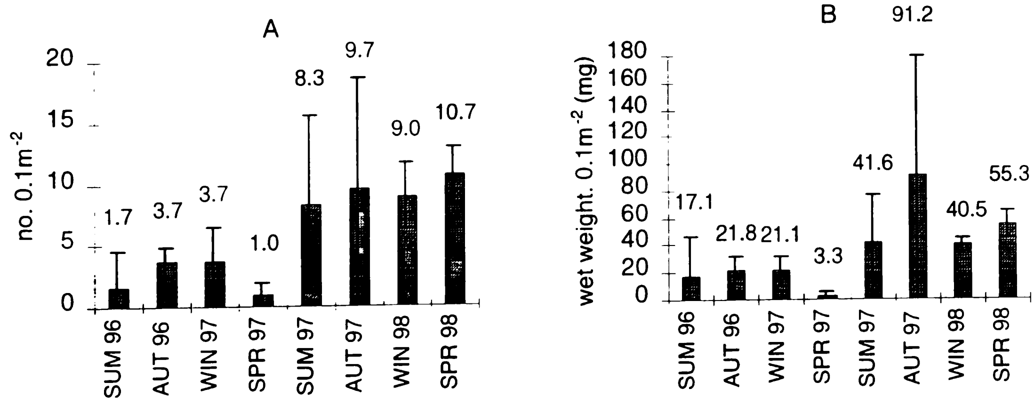
The seasonal variation in size frequency of *Lysidice ninetta* in the control ground is shown in Fig. 3.387. Small specimens (width of 3rd segment behind head = 0.3 0.5mm) were obtained in autumn and spring (autumn 1996, 1997; spring 1997 and 1998). Recruitment for this species thus seems to occur in spring and to a lesser extent in autumn.

Fig. 3.387. Size-frequency histograms for *Lysidice ninetta* collected seasonally in $0.1m^2$ grabs at UMC from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring.



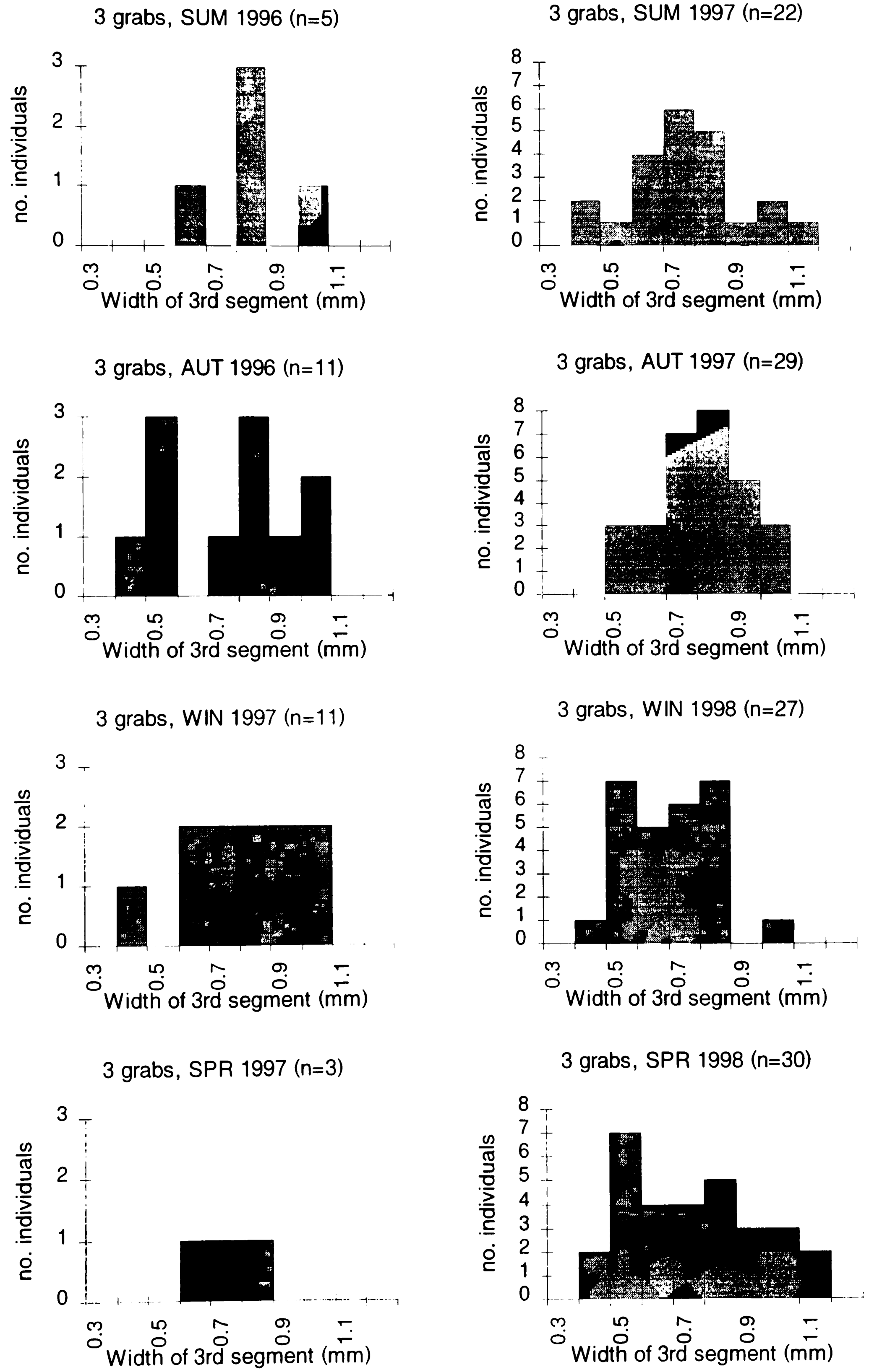
Lysidice ninetta was also very common on the impacted site, however the trends in abundance and biomass shown by this species at the control site, could not be detected at the impacted site. As opposed to the control site, the abundance of this species during winter (1998) at the impacted site was quite high and the minimum abundance was obtained in spring 1997. On the other hand, the maximum value for the abundance was obtained in spring 1998 (as in the control site). The pattern observed for *Lysidice ninetta* at the control site, could be observed to a lesser extent at the impacted site during the second year of sampling: during the second year the abundance increased from summer to autumn, decreased from autumn to winter and then increased again from winter to spring (Fig. 3.388). However this trend is not very pronounced and there were no marked differences in abundance between the seasons.

Fig. 3.388. A) Mean number and B) Biomass (mg wet weight) of *L. ninetta* per $0.1m^2$ grab at UMI. Error bars = SD.



The seasonal variation in size frequency of *Lysidice ninetta* is shown in Fig. 3.389. No particular seasonal pattern in the size-frequency distribution could be observed, except that the number of smaller specimens seems to increase from summer to winter.

Fig. 3.389. Size-frequency histograms for *Lysidice ninetta* collected seasonally in 0.1m^2 grabs at UMI from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring.



3 grabs, SUM 1996 (n=5)

3 grabs, SUM 1997 (n=22)

3 grabs, AUT 1996 (n=11)

3 grabs, AUT 1997 (n=29)

3 grabs, WIN 1997 (n=11)

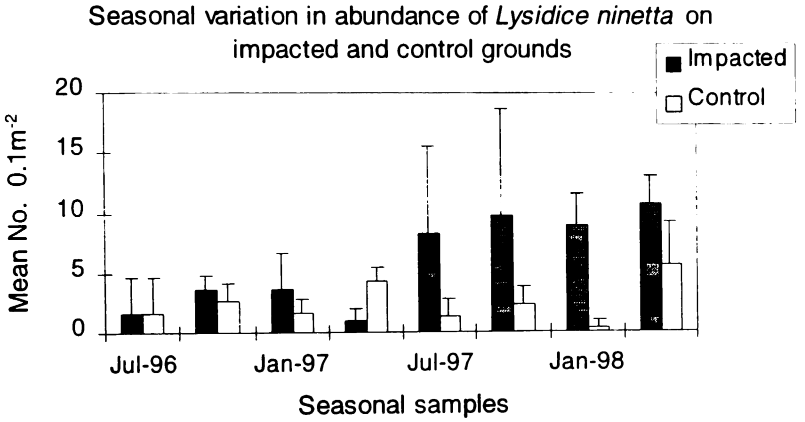
3 grabs, WIN 1998 (n=27)

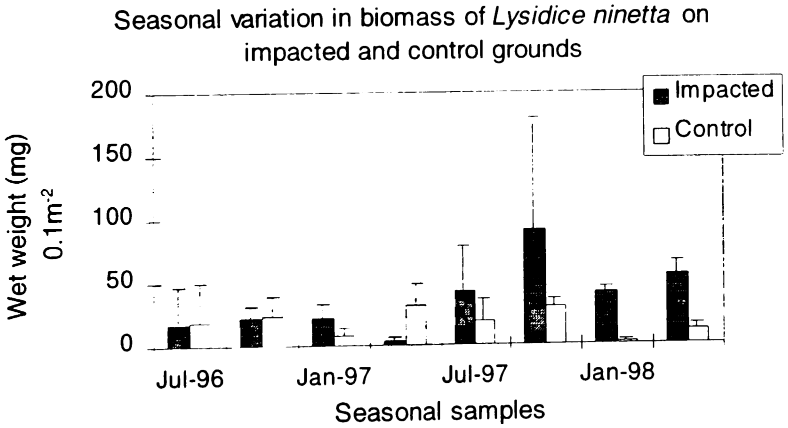
3 grabs, SPR 1997 (n=3)

3 grabs, SPR 1998 (n=30)

Figure 3.390 compares the abundance and biomass of *Lysidice ninetta* on the impacted and control sites. It is very clear that this species is much more abundant and has a greater biomass at the impacted site than at the control site.

Fig. 3.390.

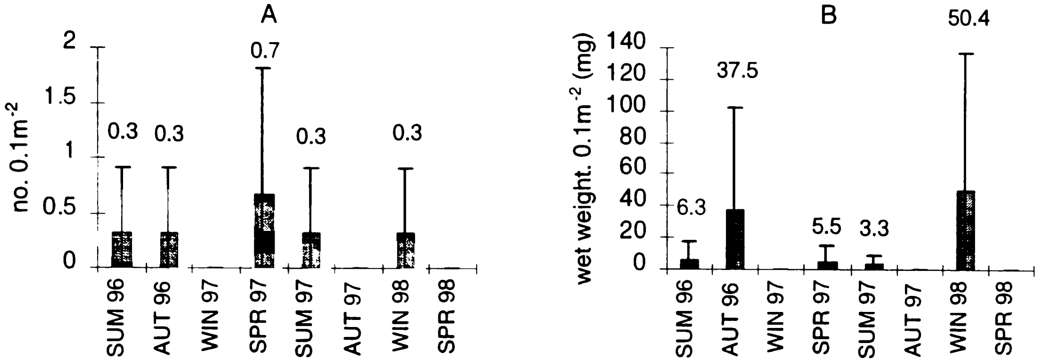




***Jujubinus exasperatus* (Pennant, 1777)**

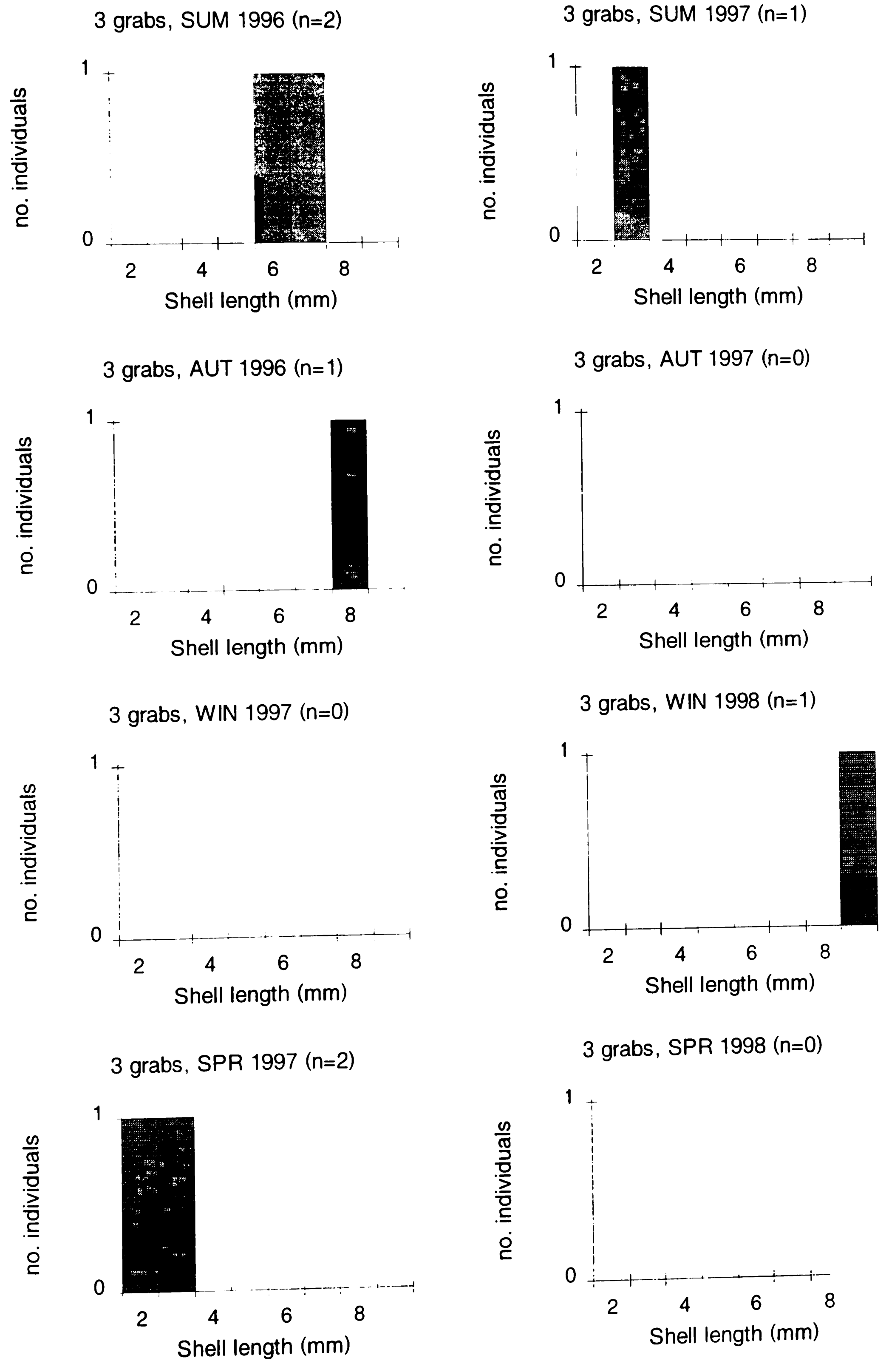
Jujubinus exasperatus was found at low abundances in both control and impacted. This gastropod is a herbivore and micrograzer on surface films of microscopic algae. Only a few individuals were collected from the control ground, and no particular seasonal pattern could be observed. The highest value was obtained in spring 1997, but this peak was not repeated in spring 1998 (*J. exasperatus* was absent in samples from this season) (Fig. 3.391).

Fig. 3.391.A) Mean number and B) Biomass (mg wet weight) of *J. exasperatus* per 0.1m^2 grab at UMC. Error bars = SD. Numbers above each column are mean values (n=3 replicates).



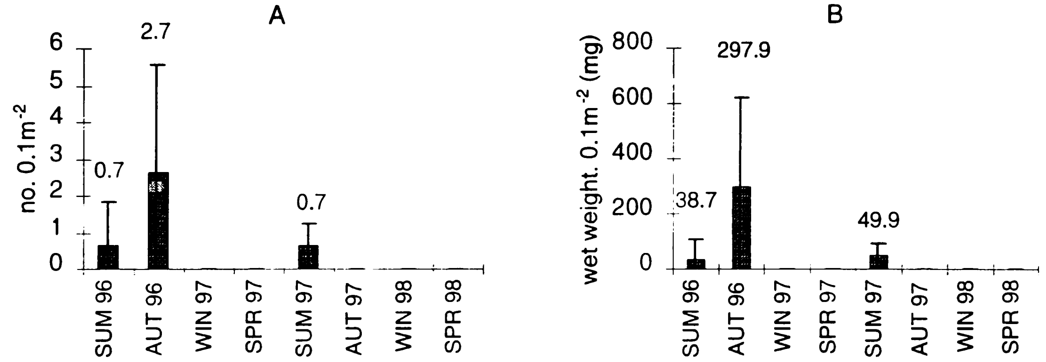
The seasonal variation in size frequency of *Jujubinus exasperatus* at the control ground is shown in Fig.3.392. Small individuals (shell length = 2-3mm) were obtained in spring 1997 and summer 1997, which might suggest recruitment during these seasons. However due to the low number of individuals collected, no patterns in the size-frequency distribution could be detected.

Fig. 3.392. Size-frequency histograms for *Jujubinus exasperatus* collected seasonally in $0.1m^2$ grabs at UMC from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring.



Jujubinus exasperatus was found in only three seasonal samples in the impacted site and similar abundances were obtained for summer 1996 and summer 1997 (Fig. 3.393). The highest value was obtained for autumn 1996, which does not correspond to the highest value obtained in spring 1997 in the control ground. Again, due to the low number of individuals collected no particular seasonal pattern could be observed.

Fig. 3.393. A) Mean number and B) Biomass (mg wet weight) of *J. exasperatus* per $0.1m^2$ grab at UMI. Error bars = SD. Numbers above each column are mean values (n=3 replicates).



The seasonal variation in size frequency of *Jujubinus exasperatus* at the impacted site is shown in Fig.3.394. Since this gastropod was present in only three seasonal samples in the impacted ground, no patterns in the size-frequency distribution could be detected.

Fig. 3.394. Size-frequency histograms for *Jujubinus exasperatus* collected seasonally in $0.1m^2$ grabs at UMI from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring.

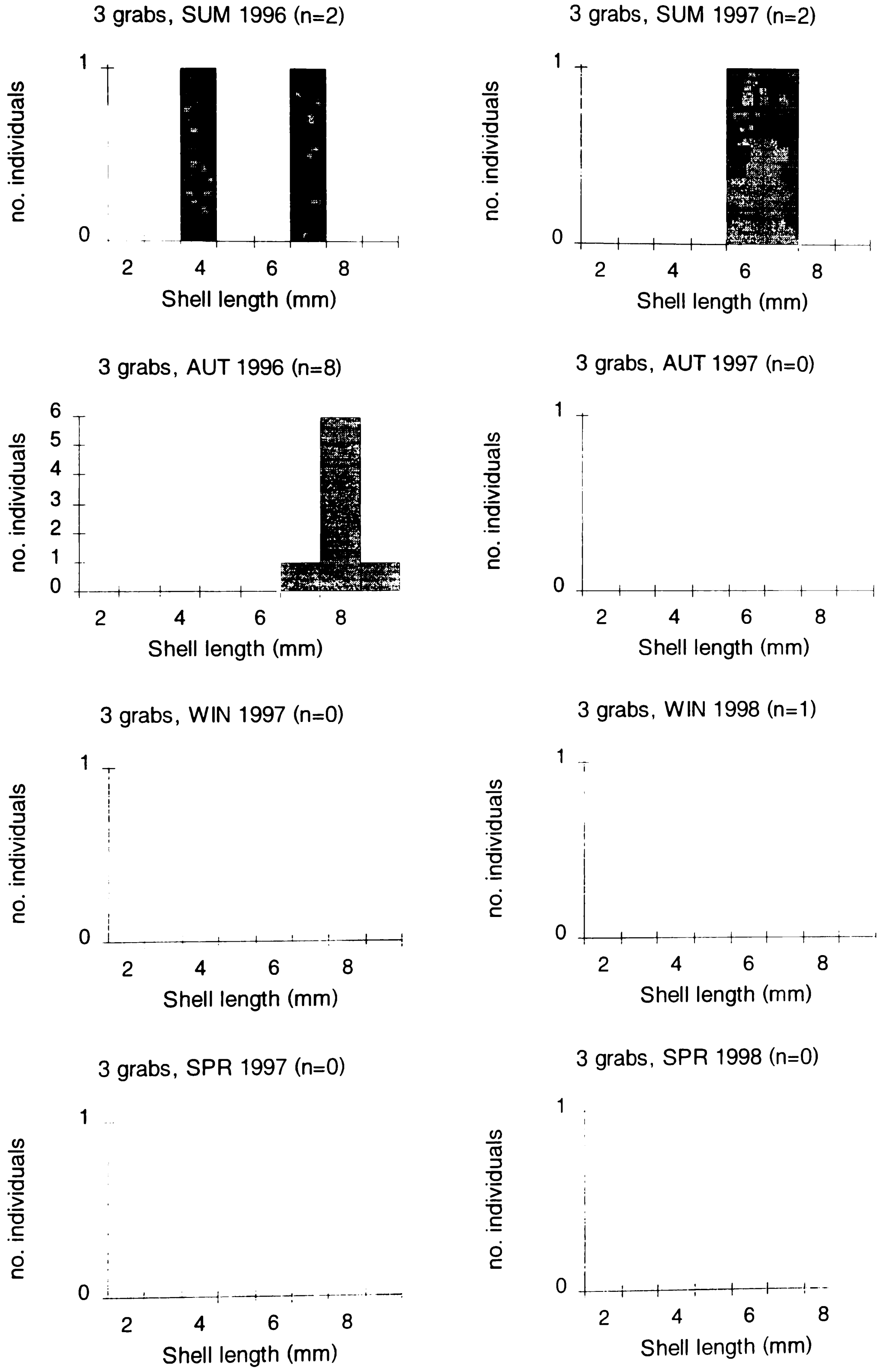
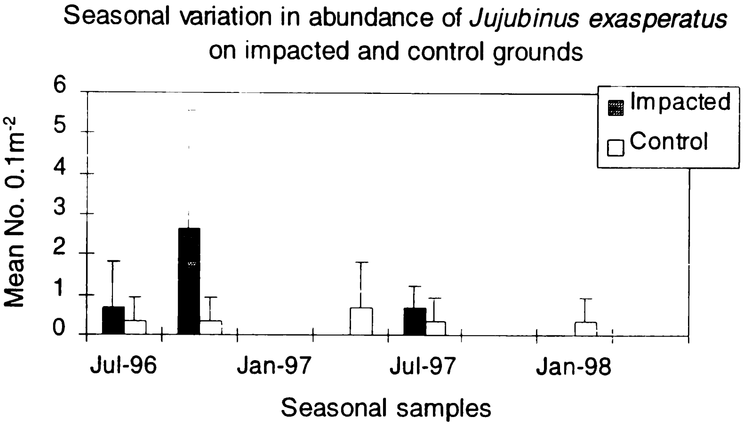
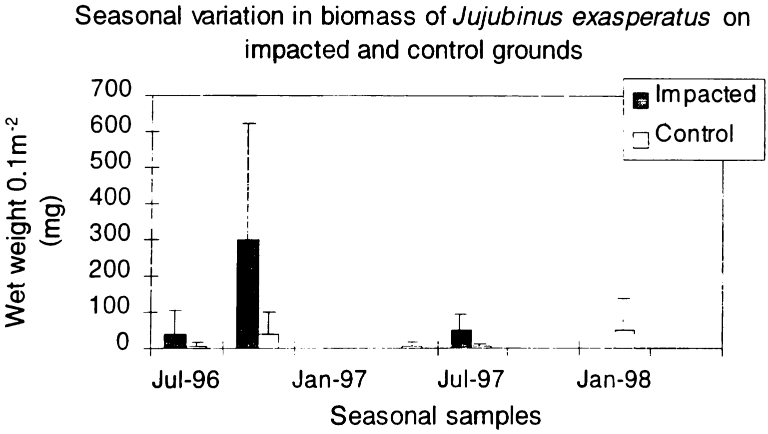


Figure 3.395 compares the abundance and biomass of *Jujubinus exasperatus* on the Impacted and Control sites. When it was present on both grounds, *J. exasperatus* was more abundant on the impacted ground. However, although in lower abundances, it seems to be more frequent at the control ground since it was present in more seasonal samples.

Fig. 3.395.

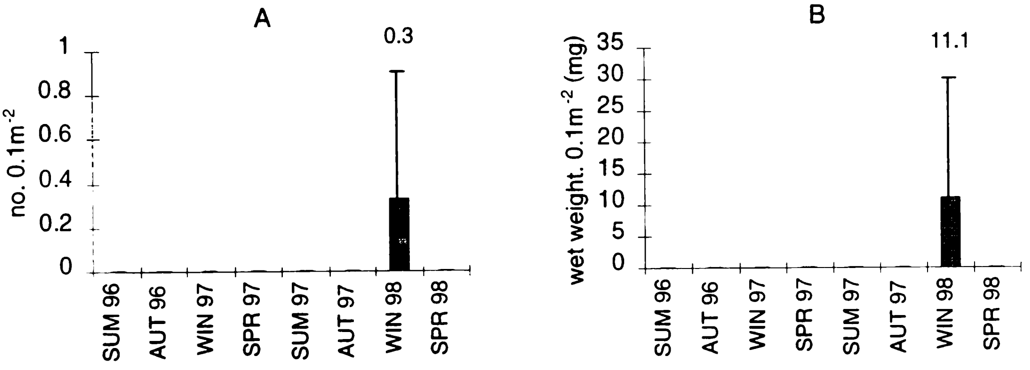




Jujubinus striatus (Linnaeus, 1758)

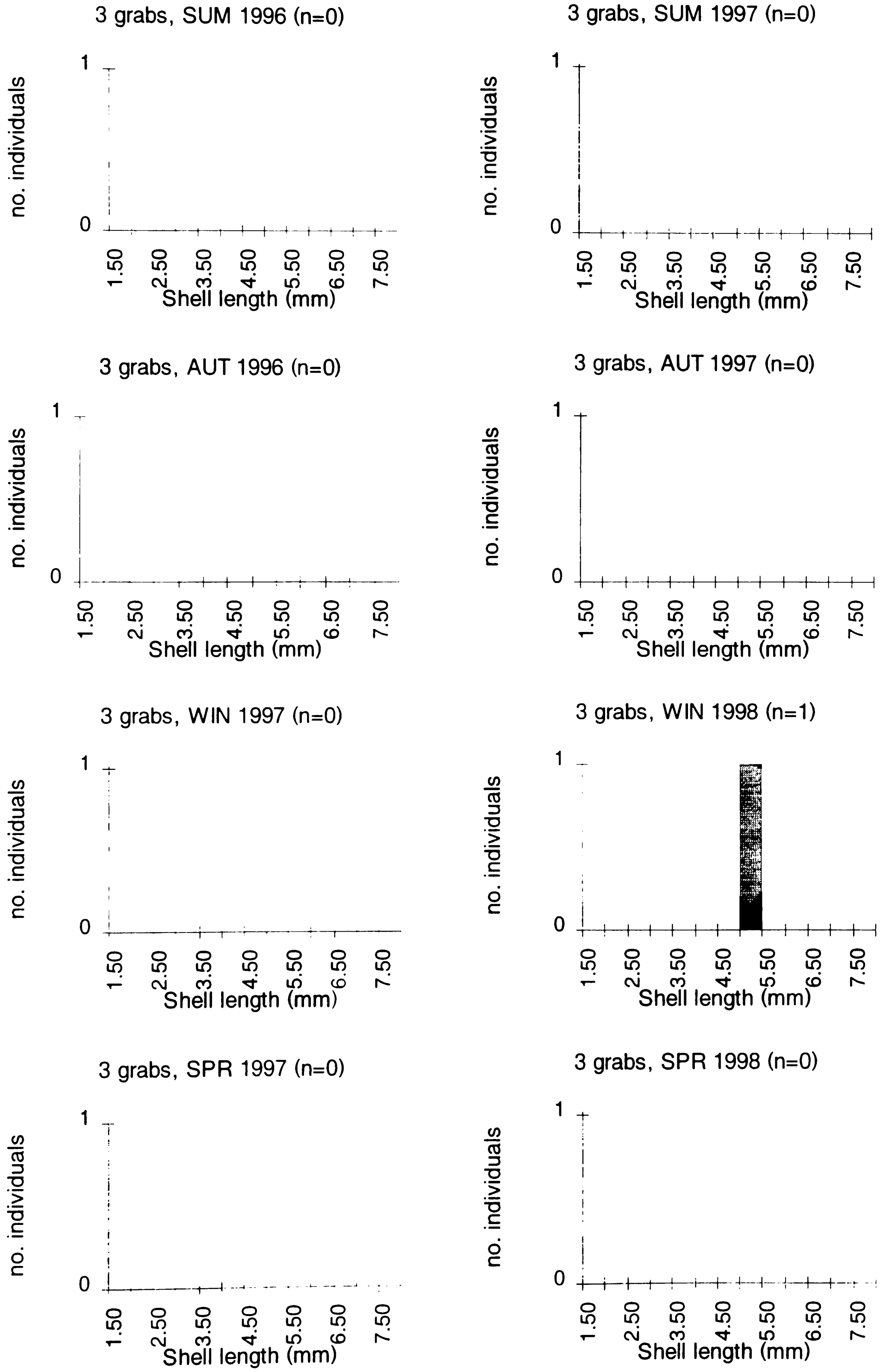
Jujubinus striatus was present in nearly all the seasonal samples although in very low numbers. It is thought to be a herbivore and micrograzer on surface films of microscopic algae. *Jujubinus striatus* was very rare in the control ground, being present in only one seasonal sample and in very low numbers (Fig. 3.396).

Fig. 3.396. A) Mean number and B) Biomass (mg wet weight) of *J. striatus* per $0.1m^2$ grab at UMC. Error bars = SD. Numbers above each column are mean values (n = 3 replicates).



The seasonal variation in size frequency of *J. striatus* at the control ground is shown in Fig. 3. 97. Only one individual was collected from the control site, so no patterns in size-frequency distribution could be detected.

Fig. 3.397. Size-frequency histograms for *Jujubinus striatus* collected seasonally in $0.1m^2$ grabs at UMC from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring.



3 grabs, SUM 1996 (n=0)

3 grabs, SUM 1997 (n=0)

3 grabs, AUT 1996 (n=0)

3 grabs, AUT 1997 (n=0)

3 grabs, WIN 1997 (n=0)

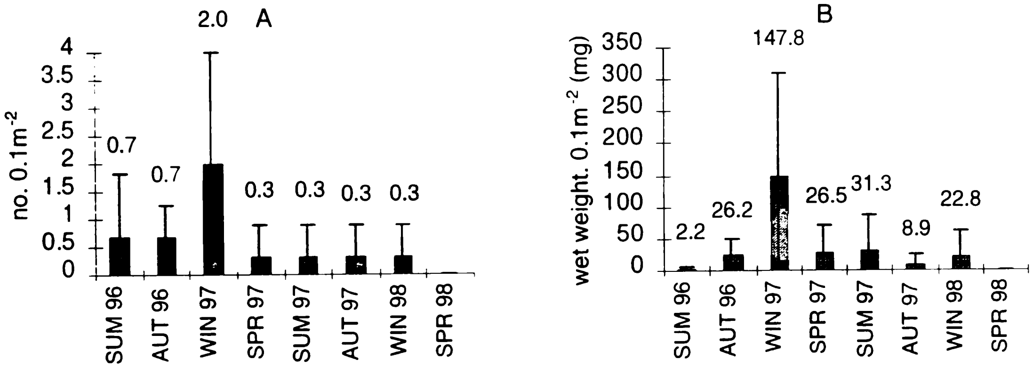
3 grabs, WIN 1998 (n=1)

3 grabs, SPR 1997 (n=0)

3 grabs, SPR 1998 (n=0)

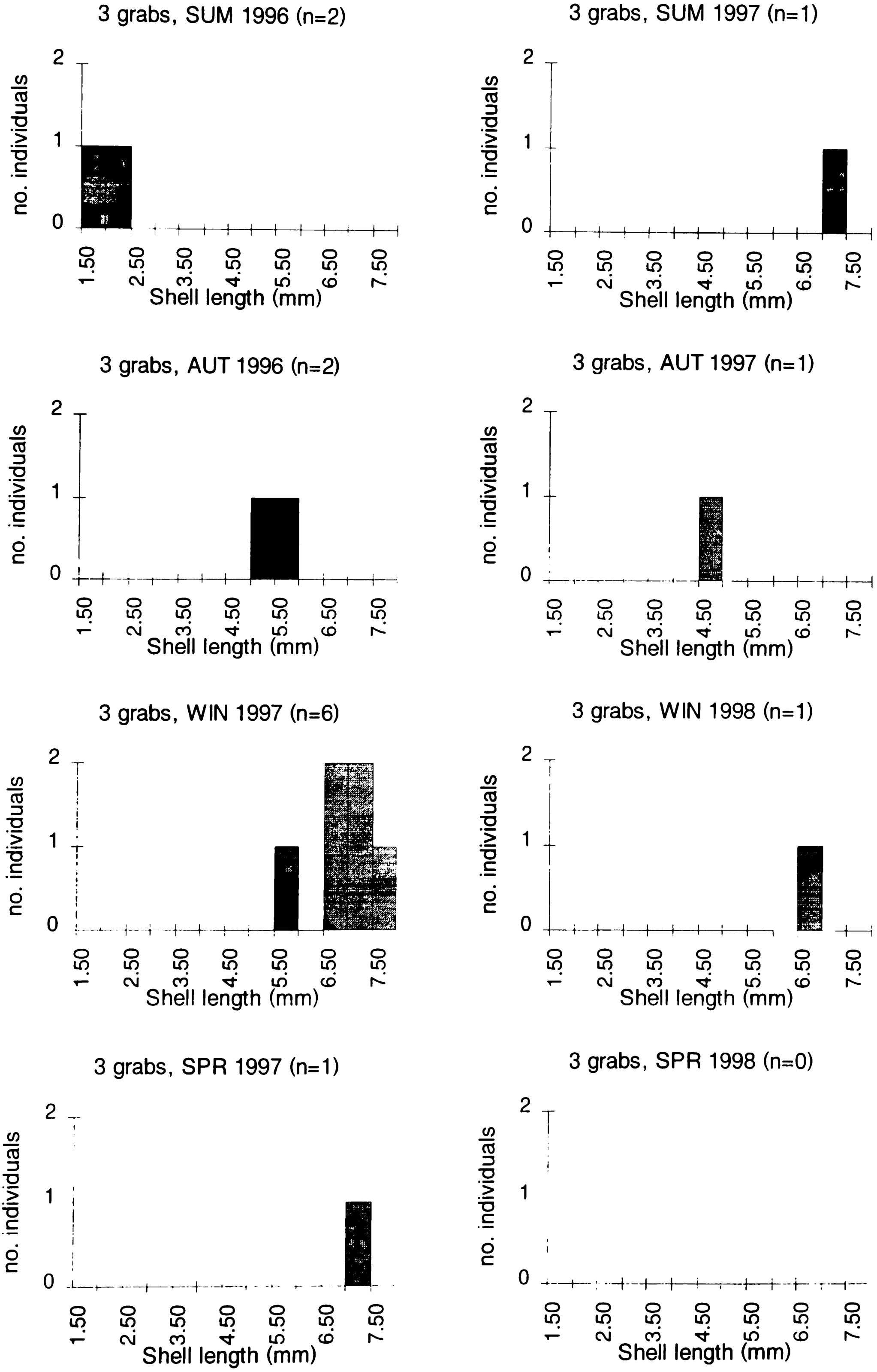
Jujubinus striatus was present in most seasonal samples from the impacted ground (Fig. 3.398). The highest value was obtained in winter 1997, however no particular seasonal pattern can be observed.

Fig. 3.398. A) Mean number and B) Biomass (mg wet weight) of *J. striatus* per 0.1m^2 grab at UMI. Error bars = SD. Numbers above each column are mean values (n=3 replicates).



The seasonal variation in size frequency of *J. striatus* at the impacted ground is shown in Fig. 3.399. Small individuals (shell length = 1.5-2.0mm) were obtained in summer 1996, but this trend was not shown in summer 1997. Again, due to the low numbers of individuals collected no pattern in the size-frequency distribution could be detected.

Fig. 3.399. Size-frequency histograms for *Jujubinus striatus* collected seasonally in $0.1m^2$ grabs at UMI from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring



3 grabs, SUM 1996 (n=2)

3 grabs, SUM 1997 (n=1)

3 grabs, AUT 1996 (n=2)

3 grabs, AUT 1997 (n=1)

3 grabs, WIN 1997 (n=6)

3 grabs, WIN 1998 (n=1)

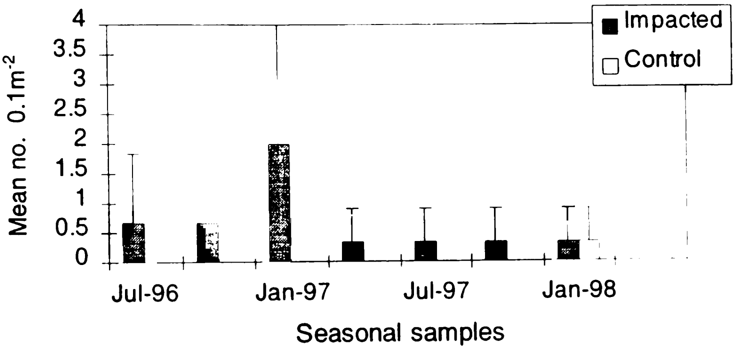
3 grabs, SPR 1997 (n=1)

3 grabs, SPR 1998 (n=0)

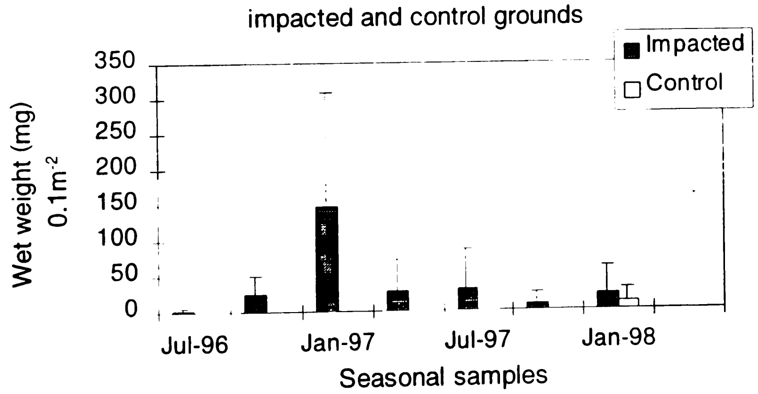
Figure 3.400 compares the abundance and biomass of *Jujubinus striatus* on the Impacted and Control sites. It is very clear that this species is much more abundant at the impacted site. However, even on the impacted site, this species is present in low numbers.

Fig. 3.400.

Seasonal variation in abundance of *Jujubinus striatus* on impacted and control grounds



Seasonal variation in biomass of *Jujubinus striatus* on impacted and control grounds

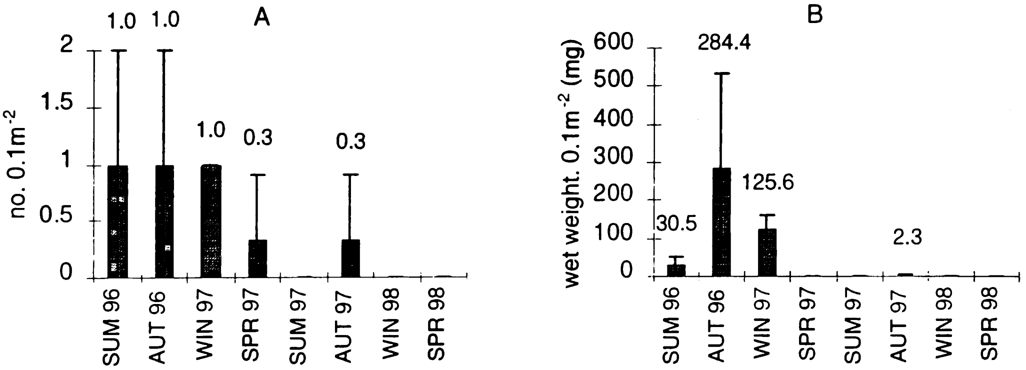


Turritella turbona Monterosato, 1877

Turritella turbona was fairly common on Maltese maerl grounds and it was present on both control and impacted sites. It is a suspension-feeding gastropod that appears to embed itself in the uppermost layers of the maerl.

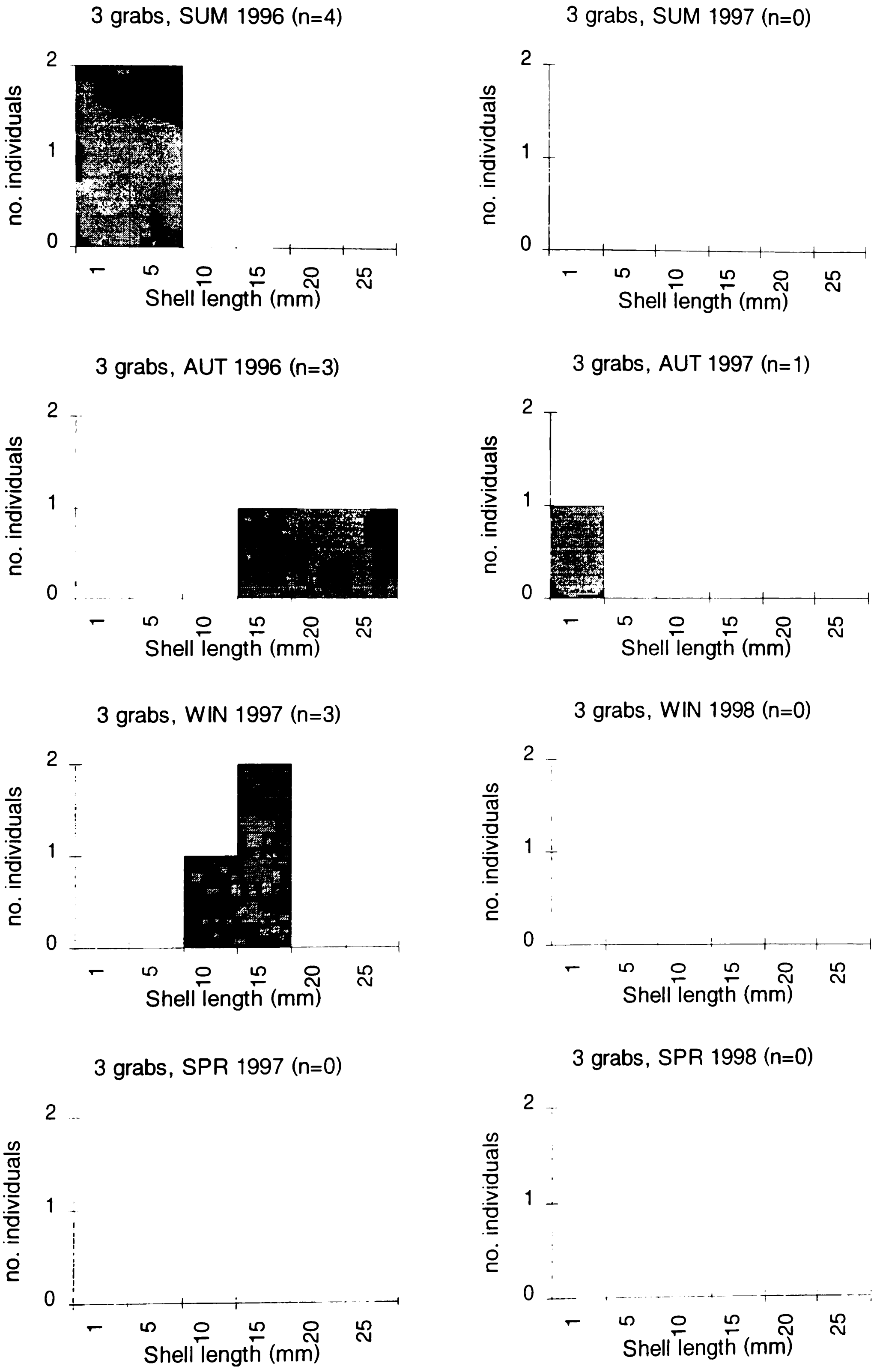
Turritella turbona was more frequently collected during the first year of sampling . from the control site and its abundance was constant throughout the first three seasons. In spring 1997, its abundance decreased and subsequently it was only collected in autumn 1997 (Fig. 3.401). Thus, no particular seasonal variation in either abundance or biomass could be observed.

Fig. 3.401. A) Mean number and B) Biomass (mg wet weight) of *T. turbona* per $0.1m^2$ grab at UMC. Error bars = SD. Numbers above each column are mean values (n = 3 replicates).



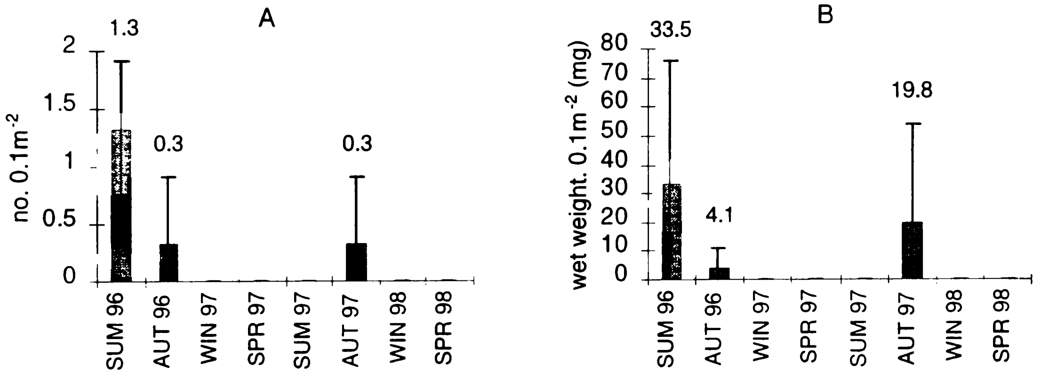
The seasonal variation in size-frequency of *T. turbona* at the control ground is shown in Fig. 3.402. Since this species was mostly collected during the first year of sampling and was practically absent from subsequent samples no patterns in the size-frequency distribution could be discerned. However, small-sized individuals (shell length = 1mm) occurred in summer (1996) and autumn (1997).

Fig. 3.402. Size-frequency histograms for *Turritella turbona* collected seasonally in $0.1 m^2$ grabs at UMC from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring



Turritella turbona was collected in very low numbers from only three seasonal samples at the impacted site (Fig. 3.403). Due to this, no pattern in the seasonal variation of abundance and biomass could be detected.

Fig. 3.403. A) Mean number and B) Biomass (mg wet weight) of *T. turbona* per 0.1m^2 grab at UMI. Error bars = SD. Numbers above each column are mean values (n=3 replicates).



The seasonal variation in size-frequency of *T. turbona* at the impacted ground is shown in Fig. 3.404. Due to the low number of individuals collected, no patterns in the size-frequency distribution could be detected, although as at the control site, small-sized individuals (shell length = 1mm) occurred in summer (1996).

Fig. 3.404. Size-frequency histograms for *Turritella turbona* collected seasonally in 0.1m^2 grabs at UMI from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring

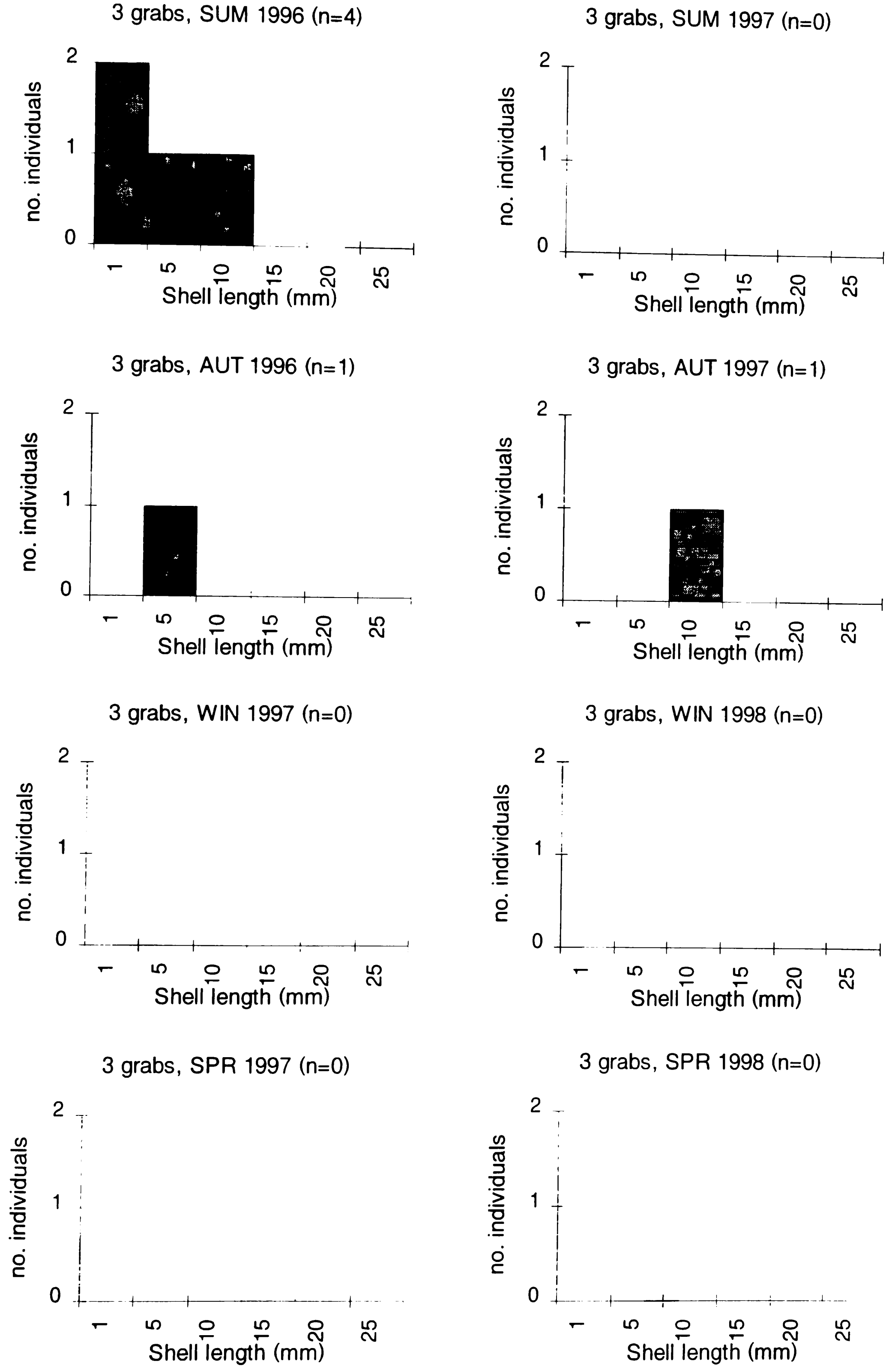
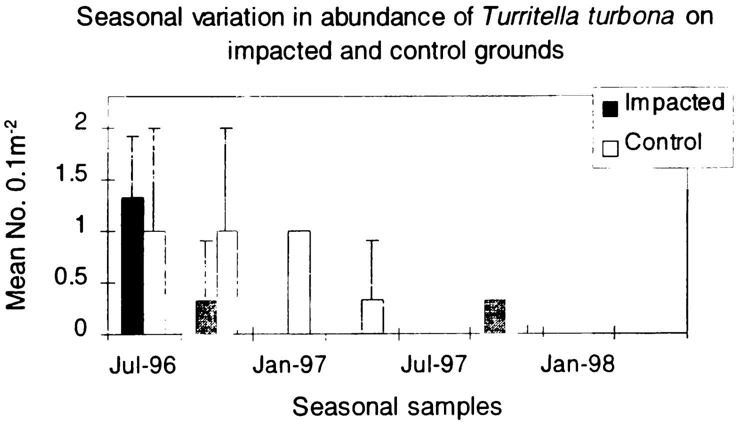
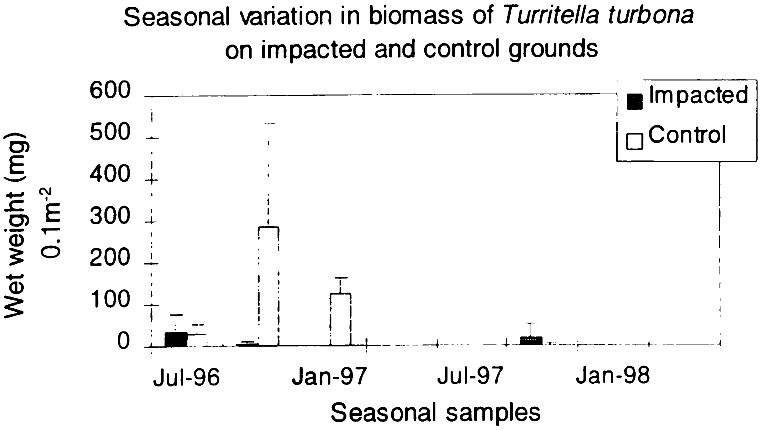


Figure 3.405 compares the abundance and biomass of *Turritella turbona* on the Impacted and Control sites. The highest value for abundance was obtained at the impacted site in summer 1996. However during the other seasons, it was generally more abundant and more frequent at the control site. Also, the highest value for biomass was obtained from the control samples (autumn 1996).

Fig. 3.405.



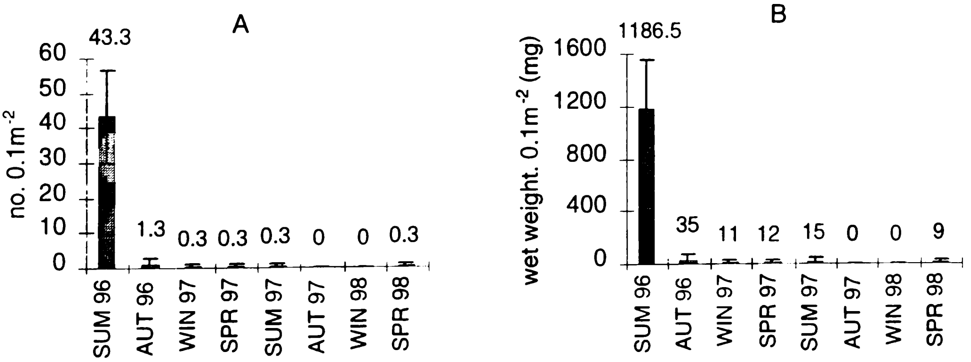


***Bittium latreillii* (Payraudeau, 1826)**

Bittium latreillii is a surface-dwelling detrivorous gastropod which was very common on Maltese maerl grounds. It was found at both control and impacted sites and it reached relatively high abundances when compared with other fauna.

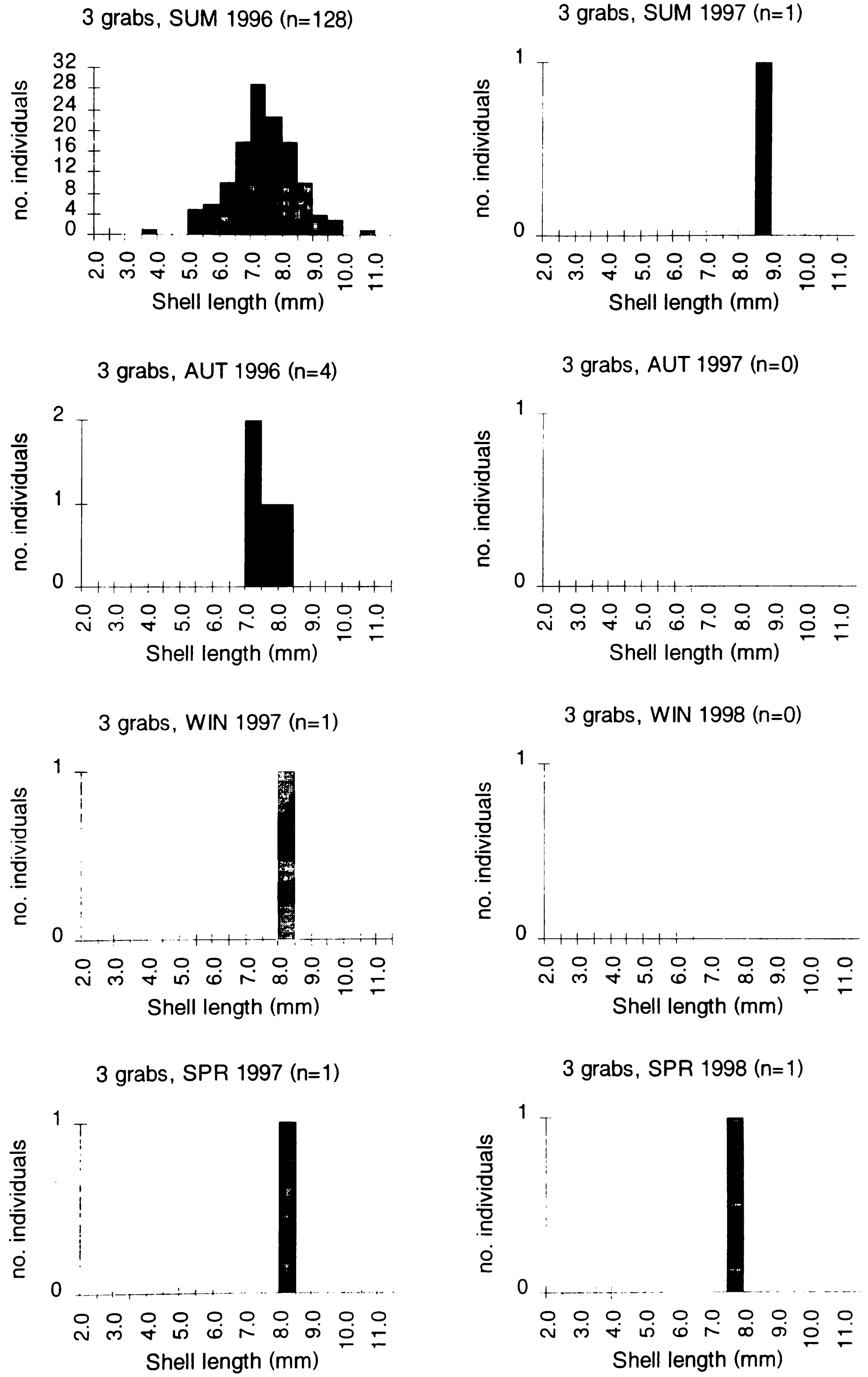
Bittium latreillii was not very common on the control ground. High values for abundance and biomass were obtained for only one season: summer 1996 (Fig. 3.406). During the following seasons, the abundances were extremely low and the peak observed in July 1996 (summer) was not repeated in July 1997 (summer). Thus, no particular seasonal pattern can be discerned.

Fig. 3.406.A) Mean number and B) Biomass (mg wet weight) of *B. latreillii* per $0.1m^2$ grab at UMC. Error bars = SD. Numbers above each column are mean values (n=3 replicates).



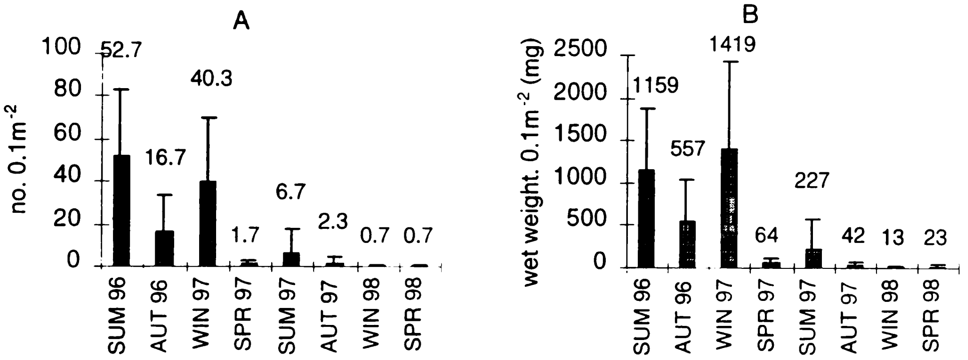
The seasonal variation in size frequency of *B. latreillii* at the control ground is shown in Fig. 3.407. *Bittium latreillii* was abundant during summer 1996, where most of the individuals had a shell length between 5 and 9mm. During the remainder of the year it was found in very low numbers, so it is not possible to detect any pattern in the size-frequency distribution.

Fig. 3.407. Size-frequency histograms for *Bittium latreillii* collected seasonally in $0.1m^2$ grabs at UMC from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring.



Bittium latreillii was more common on the impacted site (Fig. 3.408). However, it was mostly abundant during the first year of sampling. During the second year of sampling, this species was collected in low numbers. As in the control ground, the highest value was obtained in summer 1996.

Fig. 3.408. A) Mean number and B) Biomass (mg wet weight) of *B. latreillii* per $0.1m^2$ grab at UMI. Error bars = SD. Numbers above each column are mean values (n = 3 replicates).



The seasonal variation in size frequency of *B. latreillii* at the impacted site is shown in Fig. 3.409. A pattern in the size-frequency distribution of this gastropod can be observed for the first year of sampling. During the period between summer 1996 and winter 1997, larger gastropods became more frequent (in summer 1996 gastropods with a shell length of 7mm were more abundant; in autumn 1996, gastropods with a shell length of 7.5mm were more abundant; and in winter 1997 gastropods with a shell length of 8mm were more abundant); this pattern could not be followed after winter 1997 as very few *B.latreillii* were collected during the rest of the seasons. The indication is that recruitment into the maerl population occurred in spring/early summer, at least in 1996.

Fig. 3.409. Size-frequency histograms for *Bittium latreillii* collected seasonally in $0.1m^2$ grabs at UMI from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring.

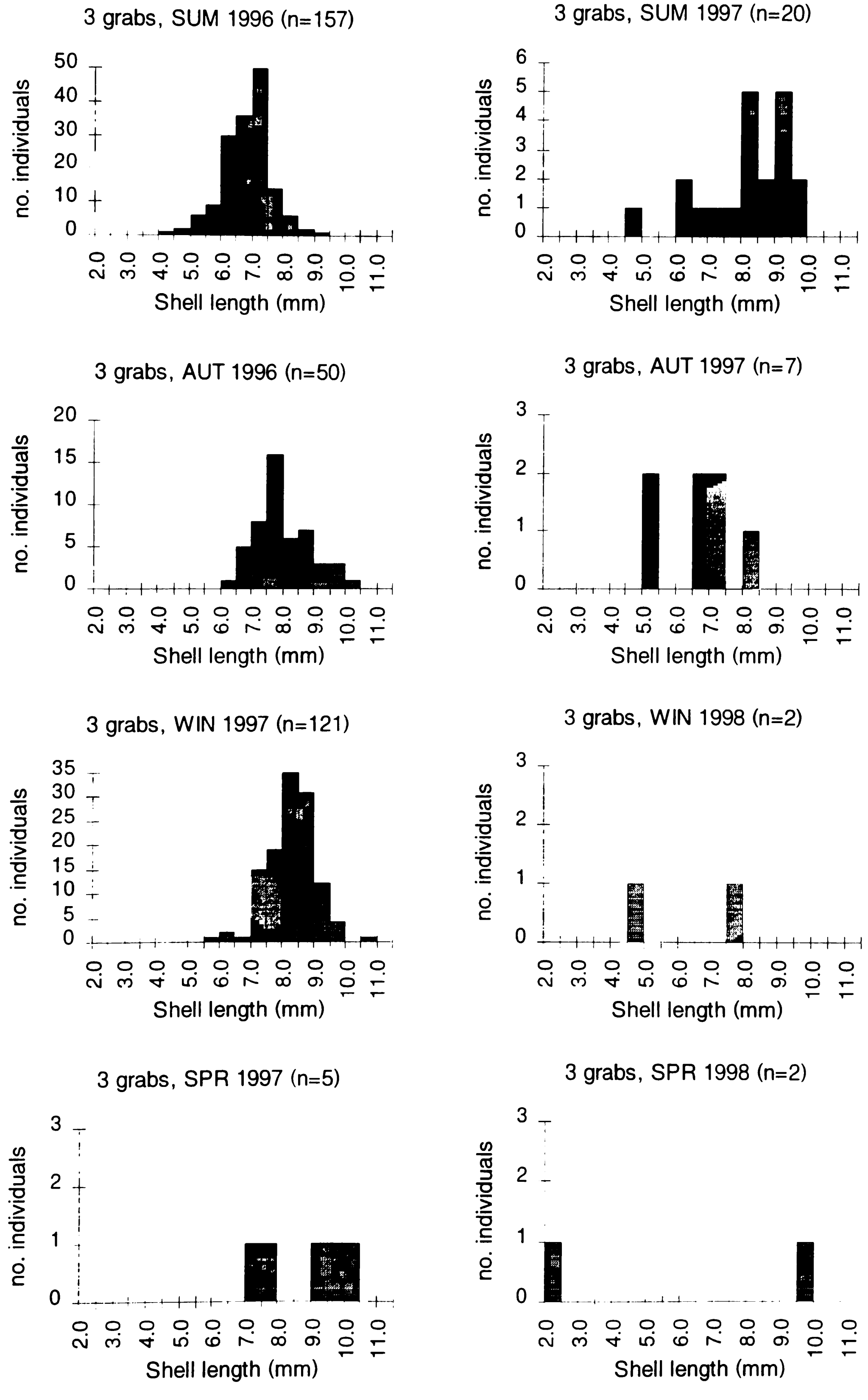
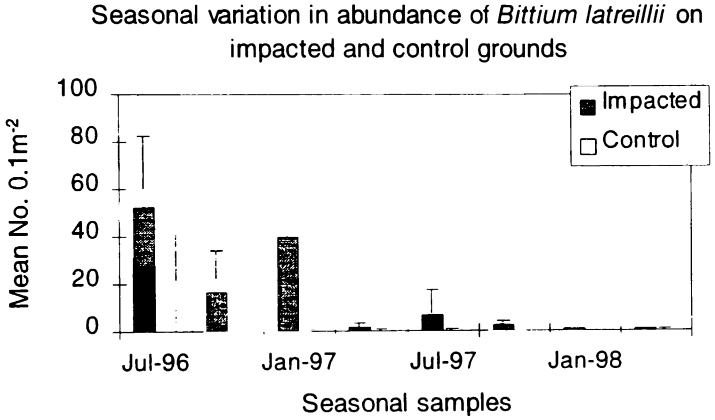
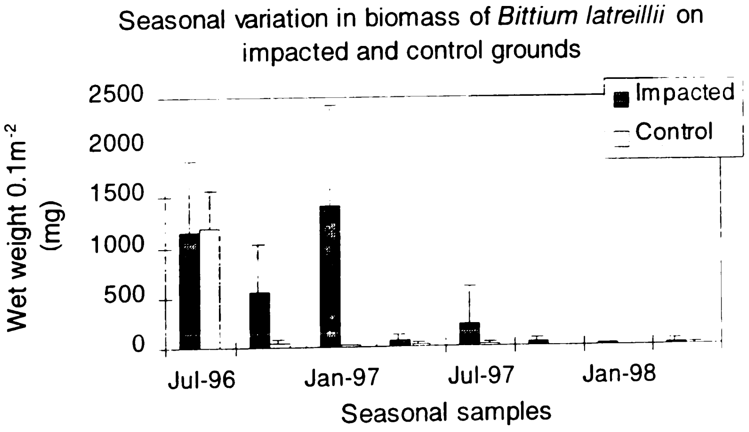


Figure 3.410 compares the abundance and biomass of *Bittium latreillii* on the impacted and control sites. This gastropod was clearly more abundant at the impacted site than at the control site. On both grounds the highest value was obtained in summer 1996, but its abundance decreased during the second year of sampling.

Fig. 3.410.



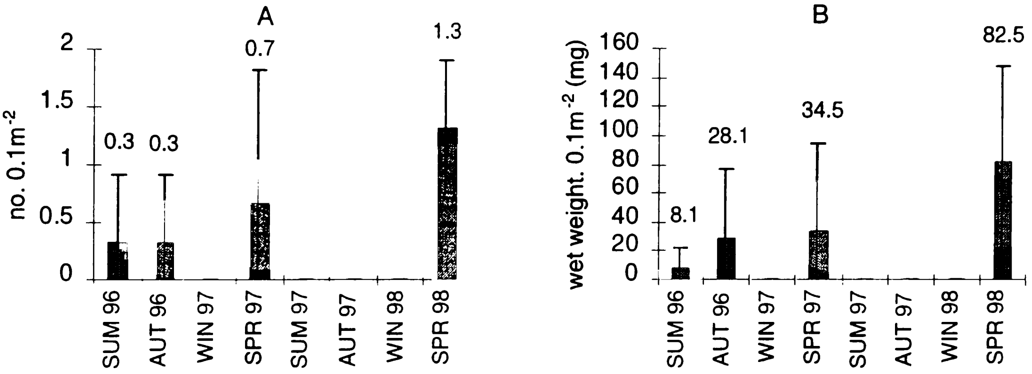


Volvarina mitrella **(Risso, 1826)**

Volvarina mitrella was not very common on Maltese maerl grounds. It was collected from both control and impacted sites but only in very low numbers. This gastropod is probably carnivorous, a predator on microfauna.

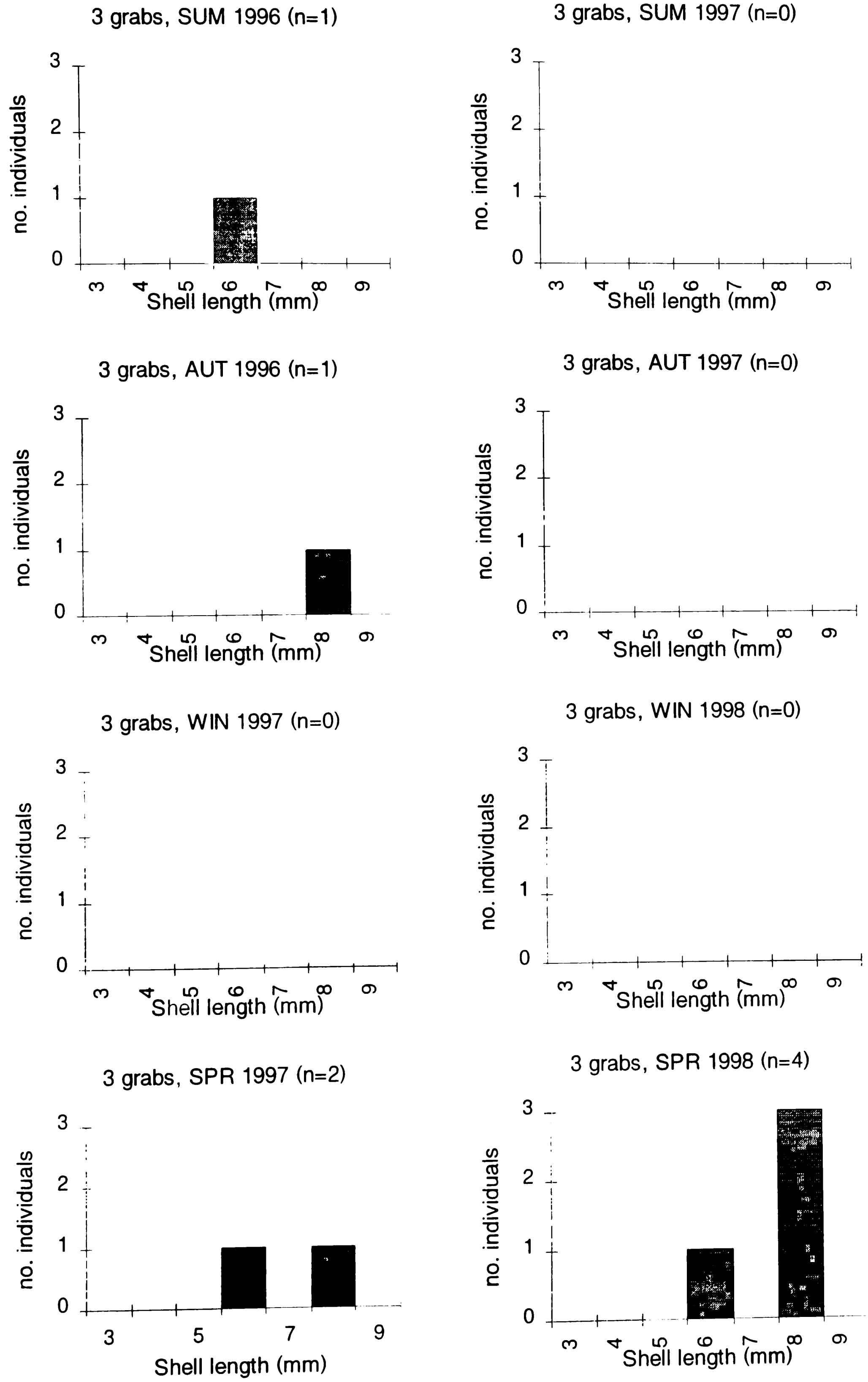
It was collected in only four seasonal samples in the control site, so no seasonal pattern in abundance or biomass could be discerned (Fig. 3.411). The highest values were obtained in spring 1997 and 1998.

Fig. 3.411. A) Mean number and B) Biomass (mg wet weight) of *Volvarina mitrella* per 0.1m^2 grab at UMC. Error bars = SD. Numbers above each column are mean values (n = 3 replicates).



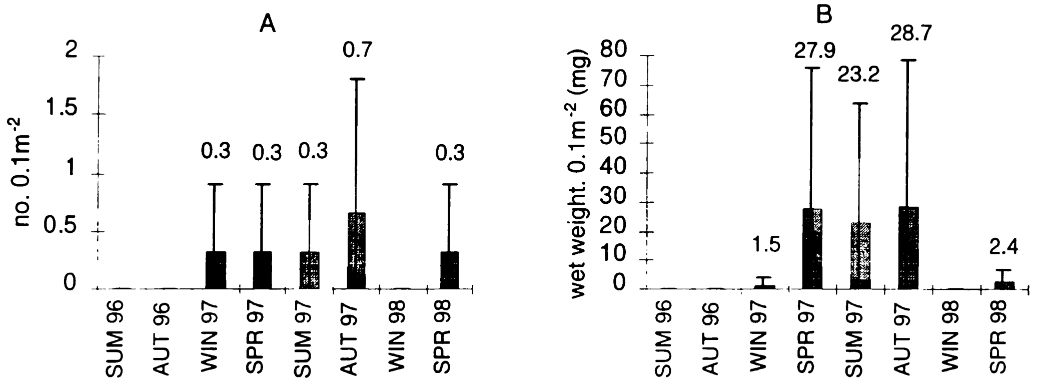
The seasonal variation in size frequency of *V. mitrella* at the control ground is shown in Fig. 3.412. Due to the low number of individuals collected, no patterns in the size-frequency distribution could be detected.

Fig. 3.412. Size-frequency histograms for *Volvarina mitrella* collected seasonally in 0.1m^2 grabs at UMC from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring.



As in the control site, *Volvarina mitrella* was not very abundant at the impacted site. It was present in five seasonal samples with nearly equal abundances, the highest value being obtained in autumn 1997 (Fig. 3.413). No particular seasonal pattern could be observed.

Fig. 3.413. A) Mean number and B) Biomass (mg wet weight) of *Volvarina mitrella* per $0.1m^2$ grab at UMI. Error bars = SD. Numbers above each column are mean values (n=3 replicates).



The seasonal variation in size frequency of *V. mitrella* at the impacted ground is shown in Fig. 3. 414. Due to the low number of individuals collected, no patterns in the size-frequency distribution could be detected, except that small-sized specimens (shell length = 3mm) occurred in the cooler seasons (winter 1997, autumn 1997).

Fig. 3.414. Size-frequency histograms for *Volvarina mitrella* collected seasonally in 0.1m^2 grabs at UMC from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring.

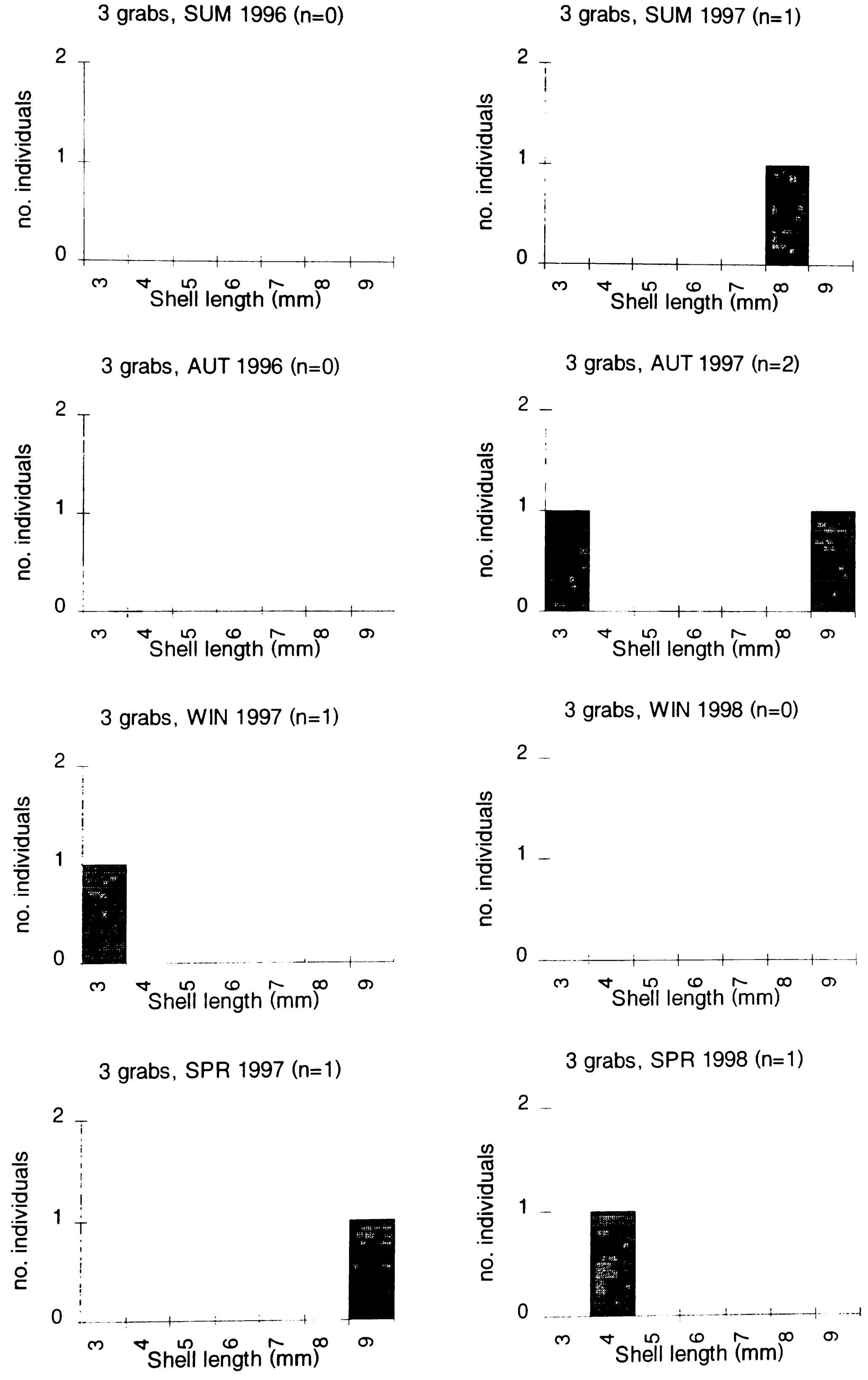
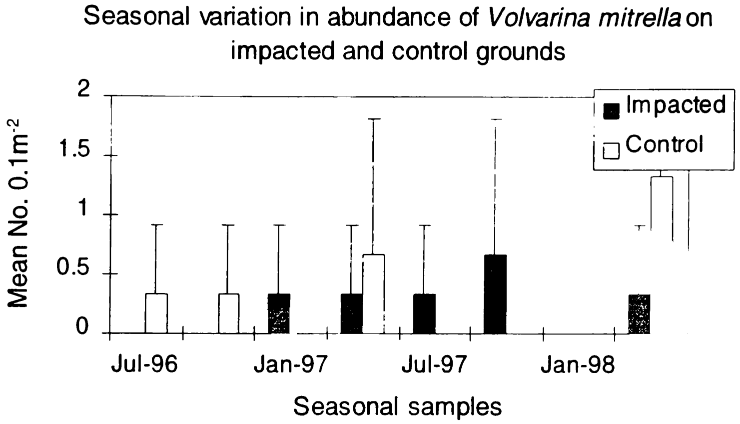
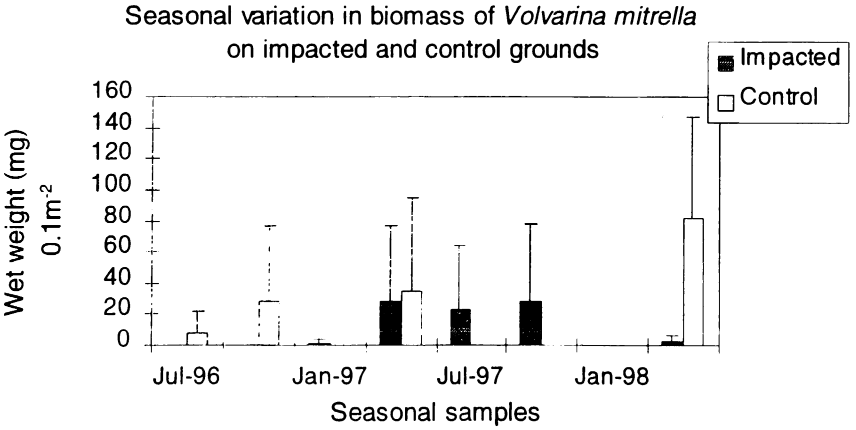


Figure 3.415 compares the abundance and biomass of *Volvarina mitrella* on the impacted and control sites. When this species was present in both sites, it was more abundant at the control than at the impacted one. However, for some seasonal samples (autumn 1996, summer 1996 and autumn 1997) this species was only collected from the impacted site. Thus no general conclusions on the differences between the abundances of this species at the impacted and control sites can be made.

Fig. 3.415.



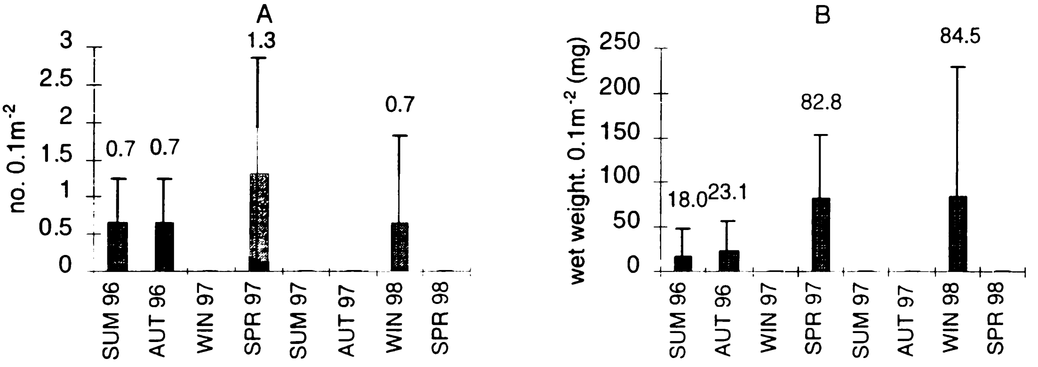


Mitrella scripta (Linnaeus, 1758)

Mitrella scripta was found on both impacted and control sites and although its abundances were not very high, it is not a rare species. There is very little information about its feeding habits and it could be either a herbivore feeding on macroalgae or a carnivore. It appears to be a surface dweller.

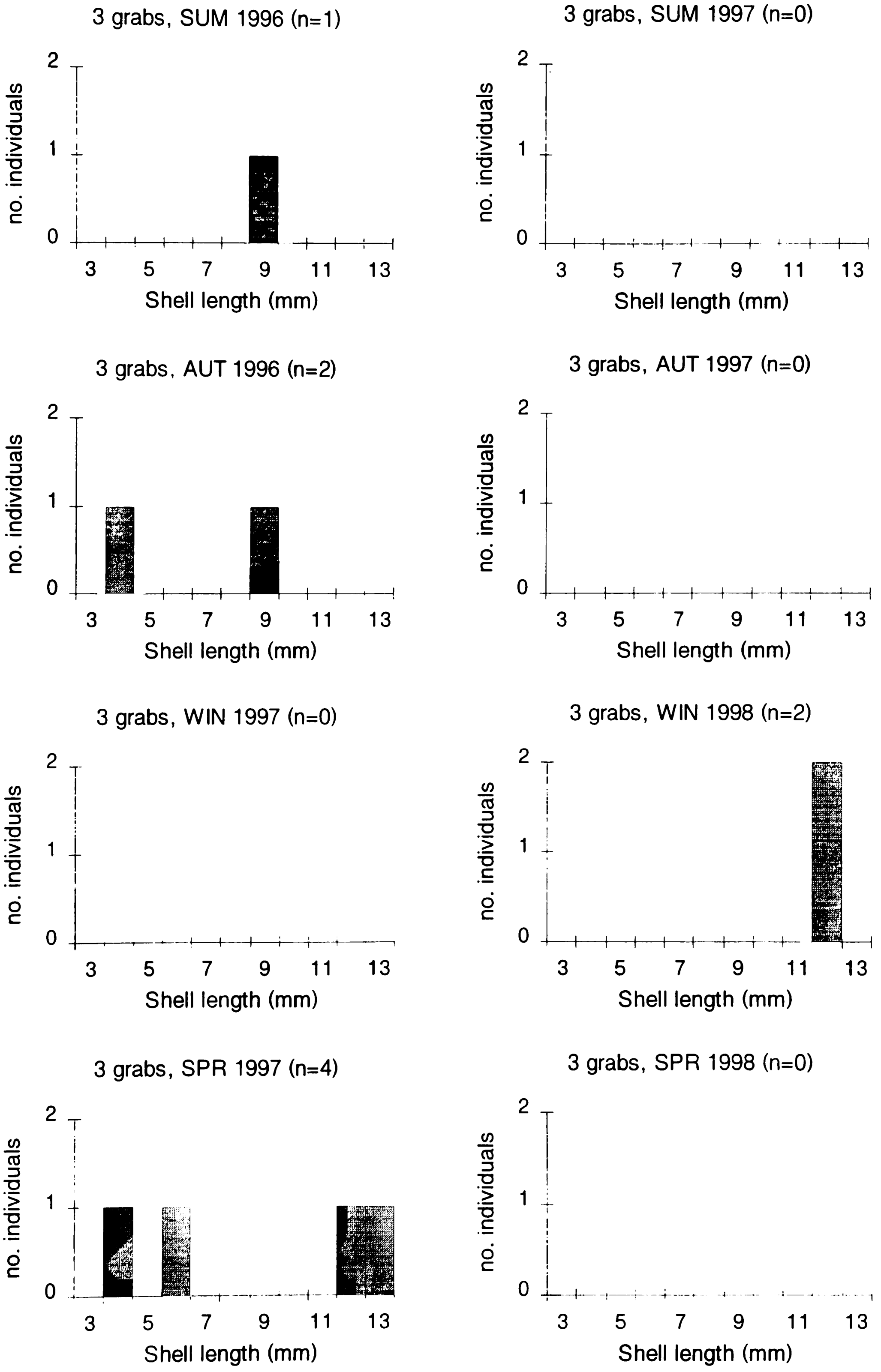
Mitrella scripta was present in only four seasonal samples in the control ground (Fig. 3.416). No particular seasonal pattern can be discerned, but the highest value was obtained in spring 1997.

Fig. 3.416. A) Mean number and B) Biomass (mg wet weight) of *M. scripta* per 0.1m^2 grab at UMC. Error bars = SD. Numbers above each column are mean values (n = 3 replicates).



The seasonal variation in size frequency of *M. scripta* at the control ground is shown in Fig. 3.417. Due to the low number of individuals collected, no patterns in the size-frequency distribution could be detected.

Fig. 3.417. Size-frequency histograms for *Mitrella scripta* collected seasonally in $0.1m^2$ grabs at UMC from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring.


