# REPORT OF THE
# STUDY GROUP ON SPATFALL AND RECRUITMENT IN BIVALVE STOCKS