3 grabs, SUM 1996 (n=1)

3 grabs, SUM 1997 (n=0)

3 grabs, AUT 1996 (n=2)

3 grabs, AUT 1997 (n=0)

3 grabs, WIN 1997 (n=0)

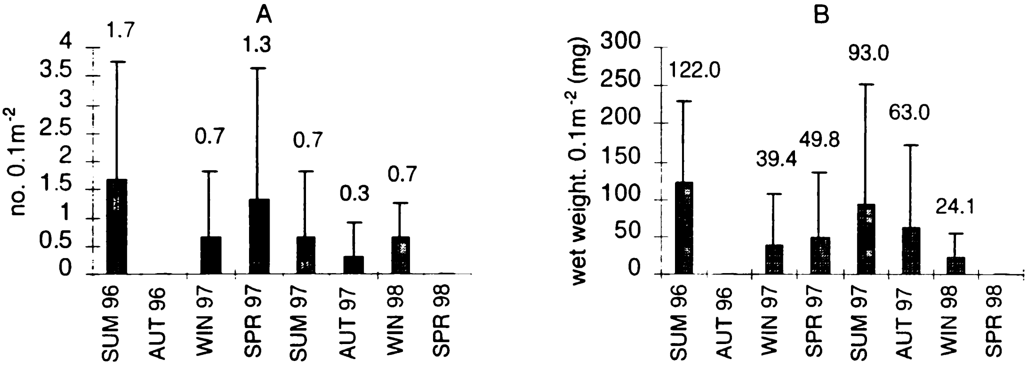
3 grabs, WIN 1998 (n=2)

3 grabs, SPR 1997 (n=4)

3 grabs, SPR 1998 (n=0)

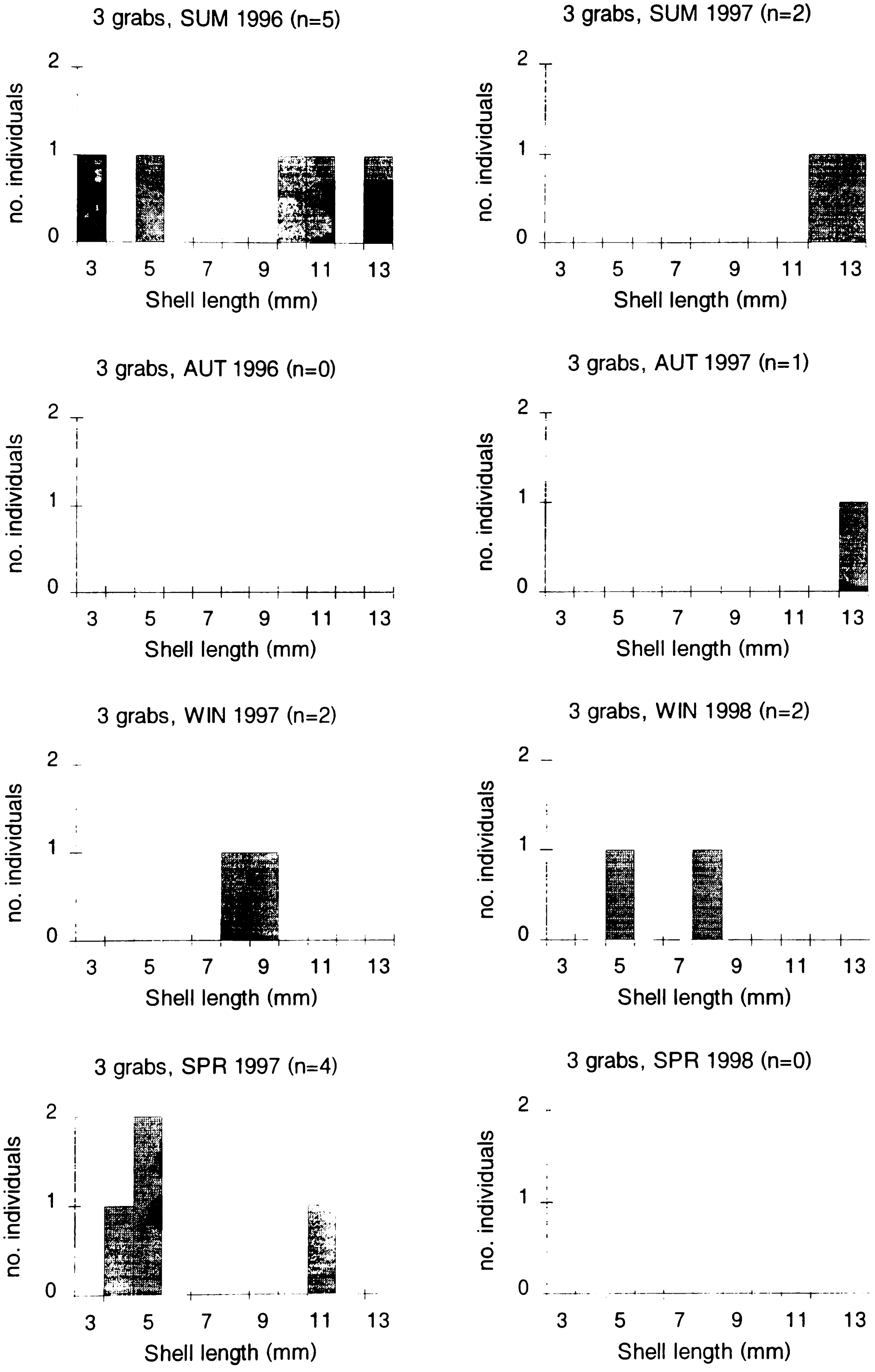
Mitrella scripta was present in nearly all the seasonal samples at the impacted site. The highest value was obtained in summer 1996, however, this peak was not repeated in summer 1997 (Fig. 3.418). No particular seasonal pattern can be detected.

Fig. 3.418. A) Mean number and B) Biomass (mg wet weight) of *M. scripta* per 0.1m^2 grab at UMI. Error bars = SD. Numbers above each column are mean values (n = 3 replicates).



The seasonal variation in size frequency of *M. scripta* at the impacted ground is shown in Fig. 3.419. Small individuals (shell length = 3mm) were obtained in summer 1996 and spring 1997. However, due to the low number of individuals collected, no patterns in the size-frequency distribution could be detected.

Fig. 3.419. Size-frequency histograms for *Mitrella scripta* collected seasonally in $0.1m^2$ grabs at UMI from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring.



3 grabs, SUM 1996 (n=5)

3 grabs, SUM 1997 (n=2)

3 grabs, AUT 1996 (n=0)

3 grabs, AUT 1997 (n=1)

3 grabs, WIN 1997 (n=2)

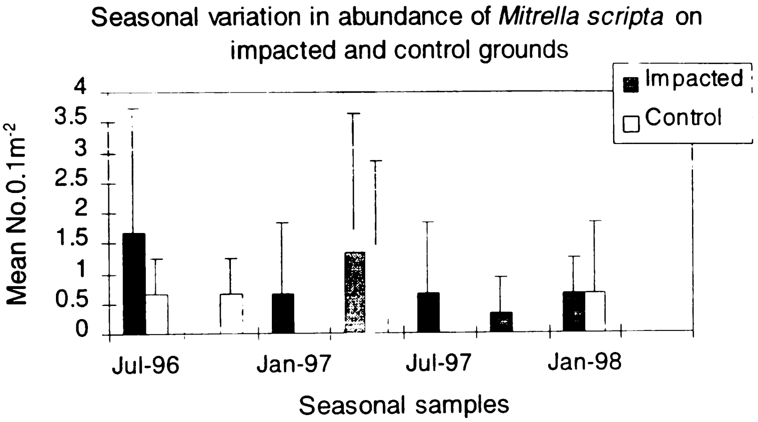
3 grabs, WIN 1998 (n=2)

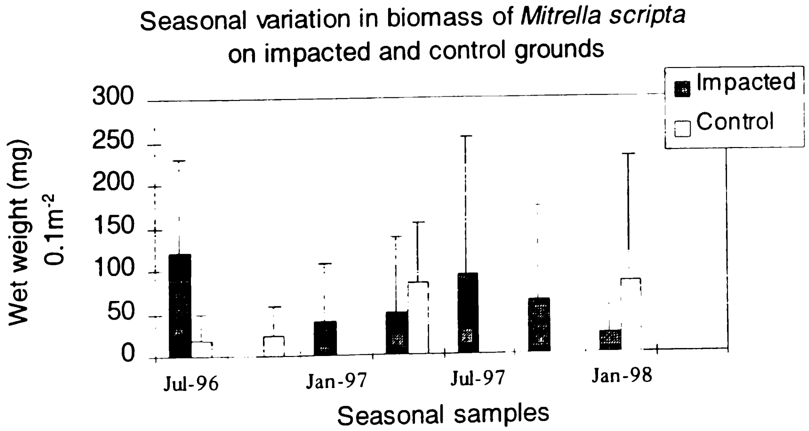
3 grabs, SPR 1997 (n=4)

3 grabs, SPR 1998 (n=0)

Figure 3.420 compares the abundance and biomass of *Mitrella scripta* at the impacted and control sites. The highest value for this species was obtained in summer 1996 at the impacted site. When present, it occurred at comparable abundances at both control and impacted sites. On the other hand, this species was more frequent at the impacted site, since it was present in most of the seasonal samples, while on the control ground, it was only present in four seasonal samples.

Fig.3.420.





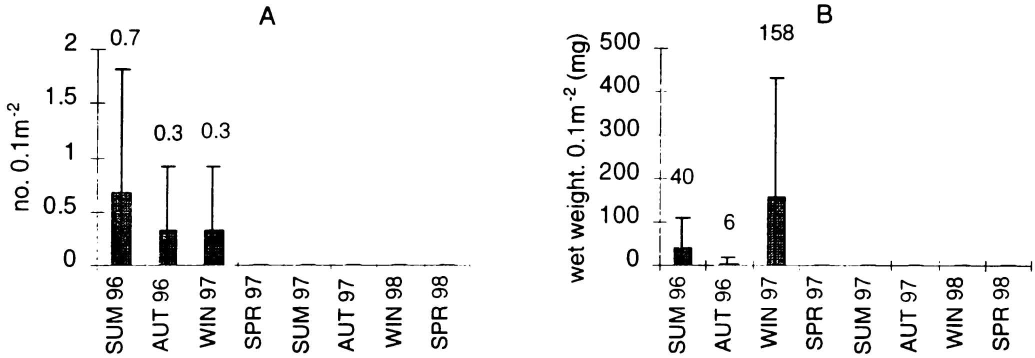
Haminoea hydatis **(Linnaeus, 1758)**

On the basis of the results obtained in the pilot survey, *Haminoea hydatis* was thought to be common on Maltese maerl grounds. However it turned out to be quite rare.

Although it was found at both the impacted and control sites, only very few live individuals were collected. The feeding habit of this opisthobranch is uncertain and the literature reports it to be either a predator on small bivalves or a grazer on algae.

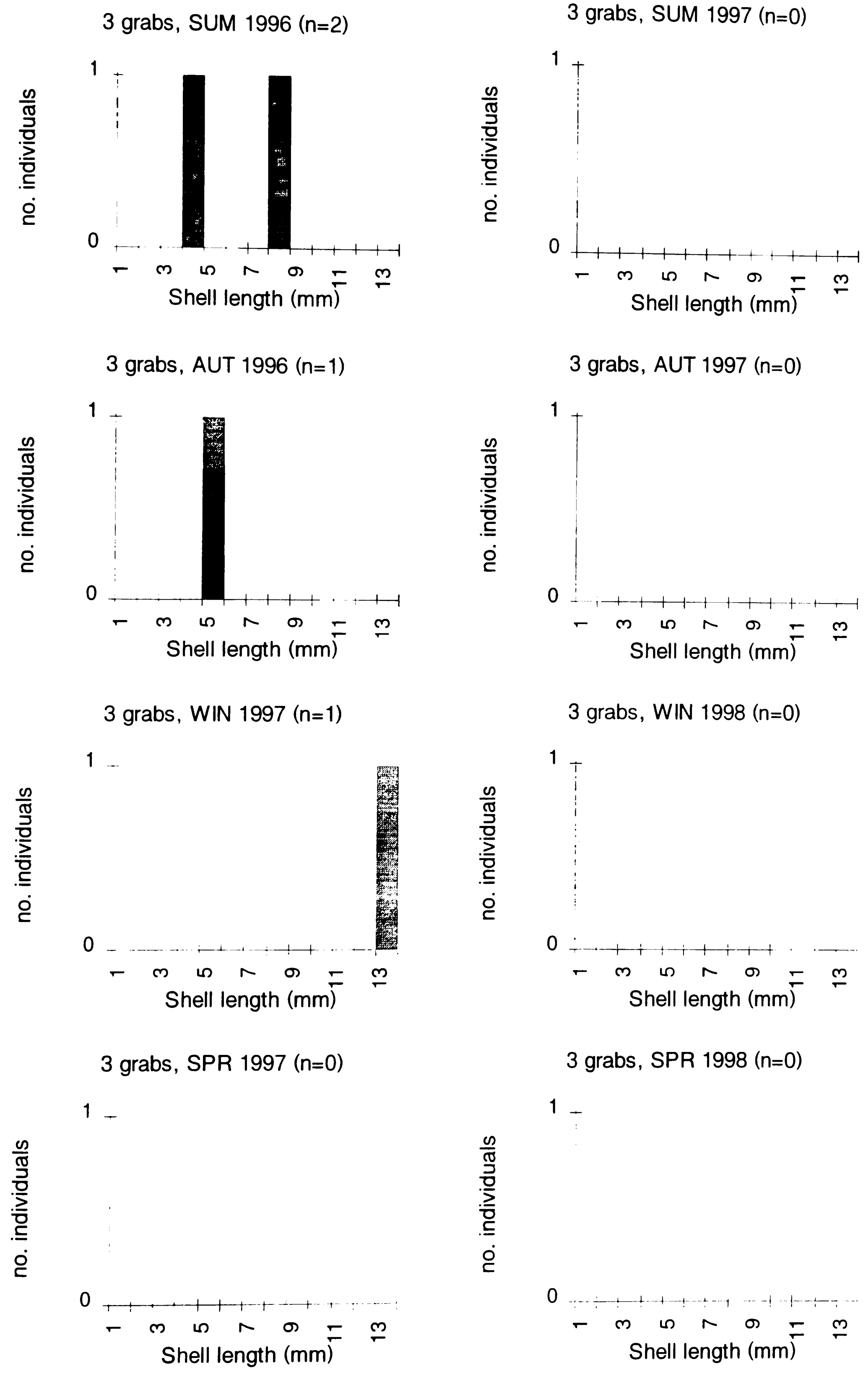
Haminoea hydatis was present in the first three seasonal samples from the control ground (summer and autumn 1996 and winter 1997) and it was absent from the other seasonal samples (Fig. 3.421). Even when it was present, the abundance of this opisthobranch was very low and it is not possible to detect any seasonal patterns.

Fig. 3.421. A) Mean number and B) Biomass (mg wet weight) of *H. hydatis* per $0.1m^2$ grab at UMC. Error bars = SD. Numbers above each column are mean values (n=3 replicates).



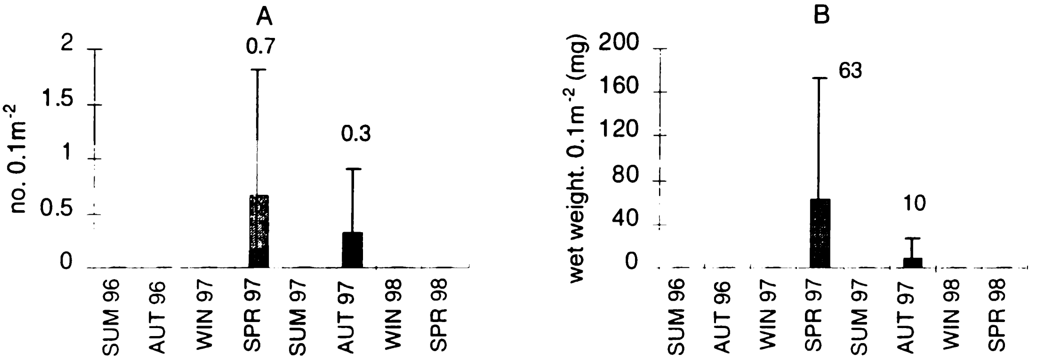
The seasonal variation in size frequency of *Haminoea hydatis* in the control ground is shown in Fig. 3.422. Very few individuals have been collected so it is not possible to detect any patterns in the size-frequency distribution of this species.

Fig. 3.422. Size-frequency histograms for *Haminoea hydatis* collected seasonally in $0.1m^2$ grabs at UMC from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring.



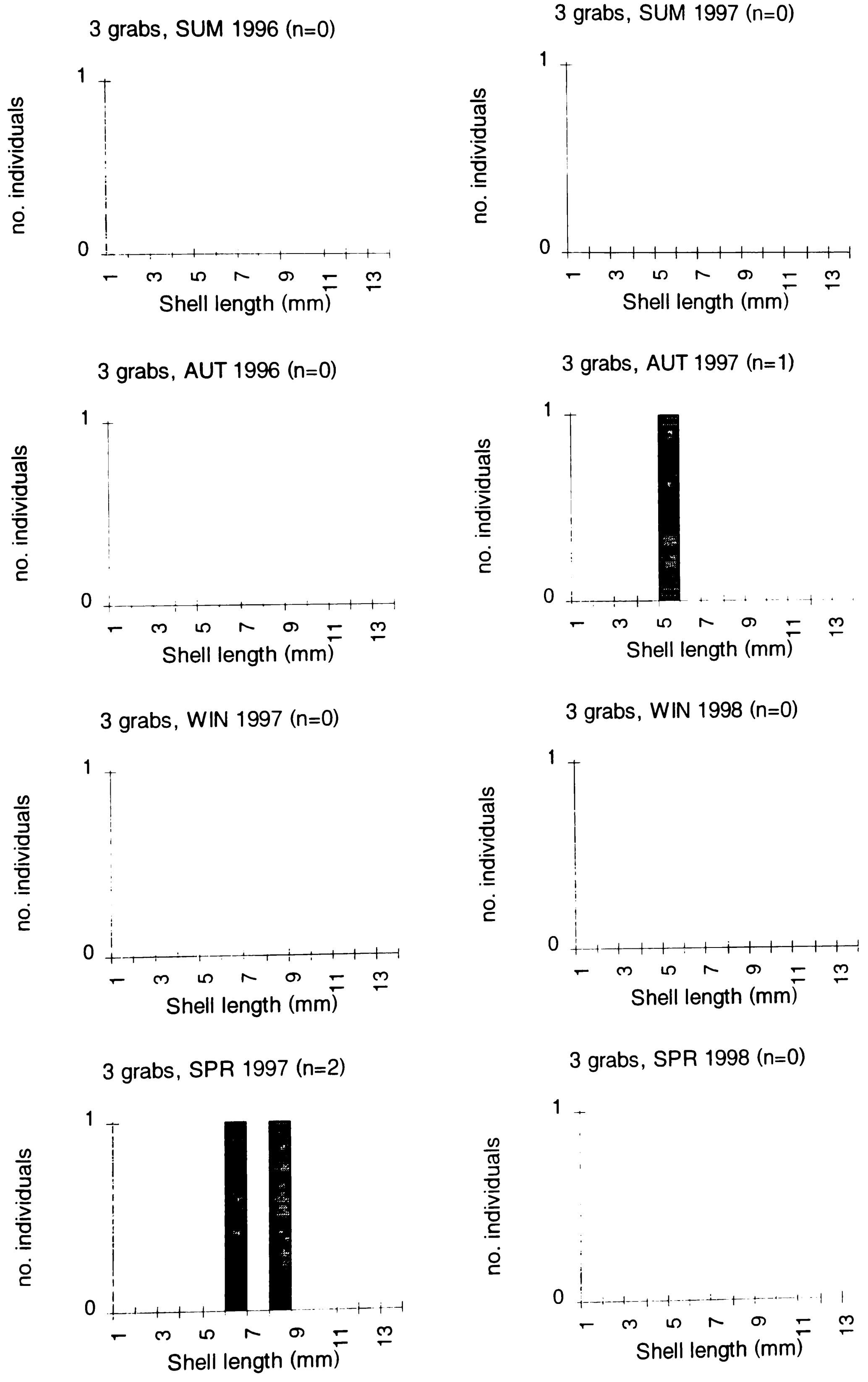
Haminoea hydatis was also very rare in the impacted site. It was present in only two seasonal samples (spring and autumn 1997) and the abundance was again very low (Fig. 3.423). No particular seasonal pattern in either abundance or biomass could thus be discerned.

Fig. 3.423. A) Mean number and B) Biomass (mg wet weight) of *H. hydatis* per 0.1m^2 grab at UMI. Error bars = SD. Numbers above each column are mean values (n = 3 replicates).



The seasonal variation in size frequency of *Haminoea hydatis* is shown in Fig. 3.424. As in the control ground, the number of individuals collected is too low to detect any patterns in the size-frequency distribution of this species.

Fig. 3.424. Size-frequency histograms for *Haminoea hydatis* collected seasonally in $0.1 m^2$ grabs at UMI from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring.



3 grabs, SUM 1996 (n=0)

3 grabs, SUM 1997 (n=0)

3 grabs, AUT 1996 (n=0)

3 grabs, AUT 1997 (n=1)

3 grabs, WIN 1997 (n=0)

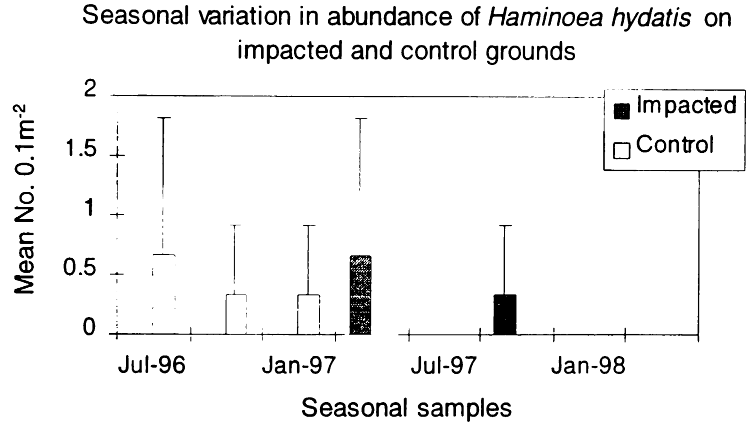
3 grabs, WIN 1998 (n=0)

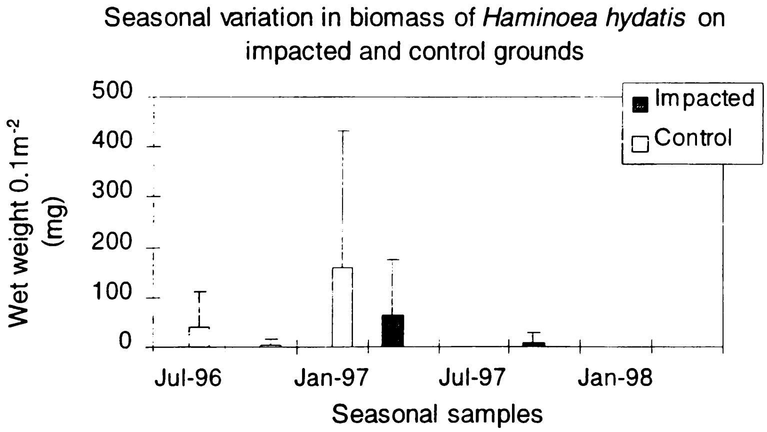
3 grabs, SPR 1997 (n=2)

3 grabs, SPR 1998 (n=0)

Figure 3.425 compares the abundance and biomass of *Haminoea hydatis* on the control and impacted sites. This species was collected from both sites in different seasons. It is a rare species and thus its collection depended mainly on chance.

Fig.3. 425.



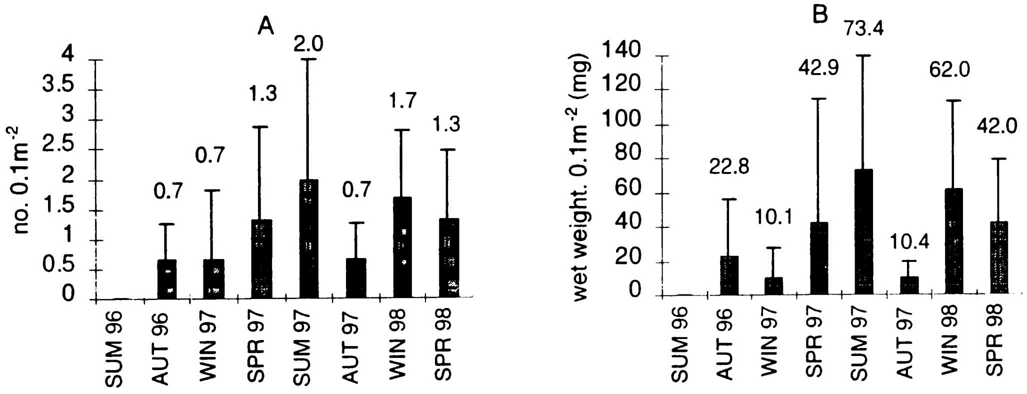


Pteromeris minuta (Scacchi, 1836)

Pteromeris minuta is a filter-feeding bivalve which was fairly common on Maltese maerl grounds. It was found at both the control and impacted sites and was present in nearly all the grab samples collected.

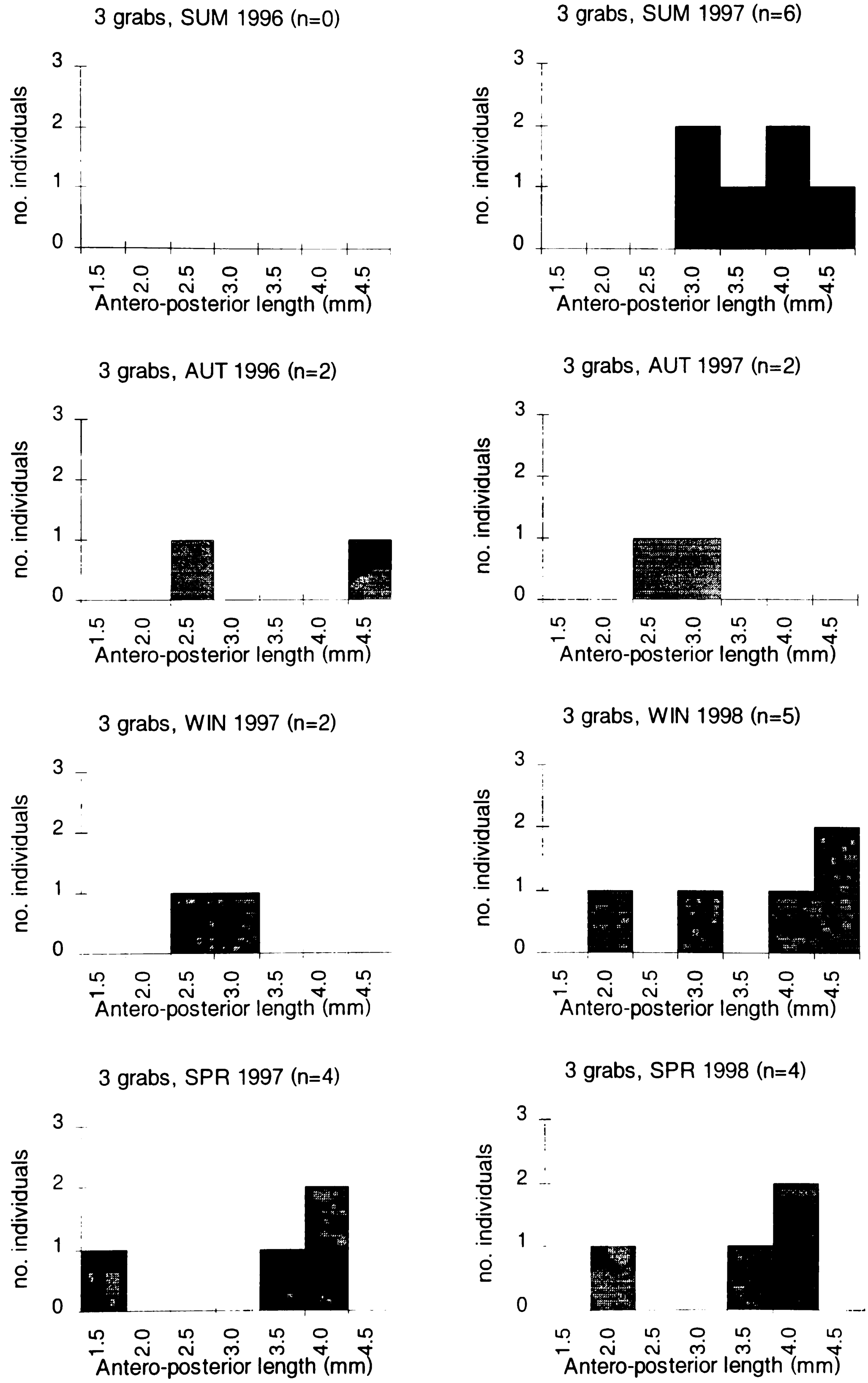
No particular seasonal pattern in abundance and biomass was observed for this species at the control ground (Fig. 3.426). Although it was absent in summer 1996, the highest value for the abundance and biomass of this species was obtained in summer 1997.

Fig. 3.426.A) Mean number and B) Biomass (mg wet weight) of *P. minuta* per 0.1m^2 grab at UMC. Error bars = SD. Numbers above each column are mean values (n=3 replicates).



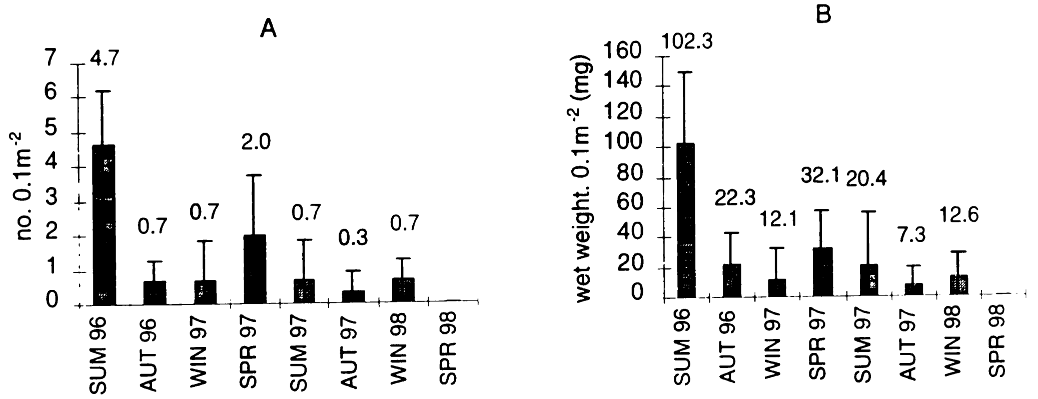
The seasonal variation in size frequency of *P. minuta* at the control ground is shown in Fig. 3.427. Small individuals (antero-posterior length = 1.5-2.0mm) were obtained in spring 1997 and 1998 and in winter 1998. However, due to the low number of individuals collected, no patterns in the size-frequency distribution could be detected.

Fig. 3.427. Size-frequency histograms for *Pteromeris minuta* collected seasonally in 0.1m^2 grabs at UMC from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring



The abundance of *Pteromeris minuta* at the impacted site was fairly constant throughout the seasons, except for a peak in summer 1996 and another in spring 1997. (Fig. 3.428). On the other hand it was not very abundant in summer 1997 and was absent in spring 1998. Thus, there is no evident seasonal pattern in either abundance or biomass of this species at the impacted site.

Fig. 3.428. A) Mean number and B) Biomass (mg wet weight) of *P. minuta* per $0.1m^2$ grab at UMI. Error bars = SD. Numbers above each column are mean values (n = 3 replicates).



The seasonal variation in size frequency of *P. minuta* at the impacted site is shown in Fig. 3.429. Small individuals (antero-posterior length = 1.5mm) were obtained in spring 1997. The number of individuals collected was too low, however, to detect any patterns in the size-frequency distribution of the species.

Fig. 3.429. Size-frequency histograms for *Pteromeris minuta* collected seasonally in $0.1m^2$ grabs at UMI from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring

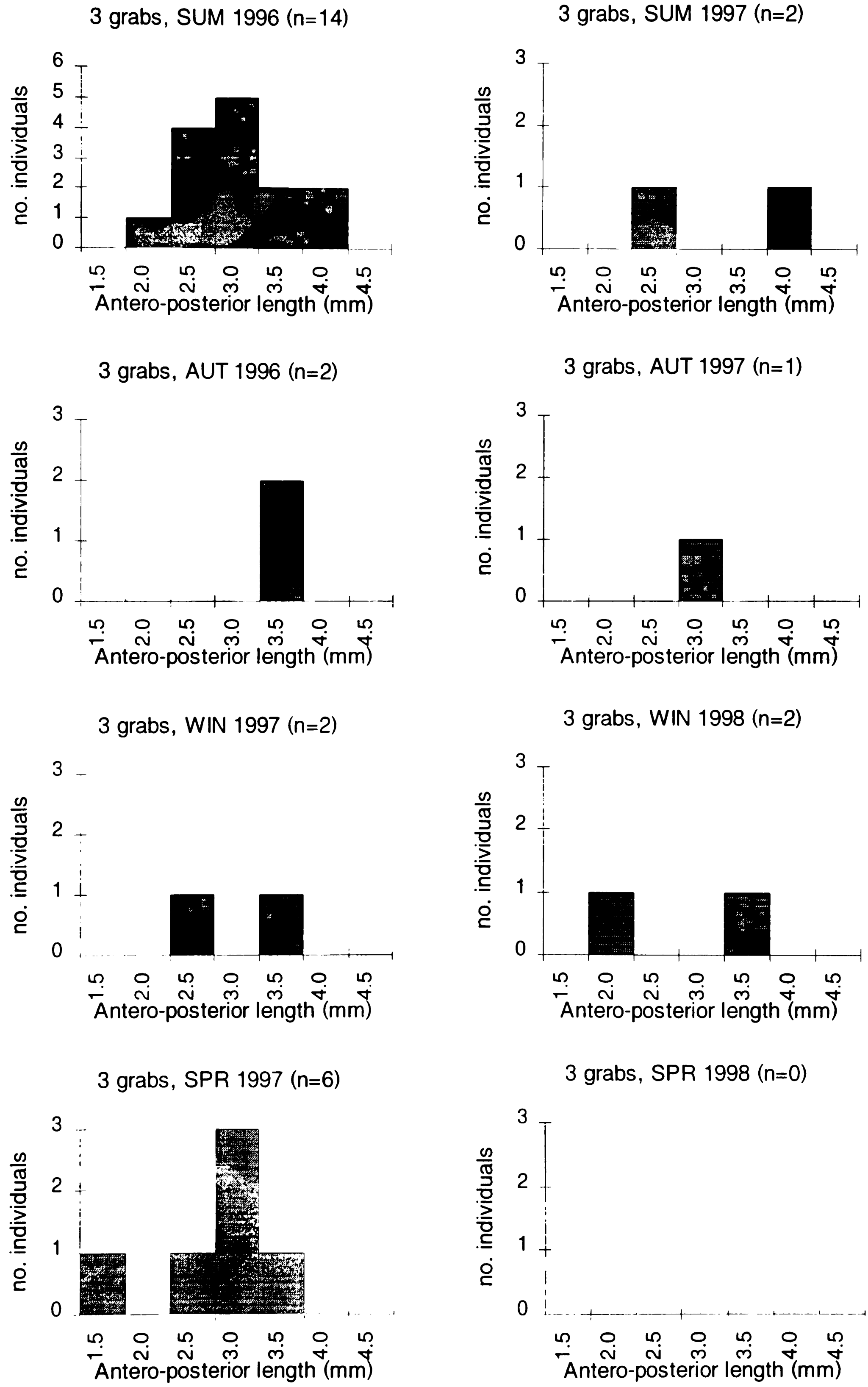
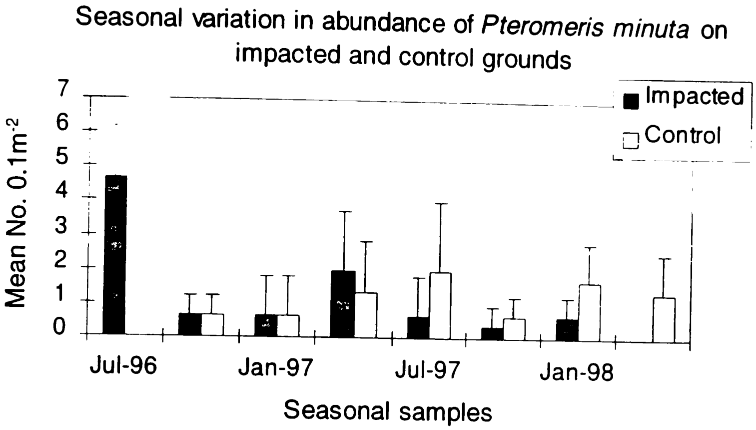
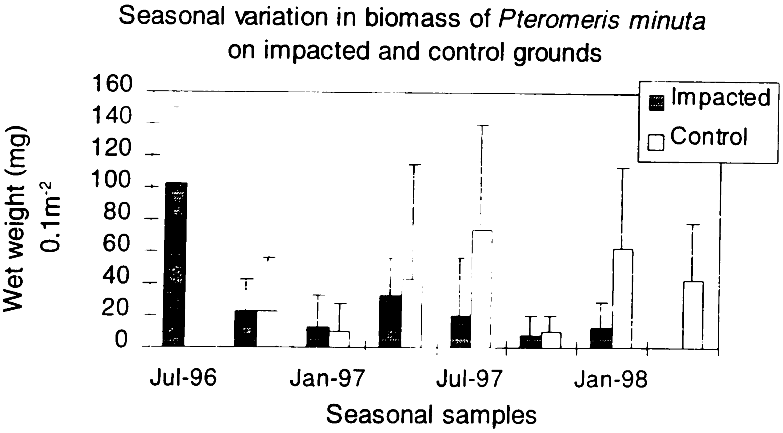


Figure 3.430 compares the abundance and biomass of *Pteromeris minuta* on the impacted and control sites. There seems to be no trend in either abundance or biomass of this bivalve. During the first sampling year it was more abundant at the impacted site, while the opposite was observed during the second year of sampling. The same can be said for the biomass.

Fig. 3.430.



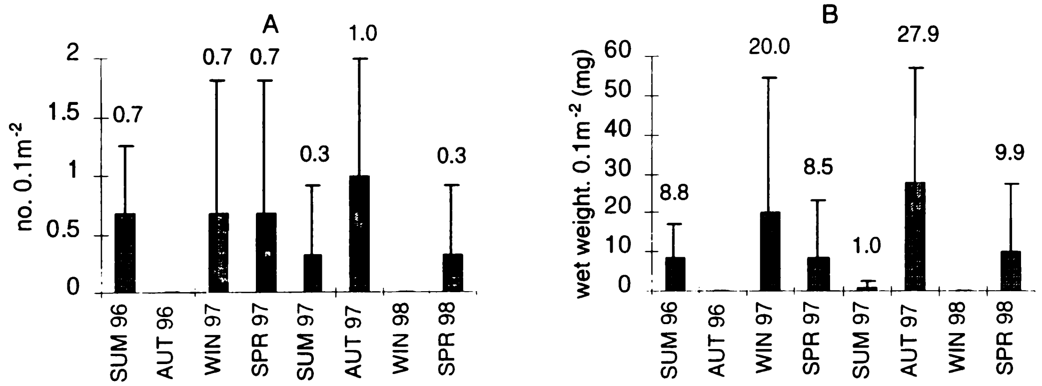


Digitaria digitaria (Linnaeus, 1758)

Digitaria digitaria was a relatively common bivalve on Maltese maerl grounds which was collected from both control and impacted sites. It is a very small (length c. 5mm) filter-feeding bivalve which finds shelter between the maerl thalli.

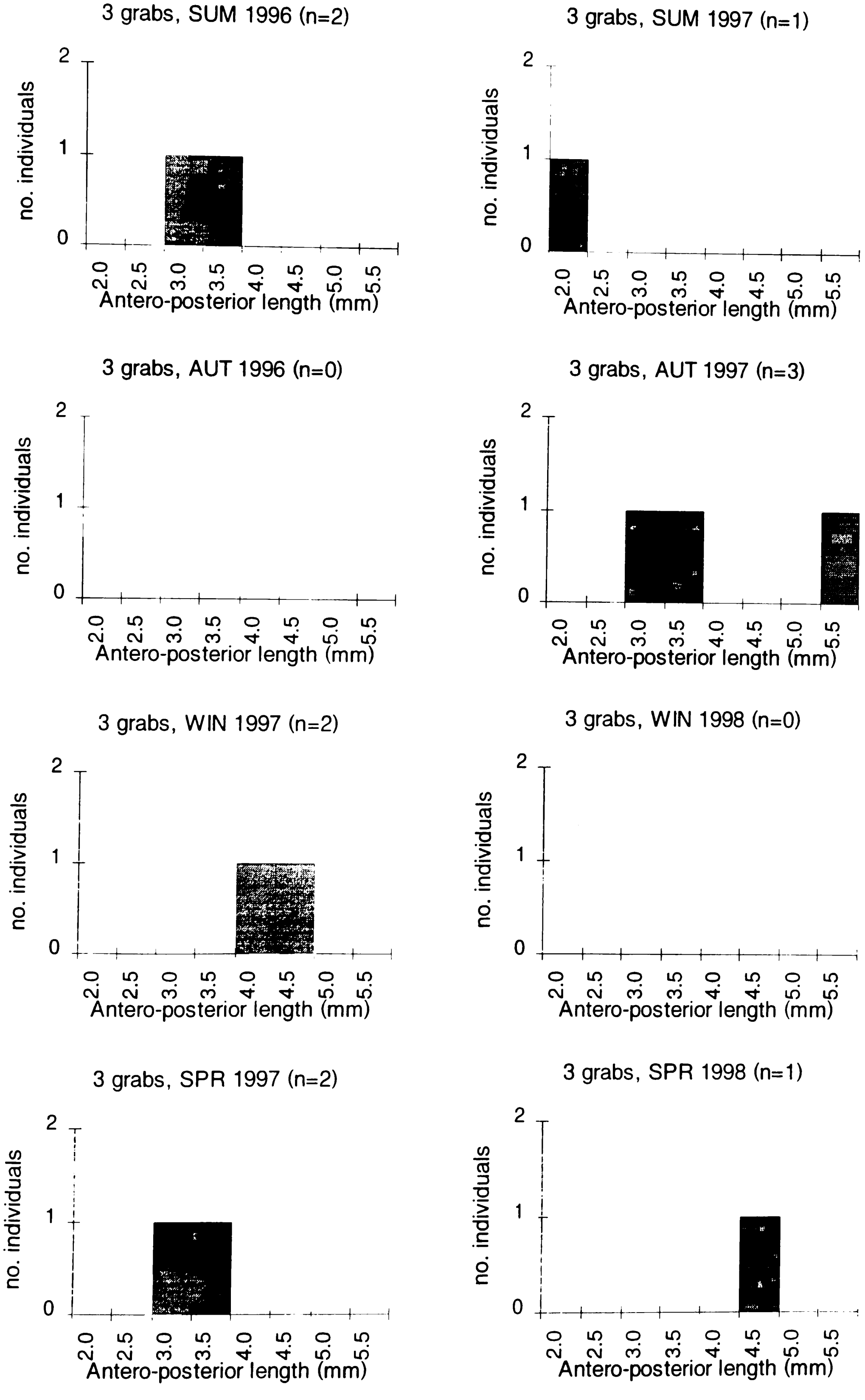
No particular seasonal pattern was observed in the abundance and biomass of this . species at the control site (Fig. 3.431). The highest value was obtained in autumn 1997 but was absent in autumn 1996.

Fig. 3.431. A) Mean number and B) Biomass (mg wet weight) of *D. digitaria* per 0.1m^2 grab at UMC. Error bars = SD. Numbers above each column are mean values (n=3 replicates).



The seasonal variation in size frequency of *Digitaria digitaria* at the control ground is shown in Fig. 3.432. Due to the low number of individuals collected, no patterns in the size-frequency distribution could be detected. The smallest individuals (antero-posterior length = 2.0mm) were collected in summer (summer 1997).

Fig. 3.432. Size-frequency histograms for *Digitaria digitaria* collected seasonally in 0.1m^2 grabs at UMC from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring.



3 grabs, SUM 1996 (n=2)

3 grabs, SUM 1997 (n=1)

3 grabs, AUT 1996 (n=0)

3 grabs, AUT 1997 (n=3)

3 grabs, WIN 1997 (n=2)

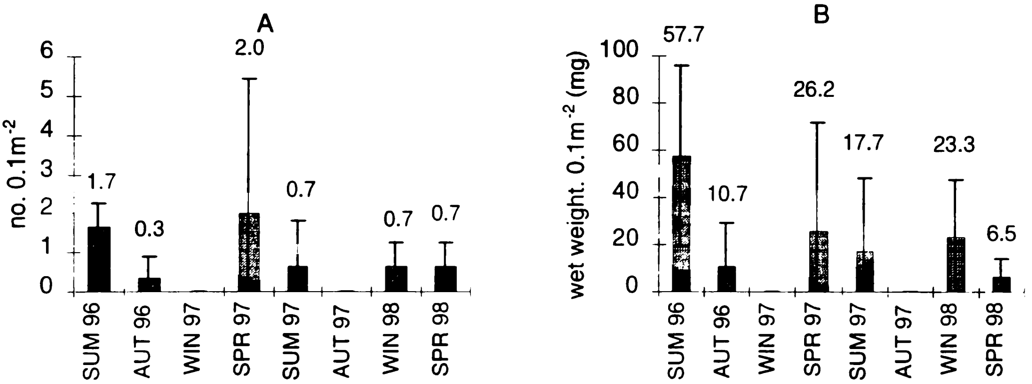
3 grabs, WIN 1998 (n=0)

3 grabs, SPR 1997 (n=2)

3 grabs, SPR 1998 (n=1)

Again, no particular seasonal pattern in either abundance or biomass can be observed for *Digitaria digitaria* at the impacted site (Fig. 3.433). The highest value was obtained in spring 1997, but was not repeated in spring 1998. In summer 1997, winter and spring 1998, it was collected in very low, but comparable, numbers and there was no significant variation in abundance between these seasonal samples.

Fig. 3.433. A) Mean number and B) Biomass (mg wet weight) of *D. digitaria* per $0.1m^2$ grab at UMI. Error bars = SD. Numbers above each column are mean values (n=3 replicates).



The seasonal variation in size frequency of *Digitaria digitaria* at the impacted ground is shown in Fig. 3. 434. Due to the low number of individuals collected, no patterns in the size-frequency distribution could be detected. The smallest individuals (antero-posterior length = 2.0mm) were collected in spring (spring 1997).

Fig. 3.434. Size-frequency histograms for *Digitaria digitaria* collected seasonally in $0.1m^2$ grabs at UMI from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring.

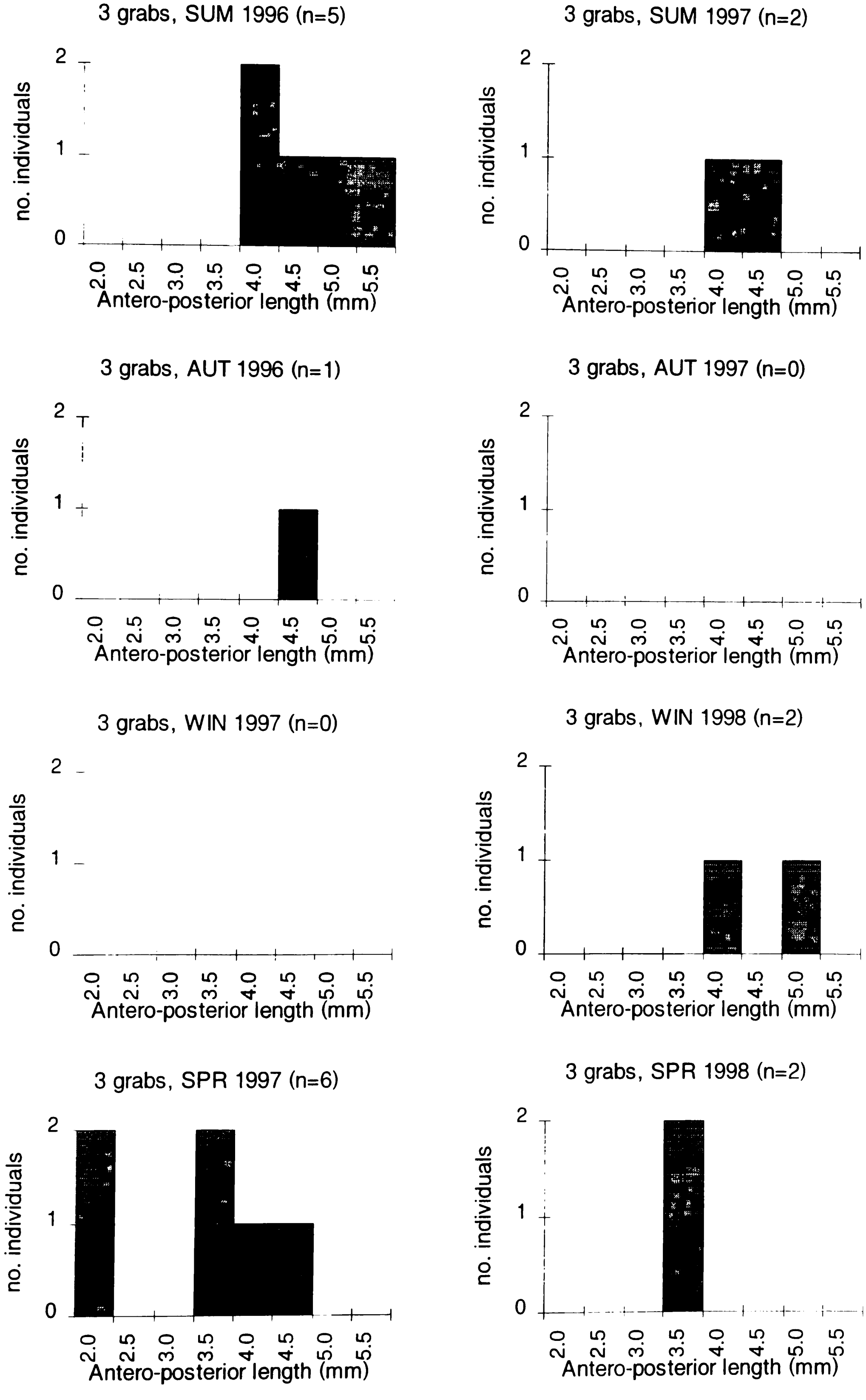
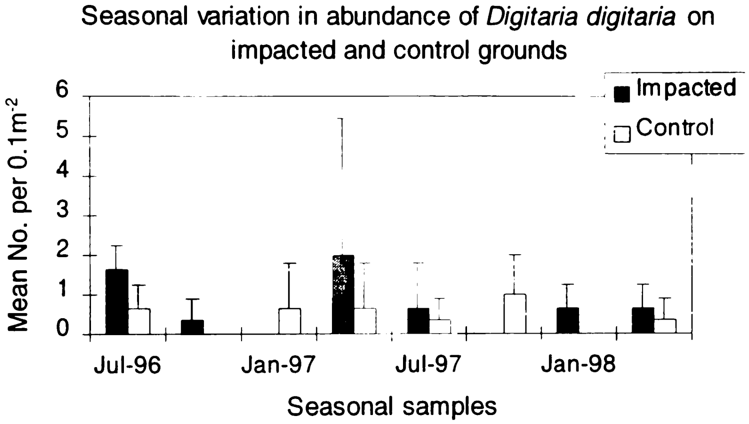
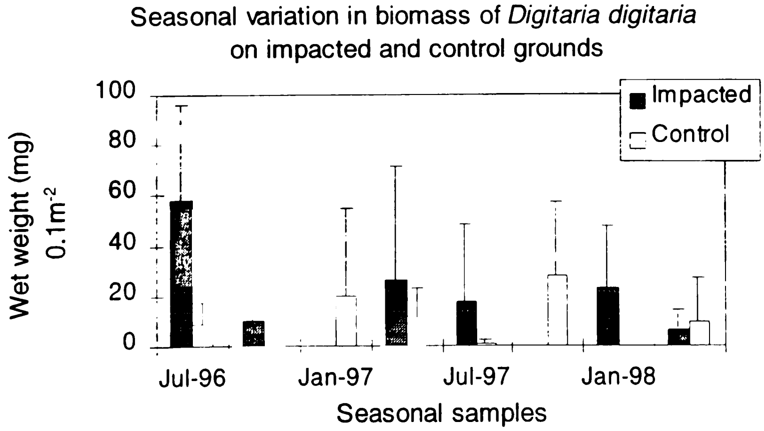


Figure 3.435 compares the abundance and biomass of *Digitaria digitaria* on the impacted and control sites. In general this species was more abundant at the impacted site, but in some seasonal samples (autumn 1996 and winter 1998) it was absent from the impacted and present on the control ground. For biomass, the same trend was observed, except that in spring 1998 biomass was higher at the control site.

Fig. 3.435.



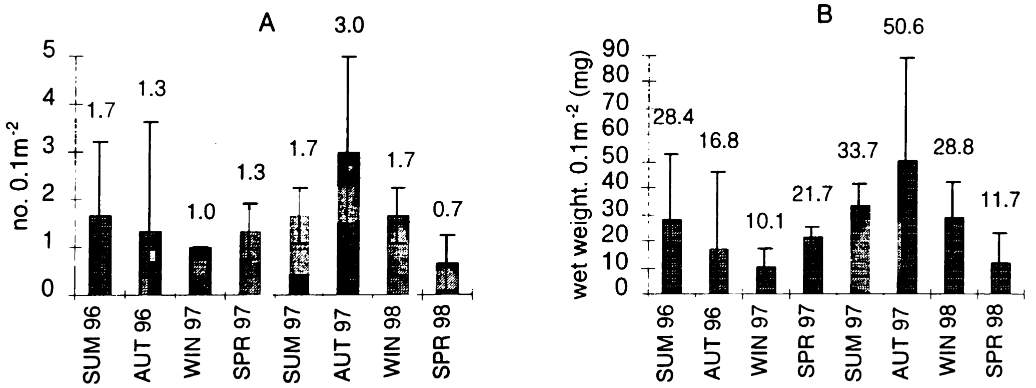


Gonilia calliglypta (Dall, 1903)

Gonilia calliglypta was one of the most common bivalves on Maltese maerl grounds. It was collected from both control and impacted sites in most of the grab samples. It is a filter-feeding bivalve.

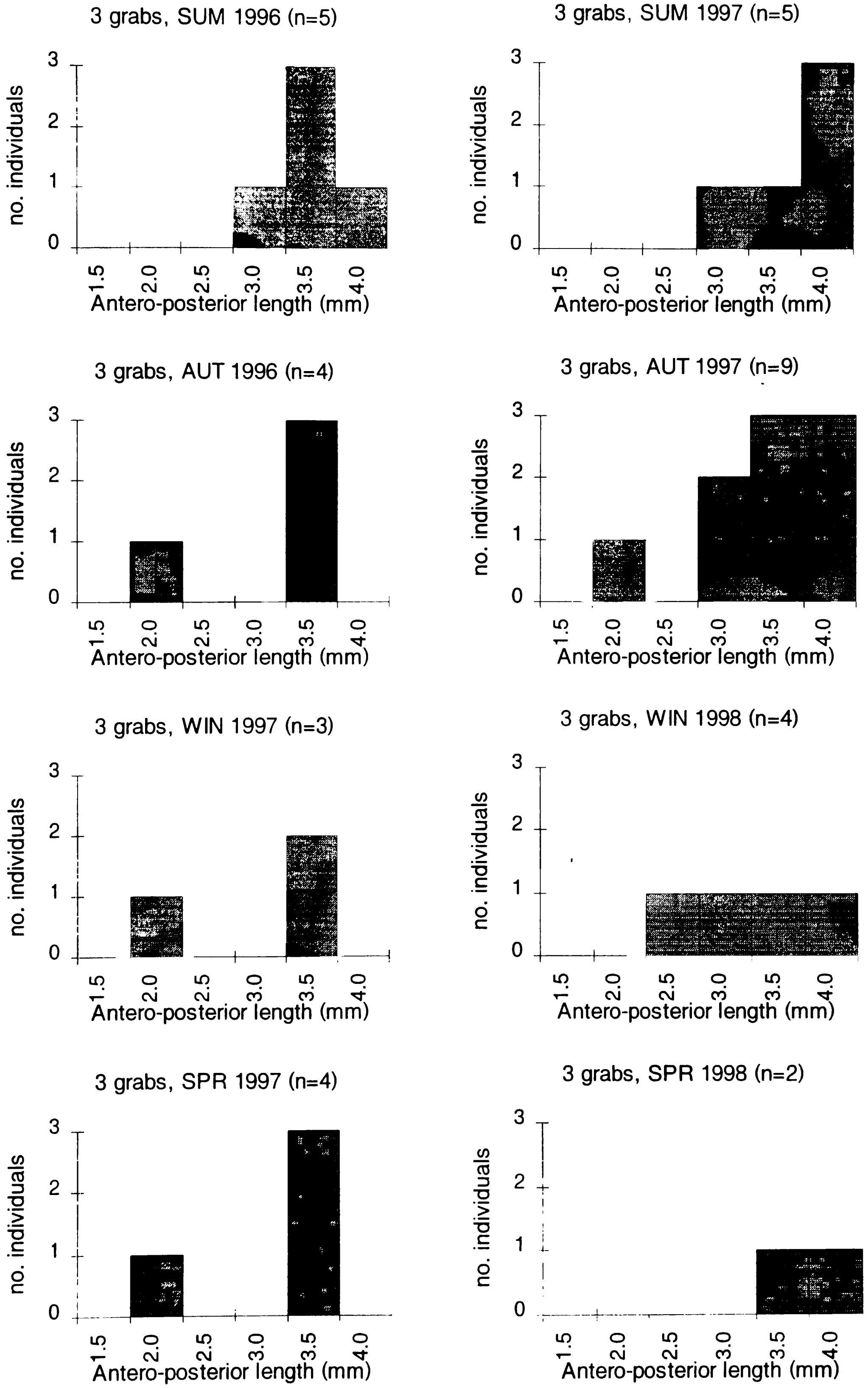
This species was very common on the control ground, being present in all the seasonal samples (Fig. 3.436). Still, no particular seasonal pattern was observed. The highest value for both abundance and biomass was obtained in autumn 1997, but no equivalent peak was observed in autumn 1996.

Fig. 3.436.A) Mean number and B) Biomass (mg wet weight) of *G. calliglypta* per 0.1m^2 grab at UMC. Error bars = SD. Numbers above each column are mean values (n=3 replicates).



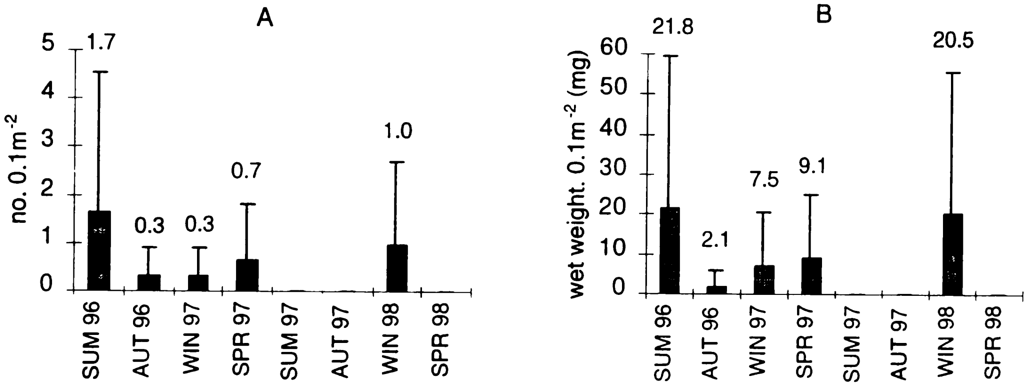
The seasonal variation in size frequency of *G. calliglypta* at the control ground is shown in Fig. 3. 437. Due to the low number of individuals collected, no patterns in the size-frequency distribution could be detected.

Fig. 3.437. Size-frequency histograms for *Gonilia calliglypta* collected seasonally in $0.1 m^2$ grabs at UMC from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring.



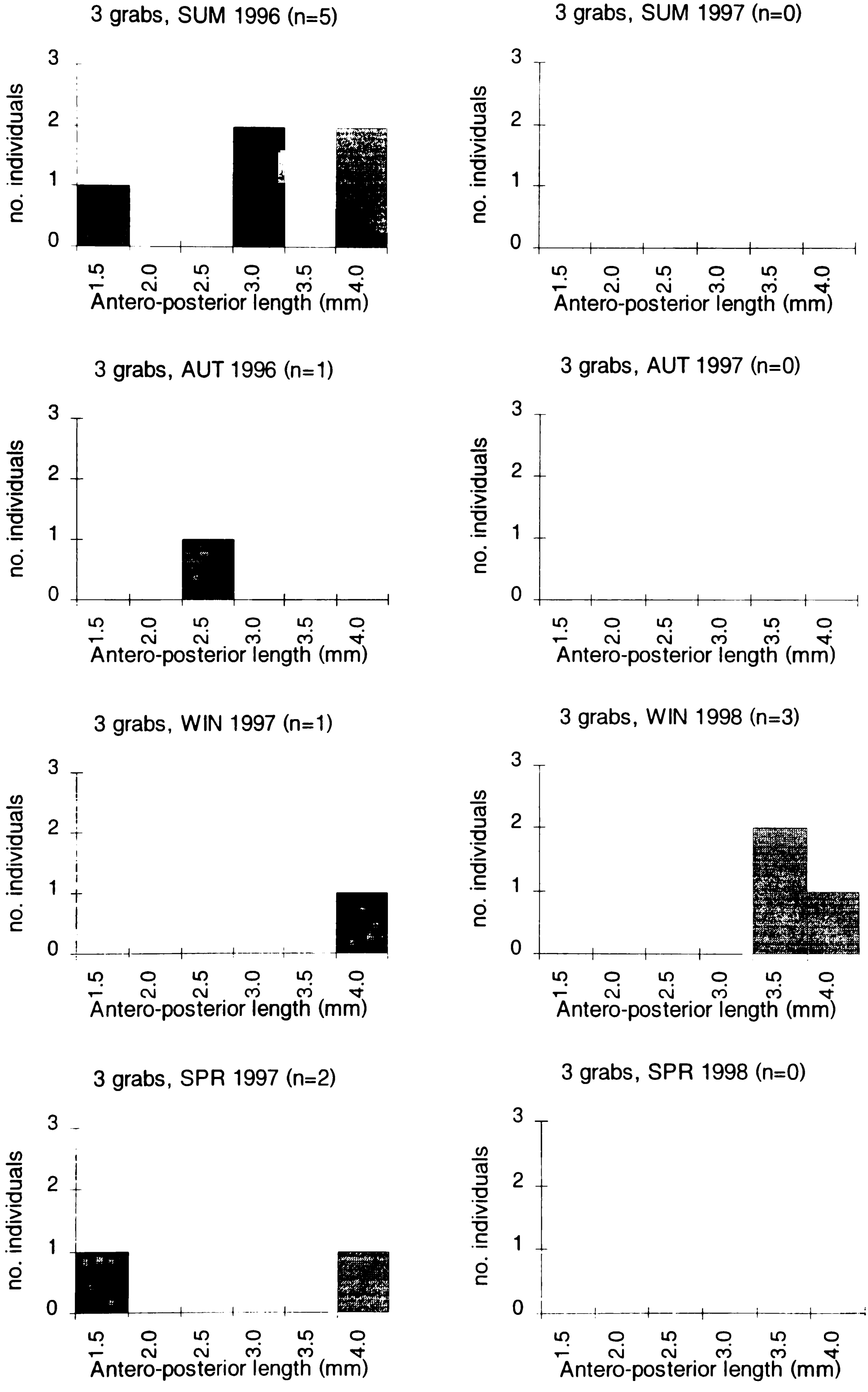
Gonilia calliglypta was not very abundant at the impacted site and it was collected mainly during the first year of sampling (Fig. 3.438). Due to the low number of individuals collected, no particular seasonal pattern can be observed.

Fig. 3.438.A) Mean number and B) Biomass (mg wet weight) of *G. calliglypta* per $0.1m^2$ grab at UMI. Error bars = SD. Numbers above each column are mean values (n=3 replicates).



The seasonal variation in size frequency of *G. calliglypta* at the impacted ground is shown in Fig. 3.439. Again, due to the low number of individuals collected, no patterns in the size-frequency distribution could be detected. The smallest individuals (antero-posterior length = 1.5mm) occurred in spring and summer (summer 1996, spring 1997).

Fig. 3.439. Size-frequency histograms for *Gonilia calliglypta* collected seasonally in 0.1m^2 grabs at UMI from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring.



3 grabs, SUM 1996 (n=5)

3 grabs, SUM 1997 (n=0)

3 grabs, AUT 1996 (n=1)

3 grabs, AUT 1997 (n=0)

3 grabs, WIN 1997 (n=1)

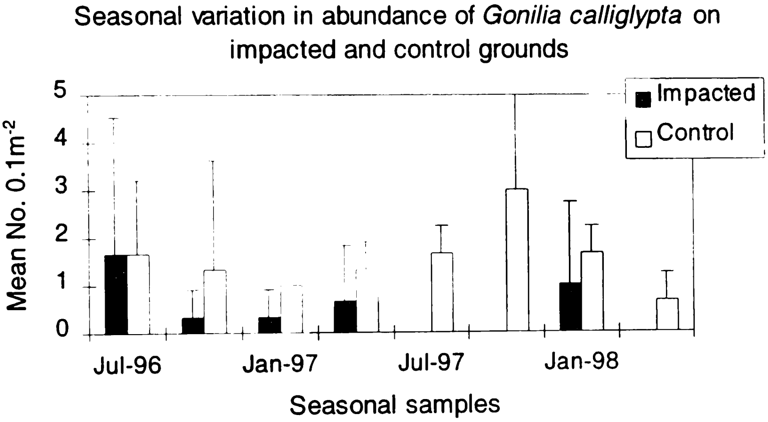
3 grabs, WIN 1998 (n=3)

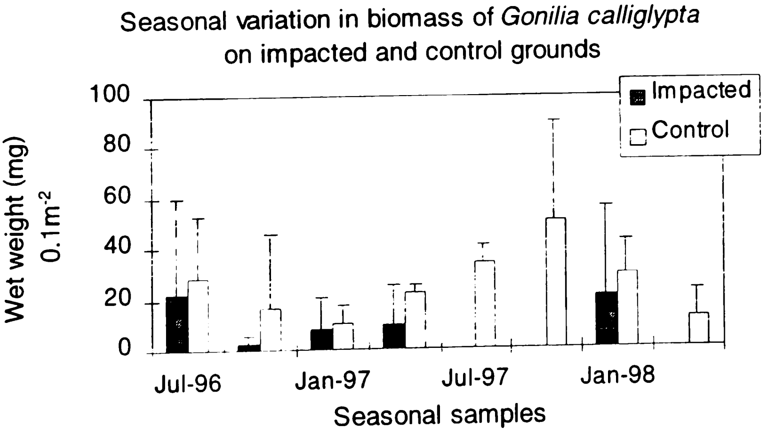
3 grabs, SPR 1997 (n=2)

3 grabs, SPR 1998 (n=0)

Figure 3.440 compares the abundance and biomass of *Gonilia calliglypta* on the impacted and control sites. This species was more abundant and had a higher biomass at the control site where it was present in all the seasonal samples.

Fig. 3.440.



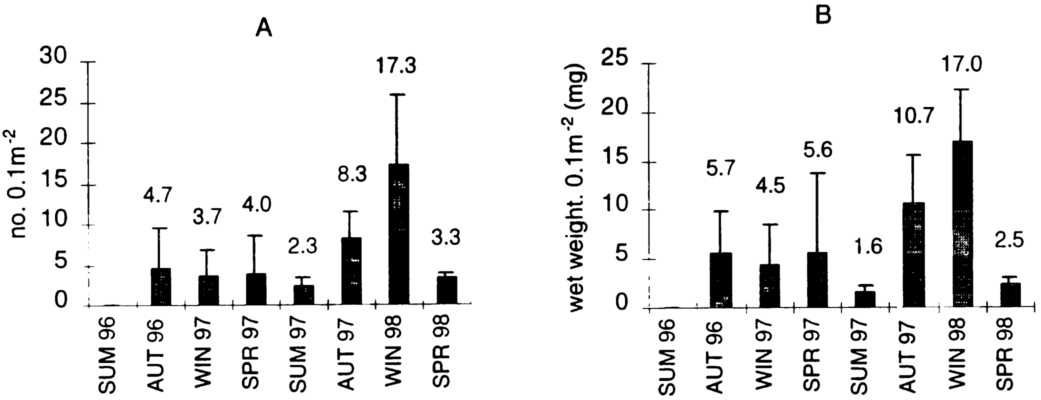


Leptochelia savignyi (Kröyer, 1842)

Leptochelia savignyi was common on the Maltese maerl grounds studied, especially at the control site. This tanaid is known to build tubes which are attached to solid substrata. *Leptochelia savignyi* is probably a deposit- or suspension-feeder (or both).

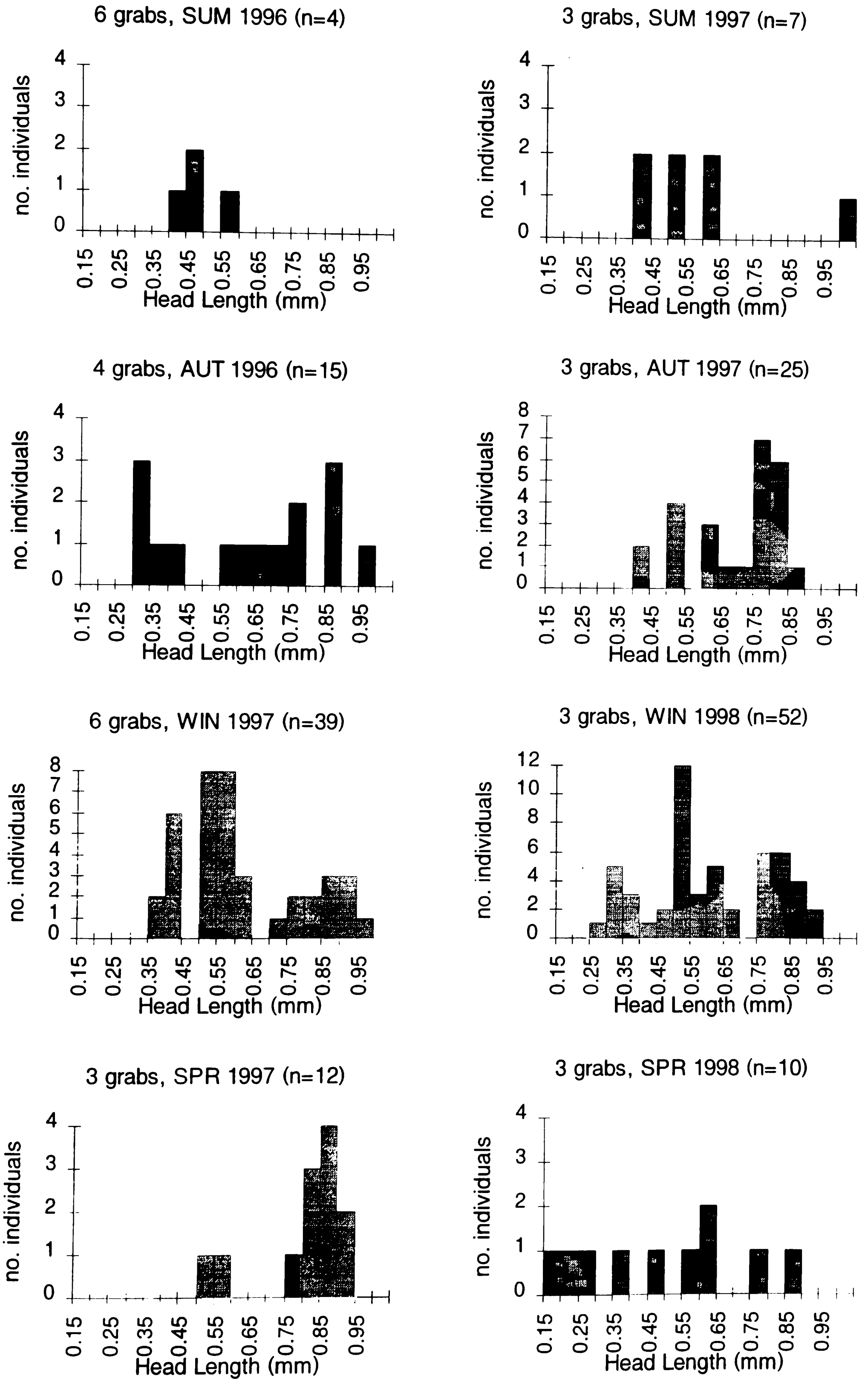
No particular seasonal pattern was observed in either abundance or biomass of this species at the control ground (Fig. 3.441). However, a minimum value was obtained in summer 1997 and it was absent (from three grabs) in summer 1996. Thus its abundance seems to decrease during summer. The highest value was obtained in winter 1998, but *L. savignyi* was not particularly abundant in winter 1997.

Fig. 3.441. A) Mean number and B) Biomass (mg wet weight) of *L. savignyi* per $0.1m^2$ grab at UMC. Error bars = SD. Numbers above each column are mean values (n=3 replicates).



The seasonal variation in size frequency of *L. savignyi* at the control site is shown in Fig. 3.442. Small individuals (head length = 0.15-0.20mm) were more frequent in spring 1998. However no patterns in the size-frequency distribution could be detected.

Fig. 3.442. Size-frequency histograms for *Leptochelia savignyi* collected seasonally in 0.1m^2 grabs at UMC from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring.



6 grabs, SUM 1996 (n=4)

3 grabs, SUM 1997 (n=7)

4 grabs, AUT 1996 (n=15)

3 grabs, AUT 1997 (n=25)

6 grabs, WIN 1997 (n=39)

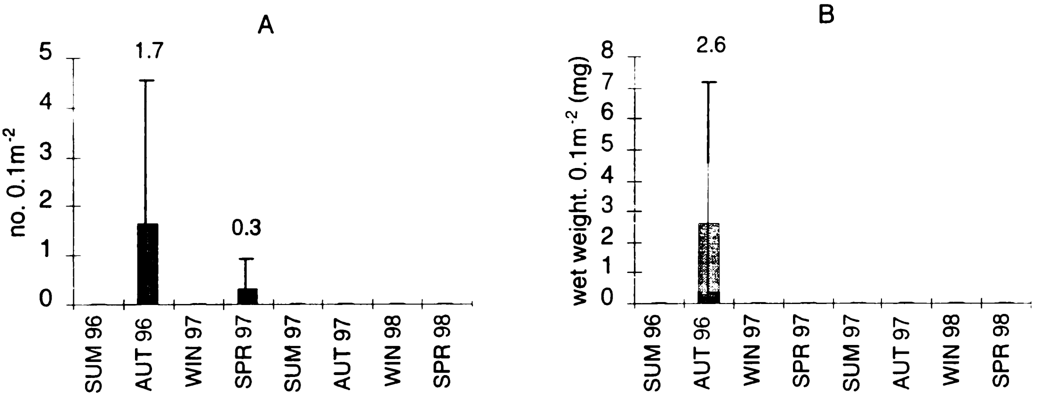
3 grabs, WIN 1998 (n=52)

3 grabs, SPR 1997 (n=12)

3 grabs, SPR 1998 (n=10)

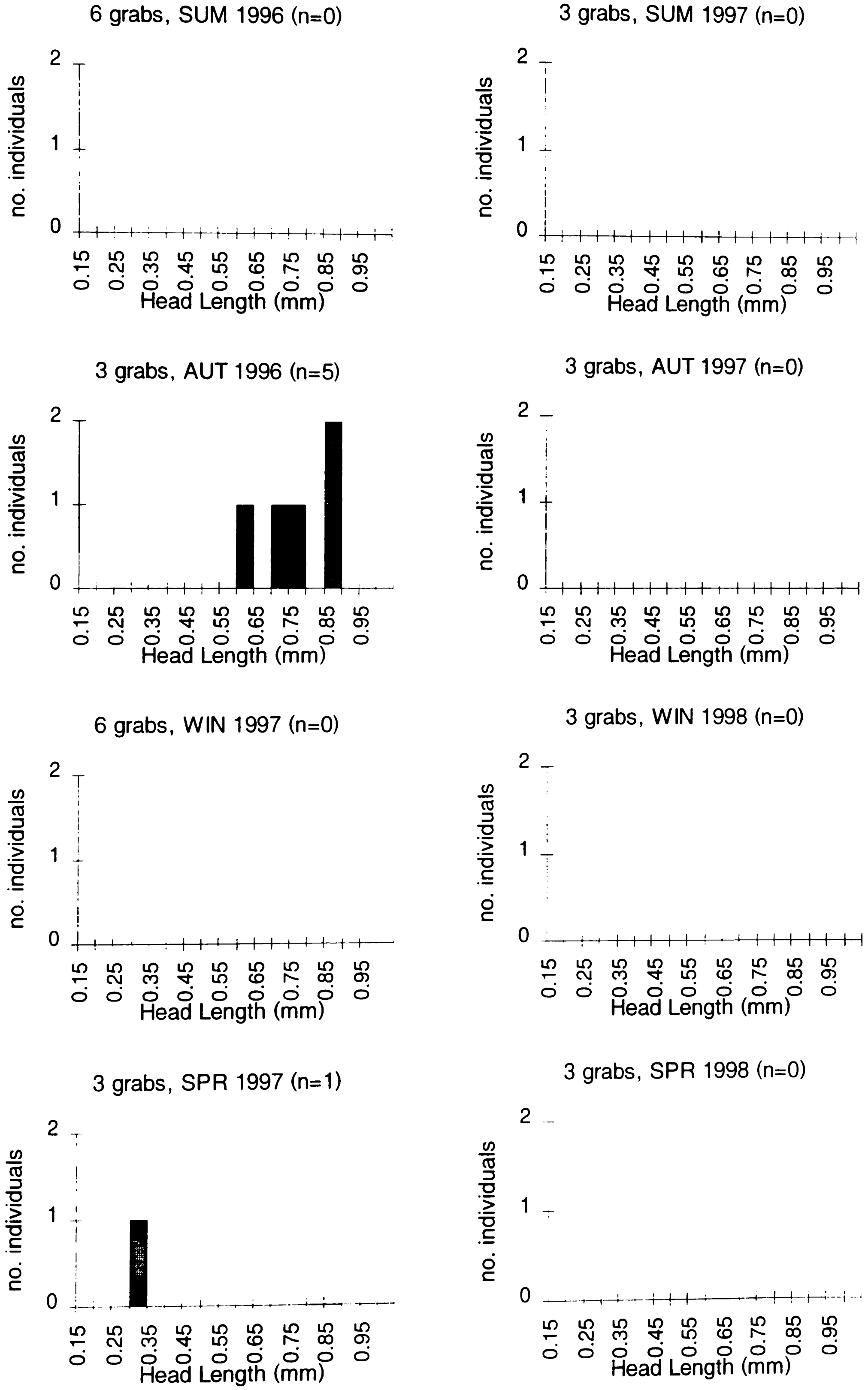
Leptochelia savignyi was very rare at the impacted site and was collected from only two seasonal samples (autumn 1996 and spring 1997) in very low numbers (Fig. 3.443). No seasonal pattern in either abundance or biomass could thus be detected.

Fig. 3.443. A) Mean number and B) Biomass (mg wet weight) of *L. savignyi* per $0.1m^2$ grab at UMI. Error bars = SD. Numbers above each column are mean values (n=3 replicates).



The seasonal variation in size frequency of *L. savignyi* at the impacted site is shown in Fig. 3.444. Due to the low number of individuals collected, no patterns in the size-frequency distribution could be detected.

Fig. 3.444. Size-frequency histograms for *Leptochelia savignyi* collected seasonally in 0.1m^2 grabs at UMI from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring.



6 grabs, SUM 1996 (n=0)

3 grabs, SUM 1997 (n=0)

3 grabs, AUT 1996 (n=5)

3 grabs, AUT 1997 (n=0)

6 grabs, WIN 1997 (n=0)

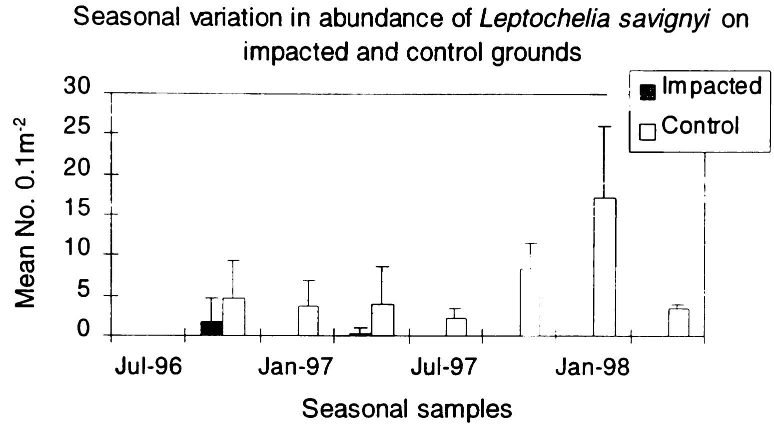
3 grabs, WIN 1998 (n=0)

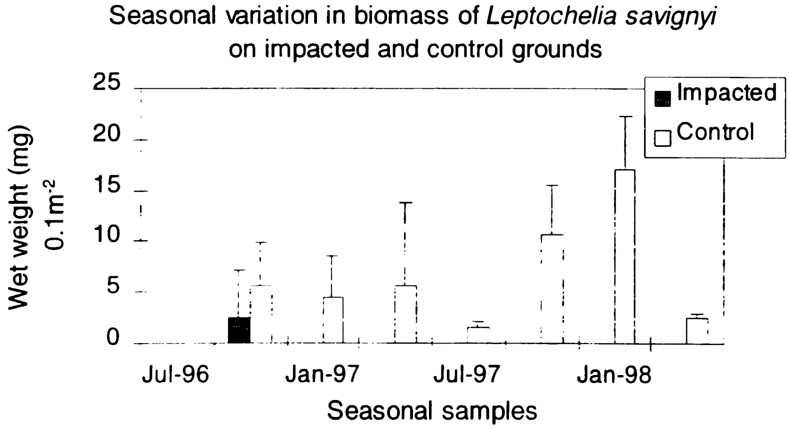
3 grabs, SPR 1997 (n=1)

3 grabs, SPR 1998 (n=0)

Figure 3.445 compares the abundance and biomass of *Leptochelia savignyi* on the impacted and control sites. This tanaid was much more abundant at the control site, . where it is quite common. It was very rare at the impacted site.

Fig. 3.445.



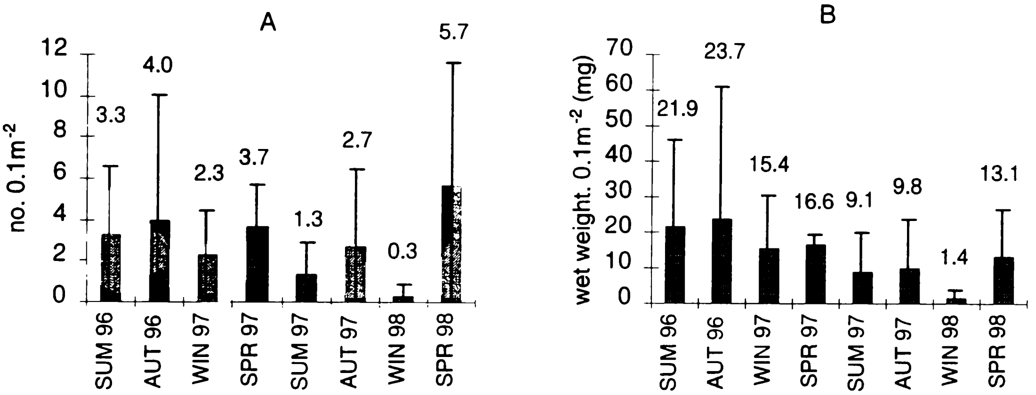


Maera grossimana **(Montagu, 1808)**

Maera grossimana was one of the most common amphipods on the Maltese maerl grounds studied. It was found on both the control and impacted sites and was present in nearly all the grab samples collected. There is little information about the feeding habits of this crustacean, but it is probably a deposit feeder.

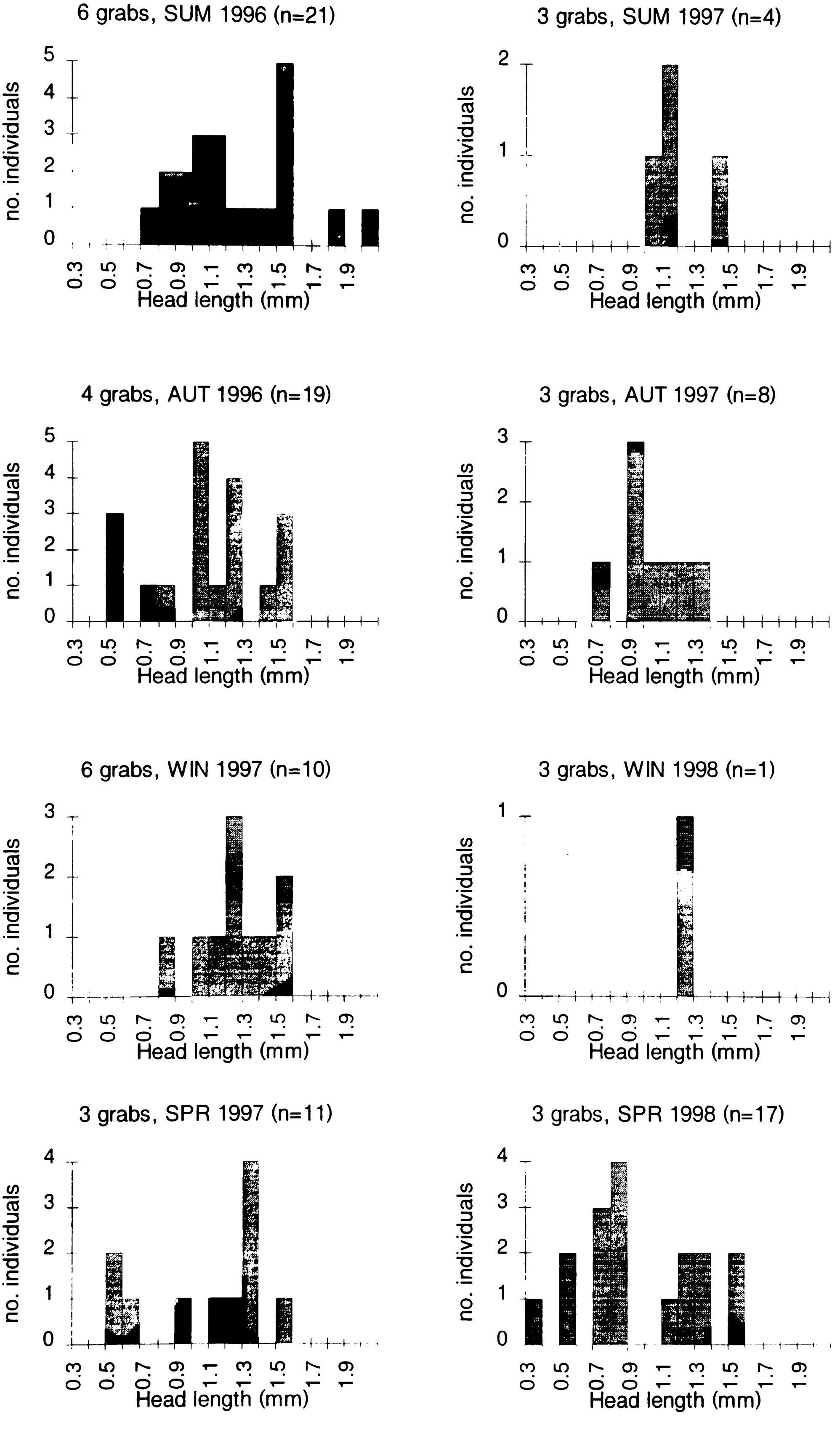
No particular seasonal pattern was observed in either abundance or biomass of this species at the control ground (Fig. 3.446). However, the lowest values for both parameters during the two years were obtained in winter.

Fig. 3.446.A) Mean number and B) Biomass (mg wet weight) of *M. grossimana* per 0.1m^2 grab at UMC. Error bars = SD. Numbers above each column are mean values (n=3 replicates).



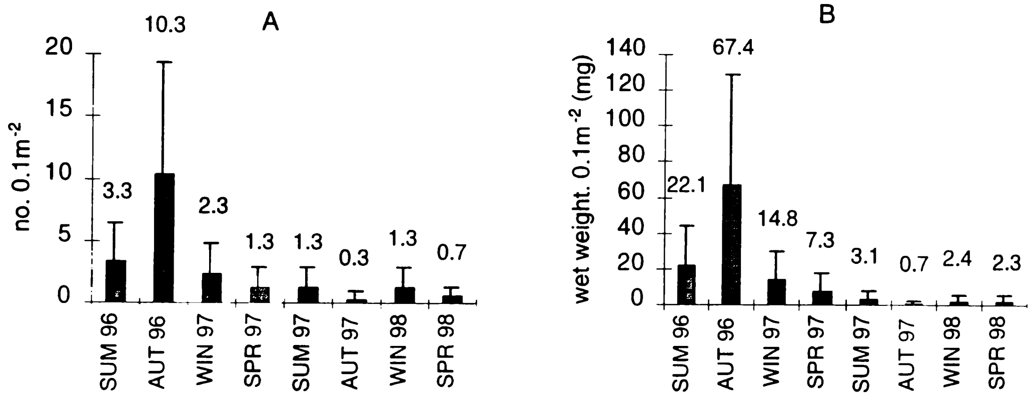
The seasonal variation in size frequency of *M. grossimana* at the control site is shown in Fig. 3.447. Small individuals (head length = 0.3-0.5mm) were more frequent in spring. However due to the low number of individuals collected, no patterns in the size-frequency distribution could be detected.

Fig. 3.447. Size-frequency histograms for *Maera grossimana* collected seasonally in $0.1 m^2$ grabs at UMC from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring.



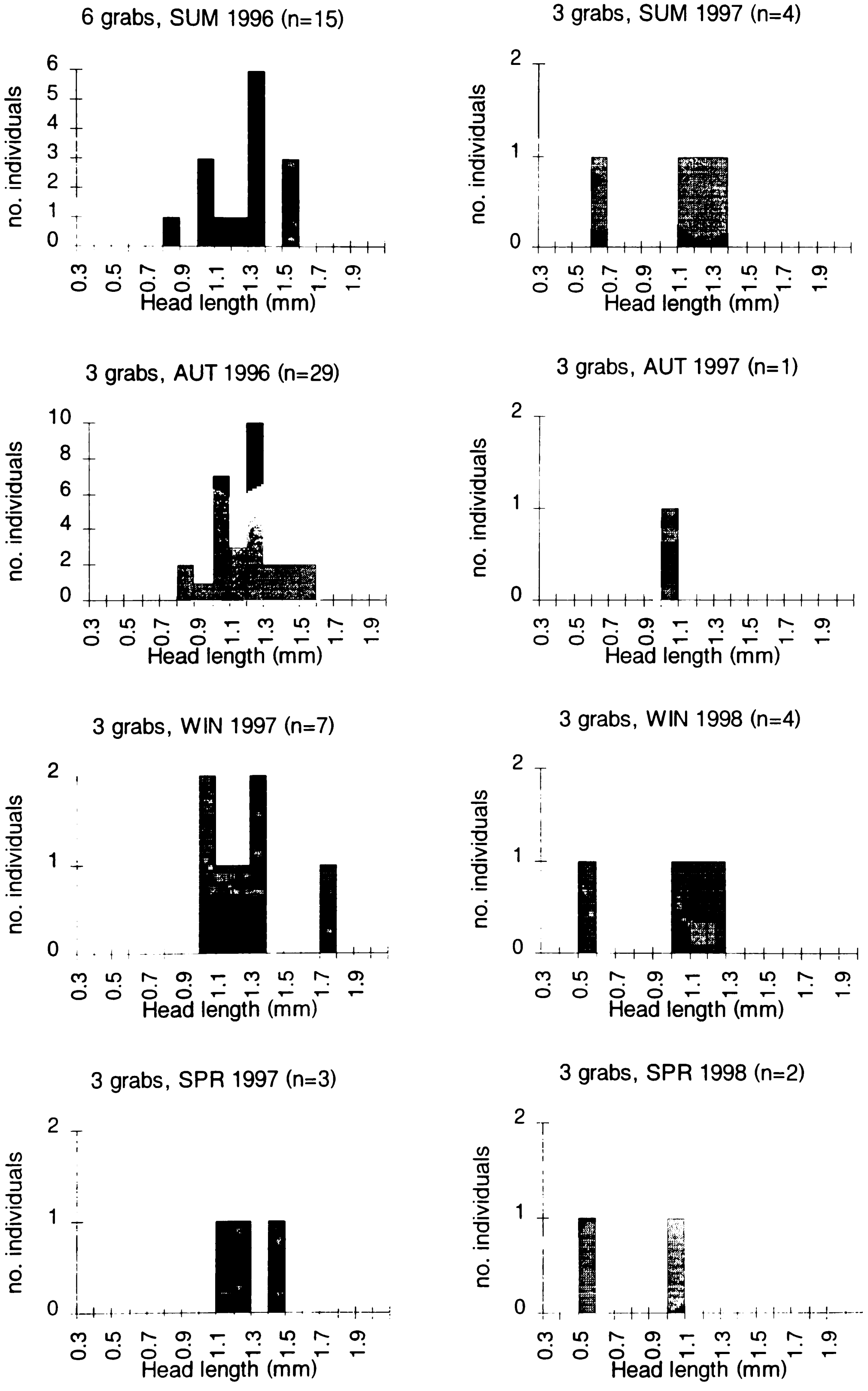
As in the control ground, there is no evident seasonal pattern in the abundance and biomass of *Maera grossimana* at the impacted site (Fig. 3.448). The highest value was obtained in autumn 1996, but this peak was not repeated in autumn 1997. Instead, the lowest value was obtained in autumn 1997.

Fig. 3.448. A) Mean number and B) Biomass (mg wet weight) of *M. grossimana* per 0.1m^2 grab at UMI. Error bars = SD. Numbers above each column are mean values (n=3 replicates).



The seasonal variation in size frequency of *M. grossimana* at the impacted site is shown in Fig. 3.449. Due to the low number of individuals collected, no patterns in the size-frequency distribution could be detected.

Fig. 3.449. Size-frequency histograms for *Maera grossimana* collected seasonally in $0.1m^2$ grabs at UMI from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring.



6 grabs, SUM 1996 (n=15)

3 grabs, SUM 1997 (n=4)

3 grabs, AUT 1996 (n=29)

3 grabs, AUT 1997 (n=1)

3 grabs, WIN 1997 (n=7)

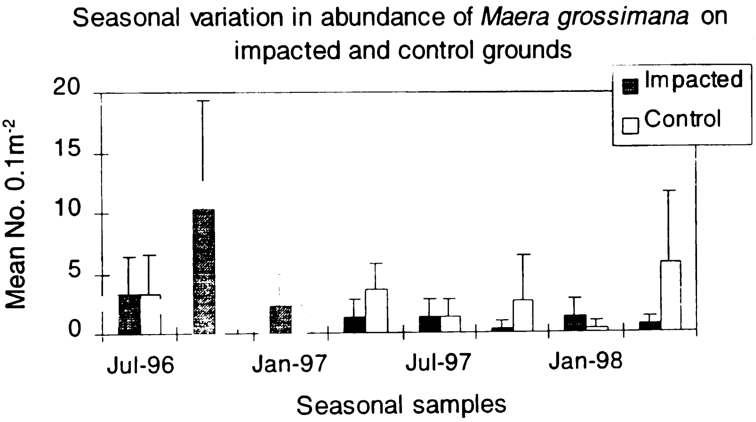
3 grabs, WIN 1998 (n=4)

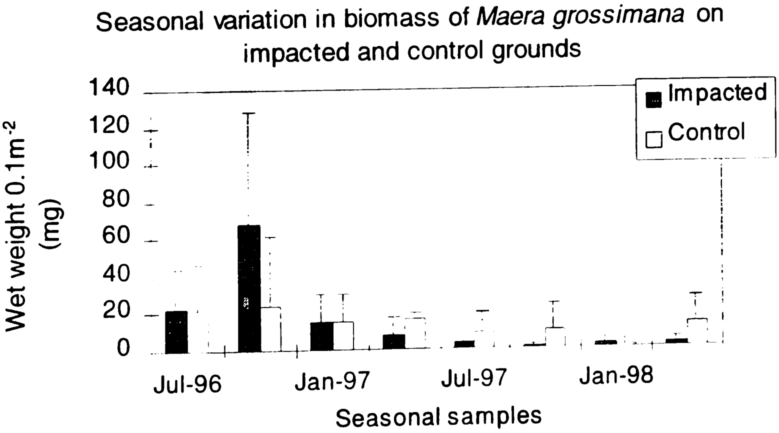
3 grabs, SPR 1997 (n=3)

3 grabs, SPR 1998 (n=2)

Figure 3.450 compares the abundance and biomass of *Maera grossimana* on the Impacted and Control sites. The highest value for this species was obtained at the Impacted site in November 1996. However, during the other seasons *M. grossimana* seems to be equally abundant or slightly more abundant in the Control site. The peak observed in November 1996 (Autumn 1996) at the Impacted site was not repeated in October 1997 (Autumn 1997). Overall therefore, no particular seasonal pattern seems to be present.

Fig. 3.450.



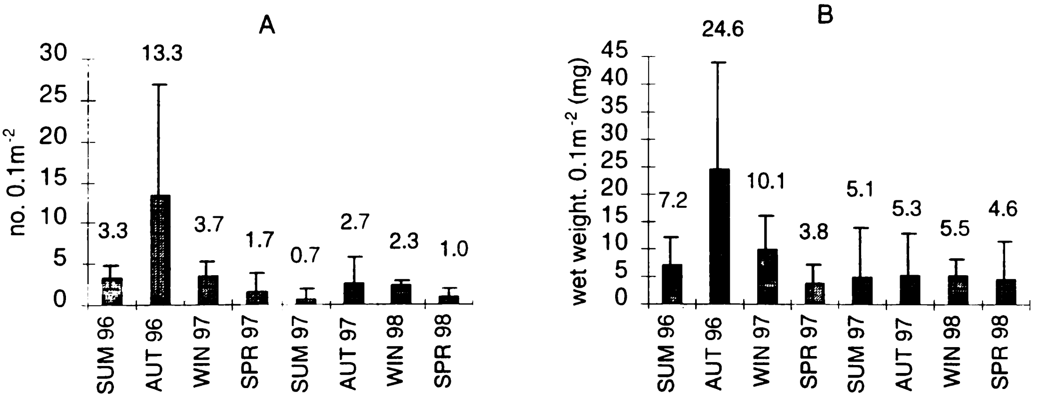


Ampithoe ramondii Audouin, 1826

Ampithoe ramondii was quite common on the Maltese maerl grounds studied. It was found on both controil and impacted sites and was present in nearly all the grab samples collected. This tubicolous amphipod feeds on decaying macroalgae.

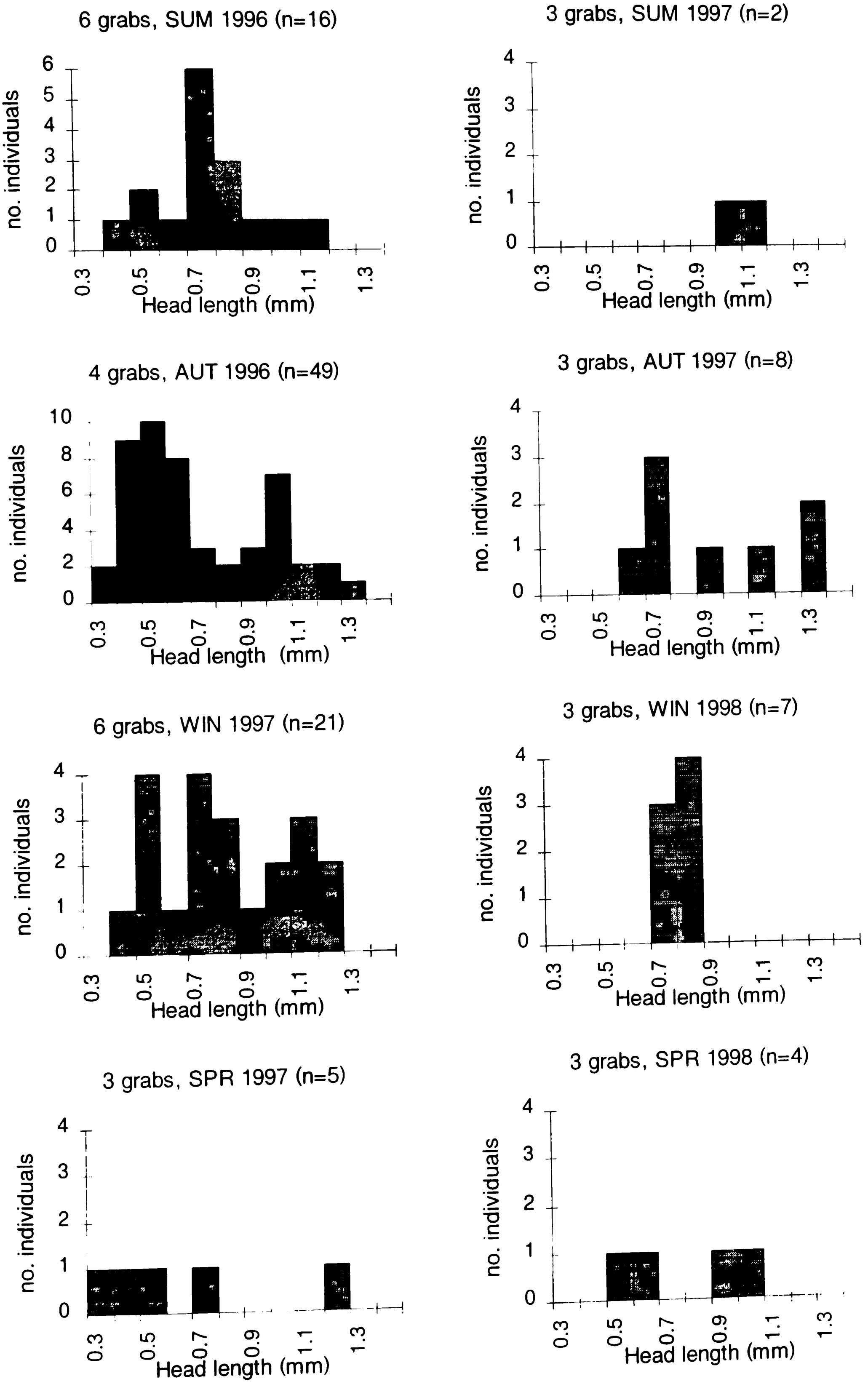
A seasonal pattern in the abundance and biomass of *A. ramondii* at the control site is evident. For both years, the abundance increased from summer to a peak in autumn. The numbers then decreased from autumn to a minimum in spring (Fig. 3.451). The exception was summer 1997, where the abundance was lower than that of spring 1998, however the biomass was higher.

Fig. 3.451. A) Mean number and B) Biomass (mg wet weight) of *A. ramondii* per 0.1m^2 grab at UMC. Error bars = SD. Numbers above each column are mean values (n=3 replicates).



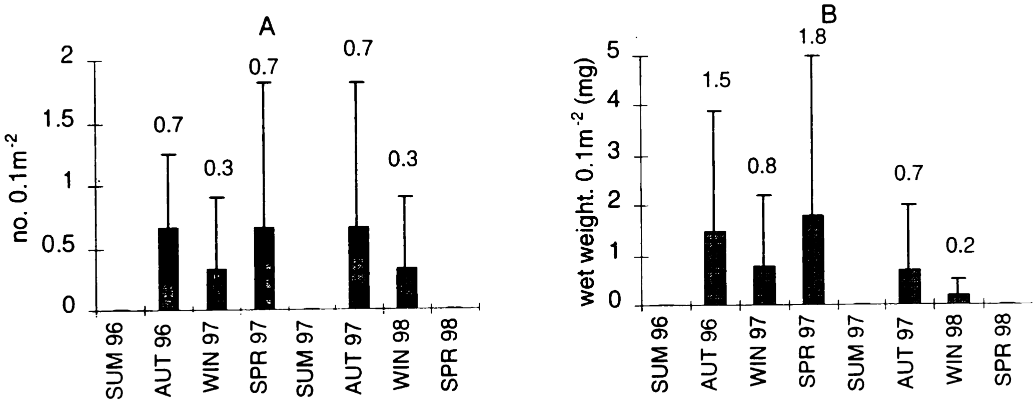
The seasonal variation in size frequency of *A. ramondii* at the control site is shown in Fig. 3.452. Small individuals (head length = 0.3mm) were obtained in autumn 1996 and spring 1997. Where abundant material was collected (summer 1996, autumn 1996, winter 1997) there is a suggestion that a bimodal size-frequency distribution may be present. The number of individuals collected during the second sampling year was much lower than that collected during the first year. Thus, no particular seasonal pattern in the size-frequency distribution could be detected.

Fig. 3.453. Size-frequency histograms for *A. ramondii* collected seasonally in 0.1m^2 grabs at UMC from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring.



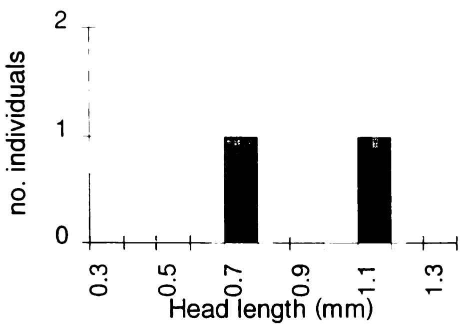
Ampithoe ramondii was not very common at the impacted site. It was collected from 5 seasonal samples and its abundance was very low (Fig. 3.454). No particular seasonal pattern in either abundance or biomass could be detected.

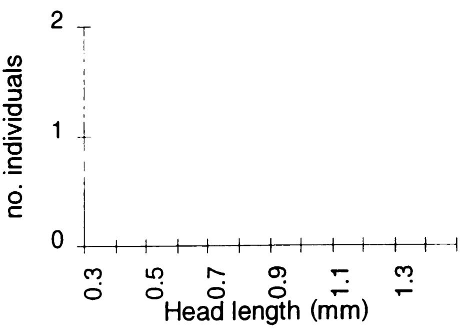
Fig. 3.454. A) Mean number and B) Biomass (mg wet weight) of *A. ramondii* per $0.1m^2$ grab at UMI. Error bars = SD. Numbers above each column are mean values (n=3 replicates).

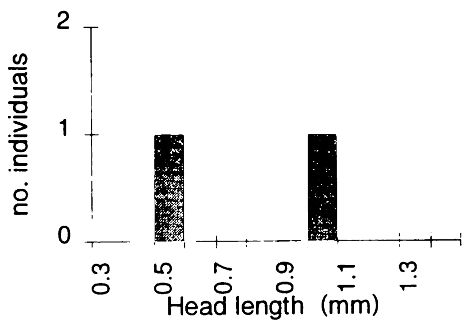


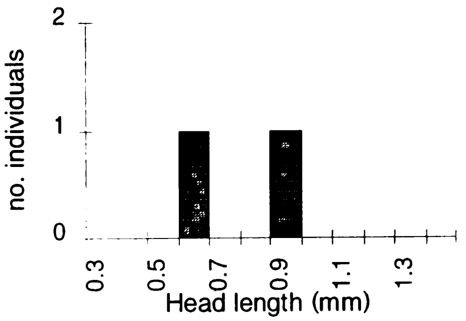
The seasonal variation in size frequency of *A. ramondii* at the impacted site is shown in Fig. 3.455. Due to the low number of individuals collected, no patterns in the size-frequency distribution could be detected.

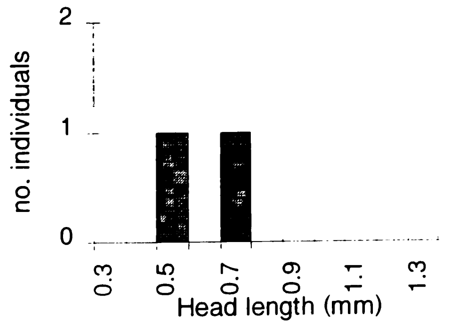
Fig. 3.455. Size-frequency histograms for *Ampithoe ramondii* collected seasonally in 0.1m^2 grabs at UMI from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring.

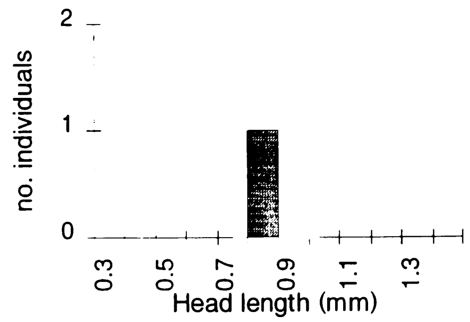

6 grabs, SUM 1996 (n=2)

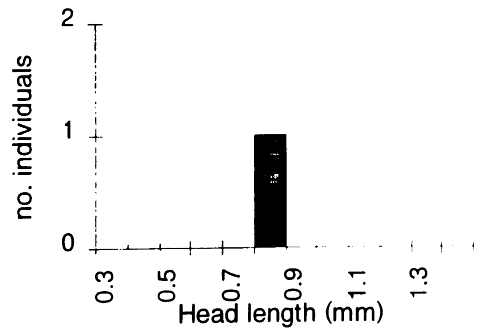

3 grabs, SUM 1997 (n=0)


3 grabs, AUT 1996 (n=2)


3 grabs, SPR 1997 (n=2)


3 grabs, AUT 1997 (n=2)


3 grabs, WIN 1997 (n=1)


3 grabs, WIN 1998 (n=1)

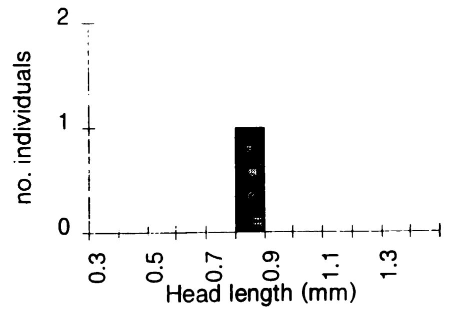
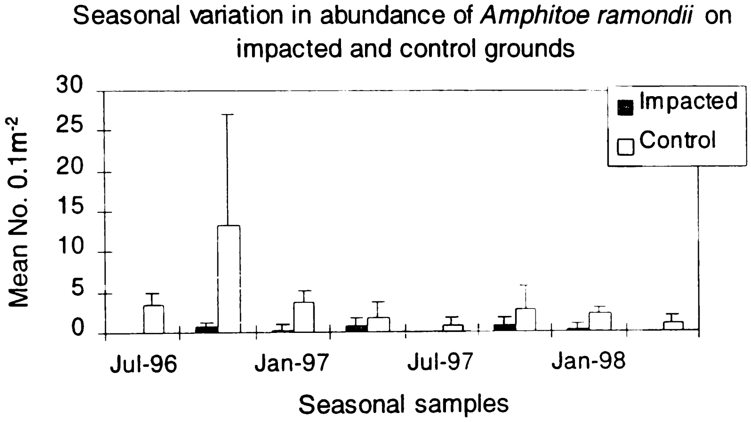
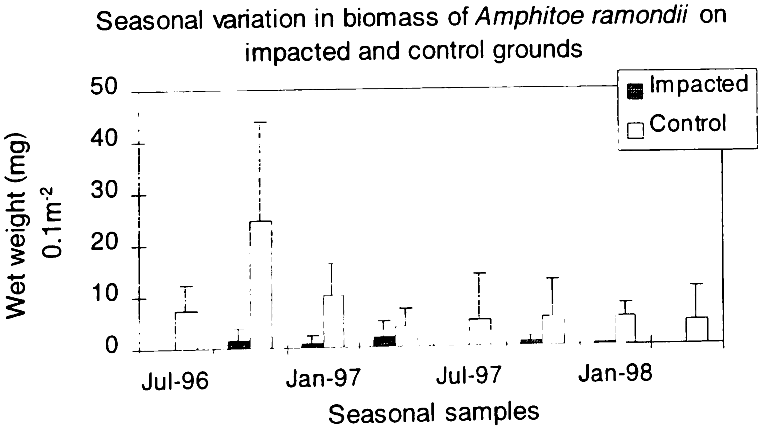

3 grabs, WIN 1998 (n=1)

Figure 3.456 compares the abundance and biomass of *Ampithoe ramondii* on the Impacted and Control sites. *A. ramondii* was much more abundant at the control site . and the highest value was obtained here in autumn 1996. It also had a higher biomass at the control site. As *A. ramondii* feeds on decomposing macroalgae and since macroalgae were more abundant at the control site, such a result is not unexpected.

Fig. 3.456.



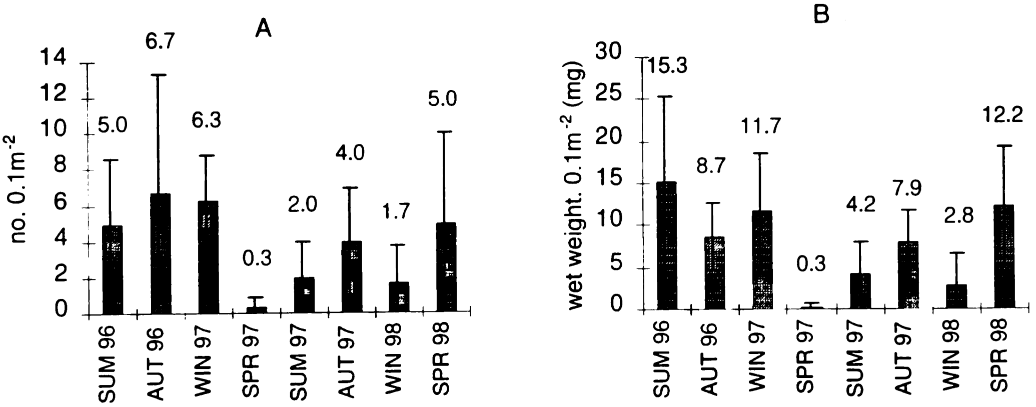


Lysianassa costae Milne Edwards, 1830

Lysianassa costae was one of the most common amphipods on the Maltese maerl grounds studied. It was found on both control and impacted sites and was present in nearly all the grab samples collected. The feeding habits of this amphipod are not known with certainty but it is likely to be either a scavenger or a carnivore (or both).

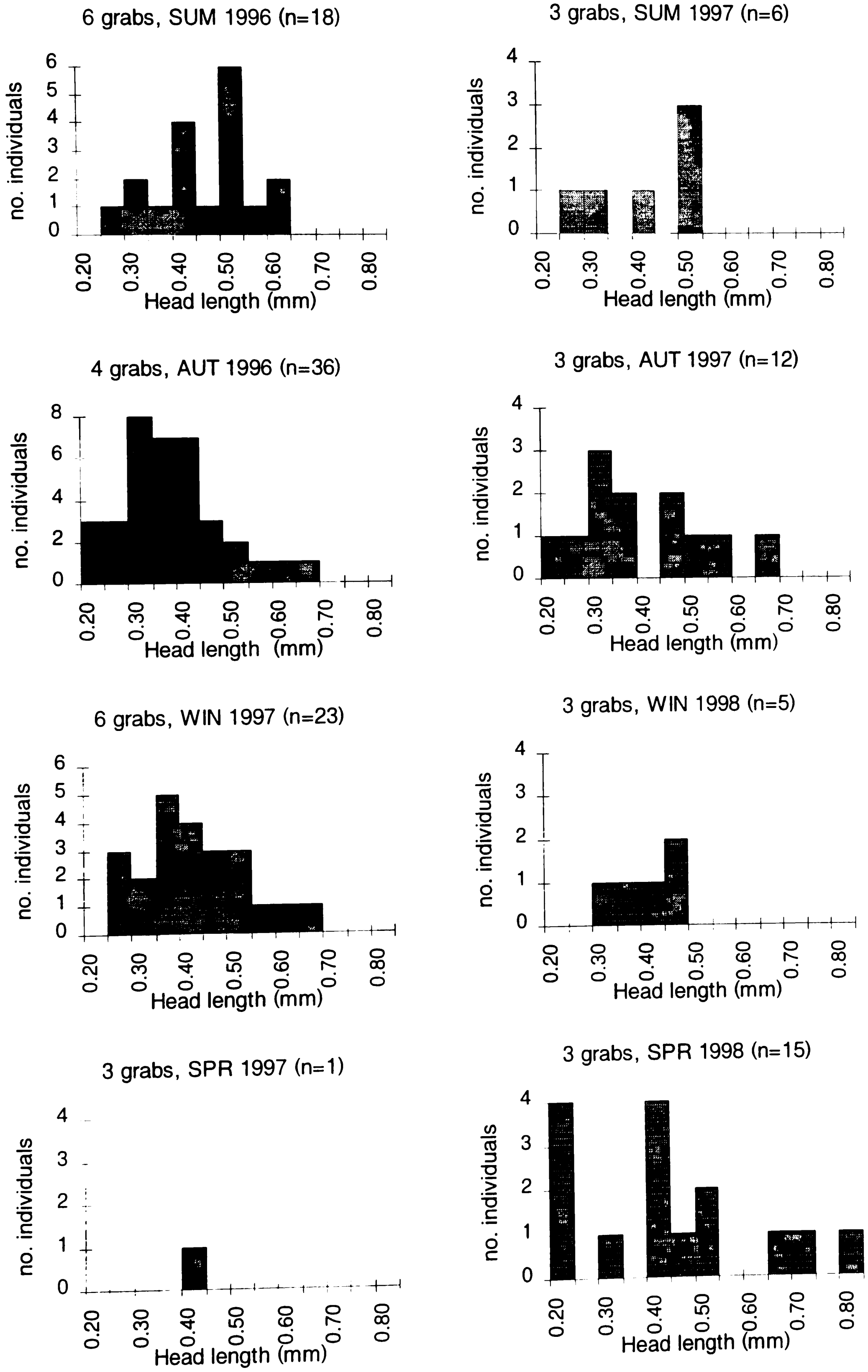
With the exception of spring 1998, the abundance of this amphipod at the control site increased from summer to autumn, and then decreased to reach a minimum in spring (Fig. 3.457). This trend was very clear during the first sampling year, but it was not continued during the second sampling year due to a high value obtained in spring 1998. The highest value for abundance was obtained in autumn 1996. The biomass showed no particular seasonal pattern.

Fig. 3.457. A) Mean number and B) Biomass (mg wet weight) of *L. costae* per $0.1m^2$ grab at UMC. Error bars = SD. Numbers above each column are mean values (n=3 replicates).



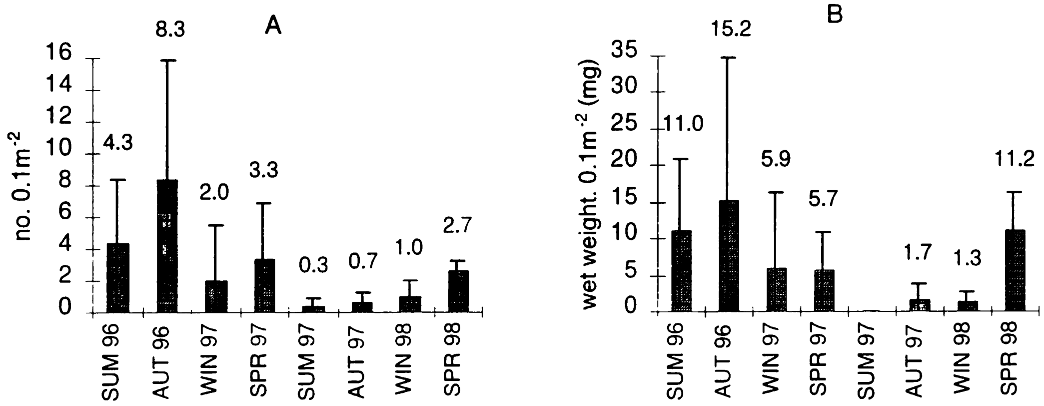
The seasonal variation in size frequency of *Lysianassa costae* at the control site is shown in Fig. 3.458. Small individuals (head length = 0.2mm) were more frequent in autumn 1996 and 1997 and in spring 1998. However, no particular pattern in the size-frequency distribution could be detected.

Fig. 3.458. Size-frequency histograms for *Lysianassa costae* collected seasonally in 0.1m^2 grabs at UMC from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring.



As in the control ground, the highest value for the abundance of *Lysianassa costae* at the impacted site was obtained in autumn 1996 (Fig. 3.459). However, no particular seasonal pattern in either abundance or biomass of this species can be discerned, except for a gradual increase in abundance from summer to spring of the second sampling year.

Fig. 3.459. A) Mean number and B) Biomass (mg wet weight) of *L. costae* per $0.1m^2$ grab at UMI. Error bars = SD. Numbers above each column are mean values (n=3 replicates).



The seasonal variation in size frequency of *L. costae* at the impacted site is shown in Fig. 3.460. In this case, small individuals (head length = 0.2mm) were obtained in winter 1998. No seasonal pattern in size-frequency distribution can be observed.

Fig. 3.460. Size-frequency histograms for *Lysianassa costae* collected seasonally in $0.1m^2$ grabs at UMI from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring.

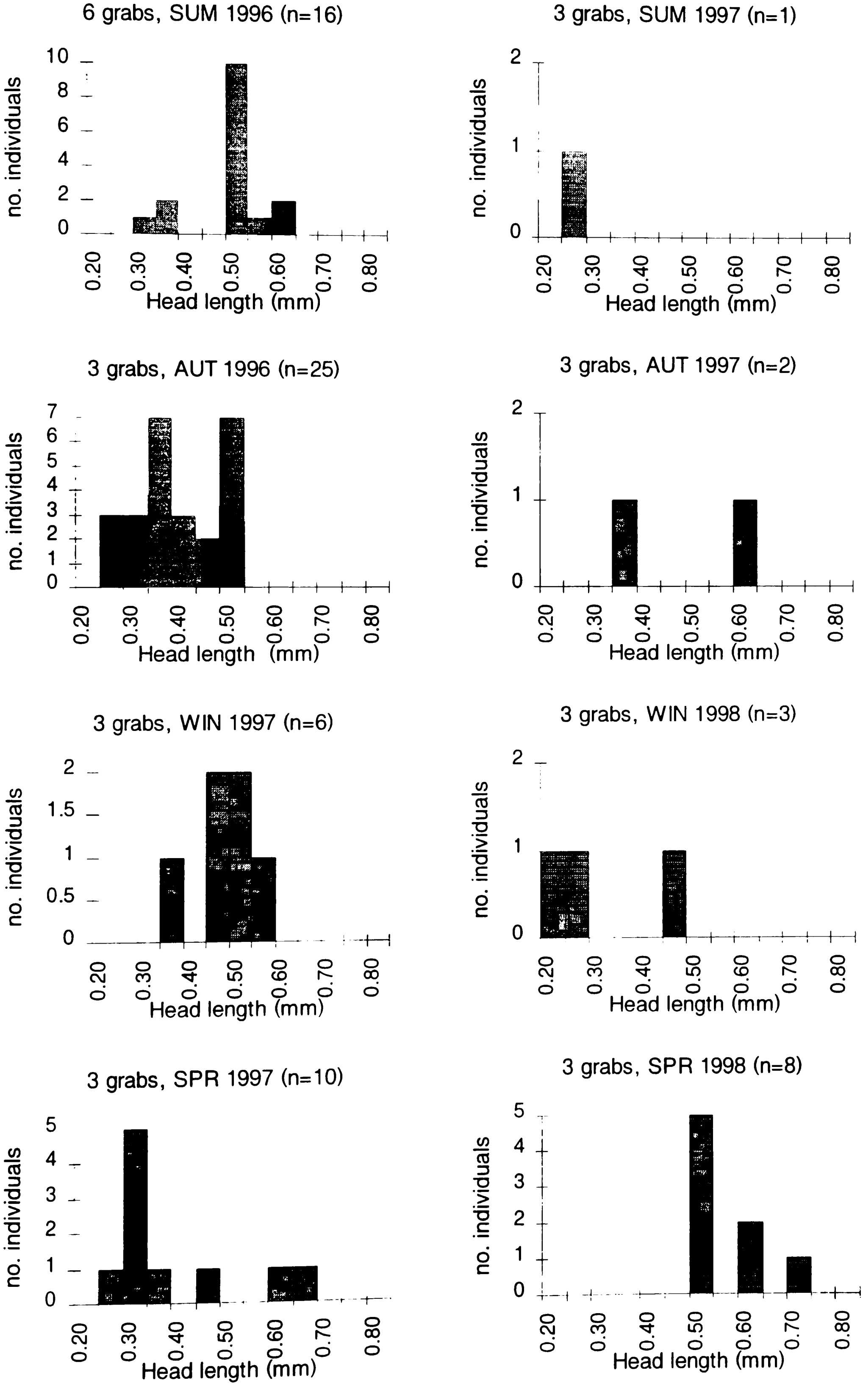
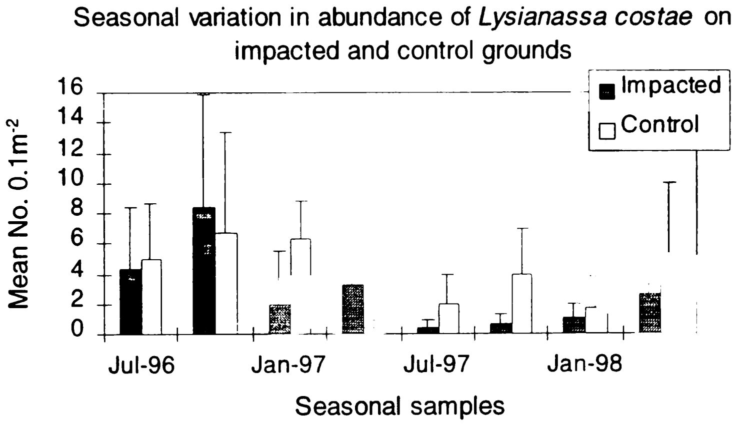
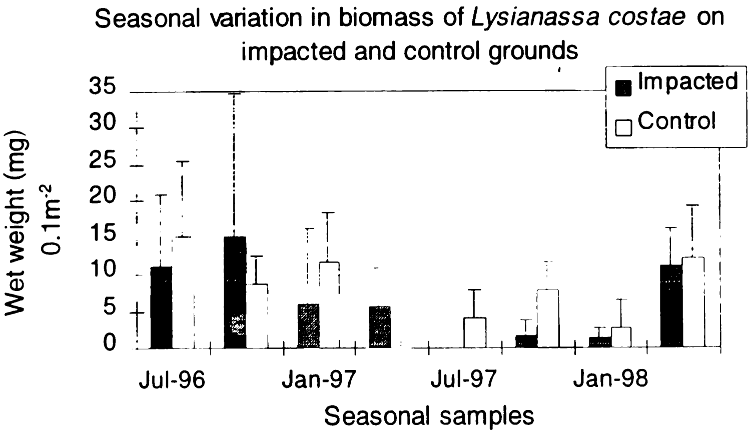


Figure 3.461 compares the abundance and biomass of *Lysianassa costae* on the Impacted and Control sites. This amphipod was more abundant at the impacted site in autumn 1996 and in spring 1997, while it was more abundant at the control site during the other seasons. Thus it seems that it is generally more abundant at the control site. However the highest value for abundance was obtained in autumn 1996 at the impacted site. Biomass followed the same trend.

Fig. 3.461.



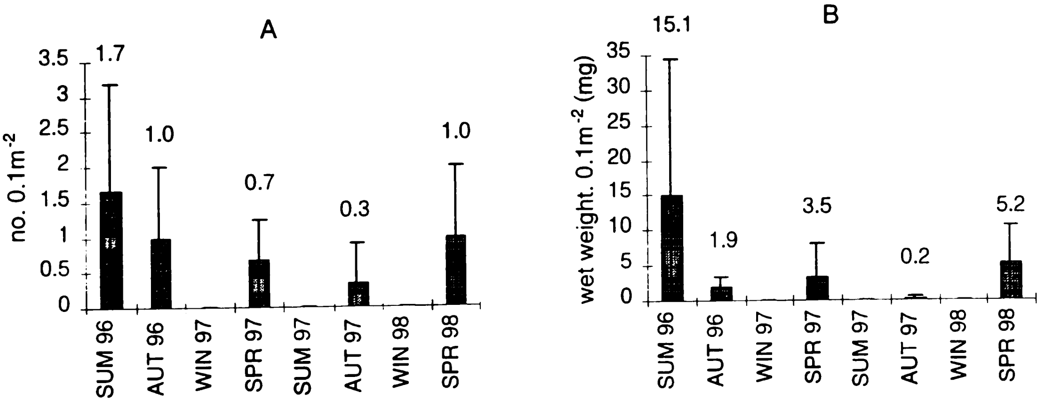


***Athanas nitescens* (Leach, 1814) var. *laevirhincus* (Risso, 1816)**

Athanas nitescens was collected from both control and impacted grounds, and although it was not very abundant, it was relatively common. The feeding habit of this decapod is not known with certainty but it is possibly omnivorous. *A. nitescens* is a surface-dwelling species.

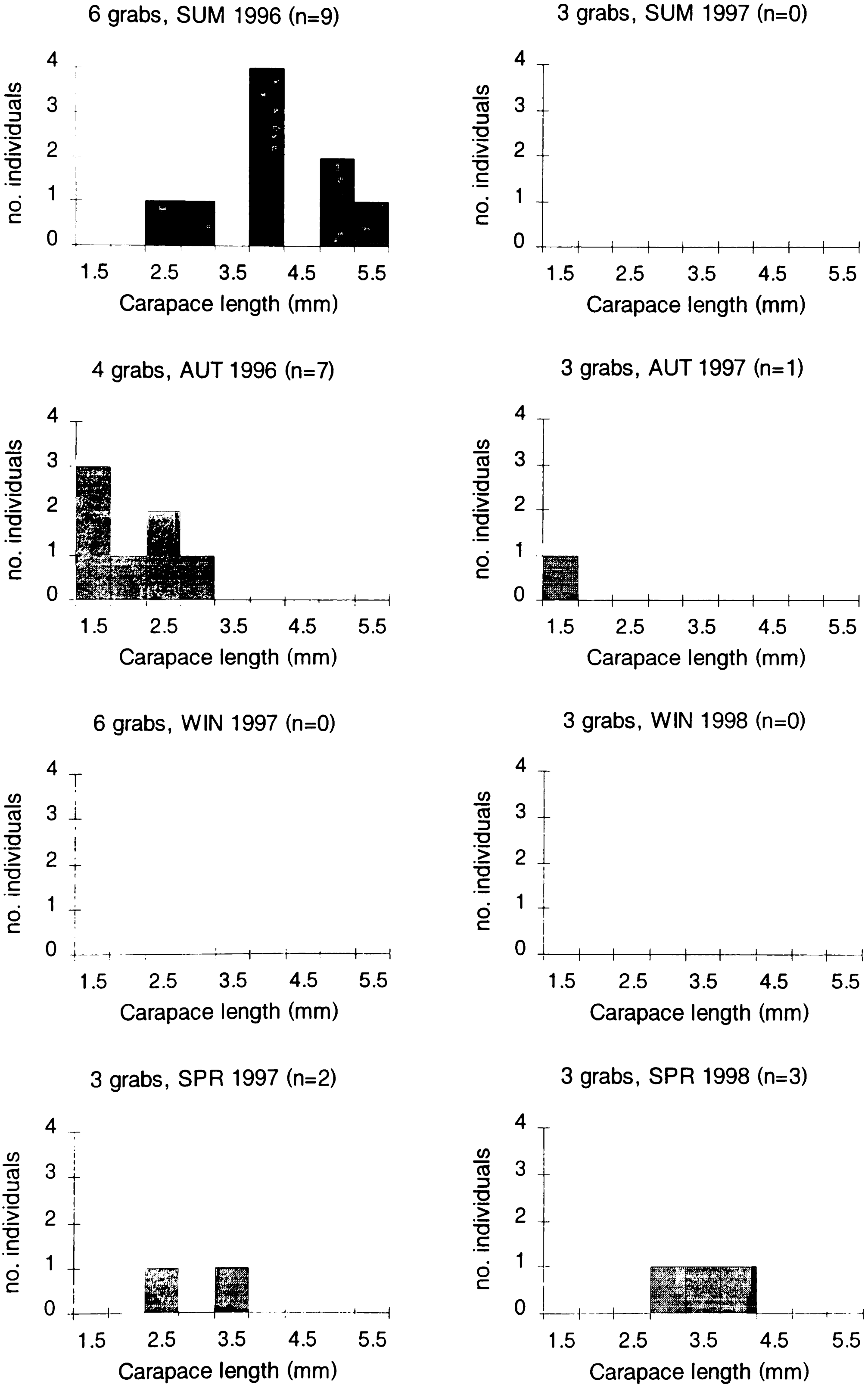
No particular seasonal pattern was observed in either abundance or biomass of this species at the control ground. The highest value was obtained in summer 1996, but it was absent in summer 1997 (Fig. 3.462). It was also absent from the samples collected in winter 1997 and 1998.

Fig. 3.462. A) Mean number and B) Biomass (mg wet weight) of *A. nitescens* per 0.1m^2 grab at UMC. Error bars = SD. Numbers above each column are mean values (n=3 replicates).



The seasonal variation in size frequency of *A. nitescens* at the control ground is shown in Fig. 3.463. Due to the low number of individuals collected, no patterns in the size-frequency distribution could be detected. The smallest individuals (carapace length = 1.5mm) occurred in autumn (autumn 1996).

Fig. 3.463. Size-frequency histograms for *Athanas nitescens* collected seasonally in 0.1m^2 grabs at UMC from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring.



6 grabs, SUM 1996 (n=9)

3 grabs, SUM 1997 (n=0)

4 grabs, AUT 1996 (n=7)

3 grabs, AUT 1997 (n=1)

6 grabs, WIN 1997 (n=0)

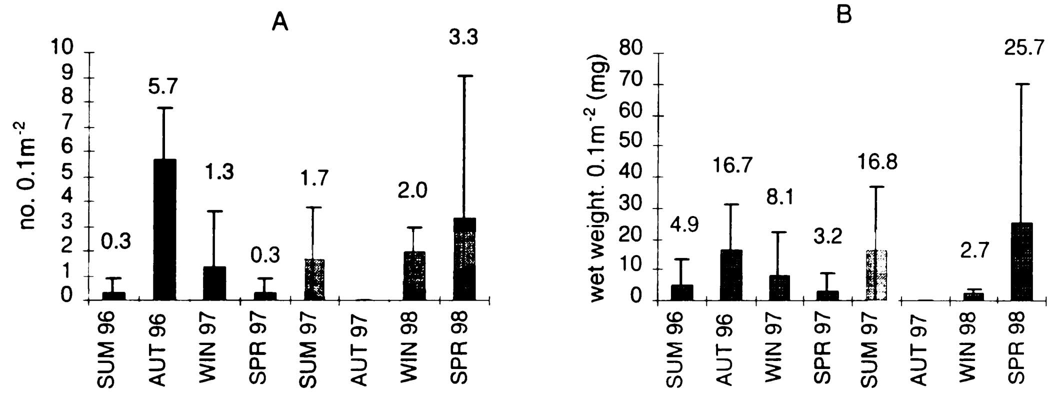
3 grabs, WIN 1998 (n=0)

3 grabs, SPR 1997 (n=2)

3 grabs, SPR 1998 (n=3)

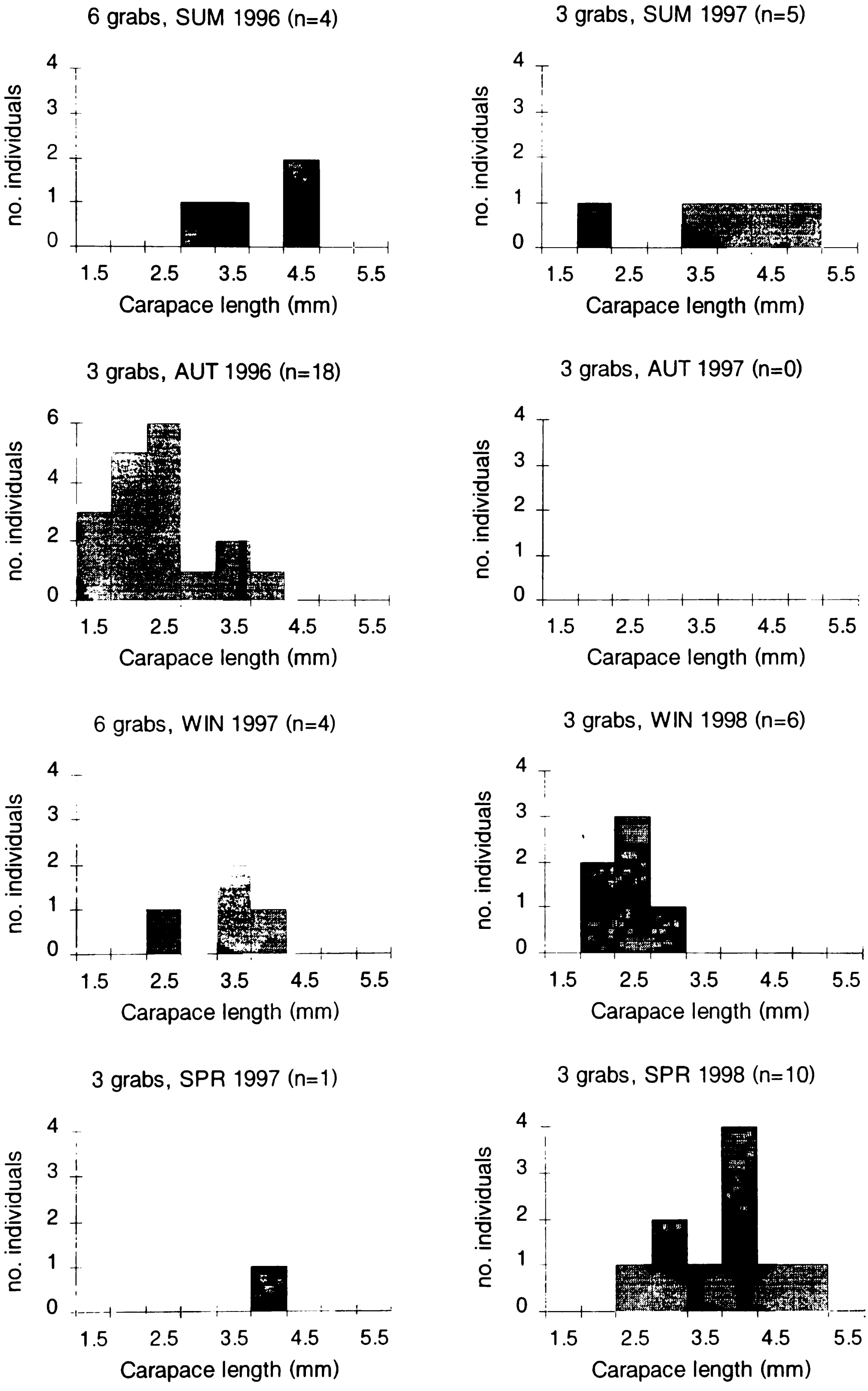
Although *Athanas nitescens* was present in most of the seasonal samples collected from the impacted site, no particular seasonal pattern in the abundance or biomass of this species was observed (Fig. 3.464). The highest value was obtained for autumn 1996, but this was not repeated in autumn 1997, when *Athanas nitescens* was absent.

Fig. 3.464. A) Mean number and B) Biomass (mg wet weight) of *A. nitescens* per 0.1m^2 grab at UMI. Error bars = SD. Numbers above each column are mean values (n=3 replicates).



The seasonal variation in size frequency of *A. nitescens* at the impacted ground is shown in Fig. 3.465. Small individuals (carapace length = 1.5mm) were present in autumn 1996, but due to the low number of individuals collected, no patterns in the size-frequency distribution could be detected. As in the control ground the smallest specimens (carapace length = 1.5mm) occurred in autumn (autumn 1996).

Fig. 3.465. Size-frequency histograms for *Athanas nitescens* collected seasonally in $0.1m^2$ grabs at UMI from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring.


6 grabs, SUM 1996 (n=4)

3 grabs, SUM 1997 (n=5)

3 grabs, AUT 1996 (n=18)

3 grabs, AUT 1997 (n=0)

6 grabs, WIN 1997 (n=4)

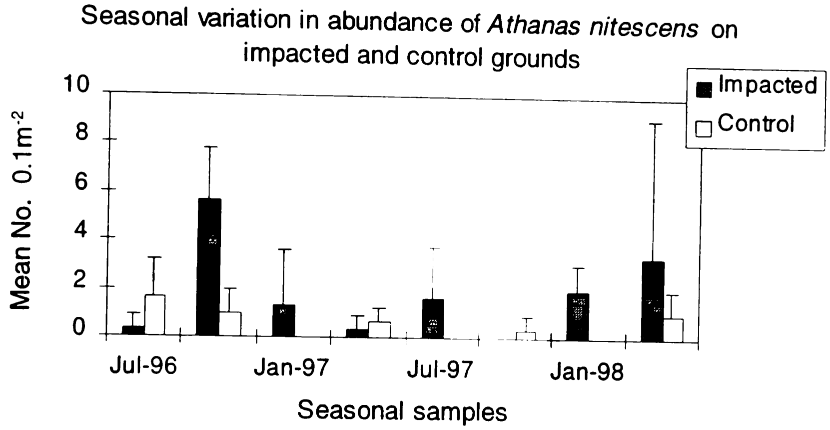
3 grabs, WIN 1998 (n=6)

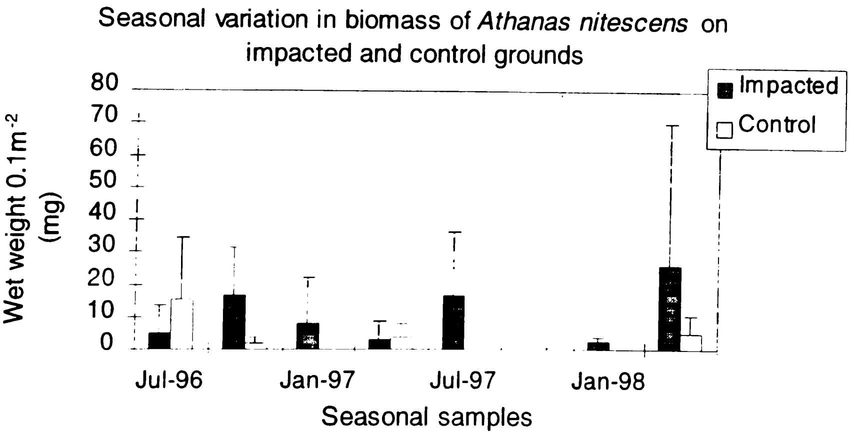
3 grabs, SPR 1997 (n=1)

3 grabs, SPR 1998 (n=10)

Figure 3.466 compares the abundance and biomass of *Athanas nitescens* on the Impacted and Control sites. The highest value was obtained in autumn 1996 at the impacted site, and in general this decapod was more abundant at the impacted site. However in summer 1996 and spring 1997, *Athanas nitescens* was more abundant at the control site. The same trend was observed for biomass.

Fig. 3.466.



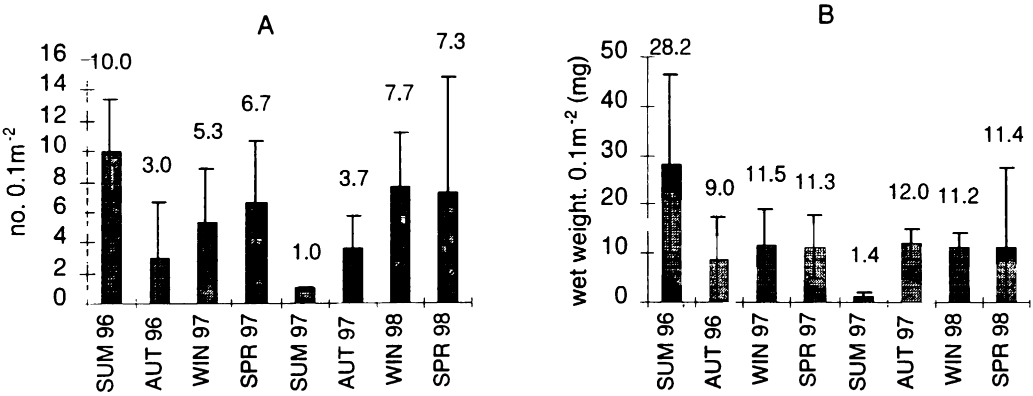


Cestopagurus timidus (Roux, 1828)

Cestopagurus timidus was one of the most common decapods of the Maltese maerl grounds. It was found in relatively high numbers at both the impacted and control sites and was present in nearly all the grab samples collected. This hermit crab is omnivorous but is mainly a deposit feeder. It probably seeks shelter in cavities and narrow spaces on the surface of the maerl.

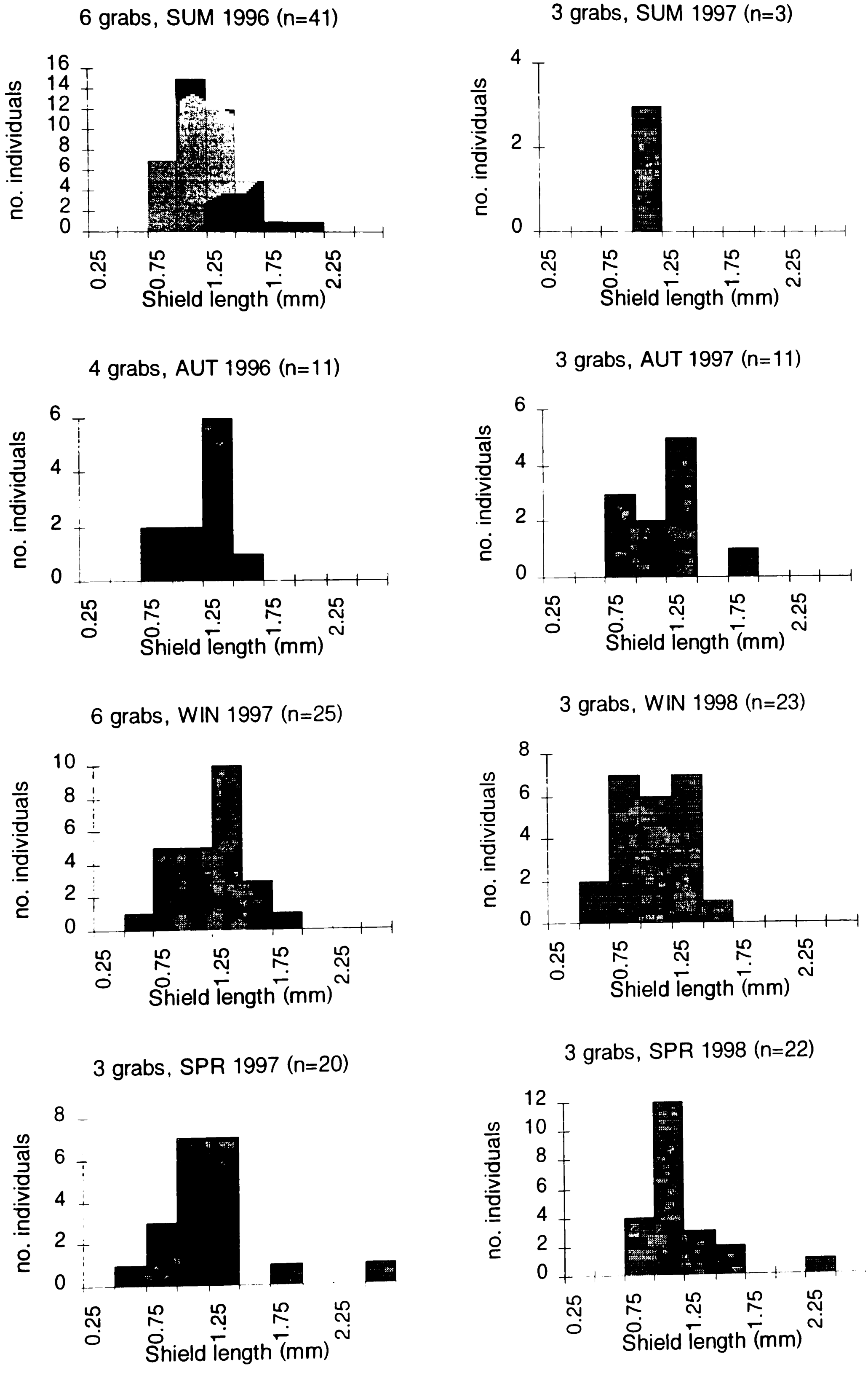
Cestopagurus timidus was very common on the control ground, being present in all seasonal samples. Its abundance decreased in autumn (1996 and 1997); however the lowest value was obtained in summer 1997 (Fig. 3.467). The latter does not correspond to the situation in summer 1996, where the highest value for both abundance and biomass was obtained.

Fig. 3.467. A) Mean number and B) Biomass (mg wet weight) of *C. timidus* per $0.1m^2$ grab at UMC. Error bars = SD. Numbers above each column are mean values (n=3 replicates).



The seasonal variation in size frequency of *C. timidus* at the control ground is shown in Fig. 3.468. Small individuals (shield length = 0.5mm) were present in winter 1997 and 1998 and in spring 1997. This may indicate recruitment. However the low number of individuals obtained in summer 1997 does not conform to this pattern.

Fig. 3.468. Size-frequency histograms for *Cestopagurus timidus* collected seasonally in 0.1m^2 grabs at UMC from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring.



6 grabs, SUM 1996 (n=41)

3 grabs, SUM 1997 (n=3)

4 grabs, AUT 1996 (n=11)

3 grabs, AUT 1997 (n=11)

6 grabs, WIN 1997 (n=25)

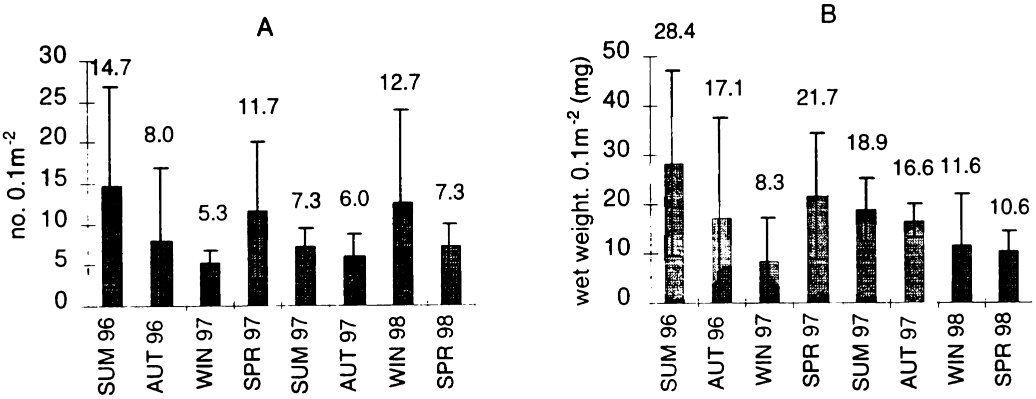
3 grabs, WIN 1998 (n=23)

3 grabs, SPR 1997 (n=20)

3 grabs, SPR 1998 (n=22)

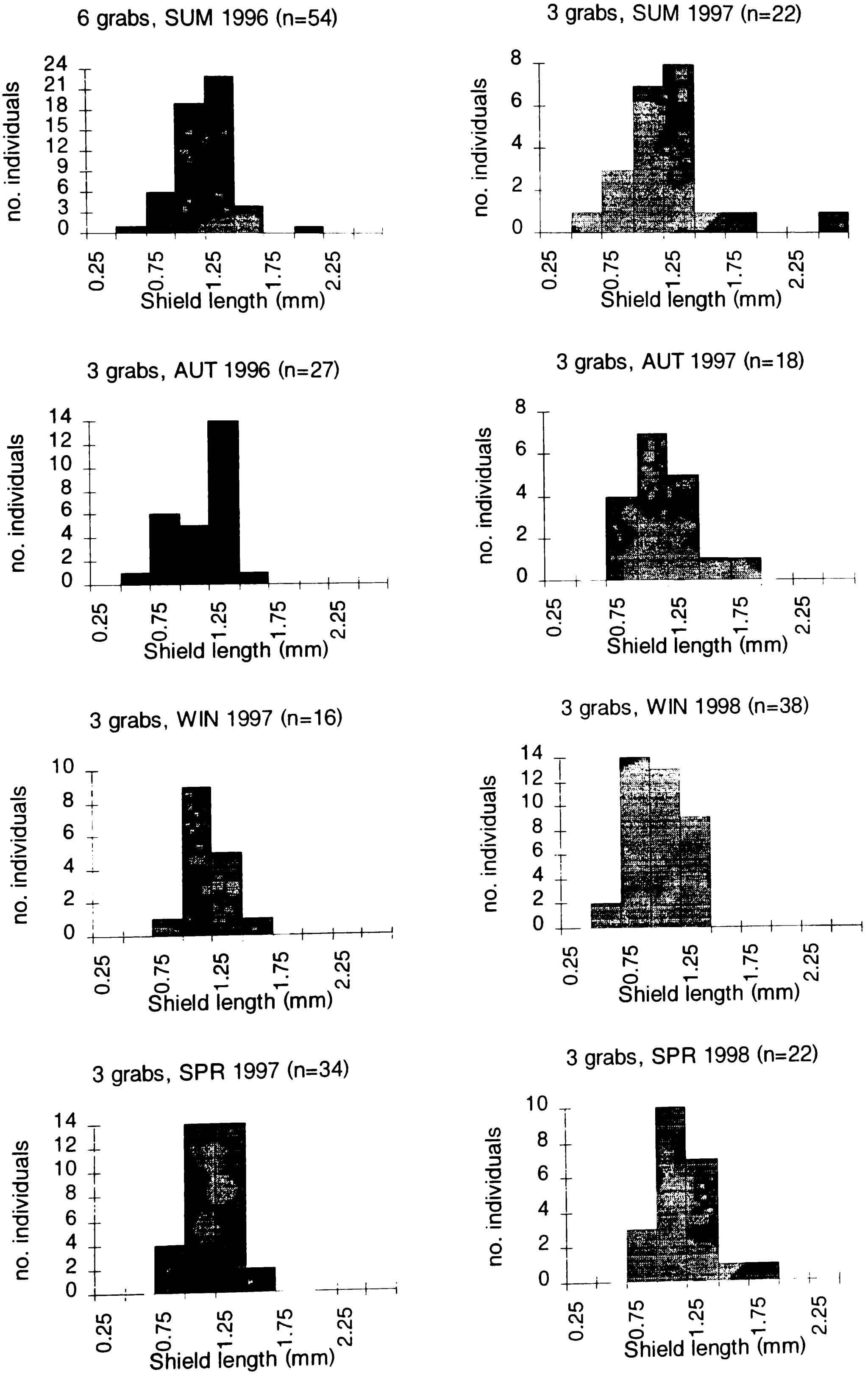
Cestopagurus timidus was also abundant at the impacted site and as in the control ground, the highest value was obtained in summer 1996 (Fig. 3.469). In the first sampling year, its abundance decreased between summer 1996 and winter 1997, and then increased again in spring 1997. This trend was not observed during the second year due to a peak in winter 1998.

Fig. 3.469. A) Mean number and B) Biomass (mg wet weight) of *C. timidus* per 0.1m^2 grab at UMI. Error bars = SD. Numbers above each column are mean values (n=3 replicates).



The seasonal variation in size frequency of *C. timidus* at the impacted ground is shown in Fig. 3.470. There may be a tendency for smaller individuals to be more abundant in winter (1997 and 1998), however, seasonal patterns in size-frequency distributions are not very evident.

Fig. 3.470. Size-frequency histograms for *Cestopagurus timidus* collected seasonally in 0.1m^2 grabs at UMI from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring.



6 grabs, SUM 1996 (n=54)

3 grabs, SUM 1997 (n=22)

3 grabs, AUT 1996 (n=27)

3 grabs, AUT 1997 (n=18)

3 grabs, WIN 1997 (n=16)

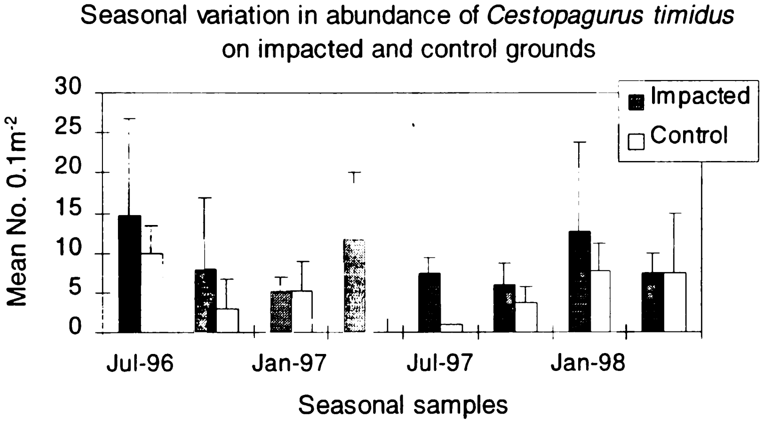
3 grabs, WIN 1998 (n=38)

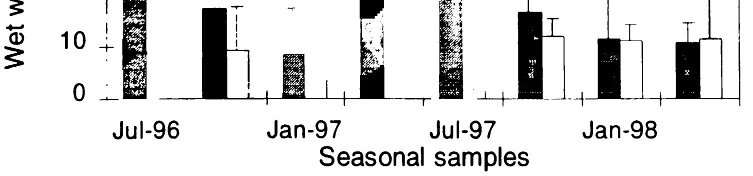
3 grabs, SPR 1997 (n=34)

3 grabs, SPR 1998 (n=22)

Figure 3.471 compares the abundance and biomass of *Cestopagurus timidus* on the Impacted and Control sites. This species was more abundant at the impacted than at the control site. The variation in abundance with season followed the same pattern at the two grounds. Biomass followed the same trend as for abundance, except in winter 1997 and spring 1998, where the biomass was higher at the control than at the impacted ground.

Fig. 3.471.



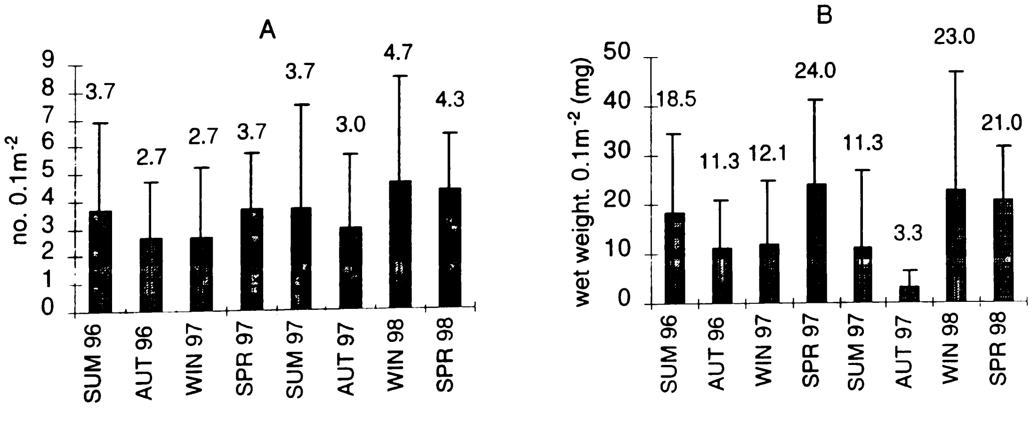


Galathea intermedia Lilljeborg, 1851

Galathea intermedia was fairly common on the Maltese maerl grounds studied. It was found at both the control and impacted sites in nearly all the grab samples collected. It feeds on organic matter deposited on the bottom or stirred-up into suspension. *Galathea intermedia* shelters under stones and shells and inhabits narrow spaces amongst gravel particles and maerl thalli.

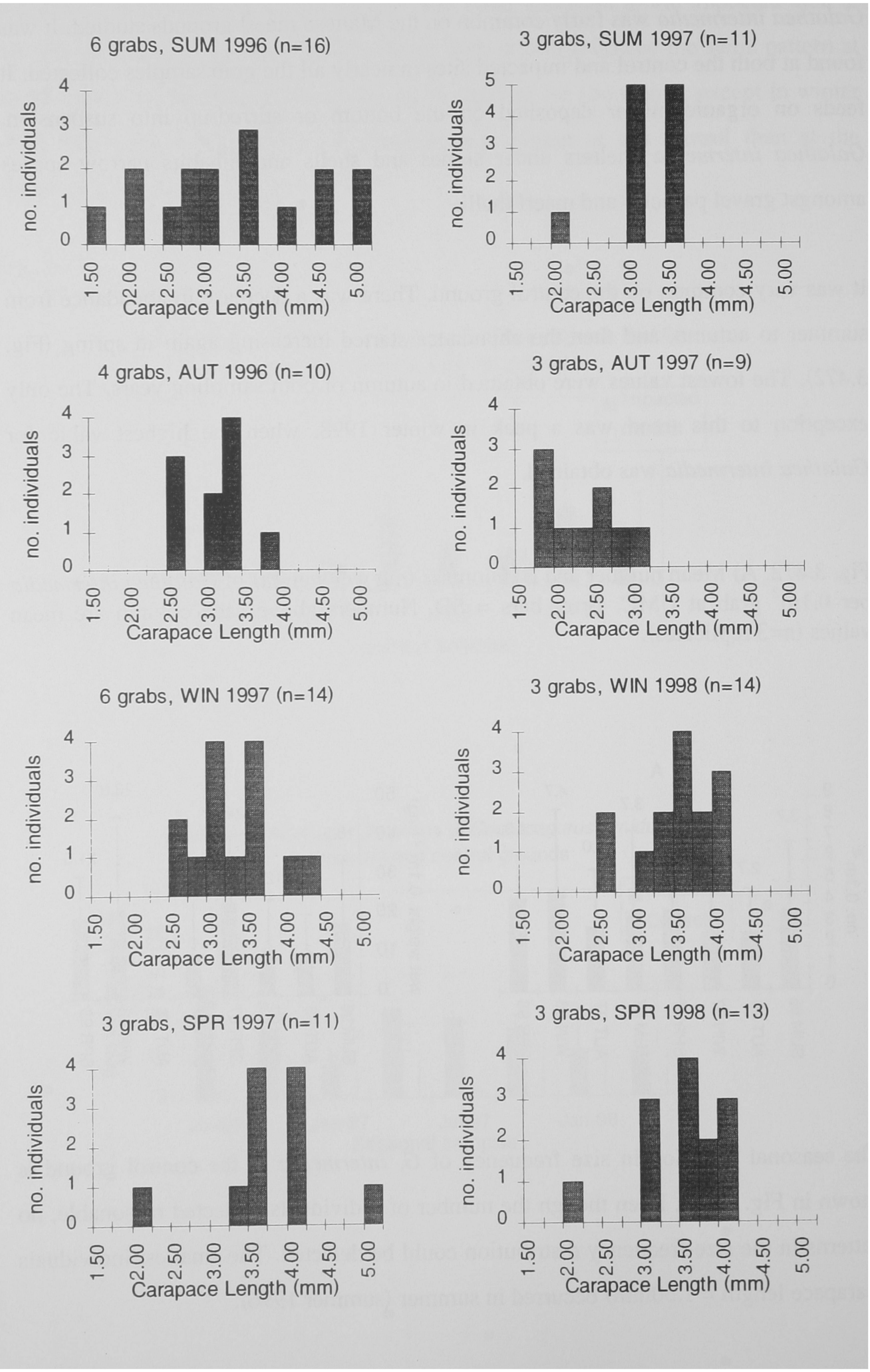
It was very common on the control ground. There was a decrease in abundance from summer to autumn, and then the abundance started increasing again in spring (Fig. 3.472). The lowest values were obtained in autumn of both sampling years. The only exception to this trend was a peak in winter 1998, when the highest value for *Galathea intermedia* was obtained.

Fig. 3.472. A) Mean number and B) Biomass (mg wet weight) of *Galathea intermedia* per $0.1m^2$ grab at UMC. Error bars = SD. Numbers above each column are mean values (n=3 replicates).



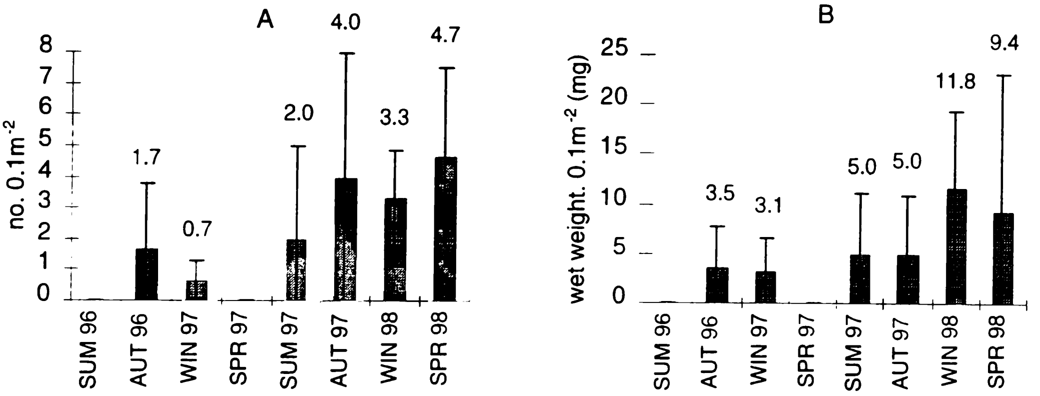
The seasonal variation in size frequency of *G. intermedia* at the control ground is shown in Fig. 3.473. Even though the number of individuals collected reasonable, no patterns in the size-frequency distribution could be detected. The smallest individuals (carapace length = 1.50mm) occurred in summer (summer 1996).

Fig. 3.473. Size-frequency histograms for *Galathea intermedia* collected seasonally in 0.1m^2 grabs at UMC from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring.



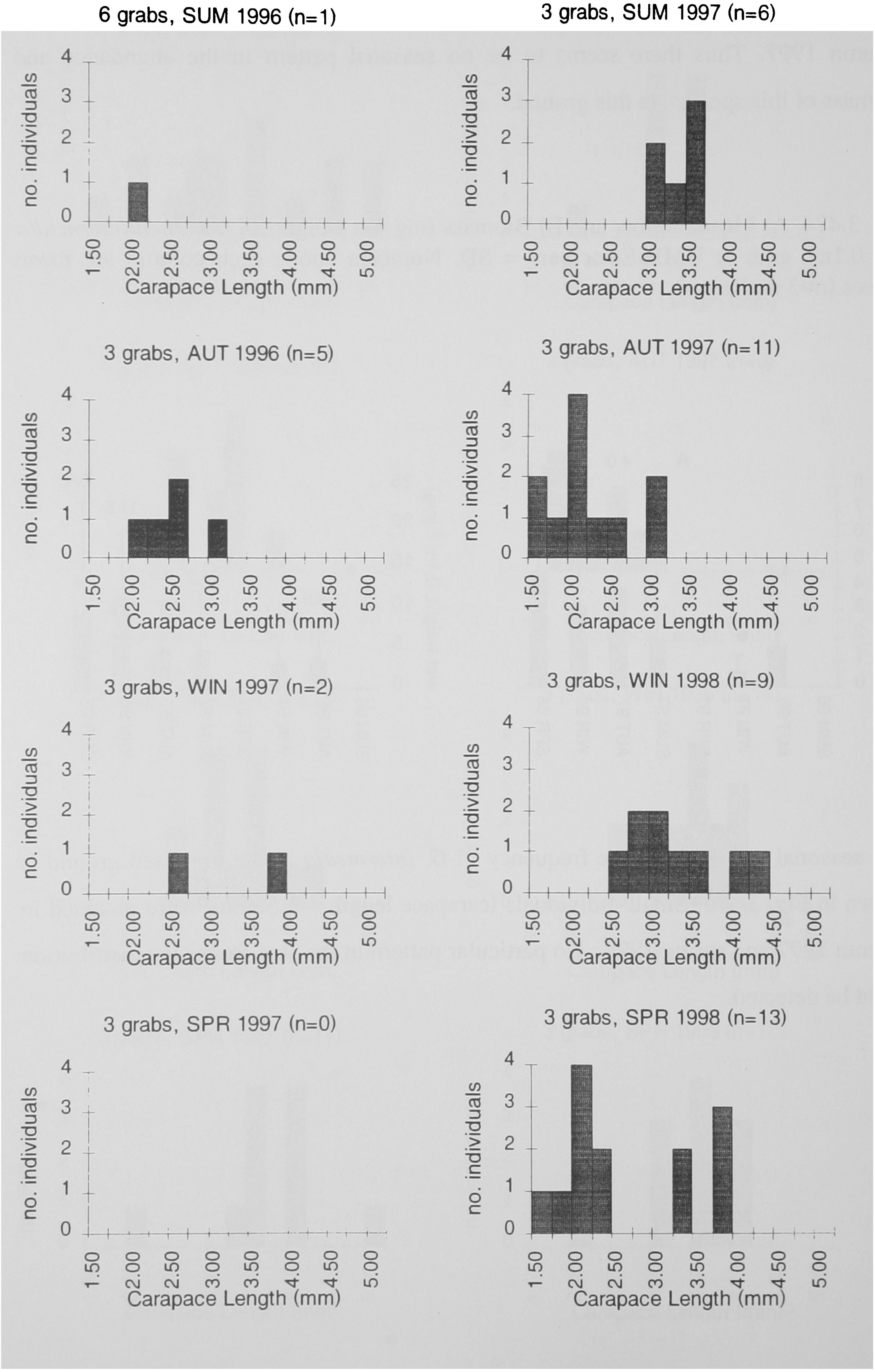
The trend which was observed for *Galathea intermedia* at the control site was not observed at the impacted site (Fig. 3.474). The highest value for this decapod at the impacted site was obtained in spring 1998, and a high value was also obtained in autumn 1997. Thus there seems to be no seasonal pattern in the abundance and biomass of this species on this ground.

Fig. 3.474. A) Mean number and B) Biomass (mg wet weight) of *Galathea intermedia* per 0.1m^2 grab at UMI. Error bars = SD. Numbers above each column are mean values (n=3 replicates).



The seasonal variation in size frequency of *G. intermedia* at the impacted ground is shown in Fig. 3.475. Small individuals (carapace length = 1.50mm) were obtained in autumn 1997 and spring 1998. No particular pattern in the size-frequency distribution could be detected.

Fig. 3.475. Size-frequency histograms for *Galathea intermedia* collected seasonally in $0.1m^2$ grabs at UMI from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring.



6 grabs, SUM 1996 (n=1)

3 grabs, SUM 1997 (n=6)

3 grabs, AUT 1996 (n=5)

3 grabs, AUT 1997 (n=11)

3 grabs, WIN 1997 (n=2)

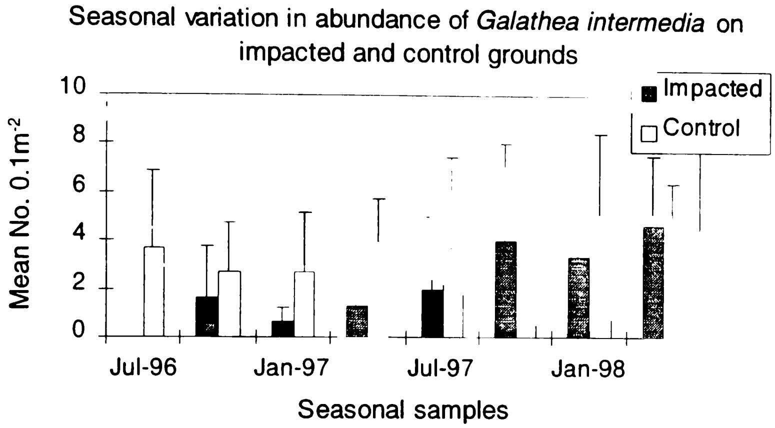
3 grabs, WIN 1998 (n=9)

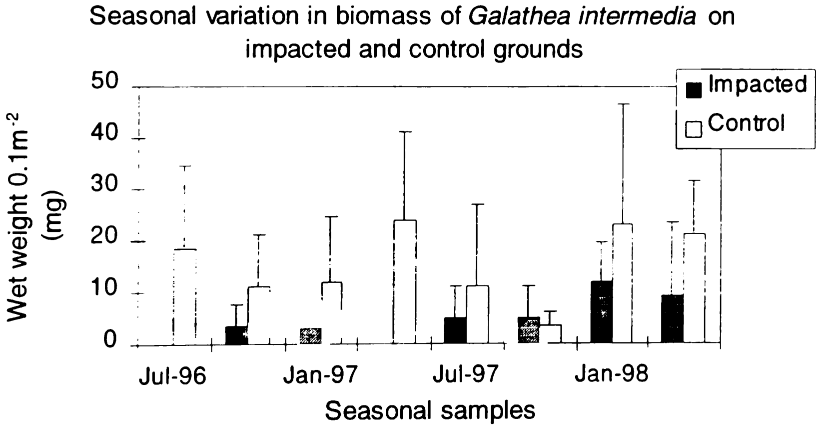
3 grabs, SPR 1997 (n=0)

3 grabs, SPR 1998 (n=13)

Figure 3.476 compares the abundance and biomass of *Galathea intermedia* on the Impacted and Control sites. In general, *G. intermedia* was more abundant at the control site, with the exception of autumn 1997 and spring 1998.

Fig. 3.476.



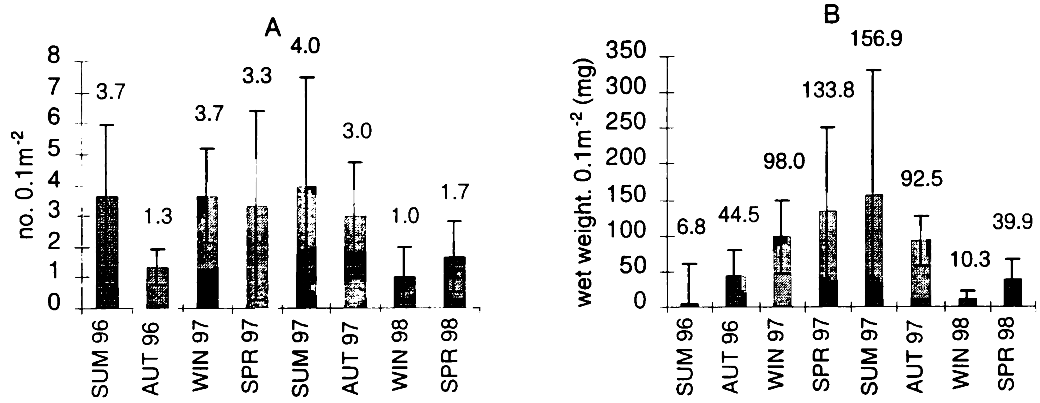


Echinocyamus pusillus (O.F. Müller, 1776)

Echinocyamus pusillus was one of the most common echinoderms on the Maltese maerl grounds studied. It was collected from nearly all the grab samples throughout the two sampling years and was found on both control and impacted sites. This sea urchin is a deposit feeder and micrograzer that lives in cavities and narrow spaces near the surface of the maerl.

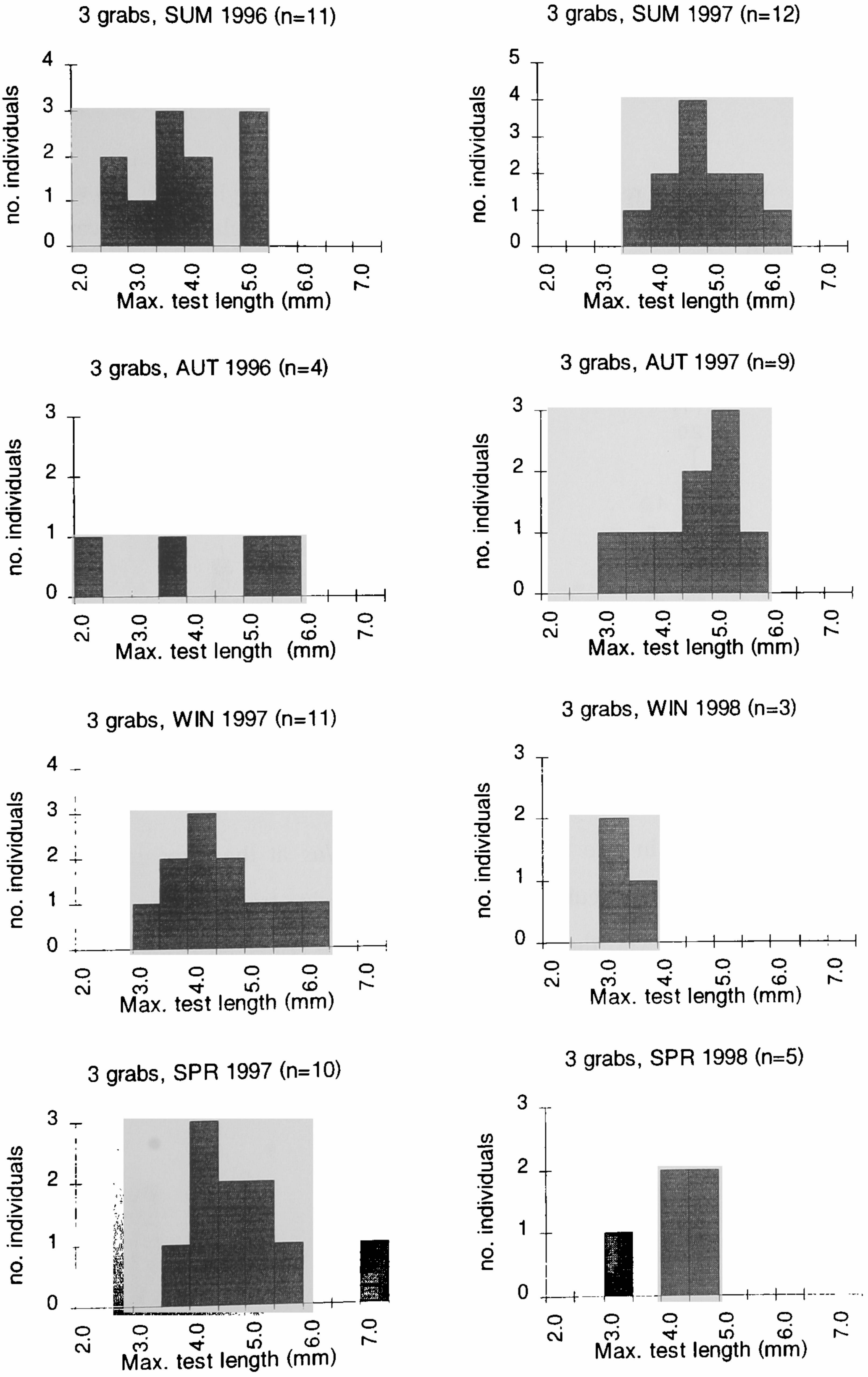
Echinocyamus pusillus was quite common on the control ground where it was found in all the seasonal samples (Fig. 3.477). It was particularly abundant in summer 1997. The lowest abundance was obtained in winter 1998. Despite the fact that it was quite common no particular seasonal pattern in either abundance or biomass can be observed.

Fig. 3.477. A) Mean number and B) Biomass (mg wet weight) of *E. pusillus* per $0.1m^2$ grab at UMC. Error bars = SD. Numbers above each column are mean values (n=3 replicates).



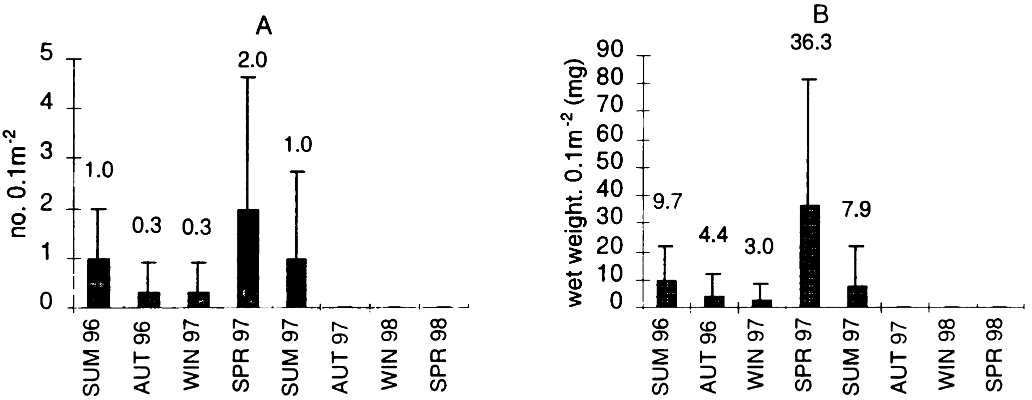
The seasonal variation in size frequency of *E. pusillus* at the control ground is shown in Fig. 3.478. Small individuals (max. test length = 2-3mm) were collected in summer and autumn 1996, but this trend was not repeated in 1997. No particular seasonal pattern in size-frequency distribution can be observed.

Fig. 3.478. Size-frequency histograms for *Echinocyamus pusillus* collected seasonally in $0.1m^2$ grabs at UMC from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring.



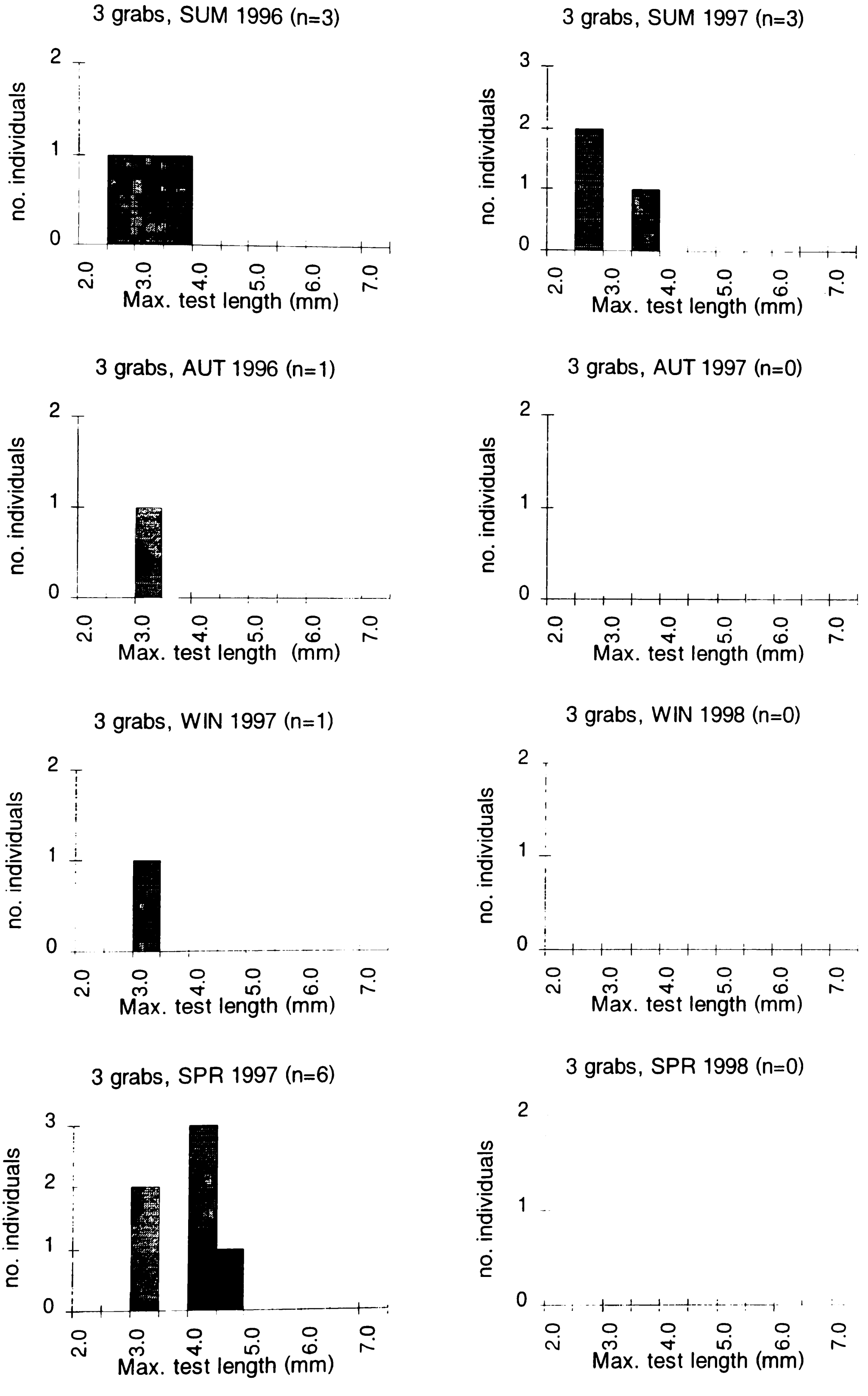
Echinocyamus pusillus was not very frequent at the impacted site. It was absent from the last three seasonal samples and was never collected in large numbers (Fig. 3.479). The highest values for both biomass and abundance were obtained in spring 1997, which do not correspond with the peaks obtained at the control ground.

Fig. 3.479. A) Mean number and B) Biomass (mg wet weight) of *E. pusillus* per 0.1m^2 grab at UMI. Error bars = SD. Numbers above each column are mean values (n=3 replicates).



The seasonal variation in size frequency of *E. pusillus* at the impacted ground is shown in Fig. 3.480. No particular seasonal pattern in size-frequency distribution can be observed (note, however, that few individuals were collected from the impacted site).

Fig. 3.480. Size-frequency histograms for *Echinocyamus pusillus* collected seasonally in 0.1m^2 grabs at UMI from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring.



3 grabs, SUM 1996 (n=3)

3 grabs, SUM 1997 (n=3)

3 grabs, AUT 1996 (n=1)

3 grabs, AUT 1997 (n=0)

3 grabs, WIN 1997 (n=1)

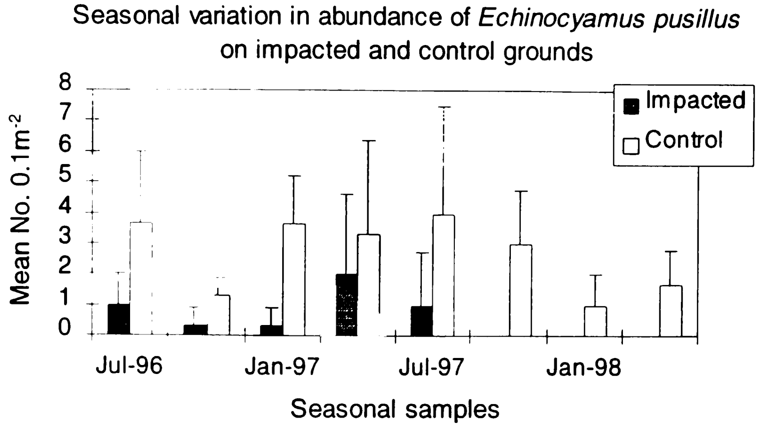
3 grabs, WIN 1998 (n=0)

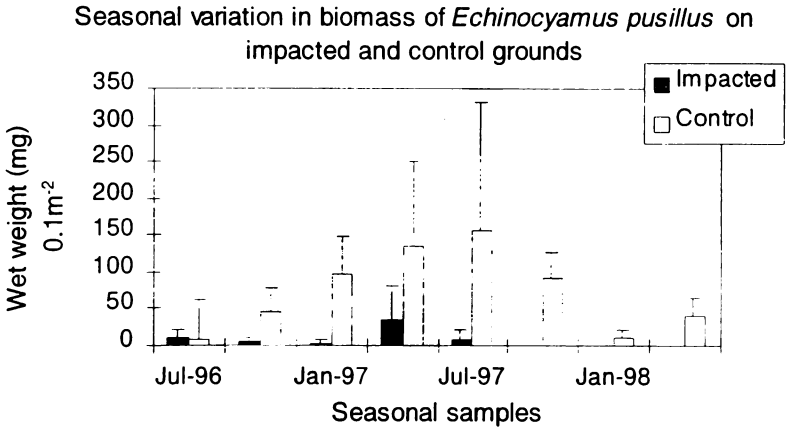
3 grabs, SPR 1997 (n=6)

3 grabs, SPR 1998 (n=0)

Figure 3.481 compares the abundance and biomass of *Echinocyamus pusillus* on the Impacted and Control sites. This species was much more abundant at the control site.

Fig. 3.481.



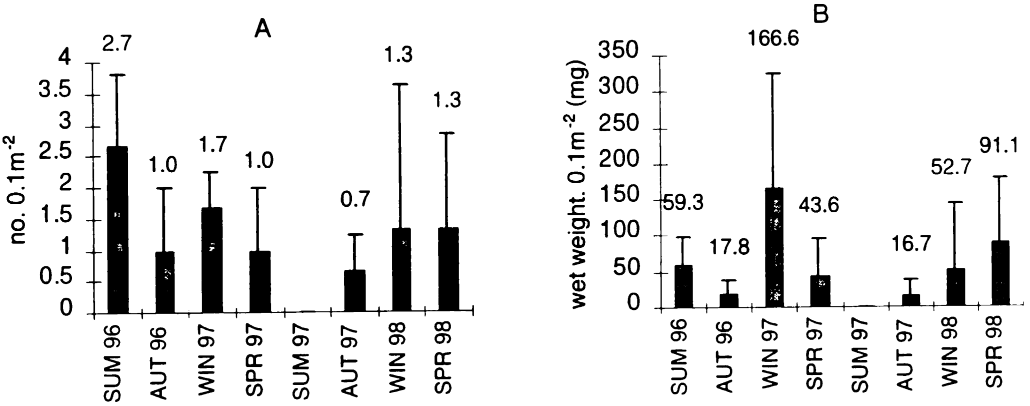


Genocidaris maculata A. Agassiz, 1869

Genocidaris maculata is a small (max. diameter *ca* 9.0mm) regular echinoid that was fairly common on the Maltese maerl grounds studied. It was collected from both control and impacted sites and was found in most of the grab samples. Its feeding habits are not known with certainty, but it is possibly a deposit-feeder or a micrograzer. It appears to be a surface dweller.

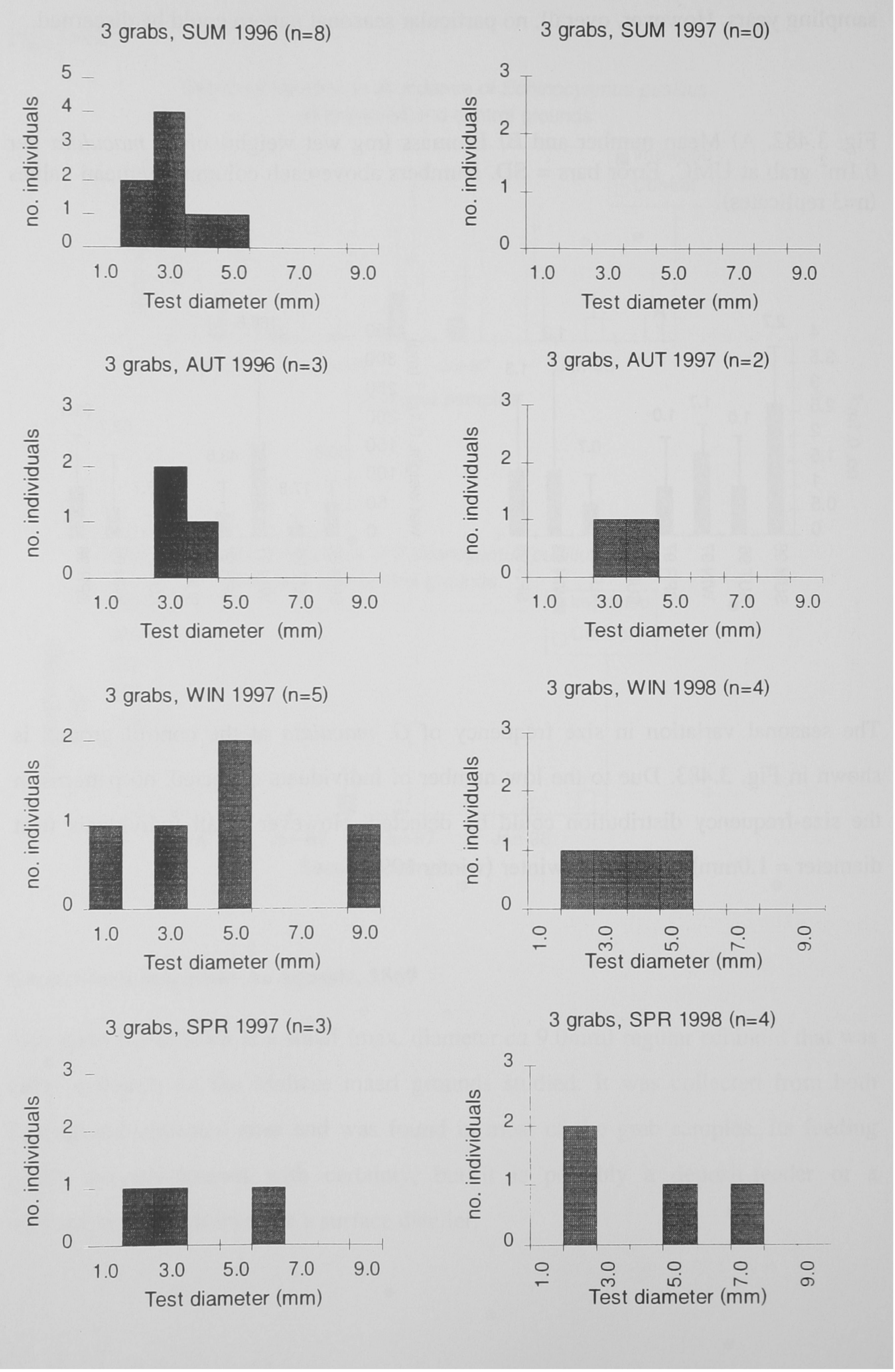
The highest value for the abundance of this species at the control site was obtained in summer 1996, but this peak was not repeated in summer 1997, when it was absent (Fig. 3.482). On the other hand, low values were obtained during autumn of both . sampling years. However, overall, no particular seasonal pattern could be discerned.

Fig. 3.482. A) Mean number and B) Biomass (mg wet weight) of *G. maculata* per $0.1m^2$ grab at UMC. Error bars = SD. Numbers above each column are mean values (n=3 replicates).



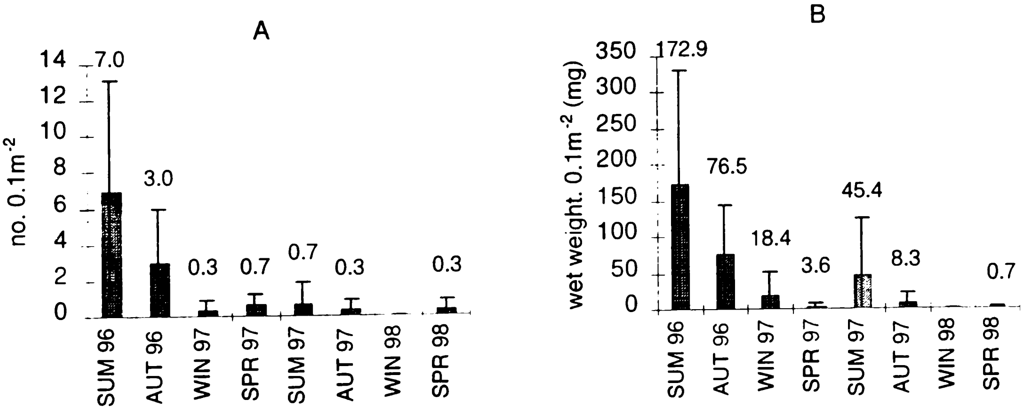
The seasonal variation in size frequency of *G. maculata* at the control ground is shown in Fig. 3.483. Due to the low number of individuals collected, no patterns in the size-frequency distribution could be detected. However small individuals (test diameter = 1.0mm) occurred in winter (winter 1997).

Fig. 3.483. Size-frequency histograms for *Genocidaris maculata* collected seasonally in 0.1m^2 grabs at UMC from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring.



Genocidaris maculata was particularly abundant in summer 1996 at the impacted site, but subsequently its numbers decreased and it was collected in very low numbers from the other seasonal samples (Fig. 3.484). For each year, however, the highest abundance and biomass of this echinoderm were obtained in summer 1996. This also corresponded to the peak obtained in the control ground. Apart from this, no particular seasonal pattern could be observed.

Fig. 3.484. A) Mean number and B) Biomass (mg wet weight) of *G. maculata* per $0.1m^2$ grab at UMC. Error bars = SD. Numbers above each column are mean values (n=3 replicates).



The seasonal variation in size frequency of *G. maculata* at the impacted ground is shown in Fig. 3.485. Small individuals (test diameter = 1.0mm) were present in summer and autumn 1996, when this species was relatively abundant. It was not very abundant during the second sampling year, so no seasonal pattern in size-frequency distribution could be discerned.

Fig. 3.485. Size-frequency histograms for *Genocidaris maculata* collected seasonally in 0.1m^2 grabs at UMI from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring.

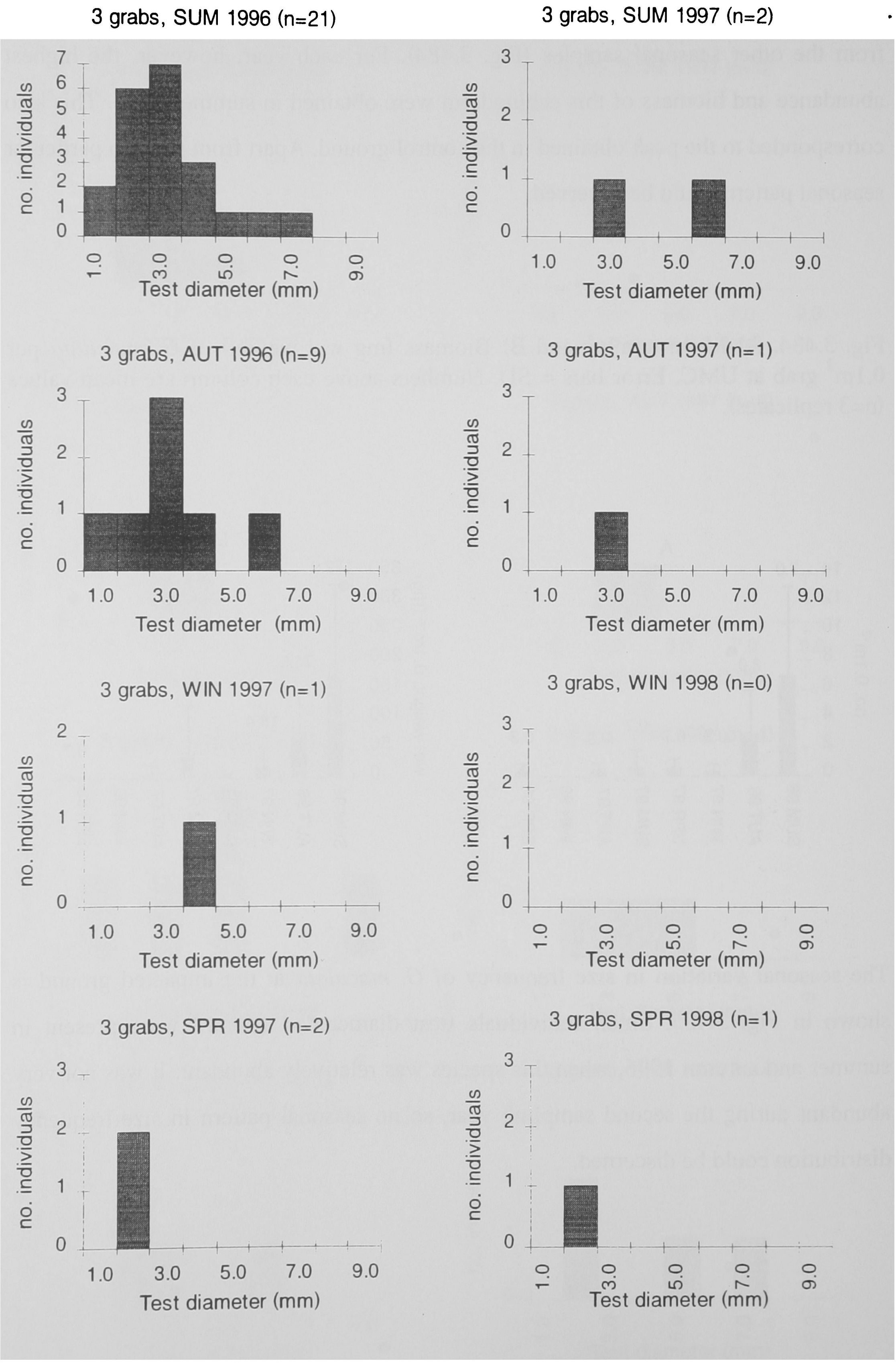
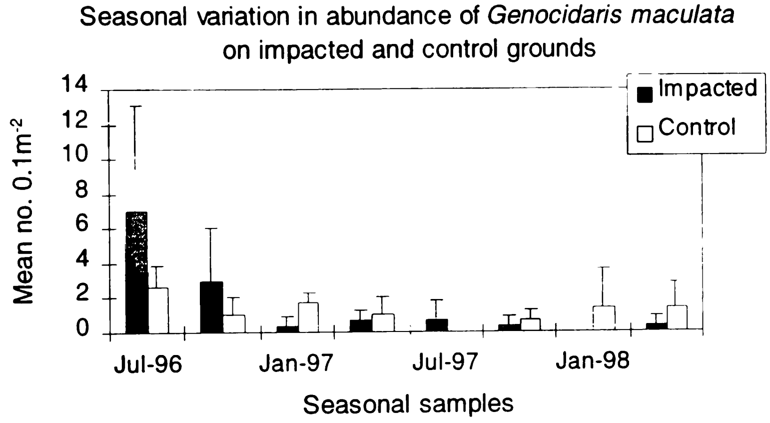
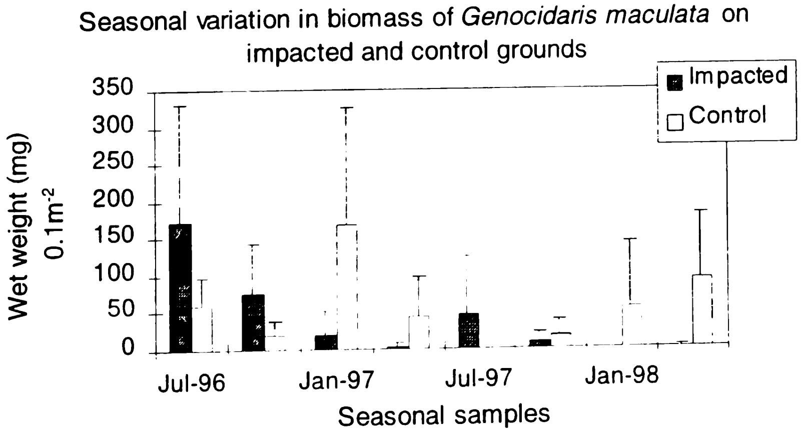


Figure 3.486 compares the abundance and biomass of *Genocidaris maculata* on the control and impacted sites. In summer and autumn 1996 this species was more abundant at the impacted site. However, during the other seasons *Genocidaris maculata* was more common on the control ground. This trend was also observed for biomass.

Fig. 3.486.



Seasonal variation in abundance of *Genocidaris maculata* on impacted and control grounds



Seasonal variation in biomass of *Genocidaris maculata* on impacted and control grounds

Summary comments

The two UK grounds (control and impacted) studied showed significant ecological differences, despite their being the same class of biotope, in close proximity (N. Clyde Sea area) and at the same depth (-10m CD) with no differences in salinity, temperature, or tidal amplitude. The sites were selected to compare a pristine site (control), that had never been exploited using towed demersal fishing gear, with a site that had been repeatedly fished over the past 30 years using toothed scallop dredges (impacted). A monitoring programme was set up on both grounds to quantify the effects of scallop-dredging experiments that were conducted using commercial fishing gear. The results of these experiments left no doubt that scallop dredging has long-term detrimental effects on maerl-forming species, which are killed through burial (Hall-Spencer & Moore, in press a). The experiments also showed that scallop dredging had little effect on major components of the infauna, such as *Dosinia exoleta* and *Upogebia deltaura,* which escape damage due to their deep-burrowing habit (Hall-Spencer & Atkinson, in press). At the same time, scallop dredging has led to the long-term loss of numerous species associated with the surface of maerl habitats, such as the delicate bivalve, *Limaria hians* (Hall-Spencer & Moore, in press b). Thus the history of scallop dredging experienced at UKI explains several obvious differences between the two sites, such as the higher population densities of scallops and the greater abundance of live maerl at the control site.

Quantitative monitoring of seasonal dynamics of the benthos showed that several natural factors interacted to bring about additional ecological differences between the maerl grounds studied. One prominent physical difference related to the hydrography of the two sites. UKC experienced benthic currents of <54cm s^{-1} since it was subjected to constricted water flow over a fjordic sill at the entrance to Loch Fyne. UKI, by contrast, was in an open bay where benthic currents were more sluggish (<11 cm s-1). This difference is thought to have exerted a major influence on the benthos of each site. Strong water flow is known to encourage the growth of hydroids, for example, which are in turn food for nudibranchs. Both hydroids and nudibranchs were more numerous and diverse at UKC than at UKI (Hall-Spencer, 1998). The difference in current speed may also explain why *Ophiocomina nigra* was much more abundant at UKC, where it had a more abundant source of particulate food in the passing flow of water.

Another major physical difference between UK sites was that UKC was more muddy than at UKI. This may be related to the effects of scallop dredging which erodes fine sediment from maerl habitats (Hall-Spencer, 1995). Whatever the cause, this edaphic difference strongly affected the species composition at each site. Mud specialists (e.g. *Priapulus caudatus*) were present only at UKC, whereas species that thrive best in clean gravel (e.g. *Spatangus purpureus* and *Neopentadactyla mixta*) were present only at UKI. The most dramatic difference between the two grounds studied was the effect that storms had on the stability of the deposits. While UKC was sheltered and remained unaffected by wave action, UKI was more exposed with large-scale shifts in surface sediment noted 2-3 times a year (Hall-Spencer & Atkinson, in press). This natural source of disturbance favoured opportunistic species in the surface layer of sediment at UKI (e.g. *Polygordius lacteus*, *Mediomastus fragilis*). The opportunists exhibited marked increases in abundance during spring to autumn each year followed by population crashes during winter storms. UKC, in contrast, was characterized by a more stable assemblage of species with larger, longer-lived species common year-round (e.g. *Metridium senile*, *Pista cristata*).

Thus, while many elements of the benthos were common to each UK maerl ground, significant ecological differences were noted between sites. Some differences were attributable to natural differences between sites, such as the strength of benthic currents or the relative exposure to wave action. Controlled scallop dredging experiments showed that additional, long-lasting differences were attributable the effects of scallop dredging. The low live-maerl cover, reduced species diversity and lack of large, long-lived species at the sediment surface of UKI were all consistent with the effects of scallop dredging.

With regard to the Alicante maerl grounds, there were pronounced differences between control and impacted sites. One of the most striking features about these bottoms is the difference between the colours at the control and impacted sites. The control site presented a wide spectrum of colours (yellow, red, orange, rose, white, blue etc.), in contrast to the impacted site which appeared a homogenous dark red or garnet. That contrast is due to the higher biodiversity at the control site than the impacted site. The greater abundance of sessile organisms (poriferans, cnidarians, serpulids, bryozoans, ascidians) at the control site was responsible for this highly visible difference. Calcareous Corallinaceae (*Phymatolithon calcareum, Lithothamnion minervae, Lithophyllum racemus, Mesophyllum* sp.) were more diverse and abundant on the control site cf. the calcareous and incrusting Peyssonneliaceae (*Peyssonnelia rosa-marina, P. dubyi*). By contrast, at the impacted site, with the exception of very small thalli of *Lithothamnion corallioides*, the dominant species was the soft *Peyssonnelia orientalis*, i.e. a more opportunistic species. Also, some erect fleshy algae were more abundant at the control site, e.g. the rhodophytes *Osmundaria volubilis, Rytiphloea tinctoria* and *Phyllophora crispa,* and the phaeophytes *Dictyopoteris polypodioides* and *Cystoseira spinosa*. By contrast, the chlorophytes *Flavellia petiolata* and *Codium bursa* were more abundant at the impacted site. *Cladophora rupestris* (an opportunistic species) was also more frequent at the impacted site. The sediment-binding species, like *Aglaozonia chilosa, Polysiphonia subulifera, Feldmannophycus rayssiae, Pterosiphonia pennata* and *Gelidiella* cf. *calcicola,* were similar in both grounds.

Regarding the macrofauna, the comparison (Table 3.1) between Alicante control and impacted grounds showed the lower abundance (and biomass) of sessile filter-feeding taxa (sponges, cnidarians, serpulid polychaetes, bryozoans and ascidians) and the microalgal grazing component (Polyplacophora, Archaeogastropoda, *Genocidaris maculata*) at the impacted site. By contrast, the carnivore/scavenger component (Polychaeta errantia and Ophiuridea), and to a lesser extent the Crustacea Decapoda, were more abundant at the impacted site.

Table 3.1. Comparison of the number of species between control (UAC) and impacted (UAI) sites with regard to higher taxa. Nº spp. = total number of determined species; C/I % = control site species as a percentage of impacted species.

Taxa	Nºspp	UAC	UAI	C/I %
Chlorophyta	24	22	23	- 4.3
Phaeophyta	24	22	19	+ 15.8
Rhodophyta	167	112	113	- 0.9
Porifera	5	5	3	+ 66.7
Cnidaria	11	10	4	+ 150.0
Polychaeta	78	72	74	- 2.7
Crustacea	104	79	64	+ 23.4
Mollusca	96	76	45	+ 68.9
Bryozoa	9	9	6	+ 50.0
Echinodermata	25	25	13	+ 92.3
Ascidiacea	14	13	3	+ 333.3
Pisces	13	10	9	+ 11.1
Total spp. **% of total spp.**	**570**	**455** **79.8**	**376** **66.0**	**+ 21.0**

A similar pattern has been reported for seagrass meadows (Ramos-Esplá *et al.*, 1996), where carnivores and scavengers were more frequent on *Posidonia* beds that had been degraded by trawling, i.e. due to the increased disturbance and greater vulnerability of their prey organisms caused by the loss of refugia (leafs and rhizomes). A similar scenario exists on maerl grounds, where both structural complexity (supplied by the calcareous Corallinaceae) and habitat integrity is reduced by trawling.

Thus, the mechanical impact of trawling over Alicante maerl grounds has produced a diminution of specialist calcareous algae (Corallinaceae and Peyssonneliaceae), which are replaced by opportunistic soft algae (*Peyssonnelia orientalis*) and an increase of the fine (silt) fraction of the sediment. That entails a loss of hard substrata and structural complexity (and refuge potential) with the consequent loss of epilithic algae and sessile macrofauna. Therefore, the micrograzer and filter-feeding components decrease on the impacted ground, while the carnivores are much more frequent due to the enhanced vulnerability of their prey.

At both UMC and UMI, off Malta, the abundance of all species was very low, cf. Atlantic sites. On the impacted ground, the highest abundance was obtained for *Bittium latreillii*: the highest mean value was of 52.7 individuals per grab in July 1996. The most abundant species at the control site was *Leptochelia savignyi* which attained a mean of 17.3 individuals per grab in January 1998. This is at least an order of magnitude lower than densities recorded from Atlantic sites and reflects the generally oligotrophic status of Mediterranean waters.

The question of whether the temporal stability revealed in some data sets (e.g. Clyde Sea control ground [UKC]; Malta) is real or apparent requires consideration. In the case of Malta, it seems likely that this may be artefactual, i.e. an impression due, at least in part, to the low population densities of most species sampled. That the UKC data represent a mature ecosystem with little extrinsic perturbation is, however, more substantiable. The fact that more pronounced temporal variation occurred at the impacted site (UKI) would support this interpretation.

In the Bay of Brest (Brittany), the control ground was located within the southern basin (apparently away from anthropogenic impacts), while the impacted ground was located within the northern basin under the direct influence of discharges from the environs of the city of Brest (industrial and urban wastes) and from run-off from surrounding agricultural land. This results in heavy metals and organic matter inputs to the maerl bed sediments at UBBI and to increased sedimentation of small particles onto the maerl surface and into the maerl interstices.

In the ria de Arosa (Galicia), the impacted site was located in the vicinity of mytiliculture rafts. Mussel faeces rain down onto the maerl surface altering the sediment structure and compromising the ability of maerl thalli to photosynthesise and grow.

Maerl sediments at the impacted site in the Bay of Brest had a higher content of fine particles (<63μm) than did the control ground. This does not, however, completely explain the higher densities of the surface-deposit feeders on the impacted site represented mostly by the opportunistic species *Cirriformia tentaculata* and *Chaetozone setosa*. Regular organic inputs to this ground could be the explanation. (Grall& Glémarec 1997a). The turbidity observed over this ground may account for the low number of suspension feeders observed there The higher turbidity over UBBI may also restrict the development of the microphytobenthos since lower abundances of micrograzers were also observed on this ground. On the other hand, macroalgal production seemed to be stimulated on the impacted site and could then be related to high population densities of macrophyte detritus feeders, especially the amphipod *Gammarella fucicola*. Total abundance and biomass were higher, while total number of species was lower, on the impacted ground at any season (28% fewer species and 40% higher abundance on UBBI than on UBBC). This is clearly a sign of the first stages of eutrophication (Gray, 1992; Grall & Glémarec, 1997b). Seasonal variation of these parameters were also higher on UBBI than on UBBC, showing that the latter ground was more 'stable' than the former. It seemed that the two grounds were somewhat similar in the winter and then moved away from each other during the year.

Study of the two Galician sites showed a similar pattern, with an increase of abundance and decrease of the total species richness on the impacted compared with the control. A reduction in suspension feeders, and micrograzers abundance and number of species was also observed, and an increase in subsurface deposit feeders and macrophyte deposit feeders.

In addition to these effects, a notable reduction of carnivores occurred on the impacted site in Brittany and Galicia, both in terms of species richness and abundance. Carnivores represented more than the third of the total abundance on both control grounds (38% USC: 36% UBBC) while this percentage remained under 20% for both impacted grounds.

In the Bay of Brest, the year 1997 had higher abundances (for most of the key species as well as for total abundance), and a larger number of species than 1996. However, no major changes were observed in species composition (e.g. dominant species,whether in terms of abundance or biomass) between years. Thus variation within years there was greater than variation between years.

Off Malta, however, the second year samples generally had lower abundances of key species than the first year samples. This was more pronounced for the impacted site and may reflect the 'instability' of this ground with respect to the control ground. The impacted ground is subject to disturbance than the control site and this might be inducing year-to-year changes in abundances of the species present. On the other hand the abundances of some species (*Barleeia unifasciata*, *Galathea intermedia*, *Lysidice ninetta* and *Eunice vittata*) seemed to increase during the second year of sampling at the impacted site, and might justify consideration of these species as opportunists or as survivors, since they possibly seek shelter within the maerl thalli.

Impact of natural causes of disturbance and effects on maerl bed stability

Monitoring at UKI (depth -10m) showed that the maerl surface was only moved twice during winter storms in 1995, and three times in both 1996 and 1997. On each occasion, maerl gravel was piled into regular interspersed with strips of level, more mixed, sediment. Permanently marked megafaunal burrows (e.g. of *Upogebia, Chaetopterus, Cerianthus*) revealed that only the coarse upper layer of sediment was moved by wave action; the underlying layer and burrows within it remaining stable. After storms abated, infaunal organisms quickly (<7 days) reinstated their burrow linings to conform with the new pattern of gravel megaripples.

In situ observations on maerl grounds off Alicante, made six days after a major storm (September 1996, duration 2 days, wave height 4-5m, wavelength 100-120m), showed no significant topographic rearrangement of the bottom at 38m depth. Maerl thalli were dispersed (i.e. not arranged in strips; see above), although unattached shoots and leaves of *Posidonia* were present in greater abundance on the sea bed, and near-bottom visibility was much reduced (<2m) due to residual fine sediment in suspension. Storms may thus result in an elevated input of detritus to maerl systems.

Off Brittany, between autumn and winter, large differences in total abundances and number of species were observed on maerl grounds. Presumably this was due to storm action. Indeed, after severe storms, it was common to find large maerl-bed epifaunal species (like *Crepidula fornicata* or *Modiolus modiolus*) washed up onto adjacent beaches in the Bay of Brest. It is therefore suspected that storms have a significant impact on the fauna, but no direct observations (cf. sites abovementioned) were made on these grounds. Certainly, the fact that water column turbidity was high during the winter months, was probably because of storms.

Off Malta, however, typical bottom currents were not thought to be sufficient to roll the larger rhodoliths, although occasional violent storms might create enough benthic disturbance to move them (Bosellini & Ginsburg, 1971; Di Geronimo & Giaccone, 1994; Harris *et al.*, 1996; Borg *et al.*, in press).

Diving observations made at UKI during the annual spring phytoplankton bloom (April 1997) showed that a floc of decaying phytoplankton, consisting mainly of the diatom *Skeletonema costatum*, blanketed the maerl surface. Epibenthic water samples revealed elevated concentrations of chlorophyll-*a* (9.6 μg l^{-1}) and a lowered oxygen tension from 175.9 ± 9.5 μmol.l^{-1} on 2 April to 147.8 ± 18.2 μmol.l^{-1} on 17 June 1997. For most of the year, chlorophyll-*a* concentrations in the Clyde Sea vary between <0.1 and <1g l^{-1}, though values as high as those we recorded are typical of the spring plankton bloom (Hannah & Boney, 1983). The biological oxygen demand (BOD) created by this pulse of organic matter settling to the bottom lowered within-sediment oxygen tensions and infaunal sea urchins (*Spatangus purpureus* and *Echinocardium pennatifidum*) were seen on the sediment surface. The implication from repeat surveys during the following weeks was that they survived the incident, since no empty tests were visible on the sediment surface.

TASK 4 : Assessment of anthropogenic threats to maerl ecosystems

Objectives:

To identify local anthropogenic threats to, and assess the resilience of, maerl grounds . over a wide geographical spectrum.

To compare population density, biomass and size-distribution of the key species (selected under Task 1, sub task 1.2) on existing impacted grounds or areas that have been deliberately impacted, to do this four times a year for two years and compare them with similar data gathered under Task 3 (see results above). Where necessary to deliberately impact a small area of control ground to elucidate and quantify the effect of a known impact (above).

To collect qualitative data on species occurrence to contribute to Task 5.

Threats to maerl grounds

The major threats to maerl beds are four-fold: direct exploitation, impacts from towed fishing gear, aquaculture and eutrophication. The impacted grounds studied during the BIOMAERL programme have been considered as being subjected to these threats, as follows: direct exploitation (UBO), mechanical impact caused by towed fishing gear (UMBSM, UA, UM), aquaculture (USC), eutrophication (UBO).

The thickest maerl deposits have been recorded around the îsles de Glenan in Brittany (>15m thick) and such (dead) beds represent attractive resources for commercial exploitation, principally as a source of lime and trace minerals for improving soil condition or water potability (Augris & Berthou, 1986; Guiry & Blunden, 1991). Since maerl-forming rhodophytes grow so slowly (millimetres per year; Potin *et al.*, 1990; Hall-Spencer, 1994), it is impossible for the commercial extraction of thousands of tonnes to be self-sustaining. Carbon-dating has established that some maerl beds are thousands of years old (Farrow *et al.*, 1979) . These beds, therefore, need to be regarded as essentially non renewable resources (Farrow, 1983), since recovery takes so long (Hall-Spencer & Moore, in press a).

European maerl grounds are exploited commercially for scallops (*Pecten maximus* and *Aequipecten opercularis*) in Scotland (Hall-Spencer, 1998) as well as for demersal resources like *Octopus vulgaris* (off Alicante; Ramos Esplá, pers.obs.) and fish, like *Mullus surmuletus* and *Spicara smaris,* off Mallorca (Massutí *et al.*, 1996). Scallop dredging is particularly efficient over maerl. Hall-Spencer & Moore (in press . b) reported efficiencies of scallop extraction of 85% on maerl in the Clyde Sea area, Scotland compared with only 14-27% over coarse sand and gravel ground (Gruffydd, 1972; Chapman *et al.*, 1977). Unsurprisingly, therefore, maerl beds represent attractive targets for fishers.

Heavy toothed gears, like scallop dredges (each of which weighs ~85kg), when towed commercially in gangs (of <16) over maerl beds results in extensive comminution of maerl thalli (Hall-Spencer & Moore, in press *a*), or burial under silt which can kill the fragile living veneer. Penetrating <10cm into the maerl-sediment surface, such gears have been reported recently (Hall-Spencer & Moore, in press *a*) to kill 70% of living maerl (by burial) in one pass over a Clyde maerl ground. Resuspended bottom sediment also increases turbidity which will have negative impacts on photosynthetic benthic autotrophs. In addition, towed gear reduces spatial heterogeneity, homogenizing the topography of the bottom, levelling megaripples (BIOMAERL team, 1998; Hall-Spencer, 1998), tearing through surface-binding algal mats (Borg *et al.*, in press) and animal constructs, like nests of *Limaria hians* (Hall-Spencer & Moore, in press *b*) and in-filling animal pits and burrows (Hall-Spencer & Atkinson, in press).

Eutrophication has several effects on maerl beds: it increases in the proportion of fine particles (and therefore is responsible for the disappearance of some of the maerl structure microhabitats by clogging interstices and reducing permeability); it increases the total abundance and biomass of infauna and epifauna; it decreases species richness; it changes the trophic structure of the grounds, favouring surface- and subsurface-deposit feeders and threatening suspension-feeders and micrograzers. All these features lead to a simplification of the otherwise exceptionally rich and diversified ecosystems that maerl beds represent.

Resilience of maerl beds

Most maerl beds investigated in the Clyde Sea area exhibit damage caused by scallop-dredging. Only one small ground has so far been identified that seems to be pristine (that used as the UKC control ground). The brittleness of maerl thalli coupled with their slow growth rate mean that maerl habitats are vulnerable to mechanical impact and are not resilient, even in the long term. Damage caused by a single inappropriate impact may take centuries to repair.

Paradoxically, however, Borg *et al.* (in press) discerned no ill-effects of intermittent (if illegal) otter trawling over Maltese maerl grounds. This they attributed to the limited sediment penetration of otter trawls (cf. also Van Dolah *et al.*, 1991). Indeed, the low intensity of illegal trawling taking place over the Maltese ground was conceivably benefiting the maerl, creating enough disturbance to roll, but not damage, large rhodoliths, thereby preventing the settlement of fleshy non coralline algae which otherwise tend to bind the rhodoliths (Borg *et al.,* in press). On the other hand, otter trawling activity over maerl grounds off Alicante has had a greater impact. The heavy trawl gear used (*ca*1.5-2 metric tons), in particular the otter boards weighing 200-400kg/unit, erodes the bottom (the tracks being readily visible underwater) and has produced both a shift in the dominant species (to soft Peyssonneliaceae, probably more opportunistic species, from hard Corallinaceae) and in the sizes of rhodoliths (smaller at the impacted site). On heavily impacted sites maerl disappears altogether and muddy-sand bottoms dominate (analogous observations have been reported for Mediterranean seagrass meadows; see Sánchez-Jérez & Ramos-Esplá (1996)).

During the course of this study, another impact of fishing, that resulting from bottom-set gill-nets (*'parit'* in Maltese) has also been identified. The *'parit'* nets are about 2m in height and are designed to remain in a vertical position, perpendicular to the seabed. The impact of this type of fishing varies depending on the strength of bottom currents. Currents tend to deflect the nets from their normal vertical position so that the nets may come to lie horizontally; sometimes in direct contact with the seabed. In such circumstances, relatively large amounts of maerl rhodoliths become entangled in the nets and are taken up with the catch. For the fishers, the rhodoliths are a nuisance since they tear up the nets and cause considerable damage. They are difficult to release from the net and the fishers have to crush the individual thalli using a heavy object, sometimes extending to driving a road vehicle over the nets.

According to the Maltese fishers interviewed, it seems that professionals rarely cast their nets on maerl grounds, due to the problems mentioned above. However, amateur fishers often fish these grounds.

In order to assess the potential impact of *parit* fishing, an experiment was carried out as follows. *Parit* nets were deployed on each maerl ground and left to fish overnight (c. 12 hours) between 9 and 10 December 1997. Each net had a height of 2m and a 3cm stretch mesh; 400m of net were deployed on the control bottom and 440m on the impacted bottom. All biota and rhodoliths entangled by the nets were collected. The biota were identified and counted and the longest axis and the weight of each rhodolith were determined.

Large numbers of live rhodoliths were entangled with the nets on both grounds; 188 rhodoliths (total weight 5684.6g) were obtained from the impacted site and 110 rhodoliths (total weight 150.0g) from the control. Many of these rhodoliths were much larger than any sampled by grab and it was also noted that rhodoliths collected from the impacted site were much larger than rhodoliths collected from the control. (The largest rhodolith from the impacted ground had a maximum length of 85.90mm, while for the control site, the largest rhodolith had a long axis of only 46.50mm).

Fourteen species of fish were caught by the parit nets off Malta, of which twelve species were caught from the impacted site and three from the control. Fish were clearly more abundant at the impacted site, while only *Mullus surmuletus* was common to both grounds.

Species	Numbers	Station
Aulopus filamentosus (Bloch)	1	Control
Boops boops (Linnaeus)	1	Impacted
Dactylopterus volitans (Linnaeus)	1	Impacted
Diplodus vulgaris (E. Geoffroy St. Hilaire)	1	Impacted
Echiichthys vipera (Cuvier)	1	Impacted
Mullus surmuletus Linnaeus	15/1	Impacted/Control
Mustelus mustelus (Linnaeus)	2	Impacted
Pagellus erythrinus (Linnaeus)	35	Impacted
Pagrus pagrus (Linnaeus)	2	Impacted
Scyliorhinus stellaris (Linnaeus)	1	Control
Seriola dumerili (Risso)	1	Impacted
Serranus cabrilla (Linnaeus)	3	Impacted
Spondyliosoma cantharus (Linnaeus)	3	Impacted
Trachinus sp.	1	Impacted

Apart from demonstrating the different character of the grounds studied, this experiment also demonstrated that *parit* fish may have a significant impact since it selectively removes the larger rhodoliths which are presumably the oldest and the one that are slowest to be replaced. However, since the impact of this type of fishing depends not only on the intensity of fishing but also on the environmental conditions at the time of fishing (especially the strength and duration of bottom currents), the actual impact on Maltese maerl bottoms is difficult to quantify.

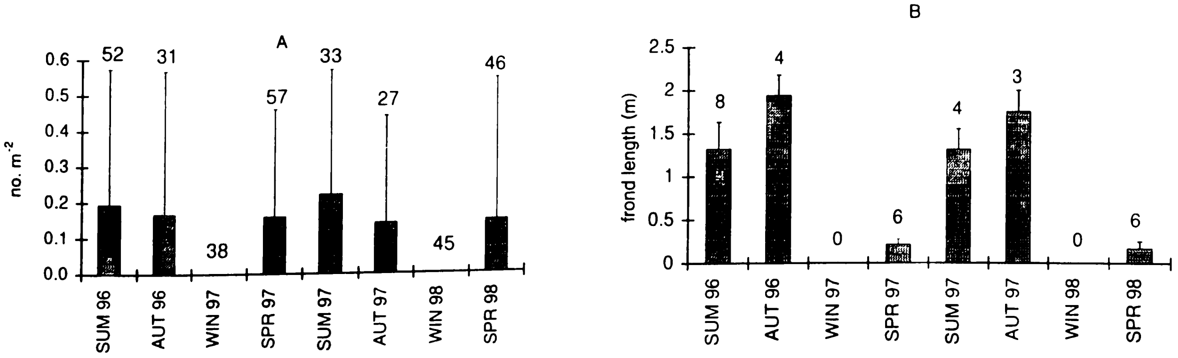
Data on seasonal variation in population parameters of key species that did not occur on the control grounds

1) Clyde Sea area

Laminaria saccharina (L.) Lamour.

A major difference between the two Clyde maerl grounds studied pertained to the macroalgae. While crustose algae were common at both sites, erect forms were sparse and had low diversity in all seasons at the control ground (UKC) due perhapos to the abundance of grazers noted during the 1996-98 monitoring period (e.g. *Jujubinus miliaris, Gibbula magus, Psammechinus miliaris, Echinus esculentus*). In contrast, erect macroalgae were diverse and had a high biomass each summer and autumn at the impacted ground (UKI), although most were removed during winter storms. *Laminaria saccharina* was the largest macroalga present (fronds were <3m long). This is a cold-water species that occurs in the Arctic, north Pacific and north Atlantic with a southern limit in Galicia, Spain (Lüning, 1990). The large size of these algae meant that they were not sampled quantitatively in van Veen grabs so seasonal variations in abundance and size were monitored by divers equipped with 1m^2 quadrats. This kelp species was rare on the maerl ground each winter with about one individual every 5 m^2 from spring to autumn with biomass peaking in the autumn of each year (Fig. 4.1 A,B).

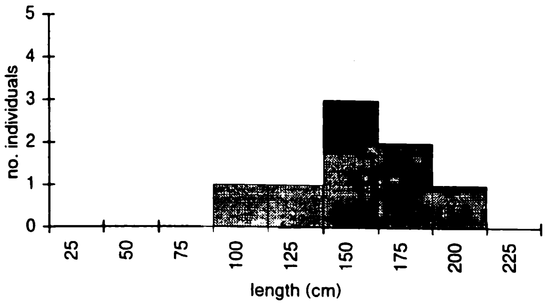
Fig. 4.1 A) Mean number of *L. saccharina* per 1 m^2 quadrat at UKI, N = number of quadrats taken, B) mean size (frond length) of *L. saccharina*, N = number of thalli measured *in situ*. Error bars = SD. Numbers of replicates above error bars.



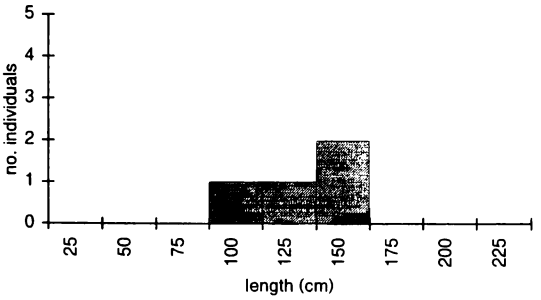
The seasonal variation in size-frequency of *L. saccharina* recorded in quadrats at UKI are given in Fig. 4.2. Most of the *L. saccharina* present were annuals, <5% survived the winter with renewed growth in the following spring. These algae exhibited a high level of primary production with fronds growing at a rate of 5–10 cm per week each summer. In summer and autumn the fronds of these algae formed a patchy canopy over about 15% of the maerl bed. Their distribution depended on the availability of cobbles and large shells since surfaces for attachment were at a premium. The kelp canopy and holdfasts increased the heterogeneity of the habitat, providing shelter from predation and a surface for the attachment of rapidly growing sessile species such *Obelia* spp., *Membranipora membranacea* and *Electra pilosa*. In winter, accumulations of rotting *L. saccharina* created small hypoxic areas (typically on the scale of $1m^2$) on the maerl surface where organic enrichment favoured opportunistic polychaetes. This also contributed to the mosaic of conditions available and thus to the high diversity of the system. An examination of the site following storms provided an insight into how maerl may colonize new areas of sediment since bundles of living thalli were transported in the holdfasts of drifting *L. saccharina* plants.

Fig. 4.2. Size-frequency histograms for *L. saccharina* measured seasonally in 1 m^2 quadrats at UKI from 1996-1998. SUM = summer, AUT = autumn, WIN = winter, SPR = spring and N = number of individuals measured.

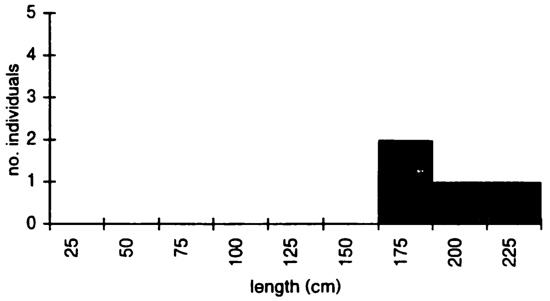
52 quadrats, SUM 1996 (n=8)



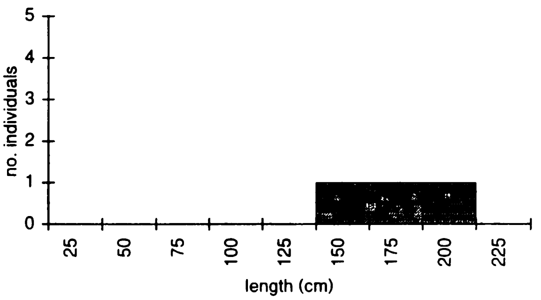
33 quadrats, SUM 1997 (n=4)



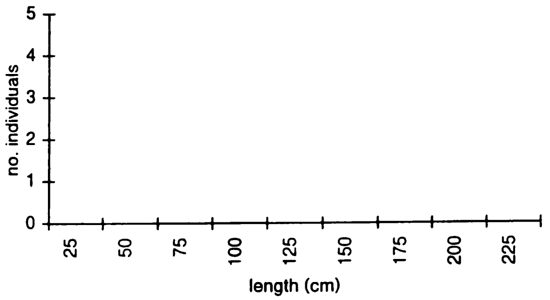
31 quadrats, AUT 1996 (n=4)



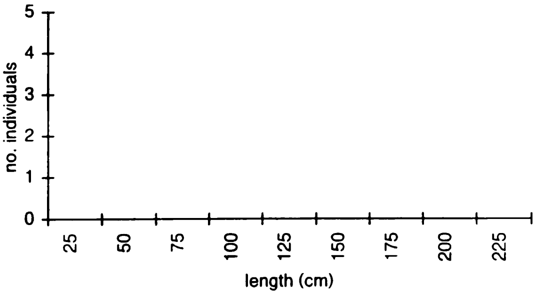
27 quadrats, AUT 1997 (n=3)



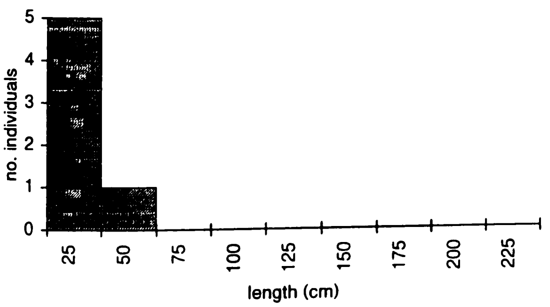
38 quadrats, WIN 1997 (n=0)



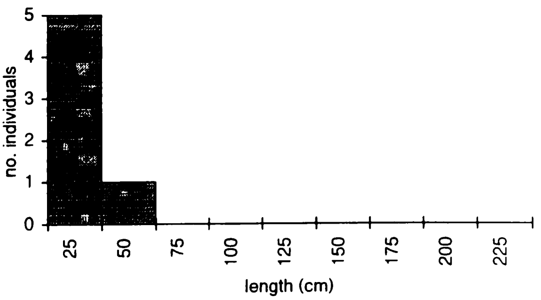
45 quadrats, WIN 1998 (n=0)



57 quadrats, SPR 1997 (n=6)



46 quadrats, SPR 1998 (n=6)



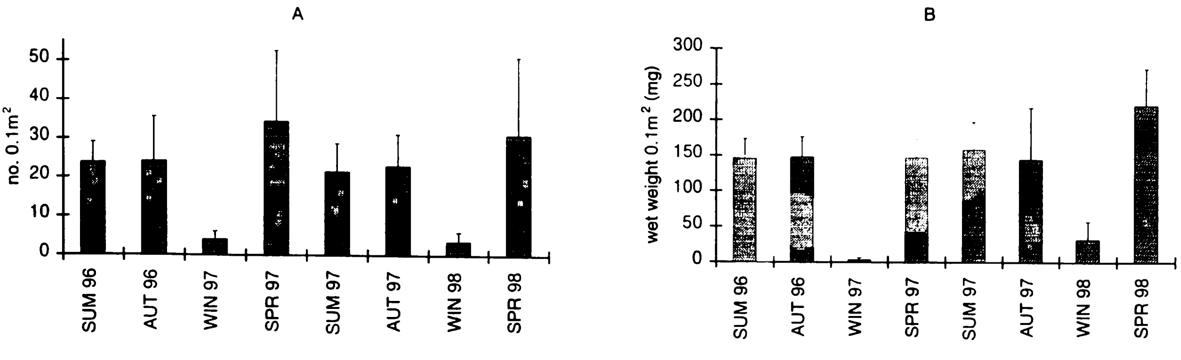
Polygordius lacteus Schneider, 1868

One of the main faunal differences between the two Clyde maerl grounds studied was the abundance of *P. lacteus* at UKI and its absence from UKC. It occurred in all Ring Dredge, core and van Veen grab samples taken at UKI over 1996–1998 and was the third most abundant annelid caught, after *Aonides paucibranchiata* and *Pomatoceros triqueter*. The abundance of *P. lacteus* varied widely between seasons with 20–35 per 0.1 m^2 from April to December but <5 m^{-2} each winter (Fig. 4.3A).

This species burrows actively. When divers moved the surface layer of maerl away by hand *P. lacteus* up to 10 cm long moved in a violent wriggling motion to re-burrow. *Polygordius lacteus* appears to favour coarse, near-shore sediments such as maerl. Jones (1950) included it in his boreal offshore gravel section and Keegan (1973) recorded it in Irish maerl beds. Fauvel (1923) noted it as having a wide European distribution from Helgoland in the North Sea south to Villefranche on the French Mediterranean coast.

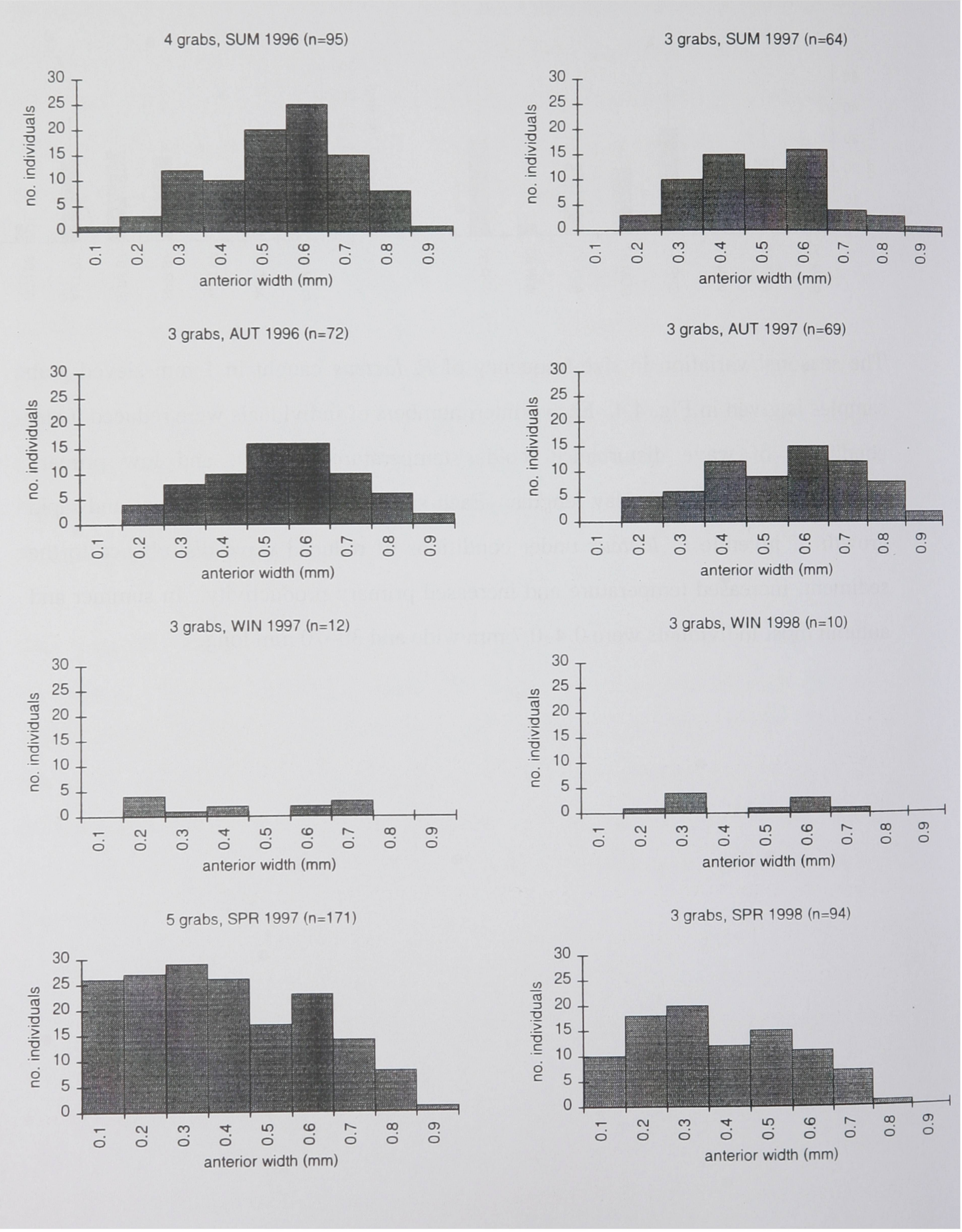
The observed variation in biomass of *P. lacteus* closely followed that of its abundance. Mean wet weights of *ca* 150–200 mg per 0.1m^2 grab occurred in spring to autumn with a significant drop each winter to <25 mg per grab (Fig. 4.3B). Some of the other annelids that were abundant at UKI (e.g. *Aonides paucibranchiata*, *Mediomastus fragilis*) also exhibited population crashes each winter. This fluctuation in the abundance of opportunistic species contrasts with the more stable populations that were present at UKC.

Fig. 4.3. A) Mean number and B) biomass (wet weight) of *P. lacteus* per 0.1m^2 grab at UKI. Error bars = SD. Five grab samples were analysed in spring 1997, four in summer 1996 and three in all other seasons.



The seasonal variation in size-frequency of *P. lacteus* caught in 1 mm sieved grab samples is given in Fig. 4.4. Each winter, numbers of individuals were reduced under conditions of wave disturbance, colder temperatures (<8°C), and low primary productivity due to short day lengths. Each spring there was recruitment and rapid growth of juvenile *P. lacteus* under conditions of reduced wave disturbance to the sediment, increased temperature and increased primary productivity. In summer and autumn most individuals were 0.4–0.7 mm wide and 30–70 mm long.

Fig. 4.4. Size-frequency histograms for *P. lacteus* collected seasonally in 0.1m^2 grabs at UKI from 1996-1998. SUM = summer, AUT = autumn, WIN = winter, SPR = spring and n = number of individuals measured. Anterior widths measured across the head.

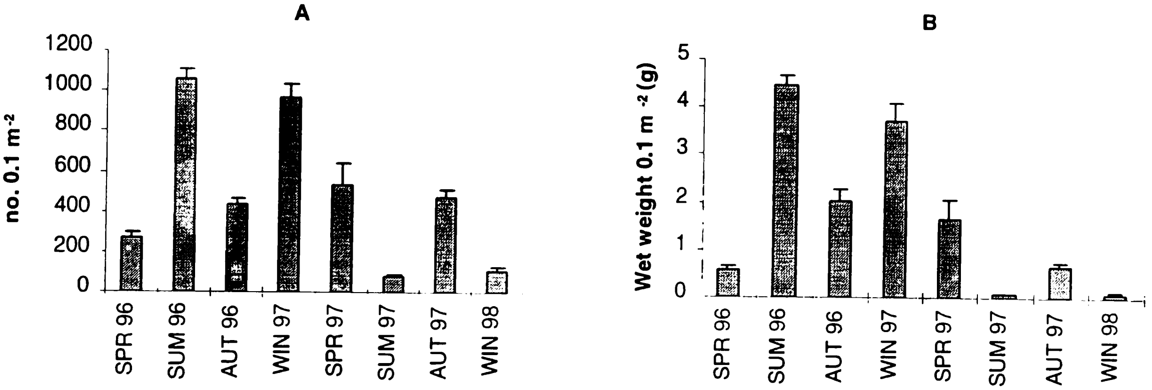


2) Galicia

Mediomastus fragilis Rasmussen, 1973

This polychaete is considered to be a selective deposit-feeder. The list of gut contents, however, nearly always includes algal fragments mixed with sediment.

Fig. 4.5. A) Mean number and B) biomass (g wet weight) of *Mediomastus fragilis* per 0.1 m^2 grab at USI. Error bars = SD, N = six grabs analysed

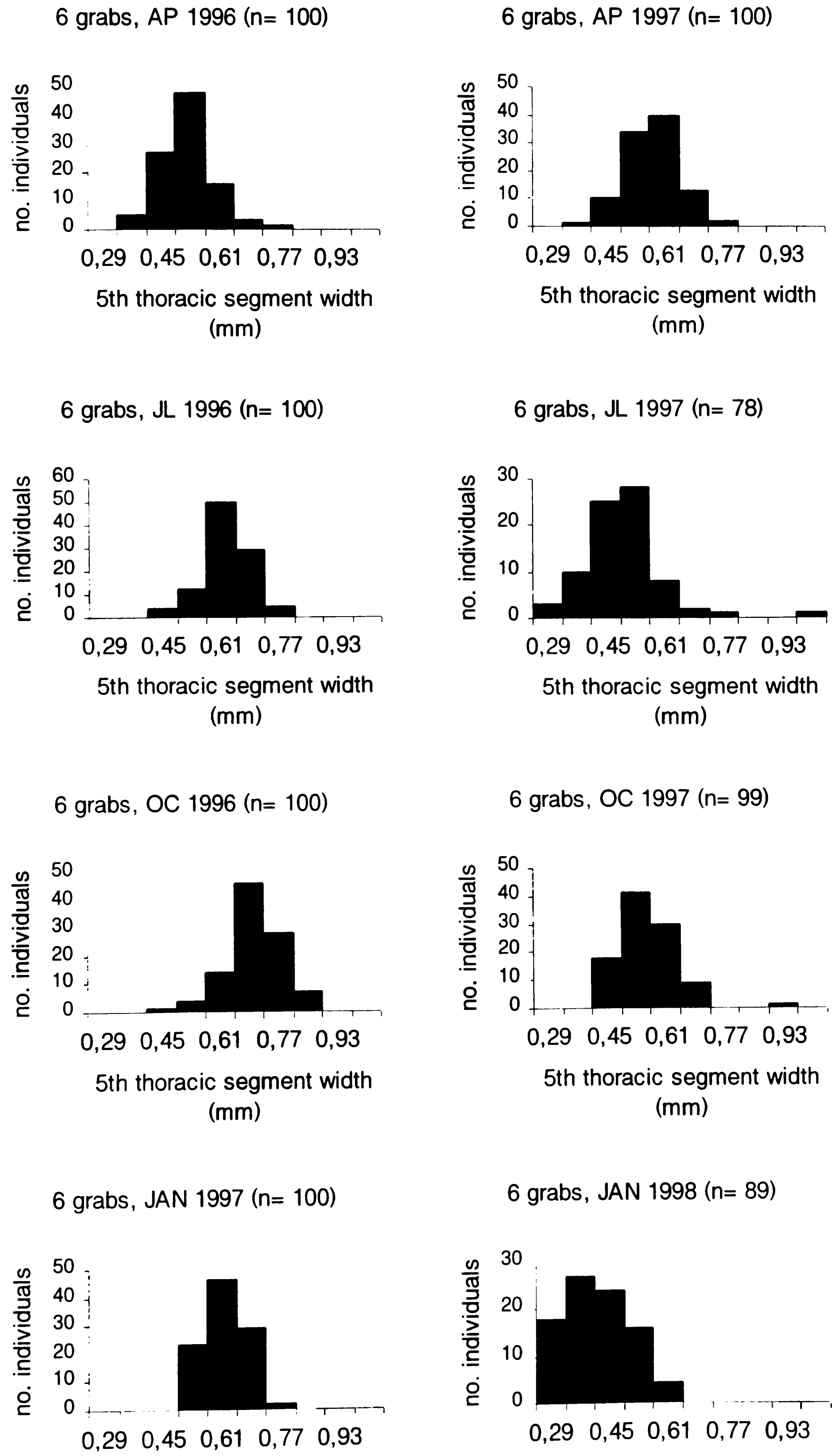


One of the key species that was only present at the impacted site, it was present there in very high numbers. *Mediomastus fragilis* was consistently present throughout the two-year period of study.This species contributed some of the highest numbers, compared with the rest of the key species characterizing the impacted site.

Its seasonal pattern (Fig. 4.5 A) suggests that the recruitment takes place once every two years due to the highest numbers found in summer and winter 1996 *cf.* the lowest found in the same seasons one year after (1997). This observation is also corroborated in the biomass data by the same pattern of seasonality (Fig. 4.5 B).

The seasonal variation of size-frequency of the *Mediomastus fragilis* population at the control station USC is shown in Fig. 4.6. It reveals a stable population with individuals measuring between 0.45 and 0.85 mm (width at the thoracic segments), throughout two-year period. A new bigger cohort can be detected in summer and automn 1997.

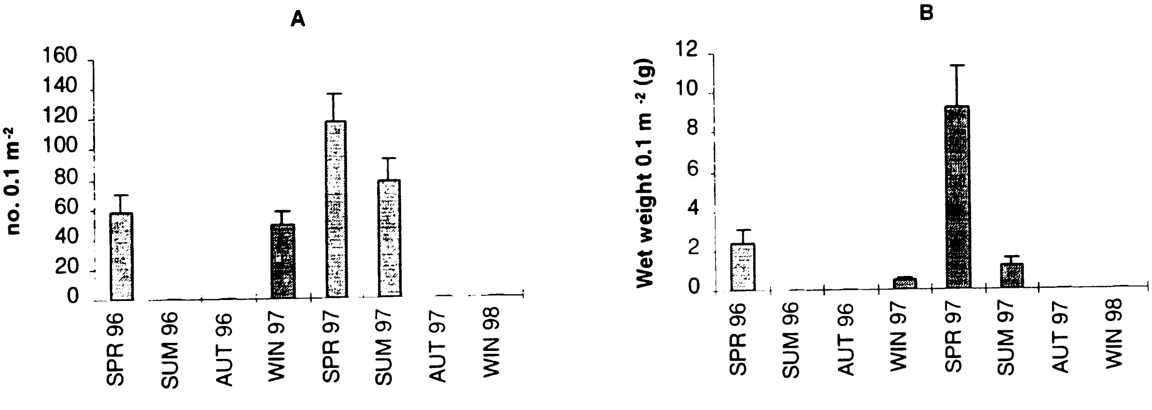
Fig. 4.6. Size-frequency histograms for *Mediomastus fragilis* per 0.1 m^2 grab at USI from 1996-1998. AP= April, JL= July, OC= October, JAN= January.



Lumbrineris tetraura (Schmarda, 1961)

The lumbrinerids are generally to be considered carnivores or carrion-feeders, but at least *Lumbrineris tetraura* is known to be herbivorous. However, this species has been also reported as a carnivore. All three modes of feeding are probably utilized among the lumbrinerids, but each species may use only one mode. They are not usually tubicolous, but are capable of secreting temporary mucous housings, at least in aquaria.

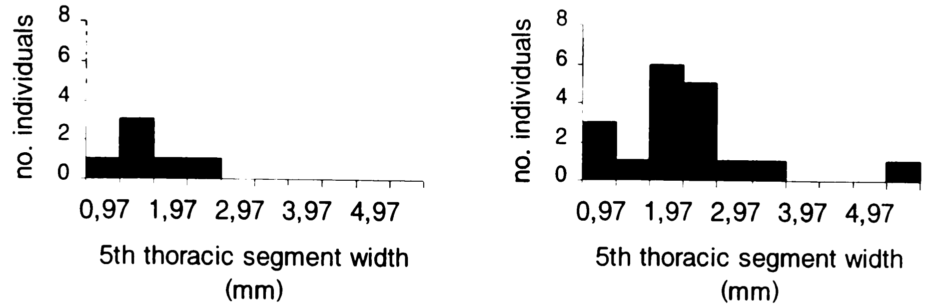
Fig. 4.7. A) Mean number and B) biomass (g wet weight) of *Lumbrineris tetraura* per 0.1 m^2 grab at USI. Error bars = SD, N = six grabs analysed



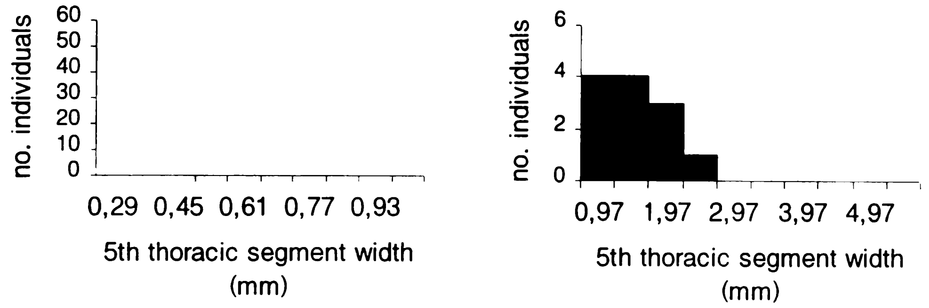
Lumbrineris tetraura is another of the occasional species only found at the impacted site.

A relatively high number of individuals were collected in the seasons where it was present (spring 1996, winter, spring and summer 1997) (Fig. 4.7 A). The maximum numbers corresponded to spring 1997 (120 ind./0,1 m^2) and minimum values were those of winter 1997 (55 ind./0,1 m^2). Biomass reached its maximum in spring 1997 (9 g/0,1 m^2) (Fig. 4.7 B). The size frequency distribution of *L. tetraura* at USI is seen in Fig. 4.8.

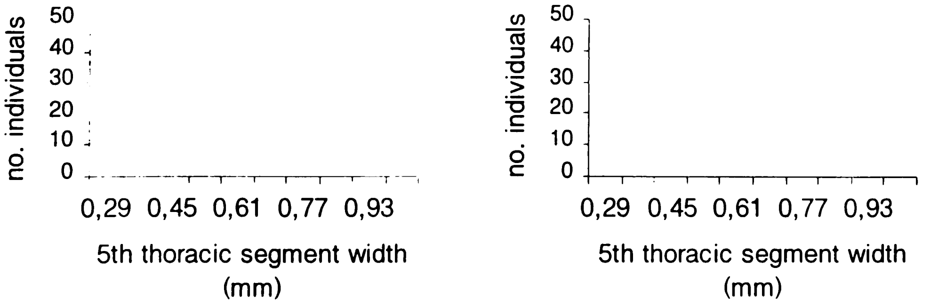
Fig. 4.8. Size-frequency histograms for *Lumbrineris tetraura* per 0.1 m^2 grab at USI from 1996-1998. AP= April, JL= July, OC= October, JAN= January.


6 grabs, AP 1996 (n= 6)

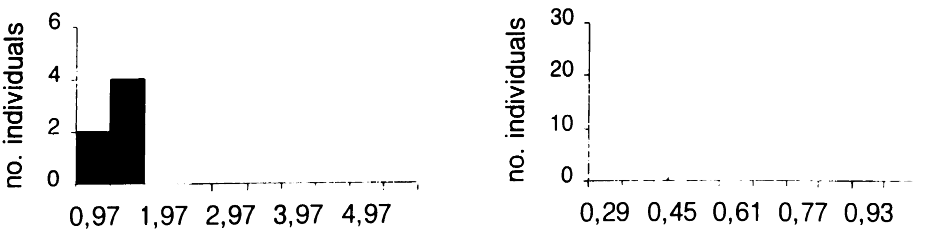
6 grabs, AP 1997 (n= 18)


6 grabs, JL 1996 (n= 0)

6 grabs, JL 1997 (n= 12)


6 grabs, OC 1996 (n= 0)

6 grabs, OC 1997 (n= 0)

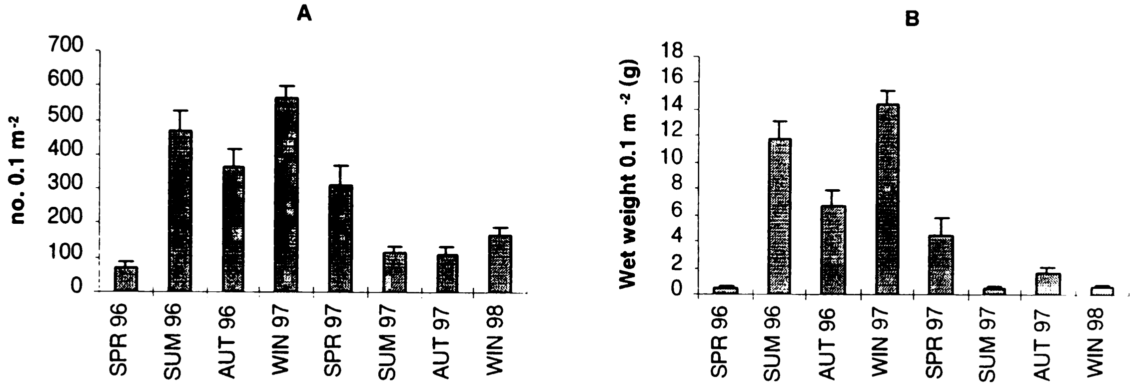

6 grabs, JAN 1997 (n= 6)

6 grabs, JAN 1998 (n= 0)

Aonides oxycephala (M Sars, 1862)

This spionid often lives in shifting sand, building only loosely constructed burrows at best. Like all spionids, *Aonides* is considered to be a surface deposit-feeder with good discriminatory powers to select particles both on the basis of size and composition, using its ciliated palps to select food particles from the surrounding medium .

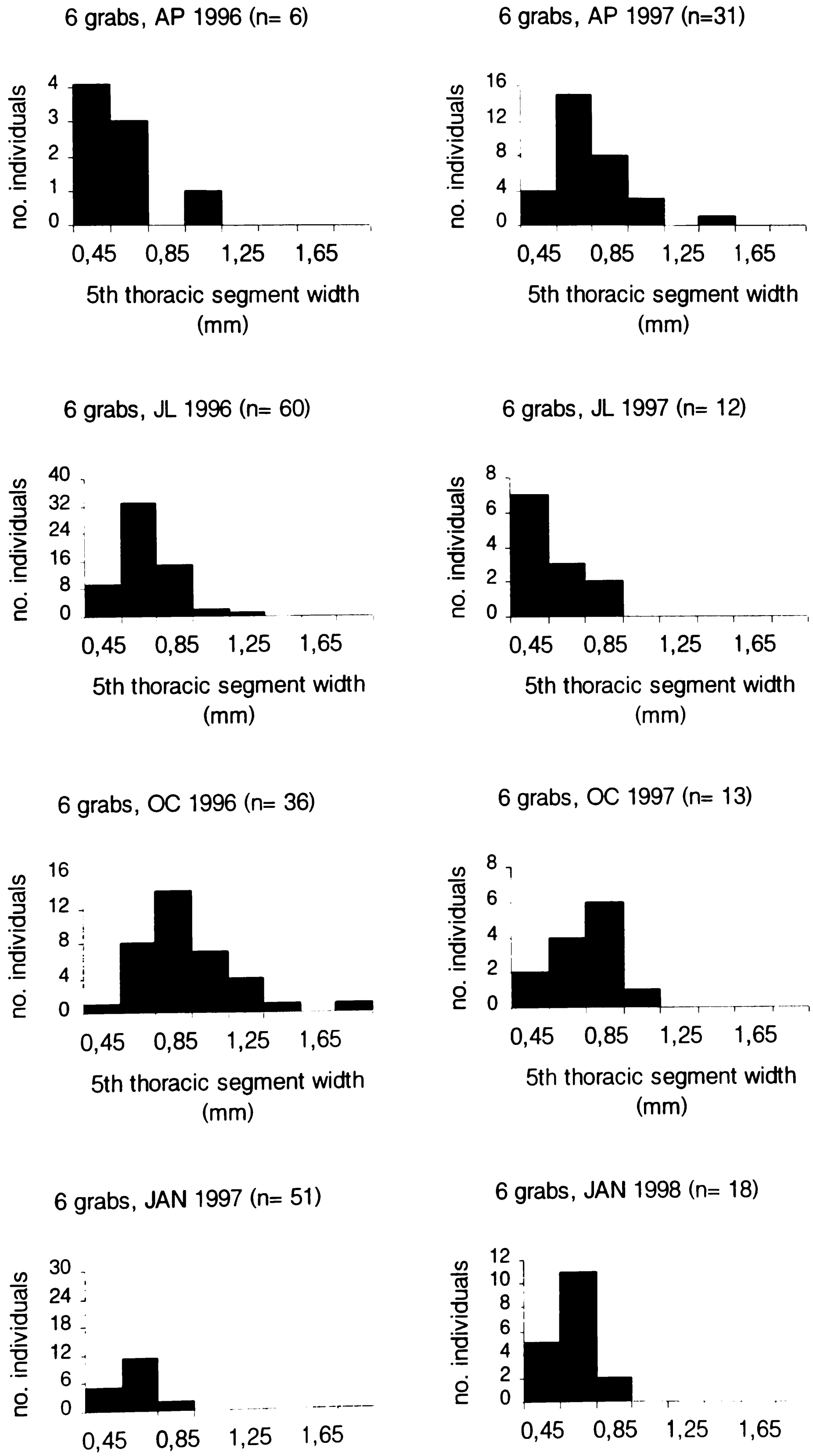
Fig. 4.9. A) Mean number and B) biomass (g wet weight) of *Aonides oxycephala* per 0.1 m^2 grab at USI. Error bars = SD, N = six grabs analysed



This species has only been found at the impacted site, reaching abundances near to 600 ind/0.1m^2 over the winter period and not less than 450 ind./0.1m^2 during the summer (Fig. 4.9 A). Fluctuations in numbers during the two-year period does not follow any obvious trend. Differences in numbers between winter 1997 and winter 1998 are probably due to the calm winter of 1997 in contrast with the stormy period that characterized December 1997-January 1998. This fact is also reflected in the biomass of this non-selective deposit-feeder species,with maximum biomass being reached in winter 1997, while minimum values were registered for the following year at the same period. Total biomass values for this species ranged between 0.5 and 14.5 g/0.1m^2 (Fig.4.9 B).

Aonides oxycephala is one of the few key species to be found only at the impacted site and there in very high numbers. Suspended organic matter derived from the extensive mussel raft culture where this site is located must have created conditions conducive to the high numbers of this species in the area. Fig. 4.10 shows the size-frequency distribution of *A. oxycephala* at USI.

Fig. 4.10. Size-frequency histograms for *Aonides oxycephala* is per 0.1 m^2 grab at USI from 1996-1998. AP= April, JL= July, OC= October, JAN= January.

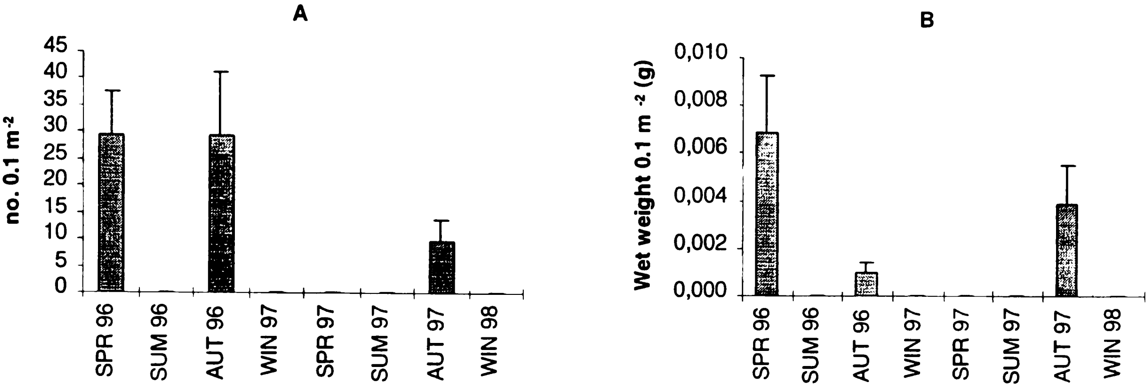


Aora gracilis (Bate, 1857)

This amphipod is a shallow-water inhabitant, building tubes amongst algae and hydroids.

It is a surface deposit-feeder and suspension-feeder, behaving mainly as a non-selective deposit-feeder in the maerl grounds of Ría de Vigo.

Fig. 4.11. A) Mean number and B) biomass (g wet weight) of *Aora gracilis* per 0.1 m^2 grab at USI. Error bars = SD, N = six grabs analysed

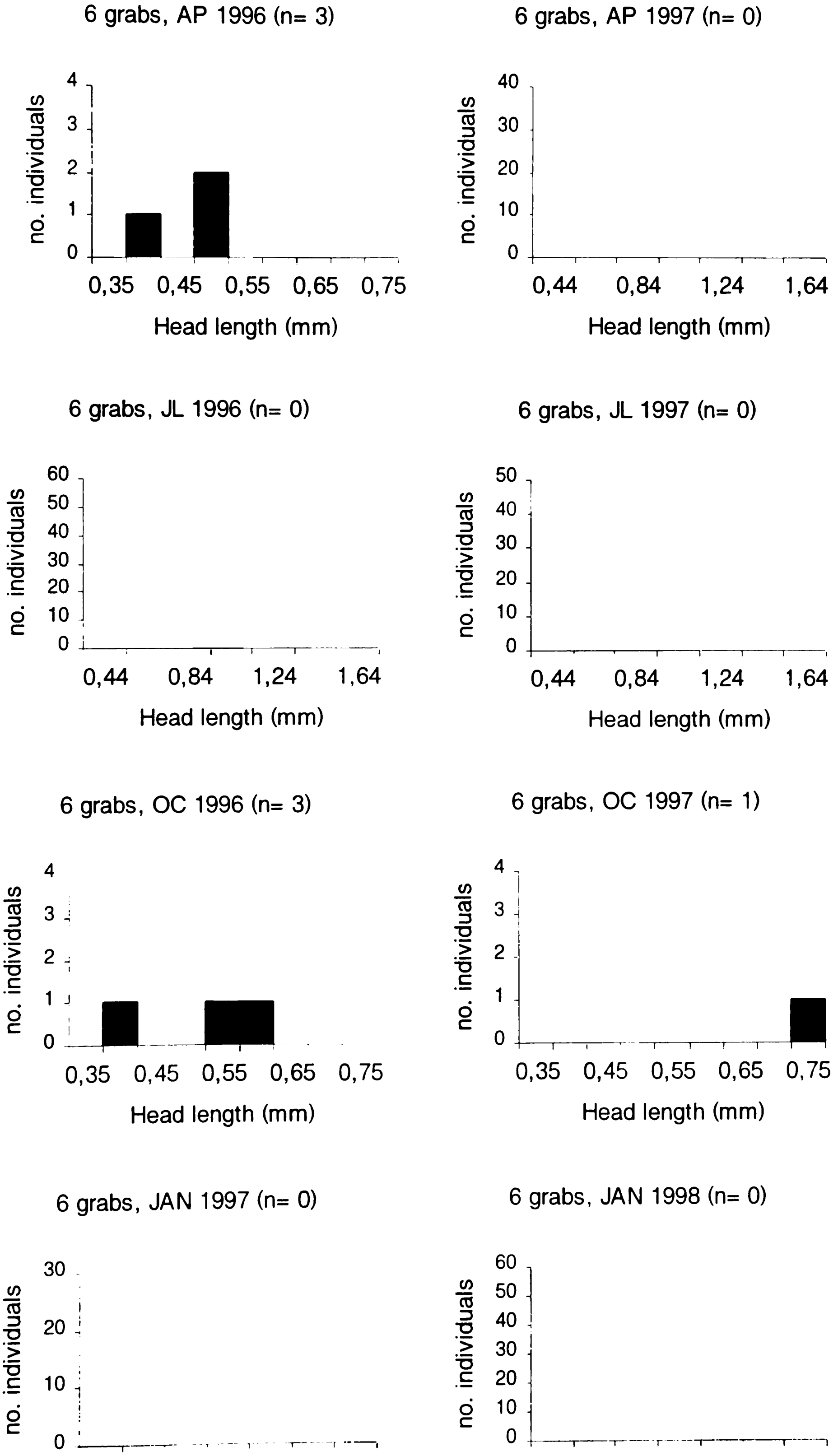


A. gracilis was only found occasionally at the impacted site (USI) with relatively similar abundances ranging from maximum values of 29 ind./0,1m^2 in spring and autumn 1996 (Fig. 4.11), to absence during the summer 1996 and the following year (from winter 1997 to summer 1997). It appeared again in autumn 1997 with minimum numbers of 9 ind./0,1m^2 and disappeared again in winter 1998.

That *Aora gracilis* was only found at the impacted site may be a consequence of its trophic behaviour on this site being directed to non-selective deposit-feeding more than suspension-feeding.

In Fig. 4.12 the seasonal variation in size frequency of the *Aora gracilis* population is shown for the impacted site.

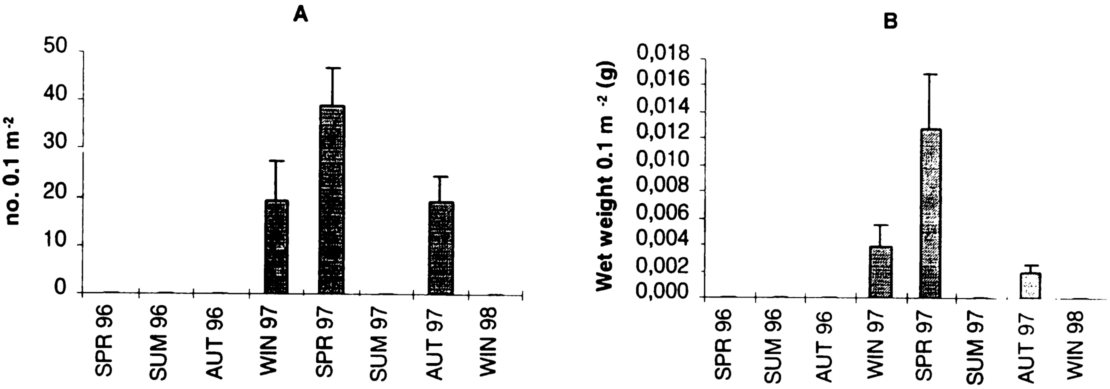
Fig. 4.12. Size-frequency histograms for *Aora gracilis* is per 0.1 m^2 grab at USI from 1996-1998. AP= April, JL= July, OC= October, JAN= January.



Listriella picta (Norman, 1889)

L. picta lives on sand gravel, from 5 to 16 m deep.

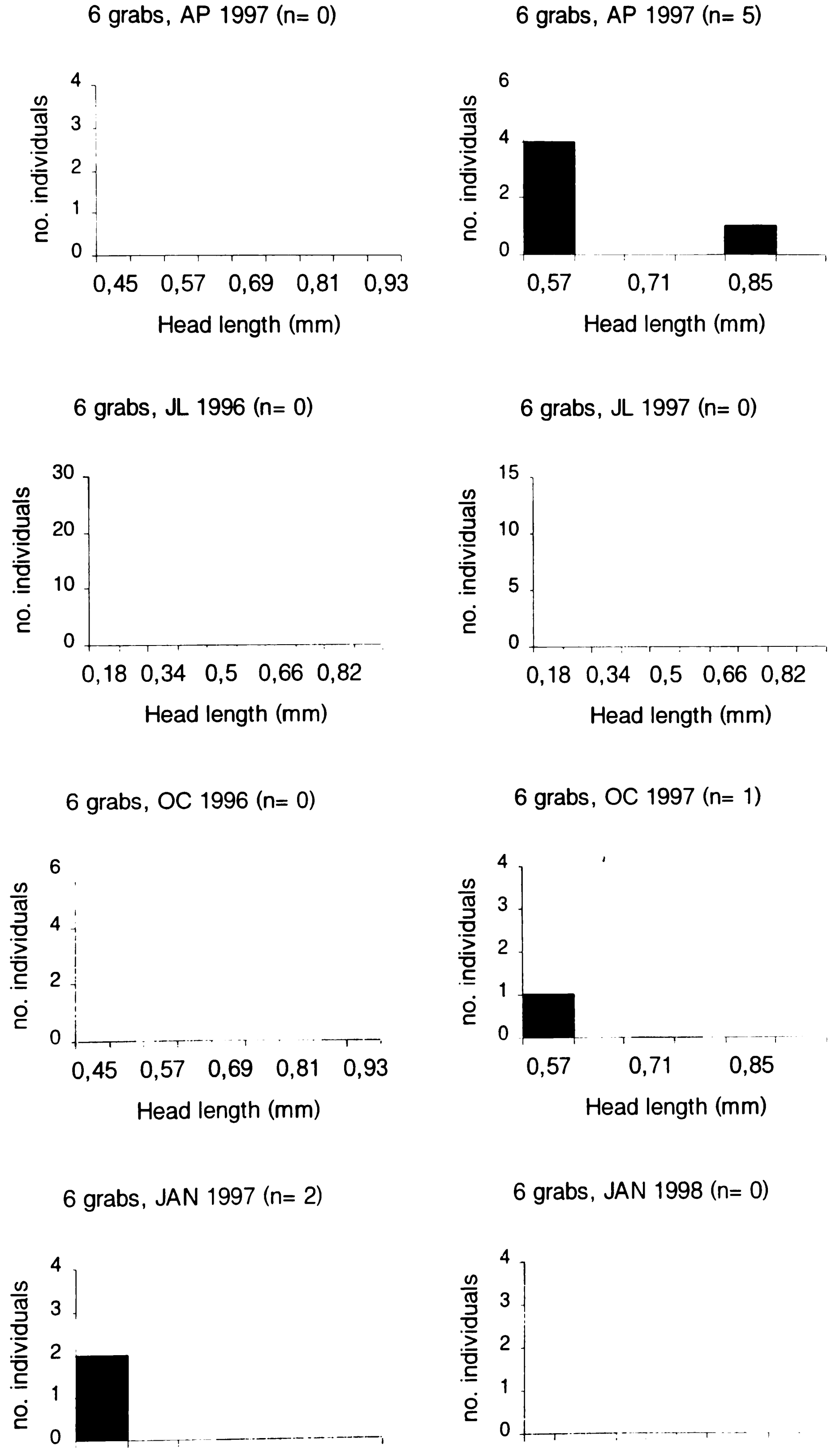
Fig. 4.13. A) Mean number and B) biomass (g wet weight) of *Listriella picta* per 0.1 m^2 grab at USI. Error bars = SD, N = six grabs analysed



Listriella picta may be a non selective deposit-feeder. It was only present at the impacted site where it was found to be neither abundant nor constant (maximum density in spring 1997, 38 individuals /0.1 m^2). In fact it was only recorded very occasionally during the second year of study (in winter and spring 1997 and in autum 1997 (Fig. 4.13 A).

The highest biomass for these three months were found in spring 1997 (0.013 g/0.1 m^2) (Fig. 4.13 B).The seasonal variation in size frequency of the *Listriella picta* population is shown for the impacted site in Fig. 4.14.

Fig. 4.14. Size-frequency histograms for *Listriella picta* per 0.1 m^2 grab at USI from 1996-1998. AP= April, JL= July, OC= October, JAN= January.

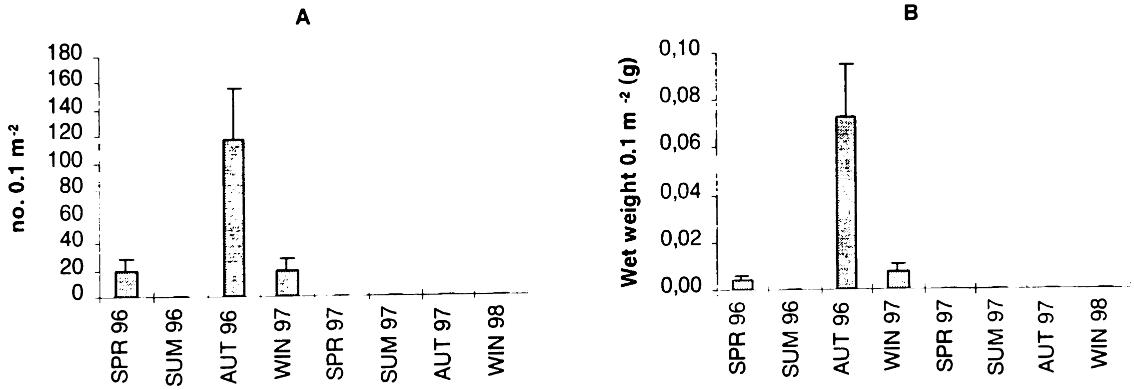


Maera grossimana (Montagu, 1808)

M. grossimana lives both in hard substrata and soft substrata, from the mesolittoral zone to bathyal zone, in coral bottoms and among the roots of *Posidonia*. It also lives in gravelly sediments, especially in *Amphioxus* sands.

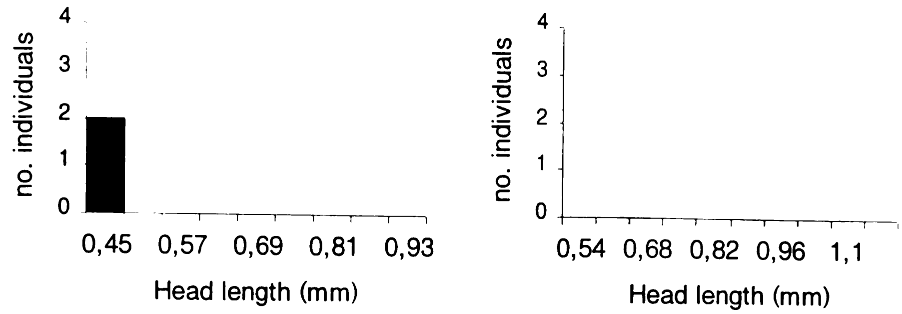
It rarely occurs on muddy bottoms. Usually it lives at depths from 20-100 m, rarely in shallow water (2 m, Venecia) or in deep water (1600 m, off Balearic Islands), Sometimes among algae, or in association with the sponge *Suberites*.

Fig. 4.15 A) Mean number and B) biomass (g wet weight) of *Maera grossimana* per 0.1 m^2 grab at USI. Error bars = SD, N = six grabs analysed

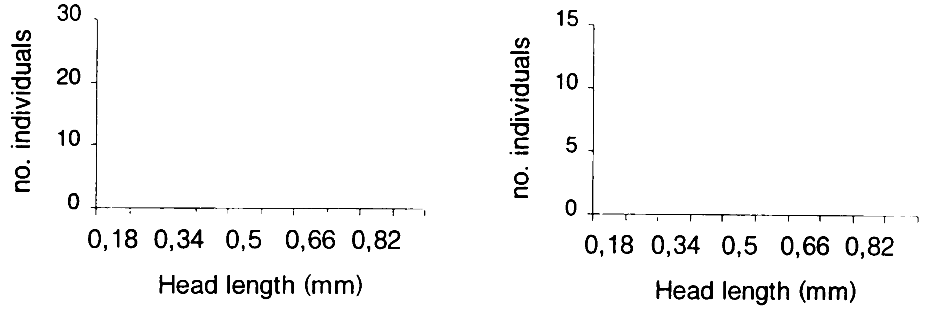


A very occasional species, it was only present at the impacted site. Maximum numbers were found in autumn 1996 and minimum numbers in spring 1996 and winter 1997 (Fig. 4.15).

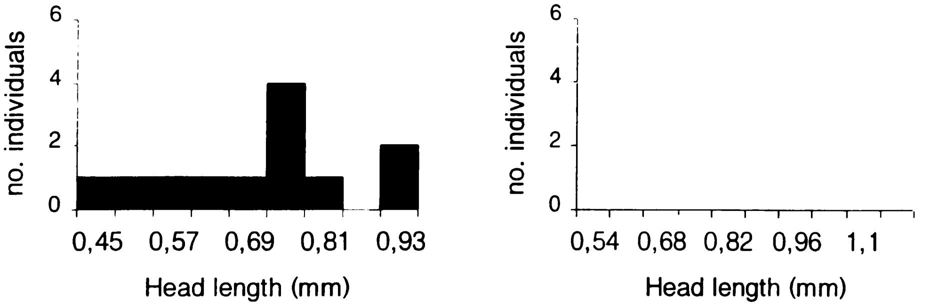
Fig. 4.15. Size-frequency histograms for *Maera grossimana* per 0.1 m^2 grab at USI from 1996-1998. AP= April, JL= July, OC= October, JAN= January.


6 grabs, AP 1997 (n= 2)

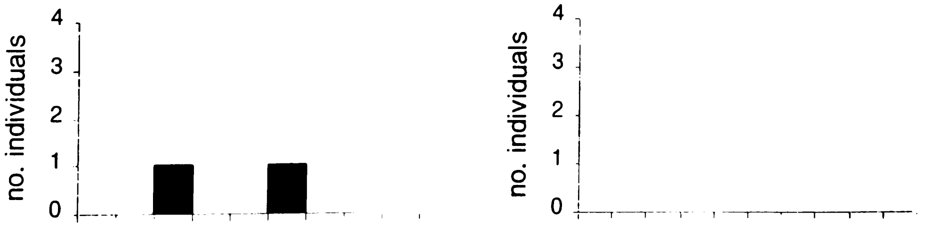
6 grabs, AP 1997 (n= 0)


6 grabs, JL 1996 (n= 0)

6 grabs, JL 1997 (n= 0)


6 grabs, OC 1996 (n= 12)

6 grabs, OC 1997 (n= 0)

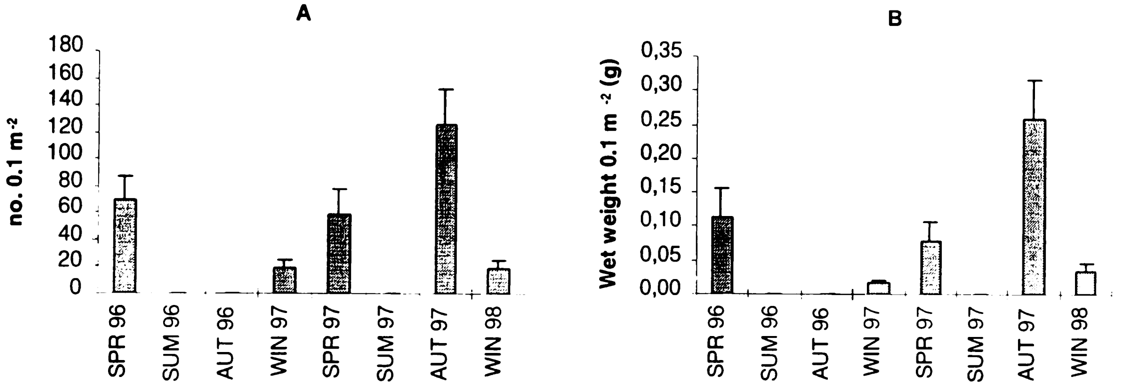

6 grabs, JAN 1997 (n= 2)

6 grabs, JAN 1998 (n= 0)

Maera othonis (H Milne-Edwards, 1830)

In the Atlantic, the amphipod *Maera othonis* burrows in gravelly bottoms or sandy bottoms with shells, *i.e.* mixed bottoms. *M. othonis* is a surface deposit-feeder which has only been found at the impacted site in our study.

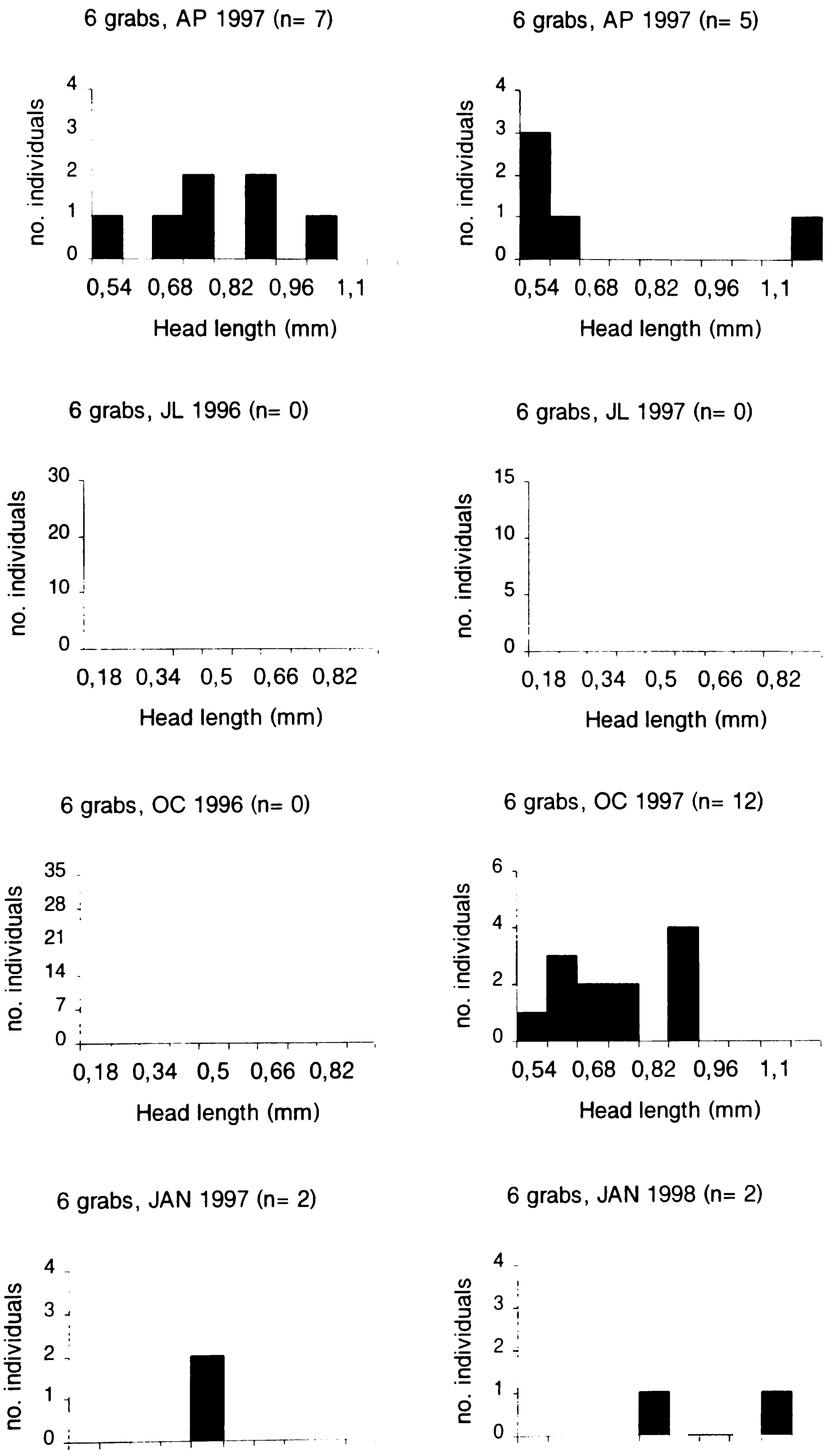
Fig. 4.16. A) Mean number and B) biomass (g wet weight) of *Maera othonis* per 0.1 m^2 grab at USI. Error bars = SD, N = six grabs analysed



It was not present in all seasons, reaching its highest abundances during the autumn period (though it was not found at all in autumn 1996). During the first year of the study *Maera othonis* was not collected in any of the summer and autumn samples (Fig. 4.16).

The size-frequency diagrams of Fig. 4.17 show a population structure spread across sizes with an unclear cohort distribution which is not consistent from one year to the next (maybe due to the scarcity of individuals).

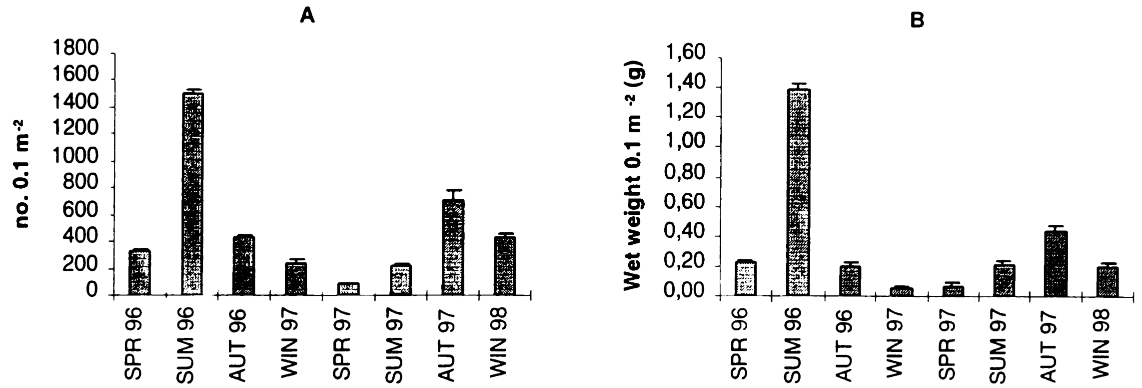
Fig. 4.17. Size-frequency histograms for *Maera othonis* per 0.1 m^2 grab at USI from 1996-1998. AP= April, JL= July, OC= October, JAN= January.



Apseudes latreillii (Milne-Edwards, 1828)

This tanaid species is found on the mid to lower shore under stones, in rock crevices, and in muddy gravel. It also occurs in kelp holdfasts, coralline algae and *Zostera* roots.

Fig. 4.18. A) Mean number and B) biomass (g wet weight) of *Apseudes latreillii* per 0.1 m^2 grab at USI. Error bars = SD, N = six grabs analysed

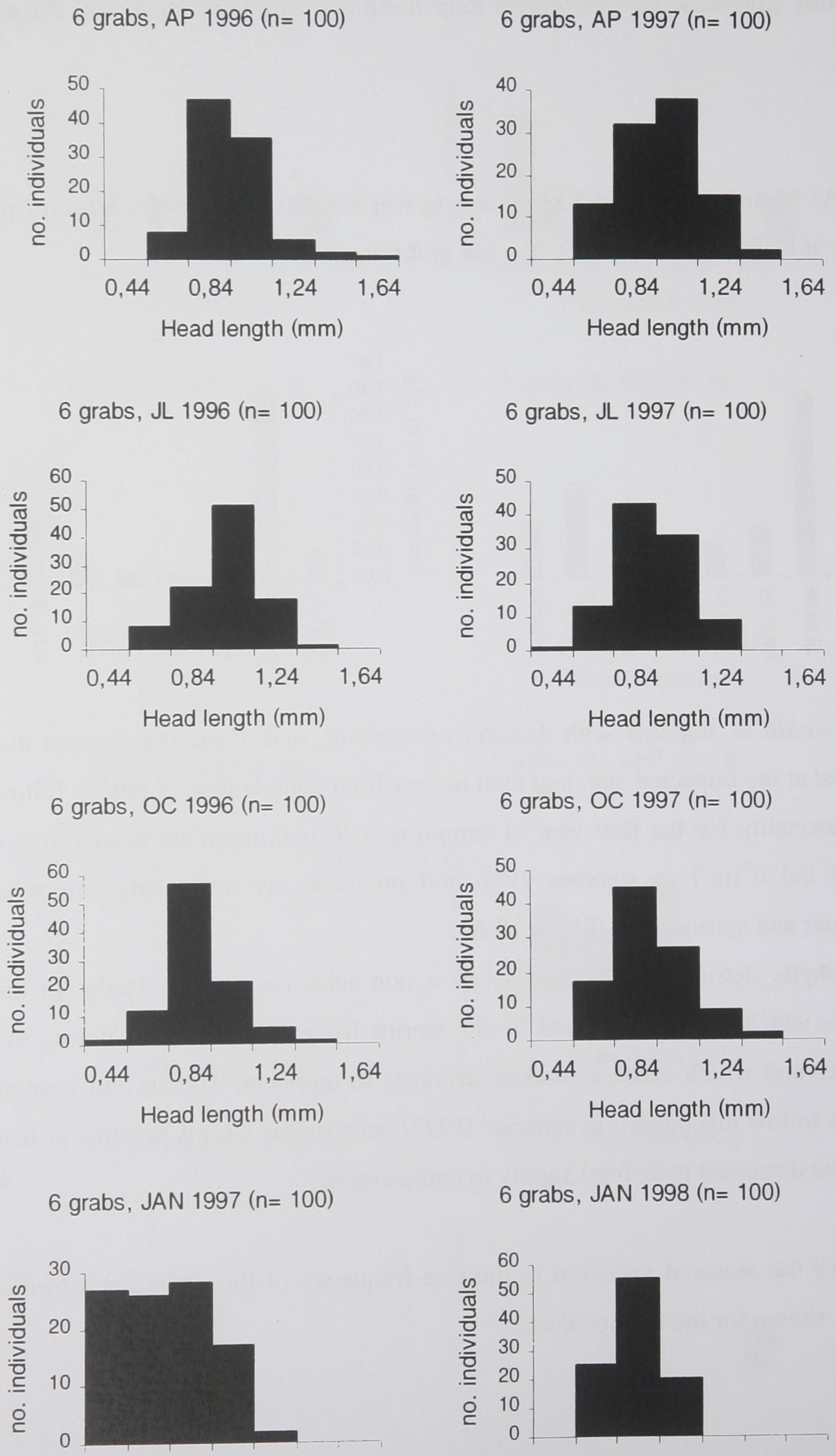


Apseudes latreillii is, together with *Aonides oxycephala*, one of the few species that only occurred at the impacted site, and then in very high abundances. Numbers follow a sort of seasonality for the first year of sampling with maximum abundance (more than 15,000 ind./0.1m^2) in summer 1996 and progressively decreasing values in autumn, winter and spring 1996 (Fig. 4.18 A).

This macrophytic detritus feeder behaves as a non selective detritus feeder in the impacted site which is only disturbed by the storms from the south-west during the winter period, and which cause a marked decrease in numbers. The second year of study did not follow this pattern in summer (1997) because the stormy weather at that time may have dispersed their food supply to some extent.

In Figure 4.19 the seasonal variation in the size frequency of the *Apseudes latreillii* population is shown for the impacted site.

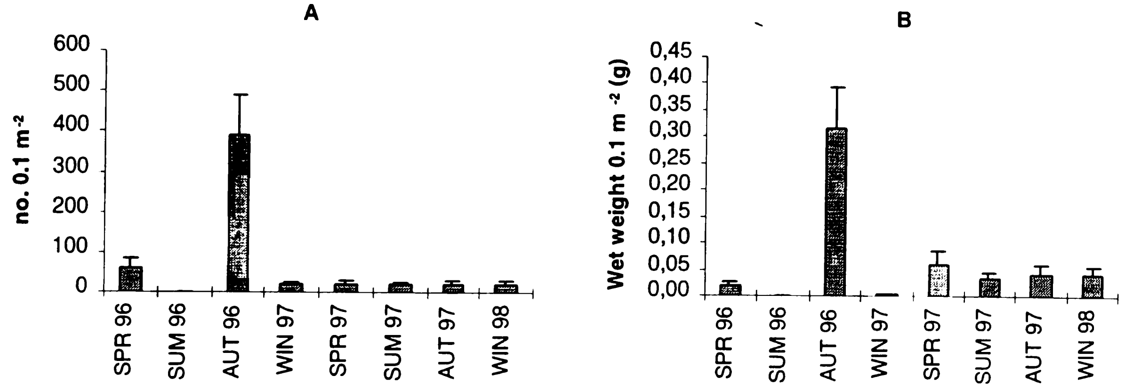
Fig. 4.19. Size-frequency histograms for *Apseudes latreillii* is per 0.1 m^2 grab at USI from 1996-1998. AP= April, JL= July, OC= October, JAN= January.



Apseudes talpa (Montagu, 1808)

This tanaid species is mainly found on the mid to lower shores associated with mud or sand under stones and in crevices, and from *Laminaria* holdfasts and coralline algae. It also occurs in the sublittoral zone.

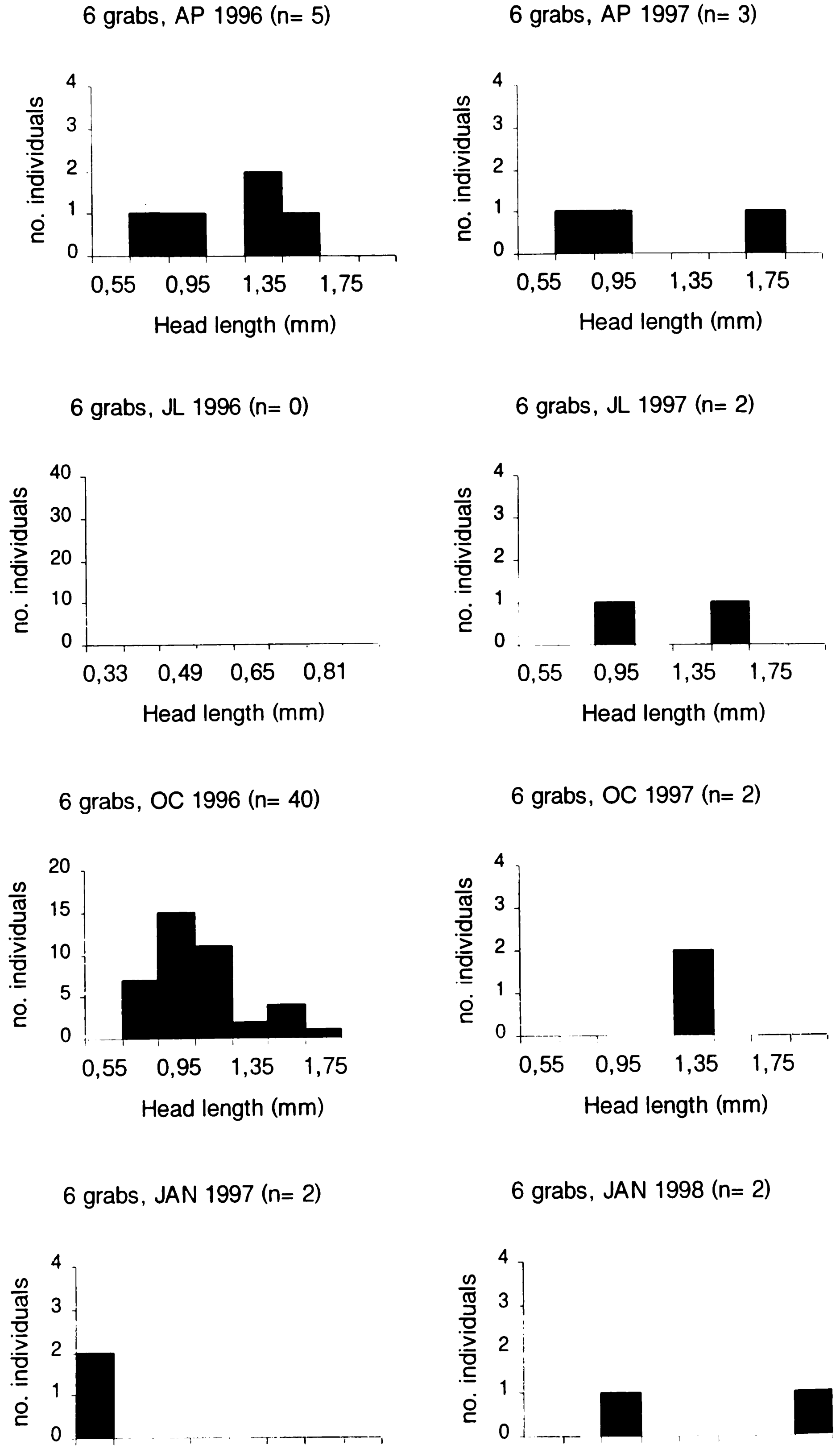
Fig. 4.20. A) Mean number and B) biomass (g wet weight) of *Apseudes talpa* per 0.1 m^2 grab at USI. Error bars = SD, N = six grabs analysed



Apseudes talpa shows the same behaviour as *Apseudes latreillii*, though to a lesser extent, due to lesser numbers at the impacted site. The seasonal changes of this species (Fig. 4.20 A & B) are also related to the high detrital input in the area, supplied by the metabolic activity of mussels which is highest during summer. The same effect of storms and water movement as for *Apseudes latreillii* may be seen for this species whose highest numbers were registered in autumn 1996.

The seasonal variation in size frequency of the *Apseudes talpa* population is shown for the impacted site in Fig. 4.21.

Fig. 4.21. Size-frequency histograms for *Apseudes talpa* per 0.1 m^2 grab at USI from 1996-1998. AP= April, JL= July, OC= October, JAN= January.



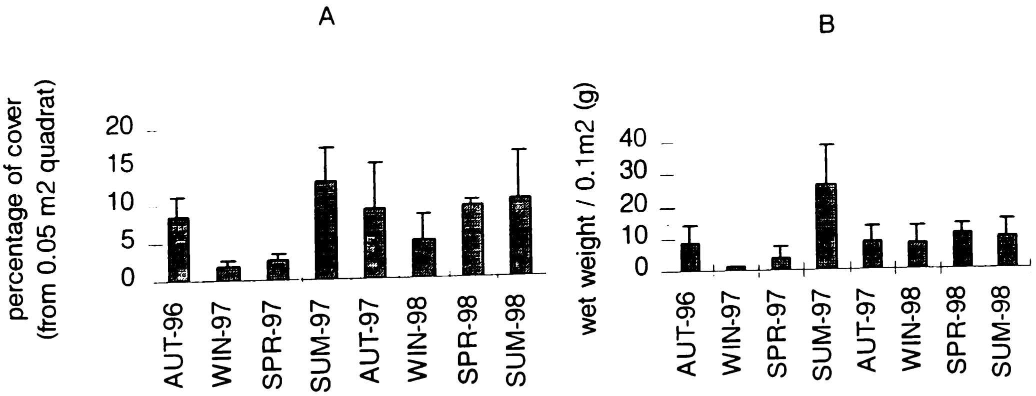
3) Alicante

Lithothamnion corallioides **Crouan & Crouan**

Although the percentage cover of this species was almost imperceptible, *L. corallioides* was still the most common calcareous Corallinaceae at the impacted site. The shape was open branched and thalli were all very small (10mm max. length), and patchy in spatial distribution. The small size may be due to the impact of trawling and to the importance of the fine fraction in sediments from the impacted site.

It was present in all seasonal samples at the impacted site (Fig. 4.22), but it was very rare at the control site. Only a few thalli were collected there. The apparent differences between seasons in cover and biomass are probably artefactual and due to spatial patchiness, so no seasonal patterns could be detected with certainty.

Fig.4.22. A) Mean cover of rhodoliths, and B) Biomass (wet weight) of *Lithothamnion corallioides* per 0.1 m^2 (from 0.05 m^2 quadrats) at UAI. Errors bars = SD, N = 3 in all cases.

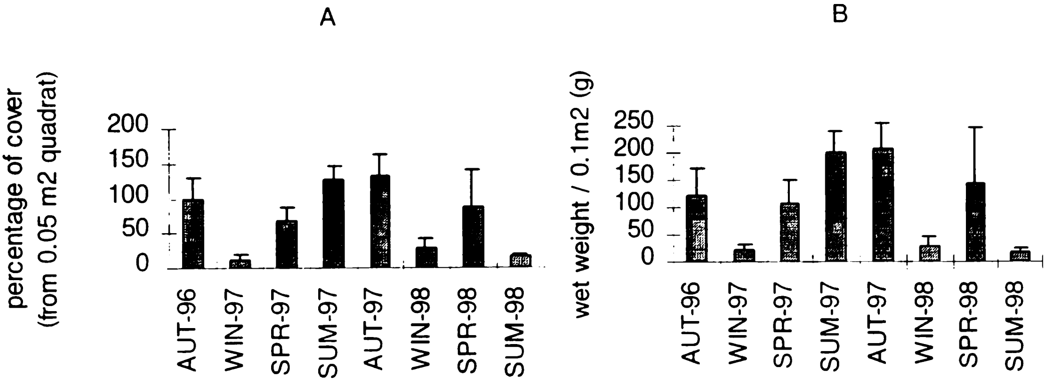


Peyssonnelia orientalis **(Weber van Bosse) Boudouresque**

Peyssonnelia orientalis was the most abundant macroalga both in terms of cover and biomass at the impacted site. It dominated the algal assemblage there, creating the habitat for the great part of the vagile invertebrates encountered.

Although present at the control site, *P. orinetalis* did not represent more than 1% of the algal cover there. Although this species accumulates carbonates, it does not form hard calcareous structures, the thalli are more or less soft laminar structures. Such a substratum is not suitable to sessile Invertebrata, perhaps due to the flexibility of the thalli and their mucilaginous surface. Only few ascidians of the family Didemnidae were collected settled on the *P. orientalis* thalli, but all of them were very small (<10 mm^2).

Fig. 4.23. A) Mean cover and B) Biomass (wet weight) of *Peyssonnelia orientalis* per 0.1 m^2 at UAI. Errors bars = SD.



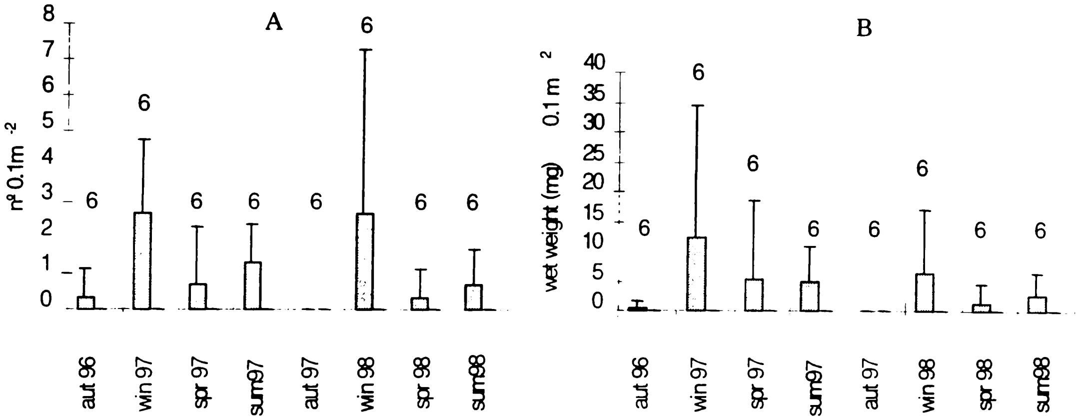
P. orientalis is dispersed on the bottom in patches forming a layer of about 2 centimetres across. The lower values of cover (excepting in summer 1998) have been obtained in winter periods (1997 and 1998). These differences may be due to the greater dispersion of the *P. orientalis* thalli during the winter. The highest values of cover and biomass (excepting summer 1997) were obtained in autumn (1996 and 1997) (Fig. 4.23). The data for this species from the control site have not been represented due to the very low (often only <1% cover) there cf. 30-97% cover at the impacted site.

Ophiura grubei Meller, 1863

Ophiura grubei was fairly common on the Alicante maerl beds. It was collected in quantitative quadrats at the impacted site, but only observed in dredge samples at the control site. It is a carnivorous/scavenger brittlestar that predates on small benthic invertebrates. It is considered to be a characteristic species of detritic coastal communities (Picard, 1965). However, it can also be found on muddy sand bottoms.

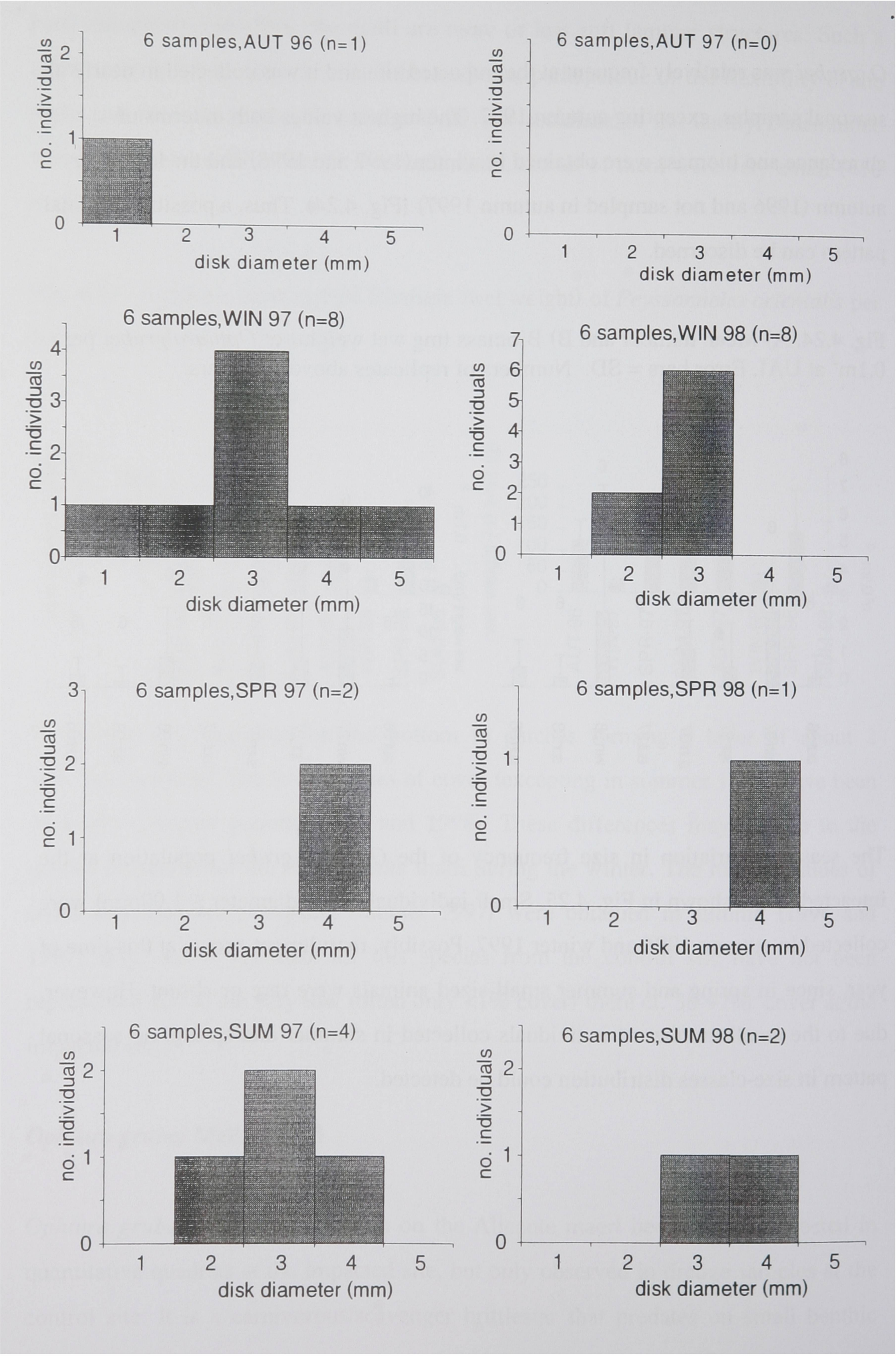
O. grubei was relatively frequent at the impacted site and it was collected in nearly all seasonal samples, excepting autumn 1997. The highest values both in terms of abundance and biomass were obtained in winter (1997 and 1998) and the lowest in autumn (1996 and not sampled in autumn 1997) (Fig. 4.24). Thus, a possible seasonal pattern can be discerned.

Fig. 4.24. A) Mean number and B) Biomass (mg wet weight) of *Ophiura grubei* per 0.1m^2 at UAI. Error bars = SD. Numbers of replicates above error bars.



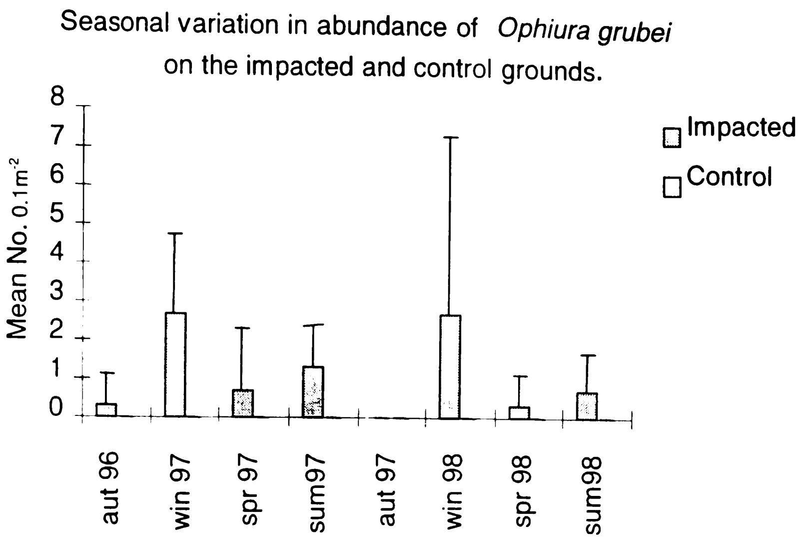
The seasonal variation in size frequency of the *Ophiura grubei* population at the impacted site is shown in Fig. 4.25. Small individuals (disc diameter ≤ 1.00mm) were collected in autumn 1996 and winter 1997. Possibly, recruitment occurs at this time of year, since in spring and summer small-sized animals were rare or absent. However, due to the small number of individuals collected in summer and spring, no seasonal pattern in size-classes distribution could be detected.

Fig.4.25.Size-frequency histograms for *Ophiura grubei* collected seasonally in $0.05m^2$ quadrats at UAI from 1996-1998. SUM = summer, AUT = autumn, WIN = winter, SPR=spring.



This species was not taken in quadrats at the control site, it was only collected in low numbers from dredge samples. It was present at the impacted site in nearly all the seasonal samples and both abundance and biomass varied seasonally, with higher values in winter and lower ones in autumn in both years. Possibly, the difference in abundance between sites could be due to the greater availability of food to predators on impacted grounds (due to disruption of refugia), as has been observed on trawling-degraded *Posidonia* meadows where carnivores and scavengers were more abundant than at the control site.

Figure 4.26 compares the abundance and biomass of *Ophiura grubei* on the control and impacted sites. This species only appeared at the impacted site in quantifiable numbers.



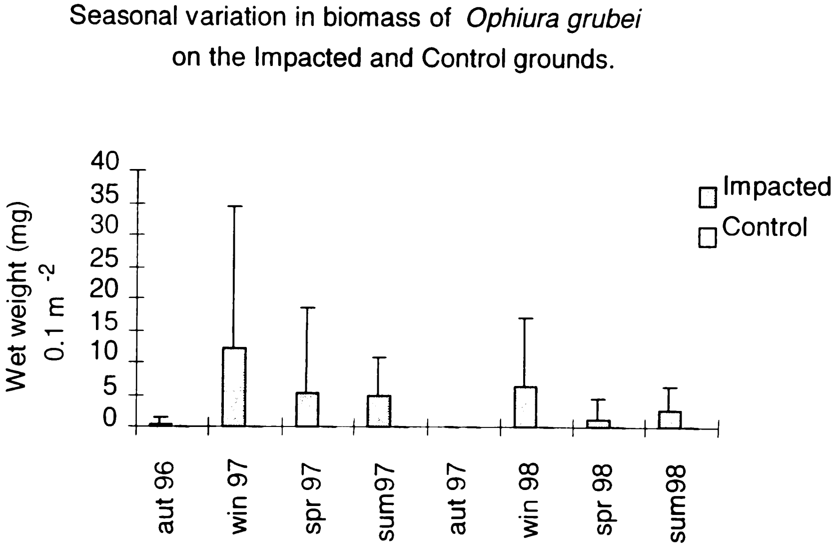


Fig. 4.26.

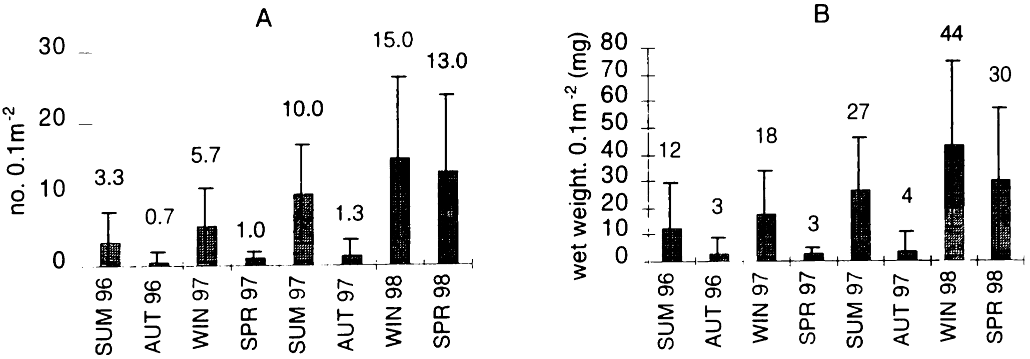
4) Malta

Barleeia unifasciata (Montagu, 1803)

Barleeia unifasciata was quite abundant at the impacted site but was absent from the control ground. This gastropod is known to feed on algae and epiphytic diatoms.

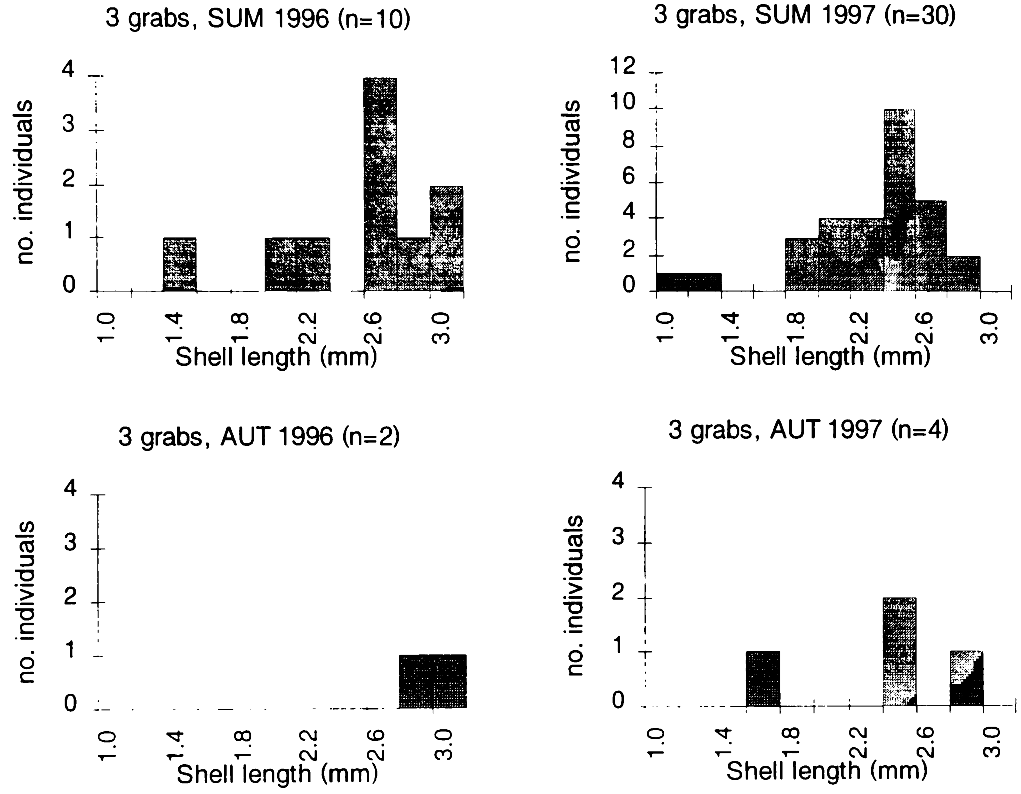
Barleeia unifasciata was more abundant in the samples collected during the second year of sampling and the highest value for this species' population density was obtained in winter 1998. Although its numbers were much lower during the first year of sampling, the same pattern was observed during the two years. For both years, the highest values were obtained in winter and the lowest values in autumn. Thus, although not very evident, there seems to be a seasonal pattern, where the abundance of this gastropod reached a maximum in winter and a minimum in autumn.

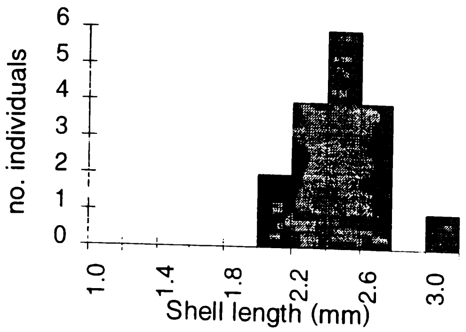
Fig. 4.27. A) Mean number and B) Biomass (wet weight) of *B. unifasciata* per 0.1m^2 grab at UMI. Error bars = SD. Numbers above each column are mean values (n = 3 replicates).

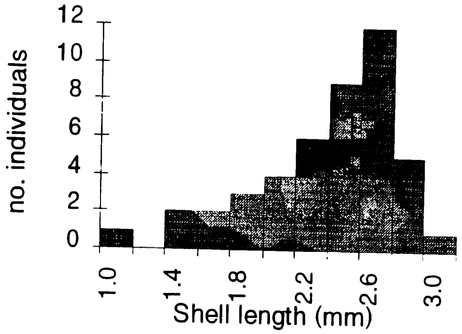


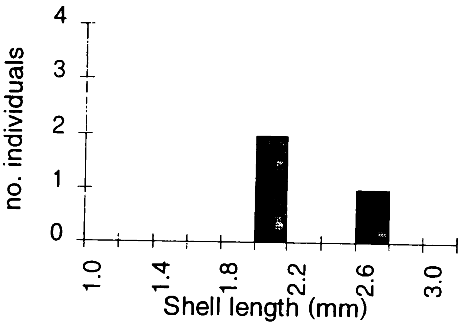
The seasonal variation in size frequency of *Barleeia unifasciata* at the impacted site is shown in Fig. 4.28. Small individuals (shell length = 1.0-1.2mm) were obtained in summer 1997, winter 1998 and spring 1998. However the number of these individuals was too small to say with certainty when recruitment was taking place.

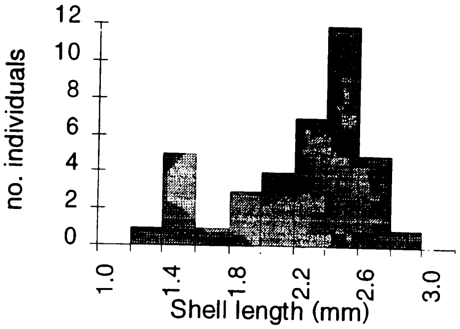
Fig. 4.28.Size-frequency histograms for *Barleeia unifasciata* collected seasonally in $0.1m^2$ grabs at UMI from 1996-1998. SUM = summer, AUT = autumn; WIN = winter, SPR = spring.




3 grabs, WIN 1997 (n=17)

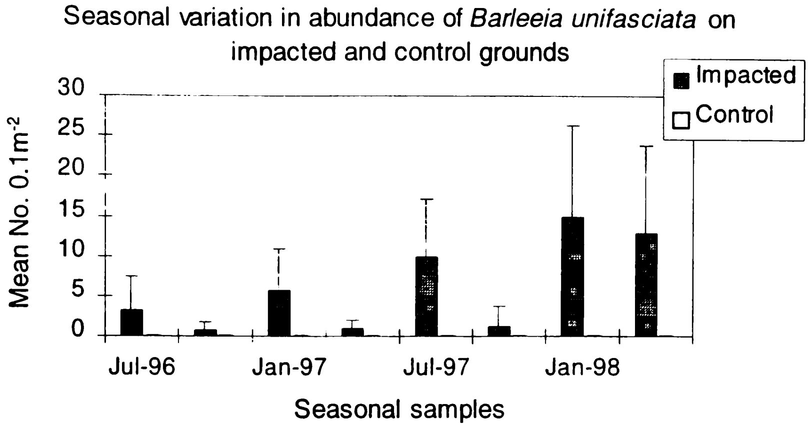

3 grabs, WIN 1998 (n=45)

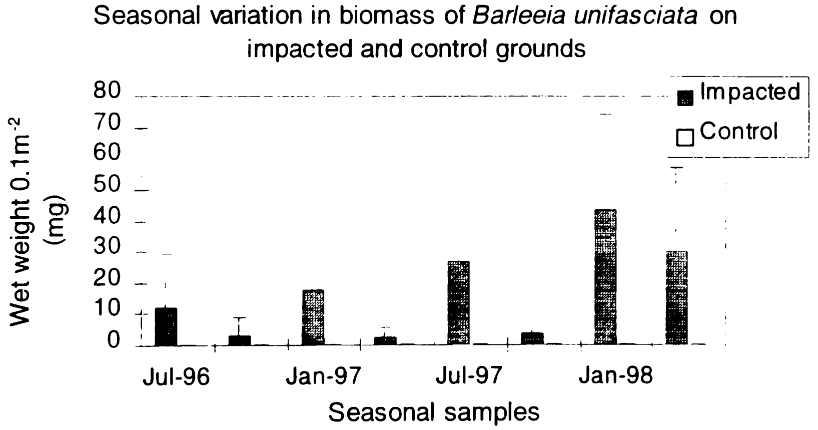

3 grabs, SPR 1997 (n=3)


3 grabs, SPR 1998 (n=39)

Barleeia unifasciata was found exclusively on the impacted ground. It was present in nearly all the grab samples collected at this site and its abundance varied with season (as explained above).

Fig.4.29.


Seasonal variation in abundance of *Barleeia unifasciata* on impacted and control grounds


Seasonal variation in biomass of *Barleeia unifasciata* on impacted and control grounds

Summary comments on population data comparing impacted with control sites

As highlighted under Task 3, most notable was the fact that the impacted grounds subjected to eutrophication had higher population densities than their local control grounds (e.g. in Galicia and the Bay of Brest), reflecting their elevated nutrient status.

Impacted grounds may be more characterized by opportunistic species. In the Clyde Sea area, the control site (UKC) supported only slow-growing encrusting algae, which invest a great deal of energy in structural defences against herbivory (although *Phycodrys rubens* was also present, it may have a suite of anti-herbivory allelochemicals). UKC thus represents a climax community with a high intensity of herbivory that suppresses the standing stock of macroalgae. By contrast, UKI has a frequently disturbed community with fewer herbivores. There was a massive seasonal change in the standing crop of macroalgae there, with a rich opportunistic flora each spring/summer that was almost completely removed annually by autumn/winter storms. Such differences between the floral attributes of different grounds drive many of the other ecological differences between disturbed and undisturbed grounds.

Off Brittany, opportunistic species were more abundant on the impacted ground, especially in autumn. The control and impacted sites were similar in total abundances, species richness and assemblage composition during the winter. But thereafter, they diverged. UBBI had a lower number of animal species than UBBC, with a higher abundance (animal density was 5-10x higher), mostly of opportunistic species. For the Glenan site, commercial maerl extraction resulted in total habitat removal and hence defaunation of the targeted maerl bank. On the "impacted" site (UBGI; adjacent to the extraction pit), the secondary effects of extraction resulted in a reduction of species diversity and abundance. Only *Capitella capitata*, a species typical of disturbed habitats, survived on the impacted site in low numbers. One would anticipate that recolonization of the extraction zone sensu stricto, whenever it commences, will begin with invasion by opportunistic species.

Off Malta, the gastropod *Barleeia unfasciata* was found exclusively at the impacted site (UMI). This species is very small (shell length <3mm) and feeds on algae and epiphytic diatoms. Thus, its presence at the impacted site may be related to the presence there of large rhodoliths which offer both shelter amongst the algal thalli and a large surface area for feeding. In general, micrograzers (apart from *Barleeia unifasciata*, also *Jujubinus exasperatus* and *Jujubinus striatus*) seemed to be more abundant at the Maltese impacted site, and this is probably related to the presence there of larger and more compact rhodoliths. In contrast, the rhodoliths at the control ground were generally more delicate and more open-branched and thus did not offer such a conducive surface for feeding. One exception, however, was *Echinocyamus pusillus* which is a micrograzer but which is clearly more abundant at the control site: a total of 65 individuals at the control site and a total of 14 individuals at the impacted site were collected over the two year sampling period. This may be due to its size (mean test length = 4.30mm) which might not allow it to exploit the surface films within compact rhodoliths. These films are however accessible to the gastropod micrograzers which are either small (e.g. *Barleeia unifasciata*) or if large (*Jujubinus exasperatus* shell length up to 8.5mm; *Jujubinus striatus* shell length up to 7mm) are able to protrude their bodies outside the shell and hence penetrate between the closely spaced branches of compact rhodoliths. *Echinocyamus pusillus* is limited to grazing on surfaces over which its entire test can comfortably fit.

Small-scale deliberate impaction of control ground

This approach was only possible at the control ground in the Clyde Sea area. Details are given in the enclosed publications (Hall-Spencer & Moore, in press a,b) submitted herein as part of the Scientific report, and are not repeated here in order to save space.

The scale of anthropogenic perturbation and scope for recovery

Maerl bed biota appear to be well adapted to natural perturbations, e.g. the vagaries of sediment mobility brought about by episodic storm activity, sedimenting phytoplankton blooms (see Task 3, above). Fishers tend to trawl and dredge in particular, productive areas repeatedly where gear is damaged least by bottom obstructions, aquaculture enterprises tend to be a constant feature of those areas selected for cultivation, estuarine eutrophication is accelerating with time, not diminishing. Thus exploited maerl beds have no opportunity for recovery. The lengthy time scale involved can be judged from the following side-shoot investigation to the main programme.

Historical assessment of a Clyde maerl bed

As an adjunct to the main programme, the opportunity was taken to examine Clyde maerl material in British Museum collections, that had been archived since the last century, to look for differences cf. present-day material from the same site. Identifications based on modern taxonomic criteria revealed that the variously labelled maerl thalli obtained between 1885 and 1891 at The Tan Buoy, Cumbrae (Site 3 of Hall-Spencer & Moore, in press a) were all *Phymatolithon calcareum*. Microscopic examination showed that these algae had been alive at the time of their collection. *Limaria hians* nests collected in 1885 had >100 maerl thalli to 58 mm long entwined with byssus threads to form a protective mat. Three boxed collections at the British Museum had the following contents; Box 516 had >100 thalli (to 38 mm long), Box 519 had 65 thalli (to 50 mm long) and Box 521 had 18 thalli (to 43 mm long). In 1995-1997, detailed surveys of the entire maerl bed at Site 3 yielded just 16 live *P. calcareum* thalli, all of which were substantially smaller than those collected in the last century (<20 mm long).

This suggests that substantial degradation of this maerl bed has taken place over the last century. The most likely culpable agency will be scallop-dredging, which has expanded hugely in economic significance over the last 30 years. Scallop dredging began in the Clyde Sea area in the 1930s with Scottish yields of <3 t y^{-1} (Elmhirst, 1945). Landings increased with expansion of the fishery in the 1960s with the advent of more powerful boats, more efficient dredges and better processing facilities (Mason and Fraser, 1986). Local catches per unit effort have since declined in the Clyde Sea area due to dwindling stocks, although scallops remain the most important mollusc fishery in Scotland with 11300 t landed in 1995 (Ministry of Agriculture, Fisheries & Food, 1996). The impacts on local maerl beds are thus likely to have been sustained mainly in the past 30-40 years. These historical data from the Tan Buoy, Cumbrae show extensive changes over the past 100 years from a living maerl bed with abundant large thalli and nests of the gaping file shell *Limaria hians* to a bed of predominantly dead maerl with few, small live thalli and no *L. hians*. That the legacy of impacts, even single destructive episodes, on maerl beds is likely to be on decadal time scales (at least) presuming that these ecosystems are reinstatable at all should caution against the wanton destruction of this habitat.

TASK 5 : NE Atlantic vs Mediterranean comparison: final integration of Tasks 1-4

Objectives

To create an inventory of macro / megabenthos (fauna and flora) of European maerl beds, comparing the NE Atlantic and W Mediterranean ecosystems biogeographically. This qualitative objective complements the quantitative studies of important elements of the biota in other Task areas.

To integrate knowledge derived from all preceding objectives into a coherent management strategy for conservation of European maerl beds.

Inventory

The complete inventory of species records collected during the BIOMAERL programme is presented below. Considerable effort has been expended to identify to species as many taxa as possible. This was achieved through regular exchange of taxonomic expertise or specimens (or both) between BIOMAERL participants (and, where necessary, other experts). The results summarized below provide the most extensive inventory of the biodiversity of European maerl beds available to date. That said, it should be stressed that even this listing remains provisional. Major groups, like the Polychaeta, still remain poorly understood in some places, e.g. the Mediterranean, with much BIOMAERL material in such taxa remaining undetermined to species. Important taxa, like the Nematoda and harpacticoid Copepoda (meiofaunal constituents) were deliberately excluded from consideration at the outset of the project.

The following tabulation provides a complete inventory of species recorded during the BIOMAERL investigation, together with information on sites where they occurred. Atlantic species are also cross-referenced by code number to the Ulster Museum/ Marine Conservation Society's Species Directory (Howson & Picton, 1997).

PHYLUM	CLASS: ORDER	FAMILY	Species	Authority	Code	Clyde	Brest	Glenan	Galicia	Alicante	Malta
CYANOPHYTA	CYANOPHYCEAE	RIVULARIACEAE	*Rivularia ?polyotis*	(C. Agardh) Bornet & Flahault							UMI
			Calothrix sp.								UMC, I
		OSCILLATORIACEAE	*Lyngbya* sp.								UMC, I
		CHROOCOCCACEAE	*Aphanocapsa littoralis*	Hansgirg							UMC
RHODOPHYCOTA	NEMALIONALES	ACROCHAETIACEAE	*Audouinella* sp.1	Bory	ZM69	UKI, C	UBBC				
			Acrochaetium savianum	(Meneghini) Nageli							UMC
			Acrochaetium virgatulum	(Harvey) J. Agardh							UMI
			Audouinella daviesii	(Dillwyn) Woelkerling						UAI, C	
			Audouinella trifila	(Buffham) Dixon						UAI, C	
	PORPHYRIDIALES	GONIOTRICHACEAE	*Chroodactylon ornatum*	(C. Agardh) Basson						UAI, C	UMC, I
			Stylonema alsidii	(Zanardini) Drew						UAI, C	
			Stylonema cornu-cervi	Reinsch						UAI, C	
	BANGIALES	BANGIACEAE	*Porphyra (Conchocelis* phase)	C Agardh	ZM53	UKI, C					
			Porphyra miniata	(C Agardh) J Agardh	ZM60	UKI					
		BONNEMAISONIACEAE	*Bonnemaisonia asparagoides*	(Woodward) C Agardh	ZM146	UKI				UAI, C	
			Falkembergia rufulanosa	(Harvey) Schmitz						UAI, C	
	GELIDIALES	GELIDIACEAE	*Gelidium pusillum*	(Stackhouse) Le Jolis	ZM160	UKI					
			Gelidium sp.								UMC
			Gelidium sp.							UAI	
			Gelidiella sp.		ZM162		UBBC, I				
			Gelidiella sp.							UAI, C	
			Gelidiella sp.								UMC, I
			Gelidiella calcicola	Maggs et Guiry	ZM163	UKI					
		GIGARTINACEAE	*?Gigartina teedii*	(Roth) Lamouroux							UMC
	PALMARIALES	PALMARIACEAE	*Palmaria palmata*	(Linnaeus) Kuntze	ZM170		UBBI				
	HILDENBRANDIALES	HILDENBRANDIACEAE	*Hildenbrandia* sp.1	Nardo	ZM189	UKI, C					
	CORALLINALES	CORALLINACEAE	*Jania adhaerens*	Lamouroux						UAI, C	UMC, I
			Neogoniolithon brassica-florida	(Harvey) Setchell et Mason						•	UMC, I
			Corallina elongata	Ellis et Solander						UAI	

PHYLUM	CLASS: ORDER	FAMILY	Species	Authority	Code	Clyde	Brest	Glenan	Galicia	Alicante	Malta
			Hydrolithon farinosum	(Foslie) Serio						UAI, C	UMC, I
			Corallina granifera	Ellis & Solander						UAI, C	
			Lithophyllum incrustans	Philippi							UMC, I
			Pneophyllum lejolisii	(Rosanoff) Chamberlain						UAI, C	
			Mesophyllum lichenoides	(Ellis) Lemoine						UAI, C	
			Jania longifurca	Zanardini						UAI	
			Lithothamnion minervae	Basso						UAI, C	UMC, I
			Lithophyllum racemus	(Lamarck) Foslie						UAI, C	UMC, I
			Mesophyllum sp.								UMC, I
			Lithothamnion valens	Foslie						UAI, C	
			Corallina officinalis	Linnaeus	ZM205	UKI, C					
			Jania rubens	(Linnaeus) Lamouroux	ZM220				USC	UAI,C	UMC
			Lithothamnion corallioides	P Crouan et H Crouan	ZM236		UBBC, I		USC/USI	UAI, C	UMC, I
			Lithothamnion glaciale	Kjellman	ZM237	UKI, C					
			Lithothamnion sonderi	Hauck	ZM243	UKI, C					
			Melobesia membranacea	(Esper) Lamouroux	ZM246	UKI, C					
			Phymatolithon calcareum	(Pallas) Adey et McKibbin	ZM255	UKI, C	UBBC, I	UBGC, I	USC/USI	UAI, C	UMC, I
			Phymatolithon laevigatum	(Foslie) Foslie	ZM256	UKI, C					
			Phymatolithon lenormandii	(Areschoug) Adey	ZM258	UKI					
			Titanoderma pustulatum	(Lamouroux) Nageli	ZM279	UKI, C					
	HALYMENIALES	HALYMENIACEAE	*Halymenia* sp.		ZM293		UBBC				
			Cryptonemia tunaeformis	(Bertolini) Zanardini						UAI, C	UMC, I
	GIGARTINALES	RHIZOPHYLLIDACEAE	*Contarinia peyssonneliaeformis*	Zanardini						UAC	
			Contarinia squamariae	(Meneghini) Denizot						UAC	
		CAULACANTHACEAE	*Feldmannophycus rayssiae*	(J. Feldmann & G. Feldmann) Augier & Boudouresque						UAI, C	
		CRUORIACEAE	*Cruoria cruoriaeformis*	(P Crouan et H Crouan) Denizot	ZM314				USC		UMC, I
			Cruoria pellita	(Lyngbye) Fries	ZM315	UKI, C					
		CYSTOCLONIACEAE	*Calliblepharis jubata*	(Goodenough et Woodward) Kutzing	ZM320		UBBC, I				
			Rhodophyllis divaricata	(Stackhouse) Papenfuss	ZM324		UBBC, I				
		ERYTHROPELIDACEAE	*Erythrotrichia carnea*	(Dillwyn) J. Agardh	ZM						

PHYLUM	CLASS: ORDER	FAMILY	Species	Authority	Code	Clyde	Brest	Glenan	Galicia	Alicante	Malta
		DUMONTIACEAE	*Halymenia floresia*	Codomier						UAI, C	
			Cryptonemia lomation	(Bertolini) J Agardh						UAI, C	
			Acrosymphyton purpuriferum	(J. Agardh) Sjösted						UAI, C	
			Dudresnaya verticillata	(Withering) Le Jolis						UAI, C	
			Dumontia contorta	(S Gmelin) Ruprecht	ZM332	UKI					
		FURCELLARIACEAE	*Rhodophyllis divaricata*	(Stackhouse) Papenfuss						UAI, C	
			Rhodophyllis strafforelii	Ardissone						UAI, C	
			Halarachnion lingulatum	(Woodward) Kützing	ZM339		UBBC, I		USC	UAI, C	
		GIGARTINACEAE	*Chondrus crispus*	Stackhouse	ZM345	UKI					
		HYPNEACEAE	*Hypnea cervicornis*	J. Agardh						UAI, C	
		KALLYMENIACEAE	*Callophyllis* sp.		ZM368		UBBC, I				
			Kallymenia feldmanni	Codomier						UAI, C	
			Meredithia microphylla	(J. Agardh) J. Agardh						UAI, C	UMC, I
			Kallymenia patens	(J. Agardh) Codomier						UAI, C	
			Kallymenia requienii	J. Agardh						UAI, C	
			Callophyllis cristata	(Linnaeus ex Turner) Kutzing	ZM369	UKI					
		LOMENTARIACEAE	*Lomentaria chylocladiella*	Funk						UAI, C	
		PEYSSONNELIACEAE	*Peyssonnelia bornetti*	Boudouresque & Denizot						UAC	
			Peyssonnelia dubyi	Crouan & Crouan						UAC	
			Peyssonnelia orientalis	(Bosse) Boudouresque & Denizot						UAI, C	
			Peyssonnelia rosa-marina	Boudouresque & Denizot						UAI, C	UMC
			Peyssonnelia rubra	(Greville) J. Agardh						UAI, C	
			Peyssonnelia sp.								UMC
			Coccotylus truncata	(Pallas) M Wynne et J Heine	ZM395	UKI					
			Gymnogongrus crenulatus	(Turner) J. Agardh						UAI, C	
			Erythrodermis traillii	(Holmes ex Batters) Guiry et Garbary	ZM399	UKI					
			Mastocarpus stellatus	(Stackhouse) Guiry	ZM405	UKI					
			Phyllophora crispa	(Hudson) Dixon	ZM407	UKI, C				UAI, C	
			Stenogramme interrupta	(C agardh) Montagne ex Harvey	ZM414		UBBC, I				
	GRACILARIALES	GRACILARIACEAE	*Gracilaria* sp.		ZM431		UBBI				

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			Gracilaria dura	(C. Agardh) J. Agardh							UMC, I
			Gracilaria sp.							UAI, C	
			Gracilaria gracilis	(Stackhouse) Steentoft, L Irvine & Farnham	ZM433	UKI			USC		
			Gracilaria multipartita	(Clemente y Rubio) Harvey	ZM434				USC		
	PLOCAMIALES	PLOCAMIACEAE	*Plocamium cartilagineum*	(Linnaeus) Dixon	ZM443	UKI	UBBC, I		USC	UAI, C	
	RHODYMENIALES	CHAMPIACEAE	*Champia parvula*	(C Agardh) Harvey	ZM447		UBBI			UAI, C	
			Chylocladia verticillata	(Lightfoot) Bliding	ZM449	UKI	UBBC, I			UAI, C	
		LOMENTARIACEAE	*Lomentaria clavellosa*	(Turner) Gaillon	ZM456	UKI					
		RHODYMENIACEAE	*Rhodymenia ardissonei*	J. Feldmann						UAI, C	
			Botryocladia boergesenii	J. Feldmann						UAI, C	
			Botryocladia chiajeana	(Meneghini) Kylin						UAI, C	
			Rhodymenia delicatula	Dangeard						UAI, C	
			Gloiocladia furcata	(C. Agardh) J. Agardh						UAI, C	
			Cordylecladia guiry	Gargiulo, Furnari & Cormaci						UAI, C	
			Botryocladia microphysa	(Hauck) Kylin							UMC
			Fauchea microspora	Bornet						UAI, C	
			Fauchea repens	(C. Agardh) Montagne						UAI, C	
			?*Cordylecladia* sp.								UMC, I
			Rhodymenia sp.							UAI, C	
	CERAMIALES	CERAMIACEAE	*Crouania attenuata*	(C. Agardh) J. Agardh						UAI, C	UMC
			Centroceras cinnabarium	(Grateloup) J. Agardh						UAI	
			Ceramium codii	(Richards) Mazoyer						UAI, C	
			Ceramium comptum	Börgesen						UAI, C	
			Pterothamnion crispum	(Ducluzeau) Nägeli						UAI, C	
			Antithamnion cruciatum	(C. Agardh) Nägeli						UAI, C	
			Ceramium diaphanum	(Lightfoot) Roth						UAI, C	
			Antithamnionella elegans	(Berthold) Price & John						UAI, C	
			Sphyridia filamentosa	(Wulfen) Harvey in Hooker						UAI, C	UMC
			Spermothamnion flabellatum	Bornet						UAI, C	

PHYLUM	CLASS: ORDER	FAMILY	Species	Authority	Code	Clyde	Brest	Glenan	Galicia	Alicante	Malta
			Spermothamnion irregulare	(J. Agardh) Ardissone						UAI, C	
			Lejolisia mediterranea	Bornet							UMC
			Sphondylothamnion multifidum	(Hudson) Nageli						UAI, C	UMC
			Antithamnion ogdeniae	Abbot						UAI, C	
			Monosporus pedicellatus	G. Feldmann						UAI, C	
			Antithamnion piliferum	Cormaci & Furnari						UAI, C	
			Spermothamnion repens	(Dillwyn) Rosenvinge						UAI, C	
			?Aglaothamnion sp.								UMI
			?Callithamnion sp.								UMI
			?Seirospora sp.								UMC, I
			Griffithsia sp.							UAI, C	
			Seriospora sphaerospora	J. Feldmann						UAI, C	
			Antithamnionella spirographidis	Schiffner						UAI, C	
			Ceramium strictum	Harvey						UAI, C	
			Ceramium tenerrimum	(Martens) Okamura							UMC, I
			Aglaothamnion tenuissimum	(Bonnemaison) Feldmann-Mazoyer							UMC, I
			Antithamnion tenuissimum	(Hauck) Shiffner						UAI, C	
			Antithamnionella ternifolia	(J D Hooker et Harvey) Lyle	ZM498		UBBC				
			Callithamnion sp.		ZM501		UBBI				
			Callithamnion corymbosum	(J E Smith) Lyngbye	ZM502				USC	UAC, I	
			Ceramium cf. *echionotum*		ZM507		UBBC				
			Ceramium sp.1	Roth	ZM507	UKI	UBBI				
			Ceramium sp.2		ZM508		UBBI				
			Ceramium cimbricum	H Petersen	ZM512		UBBC, I				
			Ceramium diaphanum	(Lightfoot) roth	ZM515		UBBI				
			Ceramium echionotum	J Agardh	ZM516		UBBC, I				
			Compsothamnion thuyoides	(J E Smith) Nageli	ZM529	UKI					
			Griffithsia corallinoides	(Linnaeus) Trevisan	ZM533	UKI					
			Halurus flosculosus	(Ellis) Maggs et Hommersand	ZM539	UKI					
			Microcladia glandulosa	(Solander ex Turner) Greville	ZM543		UBBC				

PHYLUM	CLASS: ORDER	FAMILY	Species	Authority	Code	Clyde	Brest	Glenan	Galicia	Alicante	Malta
			Plumaria plumosa	(Hudson) Kuntze	ZM551	UKI					
			Pterothamnion plumula	(Ellis) Nageli	ZM554	UKI				UAI, C	
			Ptilota gunneri	P Silva, Maggs et L Irvine	ZM556	UKI					
			Ptilothamnion pluma	(Dilwyn) Thuret	ZM558	UKI				UAI, C	
			Spyridia filamentosa	(Wulfen) Harvey	ZM572		UBBC, I		USC	UAI, C	UMC
		DASYACEAE	*Dasya corallicola*	Funk							UMC
			Dasya corymbifera	J. Agardh							UMC, I
			Heterosiphonia crispella	(C. Agardh) Wynne						UAI, C	
			Dasya hutchinsiae	Harvey							UMI
			Eupogon planus	(C. Agardh) Kützing						UAI, C	
			Dasya punicea	Meneghini							UMC
			Dasya rigidula	(Kützing) Ardissone						UAI, C	UMC
			Eupogon spinellus	(C. Agardh) Kützing						UAI, C	
			Dasya corymbifera	J Agardh	ZM576		UBBC, I				
			Heterosiphonia sp.		ZM580		UBBC				
			Heterosiphonia plumosa	(Ellis) Baters	ZM581		UBBC, I				
		DELESSERIACEAE	*Nithophyllum micropunctatum*	Funk						UAI, C	
			Myriogramme minuta	Kylin						UAI, C	
			Radicilingua reptans	(Zanardini) Papenfuss						UAI, C	
			Apoglossum ruscifolium	(Turner) J. Agardh						UAI, C	
			Erythroglossum sandrianum	(Zanardini) Kylin						UAI, C	
			Acrosorium uncinatum	(Turner) Kylin						UAI, C	
			Cryptopleura ramosa	(Hudson) Kylin ex Lily Newton	ZM592	UKI	UBBC, I		USC		
			Delesseria sanguinea	(Hudson) Lamouroux	ZM594	UKI					
			Hypoglossum hyoglossoides	(Stackhouse) F Collins et Hervey	ZM610	UKI	UBBC, I			UAI, C	UMC
			Membranoptera alata	(Hudson) Stackhouse	ZM612	UKI					
			Nitophyllum sp.		ZM613		UBBC, I				
			Nitophyllum punctatum	(Stackhouse) Greville	ZM614	UKI				UAI, C	
			Phycodrys rubens	(Linnaeus) Batters	ZM616	UKI, C					

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			Radicilingua thysanorhizans	(Holmes) Papenfuss	ZM620		UBBI				
		RHODOMELACEAE	*Brongniartella byssoides*	(Goodenough et Woodward) Schmitz	ZM628	UKI	UBBC, I			UAI, C	
			Chondria capillaris	(Hudson) Wynne							UMI
			Polysiphonia cf.*ornata*	J. Agardh							UMI
			Laurencia cf.*paniculata*	(C. Agardh) J. Agardh							UMC
			Streblocladia collabens	(C. Agardh) Falkenberg							UMC
			Polysiphonia denudata	(Dillwyn) Greville ex Harvey in Hooker						UAI, C	
			Polysiphonia furcellata	(C. Agardh) Harvey in Hooker						UAI, C	
			Halopitys incurvus	(Hudson) Batters						UAI, C	UMC, I
			Laurencia microcladia	Kützing						UAI	
			Laurencia minuta ssp.*scammacae*	Furnari & Cormaci							UMC, I
			Halodictyon mirabile	Zanardini							UMC
			Polysiphonia mottei	Lauret							UMI
			Laurencia obtusa	(Hudson) Lamouroux							UMC, I
			Osmundea pelagosae	(Schiffner) Nam						UAI, C	UMC, I
			Polysiphonia ruchingeri	C. Agardh							UMC
			Lophosiphonia scopulorum	(Harvey) Womersley						UAI, C	
			Herposiphonia secunda	(C. Agardh) Hollemberg						UAI, C	
			Womersleyella setacea	(Hollenberg) R.E. Norris							UMC, I
			Polysiphonia setigera	Kützing							UMI
			Chondria sp.							UAI, C	
			Laurencia sp.							UAI, C	
			Laurencia sp.1								UMC, I
			Polysiphonia sp.1								UMI
			Laurencia sp.2								UMI
			Polysiphonia sp.2								UMI
			Laurencia sp.3								UMC, I
			Polysiphonia spinosa	(C. Agardh) J. Agardh							UMC, I
			Polysiphonia subulifera	(C. Agardh) Harvey						UAI, C	
			Herposiphonia tenella	(C. Agardh) Ambronn						UAI, C	

PHYLUM	CLASS: ORDER	FAMILY	Species	Authority	Code	Clyde	Brest	Glenan	Galicia	Alicante	Malta
			Rytiphloea tinctoria	(Clemente) C. Agardh						UAI, C	UMI, C
			Polysiphonia urceolata	(Dillwyn) Greville							UMC
			Osmundaria volubilis	(Linnaeus) R.E. Norris						UAI, C	UMC, I
			Chondria dasyphylla	(Woodward) C Agardh	ZM632		UBBC, I		USC		
			Halopithys incurvus	(Hudson) Batters	ZM637		UBBC				
			Laurencia sp.		ZM640		UBBC				
			Odonthalia dentata	(Linnaeus) Lyngbye	ZM649	UKI					
			Osmundea pinnatifida	(Hudson) Stackhouse	ZM653		UBBI				
			Polysiphonia sp.1		ZM655		UBBI				
			Polysiphonia sp.2		ZM655		UBBI				
			Polysiphonia sp.3		ZM655		UBBI				
			Polysiphonia sp.4		ZM655		UBBI				
			Polysiphonia sp.5		ZM655		UBBC, I				
			Polysiphonia sp.6		ZM655		UBBC, I				
			Polysiphonia elongata	(Hudson) Sprengel	ZM661	UKI				UAI, C	UMC, I
			Polysiphonia fucoides	(Hudson) Greville	ZM667	UKI, C					
			Polysiphonia nigra	(Hudson) Batters	ZM672	UKI					
			Polysiphonia stricta	(Dillwyn) Greville	ZM679	UKI	UBBI				
			Pterosiphonia complanata	(Clemente y Rubio) Falkenberg	ZM684		UBBI				
			Pterosiphonia parasitica	(Hudson) Falkenberg	ZM685	UKI, C				UAI	
			Pterosiphonia pennata	(C Agardh) Sauvageau	ZM686	UKI				UAI, C	
			Pterosiphonia pinnulata	(Kützing) Maggs et Hommersand	ZM687		UBBC, I				
			Rhodomela sp.		ZM689		UBBC, I				
			Rhodomela confervoides	(Hudson) P Silva	ZM690	UKI					
CHROMOPHYCOTA	ECTOCARPALES	PUNCTARIACEAE	*Asperococcus bullosus*	Lamouroux						UAI, C	
			Asperococcus turneri	(Smith) Hooher						UAI, C	
		ECTOCARPACEAE	*Ectocarpale* sp.1		ZR3		UBBC, I				
			Ectocarpale sp.2		ZR3		UBBC				
			Ectocarpus siliculosus	(Dillwyn) Lyngbye						UAI, C	

PHYLUM	CLASS: ORDER	FAMILY	Species	Authority	Code	Clyde	Brest	Glenan	Galicia	Alicante	Malta
			spp		ZR4	UKI					
			Ectocarpus fasciculatus	Harvey	ZR17	UKI					
		ELACHISTACEAE	*Elichistia stellaris*	Areschoug						UAI	
		LITHODERMATACEAE	*Pseudolithoderma extensum*	(P Crouan et H Crouan) S Lund	ZR101	UKI, C					
	DICTYOSIPHONIALES	MYRIONEMATACEAE	*?Hecatonema* sp.								UMC
		SCYTOSIPHONACEAE	*Scytosiphon simplicissimus*	(Clemente) Cremades							UMC
			Colpomenia peregrina	(Sauvageau) G Hamel	ZR184		UBBC, I				
			Scytosiphon lomentaria	(Lyngbye) Link	ZR194	UKI					
	CHORDARIALES	CHORDARIACEAE	*Cladosiphon irregularis*	(Sauvageau) Kylin							UMC, I
		CORYNOPHLOEACEAE	*Leathesia* sp.								UMC
			Myriactula rivulariae	(Suhr) J. Feldmann							UMC, I
			Myriactula sp.								UMC, I
		SPERMATOCHNACEAE	*Stilophora rhizodes*	(Turnerr) J. Agardh							UMC, I
	CUTLERIALES	CUTLERIACEAE	*Aglaozonia chilosa*	Falkemberg						UAI, C	
			Aglaozonia melanoidea	(Falkenberg) Silva						UAC	
			Cutleria sp.								UMC, I
			Zanardinia prototypus	(Nardo) Nardo						UAC	UMC
			Cutleria multifida	(J E Smith) Greville	ZR271	UKI					
	SPHACELARIALES	SPHACELARIACEAE	*Sphacelaria* sp.								UMC, I
			Sphacelaria sp.1	Lyngbye	ZR288	UKI					
			Sphacelaria fusca	(Hudson) Gray						UAI, C	
			Sphacelaria plumula	Zanardini						UAI, C	
			Sphaelaria rigidula	Kutzing						UAI, C	
			Sphacelaria cirrosa	(Roth) C Agardh	ZR291	UKI, C				UAI, C	UMI
		STYPOCAULACEAE	*Halopteris filicina*	(Grateloup) Kützing						UAI, C	UMC, I
			Halopteris scoparia	(Linnaeus) Sauvageau						UAI	UMC
	DICTYOTALES	DICTYOTACEAE	*Dictyopteris polypodioides*	(DC.) Lamouroux						UAI, C	UMI
			Dictyota mediterranea	(Schiffner) Furnari							UMC, I
			Dictyota sp.								UMC, I
			Dictyota linearis	(C. Agardh) Greville						UAI, C	UMC, I

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			Padina pavonica	(Linnaeus) Thivy						UAI	
			Spatoglossum solieri	(Chauvin) Kützing		UKI				UAC	
			Zonaria tournefortii	(Lamouroux) Montagne							UMC
			Dictyota dichotoma	(Hudson) Lamouroux	ZR313	UKI	UBBC, I		USC	UAI, C	UMC, I
	DESMARESTIALES	SPOROCHACEAE	*Nereia filiformis*	(J. Agardh) Zanarini						UAI, C	
			Sporochnus pedunculatus	(Hudson) C. Agardh						UAC	
		ARTHROCLADIACEAE	*Arthrocladia villosa*	(Hudson) Duby						UAI, C	
		DESMARESTIACEAE	*Desmarestia aculeata*	(Linnaeus) Lamouroux	ZR334	UKI, C					
	LAMINARIALES	CHORDACEAE	*Chorda filum*	(linnaeus) Stackhouse	ZR346	UKI					
		LAMINARIACEAE	*Laminaria saccharina*	(Linnaeus) Lamouroux	ZR354	UKI					
	FUCALES	CYSTODEIRACEAE	*Cystoseira zosteroides*	(Turner) C. Agardh						UAC	
			Cystoseira cf.*dubia*	Valiante							UMI
			Cystoseira corniculata	(Wulfen) Zanardini							UMC, I
			Cystoseira sp.								UMC, I
			Cystoseira spinosa	Sauvageau						UAI, C	UMC
			Phyllariopsis brevipes	Henry & South						UAC	
CHLOROPHYCOTA	DASYCLADALES	ACETABULARIEACEAE	*Polyphisa parvula*	(Soms-Laubach) Schnetter						UAI	
	CHLOROPHYCEAE	CHAETOPHORACEAE	*Bolbocoleon piliferum*	Pringsheim							UMC
			Phaeophila dendroides	(P.L. & H.M. Crouan) Batters						UAI, C	UMC, I
	CODIOLALES	MONOSTROMATACEAE	*Gomontia polyrhiza*	(Lagerheim) Bornet et Flahault	ZS45				USC		
		ULOTRICHACEAE	*Ulothrix flacca*	(Dillwyn) Thuret						UAI, C	
			Ulothrix subflaccida	Wille							UMC
	ULVALES	ULVACEAE	*Enteromorpha* sp.							UAI	
			Didymosporangium repens	Lambert						UAI, C	
			Endoderma majus	J. Feldman						UAI, C	
			Pringsheimiella scutata	(Reinke) Marchewianka						UAI, C	
			Ulvella lens	Crouan & Crouan						UAI, C	
			Blidingia marginata	(J. Agardh) P Dangeard ex Bliding	ZS144		UBBI				
			Enteromorpha sp.		ZS149		UBBC				

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			Ulva sp.1	Linnaeus	ZS174	UKI	UBBC, I				
			Ulva olivascens	P Dangeard	ZS180				USC		
	CLADOPHOROPHYCEAE	VALONIACCEAE	*Valonia utricularis*	(Roth) C Agardh							UMC, I
			Valonia macrophysa	Kützing						UAI, C	
	CLADOPHORALES	CLADOPHORACEAE	*Chaetomorpha aerea*	(Dillwyn) Kützing						UAI, C	
			Chaetomorpha linum	(O.F. Müller) Kutzing						UAI, C	
			Cladophora albida	(Hudson) Kützing						UAI, C	
			Cladophora pellucida	(Hudson) Kützing						UAI, C	
			Cladophora prolifera	(Roth) Kützing						UAI, C	
			Cladophora rupestris	(Linnaeus) Kützing						UAI, C	
			Cladophora seriacea	(Hudson) Kützing						UAI, C	
			Cladophora patentiramea	(Montagne) Kützing							UMI
			Cladophora sp.								UMC, I
		CLADOPHORACEAE	*Rhizoclonium kochianum*	Kützing							UMC
			Chaetomorpha linum	(O F Muller) Kützing	ZS192		UBBI				
			Cladophora sp.		ZS195		UBBC, I				
			Cladophora sp.	Kützing	ZS195				USC		
			Cladophora sp.1	Kutzing	ZS195	UKI					
			Cladophora pygmaea	Reinke	ZS210		UBBC, I				
		ANADYOMENACEAE	*Microdictyon tenuius*	(G. Agardh) Decaisne						UAI, C	UMC, I
	BRYOPSIDALES	POLYPHYSACEAE	*Acetabularia acetabulum*	(Linnaeus) Silva						UAC	UMC
		CAULERPACEAE	*Caulerpa prolifera*	(Forskal) Lamouroux						UAI, C	
		DASYCLADACEAE	*Dasycladus vermicularis*	(Scopoli) Krasser							UMC
		UDOTEACEAE	*Flabellia petiolata*	(Turra) Nizamuddin						UAI, C	UMC, I
			Halimeda tuna	(Ellis & Solander) Lamouroux							UMC, I
		UDOTEACEAE	*Pseudochlorodesmis furcellata*	(Zanardini) Börgensen						UAI, C	
		DERBESIACEAE	*Halycystis parvula*	Schmitz						UAI, C	
		BRYOPSIDACEAE	*Bryopsis* sp.							• UAI, C	
			Derbesia sp.		ZS233		UBBC				
			Derbesia marina	(Lyngbye) Solier	ZS234	UKI					

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			Ostreobium quikettii	Bornet et Flahault	ZS237	UKI, C					
		CODIACEAE	*Codium bursa*	(Linnaeus) C. Agardh						UAI, C	UMC, I
ANGIOSPERMAPHYTA			*Posidonia oceanica*	(Linnaeus) Delile						UAI, C	
			Cymodocea nodosa	(Ucria) Ascherson						UAC	

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PORIFERA	CALCAREA	LEUCOSOLENIIDAE	*Leucosolenia* sp.A	Bowerbank, 1861	C0053	UKI, C					
	LEUCOSOLENIDA	GRANTIIDAE	*Grantia compressa*	(Fabricius, 1780)	C77		UBBC				
		SYCETTIDAE	*Scypha ciliata*	(Fabricius, 1780)	C133		UBBI				
			Scypha raphanus	(Schmidt, 1862)	C138				USC		
			Sycon sp.A		C0152	UKC					
	HADROMERIDA	TETHYIDAE	*Tethya aurantium*	(Pallas, 1766)	C340		UBBC, I		USC		
			Suberites ficus	(Linnaeus, 1767)	C0418	UKC	UBBC, I	UBGC	USC		
		CLIONIDAE	*Cliona celata*	Grant, 1826	C0480	UKI, C	UBBC, I				
			Halichondria bowerbanki	Burton, 1930	C0638	UKC					
	HALICHONDRIDA	HALICHONDRIDAE	*Hymeniacidon sanguinea*	(Grant, 1826)	C669		UBBC				
			Mycale macilenta	(Bowerbank, 1866)	C0726	UKC					
		MYCALIDAE	*Esperiopsis fucorum*	(Esper, 1794)	C0758	UKI, C					
		MYXILLIDAE	*Myxilla incrustans*	(Johnston, 1842)	C1085	UKC					
	DEMOSPONGIAE	CHALINIDAE	*Haliclona* sp.A	Grant, 1835	C1420	UKI, C					
			Haliclona urceolus	(Rathke & Vahl, 1806)	C1431	UKC					
	DENDROCERATIDA	DYSIDAE	*Dysidea fragilis*	(Montagu, 1818)	C1670		UBBC				
			Sponges indet.				UBBC				
		SYCETTIDAE	*Sycon* sp.							UAI, C	
		CLIONIDAE	*Axinella damicornis*	(Esper, 1794)						UAI, C	
			Cliona viridis	(Schmidt, 1862)						UAI, C	
			Chondrosia reniformis	Nardo, 1833						UAC	
		SUBERITIDAE	*Spirastrella cunctatrix*	Schmidt, 1868						UAC	
CNIDARIA	SCYPHOMEDUSAE	CYANEIDAE	*Cyanea capillata*	(Linnaeus, 1758)	D0044	UKI, C					
		ULMARIDAE	*Aurelia aurita*	(Linnaeus, 1758)	D0048	UKI, C					
		RHIZOSTOMATIDAE	*Rhizostoma octopus*	(Linnaeus, 1758)	D0052	UKI, C					
	LEPTOLIDA	CORYMORPHIDAE	*Corymorpha nutans*	M Sars, 1835	D0155	UKC					
		TUBULARIIDAE	*Tubularia indivisa*	Linnaeus, 1758	D0166	UKC					
			Tubularia larynx	Ellis & Solander, 1786	D0167	UKC					
	CAPITATA	CORYNIDAE	*Sarsia eximia*	(Allman, 1859)	D182		UBBC				
	LEPTOLIDA	EUDENDRIIDAE	*Eudendrium ramosum*	(Linnaeus, 1758)	D0227	UKC					
		HYDRACTINIIDAE	*Hydractinia echinata*	(Fleming, 1828)	D0273	UKI, C					
		LAFOEIDAE	*Lafoea dumosa*	(Fleming, 1828)	D0386	UKC					
		HALECIIDAE	*Halecium halecinum*	(Linnaeus, 1758)	D0392	UKC					
		SERTULARIIDAE	*Abietinaria abietina*	(Linnaeus, 1758)	D0409	UKI, C					
			Dynamena pumila	(Linnaeus, 1758)	D0422	UKI					

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			Hydrallmania falcata	(Linnaeus, 1758)	D0424	UKC					
			Sertularella gayi	(Lamouroux, 1821)	D0429	UKC			USC / USI		
			Sertularella polyzonias	(Linnaeus, 1758)	D0430	UKC					
			Sertularia argentea	Linnaeus, 1758	D0434	UKC					
			Thuiaria articulata	(Pallas, 1766)	D0442	UKC					
		PLUMULARIDAE	*Halopteris catharina*	(Johnston, 1833)	D0452	UKC					
			Kirchenpaueria pinnata	(Linnaeus, 1758)	D0455	UKC					
			Nemertesia antennina	(Linnaeus, 1758)	D0463	UKC					
		CAMPANULARIIDAE	*Rhizocaulus verticillatus*	(Linnaeus, 1758)	D0499	UKC					
			Clytia hemisphaerica	(Linnaeus, 1767)	D0503	UKI, C					
			Obelia dichotoma	(Linnaeus, 1758)	D0519	UKI, C					
			Obelia geniculata	(Linnaeus, 1758)	D0520	UKC					
	HEXACORALLIA	ALCYONIIDAE	*Alcyonium digitatum*	Linnaeus, 1758	D0597	UKI, C	UBBC				
		VIRGULARIIDAE	*Virgularia mirabilis*	(O F Muller, 1776)	D0618	UKC					
		CERIANTHIDAE	*Cerianthus lloydii*	Gosse, 1859	D0632	UKI, C	UBBC	UBGC	USC		
		ACTINIIDAE	*Actinia equina*	(Linnaeus, 1758)	D675		UBBI		USC		
			Anemonia viridis	(Forsskal, 1775)	D0679	UKI, C	UBBC, I		USC		
			Bolocera tuidiae	(Johnston, 1832)	D0681	UKC					
			Urticina felina	(Linnaeus, 1761)	D0684	UKC					
		AURELIANIIDAE	*Aureliana heterocera*	(Thompson, 1853)	D692		UBBC, I				
		METRIDIIDAE	*Metridium senile*	(Linnaeus, 1761)	D0710	UKI, C					
		SAGARTIIDAE	*Sagartia* sp.	Gosse, 1855	D712				USC		
			Sagartia elegans	(Dalyell, 1848)	D0713	UKC					
			Cereus pedunculatus	(Pennant, 1777)	D0717	UKC	UBBC, I		USC		
		HORMATHIIDAE	*Calliactis parasitica*	(Couch, 1842)	D741		UBBC, I	UBGC, I	USC / USI	UAC	
			Adamsia carcinipados	(Otto, 1823)	D0743	UKC	UBBC, I	UBGI	USI	UAC	
		HALCAMPIDAE	*Halcampa chrysanthellum*	(Peach, in Johnston, 1847)	D758		UBBC, I		USC / USI		
		EDWARDSIIDAE	*Edwardsia claperedii*	(Panceri, 1869)	D0766	UKI, C	UBBC				
	ANTHOZOA	SAGARTIIDAE	*Epizoanthus* sp.								UMC
			Cerianthus cf. *membranaceus*				UBBC				
	ACTINAIRIA	ACTINIIDAE	*Anemone* sp.1				UBBC				
			Anemone sp.2				UBBC				
			Caryophyllia smithii	Stokes & Broderip, 1828						UAI	
			Alcyonum acaule	Marion, 1878						UAC	

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			Epizoanthus arenaceus	(Delle Chiaje, 1823)						UAC	
			Eunicella singularis	(Esper, 1791)						UAC	
			Leptogorgia sarmentosa	(Esper, 1789)						UAC	
	HYDROZOA		*Eudendrium* sp.							UAC	
			Nemertesia sp.							UAC	
			Sertularella sp.							UAC	
CTENOPHORA		PLEUROBRACHIIDAE	*Pleurobranchia pileus*	(O F Muller, 1776)	E0006	UKI, C					
	NUDA	BEROIDAE	*Beroe cucumis*	Fabricius, 1780	E0015	UKI, C					
PLATYHELMINTHES	TURBELLARIA		spp.		F002	UKI, C					
	TURBELLARIA	LEPTOPLANIDAE	sp.A		F0080	UKI, C					
			indet.				UBBC				
NEMERTEA	ANOPLA		sp.A		G0002	UKI, C					
			sp.C		G0002	UKI, C					
			sp.B		G0002	UKI					
		CEPHALOTHRICIDAE	*Cephalothrix rurifrons*	(Johnston, 1837)	G11		UBBC				
		TUBULANIDAE	*Tubulanus annulatus*	(Montagu, 1804)	G0028	UKI, C					
			Tubulanus polymorphus	Renier, 1804	G34	UKI, C	UBBC				
		CEREBRATULIDAE	*Cerebratulus marginatus*	Renier, 1804	G0042	UKI					
			Cerebratulus roseus	(Delle Chiaje, 1841)	G44		UBBC, I				
		LINEIDAE	*Lineus bilineatus*	(Renier, 1804)	G0052	UKI					
			Lineus longissimus	(Gunnerus, 1770)	G0054	UKI, C					
			Nemertea sp1								UMC, I
			Nemertea sp.					UBGC, I			
			Nemertea sp.				UBBC, I				
NEMATODA			spp.		HD0001	UKI, C					
	ADENOPHOREA	LEPTOSOMATIDAE	*Cylicolaimus* sp.A	De Man, 1889	HD0068	UKI, C					
		ONCHOLAIMIDAE	*Pontonema vulgare*	(Bastian, 1865)	HD0127	UKI, C					
			sp.5								UMI
			Nematoda sp.1				UBBC, I				
			Nematoda sp.2				UBBC, I				
PRIAPULIDA		PRIAPULIDAE	*Priapulus caudatus*	Lamarck, 1816	J0007	UKC					
ENTOPROCTA		PEDICELLINIDAE	*Pedicellina cernua*	(Pallas, 1774)	K0046	UKI, C					
		BARENTSIIDAE	*Barentsia* sp.A	Hincks, 1880	K0050	UKI, C					
CHAETOGNATHA			*Spadella cephaloptera*	(Busch, 1851)	L0029	UKC					
SIPUNCULA	POLYCHAETA	GOLFINGIIDAE	*Golfingia elongata*	(Keferstein, 1862)	N0014	UKI, C	UBBC, I	UBGC, I	USC / USI		

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			Golfingia vulgaris	(de Blainville, 1827)	N0017	UKI, C	UBBC, I				
			Nephasoma minutum	(Keferstein, 1862)	N0025	UKC					
		PHASCOLIONIDAE	*Phascolion strombus*	(Montagu, 1804)	N0034	UKC	UBBC	UBGC, I	USI		
			Phascolosoma spp.				UBBC, I				
		ASPIDOSIPHONIDAE	*Aspidosiphon muelleri*	Diesing, 1851							UMC, I
		SIPUNCULIDAE	*Sipunculus nudus*	Linnaeus, 1766							UMC
ECHIURA	ECHIURIDA	ECHIURIDAE	*Thalassema thalassemum*	(Pallas, 1766)	O9		UBBC		USI		
ANNELIDA	POLYCHAETA	CHRYSOPETALIDAE	*Chrysopetalum debile*	(Grube, 1855)	P8				USC / USI	UAI, C	
			Bhawania reyssi	(Katzmann, Laubier & Ramos, 1974)						UAI, C	
		PISIONIDAE	*Pisione* sp.	Grube, 1856	P14				USC		
			Pisione remota	(Southern, 1914)	P0015	UKI, C	UBBC		USI		
		APHRODITIDAE	*Aphrodita aculeata*	Linnaeus, 1758	P0019	UKC	UBBC		USC / USI		
			Aphroditidae indet.				UBBC, I				
			Harmothoe longisetis	(Grube, 1863)							UMC
			Harmothoe sp.								UMI
			Hermonia hystrix	(Savigny in Lamarck, 1818)	P21		UBBC, I	UBGC	USC / USI		
			Laetmonice hystrix	(Savigny, 1820)						UAI, C	
		POLYNOIDAE	*Alentia gelatinosa*	(M Sars, 1835)	P0034	UKI, C	UBBC, I		USC / USI		
			Harmothoe sp.	Kinberg, 1855	P50				USC / USI		
			Harmothoe extenuata	(Grube, 1840)	P58		UBBC, I	UBGC, I	USC / USI		
			Harmothoe glabra	(Malmgren, 1865)	P62				USC		
			Harmothoe imbricata	(Linnaeus, 1767)	P0064	UKI, C	UBBC, I	UBGI			
			Harmothoe impar	(Johnston, 1839)	P0065	UKI, C	UBBC, I	UBGC	USC		
			Harmothoe ljungmani	(Malmgren, 1867)	P0066	UKI, C			USC / USI		
			Harmothoe lunulata	(Chiaje, 1841)	P67		UBBC, I	UBGC	USC / USI	UAI	
			Harmothoe mcintoshi	Tebble & Chambers, 1982	P0070	UKI, C					
			Harmothoe spinifera	(Ehlers, 1864)	P0074	UKI, C			USC / USI	UAI, C	UMC
			Harmothoe longisetis				UBBC				
			Lepidonotus clava	(Montagu, 1808)	P81		UBBC, I		USC		
			Lepidonotus squamatus	(Linnaeus, 1758)	P0082	UKI, C	UBBC, I		USC		
			Polynoe scolopendrina	Savigny, 1822	P84		UBBC, I	UBGC	USC		
			Harmothoe antilopes	(McIntosh, 1876)						UAI, C	
			Harmothoe maxillospinosa	(Saint-Joseph, 1888)						UAI, C	
			Harmothoe reticulata	(Claparède, 1870)						UAI, C	
		PHOLOIDAE									

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			Pholoe synophthalmica	Claparède, 1868	P94		UBBC		USC		
		SIGALIONIDAE	*Pholoe minuta*				UBBC, I	UBGC, I		UAI, C	
			Psammolyce arenosa	(Chiaje, 1841)	P102		UBBC, I		USC		UMC
			Sigalion mathildae	Audouin & Milne-Edwards, 1830	P104		UBBC, I				
			Sthenelais boa	(Johnston, 1839)	P107		UBBC, I	UBGI	USC / USI		UMC
			Sthenelais minor	Pruvot & Racovitza, 1895	P110		UBBC		USC		
		PHYLLODOCIDAE	*Eteone flava*	(Fabricius, 1780)	P117		UBBC, I				
			Eteone longa	(Fabricius, 1780)	P0118	UKI, C			USC		
			Mysta picta	(Quatrefages, 1866)	P0127	UKI, C	UBBC, I	UBGI	USC / USI		
			Pseudomystides limbata	(Saint-Joseph, 1888)	P0136	UKI, C	UBBC, I		USC / USI		
			Eulalia sp							UAI, C	
			Phyllodoce sp.							UAI, C	
			Protomystides sp.							UAI, C	
			Anaitides maculata	(Linnaeus, 1767)	P144		UBBC, I	UBGC	USC		
			Eulalia aurea	Gravier, 1896	P151		UBBC		USC		
			Eulalia bilineata	(Johnston, 1839)	P 0152	UKI, C					
			Eulalia viridis	(Linnaeus, 1767)	P 0161	UKI, C	UBBC		USC		
			Eumida parva	(Saint-Joseph, 1888)	P166		UBBC, I	UBGC	USC		
			Eumida sanguinea	(Œrsted, 1843)	P0167	UKI, C	UBBC, I		USC / USI		UMC
			Nereiphylla paretti	Blainville 1828	P170		UBBC		USC		
			Nereiphylla rubiginosa	(Saint-Joseph, 1888)	P171		UBBC, I	UBGI	USC		
			Notophyllum foliosum	(M Sars, 1835)	P0174	UKC					
			Phyllodoce sp.	Lamarck, 1818	P178				USC		
			Phyllodoce sp.A	Lamarck, 1818	P0178	UKI, C					
			Phyllodoce sp.B					UBGC, I			
			Phyllodocidae spp.								UMI
			Phyllodocidae spp.				UBBC, I				
			Phyllodoce laminosa	Lamarck, 1818	P180		UBBC, I		USC		
			Phyllodoce paretti	(Blainville, 1828)							UMC
			Phyllodoce sp.				UBBC, I				
			Pirakia fuscescens	(Saint-Joseph, 1888)	P184		UBBC	UBGC	USC		
			Pirakia punctifera	(Grube, 1860)	P0185	UKC					
		GLYCERIDAE	*Glycera* sp.	Savigny, 1818	P255				USC / USI		
			Glycera convoluta	Rioja, 1918							UMC, I
			Glycera gigantea	Quatrefages, 1866	P0259	UKI			USC / USI		

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			Glycera lapidum	Quatrefages, 1866	P0260	UKI, C	UBBC		USC / USI		
			Glycera rouxii	Audouin & Milne-Edwards, 1833	P0263	UKI, C	UBBC		USC / USI		
			Glycera tesselata	Grube, 1863	P264				USC / USI	UAI, C	
			Glycera tridactyla	Schmarda, 1861	P265		UBBC, I	UBGC	USC / USI		
			Glycera unicornis	Savigny	(4)		UBBC, I		USC / USI		
			Glycera sp.				UBBC				
		GONIADIDAE	*Goniada* sp.	Audouin & Milne-Edwards, 1834	P269				USC		
			Goniada emerita	Audouin & Milne-Edwards, 1834	P270		UBBC		USC		
			Goniada maculata	Oersted, 1843	P0271	UKC	UBBC, I		USC / USI		
		SPHAERODORIDAE	*Ephesiella abyssorum*	(Hansen, 1878)	P0282	UKC			USC		
			Sphaerodoridae indet.				UBBC, I				
			Sphaerodoropsis sp.A	Hartman & Fauchald, 1971	P0285	UKC					
			Sphaerodorum gracilis	(Rathke, 1843)	P0291	UKI, C					
			Sphaerodorum sp.							UAI, C	
		HESIONIDAE	sp.A		P0293	UKI, C					
			sp.B		P0293	UKI, C					
			Gyptis sp.A	Marion & Bobretzky, 1875	P0297	UKI, C					
			Hesione pantherina	(Risso)	P297		UBBC, I	UBGC	USC		
			Hesiospina similis	(Hessle, 1925)	P0303	UKI, C					
			Kefersteinia cirrata	(Keferstein, 1862)	P0305	UKI, C	UBBC, I		USC / USI	UAI, C	
			Magalia sp.				UBBC, I				
			Nereimyra sp.	Blainville 1828	P310				USC		
			Nereimyra punctata	(O F Muller, 1788)	P0311	UKI, C					
			Ophiodromus flexuosus	(Chiaje, 1827)	P313		UBBC, I		USC / USI		
			Syllidia armata	Quatrefages, 1866	P321		UBBC, I		USC / USI		
		PILARGIDAE	*Pilargis verrucosa*	Saint-Joseph, 1899	P344		UBBC, I		USC		
		SYLLIDAE	sp.A		P0346	UKI, C					
			sp.B		P0346	UKI, C					
			Sphaerosyllis sp.							UAI, C	
			Streptosyllis sp.							UAI, C	
			Syllis sp.							UAI, C	
			Ehlersia cornuta	(Rathke, 1843)	P349		UBBC		USC		
			Ehlersia ferrugina	(Langerhans, 1881)	P350				USI		
			Ehlersia garciai	Campoy, 1981	P351				USC / USI		

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			Eusyllis lamelligera	Marion & Bobretzky, 1875							UMC
			Syllis sp.	Savigny, 1818	P358				USC		
			Syllis sp.				UBBC				
			Syllis amica	Quatrefages, 1866	P359		UBBC, I	UBGC	USC		UMC
			Syllis gracilis	Grube, 1840	P360		UBBC, I		USC		
			Syllis prolifera	Krohn, 1852							UMC
			Trypanosyllis sp.	Claparéde, 1868	P361				USC		
			Trypanosyllis coeliaca	Claparéde, 1868	P0362	UKI, C					
			Trypanosyllis zebra	(Grube, 1860)	P363		UBBC, I		USC	UAI, C	
			Typosyllis sp.A	Langerhans, 1879	P0364	UKI, C					
			Typosyllis hyalina	(Grube, 1863)	P368		UBBI	UBGI	USI		
			Typosyllis krohnii	(Ehlers, 1864)	P369		UBBC, I				
			Typosyllis prolifera	(Krohn, 1852)	P370		UBBI	UBGC	USI		
			Typosyllis variegata	(Grube, 1860)	P371		UBBC				
			Typosyllis vittata	(Grube, 1840)	P372		UBBC				
			Pionosyllis pulligera	(Krohn, 1852)	P400		UBBC		USC / USI		
			Streptosyllis bidentata	Southern, 1814	P403		UBBC, I				
			Syllidae indet.				UBBC, I				
			Brania sp.A	Quaterfages, 1865	P0411	UKI, C					
			Exogone hebes	(Webster & Benedict, 1884)	P421		UBBC		USC / USI		
			Exogone verugera	Claparéde, 1868	P0423	UKI, C					
			Sphaerosyllis sp.	Claparéde, 1863	P424				USC / USI		
			Sphaerosyllis sp.A	Claparéde, 1863	P0424	UKI, C					
			Sphaerosyllis bulbosa	Southern, 1914	P0425	UKI, C	UBBC		USC / USI		
			Sphaerosyllis hystrix	Claparéde, 1863	P427				USC / USI		
			Sphaerosyllis taylori	Perkins, 1980	P430	UKI, C	UBBI		USC / USI		
			Autolytus sp.	Grube, 1850	P434				USI		
			Autolytus sp.		P434						UMC
			Autolytus aurantiacus	(Claparède, 1868)	P436		UBBC, I				
			Autolytus brachycephalus	(Marenzeller, 1874)	P437		UBBC	UBGC	USC		
			Autolytus edwarsi	Saint-Joseph, 1886	P438				USC		
			Autolytus prolifera	(O F Muller, 1788)	P0444	UKI, C	UBBC, I		USC		
			Autolytus rubropunctatus	(Grube, 1860)	P447		UBBC		USC		
		NEREIDIDAE	Nereidae spp.				UBBC				
			Nereis ?rava	Ehlers, 1868							UMC

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			Nereis sp.								UMC
			Nereis sp.				UBBC				
			Nereis sp							UAI, C	
			Nereis longissima	Johnston, 1840	P0475	UKI, C				UAI, C	
			Nereis pelagica	Linnaeus, 1758	P0476	UKI, C					
			Nereis zonata	Malmgren, 1867	P0478	UKI, C					
			Perinereis cultrifera	(Grube, 1840)	P0480	UKI, C					
			Platynereis dumerilii	(Audouin & Milne-Edwards, 1833)	P0484	UKI, C	UBBC, I	UBGC, I	USC / USI		UMC
			Websterinereis glauca	(Claparède, 1870)	P487		UBBC, I		USC		
		NEPHTYIDAE	*Aglaophamus tubella*	(Michaelsen, 1897)	P0493	UKC					
			Nephtys sp.	Cuvier, 1817	P494				USC / USI		
			Nephtys sp.	Cuvier, 1817	P494		UBBC				
			Nephtys caeca	(Fabricius, 1780)	P496				USC / USI		
			Nephtys cirrosa	Ehlers, 1868	P0498	UKC	UBBC, I	UBGI	USC		
			Nephtys hombergii	Savigny, 1818	P0499	UKI, C	UBBC, I	UBGC, I	USC		
			Nephtys hystricis	McIntosh 1900	P500		UBBC	UBGC	USC		
			Nephtys incisa	Malmgren, 1865	P0501	UKI					
		AMPHINOMIDAE	*Paramphinome jeffreysii*	(McIntosh, 1868)	P0518	UKI					
			Pareurythoe borealis	(M Sars, 1862)	P0520	UKC					
		EUPHROSINIDAE	*Euphrosine foliosa*	Audouin & Milne-Edwards, 1833	P528		UBBC, I		USI	UAI, C	
			Lumbrineriopsis indet.	(Saint-Joseph, 1888)						UAI, C	
			Lumbrineris labrofimbriata	(Saint-Joseph, 1888)						UAI, C	
		ONUPHIDAE	*Aponuphis bilineata*	(Baird, 1870)	P0539	UKC	UBBC		USC / USI	UAI, C	
			Hyalinoecia brementi	(Fauvel, 1916)						UAI	
			Hyalinoecia fauveli	(Rioja, 1918)						UAI	UMC
			Onuphis eremita	(Audouin & Milne-Edwards, 1833)						UAI	
		EUNICIDAE	*Eunice sp.A*	Cuvier, 1817	P0554	UKC					
			Eunice harasii	Audouin & Milne-Edwards, 1833	P0556	UKI, C	UBBC, I		USI		UMC
			Eunice vittata	(Chiaje, 1828)	P560		UBBC, I	UBGC, I	USC / USI	UAI, C	UMC, I
			Aponuphis grubei								UMC
			Lysidice ninetta	Audouin & Milne-Edwards, 1833	P562		UBBC, I	UBGC, I	USC	UAI, C	UMC, I
			Marphysa bellii	Audouin & Milne-Edwards, 1833	P564		UBBC, I	UBGC, I	USC		
			Marphysa fallax	Marion & Bobretzky, 1875	P565						UMC
			Marphysa sanguinea	(Montagu, 1813)	P566		UBBC, I		USC		UMC

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			Eunice pennata	(O.F. Müller, 1778)						UAI, C	
			Eunice torquata	(Quatrefages, 1865)						UAI, C	
			Marphysa sp.							UAI, C	
			Staurocephalus rubrovittatus	(Ehlers, 1868)						UAI, C	
		LUMBRINERIDAE	*Lumbrineris* sp.	de Blainville, 1828	P572				USC / USI		
			Lumbrineris sp.				UBBC, I				
			Lumbrineris gracilis	(Ehlers, 1868)							UMC, I
			Lumbrineris impatiens	Claparède, 1868							UMC
			Lumbrineris coccinea	(Renier, 1804)	P576				USC / USI	UAI, C	
			Lumbrineris fragilis	(O F Muller)	P0577	UKI, C	UBBC, I	UBGC	USC		
			Lumbrineris gracilis	(Ehlers, 1868)	P579		UBBC, I	UBGI	USC / USI	UAI, C	
			Lumbrineris impatiens				UBBC, I				
			Lumbrineris latreilli	Audouin & Milne-Edwards, 1833	P582		UBBC, I	UBGC	USC / USI		
			Lumbrineris tetraura	(Schmarda, 1861)	P0584	UKI, C			USC / USI		
		OENONIDAE	*Arabella sp.*	Grube, 1850	P587				USC		
			Arabella iricolor	(Montagu, 1804)	P588		UBBC		USI		
		ARABELLIDAE	*Arabella geniculata*	(Claparède, 1868)						UAI, C	
			Drilonereis filum	(Claparède, 1868)	P0591	UKI, C	UBBC		USC	UAI, C	UMC
		DORVILLEIDAE	*Protodorvillea kefersteini*	(McIntosh, 1869)	P0638	UKI, C	UBBC, I	UBGC	USI	UAI, C	
			Schistomeringos neglecta	(Fauvel, 1923)	P0642	UKI, C			USC		
			Schistomeringos rudolphi	(Chiaje, 1828)	P643		UBBC, I		USC		
			Staurocephalus rudolphii	(Delle Chiaje, 1828)						UAI, C	UMC, I
		ORBINIIDAE	*Orbinia latreillii*	Audouin & Milne-Edwards, 1833	P664		UBBC, I		USC / USI		
			Scoloplos armiger	(O F Muller, 1776)	P672		UBBC		USC / USI		
		PARAONIDAE	*Paradoneis armata*	Glémarec, 1966	P696		UBBC, I	UBGC, I	USC / USI		
			Paradoneis lyra	(Southern, 1914)	P699				USC / USI		
			Aricidea cerrutii	Laubier, 1960						UAI, C	
			Cirrophorus branquiatus	(Ehlers, 1908)						UAI, C	
			Paradoneis sp.							UAI, C	
			Paraonides neapolitana	(Cerruti, 1909)						UAI, C	
			Paraonis sp.							UAI, C	
			spp.								UMC
		POECILOCHAETIDAE	*Poecilochaetus serpens*	Allen, 1904	P718		UBBC, I		USI	•	
		SPIONIDAE	sp.A		P0720	UKI, C					
			Laonice cirrata	(Sars, 1851)		UKI, C			USI	UAC	

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			Aonides oxycephala	(M Sars, 1862)	P0722	UKI, C	UBBC, I	UBGC, I	USC / USI		
			Aonides paucibranchiata	Sauthern, 1914	P0723	UKI, C			USI		
			Boccardia polybranchia	(Haswell, 1885)	P727		UBBI		USI		
			Laonice cirrata	(M Sars, 1851)	P734		UBBI				
			Malacoceros fuliginosus	(Claparède, 1868)	P737		UBBC, I	UBGI	USI		
			Microspio sp.	Mesnil, 1896	P743				USI		
			Polydora sp.	Bosc, 1802	P748				USI		
			Polydora sp.				UBBC				
			Polydora caeca	(Oersted, 1843)	P750		UBBC, I	UBGC	USI		
			Polydora ciliata	(Johnston, 1838)	P752		UBBC, I	UBGC, I	USI		
			Polydora flava	Claparède, 1870	P754		UBBI	UBGI	USI		
			Polydora socialis	(Schmarda, 1861)	P762				USI		
			Prionospio sp.	Malmgren, 1867	P763				USI		
			Prionospio sp.A	Malmgren, 1867	P0763	UKI, C					
			Prionospio fallax	Soderstrom, 1920	P765		UBBC, I	UBGI	USI		
			Pseudopolydora antennata	(Claparède, 1870)	P772		UBBI	UBGI	USI		
			Pygospio elegans	Claparède, 1863	P776		UBBC, I		USI		UMC
			Scolelepis sp.A	de Blainville, 1828	P0778	UKI, C					
			Scololepis sp.				UBBC				
			Spio decorata	Bobretzky, 1870	P789				USI		
			Spio filicornis	(O F Muller, 1766)	P790		UBBC, I		USI		
			Spiophanes bombyx	(Claparède, 1870)	P794		UBBC, I	UBGI	USI		
			Spiophanes kroyeri	Grube, 1860							UMC
		MAGELONIDAE	*Magelona mirabilis*	(Johnston, 1865)	P807		UBBC, I	UBGC	USC / USI		
			Magelona rosea	Moore, 1907						UAI	
		CHAETOPTERIDAE	*Chaetopterus variopedatus*	(Renier, 1804)	P0814	UKI, C	UBBC, I	UBGI	USI		
			Phyllochaetopterus socialis	Claparède, 1870							UMC
			Telepsavus costarum	Claparède, 1868			UBBC, I		USI		
		CIRRATULIDAE	*Aphelochaeta marionii*	(Saint-Joseph, 1894)	P824		UBBI				
			Aphelochaeta multibranchiis	(Grube, 1863)	P0826	UKI, C					
			Caulleriella alata	(Southern, 1914)	P829		UBBC		USI		
			Caulleriella bioculata	(Keferstein, 1862)	P830		UBBI	UBGI	USI		
			Caulleriella zetlandica	(McIntosh, 1911)	P0831	UKI, C					
			Chaetozone setosa	Malmgren, 1867	P0834	UKI, C	UBBC, I	UBGC, I	USI	UAC	
			Cirratulus filiformis	Keferstein, 1862							UMC

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			Cirratulus cirratus	(O F Muller, 1776)	P0836	UKI, C	UBBC, I	UBGI	USI		
			Cirriformia tentaculata	(Montagu, 1808)	P0839	UKI, C	UBBC, I		USC / USI	UAI, C	
			Dodecaceria concharum	Oersted, 1843	P0842	UKI, C			USC / USI		
			Heterocirrus sp.1								UMC
			Tharyx sp.1								UMC
			Cirratulus filiformis	Keferstein, 1862						UAI, C	
			Tharyx marioni	(Saint-Joseph, 1894)						UAI, C	
		FLABELLIGERIDAE	*Diplocirrus glaucus*	(Malmgren, 1867)	P878		UBBC		USC / USI		
			Flabelligera affinis	M Sars, 1829	P0881	UKC					
			Pherusa eruca	(Claparède, 1868)	P883		UBBC, I				
			Pherusa plumosa	(O F Muller, 1776)	P0885	UKC					
			Stylarioïdes sp				UBBC				
		ACROCIRRIDAE	*Macrochaeta clavicornis*	(M Sars, 1835)	P891				USC		
		CAPITELLIDAE	sp.A		P0903	UKI, C					
			Capitella capitata	(Fabricius, 1780)	P0907	UKI, C	UBBC, I	UBGC, I	USC / USI		UMC
			Capitomastus minimus								UMC
			Mediomastus fragilis	Rasmussen, 1973	P0919	UKI, C	UBBC		USC / USI		
			Notomastus latericeus	M Sars, 1851	P0921	UKI, C	UBBC, I	UBGC, I	USC / USI		
			Notomastus profundis								UMC
		ARENICOLIDAE	*Arenicolides ecaudata*	(Johnston, 1865)	P0934	UKI, C					
		MALDANIDAE	~~sp.A~~		P0938	UKC					
			Axiothella constricta	(Claparède, 1870)						UAI, C	
			Euclymene sp.							UAI, C	
			Lumbriclymene sp.A	M Sars, 1872	P0940	UKI, C					
			Maldanidae indet.				UBBC, I	UBGC			
			Euclymene sp.	Verrill, 1900	P960				USI		
			Euclymene sp.A	Verril, 1900	P0960	UKI, C					
			Euclymene lumbricoides	(Quatrefages 1866)	P963		UBBC, I		USI		
			Euclymene modesta				UBBC				
			Euclymene oerstedii	(Claparède, 1863)	P964		UBBC, I		USC / USI		
			Heteroclymene robusta	Arwidsson, 1906	P0967	UKC					
			Praxillella praetermissa	(Malmgren, 1865)	P973				USI		
			Praxillella praetermissa	(Malmgren, 1865)	P973		UBBC				
			Nicomache personata	Johnson, 1901	P981		UBBC	UBGI			
		OPHELIIDAE	*Ophelia bicornis*	Savigny, 1818	P998		UBBC		USC / USI		

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			Ophelina acuminata	Oersted, 1843	P1014	UKI, C					
			Polyophthalmus pictus	(Dujardin, 1839)	P1019	UKC					
		SCALIBREGMATIDAE	*Polyphysia crassa*	(Oersted, 1843)	P1024	UKC					
			Scalibregma inflatum	Rathke, 1843	P1027	UKI, C	UBBC, I	UBGC	USC / USI		
			Scalibregma sp.1								UMC
			Sclerocheilus minutus	Grube, 1863						UAI, C	
		POLYGORDIIDAE	*Polygordius lacteus*	Schneider, 1868	P1065	UKI	UBBC, I	UBGC, I	USI		
		PROTODRILIDAE	*Protodrilus* sp.	Hatschek, 1882	P1069				USI		
		OWENIIDAE	*Owenia fusiformis*	Chiaje, 1842	P1098	UKI, C	UBBC, I	UBGC, I			
		PECTINARIIDAE	*Amphictene auricoma*	(O F Muller, 1776)	P1102	UKI, C	UBBC				
			Lagis koreni	Malmgren, 1866	P1107	UKI, C	UBBC		USC / USI		
			Petta pusilla	Malmgren, 1867	P1111	UKI, C					
			Pectinaria auricoma	(Lo Bianco, 1893)						UAI	
		AMPHARETIDAE	*Melinna palmata*	Grube, 1869	P1124	UKC	UBBC, I	UBGC	USC / USI	UAI, C	
			Amage adspersa	Grube, 1863						UAI, C	UMC
			Aricidea simonae	(Laubier y Ramos, 1973)						UAI, C	
			Ampharete grubei	(Malmgren, 1866)	P1138		UBBC, I		USC / USI		
			Amphicteis gunneri	(M Sars,1835)	P1142				USC / USI		
		TRICHOBRANCHIDAE	*Terebellides stroemi*	M Sars, 1835	P1175	UKI, C	UBBC, I	UBGI	USI	UAI, C	UMC
			Trichobranchus glacialis	Malmgren, 1866	P1177	UKI, C	UBBC	UBGC			
		TEREBELLIDAE	*Trichobranchus* sp.A		P1179	UKC					
			Amphitrite affinis	Malmgren, 1865						UAI, C	
			Polycirrus denticulatus	(Saint-Joseph, 1894)						UAI, C	
			Proclea sp.							UAI, C	
			Terebella lapidaria	Linnaeus, 1767						UAI, C	
			Terebella spp.								UMC
			Amphitrite cirrata	O F Muller, 1771	P1182	UKC			USC / USI		
			Amphitritides gracilis	(Grube, 1860)	P1185	UKC	UBBC		USC		
			Axionice maculata	(Dalyell, 1853)	P1187				USC		
			Eupolymnia sp.	Verrill, 1900	P1188				USC / USI		
			Eupolymnia nebulosa	(Montagu, 1819)	P1189	UKI, C	UBBI		USC / USI		
			Eupolymnia nesidensis	(Chiaje, 1828)	P1190				USC / USI		
			Lanice conchilega	(Pallas, 1766)	P1195	UKI, C	UBBC, I		USC / USI		
			Neoamphitrite figulus	(Dalyell, 1853)	P1206		UBBC, I	UBGI	USC / USI		
			Nicolea venustula	(Montagu, 1819)	P1210		UBBC		USC / USI		

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			Pista cristata	(O F Muller, 1776)	P1217	UKI, C	UBBC, I	UBGC	USC / USI	UAI, C	UMC
			Proclea grafii	(Langerhans, 1884)	P1221	UKC	UBBC, I		USC / USI		
			Terebella lapidaria	(Linnaeus, 1767)	P1223		UBBC, I				
			Terebellidae indet.				UBBC, I				
			Thelepus cincinnatus	(Fabricius, 1780)							UMC
			Thelepus sp.1								UMC
			Amaeana trilobata	(M Sars, 1863)	P1229	UKI, C	UBBC, I	UBGC	USC / USI		
			Polycirrus sp.A	Grube, 1850	P1235	UKI, C					
			Polycirrus aurantiacus	Grube, 1860	P1237		UBBC, I				
			Polycirrus medusa	Grube, 1850	P1242		UBBC				
			Polycirrus sp.				UBBC				
			Thelpodinae sp.A		P1247	UKI, C					
			Paranthelepus collaris	(Southern, 1914)	P1249		UBBC		USC / USI		
		SABELLIDAE	*Amphiglena mediterranea*	(Leydig, 1851)	P1259		UBBC		USI		
			Branchiomma bombyx	(Dalyell, 1853)	P1263	UKC					
			Branchiomma vesiculosum	(Montagu, 1815)							UMC
			Chone infundibuliformis	Kroyer, 1856	P1270	UKI, C					
			Dialychone acustica								UMC
			Fabricia sp.								UMC
			Jasmineira sp.								UMC
			Euchone southerni	Banse, 1970	P1281	UKI, C	UBBC				
			Jasmineira caudata	(Langerhans, 1880)						UAI, C	
			Laonome kroyeri	Malmgren, 1866	P1292		UBBC		USC / USI		
			Megalomma vesiculosum	(Montagu 1813)	P1297		UBBC, I		USC / USI		
			Oridia armandi								UMC
			Myxicola infundibulum	(Renier, 1804)	P1300	UKI, C					UMC
			Potamilla torelli	Malmgren, 1865						UAI, C	
			Sabella bipunctata	(Baird, 1865)						UAI, C	
			Sabella spp.								UMC
			Sabella pavonina	Savigny, 1820	P1320	UKC				UAC	
			Sabellidae indet.				UBBC, I				
			Branchiomma linaresi	Rioja, 1917						UAI, C	
			Branchiomma vigilans	Claparede, 1870						UAI, C	
		SERPULIDAE	*Hydroides* sp.	Gunnerus, 1768	P1330				USC / USI		
			Hydroides norvegica	Gunnerus, 1768	P1334	UKI, C	UBBC, I		USC / USI		

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			Pomatoceros triqueter	(Linnaeus, 1758)	P1341	UKI, C	UBBC, I	UBGC, I	USC / USI		
			Serpula sp.	Linnaeus, 1767	P1342				USC / USI		
			Serpula vermicularis	Linnaeus, 1767	P1343		UBBC, I	UBGC, I	USC / USI	UAI, C	
			Ditrupa arietina	(Müller, 1776)						UAI, C	
			Filograna implexa	(Berkeley, 1827)						UAC	
			Vermiliopsis striaticeps	(Grube, 1862)						UAI, C	
			Apomatus sp.	Philippi, 1844	P1347				USC / USI		
			Protula tubularia	(Montagu, 1803)	P1359	UKC					
		SPIRORBIDAE	*Janua pagenstecheri*	(Quatrefages, 1865)	P1372	UKI, C					
			Paradexiospira vitrea	(Fabricius, 1780)	P1382	UKI, C					
			Spirorbis sp.	Daudin, 1800	P1391				USC / USI		
			Spirorbis spirorbis	(Linnaeus, 1758)	P1396	UKI, C	UBBC, I	UBGC, I	USC / USI		
		ENCHYTRAEIDAE	*Grania* sp.A	Southern, 1913	P1524	UKI, C					
CHELICERATA	PYCNOGONIDA	NYMPHONIDAE	*Nymphon brevirostre*	Hodge, 1863	Q5		UBBC, I				
			Nymphon gracile	Leach, 1814	Q7		UBBC		USC / USI		
		AMMOTHEIDAE	*Achelia echinata*	Hodge, 1864	Q15	UKI, C	UBBC, I		USC / USI		
			Achelia hispida	Hodge, 1865	Q16		UBBC		USC / USI		
			Achelia laevis	Hodge, 1866	Q17		UBBC		USC / USI		
		ENDEIDAE	*Endeis spinosa*	(Montagu, 1808)	Q0030	UKC	UBBI				
		CALLIPALLENIDAE	*Callipallene phantoma*	(Dohrn, 1881)	Q35		UBBC		USC / USI		
		PHOXICHILIDIIDAE	*Anoplodactylus petiolatus*	(Kröyer, 1844)	Q44				USC / USI		
			Anoplodactylus virescens	(Hodge, 1864)	Q46		UBBC		USC / USI		
			Phoxichilidiidae indet.		Q		UBBC				
		HALACARIDAE	sp.A		Q0056	UKI					
CRUSTACEA	THORACICA*	VERRUCIDAE	*Verruca stroemia*	(O F Muller, 1776)	R0041	UKI, C					
		ARCHAEOBALANIDAE	*Chirona hameri*	(Ascanius, 1767)	R0066	UKC					
		BALANIDAE	*Balanus balanus*	(Linnaeus, 1758)	R0076	UKI, C					
			Balanus crenatus	Brugiere, 1789	R0077	UKI, C					
	RHIZOCEPHALA*	SACCULINIDAE	*Sacculina* sp.A	J.V. Thompson, 1836	R0120	UKC					
	COPEPODES	COPEPODA	Copepoda indet.				UBBC, I				
	CYCLOPOIDA*	NOTODELPHYIDAE	*Notodelphys* sp.A	Allman, 1847	R0704	UKI, C					
			Stenhelia spp.		R0785	UKI, C					
	HARPACTICOIDA*	AMBUNGUIPEDIDAE	*Ambunguipes* sp.A	Huys, 1990	R1133	UKI, C					
			Ambunguipes rufocincta	(Brady, 1880)	R1134	UKI, C					
		DIOSACCIDAE	*Stenhelia* sp.A	Boeck, 1864	R1256	UKI, C					

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	SIPHONOSTOMATOIDA*	ASTEROCHEIRIDAE	*Collocheres elegans*	A. Scott, 1896	R2084	UKI, C					
	OSTRACODA *		*Collocheres* spp.		R2412	UKI, C					
			Collocheres sp.a								UMC, I
			Collocheres sp.b								UMC, I
	LEPTOSTRACA	NEBALIIDAE	*Nebalia bipes*	(O Fabricius, 1780)	S6		UBBC, I	UBGC, I	USC / USI		UMC, I
	STOMATOPODA *	SQUILLIDAE	*Rissoides desmaresti*	(Risso, 1816)							UMC
			Praunus spp.		S0031	UKI, C					
			Praunus sp.1								UMC, I
			Praunus inermis	(Rathke, 1843)	S0083	UKC					
	MYSIDACEA	MYSIDAE	*Heteromysis armoricana*	Nouvel, 1940			UBBC		USC		
			Heteromysis formosa	S I Smith, 1874	S0092	UKC					
	AMPHIPODA		Amphipoda indet. 1				UBBC				
			Amphipoda indet. 2				UBBC				
		CALLIOPIIDAE	*Apherusa bispinosa*	(Bate, 1856)	S102	UKI, C			USC / USI		UMC, I
			Apherusa chiereghinii	Giordani-Soika, 1950						UAI, C	
		EUSIRIDAE	*Apherusa cirrus*	(Bate, 1862)	S103		UBBC, I				
			Eusirus longipes	Boeck, 1861						UAI, C	UMI
			Rhacotropis sp.							UAC	
		CALLIOPIIDAE	*Apherusa jurinei*	(H Milne-Edwards, 1830)	S106	UKI, C	UBBC		USC / USI		
			Apherusa vexatrix	Krapp-Schickel, 1979						UAC	
			Apherusa ovalipes	Norman & T Scott, 1906	S107		UBBC, I		USC / USI		
			Calliopius laeviusculus	(Kröyer, 1838)	S112		UBBC		USC / USI		
		OEDICEROTIDAE	*Monoculodes carinatus*	(Bate, 1856)	S125	UKC	UBBC, I		USC / USI		
			Monoculodes acutipes	Ledoyer, 1983							UMC
			Oedicerotidae indet.				UBBC				
			Perioculodes aequimanus	(Kossmann, 1880)						UAI	
			Synchelidium longidigitatum	Ruffo, 1947						UAC	
			Synchelidium maculatum	Stebbing, 1906	S138		UBBC, I	UBGC	USC / USI		
			Westwoodilla caecula	(Bate, 1856)	S0140	UKC					
		AMPHILOCHIDAE	*Amphilochus neopolitanus*	Della Valle, 1893	S159		UBBC				
			Gitana sarsi	Boeck, 1871	S0164	UKI, C					
		CYPROIDEIDAE	*Peltocoxa brevirostris*	(Stebbing, 1885)	S173		UBBC, I				
		LEUCOTHOIDAE	*Leucothoe ?incisa*	Robertson, 1892							UMC, I
			Leucothoe ?spinicarpa	(Abildgaard, 1789)							UMI
			Leucothoe incisa	Robertson, 1892	S177		UBBC, I	UBGC	USC / USI		

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			Leucothoe lilljeborgi	Boeck, 1861	S178		UBBC, I		USC / USI		
			Leucothoe richiardii				UBBC				
			Leucothoe spinicarpa	(Abildgaard, 1789)	S180		UBBC, I		USC / USI		
		CRESSIDAE	*Cressa dubia*	(Bate, 1857)	S186		UBBC				
			Stenothoe marina	(Bate, 1856)	S0213	UKI, C	UBBC, I	UBGC, I			
		HYALIDAE	*Hyale prevostii*	(Milne Edwards)	S224				USC		
		TALITRIDAE	*Hyale camptonyx*	(Heller, 1866)							UMC
		UROTHOIDAE	*Urothoe elegans*	(Bate, 1856)	S0248	UKC	UBBC, I	UBGC, I			UMC
		PHOXOCEPHALIDAE	*Harpinia ala*	G. Karaman, 1987						UAI, C	
			Harpinia antennaria	Meinert, 1890	S254				USC / USI		UMC
			Harpinia crenulata	(Boeck, 1871)	S0255	UKC				UAI	
			Harpinia pectinata	G O Sars, 1891	S257		UBBC, I		USC / USI		
			Harpinia serrata	G O Sars, 1885	S258				USC / USI		
			Metaphoxus simplex	(Bate, 1857)						UAI, C	
			Metaphoxus pectinatus	(A O Walker, 1896)	S262		UBBC, I		USC / USI		
			Parametaphoxus fultoni	(T Scott, 1890)	S265	UKC	UBBC		USC / USI	UAI, C	UMC, I
			Phoxocephalus holbolli	(Kröyer, 1842)	S269		UBBC, I		USC / USI		
		LYSIANASSIDAE	*Acidostoma obesum*	(Bate &Westwood, 1861)	S0275	UKC					
			Hippomedon oculatus	Chevreux & Fage, 1925							UMC, I
			Lysianassa ceratina	(A O Walker, 1889)	S303	UKI, C	UBBC, I		USC		
			Lysianassa cf.	Ruffo, 1987						UAC	
			Lysianassa longicornis	Lucas, 1849						UAI, C	UMC, I
			Lysianassa costae	Milne Edwards, 1830							UMC, I
			Lysianassa pilicornis	Heller, 1866						UAC	
			Lysianassa plumosa	Boeck, 1871	S305	UKI, C			USC		
			Lysianassidae sp1				UBBC, I				
			Normanion chevreuxi	Diviacco & Vader, 1988						UAC	
			Orchomene humilis	(A. Costa, 1853)						UAC	
			Orchomene nanus	(Kroyer, 1846)	S0321	UKI, C	UBBC, I			UAC	
			Perrierella audouiniana	(Bate, 1857)						UAC	
			Scopelocheirus hopei	(Costa, 1851)	S0328	UKI, C					
			Socarnes erythrophthalmus	Robertson, 1892	S330	UKI	UBBC, I		USC		
			Socarnes filicornis	(Heller, 1866)						UAI, C	UMC, I
			Tryphosella horingi	(Boeck, 1871)	S0342	UKI, C			USC / USI		
			Tryphosella nanoides	(Liljeborg, 1865)	S343		UBBC, I		USC		

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			Tryphosella sarsi	(Bonnier, 1893)	S344		UBBC				
		SYNOPIIDAE	*Austrosyrrhoe fimbriatus*	(Stebbing & Robertson, 1891)	S0351	UKC					
		ACANTHONOTOZOMATIDAE	*Iphimedia minuta*	G.O. Sars, 1882						UAI, C	UMC, I
		IPHIMEDIIDAE	*Iphimedia nexa*	Myers & McGrath, 1987	S0381	UKI, C					
		ISAEIDAE	*Gammaropsis* sp.	(Johnston, 1827)						UAI, C	
		IPHIMEDIIDAE	*Iphimedia obesa*	Rathke, 1843	S0382	UKI, C	UBBC, I	UBGC			
		PHLIANTIDAE	*Pereionotus testudo*	(Montagu, 1808)			UBBC			UAC	UMC, I
		LILJEBORGIIDAE	*Idunella pirata*	Krapp-Schickel, 1975						UAC	
			Liljeborgia kinahani	(Bate, 1862)	S0396	UKI					
			Liljeborgia dellavallei	Stebbing, 1906							UMI
			Liljeborgia pallida	(Bate, 1857)	S0397	UKC					
			Listriella picta	(Norman, 1889)	S400		UBBC, I	UBGC, I	USC		
		DEXAMINIDAE	*Atylus guttatus*	(Costa, 1851)	S411		UBBC, I		USC / USI		
			Atylus swammerdamei	(H Milne-Edwards, 1830)	S412		UBBC	UBGC	USC		
			Atylus vedlomensis	(Bate & Westwood, 1862)	S413	UKI			USC		
			Dexamine spinosa	(Montagu, 1813)	S415		UBBC, I		USC	UAI, C	UMC, I
			Dexamine thea	Boeck, 1861	S0416	UKI, C					
			Guernea coalita	(Norman, 1868)	S0418	UKI, C					
		AMPELISCIDAE	*Ampelisca brevicornis*	(Costa, 1853)	S427		UBBC, I	UBGI	USC / USI		
			Ampelisca pseudospinimana	Bellan-Santini & Ruffo, 1986						UAI	
			Ampelisca diadema	(A Costa, 1853)	S429		UBBC		USC / USI		
			Ampelisca sp.1.								UMC
			Ampelisca spinipes	Boeck, 1861	S0438	UKI, C					
			Ampelisca toulemonti	Dauvin & Bellan-Santini, 1982	S441				USC / USI		
			Ampelisca typica	(Bate, 1856)	S442		UBBC, I	UBGC	USC / USI		
		HAUSTORIIDAE	*Haustorius arenarius*	(Slabber, 1769)	S462		UBBC, I				
			Urothoe hesperiae							UAC	
			Urothoe intermedia	Bellan-Santini & Ruffo, 1986						UAC	
		GAMMARIDAE	*Abludomelita gladiosa*	(Bate, 1862)					USC / USI	UAC	
			Abludomelita obtusata	(Montagu, 1813)					USC / USI	UAC	
			Ceradocus orchestiipes	A. Costa, 1853							UMC, I
			Gammarus insensibilis	Stock, 1966	S476		UBBI				
			Gammarus locusta	(Linnaeus, 1758)	S0478	UKI					
			Maera knudseni	Reid, 1951						UAI, C	
		MELITIDAE	*Abludomelita gladiosa*	(Bate, 1862)	S497		UBBC, I				

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			Abludomelita obtusata	(Montagu, 1813)	S498		UBBC, I				
			Ceradocus semiserratus	(Bate, 1862)	S502	UKI, C	UBBC, I	UBGC, I	USC / USI		UMC, I
			Cheirocratus intermedius	G O Sars, 1894	S505		UBBC, I		USC / USI		
			Cheirocratus sundevallii	(Rathke, 1843)	S0506	UKI				UAC	UMC, I
			Elasmopus rapax	Costa, 1853	S508		UBBC, I		USC / USI		
			Gammarella fucicola	(Leach, 1814)	S514		UBBC, I	UBGC, I	USC / USI	UAI	UMI
			Maera grossimana	(Montagu, 1808)	S516		UBBC, I	UBGC	USC / USI	UAC	UMC, I
			Maera othonis	(H Milne-Edwards, 1830)	S519	UKI, C	UBBC	UBGC, I	USC / USI	UAC	UMC, I
			Melita palmata	(Montagu, 1804)	S525		UBBC, I				
			Melitidae indet.					UBGI			
			Melitidae sp.				UBBC, I				
			Melitidae sp.				UBBC				
		AMPITHOIDAE	*Amphitolina cuniculus*	(Stebbing, 1874)	S529		UBBC				
			Ampithoe ramondi	Audouin, 1826						UAI, C	UMC, I
			Ampithoe gammaroides	(Bate, 1856)	S531				USC / USI		
			Ampithoe rubricata	(Montagu, 1808)	S534		UBBC, I		USC / USI		
		ISAEIDAE	*Gammaropsis lobata*	(Chevreux, 1920)	S540		UBBC, I				
			Gammaropsis maculata	(Johnston, 1828)	S541	UKI, C	UBBC, I		USC		
			Gammaropsis nitida	(Stimpson, 1853)	S0542	UKI, C	UBBC				
			Gammaropsis palmata	(Stebbing & Robertson, 1891)	S543				USC		
			Isaeidae sp.				UBBC				
			Megamphopus cornutus				UBBC, I				
			Photis longicaudata	(Bate & Westwood, 1862)	S552	UKI	UBBC, I	UBGC, I	USC / USI		
		ISCHYROCERIDAE	*Ericthonius punctatus*	(Bate, 1857)	S0564	UKI, C				UAC	
			Ericthonius brasiliensis	(Dana, 1852)	(?)				USC / USI		
			Ischyrocerus anguipes	Kröyer, 1838	S567		UBBC		USC / USI		
			Jassa falcata	(Montagu, 1808)	S569	UKI	UBBC, I		USC / USI		
			Jassa herdmani	(Walker)		UKI					
			Jassa marmorata	S J Holmes, 1903	S570	UKI, C	UBBC		USC / USI		
			Parajassa pelagica	(Leach, 1814)	S0576	UKI					
		AORIDAE	indet.	s							UMC
			Aora gracilis	(Bate, 1857)	S579		UBBC, I		USC / USI		
			indet.				UBBI				
			Autonoe longipes	(Liljeborg, 1852)	S0583	UKI					

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			Leptocheirus bispinosus	Norman, 1908							UMC, I
			Leptocheirus hirsutimanus	(Bate, 1862)	S588	UKI			USC / USI	UAC	
			Leptocheirus longimanus	Ledoyer, 1973						UAI, C	
			Leptocheirus pectinatus	(Norman, 1869)	S589	UKI	UBBC, I	UBGI	USC / USI	UAI, C	UMC, I
			Leptocheirus tricristatus	(Chevreux, 1887)	S591		UBBC, I		USC		
			Microdeutopus anomalus	(Rathke, 1843)	S593		UBBC, I	UBGC, I	USC / USI		
			Microdeutopus damnoniensis	(Bate, 1856)	S595		UBBC, I	UBGC	USC / USI		
			Microdeutopus versiculatus	(Bate, 1856)	S0598	UKC	UBBC			UAI	
		COROPHIIDAE	*Corophium* sp.	Latreille, 1806	S605				USC / USI		
			Corophium sp.				UBBC				
			Siphonoecetes neapolitanus	Schiecke, 1979						UAC	
			Corophium bonnellii	(H Milne-Edwards, 1830)	S0610	UKI, C	UBBC, I				
			Corophium rotundirostre	Stephensen, 1915						UAI	
			Corophium curvispinum	Sars, 1895	(6)		UBBC		USC / USI		
		CAPRELLIDAE	*Aeginina longicornis*	(Krøyer, 1842-43)			UBBC, I		USC / USI		
			Caprella acanthifera	Leach, 1814	S641	UKI	UBBC, I	UBGC	USC / USI		
			Caprella linearis	(Linnaeus, 1767)	S0646	UKI					
			Caprella penantis	Leach, 1814	S647		UBBC		USC / USI		
			Parvipalpus capillaceus	(Chevreux, 1888)	S653		UBBC, I		USC / USI		
		PHTISICIDAE	*Phtisica marina*	Slabber, 1769	S657		UBBC, I	UBGC, I	USC / USI	UAI, C	
			Pseudoprotella phasma	(Montagu, 1804)	S659		UBBC, I				
	ISOPODA	GNATHIIDAE	*Gnathia* sp.A	Leach, 1814	S0793	UKI, C					
			Gnathia sp.				UBBC				
			Gnathia oxyuraea	(Liljeborg)	S796		UBBC, I		USC / USI		
			Gnathia vorax	Lucas							UMI
			Gnathia dentata	(Monod, 1926)						UAI	
			Gnathia maxillaris	(Monod, 1926)						UAC	
		ANTHURIDAE	*Anthura gracilis*	(Montagu, 1808)	S803		UBBC, I		USC	UAC	UMC
			Cyathura carinata	(Kröyer, 1847)	S805		UBBC, I	UBGC	USC / USI		UMC, I
			Cyathura sp.a								UMC, I
		PARANTHURIDAE	*Paranthura costana*	Bate & Westwood, 1868	S810				USC / USI		
		CIROLANIDAE	*Cirolana* sp.	Leach, 1818	S843		UBBC		USC		
			Natatolana borealis	Liljeborg, 1851	S0844	UKI, C					
			Conilera cylindracea	(Montagu, 1803)	S849	UKC	UBBI	UBGC, I	USC		
			Eurydice pulchra	Leach, 1815	S854	UKC	UBBC, I	UBGC, I	USC / USI	UAI, C	

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			Eurydice sp.1								UMC, I
			Eurydice truncata	(Norman, 1868)							UMC
			Eurydice sp.b								UMI
			Eurydice sp.a								UMC, I
		SPHAEROMATIDAE	*Cymodoce* sp.	Leach, 1814	S860				USC		
			Cymodoce truncata	Leach, 1814	S863	UKI, C	UBBC	UBGC, I	USC / USI	UAI, C	UMC, I
			Sphaeroma monodi	Bocquet Hoestlandt & Levi, 1954	S870				USC / USI		
			Cymodoce rubropunctata	(Grube)						UAC	
			Sphaeroma rugicauda	Leach, 1814	S871		UBBC, I		USC / USI		
		JANIRIDAE	*Jaera albifrons*	Leach, 1814	S885		UBBC, I		USC / USI		
		JAEROPSIDAE	*Jaeropsis brevicornis*	Koehler, 1885						UAC	UMI
			Janira maculosa	Leach, 1813	S892		UBBC, I		USC / USI		
			Janiropsis breviremis	G. O. Sars, 1899	S894		UBBC, I				
		MUNNIDAE	*Munna* sp.A	Kroyer, 1839	S0901	UKI, C					
			Munna kroyeri	Goodsir, 1842	S905		UBBC		USC / USI		
		IDOTEIDAE	*Idotea* sp.							UAI	
			Synisoma carinata	(Rezig, 1989)						UAI, C	
		ARCTURIDAE	*Astacilla intermedia*	(Sars, 1899)						UAC	
			Astacilla longicornis	(Sowerby, 1806)	S955		UBBC, I				
			Astacilla sp.1								UMI
	TANAIDACEA	TANAIDAE	*Tanais dulongii*	(Audouin, 1826)	S1106	UKI, C	UBBC, I				
			Leptochelia dubia	(Kroyer, 1842)	S1114		UBBC		USC		
		LEPTOGNATHIINAE	*Leptognathia breviremis*	(Liljeborg, 1864)	S1132	UKC					
			Pseodoparatanais batei	(G O Sars, 1882)	S1140	UKI, C					
		PARATANAIDAE	*Leptochelia savignyi*	(Krøyer, 1842)							UMC, I
			Tanaopsis graciloides	(Liljeborg, 1864)	S1142	UKC					
		APSEUDIDAE	*Apseudes latreillii*	(Milne-Edwards, 1828)	S1175		UBBC, I	UBGC, I	USC / USI	UAI, C	
			Apseudes talpa	(Montagu, 1808)	S1177		UBBC		USC / USI		UMC, I
			Apseudes spp.		S1183	UKI, C					
	CUMACEA	BODOTRIIDAE	*Vaunthompsonia cristata*	Bate, 1858	S1191	UKC					
		NANNASTACIDAE	*Cumella pygmea*	G. O. Sars, 1865	S1224		UBBC, I				
		DIASTYLIDAE	*Diastyloides biplicata*	(G. O. Sars, 1865)	S1257		UBBI				
	DECAPODA *	SICYONIDAE	*Sicyonia carinata*	(Brünnich, 1768)						UAÇ	
		PALAEMONIDAE	*Palaemon elegans*	Rathke, 1837	S1317		UBBC		USC / USI		

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			Palaemon sp.1.								UMC
			Palaemonetes varians	(Leach, 1814)	S1321		UBBC, I	UBGC	USC / USI		
			Periclimenes scriptus	(Risso, 1822)						UAI	
		ALPHEIDAE	*Synalpheus/Alpheus* sp.1								UMC
			Alpheus dentipes	Gucrin, 1832						UAI, C	
			Alpheus macrocheles	(Hailstone, 1835)							UMC, I
			Athanus sp.	Leach, 1814	S1332				USI		
			Athanus nitescens	(Leach, 1814)	S1333		UBBC, I	UBGC, I	USC / USI	UAI	UMC, I
		HIPPOLYTIDAE	*Eualus pusiolus*	(Kroyer, 1841)	S1345	UKI, C					
			Hippolyte sp.1.								UMC
			Hippolyte garciarasoi	(d'Udeken d'Acoz, 1996)						UAI, C	
			Hippolyte sp.				UBBC				
			Hippolyte varians	Leach, 1814	S1350	UKC					
			Thoralus cranchii	(Leach, 1817)	S1360		UBBC, I	UBGI		UAI, C	UMC, I
		PROCESSIDAE	*Processa* sp.1								UMC, I
			Processa sp.							UAI, C	
			Processa macrophtalma	Nouvel & Aolthuis, 1957						UAC	
		PANDALIDAE	*Pandalina brevirostris*	(Rathke, 1837)	S1374	UKC					
			Pandalus montagui	Leach, 1814	S1377	UKI, C					
		CRANGONIDAE	*Crangon vulgaris*				UBBI	UBGI			
			?Palicus caronii	(Roux, 1828)							UMC
			Crangon crangon	(Linnaeus, 1758)	S1385		UBBC, I		USC / USI		
			Philocheras sculptus	(Bell, 1847)							UMC
		THALASSINIDEA	*Gourretia minor*	(Gourret, 1887)							UMC, I
		CALLIANASSIDAE	*Callianassa subterranea*	(Montagu, 1808)	S1415	UKC					
			Callianassa tyrrhena	(Petagna, 1792)						UAI, C	
			Upogebia nitidamediterranea	Noel, 1992							UMC
		UPOGEBIIDAE	*Upogebia deltaura*	(Leach, 1815)	S1419	UKI, C	UBBC, I		USC		
			Upogebia stellata	(Montagu, 1808)	S1421	UKI, C					
		SCYLLARIDAE	*Scyllarus pygmaeus*	(Bate, 1888)						UAI, C	
		DIOGENIDAE	*Calcinus tubularis*	(Linnaeus, 1767)						UAC	UMC, I
			Diogenes pugilator	(Roux, 1829)	S1444		UBBC, I	UBGC, I	USC / USI		
			Paguristes eremita	(Linnaeus, 1767)						UAI, C	UMC, I
		PAGURIDAE	*Anapagurus hyndmanni*	(Bell, 1845)	S1448	UKI, C				UAI, C	
			Anapagurus laevis	(Bell, 1845)	S1449		UBBI	UBGC	USI		

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			Anapagurus breviaculeatus	Fenizia, 1937							UMC, I
			Cestopagurus timidus	(Roux, 1830)							UMC
			Dardanus arrosor	(Herbst, 1791)						UAC	UMC
			Pagurus bernhardus	(Linnaeus, 1758)	S1457	UKI, C	UBBC, I	UBGC, I	USC / USI		
			Pagurus cuanensis	Bell, 1845	S1460	UKI, C				UAI	UMC
			Pagurus prideaux	Leach, 1815	S1462	UKC				UAI, C	
			Anapagurus sp.							UAI	
			Anapagurus chiroacanthus	(Lilljeborg, 1856)						UAC	
			Pagurus pubescens	Kroyer, 1838	S1463	UKI, C					
			Pagurus cf.forbesii	Bell, 1845							UMC
			Pagurus sp.1								UMC
			Pagurus excavatus	(Herbst, 1791)						UAI	UMC, I
			Pagurus alatus	(Fabricius, 1775)						UAI	
		GALATHEIDAE	*Galathea* sp.				UBBC				
			Galathea dispersa	Bate, 1859	S1471	UKC					
			Galathea intermedia	Liljeborg, 1851	S1472	UKI, C	UBBC, I		USC / USI	UAI, C	UMC, I
			Galathea squamifera	Leach, 1814	S1475		UBBC, I	UBGC, I	USC		
			Galathea strigosa	(Linnaeus, 1767)	S1476		UBBC				
		PORCELLANIDAE	*Pisidia longicornis*	(Linnaeus, 1767)	S1482	UKI, C	UBBC, I	UBGC, I	USC / USI		
		MAJIDAE	*Hyas araneus*	(Linnaeus, 1758)	S1518	UKI, C					
			Achaeus cranchii	Leach, 1817						UAI, C	UMC
			Achaeus gracilis	(O. Costa, 1839)						UAI	
			Eurynome spinosa	Hailstone, 1835						UAI	
			Hyas coarctatus	Leach, 1815	S1519	UKC					
			Inachus ?thoracicus?agiuarii								UMC
			Inachus sp.							UAC	
			Macropodia linaresi	Forest & Zariquiey, 1964						UAC	
			Macropodia longirostris	(Fabricius, 1775)						UAC	
			Pisa nodipes	(Leach, 1815)						UAC	
			Pisa sp.								UMC
			Pisa armata	(Latreille, 1803)	S1539		UBBC		USC / USI	UAC	UMC
			Inachus dorsettensis	(Pennant, 1777)	S1526	UKC	UBBC, I	UBGC, I	USC / USI		
			Macropodia rostrata	(Linnaeus, 1761)	S1532	UKI, C	UBBC, I	UBGC, I	USC / USI	UAI, C	
			Macropodia tenuirostris	(Leach, 1814)	S1533		UBBC				

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			Eurynome spinosa	Hailstone, 1835	S1537		UBBC, I	UBGC, I			
		LEUCOSIIDAE	*Ebalia deshayesi*	Lucas, 1846						UAI, C	
			Ebalia tumefacta	(Montagu, 1808)						UAC	
			Ilia nucleus	(Linnaeus, 1758)						UAI	
			Ebalia cranchii	Leach, 1817	S1505				USC / USI		
			Ethusa mascarone	(Herbst, 1785)						UAI, C	
			Ebalia tuberosa	(Pennant, 1777)	S1508	UKC	UBBC, I	UBGC, I	USC / USI	UAI	
			Ebalia edwardsi	Costa, 1838						UAI, C	UMI
		PARTHENOPIDAE	*Parthenope expansa*	Miers, 1879							UMC, I
			Parthenope massena	(Roux, 1830)						UAI, C	UMC, I
		ATELECYCLIDAE	*Atelecyclus rotundatus*	(Olivi, 1792)	S1555	UKI		UBGC, I	USC / USI	UAI	
			Atelecyclus undecimdentatus	(Herbst, 1783)	S1556		UBBC	UBGC, I	USC / USI		
		CALAPPIDAE	*Calappa granulata*	(Linnaeus, 1767)						UAC	
		THIIDAE	*Thia scutellata*	(Fabricius, 1793)	S1559		UBBC		USI	UAC	
		PIRIMELIDAE	*Sirpus zariquieyi*	Gordon, 1953						UAI	
		CANCERIDAE	*Cancer pagurus*	Linnaeus, 1758	S1566	UKI, C					
		PORTUNIDAE	*Liocarcinus arcuatus*	(Leach, 1814)	S1578		UBBC, I	UBGC, I	USC / USI		
			Liocarcinus corrugatus	(Pennant, 1777)	S1579	UKI, C	UBBC	UBGC, I	USC / USI		UMC, I
			Liocarcinus depurator	(Linnaeus, 1758)	S1580	UKI, C	UBBC	UBGC, I			
			Liocarcinus holsatus	(Fabricius, 1798)	S1581	UKI	UBBC	UBGC, I			
			Homola barbata	(Fabricius, 1793)						UAI	
			Liocarcinus marmoreus	(Leach, 1814)	S1582		UBBC	UBGC, I			
			Liocarcinus pusillus	(Leach, 1815)	S1584	UKI	UBBC, I	UBGC, I	USC / USI		
			Liocarcinus maculatus	(Risso, 1827)							UMC
			Liocarcinus sp.1								UMC
			Liocarcinus zariquieyi	(Gordon, 1968)						UAI, C	UMC, I
			Necora puber	(Linnaeus, 1767)	S1589	UKC, I	UBBC, I	UBGC	USC / USI		
			Carcinus maenas	(Linnaeus, 1758)	S1594	UKC	UBBI	UBGI	USC		
		XANTHIDAE	*Pilumnus hirtellus*	(Linnaeus, 1761)	S1615		UBBC, I	UBGC, I	USI	UAI, C	
			Xantho incisus	Leach, 1814	S1619		UBBC, I	UBGC, I			
			Xantho poressa	(Olivi)	(10)				USC		
			Pilumnus villosisimus	(Rafinesque, 1814)						UAI, C	
			Xantho incisus	(Leach, 1814)	S1619					UAI	
			Xantho pilipes	A. Milne Edwards	S1620					UAI	
INSECTA	DIPTERA	CHIRONOMIDAE	*Halocladius fucicola*	(Edwards)		UKI					

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MOLLUSCA	POLYPLACOPHORA	LEPTOCHITONIDAE	*Leptochiton asellus*	(Gmelin, 1791)	W0053	UKI, C	UBBI				
			Lepidopleurus africanus	(Nierstrasz, 1906)						UAC	UMC
			Leptochiton cancellatus	(G B Sowerby II, 1840)	W0054	UKI, C	UBBC, I	UBGC, I	USC / USI	UAC	
		HANLEYIDAE	*Hanleya hanleyi*	(Bean in Thorpe, 1844)	W65		UBBC		USI		
		ISCHNOCHITONIDAE	*Ischnochiton albus*	(Linnaeus, 1767)	W0071	UKC					
			Callochiton septemvalvis	(Montagu,1803)	W75		UBBC, I		USC / USI	UAC	UMC
			Lepidochitona cinerea	(Linnaeus, 1767)	W0079	UKI, C	UBBC				
			Tonicella marmorea	(O Fabricius, 1780)	W0081	UKI, C	UBBC, I				
			Tonicella rubra	(Linnaeus, 1767)	W0082	UKI, C	UBBC, I		USC / USI		
			Chiton corallinus	(Risso, 1826)						UAC	
			Ischnochiton rissoi	(Payraudeau, 1826)						UAC	
		ACANTHOCHITONIDAE	*Acanthochitona echinata*				UBBC		USC / USI		
			Acanthochitona crinita	(Pennant, 1777)	W86		UBBC, I	UBGC	USC / USI		
			Acanthochitona fascicularis	(Linnaeus, 1767)	W87		UBBC, I	UBGC	USC / USI		uMI
	ARCHAEOGASTROPODA	CAVOLINIIDAE	*Creseis acicula*	Rang, 1828						UAC	
		SCISSURELLIDAE	*Scissurella costata*	d'Orvigny, 1824						UAI, C	
			Emarginula fissura	(Linnaeus, 1758)	W0106	UKI, C	UBBC		USC		
			Diodora sp.							UAC	
			Emarginula rosea	Bell, 1824	W107				USC / USI	UAC	
			Diodora graeca	(Linnaeus, 1758)	W116		UBBC, I				
		TURBINIDAE	*Bolma rugosa*	(Linnaeus, 1767)						UAI, C	
			Tricolia pullus	(Linnaeus, 1758)	W0139	UKI, C	UBBC, I		USC		
		TROCHIDAE	*Calliostoma* sp.							UAI, C	
			Gibbula fanulum	(Gmelin, 1791)						UAI, C U99I	UMI
			Jujubinus gravinae	(Monterosato in Issel,1878)						UAI, C	
			Margarites helicinus	(Phipps, 1774)	W0150	UKC					
			Trochidae indet.				UBBC				
			Gibbula magus	(Linnaeus, 1758)	W0159	UKI, C	UBBC, I	UBGC, I	USC / USI	UAI	
			Gibbula tumida	(Montagu, 1803)	W0161	UKI, C					
			Gibbula cineraria	(Linnaeus, 1758)	W0163	UKI, C	UBBC, I		USC / USI		
			Gibbula umbilicalis	(da Costa, 1778)	W0165	UKI, C					
			Jujubinus exasperatus	(Pennant, 1777)	W170		UBBC, I	UBGC	USC / USI	UAC, I	UMC, I
			Jujubinus miliaris	(Brocchi, 1814)	W0172	UKC	UBBC		USC / USI		
			Jujubinus striatus	(Linnaeus, 1758)	W175		UBBC, I				

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		SKENEIDAE	*Skenea serpuloides*	(Montagu, 1808)	W0198	UKI, C					
		LOTTIIDAE	*Tectura testudinalis*	(O F Muller, 1776)	W0223	UKI, C	UBBC		USC / USI		
			Tectura virginea	(O F Muller, 1776)	W0224	UKI, C	UBBC, I	UBGC, I	USC / USI		
		PATELLIDAE	*Helcion pellucidum*	(Linnaeus, 1758)	W0234	UKI	UBBC		USC / USI		
		LEPETIDAE	*Iothia fulva*	(O F Muller, 1776)	W0239	UKI, C					
	MESOGASTROPODA	CANCELLARIIDAE	*Cancellaria cancellata*	(Linnaeus, 1767)						UAI, C	
		CERITHIIDAE	*Bittium latreillii*	(Payraudeau, 1826)							UMC, I
			Bittium jadertinum	(Brusina, 1865)						UAC	UMI
			Bittium reticulatum	(da Costa, 1778)	W0263	UKI, C	UBBC, I	UBGC, I	USC	UAI, C	
			Cerithium lividulum	Risso, 1826							UMC
		TURRITELLIDAE	*Turritella turbona*	Monterosato, 1877						UAI, C	UMC, I
			Turritella communis	Risso, 1826	W0270	UKC	UBBC	UBGC, I	USC / USI		
		CERITHIOPSIDAE	*Cerithiopsis fayalensis*	Watson, 1886							UMC
			Cerithiopsis minima	(Brusina, 1865)						UAC	
			Cerithiopsis rugulosa	(Sowerby)						UAC	
			Cerithiopsis scalaris	?						UAC	
			Cerithiopsis tubercularis	(Montagu, 1803)	W0275	UKI, C	UBBC, I			UAC	UMI
		LITTORINIDAE	*Lacuna crassior*	(Montagu, 1803)	W0287	UKC					
			Lacuna parva	(da Costa, 1778)	W290		UBBC		USC / USI		
			Lacuna vincta	(Montagu, 1803)	W0292	UKI, C					
		SKENEOPSIDAE	*Skeneopsis planorbis*	(O Fabricius, 1780)	W0312	UKI, C	UBBC				
		BARLEEIDAE	*Barleeia unifasciata*	(Montagu, 1803)	W323		UBBC		USC		UMI
		RISSOIDAE	*Rissoa guerinii*	Recluz, 1843	W327		UBBC, I	UBGC, I	USC / USI		
			Rissoa interrupta	(J Adams, 1800)	W0328	UKI, C					
			Rissoa lilacina	Recluz, 1843	W0330	UKI	UBBC, I		USC / USI		
			Rissoa rufilabrum	Alder, 1844	W0332	UKC					
			Alvania sp.							UAC	
			Cingula alleryana	(Aradas & Benoit, 1874)						UAC	
			Cingula ambigua	(Brugnome, 1873)						UAC	
			Cingula semistriata	(Montagu, 1808)						UAC	
			Rissoa violacea	Desmarest, 1814						UAC	
			Rissoa parva	(da Costa, 1778)	W0334	UKC	UBBC, I	UBGC	USC		
			Weinkauffia sp.							UAC	
			Alvania discors	(Allan, 1818)							UMI
			Alvania beanii	(Hanley in Thorpe, 1844)	W0338	UKI, C					UMI

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			Rissoina bruguieri	(Payraudeau, 1826)							UMC
			Alvania cimicoides	(Forbes, 1844)	W341		UBBC		USC / USI		
			Alvania punctura	(Montagu, 1803)	W0344	UKC	UBBC, I	UBGC			
			Manzonia crassa	(Kanmacher in G Adams, 1798)	W361		UBBC, I	UBGC	USC		
			Obtusella intersecta	(S V Wood, 1857)	W0365	UKC					
			Onoba aculeus	(Gould, 1841)	W0368	UKI, C					
			Onoba semicostata	(Montagu, 1803)	W0371	UKI, C	UBBC, I	UBGC	USC		
			Pusillina inconspicua	(Alder, 1844)	W0376	UKC			USC		
			Pussillina inconspicua	(Alder, 1844)	W376		UBBC				
		CAECIDAE	*Caecum imperforatum*	(Kanmacher in G Adams, 1798)	W0414	UKI, C			USC / USI		
			Caecum trachea	(Montagu, 1803)						UAC	UMC
			Caecum subannulatum	(de Folin, 1870)						UAC	
			Caecum glabrum	(Montagu, 1803)	W0418	UKI, C	UBBC	UBGC, I	USC / USI		
		CALYPTRAEIDAE	*Crepidula unguiformis*	Lamarck, 1822							UMC, I
		ADEORBIDAE	*Circulus striatus*	(Philippi, 1836)	W424		UBBC		USC		
		APORRHAIIDAE	*Aporrhais pespelecani*	(Linnaeus, 1758)	W0430	UKC	UBBC		USC		
		CALYPTRAEIDAE	*Calyptraea chinensis*	(Linnaeus, 1758)	W436		UBBC, I	UBGC, I	USC / USI	UAC, I	UMC, I
			Crepidula fornicata	(Linnaeus, 1758)	W439		UBBC, I	UBGC, I	USI		
		CAPULIDAE	*Capulus ungaricus*	(Linnaeus, 1758)	W0443	UKI, C	UBBC	UBGC, I	USC / USI		
		TRIVIIDAE	*Trivia arctica*	(Pulteney, 1799)	W459		UBBI				
			Trivia monacha	(da Costa, 1778)	W0461	UKI, C	UBBC, I		USC		
			Erato voluta	(Montagu, 1803)	W0465	UKI					
		LAMELLARIIDAE	*Lamellaria perspicua*	(Linnaeus, 1758)						UAC	
		VELUTINIDAE	*Velutina velutina*	(O F Muller, 1776)	W0480	UKI, C					
		NATICIDAE	*Polinices montagui*	(Forbes, 1838)	W0490	UKI, C					
			Lunatia sp.							UAI	
			Natica dillwynii	Payraudeau, 1827						UAI, C U99I	UMI
			Polinices pulchellus	(Risso, 1826)	W0491	UKI, C	UBBC		USC / USI		
			Euspira catena	(da Costa, 1778)	W493			UBGC	USC / USI		
		CASSIDAE	*Phalium granulatum*	(Born, 1778)							UMC, I
		TRIPHORIDAE	*Cosmotriphora pseudocanarica*	Bouchet, 1985							UMI
			Marshallora adversa	(Montagu, 1803)	W0534	UKC					
			Marshallora adversa	(Montagu, 1803)	W534		UBBC				
			Metaxia metaxa	(Delle Chiaje, 1828)							

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		EPITONIIDAE	*Cirsotrema* sp.							UAC	
			Eulima sp.							UAC	
			Melanella polita	(Linnaeus, 1758)							UMC, I
			Nanobalcis nana	(Monterosato, 1878)							UMI
			Eulima bilineata	Alder, 1848	W0603	UKI					
			Melanella alba	(da Costa, 1778)	W0634	UKI, C	UBBC, I	UBGC, I	USC / USI		
			Vitreolina philippi	(Rayneval & Ponzi, 1854)	W0669	UKC	UBBC		USC / USI		UMI
	NEOGASTROPODA	MURICIDAE	*Trophon barvicensis*	(Johnston, 1825)	W675		UBBI	UBGI			
			Bolinus brandaris	(Linnaeus, 1758)						UAC	
			Chauvetia turritellata	(Deshayes, 1835)							UMC
			Colubraria reticulata	(Blainville, 1826)							UMI
			Dermomurex scalaroides	(Blainville, 1829)							UMC, I
			Fusinus rostratus	(Olivi, 1792)							UMC
			Fusinus rudis	(Philippi, 1844)						UAC	UMI
			Hexaplex trunculus	(Linnaeus, 1758)						UAI	
			Muricopsis sp.								UMC
			Muricopsis cristata	(Brocchi, 1814)						UAC	UMI
			Ocenebra erinacea	(Linnaeus, 1758)	W685		UBBC, I			UAC	
			Ocinebrina aciculata	(Lamarck, 1822)						UAC	UMC, I
		BUCCINIDAE	*Buccinum undatum*	(Linnaeus, 1758)	W0708	UKI, C	UBBC, I	UBGC, I	USC / USI		
			Colus gracilis	(da Costa, 1778)	W0715	UKC					
			Williamia gussonii	(Costa, 1829)							UMI
			Buccinulum corneum	(Linnaeus, 1758)						UAC	
			Chauvetia vulpecula	(Monterosato, 1874)						UAC	
			Hinia reticulata	(Linnaeus, 1758)	W0745	UKC	UBBC, I	UBGC, I	USC / USI		
			Hinia incrassata	(Strom, 1768)	W0747	UKI, C	UBBC, I	UBGC, I	USC / USI		
			Neptunea antiqua	(Linnaeus, 1758)	W0727	UKC					
			Troschelia bernicensis	(King, 1846)						UAC	
		NASSARIIDAE	*Nassarius coralligenus*	(Pallary, 1900)						UAC	
		COLUMBELLIDAE	*Mitrella scripta*	(Linnaeus, 1758)						UAC	UMC, I
		COSTELLARIIDAE	*Vexillum ebenus*	(Lamarck, 1811)							UMC, I
			Vexillum savignyi	(Payraudeau, 1826)							UMC
		MARGINELLIDAE	*Volvarina mitrella*	(Risso, 1826)							UMC, I
		TURRIDAE	*Haedropleura septangularis*	(Montagu, 1803)	W776		UBBC	UBGC			
			Mangelia attenuata	(Montagu, 1803)	W797		UBBC, I	UBGC, I			

PHYLUM	CLASS: ORDER	FAMILY	Species	Authority	Code	Clyde	Brest	Glenan	Galicia	Alicante	Malta
			Mangelia brachystoma	(Philippi, 1844)	W0798	UKC					
			Mangelia coarctata	(Forbes, 1840)	W804		UBBC, I				
			Clathromangelia quadrillum	(Dujardin, 1837)							UMI
			Comarmondia gracilis	(Montagu, 1803)	W831		UBBC	UBGC, I			
			Haedropleura secalina	(Philippi, 1844)							UMC, I
			Mitrolumna olivoidea	(Cantraine, 1835)						UAC	UMI
			Raphitoma linearis	(Montagu, 1803)	W0861	UKC				UAC	
			Mangelia nebula	(Montagu, 1803)						UAI	
			Raphitoma bicolor	(Risso, 1826)						UAC	
			Raphitoma purpurea	(Montagu, 1803)	W0862	UKI				UAC	
	HETEROSTROPHA	RISSOELLIDAE	*Rissoella opalina*	(Jeffreys, 1848)	W894		UBBC		USC	UAC	
		PYRAMIDELLIDAE	*Odostomia turrita*	Hanley, 1844	W0915	UKI, C					
			Branchystomia eulimoides	(Hanley, 1844)	W0922	UKC					
			Brachystomia scalaris	(Macgillivray, 1843)	W925				USC		
			Odostomia conoidea	(Brocchi, 1814)							UMC
			Chrysallida decussata	(Montagu, 1803)	W0933	UKC					
			Chrysallida indistincta	(Montagu, 1808)	W0935	UKC					
			Chrysallida interstincta	(J Adams, 1797)	W0937	UKC					
			Ondina divisa	(J Adams, 1797)	W0960	UKC					
			Partulida pellucida	(Dillwyn, 1817)	W0965	UKC					
			Noemiamea dolioliformis	(Jeffreys, 1848)						UAC	
			Turbonilla sp.							UAI, C	
			Turbonilla lactaea	(Linnaeus, 1758)	W971		UBBI	UBGC, I	USC		
	CEPHALASPIDA	SCAPHANDRIDAE	*Scaphander lignarius*	(Linnaeus, 1758)	W1019	UKC	UBBC		USC		
		CYLICHNIDAE	*Cylichna cylindracea*	(Pennant, 1777)	W1028	UKC	UBBC		USC		
		PHILINIDAE	*Philine aperta*	(Linnaeus, 1767)	W1038	UKC					
			Philine punctata	(J Adams, 1800)	W1043	UKC					
		DIAPHANIDAE	*Diaphana minuta*	Brown, 1827	W1059	UKC					
		HAMINOEIDAE	*Haminoea hydatis*	(Linnaeus, 1758)							UMC, I
		RETUSIDAE	*Retusa mamillata*	(Philippi, 1836)						UAC	
			Retusa truncatula	(Bruguiere, 1792)	W1080	UKC					
	SACOGLOSSA	ELYSIIDAE	*Elysia viridis*	(Montagu, 1804)	W1118	UKC					
	ANASPIDEA	APLYSIIDAE	*Aplysia punctata*	Cuvier, 1803	W1152	UKI, C				•	
	NOTASPIDEA	PLEUROBRANCHIDAE	*Pleurobranchus membranaceus*	(Montagu, 1815)	W1157	UKC					

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			Berthelina citrina	(Rüppell & Leuckart, 1828)	W1162		UBBC, I		USC / USI		
	NUDIBRANCHIA		Nudibranchia indet.				UBBC, I				
		TRITONIIDAE	*Tritonia plebeia*	Johnston, 1828	W1254	UKC					
		LOMANOTIDAE	*Lomanotus marmoratus*	(Alder & Hancock, 1845)	W1258	UKC					
		DOTIDAE	*Doto coronata*	(Gmelin, 1791)	W1272	UKI, C					
			Doto fragilis	(Forbes, 1838)	W1277	UKI, C					
		ONCHIDORIDIDAE	*Onchidoris bilamellata*	(Linnaeus, 1767)	W1322	UKI, C					
			Onchidoris muricata	(O F Muller, 1776)	W1325	UKI, C					
		POLYCERIDAE	*Polycera quadrilineata*	(O F Muller, 1776)	W1350	UKI, C					
			Limacia clavigera	(O F Muller, 1776)	W1354	UKC					
		DORIDIDAE	*Doris* sp.	Linnaeus, 1758	W1371				USC / USI		
		ARCHIDORIDIDAE	*Archidoris pseudoargus*	(Rapp, 1827)	W1376	UKI, C					
		FLABELLINIDAE	*Coryphella lineata*	(Loven, 1846)	W1419	UKC					
			Coryphella verrucosa	(M Sars, 1829)	W1422	UKC					
			Flabellina sp.							UAC	
			Flabellina pedata	(Montagu, 1815)	W1424	UKC					
		TERGIPEDIDAE	*Catriona gymnota*	(Couthouy, 1838)	W1430	UKC					
			Cuthona caerulea	(Montagu, 1804)	W1434	UKC					
		EUBRANCHIDAE	*Eubranchus* sp.A	Forbes, 1838	W1445	UKC					
			Eubranchus tricolor	Forbes, 1839	W1450	UKC					
		FACELINIDAE	*Facelina auriculata*	(O F Muller, 1776)	W1469	UKC					
			Facelina bostoniensis	(Couthouy, 1838)	W1470	UKI, C					
		AELODIIDAE	*Aeolidia papillosa*	(Linnaeus, 1761)	W1484	UKC	UBBC, I		USC / USI		
	SCAPHOPODA	SIPHONODENTALIIDAE	*Cadulus jeffreysi*	(Monterosato, 1875)						UAI	
			Dentalium novemcostatum	Lamarck, 1838					USC / USI		
			Dentalium novemcostatum	Lamarck, 1838			UBBC, I				
		DENTALIIDAE	*Antalis entalis*	(Linnaeus, 1778)	W1519	UKC		UBGC	USC / USI		
			Dentalium vulgare	da Costa, 1778						UAI, C	
			Dentalium panormum	Chenu, 1842						UAI	
	NUCULOIDA	SOLEMYIDAE	*Solemya togata*	(Poli, 1795)							UMC
		NUCULIDAE	*Nucula hanleyi*	Winckworth, 1931	W1568			UBGI			
			Nucula nitidosa	Wincworth, 1930	W1569		UBBC			UAI	UMC
			Nucula nucleus	(Linnaeus, 1758)	W1570	UKI, C	UBBC, I	UBGC, I			
	ARCOIDA	ARCIDAE	*Arca noae*	Linnaeus, 1758						UAC	UMI
			Arca tetragona	Poli, 1795						UAI, C	

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			Barbatia barbata	(Linnaeus, 1758)						UAC	
		NOETIDAE	*Striarca lactea*	(Linnaeus, 1758)							UMC
		GLYCYMERIDIDAE	*Glycymeris glycymeris*	(Linnaeus, 1758)	W1688	UKI, C	UBBC	UBGC, I	USC / USI	UAC	UMC, I
	MYTILOIDA	MYTILIDAE	*Gregariella subclavata*	(Libassi, 1859)						UAI	
			Lithophaga lithophaga	(Linnaeus, 1758)						UAI, C	
			Mytilus edulis	~~(~~Linnaeus, 1758~~)~~	W1695	UKI, C					
			Modiolus adriaticus	(Lamarck, 1819)	W1700		UBBC, I	UBGI	USC / USI	UAI	UMC
			Modiolus barbatus	(Linnaeus, 1758)	W1701		UBBC, I		USI		
			Modiolus modiolus	(Linnaeus, 1758)	W1702	UKI, C			USC / USI		
			Modiolarca tumida	(Hanley, 1843)	W1718	UKC					
			Modiolus sp.				UBBC				
	LIMOIDA	LIMIDAE	*Limaria inflata*	Link, 1807						UAI, C	
			Limatula gwyni	(Sykes, 1903)						UAI, C	
			Limaria hians	(Gmelin, 1791)	W1741	UKC					
			Limatula subauriculata	(Montagu, 1808)	W1746	UKC				UAI	UMC, I
			Limatula sulcata	(Brown, 1827)	W1748	UKC					
	OSTREOIDA	OSTREIDAE	*Ostrea edulis*	Linnaeus, 1758	W1758		UBBC				
		PECTINIDAE	*Chlamys flexuosa*	(Poli, 1795)						UAI, C	UMC, I
			Lissopecten hyalinus	(Poli, 1795)							UMC, I
			Palliolum incomparabile	(Risso, 1826)							UMC
			Pecten jacobeus	(Linnaeus, 1758)						UAI, C	
			Pecten maximus	(Linnaeus, 1758)	W1771	UKI, C	UBBC, I	UBGC, I	USC		
			Aequipecten opercularis	(Linnaeus, 1758)	W1773	UKI, C	UBBC		USC		UMC
			Chlamys distorta	(da Costa, 1778)	W1776		UBBC		USC		
			Chlamys varia	(Linnaeus, 1758)	W1779	UKI, C	UBBC, I		USC	UAC, I	UMC
			Palliolum tigerinum	(O F Muller, 1776)	W1786	UKI, C				UAC	
			Anomia ephippium	Linnaeus, 1758	W1807		UBBC, I	UBGC, I		UAC	UMI
		ANOMIIDAE	*Heteranomia squamula*	(Linnaeus, ~~1758)~~ 1758)	W1809	UKI, C					
			Pododesmus patelliformis	(Linnaeus, ~~1758)~~ 1761)	W1814	UKI, C	UBBC, I		USI		
	VENEROIDA	LUCINIDAE	*Ctena decussata*	(Costa O.G., 1829)							UMI
			Lucinoma borealis	(Linnaeus, 1767)	W1829	UKI, C	UBBI		USC / USI		
			Lucinella divaricata	(Linnaeus, 1758)	W1832		UBBC, I				
		THYASIRIDAE	*Thyasira flexuosa*	(Montagu, 1803)	W1837	UKI, C	UBBC, I	UBGC, I	USI		
		UNGULINIDAE									

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		NEOLEPTONIDAE	*Neolepton sulcatulum*	(Jeffreys, 1859)							UMC
		GALEOMMATIDAE	*Kellia suborbicularis*	(Montagu, 1803)	W1875	UKC					UMC
			Semierycina nitida	(Turton, 1822)	W1882	UKC					
		MONTACUTIDAE	*Devonia perrieri*	(Malard, 1904)	W1898		UBBC, I	UBGC	USC / USI		
			Tellimya ferruginosa	(Montagu, 1808)	W1902		UBBC, I		USC / USI		
			Mysella bidentata	(Montagu, 1803)	W1906	UKC	UBBC, I	UBGC	USC / USI		
		ASTARTIDAE	*Astarte fusca*	(Poli, 1795)						UAI, C	UMC, I
			Digitaria digitaria	(Linnaeus, 1758)							UMC, I
			Gonilia calliglypta	(Dall, 1903)							UMC, I
			Goodalia triangularis	(Montagu, 1803)	W1929	UKI, C			USC		
			Tridonta montagui	(Dillwyn, 1817)	W1936	UKC					
		CARDITIDAE	*Glans trapezia*	(Linnaeus, 1758)							UMC, I
			Pteromeris minuta	(Scacchi, 1836)							UMC, I
			Venericardia antiquata	(Linnaeus, 1758)							UMC
			Acanthocardia echinata	(Linnaeus, 1758)	W1943	UKC	UBBC	UBGC			
			Acanthocardia paucicostata	(G. B. Sowerby II, 1834)	W1944		UBBC				
			Parvicardium exiguum	(Gmelin, 1791)	W1949		UBBC, I	UBGI	USC	UAC	
			Parvicardium minimum	(Philippi, 1836)	W1950		UBBC, I		USC / USI		
			Parvicardium ovale	(G B Sowerby, 1840)	W1951	UKI, C	UBBC, I	UBGC, I	USC / USI		
			Parvicardium scabrum	(Philippi, 1844)	W1952	UKI, C	UBBC		USC		
			Acanthocardia aculeata	(Linnaeus, 1758)						UAI	
			Plagiocardium papillosum	(Poli, 1795)	W1955		UBBC			UAI, C	
			Laevicardium crassum	(Gmelin, 1791)	W1959	UKI, C	UBBC	UBGC, I	USC	UAI, C	
			Cerastoderma edule	(Linnaeus, 1758)	W1961				USC		
		MACTRIDAE	*Spisula elliptica*	(Brown, 1827)	W1975	UKC					
			Mactra stultorum	(Linnaeus, 1758)						UAC	
			Spisula subtruncata	(da Costa, 1778)	W1978			UBGC			
			Lutraria angustior	Philippi, 1844	W1983	UKI, C					
		PHARIDAE	*Ensis arcuatus*	(Jeffreys, 1865)	W1998	UKI, C					
			Ensis ensis	(Linnaeus, 1758)	W1999				USC / USI		
			Phaxas adriaticus.	(Coen, 1933)						UAI	
			Phaxas pellucidus	(Pennant, 1777)	W2006		UBBC	UBGC, I	USC / USI		
		TELLINIDAE	*Arcopagia crassa*	(Pennant, 177)	W2015	UKI		UBGC, I			
			Acropella balaustina	(Linnaeus, 1758)	W2017	UKC					UMC, I
			Moerella donacina	(Linnaeus, 1758)	W2021	UKI, C	UBBC	UBGC, I		UAI	

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			Tellina pygmaea	Lovén, 1846							UMI
			Tellina pulchella	Lamarck, 1818						UAI	
		DONACIDAE	*Donax variegatus*	(Gmelin, 1791)						UAI	
		PSAMMOBIIDAE	*Gari depressa*	(Pennant, 1777)	W2046		UBBC	UBGC, I	USC / USI		
			Gari tellinella	(Lamarck, 1818)	W2049	UKI	UBBC	UBGC, I	USC / USI		
		SEMELIDAE	*Abra alba*	(W Wood, 1802)	W2059	UKC	UBBC, I	UBGI			
		VENERIDAE	*Pitar rudis*	(Poli, 1795)						UAI	
			Venus verrucosa	Linnaeus, 1758	W2089		UBBC, I		USC	UAC	
			Circomphalus casina	(Linnaeus, 1758)	W2091	UKI, C		UBGC			
			Gouldia minima	(Montagu, 1803)	W2095	UKI, C	UBBC, I	UBGC, I	USC	UAC	UMC
			Chamelea gallina	(Linnaeus, 1758)	W2098		UBBC	UBGC, I	USC	UAC	
			Clausinella brongniartii	(Payraudeau, 1826)						UAI	UMC, I
			Clausinella fasciata	(da Costa, 1778)	W2100	UKI, C	UBBC, I	UBGC, I	USC / USI	UAI	
			Timoclea ovata	(Pennant, 1777)	W2104	UKI, C	UBBC	UBGC, I	USC		
			Tapes aureus	(Gmelin, 1791)	W2112		UBBC, I		USC		
			Tapes rhomboides	(Pennant, 1777)	W2113	UKI, C	UBBC	UBGC, I	USC / USI	UAI	
			Venerupis senegalensis	(Gmelin, 1791)	W2124	UKI, C	UBBC		USC		
			Dosinia lupinus	(Linnaeus, 1758)	W2128			UBGC	USC / USI		
			Dosinia exoleta	(Linnaeus, 1758)	W2130	UKI, C	UBBC	UBGC, I	USC / USI		
		CHAMIDAE	*Chama gryphoides*	Linnaeus, 1758						UAC	
			Pseudochama gryphina	(Lamarck, 1819)							UMI
	MYOIDA	MYIDAE	*Mya truncata*	(Linnaeus, 1758)	W2147	UKI, C					
		CORBULIDAE	*Corbula gibba*	(Olivi, 1792)	W2157		UBBC, I	UBGC, I	USC / USI	UAI	
	HIATELLACEA	HIATELLIDAE	*Hiatella arctica*	(Linnaeus, 1767)	W2166	UKI, C	UBBC, I	UBGC, I	USC / USI		UMI
	PHOLADOMYOIDA	THRACIIDAE	*Thracia phaseolina*	(Lamarck, 1818)	W2231		UBBC	UBGC, I	USC / USI		
			Thracia convexa	(Wood W., 1815)							UMI
			Thracia distorta	(Montagu, 1803)							UMC, I
			Thracia papyracea	(Poli, 1791)							UMC
			Thracia villosiuscula	(Macgillivray, 1827)	W2233	UKI, C					
		PERIPLOMATIDAE	*Cochlodesma praetenue*	(Pulteney, 1799)	W2239	UKI, C					
	PHOLADOMYOIDA	LYONSIIDAE	*Lyonsia norwegica*	(Gmelin, 1791)	W2247		UBBC	UBGC, I	USC		
	CEPHALOPODA	SEPIIDAE	*Sepia officinalis*	Linnaeus, 1758	W2307						UMI
		SEPIOLIDAE	*Sepiola atlantica*	Orbigny in Ferussac & Orbigny, 1840	W2329	UKI, C					
		LOLIGINIDAE	*Loligo vulgaris*	Lamarck, 1798						UAC	
		OCTOPODIDAE	*Eledone cirrhosa*	(Lamarck, 1798)	W2398	UKC					

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			Octopus vulgaris	Cuvier, 1797						UAI, C	UMI
BRACHIOPODA	ARTICULATA	MEGATHYRIDIDAE	*Argyrotheca cuneata*	(Risso, 1826)							UMC, I
BRYOZOA	STENOLAEMATA	CRISIIDAE	*Crisia denticulata*	(Lamarck, 1816)	Y0016	UKC					
			Crisia eburnea	(Linnaeus, 1758)	Y0017	UKI, C					
		TUBULIPORIDAE	*Tubulipora liliacea*	(Pallas, 1766)	Y0027	UKI, C					
		LICHENOPORIDAE	*Lichenopora verrucaria*	(Fabricius, 1780)	Y0064	UKI, C					
			Disporella hispida	(Fleming, 1828)	Y0066	UKI, C					
	GYMNOLAEMATA	ALCYONIDIIDAE	*Alcyonidium diaphanum*	(Hudson, 1762)	Y0076	UKI, C					
		MEMBRANIPOROIDAE	*Membranipora membranacea*	(Linnaeus, 1767)	Y0170	UKI, C					
		ELECTRIDAE	*Electra pilosa*	(Linnaeus, 1767)	Y0178	UKI, C					
		CALLOPORIDAE	*Callopora* sp.A	J E Gray, 1848	Y0201	UKI					
			Cauloramphus spiniferum	(Johnston, 1832)	Y0212	UKC					
		BUGULIDAE	*Bugula flabellata*	(Thompson in Gray, 1848)	Y0243	UKC					
		CANDIDAE	*Scrupocellaria* sp.A	van Beneden, 1845	Y0274	UKI, C					
			Scrupocellaria reptans	(Linnaeus, 1767)	Y0276	UKC					
		CELLARIIDAE	*Cellaria sinuosa*	(Hassall, 1840)	Y0302	UKC					
			sp.A		Y0306	UKC					
		HIPPOTHOIDAE	*Celleporella hyalina*	(Linnaeus, 1767)	Y0337	UKC					
		ESCHARELLIDAE	sp.A		Y0361	UKC					
		SCHIZOPORELLIDAE	*Cryptosula pallasiana*	(Moll, 1803)	Y0411	UKI, C					
		STOMACHETOSELLIDAE	*Stomachetosella sinuosa*	(Busk, 1860)	Y0448	UKI, C					
		SMITTINIDAE	*Parasmittina trispinosa*	(Johnston, 1838)	Y0465	UKI					
		MICROPORELLIDAE	*Microporella ciliata*	(Pallas, 1766)	Y0480	UKI, C					
		CELLEPORIDAE	*Cellepora pumicosa*	(Pallas, 1766)	Y0495	UKC					
			Celleporina ?caminata	(Waters, 1879)							UMC, I
			Cigclisula turrita	Smitt, 1873							UMC, I
		CLEIDOCHASMATIDAE	*Hagiosynodus latus*	(Busk, 1856)							UMC, I
		LICHENOPORIDAE	*Lichenopora radiata*	(Audouin, 1826)							UMC, I
		MICROPORIDAE	*Micropora* sp.								UMC, I
		RETEPORIDAE	*Rhynchozoon* sp.								UMC, I
			Sertella ?sudbourniensis	(Gautier, 1962)							UMC, I
		SCHIZOPORELLIDAE	*Schizoporella* sp.							UAI, C	UMC, I
	CTENOSTOMATA		*Beania histissima*	(Heller, 1867)						UAI, C	
			Cellaria salicornoides	Audouin, 1826						UAI, C	
			Myriapora truncata	(Pallas, 1766)						UAI, C	

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			Pentapora fascialis	(Pallas, 1766)						UAI, C	
			Scrupocellaria scrupea	Busk, 1851						UAI, C	
			Margaretta cereoides	Ellis & Solander, 1786						UAI	
			Amathia sp.							UAC	
			Calpensia nobilis	Esper, 1796						UAC	
	CHEILOSTOMATA: ANASCA									UAC	
	CHEILOSTOMATA: ASCOPHORA									UAC	
			Sertella septentrionalis	(Harmer, 1933)						UAC	
PHORONIDA		PHORONIDAE	*Phoronis hippocrepia*	Wright, 1856	ZA0004	UKI, C					
			Phoronis muelleri	Selys-Longchamps, 1903	ZA0005	UKI, C					
			Phoronis psammophila	Cori, 1889	ZA8		UBBC, I				UMC
			Phoronis sp.				UBBC				
ECHINODERMATA	CRINOIDEA	ANTEDINIDAE	*Antedon bifida*	(Pennant, 1777)	ZB0010	UKI, C			USC		
			Antedon mediterranea	(Lamarck, 1816)						UAC	UMC, I
	ASTEROIDEA	LUIDIIDAE	*Luidia ciliaris*	(Philippi, 1837)	ZB0022	UKI, C	UBBC		USC		UMI
		ASTROPECTINIDAE	*Astropecten irregularis*	(Pennant, 1777)	ZB0026	UKI, C					
			Astropecten aranciacus	(Linnaeus, 1758)						UAC	UM?
		PORANIIDAE	*Porania pulvillus*	(O F Muller, 1776)	ZB0054	UKI, C					
		ASTERINIDAE	*Asterina gibbosa*	(Pennant, 1777)	ZB59		UBBI				
			Anseropoda placenta	(Pennant, 1777)	ZB62		UBBC	UBGC	USC		
		SOLASTERIDAE	*Solaster endeca*	(Linnaeus, 1771)	ZB0072	UKI, C					
			Crossaster papposus	(Linnaeus, 1767)	ZB0075	UKI, C					
		ECHINASTERIDAE	*Echinaster sepositus*	(Retzius, 1783)						UAI, C	UMC
			Henricia oculata	(Pennant, 1777)	ZB0082	UKI, C					
			Henricia sanguinolenta	(O F Müller, 1776)	ZB86		UBBC	UBGC, I	USC		
		ASTERIIDAE	*Asterias rubens*	Linnaeus, 1758	ZB0100	UKI, C	UBBC		USC / USI		
			Marthasterias glacialis	(Linnaeus, 1758)	ZB0104	UKI, C	UBBC, I	UBGC, I	USC / USI	UAC	UMI
	OPHIUROIDEA	OPHIOMYXIDAE	*Ophiomyxa pentagona*	(Lamarck, 1816)						UAI, C	
		OPHIOTRICHIDAE	*Ophiothrix fragilis*	(Abildgaard, 1789)	ZB0124	UKI, C	UBBC, I		USC / USI	UAC	
			Ophiura grubei	Heller, 1863						UAI, C	
			Ophiura sp.	Lamarck, 1816						UAC	
			Ophiura ophiura	H L. Clark, 1915						UAC	
			Ophiuridae							UAC	
		OPHIOCOMIDAE	*Ophiocomina nigra*	(Abildgaard, 1789)	ZB0128	UKI, C	UBBC, I	UBGC, I			
			Ophiopsila aranea	Forbes, 1843						UAC	

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		OPHIODERMATIDAE	*Ophioconis forbesi*	(Heller, 1863) Carus, 1885						UAI, C	
		OPHIACTIDAE	*Ophiopholis aculeata*	(Linnaeus, 1767)	ZB0147	UKI, C					
		OPHIUROIDAE	*Amphiura filiformis*	(O F Müller, 1776)	ZB154		UBBC		USC / USI	UAC	
			Amphiura securigera	(Duben & Koren, 1844)	ZB0157	UKI, C					
			Amphiura chiajei	Forbes, 1843						UAI, C	
			Amphiura sp.2	Lyman, 1882						UAC	
			Amphiura sp.3	Lyman, 1882						UAC	
			Amphipholis squamata	(Chiaje, 1829)	ZB0161	UKI, C	UBBC, I		USC / USI	UAI, C	UMC, I
			Amphiura sp.1	Cherbonnier, 1958?						UAC	
			Ophiura albida	Forbes, 1839	ZB0168	UKI, C	UBBC, I			UAI, C	
	ECHINOIDEA	CIDARIDAE	*Stylocidaris affinis*	(Philippi, 1845)							UMC, I
		TEMNOPLEURIDAE	*Genocidaris maculata*	A Agassiz, 1869						UAI, C	UMC, I
		NEOLAMPADIDAE	*Neolampas rostellata*	A. Agassiz, 1869							UMC
		PARECHINIDAE	*Psammechinus miliaris*	(Gmelin, 1778)	ZB0193	UKI, C	UBBC, I	UBGC, I	USC		
		ECHINIDAE	*Echinus esculentus*	Linnaeus, 1758	ZB0198	UKI, C	UBBC	UBGC			
			Paracentrotus lividus	(Lamarck, 1816)	ZB202		UBBC I	UBGC	USC / USI		
		TOXOPNEUSTIDAE	*Sphaerechinus granularis*	(Lamarck, 1816)	ZB208		UBBC, I	UBGC, I	USC	UAI, C	
		FIBULARIIDAE	*Echinocyamus pusillus*	(O F Muller, 1776)	ZB0212	UKI, C	UBBC	UBGC, I	USC / USI	UAI, C	UMC, I
		SPATANGIDAE	*Spatangus purpureus*	O F Müller, 1776	ZB219			UBGC, I	USC	UAI, C	
		LOVENIIDAE	*Echinocardium cordatum*	(Pennant, 1777)	ZB223			UBGC, I	USC / USI		
			Echinocardium pennatifidum	Norman, 1868	ZB0225	UKI, C					
		BRISSIDAE	*Brissus unicolor*	(Leske, 1778)						UAC	
			Plagiobrissus costai	(Gasco, 1876)							UMC
	HOLOTHUROIDEA	HOLOTHURIIDAE	*Holothuria tubulosa*	Gmelin, 1788						UAI, C	
			Holothuria impatiens	(Forskal, 1775)						UAC	
		PHYLLOPHORIDAE	*Neopentadactyla mixta*	(Ostergren, 1898)	ZB0260	UKI					
			Thyone fusus	(O F Muller, 1776)	ZB0262	UKI, C	UBBC, I	UBGC			
		CUCUMARIIDAE	*Ocnus planci*	(Brandt, 1835)	ZB0276	UKC					
			Aslia lefevrei	(Barrois, 1882)	ZB278				USC / USI		
			Leptopentacta elongata	(Duben & Koren, 1845)	ZB280		UBBC, I		USC / USI		
			Thyonidium drummondi	(Thompson, 1840)	ZB0282	UKC					
		SYNAPTIDAE	*Leptosynapta inhaerens*	(O F Muller, 1776)	ZB0296	UKI, C	UBBC, I		USC / USI		
			Labidoplax digitata	(Montagu, 1815)	ZB300		UBBC, I	UBGC, I	USC		
			Labidoplax media	(Ostergren, 1905)	ZB0301	UKC					
CEPHALOCORDATA			*Branchiostoma lanceolatum*	(Pallas, 1776)				UBGC	USC / USI	UAC	UMC, I

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TUNICATA			*Ascidia* sp.								UMI
			Cystodytes dellechiajei	(Della Valle, 1877)							UMI
			Diplosoma sp.								UMC
			Polycarpa mamillaris	(Gaertner, 1774)						UAI, C	
			Polysyncraton bilobatum	Lafargue, 1968						UAC	
	ASCIDIACEA	CLAVELINIDAE	*Clavelina lepadiformis*	(O F Muller, 1776)	ZD0007	UKC					
			Didemnum coriaceum	(Drasche, 1883)						UAI, C	UMI
			Didemnum fulgens	(Milne Edwards, 1841)						UAC	
		DIDEMNIDAE	*Diplosoma listerianum*	(Milne-Edwards, 1841)	ZD0059	UKI, C					
		CIONIDAE	*Ciona intestinalis*	(Linnaeus, 1767)	ZD0071	UKI, C	UBBC, I	UBGI	USC		
			Rhopalaea neapolitana	Philippi, 1843						UAC	
		CORELLIDAE	*Corella parallelogramma*	(O F Muller, 1776)	ZD0081	UKI, C					
		ASCIDIIDAE	*Ascidiella aspersa*	(O F Muller, 1776)	ZD0084	UKI, C	UBBC, I	UBGC	USC / USI		
			Ascidiella scabra	(O F Muller, 1776)	ZD0085	UKI, C					
			Ascidia mentula	O F Muller, 1776	ZD0089	UKC					UMC
			Ascidia virginea	O F Muller, 1776	ZD0092	UKC					
			Phallusia mammillata	(Cuvier, 1815)	ZD95		UBBC, I		USC	UAI, C	
		STYELIDAE	*Dendrodoa grossularia*	(Van Beneden, 1846)	ZD0120	UKI, C					
			Botryllus schlosseri	(Pallas, 1766)	ZD0126	UKI, C				UAC	
		PYURIDAE	*Halocynthia papillosa*	(Linnaeus, 1767)							UMI
			Pyura microcosmus	(Savigny, 1816)						UAC	
			Microcosmus claudicans	(Savigny, 1816)							UMI
			Pyura tessellata	(Forbes, 1848)	ZD141		UBBC, I	UBGC	USC		
		MOLGULIDAE	*Molgula occulta*	Kupffer, 1875	ZD0152	UKI					

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CHORDATA	CARCHARHINIFORMES	SCYLIORHINIDAE	*Scyliorhinus canicula*	(Linnaeus, 1758)	ZF28	UKI, C					
			Scyliorhinus stellaris	(Linnaeus, 1758)	ZF28						UMC
		TRIAKIDAE	*Mustelus mustelus*	(Linnaeus, 1758)	ZF37						UMI
	SQUALIFORMES	OXYNOTIDAE	*Squalus acanthias*	Linnaeus, 1758	ZF66	UKI					
	TORPENIDIFORMES	TORPEDINIDAE	*Torpedo marmorata*	Risso, 1810	ZF77					UAI	
	ANGUILLIFORMES	MURAENIDAE	*Muraena helena*	Linnaeus, 1758	ZG13					UAC	
		CONGRIDAE	*Conger conger*	(Linnaeus, 1758)	ZG17		UBBC				
	AULOPIFORMES	AULOPODIDAE	*Aulopus filamentosus*	(Bloch, 1792)	ZG74					UAI	
	GOBIESOCIFORMES	GOBIESOCIDAE	*Diplecogaster bimaculata*	(Bonnaterre, 1788)	ZG86	UKI					
			Lepadogaster lepadogaster	(Bonnaterre, 1788)	ZG89		UBBC		USC		
			Lepadogaster sp.1	(Bonnaterre, 1788)	ZG89	UKI	UBBC, I	UBGC, I			
	LOPHIIFORMES	LOPHIIDAE	*Lophius piscatorius*	(Linnaeus, 1758)	ZG94	UKI					
	GADIFORMES	GADIDAE	*Gadus morhua*	Linnaeus, 1758	ZG116	UKI, C					
			Gaidropsarus sp.1	Rafinesque-Schmaltz, 1810	ZG117	UKI					
			Pollachius pollachius	(Linnaeus, 1758)	ZG135	UKI, C					
			Pollachius virens	(Linnaeus, 1758)	ZG136	UKI, C					
	OPHIDIIFORMES	CARAPIDAE	*Carapus acus*	(Brunnich, 1768)	ZG172					UAI, C	
	GASTEROSTEIFORMES	GASTEROSTEIDAE	*Spinachia spinachia*	(Linnaeus, 1758)	ZG230	UKI					
	SYNGNATHIFORMES	SYNGNATHIDAE	*Hippocampus hippocampus*	(Linnaeus, 1758)	ZG239					UAC	UMC
			Nerophis lumbriciformis	(Jenyns, 1835)	ZG242	UKI					
			Nerophis ophidion	(Linnaeus, 1758)	ZG243		UBBC, I		USC		
			Syngnathus acus	Linnaeus, 1758	ZG245	UKI					
			Syngnathus typhle	Linnaeus, 1758	ZG247		UBBC, I		USC		
	SCORPANEIFORMES	SCORPAENIDAE	*Scorpaena notata*	Rafinesque, 1810	ZG252					UAC	UMI
			Scorpaena sp.		ZG252						UMC
		TRIGLIDAE	*Aspitrigula cuculus*	Linnaeus, 1758	ZG262	UKC					
			Trigloporus lastoviza	(Brünnich, 1768)	ZG271					UAC	
		COTTIDAE	*Myxocephalus scorpius*	Linnaeus, 1758	ZG281	UKI, C					
			Taurulus bubalis	(Euphrasen, 1786)	ZG283		UBBC, I		USC		
			Agonus cataphractus	(Linnaeus, 1758)	ZG291	UKI					

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		EPITONIIDAE	*Cirsotrema* sp.							UAC	
			Eulima sp.							UAC	
			Melanella polita	(Linnaeus, 1758)							UMC, I
			Nanobalcis nana	(Monterosato, 1878)							UMI
			Eulima bilineata	Alder, 1848	W0603	UKI					
			Melanella alba	(da Costa, 1778)	W0634	UKI, C	UBBC, I	UBGC, I	USC / USI		
			Vitreolina philippi	(Rayneval & Ponzi, 1854)	W0669	UKC	UBBC		USC / USI		UMI
	NEOGASTROPODA	MURICIDAE	*Trophon barvicensis*	(Johnston, 1825)	W675		UBBI	UBGI			
			Bolinus brandaris	(Linnaeus, 1758)						UAC	
			Chauvetia turritellata	(Deshayes, 1835)							UMC
			Colubraria reticulata	(Blainville, 1826)							UMI
			Dermomurex scalaroides	(Blainville, 1829)							UMC, I
			Fusinus rostratus	(Olivi, 1792)							UMC
			Fusinus rudis	(Philippi, 1844)						UAC	UMI
			Hexaplex trunculus	(Linnaeus, 1758)						UAI	
			Muricopsis sp.								UMC
			Muricopsis cristata	(Brocchi, 1814)						UAC	UMI
			Ocenebra erinacea	(Linnaeus, 1758)	W685		UBBC, I			UAC	
			Ocinebrina aciculata	(Lamarck, 1822)						UAC	UMC, I
		BUCCINIDAE	*Buccinum undatum*	(Linnaeus, 1758)	W0708	UKI, C	UBBC, I	UBGC, I	USC / USI		
			Colus gracilis	(da Costa, 1778)	W0715	UKC					
			Williamia gussonii	(Costa, 1829)							UMI
			Buccinulum corneum	(Linnaeus, 1758)						UAC	
			Chauvetia vulpecula	(Monterosato, 1874)						UAC	
			Hinia reticulata	(Linnaeus, 1758)	W0745	UKC	UBBC, I	UBGC, I	USC / USI		
			Hinia incrassata	(Strom, 1768)	W0747	UKI, C	UBBC, I	UBGC, I	USC / USI		
			Neptunea antiqua	(Linnaeus, 1758)	W0727	UKC					
			Troschelia bernicensis	(King, 1846)						UAC	
		NASSARIIDAE	*Nassarius coralligenus*	(Pallary, 1900)						UAC	
		COLUMBELLIDAE	*Mitrella scripta*	(Linnaeus, 1758)						UAC	UMC, I
		COSTELLARIIDAE	*Vexillum ebenus*	(Lamarck, 1811)							UMC, I
			Vexillum savignyi	(Payraudeau, 1826)							UMC
		MARGINELLIDAE	*Volvarina mitrella*	(Risso, 1826)							UMC, I
		TURRIDAE	*Haedropleura septangularis*	(Montagu, 1803)	W776		UBBC	UBGC			
			Mangelia attenuata	(Montagu, 1803)	W797		UBBC, I	UBGC, I			

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			Mangelia brachystoma	(Philippi, 1844)	W0798	UKC					
			Mangelia coarctata	(Forbes, 1840)	W804		UBBC, I				
			Clathromangelia quadrillum	(Dujardin, 1837)							UMI
			Comarmondia gracilis	(Montagu, 1803)	W831		UBBC	UBGC, I			
			Haedropleura secalina	(Philippi, 1844)							UMC, I
			Mitrolumna olivoidea	(Cantraine, 1835)						UAC	UMI
			Raphitoma linearis	(Montagu, 1803)	W0861	UKC				UAC	
			Mangelia nebula	(Montagu, 1803)						UAI	
			Raphitoma bicolor	(Risso, 1826)						UAC	
			Raphitoma purpurea	(Montagu, 1803)	W0862	UKI				UAC	
	HETEROSTROPHA	RISSOELLIDAE	*Rissoella opulina*	(Jeffreys, 1848)	W894		UBBC		USC	UAC	
		PYRAMIDELLIDAE	*Odostomia turrita*	Hanley, 1844	W0915	UKI, C					
			Branchystomia eulimoides	(Hanley, 1844)	W0922	UKC					
			Brachystomia scalaris	(Macgillivray, 1843)	W925				USC		
			Odostomia conoidea	(Brocchi, 1814)							UMC
			Chrysallida decussata	(Montagu, 1803)	W0933	UKC					
			Chrysallida indistincta	(Montagu, 1808)	W0935	UKC					
			Chrysallida intersincta	(J Adams, 1797)	W0937	UKC					
			Ondina divisa	(J Adams, 1797)	W0960	UKC					
			Partulida pellucida	(Dillwyn, 1817)	W0965	UKC					
			Noemiamea dolioliformis	(Jeffreys, 1848)						UAC	
			Turbonilla sp.							UAI, C	
			Turbonilla lactaea	(Linnaeus, 1758)	W971		UBBI	UBGC, I	USC		
	CEPHALASPIDA	SCAPHANDRIDAE	*Scaphander lignarius*	(Linnaeus, 1758)	W1019	UKC	UBBC		USC		
		CYLICHNIDAE	*Cylichna cylindracea*	(Pennant, 1777)	W1028	UKC	UBBC		USC		
		PHILINIDAE	*Philine aperta*	(Linnaeus, 1767)	W1038	UKC					
			Philine punctata	(J Adams, 1800)	W1043	UKC					
		DIAPHANIDAE	*Diaphana minuta*	Brown, 1827	W1059	UKC					
		HAMINOEIDAE	*Haminoea hydatis*	(Linnaeus, 1758)							UMC, I
		RETUSIDAE	*Retusa mamillata*	(Philippi, 1836)						UAC	
			Retusa truncatula	(Bruguiere, 1792)	W1080	UKC					
	SACOGLOSSA	ELYSIIDAE	*Elysia viridis*	(Montagu, 1804)	W1118	UKC					
	ANASPIDEA	APLYSIIDAE	*Aplysia punctata*	Cuvier, 1803	W1152	UKI, C				•	
	NOTASPIDEA	PLEUROBRANCHIDAE	*Pleurobranchus membranaceus*	(Montagu, 1815)	W1157	UKC					
			Berthella plumula	(Montagu, 1803)	W1159				USC / USI		

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			Berthelina citrina	(Rüppell & Leuckart, 1828)	W1162		UBBC, I		USC / USI		
	NUDIBRANCHIA		Nudibranchia indet.				UBBC, I				
		TRITONIIDAE	*Tritonia plebeia*	Johnston, 1828	W1254	UKC					
		LOMANOTIDAE	*Lomanotus marmoratus*	(Alder & Hancock, 1845)	W1258	UKC					
		DOTIDAE	*Doto coronata*	(Gmelin, 1791)	W1272	UKI, C					
			Doto fragilis	(Forbes, 1838)	W1277	UKI, C					
		ONCHIDORIDIDAE	*Onchidoris bilamellata*	(Linnaeus, 1767)	W1322	UKI, C					
			Onchidoris muricata	(O F Muller, 1776)	W1325	UKI, C					
		POLYCERIDAE	*Polycera quadrilineata*	(O F Muller, 1776)	W1350	UKI, C					
			Limacia clavigera	(O F Muller, 1776)	W1354	UKC					
		DORIDIDAE	*Doris* sp.	Linnaeus, 1758	W1371				USC / USI		
		ARCHIDORIDIDAE	*Archidoris pseudoargus*	(Rapp, 1827)	W1376	UKI, C					
		FLABELLINIDAE	*Coryphella lineata*	(Loven, 1846)	W1419	UKC					
			Coryphella verrucosa	(M Sars, 1829)	W1422	UKC					
			Flabellina sp.							UAC	
			Flabellina pedata	(Montagu, 1815)	W1424	UKC					
		TERGIPEDIDAE	*Catriona gymnota*	(Couthouy, 1838)	W1430	UKC					
			Cuthona caerulea	(Montagu, 1804)	W1434	UKC					
		EUBRANCHIDAE	*Eubranchus* sp.A	Forbes, 1838	W1445	UKC					
			Eubranchus tricolor	Forbes, 1839	W1450	UKC					
		FACELINIDAE	*Facelina auriculata*	(O F Muller, 1776)	W1469	UKC					
			Facelina bostoniensis	(Couthouy, 1838)	W1470	UKI, C					
		AELODIIDAE	*Aeolidia papillosa*	(Linnaeus, 1761)	W1484	UKC	UBBC, I		USC / USI		
	SCAPHOPODA	SIPHONODENTALIIDAE	*Cadulus jeffreysi*	(Monterosato, 1875)						UAI	
			Dentalium novemcostatum	Lamarck, 1838					USC / USI		
			Dentalium novemcostatum	Lamarck, 1838			UBBC, I				
		DENTALIIDAE	*Antalis entalis*	(Linnaeus, 1778)	W1519	UKC		UBGC	USC / USI		
			Dentalium vulgare	da Costa, 1778						UAI, C	
			Dentalium panormum	Chenu, 1842						UAI	
	NUCULOIDA	SOLEMYIDAE	*Solemya togata*	(Poli, 1795)							UMC
		NUCULIDAE	*Nucula hanleyi*	Winckworth, 1931	W1568			UBGI			
			Nucula nitidosa	Wincworth, 1930	W1569		UBBC			UAI	UMC
			Nucula nucleus	(Linnaeus, 1758)	W1570	UKI, C	UBBC, I	UBGC, I			
	ARCOIDA	ARCIDAE	*Arca noae*	Linnaeus, 1758						UAC	UMI
			Arca tetragona	Poli, 1795						UAI, C	

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			Barbatia barbata	(Linnaeus, 1758)						UAC	
		NOETIDAE	*Striarca lactea*	(Linnaeus, 1758)							UMC
		GLYCYMERIDIDAE	*Glycymeris glycymeris*	(Linnaeus, 1758)	W1688	UKI, C	UBBC	UBGC, I	USC / USI	UAC	UMC, I
	MYTILOIDA	MYTILIDAE	*Gregariella subclavata*	(Libassi, 1859)						UAI	
			Lithophaga lithophaga	(Linnaeus, 1758)						UAI, C	
			Mytilus edulis	~~(~~Linnaeus, 1758~~)~~	W1695	UKI, C					
			Modiolus adriaticus	(Lamarck, 1819)	W1700		UBBC, I	UBGI	USC / USI	UAI	UMC
			Modiolus barbatus	(Linnaeus, 1758)	W1701		UBBC, I		USI		
			Modiolus modiolus	(Linnaeus, 1758)	W1702	UKI, C			USC / USI		
			Modiolarca tumida	(Hanley, 1843)	W1718	UKC					
			Modiolus sp.				UBBC				
	LIMOIDA	LIMIDAE	*Limaria inflata*	Link, 1807						UAI, C	
			Limatula gwyni	(Sykes, 1903)						UAI, C	
			Limaria hians	(Gmelin, 1791)	W1741	UKC					
			Limatula subauriculata	(Montagu, 1808)	W1746	UKC				UAI	UMC, I
			Limatula sulcata	(Brown, 1827)	W1748	UKC					
	OSTREOIDA	OSTREIDAE	*Ostrea edulis*	Linnaeus, 1758	W1758		UBBC				
		PECTINIDAE	*Chlamys flexuosa*	(Poli, 1795)						UAI, C	UMC, I
			Lissopecten hyalinus	(Poli, 1795)							UMC, I
			Palliolum incomparabile	(Risso, 1826)							UMC
			Pecten jacobeus	(Linnaeus, 1758)						UAI, C	
			Pecten maximus	(Linnaeus, 1758)	W1771	UKI, C	UBBC, I	UBGC, I	USC		
			Aequipecten opercularis	(Linnaeus, 1758)	W1773	UKI, C	UBBC		USC		UMC
			Chlamys distorta	(da Costa, 1778)	W1776		UBBC		USC		
			Chlamys varia	(Linnaeus, 1758)	W1779	UKI, C	UBBC, I		USC	UAC, I	UMC
			Palliolum tigerinum	(O F Muller, 1776)	W1786	UKI, C				UAC	
			Anomia ephippium	Linnaeus, 1758	W1807		UBBC, I	UBGC, I		UAC	UMI
		AN~~Y~~OMIIDAE	*Heteranomia squamula*	(Linnaeus, ~~[illegible]~~ 1758)	W1809	UKI, C					
			Pododesmus patelliformis	(Linnaeus, ~~1758)~~ 1761)	W1814	UKI, C	UBBC, I		USI		
	VENEROIDA	LUCINIDAE	*Ctena decussata*	(Costa O.G., 1829)							UMI
			Lucinoma borealis	(Linnaeus, 1767)	W1829	UKI, C	UBBI		USC / USI		
			Lucinella divaricata	(Linnaeus, 1758)	W1832		UBBC, I				
		THYASIRIDAE	*Thyasira flexuosa*	(Montagu, 1803)	W1837	UKI, C	UBBC, I	UBGC, I	USI		

PHYLUM	CLASS: ORDER	FAMILY	Species	Authority	Code	Clyde	Brest	Glenan	Galicia	Alicante	Malta
		NEOLEPTONIDAE	*Neolepton sulcatulum*	(Jeffreys, 1859)							UMC
		GALEOMMATIDAE	*Kellia suborbicularis*	(Montagu, 1803)	W1875	UKC					UMC
			Semierycina nitida	(Turton, 1822)	W1882	UKC					
		MONTACUTIDAE	*Devonia perrieri*	(Malard, 1904)	W1898		UBBC, I	UBGC	USC / USI		
			Tellimya ferruginosa	(Montagu, 1808)	W1902		UBBC, I		USC / USI		
			Mysella bidentata	(Montagu, 1803)	W1906	UKC	UBBC, I	UBGC	USC / USI		
		ASTARTIDAE	*Astarte fusca*	(Poli, 1795)						UAI, C	UMC, I
			Digitaria digitaria	(Linnaeus, 1758)							UMC, I
			Gonilia calliglypta	(Dall, 1903)							UMC, I
			Goodalia triangularis	(Montagu, 1803)	W1929	UKI, C			USC		
			Tridonta montagui	(Dillwyn, 1817)	W1936	UKC					
		CARDITIDAE	*Glans trapezia*	(Linnaeus, 1758)							UMC, I
			Pteromeris minuta	(Scacchi, 1836)							UMC, I
			Venericardia antiquata	(Linnaeus, 1758)							UMC
			Acanthocardia echinata	(Linnaeus, 1758)	W1943	UKC	UBBC	UBGC			
			Acanthocardia paucicostata	(G. B. Sowerby II, 1834)	W1944		UBBC				
			Parvicardium exiguum	(Gmelin, 1791)	W1949		UBBC, I	UBGI	USC	UAC	
			Parvicardium minimum	(Philippi, 1836)	W1950		UBBC, I		USC / USI		
			Parvicardium ovale	(G B Sowerby, 1840)	W1951	UKI, C	UBBC, I	UBGC, I	USC / USI		
			Parvicardium scabrum	(Philippi, 1844)	W1952	UKI, C	UBBC		USC		
			Acanthocardia aculeata	(Linnaeus, 1758)						UAI	
			Plagiocardium papillosum	(Poli, 1795)	W1955		UBBC			UAI, C	
			Laevicardium crassum	(Gmelin, 1791)	W1959	UKI, C	UBBC	UBGC, I	USC	UAI, C	
			Cerastoderma edule	(Linnaeus, 1758)	W1961				USC		
		MACTRIDAE	*Spisula elliptica*	(Brown, 1827)	W1975	UKC					
			Mactra stultorum	(Linnaeus, 1758)						UAC	
			Spisula subtruncata	(da Costa, 1778)	W1978			UBGC			
			Lutraria angustior	Philippi, 1844	W1983	UKI, C					
		PHARIDAE	*Ensis arcuatus*	(Jeffreys, 1865)	W1998	UKI, C					
			Ensis ensis	(Linnaeus, 1758)	W1999				USC / USI		
			Phaxas adriaticus.	(Coen, 1933)						UAI	
			Phaxas pellucidus	(Pennant, 1777)	W2006		UBBC	UBGC, I	USC / USI		
		TELLINIDAE	*Arcopagia crassa*	(Pennant, 177)	W2015	UKI		UBGC, I			
			Acropella balaustina	(Linnaeus, 1758)	W2017	UKC					UMC, I
			Moerella donacina	(Linnaeus, 1758)	W2021	UKI, C	UBBC	UBGC, I		UAI	

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			Tellina pygmaea	Lovén, 1846							UMI
			Tellina pulchella	Lamarck, 1818						UAI	
		DONACIDAE	*Donax variegatus*	(Gmelin, 1791)						UAI	
		PSAMMOBIIDAE	*Gari depressa*	(Pennant, 1777)	W2046		UBBC	UBGC, I	USC / USI		
			Gari tellinella	(Lamarck, 1818)	W2049	UKI	UBBC	UBGC, I	USC / USI		
		SEMELIDAE	*Abra alba*	(W Wood, 1802)	W2059	UKC	UBBC, I	UBGI			
		VENERIDAE	*Pitar rudis*	(Poli, 1795)						UAI	
			Venus verrucosa	Linnaeus, 1758	W2089		UBBC, I		USC	UAC	
			Circomphalus casina	(Linnaeus, 1758)	W2091	UKI, C		UBGC			
			Gouldia minima	(Montagu, 1803)	W2095	UKI, C	UBBC, I	UBGC, I	USC	UAC	UMC
			Chamelea gallina	(Linnaeus, 1758)	W2098		UBBC	UBGC, I	USC	UAC	
			Clausinella brongniartii	(Payraudeau, 1826)						UAI	UMC, I
			Clausinella fasciata	(da Costa, 1778)	W2100	UKI, C	UBBC, I	UBGC, I	USC / USI	UAI	
			Timoclea ovata	(Pennant, 1777)	W2104	UKI, C	UBBC	UBGC, I	USC		
			Tapes aureus	(Gmelin, 1791)	W2112		UBBC, I		USC		
			Tapes rhomboides	(Pennant, 1777)	W2113	UKI, C	UBBC	UBGC, I	USC / USI	UAI	
			Venerupis senegalensis	(Gmelin, 1791)	W2124	UKI, C	UBBC		USC		
			Dosinia lupinus	(Linnaeus, 1758)	W2128			UBGC	USC / USI		
			Dosinia exoleta	(Linnaeus, 1758)	W2130	UKI, C	UBBC	UBGC, I	USC / USI		
		CHAMIDAE	*Chama gryphoides*	Linnaeus, 1758						UAC	
			Pseudochama gryphina	(Lamarck, 1819)							UMI
	MYOIDA	MYIDAE	*Mya truncata*	(Linnaeus, 1758)	W2147	UKI, C					
		CORBULIDAE	*Corbula gibba*	(Olivi, 1792)	W2157		UBBC, I	UBGC, I	USC / USI	UAI	
	HIATELLACEA	HIATELLIDAE	*Hiatella arctica*	(Linnaeus, 1767)	W2166	UKI, C	UBBC, I	UBGC, I	USC / USI		UMI
	PHOLADOMYOIDA	THRACIIDAE	*Thracia phaseolina*	(Lamarck, 1818)	W2231		UBBC	UBGC, I	USC / USI		
			Thracia convexa	(Wood W., 1815)							UMI
			Thracia distorta	(Montagu, 1803)							UMC, I
			Thracia papyracea	(Poli, 1791)							UMC
			Thracia villosiuscula	(Macgillivray, 1827)	W2233	UKI, C					
		PERIPLOMATIDAE	*Cochlodesma praetenue*	(Pulteney, 1799)	W2239	UKI, C					
	PHOLADOMYOIDA	LYONSIIDAE	*Lyonsia norwegica*	(Gmelin, 1791)	W2247		UBBC	UBGC, I	USC		
	CEPHALOPODA	SEPIIDAE	*Sepia officinalis*	Linnaeus, 1758	W2307						UMI
		SEPIOLIDAE	*Sepiola atlantica*	Orbigny in Ferussac & Orbigny, 1840	W2329	UKI, C					
		LOLIGINIDAE	*Loligo vulgaris*	Lamarck, 1798						UAC	
		OCTOPODIDAE	*Eledone cirrhosa*	(Lamarck, 1798)	W2398	UKC					

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			Octopus vulgaris	Cuvier, 1797						UAI, C	UMI
BRACHIOPODA	ARTICULATA	MEGATHYRIDIDAE	*Argyrotheca cuneata*	(Risso, 1826)							UMC, I
BRYOZOA	STENOLAEMATA	CRISIIDAE	*Crisia denticulata*	(Lamarck, 1816)	Y0016	UKC					
			Crisia eburnea	(Linnaeus, 1758)	Y0017	UKI, C					
		TUBULIPORIDAE	*Tubulipora liliacea*	(Pallas, 1766)	Y0027	UKI, C					
		LICHENOPORIDAE	*Lichenopora verrucaria*	(Fabricius, 1780)	Y0064	UKI, C					
			Disporella hispida	(Fleming, 1828)	Y0066	UKI, C					
	GYMNOLAEMATA	ALCYONIDIIDAE	*Alcyonidium diaphanum*	(Hudson, 1762)	Y0076	UKI, C					
		MEMBRANIPOROIDAE	*Membranipora membranacea*	(Linnaeus, 1767)	Y0170	UKI, C					
		ELECTRIDAE	*Electra pilosa*	(Linnaeus, 1767)	Y0178	UKI, C					
		CALLOPORIDAE	*Callopora* sp.A	J E Gray, 1848	Y0201	UKI					
			Cauloramphus spiniferum	(Johnston, 1832)	Y0212	UKC					
		BUGULIDAE	*Bugula flabellata*	(Thompson in Gray, 1848)	Y0243	UKC					
		CANDIDAE	*Scrupocellaria* sp.A	van Beneden, 1845	Y0274	UKI, C					
			Scrupocellaria reptans	(Linnaeus, 1767)	Y0276	UKC					
		CELLARIIDAE	*Cellaria sinuosa*	(Hassall, 1840)	Y0302	UKC					
			sp.A		Y0306	UKC					
		HIPPOTHOIDAE	*Celleporella hyalina*	(Linnaeus, 1767)	Y0337	UKC					
		ESCHARELLIDAE	sp.A		Y0361	UKC					
		SCHIZOPORELLIDAE	*Cryptosula pallasiana*	(Moll, 1803)	Y0411	UKI, C					
		STOMACHETOSELLIDAE	*Stomachetosella sinuosa*	(Busk, 1860)	Y0448	UKI, C					
		SMITTINIDAE	*Parasmittina trispinosa*	(Johnston, 1838)	Y0465	UKI					
		MICROPORELLIDAE	*Microporella ciliata*	(Pallas, 1766)	Y0480	UKI, C					
		CELLEPORIDAE	*Cellepora pumicosa*	(Pallas, 1766)	Y0495	UKC					
			Celleporina ?caminata	(Waters, 1879)							UMC, I
			Cigclisula turrita	Smitt, 1873							UMC, I
		CLEIDOCHASMATIDAE	*Hagiosynodus latus*	(Busk, 1856)							UMC, I
		LICHENOPORIDAE	*Lichenopora radiata*	(Auduoin, 1826)							UMC, I
		MICROPORIDAE	*Micropora* sp								UMC, I
		RETEPORIDAE	*Rhynchozoon* sp.								UMC, I
			Sertella ?sudbourniensis	(Gautier, 1962)							UMC, I
		SCHIZOPORELLIDAE	*Schizoporella* sp.							UAI, C	UMC, I
	CTENOSTOMATA		*Beania histissima*	(Heller, 1867)						UAI, C	
			Cellaria salicornoides	Audouin, 1826						UAI, C	
			Myriapora truncata	(Pallas, 1766)						UAI, C	

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			Pentapora fascialis	(Pallas, 1766)						UAI, C	
			Scrupocellaria scrupea	Busk, 1851						UAI, C	
			Margaretta cereoides	Ellis & Solander, 1786						UAI	
			Amathia sp.							UAC	
			Calpensia nobilis	Esper, 1796						UAC	
	CHEILOSTOMATA: ANASCA									UAC	
	CHEILOSTOMATA: ASCOPHORA									UAC	
			Sertella septentrionalis	(Harmer, 1933)						UAC	
PHORONIDA		PHORONIDAE	*Phoronis hippocrepia*	Wright, 1856	ZA0004	UKI, C					
			Phoronis muelleri	Selys-Longchamps, 1903	ZA0005	UKI, C					
			Phoronis psammophila	Cori, 1889	ZA8		UBBC, I				UMC
			Phoronis sp.				UBBC				
ECHINODERMATA	CRINOIDEA	ANTEDINIDAE	*Antedon bifida*	(Pennant, 1777)	ZB0010	UKI, C			USC		
			Antedon mediterranea	(Lamarck, 1816)						UAC	UMC, I
	ASTEROIDEA	LUIDIIDAE	*Luidia ciliaris*	(Philippi, 1837)	ZB0022	UKI, C	UBBC		USC		UMI
		ASTROPECTINIDAE	*Astropecten irregularis*	(Pennant, 1777)	ZB0026	UKI, C					
			Astropecten aranciacus	(Linnaeus, 1758)						UAC	UM?
		PORANIIDAE	*Porania pulvillus*	(O F Muller, 1776)	ZB0054	UKI, C					
		ASTERINIDAE	*Asterina gibbosa*	(Pennant, 1777)	ZB59		UBBI				
			Anseropoda placenta	(Pennant, 1777)	ZB62		UBBC	UBGC	USC		
		SOLASTERIDAE	*Solaster endeca*	(Linnaeus, 1771)	ZB0072	UKI, C					
			Crossaster papposus	(Linnaeus, 1767)	ZB0075	UKI, C					
		ECHINASTERIDAE	*Echinaster sepositus*	(Retzius, 1783)						UAI, C	UMC
			Henricia oculata	(Pennant, 1777)	ZB0082	UKI, C					
			Henricia sanguinolenta	(O F Müller, 1776)	ZB86		UBBC	UBGC, I	USC		
		ASTERIIDAE	*Asterias rubens*	Linnaeus, 1758	ZB0100	UKI, C	UBBC		USC / USI		
			Marthasterias glacialis	(Linnaeus, 1758)	ZB0104	UKI, C	UBBC, I	UBGC, I	USC / USI	UAC	UMI
	OPHIUROIDEA	OPHIOMYXIDAE	*Ophiomyxa pentagona*	(Lamarck, 1816)						UAI, C	
		OPHIOTRICHIDAE	*Ophiothrix fragilis*	(Abildgaard, 1789)	ZB0124	UKI, C	UBBC, I		USC / USI	UAC	
			Ophiura grubei	Heller, 1863						UAI, C	
			Ophiura sp.	Lamarck, 1816						UAC	
			Ophiura ophiura	H.L Clark, 1915						UAC	
			Ophiuridae							UAC	
		OPHIOCOMIDAE									

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		OPHIODERMATIDAE	*Ophioconis forbesi*	(Heller, 1863) Carus, 1885						UAI, C	
		OPHIACTIDAE	*Ophiopholis aculeata*	(Linnaeus, 1767)	ZB0147	UKI, C					
		OPHIUROIDAE	*Amphiura filiformis*	(O F Müller, 1776)	ZB154		UBBC		USC / USI	UAC	
			Amphiura securigera	(Duben & Koren, 1844)	ZB0157	UKI, C					
			Amphiura chiajei	Forbes, 1843						UAI, C	
			Amphiura sp.2	Lyman, 1882						UAC	
			Amphiura sp.3	Lyman, 1882						UAC	
			Amphipholis squamata	(Chiaje, 1829)	ZB0161	UKI, C	UBBC, I		USC / USI	UAI, C	UMC, I
			Amphiura sp.1	Cherbonnier, 1958?						UAC	
			Ophiura albida	Forbes, 1839	ZB0168	UKI, C	UBBC, I			UAI, C	
	ECHINOIDEA	CIDARIDAE	*Stylocidaris affinis*	(Philippi, 1845)							UMC, I
		TEMNOPLEURIDAE	*Genocidaris maculata*	A. Agassiz, 1869						UAI, C	UMC, I
		NEOLAMPADIDAE	*Neolampas rostellata*	A. Agassiz, 1869							UMC
		PARECHINIDAE	*Psammechinus miliaris*	(Gmelin, 1778)	ZB0193	UKI, C	UBBC, I	UBGC, I	USC		
		ECHINIDAE	*Echinus esculentus*	Linnaeus, 1758	ZB0198	UKI, C	UBBC	UBGC			
			Paracentrotus lividus	(Lamarck, 1816)	ZB202		UBBC I	UBGC	USC / USI		
		TOXOPNEUSTIDAE	*Sphaerechinus granularis*	(Lamarck, 1816)	ZB208		UBBC, I	UBGC, I	USC	UAI, C	
		FIBULARIIDAE	*Echinocyamus pusillus*	(O F Muller, 1776)	ZB0212	UKI, C	UBBC	UBGC, I	USC / USI	UAI, C	UMC, I
		SPATANGIDAE	*Spatangus purpureus*	O F Müller, 1776	ZB219			UBGC, I	USC	UAI, C	
		LOVENIIDAE	*Echinocardium cordatum*	(Pennant, 1777)	ZB223			UBGC, I	USC / USI		
			Echinocardium pennatifidum	Norman, 1868	ZB0225	UKI, C					
		BRISSIDAE	*Brissus unicolor*	(Leske, 1778)						UAC	
			Plagiobrissus costai	(Gasco, 1876)							UMC
	HOLOTHUROIDEA	HOLOTHURIIDAE	*Holothuria tubulosa*	Gmelin, 1788						UAI, C	
			Holothuria impatiens	(Forskal, 1775)						UAC	
		PHYLLOPHORIDAE	*Neopentadactyla mixta*	(Ostergren, 1898)	ZB0260	UKI					
			Thyone fusus	(O F Muller, 1776)	ZB0262	UKI, C	UBBC, I	UBGC			
		CUCUMARIIDAE	*Ocnus planci*	(Brandt, 1835)	ZB0276	UKC					
			Aslia lefevrei	(Barrois, 1882)	ZB278				USC / USI		
			Leptopentacta elongata	(Duben & Koren, 1845)	ZB280		UBBC, I		USC / USI		
			Thyonidium drummondi	(Thompson, 1840)	ZB0282	UKC					
		SYNAPTIDAE	*Leptosynapta inhaerens*	(O F Muller, 1776)	ZB0296	UKI, C	UBBC, I		USC / USI		
			Labidoplax digitata	(Montagu, 1815)	ZB300		UBBC, I	UBGC, I	USC		
			Labidoplax media	(Ostergren, 1905)	ZB0301	UKC					
CEPHALOCORDATA			*Branchiostoma lanceolatum*	(Pallas, 1776)				UBGC	USC / USI	UAC	UMC, I

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TUNICATA			*Ascidia* sp.								UMI
			Cystodytes dellechiajei	(Della Valle, 1877)							UMI
			Diplosoma sp.								UMC
			Polycarpa mamillaris	(Gaertner, 1774)						UAI, C	
			Polysyncraton bilobatum	Lafargue, 1968						UAC	
	ASCIDIACEA	CLAVELINIDAE	*Clavelina lepadiformis*	(O F Muller, 1776)	ZD0007	UKC					
			Didemnum coriaceum	(Drasche, 1883)						UAI, C	UMI
			Didemnum fulgens	(Milne Edwards, 1841)						UAC	
		DIDEMNIDAE	*Diplosoma listerianum*	(Milne-Edwards, 1841)	ZD0059	UKI, C					
		CIONIDAE	*Ciona intestinalis*	(Linnaeus, 1767)	ZD0071	UKI, C	UBBC, I	UBGI	USC		
			Rhopalaea neapolitana	Philippi, 1843						UAC	
		CORELLIDAE	*Corella parallelogramma*	(O F Muller, 1776)	ZD0081	UKI, C					
		ASCIDIIDAE	*Ascidiella aspersa*	(O F Muller, 1776)	ZD0084	UKI, C	UBBC, I	UBGC	USC / USI		
			Ascidiella scabra	(O F Muller, 1776)	ZD0085	UKI, C					
			Ascidia mentula	O F Muller, 1776	ZD0089	UKC					UMC
			Ascidia virginea	O F Muller, 1776	ZD0092	UKC					
			Phallusia mammillata	(Cuvier, 1815)	ZD95		UBBC, I		USC	UAI, C	
		STYELIDAE	*Dendrodoa grossularia*	(Van Beneden, 1846)	ZD0120	UKI, C					
			Botryllus schlosseri	(Pallas, 1766)	ZD0126	UKI, C				UAC	
		PYURIDAE	*Halocynthia papillosa*	(Linnaeus, 1767)							UMI
			Pyura microcosmus	(Savigny, 1816)						UAC	
			Microcosmus claudicans	(Savigny, 1816)							UMI
			Pyura tessellata	(Forbes, 1848)	ZD141		UBBC, I	UBGC	USC		
		MOLGULIDAE	*Molgula occulta*	Kupffer, 1875	ZD0152	UKI					

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CHORDATA	CARCHARHINIFORMES	SCYLIORHINIDAE	*Scyliorhinus canicula*	(Linnaeus, 1758)	ZF28	UKI, C					
			Scyliorhinus stellaris	(Linnaeus, 1758)	ZF28						UMC
		TRIAKIDAE	*Mustelus mustelus*	(Linnaeus, 1758)	ZF37						UMI
	SQUALIFORMES	OXYNOTIDAE	*Squalus acanthias*	Linnaeus, 1758	ZF66	UKI					
	TORPENIDIFORMES	TORPEDINIDAE	*Torpedo marmorata*	Risso, 1810	ZF77					UAI	
	ANGUILLIFORMES	MURAENIDAE	*Muraena helena*	Linnaeus, 1758	ZG13					UAC	
		CONGRIDAE	*Conger conger*	(Linnaeus, 1758)	ZG17		UBBC				
	AULOPIFORMES	AULOPODIDAE	*Aulopus filamentosus*	(Bloch, 1792)	ZG74					UAI	
	GOBIESOCIFORMES	GOBIESOCIDAE	*Diplecogaster bimaculata*	(Bonnaterre, 1788)	ZG86	UKI					
			Lepadogaster lepadogaster	(Bonnaterre, 1788)	ZG89		UBBC		USC		
			Lepadogaster sp.1	(Bonnaterre, 1788)	ZG89	UKI	UBBC, I	UBGC, I			
	LOPHIIFORMES	LOPHIIDAE	*Lophius piscatorius*	(Linnaeus, 1758)	ZG94	UKI					
	GADIFORMES	GADIDAE	*Gadus morhua*	Linnaeus, 1758	ZG116	UKI, C					
			Gaidropsarus sp.1	Rafinesque-Schmaltz, 1810	ZG117	UKI					
			Pollachius pollachius	(Linnaeus, 1758)	ZG135	UKI, C					
			Pollachius virens	(Linnaeus, 1758)	ZG136	UKI, C					
	OPHIDIIFORMES	CARAPIDAE	*Carapus acus*	(Brunnich, 1768)	ZG172					UAI, C	
	GASTEROSTEIFORMES	GASTEROSTEIDAE	*Spinachia spinachia*	(Linnaeus, 1758)	ZG230	UKI					
	SYNGNATHIFORMES	SYNGNATHIDAE	*Hippocampus hippocampus*	(Linnaeus, 1758)	ZG239					UAC	UMC
			Nerophis lumbriciformis	(Jenyns, 1835)	ZG242	UKI					
			Nerophis ophidion	(Linnaeus, 1758)	ZG243		UBBC, I		USC		
			Syngnathus acus	Linnaeus, 1758	ZG245	UKI					
			Syngnathus typhle	Linnaeus, 1758	ZG247		UBBC, I		USC		
	SCORPANEIFORMES	SCORPAENIDAE	*Scorpaena notata*	Rafinesque, 1810	ZG252					UAC	UMI
			Scorpaena sp.		ZG252						UMC
		TRIGLIDAE	*Aspitrigula cuculus*	Linnaeus, 1758	ZG262	UKC					
			Trigloporus lastoviza	(Brünnich, 1768)	ZG271					UAC	
		COTTIDAE	*Myoxocephalus scorpius*	Linnaeus, 1758	ZG281	UKI, C					
			Taurulus bubalis	(Euphrasen, 1786)	ZG283		UBBC, I		USC		
			Agonus cataphractus	(Linnaeus, 1758)	ZG291	UKI					

PHYLUM	CLASS: ORDER	FAMILY	Species	Authority	Code	Clyde	Brest	Glenan	Galicia	Alicante	Malta
		CYCLOPTERIDAE	*Cyclopterus lumpus*	Linnaeus, 1758	ZG294	UKC					
			Liparis sp.1	Scolopi, 1777	ZG295	UKI, C					
			Monochirus hispidus	Rafinesque, 1814							UMI
	DACTYLOPTERIFORMES	DACTYLOPTERIDAE	*Dactylopterus volitans*	(Linnaeus, 1758)	ZG300						UMI
	PERCIFORMES	SERRANIDAE	*Serranus hepatus*	(Linnaeus, 1758)	ZG307					UAC	
			Serranus cabrilla	(Linnaeus, 1758)	ZG308					UAC	
		CARANGIDAE	*Seriola dumerili*	(Risso, 1810)	ZG332					UAI	
		SPARIDAE	*Diplodus vulgaris*	(E. Geoffrey St. Hilaire, 1817)	ZG348						UMI
			Boops boops	(Linnaeus, 1758)	ZG350					UAC	
			Pagellus erythrinus	(Linnaeus, 1758)	ZG354					UAC	
			Pagrus pagrus	(Linnaeus, 1758)	ZG362						UMC
			Spondyliosoma cantharus	(Linnaeus, 1758)	ZG363					UAI, C	
		MULLIDAE	*Mullus surmuletus*	Linnaeus, 1758	ZG373						UMC, I
		LABRIDAE	*Coris julis*	(Linnaeus, 1758)	ZG391					UAC	UMC
			Ctenolabrus sp.	Valenciennes,1839	ZG396		UBBC, I		USC		
		TRACHINIDAE	*Trachinus* sp.		ZG401						UMI
			Trachinus draco	Linnaeus, 1758	ZG402					UAI	
			Echiichthys vipera	Cuvier, 1829	ZG404						UMI
		BLENNIIDAE	*Blennius ocellaris*	Linnaeus, 1758	ZG407					UAC	
			Lipophrys pholis	(Linnaeus, 1758)	ZG412	UKI	UBBC		USC		
		STICHAEIDAE	*Chirolophis ascani*	(Walbaum, 1792)	ZG425	UKC					
		PHOLIDIDAE	*Pholis gunnellus*	(Linnaeus, 1758)	ZG440	UKI, C					
		AMMODYTIDAE	*Ammodytes marinus*	Raitt, 1934	ZG443	UKI					
			Ammodytes tobianus	Linnaeus, 1758	ZG444	UKI					
		CALLIONYMIDAE	*Callionymus lyra*	Linnaeus, 1758	ZG452	UKI, C	UBBC, I	UBGC, I	USC / USI		
			Callionymus maculatus	Rafinesque-Schmaltz, 1810	ZG453	UKI					
			Callionymus reticulatus	Valenciennes, 1837	ZG454	UKI, C					
		GOBIIDAE	*Gobius* sp.		ZG462		UBBC, I				

PHYLUM	CLASS: ORDER	FAMILY	Species	Authority	Code	Clyde	Brest	Glenan	Galicia	Alicante	Malta
			Gobidae sp.		ZG462					UAI, C	
			Vanneaugobius pruvoti	(Fage, 1907)						UAI	
			Gobiusculus flavescens	(Fabricius, 1779)	ZG470	UKI					
			Pomatoschistus pictus	(Malm, 1865)	ZG481	UKI, C					
			Thorogobius sp.		ZG482					UAC	
		SCOMBRIDAE	*Scomber scombrus*	Linnaeus, 1758	ZG511	UKI, C					
	PLEURONECTOFORMES	SCOPHTHALMIDAE	*Phrynorhombus norvegicus*	(Gunther, 1862)	ZG551	UKI					
		BOTHIDAE	*Arnoglossus* sp.		ZG560					UAI	
		PLEURONECTIDAE	*Microstomus kitt*	(Walbaum, 1792)	ZG574	UKI					
			Pleuronectes platessa	Linnaeus, 1758	ZG578	UKI, C					
		SOLEIDAE	*Buglossidium luteum*	(Risso, 1810)	ZG585		UBBC		USC		
	AVES	PHALACROCORACIDAE	*Phalacrocorax aristotelis*	Linnaeus, 1761	ZJ0056	UKI, C					
			Phalacrocorax carbo	(Linnaeus, 1758)	ZJ0058	UKI, C					
		SULIDAE	*Morus bassanus*	(Linnaeus, 1758)	ZJ0061	UKI, C					
	MAMMALIA	PHOCIDAE	*Halichoerus grypus*	(Fabricius, 1791)	ZK0015	UKI, C					
		DELPHINIDAE	*Delphinus delphis*	Linnaeus, 1761	ZK0026	UKC					
		PHOCOENIDAE	*Phocoena phocoena*	(Linnaeus, 1758)	ZK0042	UKI					

Interpretation of species inventory (biogeography)

The corallines *Phymatolithon calcareum*, *Lithothamnion corallioides* and *L.minervae* are important maerl-constituent species in the Atlantic and in the Mediterranean. Interestingly, however, only *Dictyota dichotoma* figures as an important non-coralline algal species on maerl grounds in both provinces. Equally, among the animals, only a few species like *Echinocyamus pusillus* and *Galathea intermedia* were present at all BIOMAERL sites investigated.

To understand properly the geographical distribution of marine species on the European continental shelf, it is necessary to consider their latitudinal and bathymetric distributions simultaneously. Thus, some species of cold-water origin can reach lower latitudes by going deeper (submergence) while, conversely, warm-water species emerge with increasing latitude (Glémarec, 1988). For maerl beds, these processes are minimized since these unique biotopes are located in the upper subtidal (circalittoral) zone where light is sufficient for photosynthesis.

Present-day distribution must also take into account recent Quaternary events, like the recolonization of the Mediterranean by the Atlantic fauna, but it is still possible to recognize geographical 'contingent' (Glémarec, *op. cit.*) or faunal groups (Franz & Merill, 1980) which accommodate species of the same origin. Species having similar ecophysiological tolerances and temperature requirements for survival and reproduction are likely to present similar geographical distribution patterns and would belong to the same contingent. With reference to the conventional biogeographical provinces of Ekman (1953), the five BIOMAERL sites are all located in the temperate Province. However, the aim here is to identify the extent of similarities and differences between sites within this province.

Because the taxonomy and European distribution of the Bivalvia are better established than for most other groups, this taxon has been used as an example. The relative importance of the different geographical contingents at each BIOMAERL study site is shown in Table 5.1.

TABLE 5.1. The percentage of species from different biogeographical contingents at different BIOMAERL study sites. Total number of bivalve mollusc species recorded to date is given for each site.

Number of species	**UMBSM** (Total = 44)	**UBO** (Total = 46)	**USC** (Total = 49)	**UA** (Total = 35)	**UM** (Total = 32)
Arctico-boreal spp.	15		4		
Cold temperate spp.	64	62	62	17	16
Mean temperate spp.	20	36	32	37	28
Warm temperate spp.				31	28
Sub-tropical spp.				6	10
Mediterranean endemic spp.				6	12
Cosmopolitan spp.	1	2	2	3	6

The Arctico-boreal contingent made a significant contribution (15%) to the bivalve faunule at the northern site (Scotland; UMBSM), but not elsewhere. Species of this contingent can be found in the Bay of Biscay, but only at great depths offshore (consistent with the bathymetric depression of south-flowing cold water). The temperate contingent, after global warming following Quaternary glaciations, has recolonized northern Atlantic latitudes. It can be divided in three sub-groups in relation to their thermal tolerance: *viz.* i) cold-temperate species that can reach the latitude of the Lofoten Is. (Norway). This sub-group was dominant in all three Atlantic sites without any significant difference between-sites; ii) mean-temperate species extend to latitude 62-64°N, and this sub-group constituted the second-most numerous group within the BIOMAERL data set. Species of this sub-group were more numerous in Brittany and Galicia than in Scotland, and this sub-group slightly dominated the Mediterranean bivalve fauna of maerl grounds; and iii) warm-temperate species that are restricted to the Mediterranean Sea. Such species may be found on the Atlantic coasts of the Iberian peninsula (Lusitanian region), up the Basque coast. However, they were not encountered at the BIOMAERL Galician site, possibly due to the tendency for bottom-water upwelling that occurs in the Ria de

Vigo in summer (the water being then colder than elsewhere in the area). Some subtropical species and endemic species were present at the Mediterranean sites, but they were too few in number for differences between Alicante and Malta to be detectable. Actually, these two sites were very similar in terms of their bivalve composition.

Accepting that the colder-water contingent made a significant contribution in Scotland (15%); the three Atlantic sites were still quite similar. The Mediterranean sites were also characterized by the significant presence of cold-temperate species (16-17%), and their links with the Atlantic sites remain evident. This analysis therefore modulates the generally accepted concept of a latitudinal cline, in that the five BIOMAERL regions studied did not show a gradient of diversity decreasing from South to North (at least for this taxon). Similar analyses, where feasible, will be attempted for other taxa and a full assessment of biogeographical aspects of the project is planned as a future BIOMAERL team publication.

Interpretation of species inventory (biodiversity)

One of the main features that was confirmed during the BIOMAERL programme was the outstanding biodiversity (both phyletic and specific) of European maerl-bed ecosystems. The Clyde data are used here to exemplify this point since these beds have been studied for longer than those of other partners and our knowledge of them is therefore more complete. That 35 species of Cnidaria were recorded on Clyde maerl grounds serves to emphasize the wide range of microhabitats and structural heterogeneity of maerl-bed habitats. Indeed, that the biodiversity supported by the two small maerl beds (0.8ha each) investigated in the Clyde Sea represented 37% of the known macro/mega-benthic invertebrate fauna, 33% of the demersal fish fauna, and 26% of macroalgae from the entire Clyde Sea area, gives additional insight into the complexity and importance of this biotope [in a Mediterranean context, the BIOMAERL data for decapod crustaceans, molluscs and algae represented (respectively) 26%, 11% and 29% of the known fauna/flora in those taxa locally]. Moreover, notwithstanding the century of taxonomic research that has taken place in Clyde waters, investigations of the macro/mega benthos of local maerl grounds still revealed a substantial number of new records of species for the area, confirming the fact that maerl is a poorly studied ecosystem.

Previously described species recorded for the first time in the Clyde Sea area are summarized in Table 5.2. These species are all known to occur elsewhere in the British Isles, often in association with maerl or other coarse sediments in shallow water. Some of the hesionid and syllid polychaetes present are likely to be new to science (P. Garwood, pers. comm. to J.H.-S.) since these could not be identified to species using the major taxonomic works.

In terms of numerical abundance, the Annelida was the dominant phylum within sieved grab samples. Annelids, mostly polychaetes, were also impressively diverse with a total of 119 species recorded from the two Clyde maerl sites. The list is similar in composition to the Annelida recorded from maerl beds further north in western Scotland (Davies & Hall-Spencer, 1996) which is more compete than other lists derived from short-term studies of maerl fauna around the British Isles. Thus, Keegan (1974) only recorded 30 Annelida from maerl in Galway Bay, Ireland. Errant, putatively carnivorous polychaetes formed a comparatively high proportion (51%) of the total polychaete species present which can be related to the coarse nature of the sediment providing shelter and facilitating locomotion. In fine sediment, most polychaetes are deposit- or suspension-feeders. Typically, the macrobenthic biomass of marine sediments is dominated by the polychaete / bivalve fraction. By contrast, hard grounds in shallow water are more typically dominated by Algae and Crustacea.

TABLE 5.2. Total number of macro/mega benthic species previously recorded in the Clyde Sea area (only including taxa considered by BIOMAERL), number recorded in BIOMAERL study areas and new records for the area.

Phyla	No. spp. recorded in Clyde Sea area	No. spp. found on two (50m radius) maerl beds	New records for the Clyde Sea area
Porifera	34	10	
Cnidaria	72	33	*Thuiaria articulata*
Platyhelminthes	3	3	
Nemertea	24	7	
Priapulida	1	1	
Entoprocta	0	2	*Pedicellina cernua, Barentsia* sp.
Chaetognatha	0	1	*Spadella cephaloptera*
Sipunculida	1	4	*Golfingia vulgaris, Nephasoma minutum, Phascolion strombus*
Annelida	201	118	*Harmothoe ljungmani, Harmothoe mcintoshi, Mysta picta, Pseudomystides limbata, Glycera lapidum, Ephesiella abyssorum, Hesiospina similis, Trypanosyllis coeliaca, Exogone verugera, Sphaerosyllis bulbosa, Sphaerosyllis taylori, Aglaophamus rubella, Paramphinome jeffresii, Paraeurythoe borealis, Aponuphis bilineata, Eunice harassi, Nematonereis unicornis, Lumbrineris tetraura, Protodorvillea kefersteini, Schistomeringos neglecta, Aonides oxycephala, Aonides paucibranchiata, Caulleriella zetlandica, Cirriformia tentaculata, Dodecaceria concharum, Mediomastus fragilis, Polyopthalmus pictus, Amaena trilobata, Janua pagenstecheri, Paradexiospira vitrea*
Crustacea	382	96	*Conilera cylindracea, Cymodoce truncata, Leptognathia breviremis, Tanaopsis graciloides, Vaunthompsonia cristata*
Mollusca	425	137	*Lacuna crassior, Lutraria angustior, Acropella balaustina*
Bryozoa	43	22	*Tubulipora liliacea, Cauloramphus spiniferum, Bugula flabellata*
Phoronida	2	2	
Echinodermata	55	26	*Labidoplax media*
Ascidiacea	29	11	
Pisces	88	29	
Rhodophycota	128	51	*Gelidiella calcicola*
Chromophycota	69	11	
Chlorophycota	56	4	

Algae (67 spp.), Crustacea (104 spp.) and Mollusca (138 spp.) were all represented on Clyde maerl grounds by a large number of species, though the exact ratio between the four major taxa (Algae, Annelida, Crustacea, Mollusca) was a function of sieve size, since qualitative observations of <1 mm sieved fractions suggested there were a more species of very small Annelida and Crustacea than there were of Algae and Mollusca (J.H.-S., pers. obs.). Thus maerl grounds are not typical sediments, but rather are intermediate in character between sedimentary and rocky grounds harbouring taxa representative of both these habitat types.

Integrated management plan

Recommendations for maerl bed management and conservation

The sustainable utilization of resources has become a high priority in marine ecosystem management. The following management recommendations stem from the researches of the BIOMAERL programme, set against the wider context of marine conservation priorities in coastal seas:

- in the context of gravel extraction, maerl grounds should be regarded as essentially non renewable resources.
- commercial extraction of maerl should not be expanded beyond present limits (even that generates secondary turbidity problems).
- the exploitation of shellfish associated with maerl grounds by means of heavy towed fishing gears (scallop dredges) should be prohibited over selected maerl grounds. In order to ensure that this happens, the establishment of artificial barriers on the most sensitive maerl grounds should be considered. The use of set gears, however, may be benign.
- exploitation of maerl beds for molluscs can be achieved without disruption of non target organisms; by diving. Asset-stripping of the target organism though, remains a potential problem.
- a moratorium on the issue of further licences permitting the installation of mariculture cages/rafts over unexploited maerl beds should be put into place.
- the mooring of fixed-cage aquaculture facilities for fin-fish or bivalve molluscs above maerl beds should be discouraged generally, to avoid smothering the bottom

with waste food, faeces and /or pseudofaeces. A single anoxic event precipitated by high organic loading of the sediment could result in irreversible loss of living maerl.

- existing mariculture facilities over maerl grounds should have monitoring of the impacts on the local maerl ecosystem built into statutory environmental quality standards.
- Permanent anchorages should not be established over maerl beds, to avoid mechanical attrition of maerl by ground tackle.
- the designation of marine protected areas, "No-take" reserves etc, should prioritize the maerl-bed resources in the vicinity.
- measures should be taken to limit the impact of practices that might adversely affect the turbidity of the water over maerl beds (like coastal construction works, landfill, channel and harbour dredging creating spoil disposal problems).
- measures to counter eutrophication of estuaries having maerl beds at the mouth should be set in train.
- a programme of monitoring of the "health" of European maerl beds requires to be initiated, and Biotic Indices developed that are sensitive, efficient and cost-effective.
- an improved awareness of the biological importance of maerl beds needs to be fostered at all levels. This can be achieved by suitable publicity and public education. In particular, the fragility of these grounds needs to be understood by fishers.
- consideration of maerl-related issues need to be included in discussions of Coastal Zone Management.
- More research information is still needed. We remain insufficiently informed about where the best maerl grounds are to be found, how big they are, how long they take to form, how productive they are, how different they are one from another, how they change with time, how they interact with surrounding habitats and exactly how long they take to recover from disturbance. The lack of meiofaunal data for maerl grounds remains a major lacuna in knowledge. No ecosystem "goods and services" approach has ever been applied to furnish a cost-benefit analysis of maerl habitats.

- in order to achieve the conservation aims (set out above) in a European context it is desirable that the status of maerl-forming algae be upgraded to give maerl beds a higher category of protection under the EC Habitats Directive (1992), i.e. from being exploited species requiring management under Annex V to a recognized Annex I habitat type or to becoming Annex II species.

3) REPORT ON DISSEMINATION AND EXPLOITATION OF RESULTS

i) Dissemination

The findings of the BIOMAERL programme have been disseminated widely through the media of scientific publications, verbal presentations at Conferences, poster presentations, reports in local newspapers and television reportage (see Managerial Report, above). Relevant material from this Final Report has been lodged on the World Wide Web, accessible via the UMBSM website (http://www.gla.ac.uk/Acad/Marine) in order to facilitate its widest possible dissemination. The web version, however, lacks the scientific papers that have been published, or are in the process of being submitted to journals, to avoid copyright infringements.

ii) Exploitation

So far as exploitation of results is concerned, since the project has not been one of technological or product development, there is no saleable output. However, recommendations from the programme will hopefully influence legislators and management decision-makers charged with responsibility for protecting the marine environment from inappropriate exploitation. It is vital that maerl beds be recognized as essentially non renewable resources that are in grave need of conservation. There is little (besides perhaps trawling with light gear over very consolidated maerl grounds; set gear fishing; or diver-collecting of commercial species) that can be categorized as sustainable use of this habitat, which supports one of the most vulnerable and fragile ecosystems in European coastal waters. In Malta, maerl beds are regarded by local fishermen as highly productive grounds for demersal and pelagic species that are exploited by off-bottom fishing. This high productivity may be related to the structure and dynamics of the maerl ecosystem. Hence it is in the interest of the fishing industry that maerl ecosystems be maintained in a state of health. That substantial degradation of maerl beds in some European countries has already taken place due to inappropriate anthropogenic impacts is then a matter of grave concern.

Large bivalve molluscs were abundant in Scottish maerl beds. Some of the species present are fished commercially elsewhere in Europe, e.g. *Tapes rhomboides, Ensis arcuatus*), and several others are edible although not yet exploited, e.g. *Laevicardium crassum, Dosinia exoleta*. This poses a potential threat to the integrity of maerl habitats. The EU-funded PESCA initiative currently encourages research into alternative methods of exploiting commercial stocks and diversification of the range of species that can be exploited as a source of human food. Our findings suggest that the highly productive maerl habitats along the Atlantic coasts of Europe would represent commercially attractive prospects for bivalve harvest. However, most of the methods currently used to harvest deep-burrowing infaunal bivalves, like hydraulic dredging, cause considerable disturbance and should not be countenanced on such fragile grounds. The conservation significance of maerl beds must be recognized. Suitable protection measures need to be developed and enforced by management practices that are, on the one hand, sensitive to the vulnerability of the biotope, yet which, on the other, recognize that scope may still exist for selective harvesting of surficial species.

The presence of maerl influenced the selection of Spain's first Marine Nature Reserve (Tabarca Is.) established in 1986. The selection of 12 Natura 2000 sites in Scotland has been influenced by the existence of important maerl grounds in particular nominated areas (three of which include maerl beds). It is to be hoped that similar prioritization of maerl grounds is reflected in the selection procedures for marine protected areas operative in other European member States.

An upgrading of the conservation status of maerl-forming algae, from being exploited species requiring management under Annex V of the EC Habitats Directive to maerl becoming an Annex I habitat or Annex II species, is desirable to facilitate the achievement of these objectives by statutory national conservation agencies responsible for the protection of the marine environment within the European Union.

INTRODUCTION

Maerl beds are sedimentary marine habitats, constructed through the growth of unattached calcareous rhodophytes that occur, often in isolated stands, in clean coastal waters from tropical to polar environments (Bosence, 1983; Freiwald, 1995). They are of international conservation interest as they form loci of high biodiversity and biomass supporting many rare and unusual species (Blunden *et al.*, 1981; Myers & McGrath, 1980, 1985; Maggs & Guiry, 1987, 1989; Bellan-Santini *et al.*, 1994; Hall-Spencer, 1998; Clemont & Moore, 1998; Birkett *et al.*, in press). In the North Atlantic they take hundreds of years to accumulate, since growth is very slow with large maerl thalli being amongst the oldest macrophytes known (Adey & McKibbin, 1970; Potin *et al.*, 1990; Hall-Spencer, 1994; Canals & Ballasteros, 1997). For these reasons, management of the exploitation of maerl-forming *Lithothamnion corallioides* (P. & H.Crouan) P.& H.Crouan and *Phymatolithon calcareum* (Pallas) Adey & McKibbin is now obligatory under the EC Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (1992).

Maerl beds form a resource that has been exploited in the seas around Europe for centuries, although it is only recently that we have become aware of the vulnerability of this unique "living sediment" to human influences (BIOMAERL team, 1998). The main use of maerl deposits is as a source of agricultural fertilizer (Guiry & Blunden, 1991). They often occur in pristine areas that are exploited either by mariculturists, or by fishers using towed demersal gear (Hall-Spencer, 1998; Hall-Spencer & Moore, in press a,b; Barberá *et al.*, in press; Borg *et al.*, in press). They are also affected by eutrophication where enclosed sea areas receive agricultural runoff and/or sewage enrichment (Glémarec, 1997; Grall & Glémarec, 1997 a, b).

Not only are maerl beds one of the most diverse ecosystems in European coastal seas, and currently threatened by a range of human activities (Hall-Spencer, 1998; Cabioch *et al.*, 1997; Grall & Glémarec, 1997a,b; Borg *et al.*, in press; Hall-Spencer & Moore, in press a,b), but they remain one of the marine ecosystems about which we know least. For example, the presence of maerl was only discovered off Malta in 1993 (Borg *et al.*, 1998). The isolated and inextensive nature of maerl grounds (cf. sandy bottoms, sea-grass meadows for example) contributes to their vulnerability. Each has its own characteristic hydrographic regime, surface topography, size and thickness of deposit, mobility, percentage of live maerl, and associated biota. A panEuropean approach was thus necessary to encompass the widest range of environmental conditions practicable and create the most inclusive database, upon which subsequent management decision-making could be reliably and soundly based.

Environmental characteristics and stability of European maerl beds

Maerl beds form on a wide variety of bottom types (e.g. gravels, sands or muds; see BIOMAERL team, submitted), with varying degrees of stability, depending on exposure to wave action and the frequency of storms. Each of the maerl beds studied had different structural and sedimentary characteristics (Table 1). The episodic movement required for the formation and growth of rhodoliths (Harris *et al.*, 1996) can be achieved by bottom currents or waves. The stochastic impact of severe storms in periodically disturbing even the deepest-situated maerl beds is likely to be of great significance to the biota (Basso, 1996).

TABLE 1. Summary data (typical values) on sedimentological characteristics [median grain size (μm), percentage fines (<63 μm), Trask index of sorting, percentage carbonates, total organic matter (%), percentage living and dead calcareous rhodophytes, shells and stones (by dry weight)] for maerl grounds studied. For site codes, see BIOMAERL team (submitted).

Site	Median grain	% Fines	Trask index	% CO_3	% Organic matter	% Live maerl	% Dead maerl	% Shells	% stones
UKC	600	22.0	2.7	62.6	4.7	23.0	67.0	8.0	2.0
UKI	1600	7.0	1.4	78.3	2.7	2.0	60.0	16.0	22.0
UBBC	900	24.0	5.2	65.8	11.5	97.0	0.0	0.0	3.0
UBBI	90	35.0	mud	61.1	9.7	92.0	4.0	2.0	2.0
UBGC	900	15.0	2.8	65.6	7.7	7.0	85.0	7.0	1.0
UBGI	900	15.0	3.0	63.4	7.0	0.0	94.0	1.0	5.0
USC	1800	3.5	1.4	89.8	5.6	49.8	39.9	10.3	0.0
USI	800	9.0	1.6	83.3	10.7	57.8	6.6	35.6	0.0
UAC	650	3.0	2.1	79.7	3.0	28.8	40.0	17.0	14.2
UAI	<63	60.0	mud	63.1	5.9	24.6	21.1	50.3	4.0
UMC	1200	6.8	1.8	95.4	7.3	4.5	87.1	3.5	5.2
UMI	1900	1.8	2.0	96.4	9.9	11.0	83.0	1.4	4.5

Maerl beds occur in shallow water (to about 30m) along the Altantic continental margin. They penetrate deeper in clearer waters and so are found to *ca* 100m off the Atlantic islands and W. Mediterranean and down to *ca* 180m in the very clear waters of the E.Mediterranean (Basso, 1996; BIOMAERL team, submitted). They also penetrate into estuarine areas although they are limited by the constraints of turbidity, sedimentation and an inability to grow below salinities of *ca* 22psu (King & Schramm, 1982).

European maerl beds are composed of a dozen or more species of calcareous red algae in the families Corallinaceae and Peyssonneliaceae, with the latter being more prominent in the Mediterranean than the Atlantic. The diversity of maerl-forming species increases from North to South (see Table 2; also BIOMAERL team, submitted).

TABLE 2. Species of calcareous rhodophytes recorded during the BIOMAERL programme from different Atlantic (Clyde Sea, Brittany, Galicia) and Mediterranean (Alicante, Malta) sites. ++ = Common, + = Present, - = Absent.

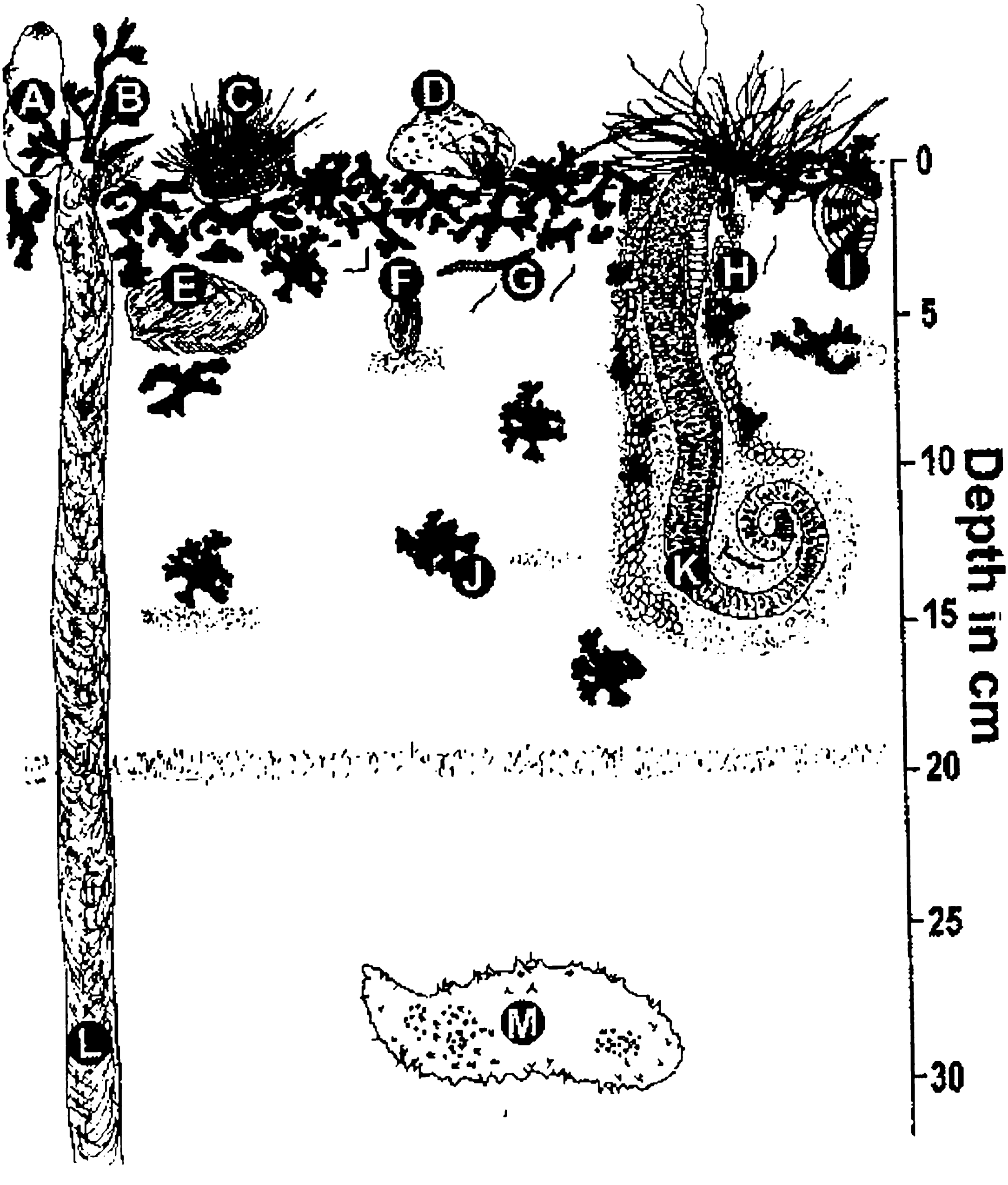
Genus	**Species**	**Clyde Sea (55-56°N)**	**Brittany (47-48°N)**	**Galicia (42°N)**	**Alicante (38°N)**	**Malta (36°N)**
Lithophyllum	*dentatum*		+			
Lithophyllum	*racemus*				+	+
Titanoderma	*pustulatum*				+	+
Lithothamnion	*corallioides*		++	++	++	++
Lithothamnion	*glaciale*	++				
Lithothamnion	*minervae*				++	++
Lithothamnion	*sonderi*	+				
Lithothamnion	*valens*				+	
Mesophyllum	*lichenoides*	+	+			
Mesophyllum	*alternans*				+	+
Phymatolithon	*calcareum*	++	++	++	++	++
Phymatolithon	*purpureum*	+	+	+		
Corallina	*officinalis*	+	+			
Neogoniolithon	*brassica-florida*					+
Peyssonnelia	*rosa-marina*			+	+	+

Maerl thalli can assume a wide range of forms (see BIOMAERL team, in press), which makes identification difficult and has resulted in a tortuous taxonomic literature such that most ecologists refer to"lithothamnia" unspecified. Accurate identification is time-consuming since two species can look identical superficially, while the same species can adopt distinctly different growth forms in different environments. Water movement affects thallus shape and branching complexity and therefore has important direct and indirect effects on maerl bed stability. Maerl beds on exposed grounds are often thrown into megaripples during storms. Movement of such megaripples takes place over an immobile underlying substratum, with deep-burrowing animals able to reinstate their tube connexions to the surface once the bed load restabilizes (Hall-Spencer & Moore, in press b; Hall-Spencer & Atkinson, in press).

The stability of maerl beds is influenced by the presence of certain organisms. Several species of algae stabilize maerl beds, e.g. *Polysiphonia* spp. and *Flabellia petiolata* (BIOMAERL team, 1998) in the Mediterranean; *Laminaria saccharina* (BIOMAERL team, 1998) and *Gelidiella calcicola* (Maggs & Guiry, 1987) in the Atlantic. Binding of maerl by animal activity, as by the byssus threads of the bivalves *Limaria hians* and *Modiolus modiolus* (BIOMAERL team, 1998; Hall-Spencer & Moore, in press b) also increases sediment stability. Sponges, e.g. *Cliona* (off Brest) and sponges together with ascidians (off Alicante), and tube-dwelling organisms (like *Cerianthus lloydii, Chaetopterus variopedatus* and *Upogebia deltaura*), additionally help to bind the surface maerl layer (BIOMAERL team, 1998). Animals that provide stable surfaces for attachment (e.g. tube tops of *C.variopedatus*, siphon tips of *Mya truncata*), also form loci for a range of clinging and adherent epibiota.

Foraging by crabs, hermit crabs and demersal fish creates small-scale patchiness at the sediment surface. The presence of large perennial bivalves, like *Dosinia exoleta* or *Tapes rhomboides,* generates faecal and pseudofaecal accumulations which accentuate granulometric patchiness within the maerl matrix. Large terebellid polychaetes (e.g. *Eupolymnia nebulosa*), also create loci of finer sediment through faecal accumulation and tube construction activities (Fig. 1).

Fig. 1. Diagrammatic representation of vertical stratification of selected macrobiota in maerl from Stravanan Bay, Scotland (UKI), showing silt accumulation around terebellids and the binding action of tubes and *Limaria* nests. Key to organisms illustrated: A.*Ascidiella aspera*, B.*Odonthalia dentata*, C.*Limaria hians*, D.*Gibbula magus*, E.*Echinocardium pennatifidum*, F.*Thracia villosiuscula*, G. *Sphaerodorum gracilis*, H. *Owenia fusiformis*, I. *Clausinella fasciata*, J. *Phymatolithon calcareum*, K. *Eupolymnia nebulosa*, L. *Chaetopterus variopedatus*, M. *Neopentadactyla mixta* [from an original drawing by G.A.Fisher].



Biodiversity of European maerl beds

Though on a lesser scale, consideration of a maerl bed as being in some ways a colder-water equivalent to a coral reef has merit. The impressive biodiversity of maerl grounds is due to the longevity of maerl thalli, both pre-and post-mortem, creating a complex, lattice-like architecture facilitating irrigation of the surface layer with oxygenated water (Glémarec, 1997; BIOMAERL team, submitted). This, together with the requirement of photosynthetic maerl-forming rhodophytes for clean water in the euphotic zone with high exchange rates of water to prevent burial by silt, creates ideal conditions for a variety of organisms utilizing the whole range of feeding types.

In some respects (like high permeability, high carbonate content) maerl beds show environmental similarities with shell-gravel or coral-rubble habitats, which are likewise rich habitats biologically (Smith, 1932; Spooner, 1960; Erwin *et al.*, 1990; Myers, 1985). Cabioch (1969), however, considered that maerl grounds were richer than gravel or shelly bottoms of equivalent granulometry.

Our BIOMAERL studies (excluding most meiofauna and microflora/fauna) have revealed a total of 1326 species of animals, 327 species of algae, 2 species of angiospermatous plants and 4 species of Cyanobacteria on European maerl beds to date. This is still only a minimal estimate of biodiversity since meiofaunal taxa were deliberately excluded from consideration and many macrofaunal taxa considered are still imperfectly known in some places (e.g. Mediterranean polychaetes). It is also necessary to urge caution to avoid the misguided interpretation of Table 3. For instance, the longer history of investigation and diversity of sampling techniques that have been applied to the Clyde grounds, will undoubtedly be factors contributing to their richness.

TABLE 3. Summary of macro/megabiota species diversity in major taxa on maerl grounds studied during the BIOMAERL programme. Note: groups which are likely to be underestimated due to incomplete knowledge are marked with an asterisk (*).

	Clyde Sea	Brittany	Galicia	Alicante	Malta
Latitude (°N)	**55-56**	**47-48**	**42**	**38**	**36**
Algae	66	58	16	168	104
Porifera	10	8	3	5*	1
Cnidaria	35	14	9	11*	2
Annelida	120	165	174	78*	57*
Crustacea	104	137	107	103	83
Mollusca	138	115	96	99*	100
Echinodermata	26	20	19	24*	13
Bryozoa	22	0*	0*	9*	8*
Ascidiacea	11	4	4	14	4
Pisces	32	12	8	15	17
Others	58	24	11	16	11
Total spp.	**611**	**557**	**447**	**542**	**400**

TABLE 4. Previous data on European maerl-bed biodiversity from the literature.

Taxon	**Jacquotte (1962)**	**Cabioch (1968)**	**Keegan (1974)**	**Hardiman *et al.* (1976)**
Algae	72			7
Porifera	17	5	7	2
Cnidaria			9	7
Annelida	71	34	35	90
Crustacea	54	37	24	33
Mollusca	140	45	63	76
Echinodermata	25	3	22	13
Others		13	6	15
Total	**379**	**127**	**166**	**243**

Seagrass (*Posidonia*) meadows have hitherto been considered to be one of the most species-rich habitats in the Mediterranean. For example, Templado (1984) listed a total of 182 species of flora and fauna from *P.oceanica* meadows in the western Mediterranean. Russo *et al.* (1984) listed 80 species of molluscs, while Scipione & Fresi (1984) listed 49 species of Amphipoda. Maerl bed biodiversity exceeds these tallies (Tables 3 & 4), and is on a par with that associated with temperate old-growth forest communities on land (Birkett *et al.*, 1998). The biodiversity of a maerl bed is not directly correlated with the proportion of living maerl within that bed (Scott & Moore, 1997; Hall-Spencer, 1998). Some dead maerl beds are quite biodiverse, though they may have a different fauna from that found on a living ground. High biodiversity is correlated with structural complexity. Dead maerl may support as high a biodiversity as living maerl since the physical environment will retain heterogeneity.

Maerl beds are not the only calcareous biogenic reef-like structures of high fragility, and hence conservation significance, in temperate waters, others like *Lophelia* corals (Jensen & Frederiksen, 1992) and serpulid reefs in the Atlantic (Moore *et al.*, 1998), or coralgal assemblages in the Mediterranean (Pérès, 1982) share the same attribute of mechanical vulnerability; but maerl beds are more structurally complex. In both maerl and shell-gravel habitats, a comparatively open calcareous matrix will facilitate irrigation of interstices, promoting a characteristic and diverse infauna (Jacquotte, 1962; Pérès & Picard, 1964; L.Cabioch, 1968; J.Cabioch, 1969; Keegan, 1974; Mora, 1980; Myers & McGrath, 1983; Ramos-Esplá, 1991; Hall-Spencer, 1998; BIOMAERL team, 1998, submitted; De Grave & Wilkins, in press; De Grave, in press). The ramifying thalli of maerl corallines prevent the formation of bioconcretions (Pérès, 1985), which is a key distinguishing feature between maerl bottoms and coralgal (coralligène) facies (which latter represent the main type of Mediterranean circalittoral benthic biocoenoses on hard substrata). Maerl and coralgal bank assemblages may grade into one another (Pérès, 1982).

One way in which maerl beds are generated is from fragments breaking away from rock-attached crusts and accumulating elsewhere (Freiwald, 1995), but this mechanism does not explain maerl accumulation processes at most of our sites (although we have independent evidence from Malta that supports this hypothesis). Maerl fragments will also be transported around, *inter alia* bound into kelp holdfasts (e.g. of *Laminaria saccharina*). Settlement of coralline spores onto sediment grains is another way in which calcareous algal gravels may be generated, and these two processes may indeed act in concert.

Maerl-bed biota are not only phylogenetically diverse, but they are also diverse in terms of functional groups. A wide variety of predators, deposit feeders, suspension feeders, grazers and detritivores were all present within the maerl beds studied. A high proportion of predators were present (~25%; see Grall & Glémarec, 1997a,b; BIOMAERL team, in prep.) which reflects the diversity of potential prey species. Increasing habitat complexity shelters benthic macrofauna from fish predation (Mattila, 1995). Perhaps the attraction that the habitat complexity of maerl beds represents to organisms, i.e. that of achieving a respite from fish predation, of itself, also creates opportunities for a greater role to be played by infaunal predators?

Further heterogeneity is introduced by stratification of the biota, each stratum supporting its own sub-assemblage. For example, where the maerl is covered by fleshy macroalgae, the epibiota of these macrophytes form one sub-assemblage (typically amphipod-dominated), different from the maerl surface assemblage itself. On the Mediterranean grounds off southern Spain, the filamentous thalli of the non-calcareous rhodophyte *Polysiphonia subulifera* permeate the superficial gravel and bind to individual particles, matting them together. The same phenomenon occurs off Malta only in more extreme form. There, thalli of *P. setacea* and rhizoids of the chlorophyte *Flabellia petiolata* diffuse through the sediment forming a crust up to 5cm thick on the surface of the maerl. This provides a semi-hard substratum which becomes colonized by a variety of epibenthic organisms. The complex three-dimensional heterogeneity of maerl-bed sediments brought about by physical (megarippling, rhodolith patchiness) and by such biological agencies (bioturbation, burrowing, incorporation of faeces and pseudofaeces proximal to sedentary macrofauna, foraging activities) thus creates a complex mosaic of microhabitats.

The extent to which maerl grounds function as nursery grounds for commercial species; e.g. for scallops or gadoid fish (J.H.-S., pers.obs.); ormers, cuttlefish, octopus, bivalves like *Venus verrucosa* or *Tapes rhomboides* (J.G., pers.obs.; A.S.M., pers.obs.; A.A.R-E., pers.obs.), remains to be quantified precisely, but is likely to be considerable. In the west of Ireland, maerl deposits have been reported to act as nursery grounds for the black sea urchin *Paracentrotus lividus* (Minchin, 1997; Birkett *et al.*, 1998).

The longest-term studies of maerl grounds that exist to-date are those of Maggs (1983) on algal phenology of certain Irish grounds, and those of Hall-Spencer & Moore (in press a,b) on maerl beds in the Clyde Sea area. Substantial seasonal changes take place at the maerl surface with the development of ephemeral algae during the summertime: only about half of the algal species being visibly present year-round (Jacquotte, 1962; Cabioch, 1969; Birkett *et al.*, 1998). Algal species diversity thus increases in summer (Maggs, 1983). Partly, this will be the result of the greater stability of the biotope as a result of calmer summertime weather (Birkett *et al.*, 1998). Several algae have heteromorphic life histories so that different phases (erect and cryptic) alternate seasonally (Birkett *et al.*, 1998).

While visible foliose algal diversity shows substantial season variation, faunal diversity on maerl beds seems more conservative. However, the seasonal changes in visible algal diversity is probably more apparent than real, reflecting as it does the heteromorphic life histories of so many algae, which remain present on the ground but are not visible to the naked eye during some period of the year. Barberá *et al.* (in press) reported little seasonal variation in the numerical abundance of higher taxa taken from the maerl bed at Tabarca Marine Reserve, off Alicante. Seasonal variation in emergence behaviour has been reported by us elsewhere (BIOMAERL team, 1998), viz. the presence of the large holothurians *Neopentadactyla mixta* and *Thyonidium drummondi* visible to divers only at certain times of year, as during the spring phytoplankton bloom, when their crowns of tentacles are extended from the sediment into the water for feeding.

One hallowed tenet of classical ecology based on equilibrium theory was the putative relationship between diversity and stability (MacArthur, 1955; Elton, 1958). Much debate centred around this topic in the 1960s and 70s (though it became ever more mired by semantics; i.e. what is meant by diversity? what by stability?; see Brookhaven Symposium,1969). In a classical paper of that period introducing his stability-time hypothesis, Sanders (1968) proposed that diverse marine communities in the deep sea were "biologically accommodated". Over time more and more species specialize to accommodate narrower niches necessitated by competition for food, increasing the diversity of the assemblage and the apparent holding capacity of the habitat. By contrast, non-equilibrium theories predict that stable environmental conditions result in reduced diversity and adherents question whether species-rich stable equilibria actually occur: rather diversity is maintained by unpredictable disturbances preventing monopolization of resources. This represents the viewpoint of Connell (1978): the so-called "intermediate disturbance" hypothesis. The postulate that food is a limiting resource is central to equilibrium theory.

Given their high permeability, the physical structure of maerl habitats absorbs hydrographic energy. Such persistence of structural organization, in concert with high irrigation rates transporting a ready flux of food (autochthonous and allocthonous; planktonic and detrital) available to secondary producers, encourages adaptive radiation and exploitation by a wide range of trophic groups (Grall & Glémarec, 1997). The plethora of predators may maintain populations of secondary producers at densities below which competitive exclusion (Gause, 1934) becomes operative, thus preventing the monopolization of resources by one trophic group or by one species ('predator cropping'; see Paine, 1966).

Many of the animals associated with maerl beds are large, long-lived, high-biomass species. Indeed, the predominance of such *K*-selected life histories among this fauna is, in itself, suggestive of maerl habitats being mature ecosystems (*sensu* Margalef, 1968). Hall-Spencer & Moore (in press b) showed that population densities of such organisms can be very stable over a 4-year period at least. Theory would predict that species from mature ecosystems would have lower relative fecundity, poorer ability to withstand exploitation and reduced capacity to recover from disturbance than *r*-selected opportunists. Population increases in smaller epifaunal species, like amphipods, tend to follow the seasonal trend for macroalgae, doubtless reflecting the increased availability of surfaces for colonization during the summer. Opportunistic species therefore supplement an underlying perennial biodiversity, and may account for some of the different dominant species compositions between listings based on numerical abundance cf. biomass (see below).

High fidelity and key species

While maerl beds are highly biodiverse, none of the species recorded from this habitat during the BIOMAERL programme was endemic to maerl. This finding is in agreement with studies on specific taxa, e.g.algae (Birkett *et al.*,1998), amphipods (Myers & McGrath,1983; De Grave, in press) and molluscs (Hall-Spencer, 1998). Some algae though, like *Halymenia latifolia* and *Scinaia turgida,* are apparently restricted to calcareous substrata. That certain algae presently appear to be peculiar to maerl grounds in the Mediterranean: viz. *Kallymenia spathula, Cryptonemia tunaeformis* and *Dasyopsis penicillata*, may reflect an, as yet, incomplete knowledge of distributions and habitat requirements of Mediterranean algae (attention has already been drawn to the faunal similarities between maerl beds and shell-gravel grounds). Most of the larger algae on maerl beds are species adapted to live on mobile substrata, e.g. *Cystoseira corniculata* and *Flabellia petiolata*.

Setting aside the question of endemicity, many species are certainly typical of maerl habitats (though not restricted to them). Along with the main maerl-forming algae (*Phymatolithon calcareum, Lithothamnion corallioides, L.minervae*), certain algae are notable for their maerl-ground fidelity, e.g. *Gelidiella calcicola* and *Cruoria cruoriformis.* Erwin *et al.* (1990) found the algae *Stenogramme interrupta* and *Gelidiella* sp. to be abundant on maerl from Ballygalley Head, N.Ireland, together with *Scinaia turgida, Halarachnion ligulatum, Schmitzia neapolitana, Dudresnaya verticellata, Peyssonnelia dubyi* and *Radicilingua thysanorhizans*.

Table 5 lists the most important algae, and Table 6 the most important invertebrate species (distinguished in terms of frequency/abundance, biomass and degree of maerl-ground fidelity) from the BIOMAERL sites investigated. The maerl-forming corallines, *Phymatolithon calcareum, Lithothamnion corallioides* and *L.minervae* are important in both the Atlantic and Mediterranean algal lists. Interestingly, only *Dictyota dichotoma* figures as an important non-coralline algal species on maerl beds in both provinces. Equally, among the animals, only a few species like *Echinocyamus pusillus*, *Galathea intermedia* span this major biogeographical divide.

TABLE 5. The most important maerl-ground macroalgae from Atlantic and Mediterranean sites investigated by BIOMAERL.

Atlantic	**Mediterranean**
Lithothamnion corallioides, L.minervae, Phymatolithon calcareum, Microcladia glandulosa, Nitophyllum sp., *Cryptopleura ramosa, Plocamium cartilagineum, Ceramium echionotum, Colpomenia perigrina, Chondria dasyphylla, Hypoglossum hypoglossoides, Phycodrys rubens, Laminaria saccharina, Gelidiella calcicola, Gracilaria verrucosa, Jania rubens, Callithamnion corymbosum, Cruoria cruoriformis, Dictyota dichotoma, Gomontia polyrhiza*	*Lithothamnion corallioides, L.minervae, Phymatolithon calcareum, Lithophyllum racemus, Mesophyllum alternans, Flabellia petiolata, Polysiphonia setacea, Cystoseira corniculata, Vidalia volubilis, Cryptonemia tunaeformis, Laurencia* sp.1, *Polysiphonia spinosa, Hydrolithon* sp. (epiphyte), *Dictyota dichotoma, Codium bursa, Polysiphonia subulosa, Valonia macrophysa, Aglaozonia chilosa, Halopteris filicina, H.incurbus, Peyssonnelia orientalis, P.rosa-marina, P.rubra, Rytiphloea tinctoria*

TABLE 6. The most important invertebrate species (distinguished in terms of frequency/abundance, biomass and degree of maerl-ground fidelity) from the BIOMAERL (control) sites investigated.

a) Frequency/abundance

Site	Most frequent/abundant species
Clyde Sea area	*Ophiocomina nigra, Scalibregma inflatum, Owenia fusiformis, Pomatoceros triqueter, Sphaerodorum gracilis, Pholoe inornata, Aonides paucibranchiata, Cerianthus lloydii, Mediomastus fragilis, Glycera lapidum, Psammechinus miliaris, Edwardsia claparedii, Kefersteinia cirrata, Terebellides stroemi, Balanus crenatus, Echinocyamus pusillus, Leptochiton asellus, Pisione remota, Pista cristata*
Brittany	*Chaetozone setosa, Gammarella fucicola, Nematonereis unicornis, Maera grossimana, Cirriformia tentaculata, Pisidia longicornis, Abludomelita gladiosa, Aonides oxycephala, Janiropsis breviremis*
Galicia	*Polydora lacteus, Mediomastus fragilis, Notomastus latericeus, Glycera lapidum, Pista cristata, Aonides oxycephala, Leptocheirus tricristatus, Socarnes erythrophthalmus, Ceradocus semiserratus, Gammarella fucicola, Pisidia longicornis, Liocarcinus corrugatus, Listriella picta, Maera othonis, Apseudes latreillii, Clausinella fasciata, Dosinia exoleta, Jujubinus exasperatus, J.miliaris, Lepidochiton cancellatus, Tectura virginea, Tapes rhomboides, Echinocyamus pusillus, Psammechinus miliaris, Branchiostoma lanceolatum*
Alicante	*Cliona viridis, Vermiliopsis striaticeps, Laetmonice hystrix, Lysidice ninetta, Lysianassa longicornis Maera knudseni, Apseudes latreillii, Galathea intermedia, Ebalia edwardsi, Paguristes eremita, Parthenope massena, Leptochiton cancellatus , Caecum trachea, Amphipholis squamata, Ophiura grubei, Echinocyamus pusillus, Didemnum coriaceum*
Malta	*Cestopagurus timidus, Echinocyamus pusillus, Eunice vittata, Galathea intermedia, Nematonereis unicornis, Lumbrineris impatiens, Syllis amica, Gonilia calliglypta,*

	Lysianassa costae, Leptochelia savignyi, Ampithoe ramondii, Lysidice ninetta, Nereis rava, Lumbrineris gracilis, Maera grossimana, Anapagurus breviaculeatus, Ceradocus semiserratus, Dexamine spinosa

b) Biomass

Site	Biomass dominants
Clyde Sea	*Ophiocomina nigra,Terebellides stroemi, Owenia fusiformis, Mya truncata, Dosinia exoleta, Clausinella fasciata, Tapes rhomboides, Gibbula magus, Upogebia deltaura, Cerianthus lloydii, Neopentadactyla mixta, Thyonidium drummondi, Psammechinus miliaris*
Brittany	*Clausinella fasciata, Gibbula magus, Hinia reticulata, Jujubinus straitus, Liocarcinus arcuatus, L.pusillus, Paracentrotus lividus, Psammechinus miliaris, Tapes rhomboides, Venus verrucosa*
Galicia	*Polygordius lacteus, Mediomastus fragilis, Notomastus latericeus, Pista cristata, Aonides oxycephala, Pisidia longicornis, Liocarcinus corrugatus, Apseudes latreillii, Clausinella fasciata, Dosinia exoleta, Jujubinus miliaris, Leptochiton cancellatus, Tapes rhomboides, Echinocyamus pusillus, Psammechinus miliaris, Branchiostoma lanceolatum*
Alicante	*Eunice vittata, Lysidice ninetta, Lysianassa longicornis Maera knudseni, Apseudes latreillii, Athanas nitescens, Galathea intermedia, Ebalia edwardsi, Leptochiton cancellatus, Amphipholis squamata, Ophiura grubei, Echinocyamus pusillus, Didemnum coriaceum, Polycarpa mamillaris*
Malta	*Nereis rava, Bittium latreillii, Cestopagurus timidus, Leptochelia savignyi, Syllis amica, Lysianassa costae, Lumbrineris impatiens, Ampithoe ramondii, Galathea intermedia, Lumbrineris gracilis, Maera grossimana, Echinocyamus pusillus, Anapagurus breviaculeatus, Lysidice ninetta, Nematonereis unicornis, Eunice vittata, Nereis* sp., *Ceradocus semiserratus*

c) High-fidelity species

Site	High fidelity species
Clyde Sea	*Gelidiella calcicola, Glycera lapidum, Sphaerodorum gracilis, Polygordius lacteus, Parametaphoxus fultoni, Atylus vedlomensis,Ceradocus semiserratus, Leptognathia breviremis,Upogebia deltaura,Galathea intermedia, Liocarcinus pusillus, Gibbula magus,Tectura virginea, Clausinella fasciata,Dosinia exoleta,Tapes rhomboides,Echinocyamus pusillus, Spatangus purpureus, Echinocardium pennatifidum, Neopentadactyla mixta*
Brittany (Bay of Brest and Glenan combined)	*Hesione pantherina, Listriella picta, Anaeana trilobata, Paracentrotus lividus, Tapes rhomboides, Venus verrucosa, Eunice vittata, Lysidice ninetta, Pisidia longicornis, Galathea squamifera, Liocarcinus pusillus, L.arcuatus, L.corrugatus,Thoralus cranchi, Eurynome spinosa, Chlamys varia, Tectura virginea, Gibbula magus,Acanthochitona fascicularis, Polygordius lacteus, Laevicardium crassum, Timoclea ovata, Tellina donacina, Gari tellinella, Parvicardium ovale, Branchiostoma lanceolatus, Limaria hians, Sphaerechinus granularis*
Galicia	*Aonides oxycephala, Glycera lapidum, Mediomastus fragilis, Notomastus latericeus, Pista cristata, Polygordius lacteus, Apseudes latreilli, Ceradocus semiserratus, Gammarella fucicola, Liocarcinus corrugatus, Leptocheirus tricristatus, Socarnes erythrophthalmus, Clausinella fasciata, Dosinia exoleta, Jujubinus miliaris, Leptochiton cancellatus, Tapes rhomboides, Tectura virginea, Echinocyamus pusillus, Branchiostoma lanceolatum*
Alicante [Note: these species are characteristic of the coastal detritic biocoenoses (mainly maerl)]	*Nemertesia tetrasticha, Ditrupa arietina, Harmothoe reticulata, Laetmonice hystrix, Vermiliopsis striaticeps, Anapagurus chiroacanthus, Ebalia deshayesi, Ebalia edwardsi, Ebalia tuberosa, Paguristes eremita, Turritella turbona, Chlamys flexuosa, Limatula gwyni, Palliolum incomparabile, Pecten jacobeus, Plagiocardium papillosum, Pitar rudis, Tellina donacina, Genocidaris maculata, Ophioconis forbesi, Ophiura albida, Ophiura grubei, Vanneagobius pruboti.*
Malta	*Antedon mediterranea, Apseudes talpa, Galathea intermedia, Genocidaris maculata, Leptochelia savignyi, Liocarcinus zariquieyi, Neolampas rostellata, Parthenope massena,*

Note that biomass dominants listed are not infrequently different species from those that are most abundant numerically. Such differentiation might be anticipated since larger, biomass dominants are likely to be more sparsely distributed. To give an extreme example: in the Maltese data, the weight of a single brissoid echinoid (the only individual found in two years of sampling) was enough to make it the top-ranking species in terms of biomass, whereas a species like *Cestopagurus timidus*, five or six individuals of which occurred in every grab taken, featured much lower down the biomass ranking. Any incongruities between sites in such a comparison will depend, in some part, on variations in the type of sampling gear available, particularly in relation to variable access to deeply buried species (which tend to be large organisms of high biomass) between BIOMAERL partners. So far as high-fidelity species nominations are concerned, it should also be stressed that our knowledge of other offshore benthic ecosystems in some places, e.g. Malta, remains as yet embryonic. It is difficult, therefore, to ascertain with certainty which species are truly favouring maerl grounds in such places. In better researched sea areas (especially Atlantic sites) such nominations can be accepted with higher degrees of confidence. Also, species with an apparent high fidelity to maerl grounds in one region may be less discriminatory elsewhere: thus *Eunice vittata* was regarded as a high-fidelity species in Brittany but, off Malta, it occurred in seagrass (*Posidonia*) beds as well as maerl.

Erwin *et al.* (1990) found that the bivalve *Glycymeris glycymeris* was particularly abundant from Ballygalley Head, N.Ireland, and other species, like *Corymorpha nutans, Neopentadactyla mixta, Antedon petasus, Gibbula tumida* and *Clelandella clelandi* were also notable. Améziane *et al.* (1995) regarded *Dosinia exoleta, Tapes rhomboides, Hinia reticulata* and *Ophiura albida* as being characteristic maerl-bed species in the Bay of Morlaix.

In Mediterranean waters there are some species that seem to be associated preferentially with maerl bottoms (Jacquotte, 1962 ; Pérès & Picard, 1964 ; Picard, 1965 ; Falconetti, 1969) : Porifera (*Raspalia vinimialis*), Cnidaria (*Nemertesia tetrasticha, Sarcodyctyon catenatum*), Polychaeta (*Ditrupa arietina, Euthalenessa dendrolepis, Hyalinoecia tubicola, Harmothoe reticulata, Laetmonice hystrix, Petta pusilla, Vermiliopsis striaticeps*), Isopoda (*Conilera cylindracea*), Decapoda (*Anapagurus chiroacanthus, A. laevis, Ebalia deshayesi, E. edwardsi, E. tuberosa, Paguristes eremita*), Gastropoda (*Crassopleura maravignae, Eulima polita, Turritella turbona*), Bivalvia (*Cardiomya costellata, Gari fervensis Glycymeris glycymeris, Chlamys flexuosa, Laevicardium oblungum, Lima lascombei, Limatula gwyni, Modiolus phaseolinus, Neaera costellata, Palliolum incomparabile, Pecten jacobeus, Plagiocardium papillosum, Pitar rudis, Tellina donacina*), Ophiuridea (*Ophioconis forbesi, Ophiura albida, O. grubei*), Asteroidea (*Anseropoda placenta*), Echinoidea (*Genocidaris maculata, Psammechinus microtuberculatus*), Holothuroidea (*Paracucumaria hyndmanni*), Ascidiacea (*Microcosmus vulgaris, Molgula appendiculata, Polycarpa mammillata*) and Pisces (*Vanneagobius pruboti*). Ruffo (1998) listed the amphipods *Harpinia ala, Tryphosella simillima* and *Unciolella lunata*, as being restricted to coralligenous biotopes in the Mediterranean.

Key species are those which have a profound structural and/or functional role in the maerl biotope and which consistently make a prominent contribution to the sampled assemblage. Such species would include the maerl-forming rhodophytes themselves which create the habitat, together with surface-binders (like *Flabellia petiolata, Polysiphonia setacea, Phycodrys rubens, Laminaria saccharina, Limaria hians, Didemnum* spp.) and deep-burrowing tube-dwellers (*Cerianthus lloydii, Chaetopterus variopedatus, Upogebia deltaura*) which help to stabilize the system (see above). The significance as to why certain grazing taxa, chitons especially (e.g. *Lepidochiton cancellatus*) although curiously not off Malta play such an important role in maerl ecosystems is unclear, but their bauplan may have certain advantages to the exploitation of maerl interstices. Other species may have particular significance at certain sites if they approximate to a geographical limit of distribution, e.g. *Hesione pantherina* in Brittany (see BIOMAERL team, 1998). Certain BIOMAERL findings, however, remain presently inexplicable, like why there were no ophiuroids in the Maltese samples (only one individual was ever found during the whole programme)?

The nature of the threats to European maerl beds

The major threats to maerl beds are various: direct exploitation, impacts from towed fishing gear, harbour dredging and eutrophication. The thickest maerl deposits have been recorded around the îsles de Glenan in Brittany (<15m thick) and such (dead) beds have been regarded as attractive resources for commercial exploitation (but see Blunden *et al.*, 1997), principally as a source of lime and trace minerals for improving soil condition or water potability (Augris & Berthou, 1986; Guiry & Blunden, 1991). Pinot (1997) has investigated the degradation of the Glenan maerl bed over the period 1961-1984, using aerial photography. No live maerl was present after 1984 (confirmed by BIOMAERL; J.Grall, pers.obs.). Since maerl-forming rhodophytes grow so slowly (millimetres per year: Potin *et al.*, 1990; Hall-Spencer, 1994; Pinot, 1997), it is impossible for the commercial extraction of thousands of tonnes to be self-sustaining (Pinot, 1997). Carbon-dating has established that some maerl beds are thousands of years old (Farrow *et al.*, 1979) . These beds, therefore, need to be regarded as essentially non renewable resources (Farrow, 1983), since recovery takes so long (Hall-Spencer & Moore, in press a). Anyway, the chemical composition and physical properties of maerl are not sufficiently different from limestone to warrant its extraction for these commercial applications (Blunden *et al.*, 1997).

European maerl grounds are exploited commercially for scallops (*Pecten maximus* and *Aequipecten opercularis*) in Scotland (Hall-Spencer, 1998), scallops and clams (*Tapes rhomboides*) in Galicia (A.S.M., pers.comm.) as well as for demersal fish, like *Mullus surmuletus* and *Spicara smaris,* off Mallorca (Massutí *et al.*, 1996). In 1986, some 200 tonnes of *Tapes rhomboides* were landed from maerl grounds off Glenan (Augris & Berthou, 1986) and this productive habitat supported 50 fishing boats catching turbot, sea bass and sea bream. Maltese fishers consider maerl beds as rich fishing grounds for off-bottom species too (Schembri, 1998). Améziane *et al.* (1995) noted that maerl beds produced organic carbon that was available to other communities. Scallop dredging is particularly efficient over maerl. Hall-Spencer & Moore (in press b) reported efficiencies of scallop extraction of 85% on maerl in the Clyde Sea area, Scotland compared with only 14-27% over coarse sand and gravel ground (Gruffydd, 1972; Chapman *et al.*, 1977). Unsurprisingly, therefore, maerl beds represent attractive targets for fishers, both commercial and recreational.

Heavy toothed gears, like scallop dredges (which individually can weigh <85kg and are fished commercially in multiple rigs), when towed over maerl beds result in comminution of maerl thalli (Hall-Spencer & Moore, in press *a*) or burial under silt which can kill the fragile living veneer. Penetrating <10cm into the maerl-sediment surface, such gears have been reported recently (Hall-Spencer & Moore, in press *a*) to kill 70% of living maerl (by burial) in one pass over a Clyde maerl ground. Resuspended bottom sediment also increases turbidity which will have negative impacts on photosynthetic benthic autotrophs. In addition, towed gear homogenizes the topography of the bottom, levelling megaripples (BIOMAERL team, 1998; Hall-Spencer, 1998), tearing through surface-binding algal mats (Borg *et al.*, in press) and animal constructs, like nests of *Limaria hians* (Hall-Spencer & Moore, in press *b*) and in-filling animal pits and burrows (Hall-Spencer & Atkinson, in press).

Trawling within three nautical miles of the shore is illegal in Malta. The same prohibition applies within the jurisdiction of all EU Mediterranean States. Interestingly, Borg *et al.* (in press) discerned no ill-effects of intermittent (if illegal) otter trawling over inshore Maltese maerl grounds. This they attributed to the limited sediment penetration of otter trawls on their grounds (cf. also Van Dolah *et al.*, 1991), which are bound into a surface crust by foliose algae (*Flabellia petiolata, Polysiphonia setacea*). However, were illicit trawling ever to become more intense then the Maltese ground would suffer adversely. On the other hand, otter trawling activity over maerl grounds off Alicante assuredly has had a greater impact. The heavy gear used there abrades the bottom and has produced *inter alia* a shift in dominant species (from soft Peyssonneliaceae to more opportunistic hard Corallinaceae).

The use of set gears is generally regarded as an environmentally preferable method of exploitation of sensitive sea beds than using heavy towed gear. Nets are not usually set by professional fishers over maerl grounds off Malta, since bottom currents cause them to become tangled with the maerl. The fouled and torn nets must then be cleaned by driving vehicles over them to pulverize the entangled maerl. However, amateur fishers often set nets on these grounds which may have a significant impact, since it selectively removes the larger rhodoliths which are the oldest and slowest to be replaced.

The quality of the water overlying maerl beds also has profound consequences for their viability, biodiversity, functional structure and continuity. Gray (1992) has expounded a general model of eutrophication. In the early enrichment phase increased growth rates result directly from nutrient increases. This can be detected by increases in benthic macroalgal and phytoplankton production. The initial effect of eutrophication on benthic macrofaunal communities results in a change in species composition, with an increased total abundance and biomass. Within the BIOMAERL programme, we had the opportunity to compare two North Atlantic sites (Brittany and Galicia) experiencing different eutrophication sources (respectively nutrient outwash from a conurbation with surrounding agriculture, and extensive mytiliculture production).

Eutrophication has several effects on maerl beds: it increases in the proportion of fine particles (and therefore is responsible for the disappearance of some of the maerl structure microhabitats by clogging interstices and reducing permeability); it increases the total abundance and biomass of infauna and epifauna; it decreases species richness; it changes the trophic structure of the grounds, favouring surface- and subsurface-deposit feeders and threatening suspension-feeders and micrograzers. All these features lead to a simplification of the otherwise exceptionally rich and diversified ecosystems that maerl beds represent.

Conservation, monitoring and management options

Why should we bother to conserve maerl grounds? Maerl beds have a high intrinsic and aesthetic value, which should appeal to our ethical concern for biodiversity; after all they do support one of the richest faunas and floras in temperate seas.

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7. REPRINTS OF PAPERS

Note: a single copy of all papers published by BIOMAERL is sent to the EC as a matter of course. Insufficient copies are available to append to each copy of the Final Report produced.

8. RESIDUE OF CRUISE SURVEY REPORTS

Only those Cruise Survey Reports that have not already appeared in previous interim reports are appended herein.

EC Biomaerl Cruise Survey Report

Cruise Reference : UMBSM 47	Site Reference Number: ST1	
Date: 17.3.98	Laboratory: UMBSM	
Vessel: R.V. AORA	Site name: STRAVANAN BAY, BUTE	
Lat./Long: N55° 45.33, W005° 4.26	Depth (sea level): 9.2	Depth (Chart Datum): 9.8

Surveyors: Dr J. Hall-Spencer and Mr K. Cameron

Equipment used: DGPS, SCUBA, SMB, search reel, collection tubs, Van Veen grab, Ring Dredge, Secchi disc, refractometer, thermometer, sediment profile gauge.

Tasks completed

Surface salinity 33 ‰	Surface water temperature 8.6 °C
Benthic salinity 33 ‰	Benthic water temperature 8.5 °C
Secchi Disk Reading 5m	Current velocity ≤10 cm s^{-1}
Suspended solids load	General photography
Sediment cores	Grab samples 8 taken
Sediment topography	Ring dredge 1 taken
Fauna/flora sampled ✓	% Live maerl assessed *ca* 2%

Other tasks completed

Dive 1; 35 mins failed attempt to locate benthic marker. A circular search was completed slightly too far north and too shallow, preventing a deeper second dive due to safe decompression considerations. Grab sampling and ring dredging was completed at the correct depth for the site and this position was marked overnight with an SMB.

Additional information

SE4 with squalls, choppy. Dry-suit leaked badly.

Surface marker removed in January storms but DGPS differential faulty so site relocation hindered.

Six *Neopentadactyla mixta* seen feeding - this probably signals the onset of the spring diatom bloom. *Polinices* egg cases quite common - collected one and placed into a laboratory aquarium to see if juveniles hatch out.

Two systems of sediment rippling were noted at -7m running in parallel lines at different angles and wavelenghts across the maerl surface. Maerl at this depth is all dead and of finer grain size than deeper down, reflecting the greater mobility of the sediment in this area where shorter wavelength waves can transport the sediment.

Signed..........................(Survey Leader)

EC Biomaerl Cruise Survey Report

Cruise Reference : UMBSM 48	Site Reference Number: ST1	
Date: 18.3.98	Laboratory: UMBSM	
Vessel: R.V. AORA	Site name: STRAVANAN BAY, BUTE	
Lat./Long: N55° 45.3301, W005° 4.2601	Depth (sea level): 10-11	Depth (Chart Datum): 9.8

Surveyors: Dr J. Hall-Spencer, Mr K. Cameron and Mr H. Brown

Equipment used: GPS, SCUBA, SMB, 1m^2 quadrats, collection tubs, thermometer, secchi disc, refractometer, Nikonos V camera system

Tasks completed

Surface salinity 33 ‰	Surface water temperature 8.8°C
Benthic salinity 33 ‰	Benthic water temperature 8.5°C
Secchi Disk Reading 5m	Current velocity $\leq$10 cm s^{-1}
Suspended solids load	General photography ✓
Sediment cores	Grab samples
Sediment topography	Ring dredge -
Fauna/flora sampled ✓	% Live maerl assessed *ca* 2%

Other tasks completed

Dive 1; 41 mins circular search, pleased to locate benthic markers. Dive 2, 38 mins, Quadrats and photography.
Replaced buoy, shackles and some chain. Need new length of chain next visit.

Additional information

Chain worn through as the site often exposed to swell.

Laminaria saccharina can be perennial since new growth now up to 36cm long seen with similar lengths of tatty, serpulid & bryozoan encrusted thallus still attached. These survivors of the previous season have had a head start since newly settled thalli only up to 10cm long.

Neopentadactyla mixta feeding, average about 1 per 8m^{-2} but up to 2m^{-2} in any one quadrat. *Cerianthus lloydii* very common (>20m^{-2}), hardly any seen per quadrat in winter. Maybe they are there in high numbers year-round but are only visible when all feeding? Need to check air-lift data. *Upogebia deltaura* also common, average about 1 burrow system per m^{-2} but up to 4m^{-2} in any one quadrat.

Signed.......................................(Survey Leader)

EC Biomaerl Cruise Survey Report

Cruise Reference : UMBSM 49	Site Reference Number: OS1	
Date: 20.4.98	Laboratory: UMBSM	
Vessel: R.V. AORA	Site name: CREAG GOBHAINN, LOCH FYNE	
Lat./Long: N56° 0.6001, W005° 22.2000	Depth (sea level): 12-14	Depth (Chart Datum): 10-12

Surveyors: Dr J. Hall-Spencer and Mr K. Cameron

Equipment used: GPS, SCUBA, SMB, 1m^2 quadrats, collection tubs, Secchi disc, refractometer, thermometer, Van Veen Grab, Ring dredge, Nikonos V camera system, sediment profile gauge.

Tasks completed

Surface salinity 33 ‰	Surface water temp. 9.0 °C
Benthic salinity 33‰	Benthic water temp. 9.0 °C
Secchi Disk Reading 2.5m; note v. low	Current velocity ≤40 cm s^{-1}
Suspended solids load	General photography
Sediment cores	Grab samples 5 taken
Sediment topography ✓	Ring dredge ✓
Fauna/flora sampled ✓	% Live maerl assessed *ca* 20%

Other tasks completed
Dive 1: 7 mins, Nikonos V flooded so dive aborted. Dive 2: 39 mins recorded 15 surface quadrats and scraped up two 1m^2 samples to count numerous small surface fauna such as *Ophiocomina nigra*. Dive 3: 48 mins to record another 15 surface quadrats and take samples of hydroids and holothurians for laboratory identification. Sediment profiles photographed.

Additional information
Calm with sunny spells. Hugh unable to dive due to sinus trouble.
Loaded up & left Keppel pier at 09.50. Started diving at 13.35. Left site at 17.30 into Ardrisaig at 18.30.
Using inflatable as dive tender to comply with H.S.E. ruling. Thick spring plankton bloom reduced light and visability but no evidence of flocculent build-up or reduced O_2 on the sea bed. Flooded camera washed in F.W. immediately and then stripped and dried. Might be OK after service. Holothurians abundant - *Thyonidium drummondii* the largest *ca* 0.33 m^{-2}, *Thyone* sp. *ca* 0.8m^{-2}, *Labidoplax media* = new Clyde record tiny but *ca* 3 m^{-2} and *Ocnus planci* also present *ca* 0.1 m^{-2}

Signed.................................(Survey Leader)

EC Biomaerl Cruise Survey Report

Cruise Reference : UMBSM 50	Site Reference Number: OS1	
Date: 21.4.98	Laboratory: UMBSM	
Vessel: R.V. AORA	Site name: CREAG GOBHAINN, LOCH FYNE	
Lat./Long: N56° 0.6001, W005° 22.2000	Depth (sea level): 13-14	Depth (Chart Datum): 10-11

Surveyors: Dr J. Hall-Spencer and Mr K. Cameron, Mr H. Brown surface cover

Equipment used: GPS, SCUBA, SMB, 1m^2 quadrats, collection tubs, Secchi disc, refractometer, thermometer, Air-lift suction sampler.

Tasks completed

Surface salinity 33 ‰	Surface water temp. 9.3 °C
Benthic salinity 33‰	Benthic water temp. 9.0 °C
Secchi Disk Reading 2.5m; note v. low	Current velocity ≤40 cm s^{-1}
Suspended solids load -	General photography
Sediment cores	Grab samples
Sediment topography ✓	Ring dredge
Fauna/flora sampled ✓	% Live maerl assessed *ca* 20%

Other tasks completed

Dive 1: 45 mins, Airlifting 1m^2 while RV Aora was double anchored over the site. Dive 2: 24 mins, completed the 1m^2 sample from inflatable tender as main vessle was blow off site.

Additional information

SE 5, rain. Managed to excavate the fauna down to ca 30cm depth but 2 *Mya truncata* and 2 *Upogebia deltaura* burrows extended below this depth into the stiff clay-like sediment. Very high biomass here; e.g. 361 *O. nigra*, 41 large *Dosinia exoleta*, 24 *O. fragilis*, 4 *Paphia rhomboides*, 2 *Echinocardium pennatifidum*, 2 *Thyone* sp., 1 35cm long *Nereis longissima* (new site record).

Signed.......(Survey Leader)

EC Biomaerl Cruise Survey Report

Cruise Reference : UMBSM 51	Site Reference Number: ST1	
Date: 19.5.98	Laboratory: UMBSM	
Vessel: R.V. AORA	Site name: STRAVANAN BAY, BUTE	
Lat./Long: N55° 45.3301, W005° 4.2601	Depth (sea level): 10-11	Depth (Chart Datum): 9.8

Surveyors: Dr J. Hall-Spencer and Mr K. Cameron

Equipment used: GPS, SCUBA, SMB, $1m^2$ quadrats, collection tubs, thermometer, secchi disc, refractometer

Tasks completed

Surface salinity 33 ‰	Surface water temperature 12.2°C
Benthic salinity 33 ‰	Benthic water temperature 10.0°C
Secchi Disk Reading 4.0m	Max. current velocity
Suspended solids load	General photography -
Sediment cores	Grab samples ✓ 5 taken
Sediment topography ✓	Ring dredge 1 taken
Fauna/flora sampled ✓	% Live maerl assessed *ca* 2%

Other tasks completed
Dive 1; 44 mins quadrats. Dive 2, 45 mins, quadrats & sediement profile gauge. *Palliolium* egg coils and young filamentous rhodophytes collected.

Replaced full length of chain on the buoy.

Additional information
Left Keppel 9.00, back at 14.45.

Calm, sunny conditions. Pronounced thermocline. Phytoplankton bloom still apparent but clumping in the water column. *Beroe* sp. bloom but no jelly fish seen. *Neopentadactyla mixta* all out (ca 1 every $5m^2$ but up to $2m^{-2}$ in any one quadrat. *Laminaria saccharina* growth has been rapid since the previous trip with fronds now up to 1.5m long. *Upogebia deltaura* burrow openings common, with *ca* 1 obvious burrow system per m^{-2} on average but many openings are occluded. Grab samples revealed many more *Polygordius lacteus* than in samples collected earlier in the year, on close inspection the gravel appeared to writhe with these animals as the dominant infauna in this size class. Very summery feel to the community with young, fresh growth of filamentous rhodophytes (predominantly *Rhodomela confervoides* and *Polysiphonia* spp) forming a 2-5% cover. A small, recently hatched Pogge = *Agonus cataphractus* (<2cm long) was a new record for the site.

Signed...(Survey Leader)

EC Biomaerl Cruise Survey Report

Cruise Reference : UMBSM 52	Site Reference Number: ST1	
Date: 17.11.98	Laboratory: UMBSM	
Vessel: RV AORA	Site name: STRAVANAN BAY	
Lat./Long: N55° 45.3301, W05° 4.2601	Depth (sea level): 12.5 m	Depth (Chart Datum): 9.8 m

Surveyors: Dr J.M. Hall-Spencer, Mr H. Brown and Dr S. Wieczorek.

Equipment used: GPS, SCUBA, SMB, 1m^2 quadrats, collection tubs, thermometer, NIO sampler, Secchi disc, refractometer, air-lift, Nikonos V underwater camera plus macrophotography attachments

Tasks completed

Surface salinity 33	Surface water temp. 9.9°C
Benthic salinity 33	Benthic water temp. 9.9°C
Secchi Disk Reading 4.5m	Max. current velocity 10 cm s^{-1}
Suspended solids load	General photography 36 shots taken
Sediment topography recently formed megaripples noted	Ring dredge
Fauna/flora sampled yes	% Live maerl assessed *ca 2%* cover

Other tasks completed

Dive 1; 35 mins, air-lift with air supply permanently on proved inefficient as it became clogged with maerl debris. *Pomatoschistus pictus* rapidly aggregated to feed on the exposed infauna.

Dive 2; 35 mins, continued use of air-lift with a walled quadrat and exchangeable collecting bags. 14 *Dosinea exoleta*, 3 *Paphes rhomboides* and 7 *Clausinella fasciata* collected from 1m^2 on a 5mm mesh.

Dive 3; 38 mins, macrophotography of maerl (*P. calcareum*) and *Lithothamnion sonderi* reproduction. Olive and white colouration patterns of small *Cerianthus loydii* photographed together with grazing *Gibbula magus*, juvenile decapods (*Liocarcinus depurator, L. pusillus* and *Galathea intermedi)* cohabiting dead bivalve shells (mostly *Dosinea exoleta*) on maerl surface with *Pisidia longicornis, Diplecogaster bimaculata* and *Pholis gunnellus*. Juvenile *Henricia* sp and *Antedon bifida* seen and photographed despite the impending winter conditions. Permanent marker shackles and chains checked.

Additional information E 4, overcast

Vessel was double anchored then dive tender was launched. Air-lift hose should be replaced. Further trials needed to determine optimum size of walled quadrats. No new site records. *Titanoderma pustulatum* recorded on *Laminaria saccharina* haptera.

Signed............................(Survey Leader)

EC Biomaerl Cruise Survey Report

Cruise Reference Number: RDV 33	Site Reference Number: USI
Date: 27/IV/98	Laboratory: Bentos U. Santiago.
Vessel: VIDAL CALVAR	Site name: LIMENS

Lat/Long.: 42°14'33,6"–8°47'44,5"	Depth (sea level): 15m	Depth (Chart Datum):

Surveyors: J. MORA

Equipment used: Van Veen grab, box-corer, Rallier dredge, Secchi disk, box-corer vertical sampler, plankton net, hand Vane tester, Van Dorn bottle, WTW Analysers

Tick tasks completed

Salinity ~~profiles~~ measures	X	Surface water transparency	X
Suspended solids loads	X	Temperature ~~Profiles~~ measures	X
Maerl collection	X	Particle size analysis	X
Sediment surface topography		Resin casting	
Fauna/flora assessed	X	% live maerl assessed	X

Other tasks completed

- Total seston & suspended organic matter
- Physico-chemical parameters
- Shear strength (maerl & sediment)
- Spring (seasonal) sample for maerl fauna determination
- plankton collection

Additional information

- Van Veen sample for seaweed determination
- Vertical samples by layers for infauna and sediment analyses.

Signed.....JOSE MORA.....(Survey Leader)

EC Biomaerl Cruise Survey Report

Cruise Reference Number: RDV34	Site Reference Number: USC
Date: 28/IV/98	Laboratory: Bentos U. Santiago
Vessel: VIDAL - CALVAR	Site name: CANGAS
Lat./Long.: 42°15'3,2"-8°46'1,2"	Depth (sea level): 7m | Depth (Chart Datum):

Surveyors: J. MORA

Equipment used: Field analysers, secchi disk, box-corer vertical sampler, box corer, Van Veen grab, Ring dredge, plankton net, Van Dorn bottle, hand vane tester

Tick tasks completed

Salinity ~~profiles~~ measure	X	Surface water transparency	X
Suspended solids loads	X	Temperature ~~Profiles~~ measure	X
Maerl collection	X	Particle size analysis	X
Sediment surface topography		Resin casting	
Fauna/flora assessed	X	% live maerl assessed	X

Other tasks completed

- Seasonal (spring) sample for maerl fauna/determination.
- Plankton collection
- Sheer strength (maerl & sediment)
- Physicochemical factors (waters & sediments)
- Organic matter & total seston in waters

Additional information

- Vertical samples by layers for infauna and sediment analyses.
- Sample (Van Veen) for seaweed determination

Signed JOSE MORA (Survey Leader)

EC Biomaerl Cruise Survey Report

Cruise Reference Number: UAB-281197

Site Reference Number: UAB-35

Date: 281197

Laboratory : UA Marine Biology

Vessel: "Odón de Buen"

Site Name: Alicante Bay (South)

Lat./Long.: 38° 13.95'N - 00° 25.70'W

Depth (sea level):37-41m

Depth (Chart d.):

Surveyors: C. Barberá, C. Bordehore, J.L. Patiño, A.A. Ramos

Equipment used: runner dredge (1.0 x 0.3 m frame), Van Veen grab (0.05m^2), echosounder

Surface Salinity :

Surface water temp.

Benthic Salinity :

Benthic water temp.

Secchi Disk Reading :

Max. current surf.: bottom:

Tick tasks completed surveying of a new area by echosounder, grab and dredge samples (to know sedimentological and bionomical features of the bottoms)

Suspended solids load :

General photography :

Sediment cores :

Grab/Dredge samples :

Sediment surface topography :

Resin casting :

Fauna/flora assessed :

% live maerl assessed :

Other tasks completed: checking the new runner dredge (length of warp=90m), training of the crew and maerl team about big ship board works (fishing, sieving, and samples treatment).

Additional information: The bottoms are a mixture of maerl, stones, sand and coralligenous blocks, and a irregular topography.

2 echosounder transects; 9 grab samples (2 default); 1 dredge sample. The runner dredge has not worked well on these bottoms, and it was damaged

Signed: Alfonso A. Ramos Esplá (Survey Leader)

EC Biomaerl Cruise Survey Report

Cruise Reference Number: UAI-291197

Site Reference Number: UAI-36

Date: 29.11.97

Laboratory : UA Marine Biology

Vessel: "Odón de Buen" y "Sirpus"

Site Name: Benidorm Island

Lat/Long:

Area 1: 38°30.06-30.22'N / 00°08.15-08.30'W;
Area 2: 38°30.32-30.20'N / 00°08.72-08.66'W

Depth (sea level): 31-38m

Dive depth: 34.7m

Depth (Chart d.)

Surveyors: C. Barberá, C. Martínez, J.L. Patiño, C. Valle, A. A. Ramos

Equipment used: SCUBA, quadrats with mesh bag, corer, runner dredge (frame = 1.0 x 0.3m), Van Veen grab, Secchi disk, thermometer,

Surface Salinity :

Surface water temp. : 16.6°C

Benthic Salinity :

Benthic water temp. : 16.5°C

Secchi Disk Reading : 26m

Max. current surf.: bottom: <0.1kn. N.E

Tick tasks completed (Area 1): dredge (3 samples: time 2' and 1.2 knots) and SCUBA sampling (6 quadrats), oceanographic parameters, sedimentological sampling (1); bottom topography by echousounder.

Suspended solids load : +

General photography :

Sediment cores : +

Grab/Dredge samples : +

Sediment surface topography : +

Resin casting :

Fauna/flora assessed : +

% live maerl assessed : +

Other tasks completed: exploring a new site in the Benidorm sector (Area 2) by echosounder, grab (3) and dredge (3) samples.

Additional information: SCUBA observations: high visibility (>15m), wide patches of *Peyssonnelia rubra* (in development?); *Flavelia petiolata* (r), *Valonia macrophysa* (c.), *Lithophyllum expansum* (1ex.), *Echinaster sepositus* (1ex.), *Serranus hepatus* (1ex.), Briozoa (*Aldeonella calveti* ?).
Dredge samples (**Area 1**): *Peyssonnelia spp* (cc), Porifera (*Cliona viridis* c, *Axinella damicornis* r.), Aphroditidae (c.), Crustacea Decapoda (*Scyllarus pygmaeus* r, *Macropodia spp.* c, *Parthenope spp.* r), Echinodermata (*Echinaster sepositus* c, *Sphaerechinus granularis* cc), Pisces (*Serranus hepatus* c, *S. cabrilla* r, *Monochirus hispidus* r, *Hippocampus hippocampus* r).
Area 2: it seems more impacted by trawlers: *Peyssonnelia spp.* and Corallinacea lesser abundant than area 1, Porifera (*Cliona viridis*), Aphroditidae (c.), Mollusca (dead shells, *Bolma rugosa* r, *Turritella turbona* r), Decapoda (hermit crabs c), Pisces (*Trigloporus lastoviza* r)

Signed: Alfonso A. Ramos Esplá (Survey Leader)

EC Biomaerl Cruise Survey Report

Cruise Reference Number: UAC131297	Site Reference Number: UAC-37	
Date: 13.12..97	Laboratory · UA Marine Biology	
Vessel: "Odón de Buen" and "Sirpus"	Site Name: Tabarca Marine Reserve	
Lat./Long.: 38° 09.1-08.6 N / 00° 25.8-26.2 W	Depth (sea level): 33-41m	Depth (Chart d.)

Surveyors: C. Bordehore, J.A. Moya, J.L. Patiño, A.A. Ramos, C. Valle

Equipment used: SCUBA, diver quadrats, cores, runner dredge (1.0 x 0.3m), U/W video-camera, thermo-salinometer Hugrun, Secchi disk, Niskin bottle, echosounder.

Surface Salinity : +	Surface water temp. : 16.4°C
Benthic Salinity : +	Benthic water temp. : 16.4°C
Secchi Disk Reading : 10m	Max. current surf.: bottom:

Tick tasks completed : diving quadrat samples (6), dredge samples (3), hydrographic paramethers (transparence, temperature, salinity, seston), core samples (2) .

Suspended solids load +	General photography : video records
Sediment cores : +	Grab/Dredge samples : +
Sediment surface topography · +	Resin casting .
Fauna/flora assessed : +	% live maerl assessed . +

Other tasks completed: Video records in surface and bottom; topography of the sampling bottoms, dredging at different depths (33-35m and 38-41m) to compare; echousounding of the maerl beds (30-44m).

Additional information: Diving at 41m
Maerl beds in thin strips (lesser than 38m); about 10% maerl of the bottom coverture, on sand-mud bottom.
Flora: *Phymatolithon calcareum, Lithophyllum duckeri, Lithothamniim cf. corallioides, Osmundaria volubilis, Flavellia petiolata, Halopitis incurvus, Valonia macrophysa*
Fauna: Crustacea: *Eupagurus prideauxi, Lissa chiragra, Calcynus erithropus*; Echinodermata: *Echinaster sepositus, Sphaerechinus granularis*; Ascidiacea: Didemnidae spp. (*Didemnum fulgens ?, D. coriaceum*); Pisces: *Scorpaena notata.*

Signed: Alfonso A. Ramos Esplá (Survey Leader)

EC Biomaerl Cruise Survey Report

Cruise Reference Number: UAB-38	Site Reference Number: Alicante Bay	
Date: 16.01.98	Laboratory : Marine Biology UA	
Vessel: Kontiki II	Site Name: Alicante Bay	
Lat./Long.: 38°18.37’-19.64’ N / 00°24.36’-25.07’ W	Depth (sea level): 34-44..5	Depth (Chart d.)

Surveyors: C. Bordehore, J. Mallol, J.L. Patiño, A.A. Ramos

Equipment used: GPS, Echosounder, Secchi Disk, Van Veen grab ($0.04m^2$), small runner dredge (45 x 25 cm), thermometer

Surface Salinity :	Surface water temp. 14.8°C
Benthic Salinity	Benthic water temp. :

Secchi Disk Reading : 9-11m	Max. current surf.:	bottom:

Tick tasks completed : survey a new area of possible degraded maerl beds on the NE of the Alicante Bay by remote sampling with Van Veen grab and small runner dredge

Suspended solids load :	General photography :
Sediment cores	Grab/Dredge samples : 16
Sediment surface topography :	Resin casting :
Fauna/flora assessed :	% live maerl assessed :

Other tasks completed: measure of hydrological parameters (temperature, transparency)

Additional information:

The selected zone has been proposed as harbour sediment dumping area (35-40m depth). The small dredge has not work well.
The bottoms are sand-muddy sediments with dead mollusca shells (mainly bivalves) and dead Posidonia rhizomes. The fauna is impoverished, mainly polychaetes and ophiurids.

Signed: Alfonso A. Ramos Esplá (Survey Leader)

EC Biomaerl Cruise Survey Report

Cruise Reference Number: UAC-39	Site Reference Number: UAC
Date: 04.03.98	Laboratory : Marine Biology UA
Vessel: Sirpus	Site Name: Tabarca Marine Reserve

Lt./Lg. 38°09.08'-09.19'N/ 00°25.10-25.95'W	Depth (sea level): 36.5-37.5m	Depth (Chart d.

Surveyors: C. Barberá, C. Bordehore, J.L. Patiño

Equipment used: small runner dredge (45 x 25 cm), Niskin bottle, Secchi disk, echosounder, currentimeter

Surface Salinity :	Surface water temp.
Benthic Salinity :	Benthic water temp.

Secchi Disk Reading : 16m	Max. current surf.: 1.0 knot (?)	bottom:

Tick tasks completed : sampling of hydrological parameters (seston), transparency ; sampling by dredge

Suspended solids load	General photography :
Sediment cores :	Grab/Dredge samples : 4
Sediment surface topography :	Resin casting :
Fauna/flora assessed :	% live maerl assessed :

Other tasks completed:

Measure currents by the Kalshico currentimeter

Additional information:

The currentimeter not work well. One dredge sample has fault. Maerl bed and stone bottom.

Maerl spp : *Mesophyllum lichenoides, Lithophyllum duckeri*. Folious algae : *Phyllophora nervosa, Halopteris filicina, Psudolithophyllum expansum.* Hidrozoa : (*Eudendrium sp.*) ; Briozoa : (*Beania histissima, Margaretta cereioides*) , Polyhaeta : Serpulidae. Restos de muda d *Calappa granulata* (decapoda brachiura).

Signed: Alfonso A. Ramos Esplá (Survey Leader)

EC Biomaerl Cruise Survey Report

Cruise Reference Number: UAC-40	Site Reference Number: UAC	
Date: 06.03.98	Laboratory : Marine Biology	
Vessel: Sirpus	Site Name: Tabarca Marine Reserve	
Lat./Long.. 38°09.26'N / 00°25.78'W	Depth (sea level): 37.4m	Depth (Chart d.)

Surveyors: divers: C. Bordehore, J.L. Patiño, A.A. Ramos; on board: C. Barberá

Equipment used: SCUBA, diver quadrates and cores, U/W Nikonos and flash, Hugrún T/S

Surface Salinity :	Surface water temp. 14.0° C
Benthic Salinity :	Benthic water temp. : 14.0°C
Secchi Disk Reading :	Max. current surf.: 0.3 kn NE bottom: < 0.1 kn SE

Tick tasks completed :

Sampling by diver quadrates (6) and cores (2), vertical profile of temperature and salinity.

Suspended solids load :	General photography +
Sediment cores : 2	Grab/Dredge samples 6 quadrates
Sediment surface topography +	Resin casting :
Fauna/flora assessed : +	% live maerl assessed : +

Other tasks completed:

Transect U/W photographs using the anchor chain and a metallic quadrate (69 x 46 cm).
Current measures

Additional information:

The maerl is distributed in irregular strips (20-30 cm wide), some stones; folious algae very rare

Fauna observed: Echinoderms: *Echinaster sepositus* (1 ex.), *Genocidaris* test (1.5 cm); Gastropods: *Turritella turbona* dead shells; Pisces: small Gobidae (2 ex.)

Signed: Alfonso A. Ramos Esplá (Survey Leader)

EC Biomaerl Cruise Survey Report

Cruise Reference Number: UAI-41	Site Reference Number: UAI	
Date: 07.03.98	Laboratory : Marine Biology	
Vessel: Sirpus	Site Name: Benidorm Island	
Lt./Lg. 38°30.97'-30.15'N / 00°08.22'-08.00'W	Depth (sea level): 34-37.0m	Depth (Chart d.)

Surveyors: divers: C. Barberá, C. Bordehore, y C. Valle

Equipment used: SCUBA, diver quadrates and cores, U/W Nikonos and flash, Hugrún T/S, Secchi disk, Niskin bottle, GPS

Surface Salinity : +	Surface water temp. : 14.0° C
Benthic Salinity : +	Benthic water temp. : 14.0°C
Secchi Disk Reading : 25m	Max. current surf.: bottom: < 0.1 kn SE

Tick tasks completed :

Sampling by diver quadrates (6), cores (1) and dredges (3)

Suspended solids load : +	General photography : +
Sediment cores : 1	Grab/Dredge samples : 6 quad. + 3 dredg.
Sediment surface topography : +	Resin casting :
Fauna/flora assessed : +	% live maerl assessed : +

Other tasks completed:

Vertical profile of temperature and salinity ; transparency. U/W photographs using the anchor chain and a metallic quadrate (69 x 46 cm).

Additional information:

The maerl is distributed by patches with *Peyssonnelia rubra* (dominant), *P. orientalis* and *Flavellia petiolata* (dispersed). The dredge sampling has also catch *Lithothamnium corallioides* and *Phymatolithon calcareum*.

Fauna observed an sampled: Porifera : *Cliona viridis* (common) ; Briozoa ; Ascidian (*Diplosoma, Didemnum coriaceum*) ; Cephalopodes : *Octopus vulgaris* (juvenile 1cm mantle).

Signed: Alfonso A. Ramos Esplá (Survey Leader)

EC Biomaerl Cruise Survey Report

Cruise Reference Number: UAC-220598	Site Reference Number: UAC-42	
Date: 22.05.98	Laboratory : Marine Biology UA	
Vessel: Sirpus	Site Name: Tabarca Marine Reserve	
Lt./Lg. 38°09.27'N / 00°25.75'W	Depth (sea level): 35-37.0m	Depth (Chart d.)

Surveyors: divers: C. Barberá, J. Mallol, J.L. Patiño & A.A. Ramos

Equipment used: runner dredge, Niskin bottle, Secchi disk, echosounder, GPS-Sony

Surface Salinity :	Surface water temp. :
Benthic Salinity :	Benthic water temp. :
Secchi Disk Reading : 16m	Max. current surf.: bottom:

Tick tasks completed :

Dredges (3), hydrological parameters (transperency, seston)

Suspended solids load :	General photography :
Sediment cores :	Grab/Dredge samples : 3 dredges
Sediment surface topography :	Resin casting :
Fauna/flora assessed : +	% live maerl assessed :

Other tasks completed:

Observations on the flora and fauna sapled by dredge

Additional information:

Some stones in the samples.
Flora . *Phymatolithon calcareum, Lithothamnion corallioides Mesophyllum lichenoides, Lithophyllum duckeri, Dictyota dichotoma*
Flora : Hydrozoa (*Eudendrium sp.*), Briozoa (*Bugula turbinata*)

Signed: Alfonso A. Ramos Esplá (Survey Leader)

EC Biomaerl Cruise Survey Report

Cruise Reference Number: UAC-230598

Site Reference Number: UAC-43

Date: 22.05.98

Laboratory : Marine Biology UA

Vessel: Sirpus

Site Name: Tabarca Marine Reserve

Lt./Lg. 38°09.27'N / 00°25.75'W

Depth (sea level): 35-37.0m

Depth (Chart d.)

Surveyors: divers: J.L. Patiño C. Valle, A.A. Ramos & C. Barberá (on board)

Equipment used: SCUBA diving, diver quadrates, cores, Hugrun T/S, echosounder, GPS-Sony, Nikonos U/W camera + U/W flash.

Surface Salinity · +

Surface water temp. : +

Benthic Salinity : +

Benthic water temp. : +

Secchi Disk Reading ·

Max. current surf.: 0.1kn bottom: = 0.1kn. SW

Tick tasks completed : sampling by the diver quadrats (6), T/S perfil

Suspended solids load :

General photography : +

Sediment cores :

Grab/Dredge samples : 6 quadrats

Sediment surface topography +

Resin casting :

Fauna/flora assessed : +

% live maerl assessed :

<u>Other tasks completed</u>: filmation on board

Transect photography and observations on the flora and fauna sapled by dredge

<u>Additional information</u>: good visibility = 15m
Lost of three samples
Maerl strips 20-30cm, not in clear parallel range.

Flora : *Phymatolithon calcareum, Lithothamnion corallioides Mesophyllum lichenoides, Lithophyllum duckeri*.
Flora : Crustacea (*Dardanus arrosor* with *Callynactis parasitica*) ; Ascidiacea (*Rhopalaea neapolitana, Didemnum fulgens ?*) ; Cepalopoda (juvenile of *Octopus vulgaris*, 1-2cm mantle).

Signed: Alfonso A. Ramos Esplá (Survey Leader)

EC Biomaerl Cruise Survey Report

Cruise Reference Number: UAI-100698

Site Reference Number: UAI-44

Date: 10.06.98

Laboratory : UA Marine Biology

Vessel: "Sirpus"

Site Name: Benidorm Island

Lat/Long: 38º30.06-30.22'N / 00º08.15-08.30'W

Depth (sea level): 34-36m

Depth (Chart d.)

Surveyors: C. Barberá, J.L. Patiño & C. Bordehore

Equipment used: small runner dredge (frame = 0.5 x 0.25m), Secchi disk, Niskin bottle, echosounder, GPS-Sony.

Surface Salinity :

Surface water temp. :

Benthic Salinity :

Benthic water temp. :

Secchi Disk Reading : 25m

Max. current surf.:

bottom:

Tick tasks completed : dredge (3 samples: time 2' and 1.2 knots), oceanographic parameters transparency, seston)

Suspended solids load : +

General photography :

Sediment cores :

Grab/Dredge samples : dredge (3)

Sediment surface topography :

Resin casting :

Fauna/flora assessed : +

% live maerl assessed :

Other tasks completed:

Observation of a new zone (near of the rock bottoms

Additional information: Fauna and flora observations, some large rhodolithes (*Lithophyllum duckeri* = 8 cm):

Flora : *Peyssonnelia rubra, P. orientalis*, *Lithothamnium corallioides, Flavelia petiolata* (r), *Caulerpa prolifera. Codium bursa.*

Fauna : Cnidaria (*Caryophillia sp.*), Polychaeta (*Hermione hystrix*) ; Crustacea (*Ethusa mascarone*) ; Briozoa (*Myriapora truncata*) ; Ascidiacea (Didemnidae).

Signed: Alfonso A. Ramos Esplá (Survey Leader)

EC Biomaerl Cruise Survey Report

Cruise Reference Number: UAI-170698	Site Reference Number: UAI-45	
Date: 17.06.98	Laboratory : UA Marine Biology	
Vessel: "Sirpus"	Site Name: Benidorm Island	
Lat/Long: 38º30.95'N / 00º08.10'W	Depth (sea level): 35.5m	Depth (Chart d.)

Surveyors: C. Barberá (on board), C. Bordehore, & J.L. Patiño

Equipment used:

SCUBA, quadrats with mesh bag, corer, Hugrún T/S, echosounder, GPS-Sony

Surface Salinity : +	Surface water temp. : +
Benthic Salinity : +	Benthic water temp. : +
Secchi Disk Reading :	Max. current surf.: 0.2m/seg. SW bottom:

Tick tasks completed :

SCUBA sampling (6 quadrats), oceanographic parameters (temperature, salinity) sedimentological sampling (1core).

Suspended solids load :	General photography :
Sediment cores : + (1)	Grab/Dredge samples : quadrats (6)
Sediment surface topography : +	Resin casting :
Fauna/flora assessed : +	% live maerl assessed : +

Other tasks completed:

Observations of the maerl patches (larger than other observations)

Additional information:

SCUBA observations: high visibility (25-30m), thermocline at 21-22m.

Flora : wide patches of *Peyssonnelia rubra* and *P. orientalis*

Fauna : Gastropoda (*Turritella* turbona), Bivalvia (large Veneridae)

Signed: Alfonso A. Ramos Esplá (Survey Leader)

EC Biomaerl Cruise Survey Report

Cruise Reference Number: UAC250898	Site Reference Number: UAC-46	
Date: 25/08/97	Laboratory : UA Marine Biology	
Vessel: 'Sirpus'	Site Name: Tabarca Marine Reserve	
Lat./Long.: 38° 08.87'N-00° 25.67'W	Depth (sea level): 37m	Depth (Chart d.)

Surveyors: C. Barberá, J.L. Patiño, A.A. Ramos & J. Mallol (on board)

Equipment used: SCUBA divig, diver quadrats, corer, U/W photography

Surface Salinity :	Surface water temp. :
Benthic Salinity :	Benthic water temp. :
Secchi Disk Reading :	Max. current surf.: 0.2kn WNW bottom: 0.1kn NE

Tick tasks completed : diver quadrats and corer

Suspended solids load :	General photography :
Sediment cores : 1	Grab/Dredge samples : 6 quadrats
Sediment surface topography : +	Resin casting :
Fauna/flora assessed : +	% live maerl assessed : +

Other tasks completed: thermocline (17-25m), general observation on bottom

Additional information: stony bottom with maerl spp. (*Lithothamnion coralloides, Lithophyllum duckery, Mesophyllum lichenoides, Peyssonnelia spp.*). Good visibility (about 20m).

Another macroalgae observed: *Arthrocladia villosa* (more abundant)

Fauna observed: *Margaretta cereoides* (briozoan), *Echinaster sepositus* (asteroid, 2 ex.)

Corer lost and C. Barbera with problems in the hearing (not diving and not U/W photography)

Signed: Alfonso A. Ramos Esplá (Survey Leader)

EC Biomaerl Cruise Survey Report

Cruise Reference Number: UAC260898	Site Reference Number: UAC-47	
Date: 26/08/97	Laboratory : UA Marine Biology	
Vessel: 'Sirpus'	Site Name: Tabarca Marine Reserve	
Lat./Long.: 38° 08.72-87'N / 00° 25.02-67'W	Depth (sea level): 34 -38m	Depth (Chart d.)

Surveyors: C. Barberá, J. Mallol, J.L. Patiño & A.A. Ramos

Equipment used: small runner dredge (0.45m frame), Secchi disk, Niskin hydrological bottle (5l), echosounder.

Surface Salinity :	Surface water temp. :
Benthic Salinity :	Benthic water temp. :
Secchi Disk Reading : 26m	Max. current surf.: bottom:

Tick tasks completed : dredge samples, hydrological parameters (transparency, seston)

Suspended solids load : +	General photography
Sediment cores .	Grab/Dredge samples : 3
Sediment surface topography :	Resin casting :
Fauna/flora assessed . +	% live maerl assessed :

Other tasks completed: observation of the dredge bottoms and more conspicuous flora/fauna

Additional information:

1) Dredges 1 and 2 have sampled on stony-maerl bottoms with *Arthrocladia villosa* and *Dictyota dichotoma* (soft algae), and *Lithophyllum duckeri, Lithothamnion coralloides, Peyssonnelia spp.* and *Mesophyllum lichenoides.* Some thali of *Valonia macrophysa* and *Cystoseira zosteroides.*
Fauna: *Cliona viridis* (Porifera); *Filograna implexa* (Polychaeta); *Margaretta cereoides, Myriapora truncata* (Briozoa); *Macropodia spp.* (Crustacea); *Didemnum fulgens?* (Ascidiacea).

2) Dredge 3 has sampled on maerl bed with *Phymatolithon calcareum, Lithothamnion coralloides, Lithophyllum duckeri* and *Mesophyllum lichenoides*; some thali of *Osmundaria volubilis* and *Valonia macrophysa*: and dead shells of *Glycimeris* and *Pecten*. .
Fauna: *Pecten jacobeus, Chlamys,* Cardiidae, Veneridae (Bivalvia); *Paguristes eremita,* Paguridae, *Lissa chiragra, Parthenope massena* (Crustacea); *Beania hirtissima* (Briozoa); Ophiuridae; *Cystodytes dellechiajei* (Ascidiacea). .

Signed: Alfonso A. Ramos Esplá (Survey Leader)

EC Biomaerl Cruise Survey Report

Cruise Reference Number: UAI270898	Site Reference Number: UAI-48	
Date: 27.08.98	Laboratory : UA Marine Biology	
Vessel: 'Sirpus'	Site Name: Benidorm Island	
Lat./Long.: 38° 30.06-22'N / 00° 08.15-30'W	Depth (sea level): 32-38m	Depth (Chart d.)

Surveyors: C. Barberá, J. Mallol, J.L. Patiño & A.A. Ramos

Equipment used: Small runner dredge (0.45m frame), echosounder, Niskin hydrological bottle, Secchi disk

Surface Salinity :	Surface water temp.
Benthic Salinity :	Benthic water temp. :

Secchi Disk Reading : 26.4m	Max. current surf.:	bottom:

Tick tasks completed : Dredge sampling and hydrological parameters (transparency, seston)

Suspended solids load : +	General photography :
Sediment cores :	Grab/Dredge samples : 3 (≅ 20m^2/sample)
Sediment surface topography :	Resin casting :
Fauna/flora assessed : +	% live maerl assessed :

Other tasks completed: Assessment of the flora and fauna

Additional information:

Dredge 1and 2: *Gracillaria sp.* and *Polysiphonia sp.* (cc) with rare *Peyssonnelia spp.* and *Lithothamnion corallioides*; with abundant Bullomorpha sp., Cardidae sp., *Macropodia rostrata* and., also *Liocarcinus sp.*

Dredge 3: *Peyssonnelia orientalis* (cc), *P. rubra* (r) and *Lithothamnion corallioides* (c), with *Flavellia petiolata* and *Valonia macrophysa*. The more abundant fauna is represented by *Laetmodice hystrix* (Polychaeta) and Paguridae.

Signed: Alfonso A. Ramos Esplá (Survey Leader)

EC Biomaerl Cruise Survey Report

Cruise Reference Number: UAI280898	Site Reference Number: UAI-49
Date: 28.08.98	Laboratory : UA Marine Biology
Vessel: 'Sirpus'	Site Name: Benidorm Island
Lat./Long.: 38° 29.90' N - 00° 08.08' W	Depth (sea level): 34.5 Depth (Chart d.)

Surveyors: C. Barberá, J.L. Patiño and A.A. Ramos (divers); and J. Mallol (on board),

Equipment used: SCUBA diving, diver quadrats with fine mesh (∅=1mm), corer, Hugrún termo-salinometer, echosounder.

Surface Salinity : +	Surface water temp. : +
Benthic Salinity : +	Benthic water temp. : +
Secchi Disk Reading :	Max. current surf.: 0.2kn. NE bottom: >0.1kn N

Tick tasks completed . Quantitative sampling by diver quadrats (0.05m^2) and corer, temperature and salinity profiles

Suspended solids load .	General photography
Sediment cores :	Grab/Dredge samples :
Sediment surface topography : +	Resin casting :
Fauna/flora assessed : +	% live maerl assessed : +

Other tasks completed:

Thermocline layer, surface and bottom currents, and flora/fauna general observation

Additional information: This muddy bottom is not similar to the another previously studied (seasonal change?). Some otter-trawl tracks on the bottom.

Flora: Phaeophyta abundant (*Arthrocladia villosa ?*) and homogeneous dispersed, scarce *Peyssonnelia spp.* and not in patches.

Fauna: Only *Sphaerechinus* dead shells and a small gobid fish.

Very good visibility, about 25m; thermocline at 18-25m.

Signed: Alfonso A. Ramos Esplá (Survey Leader)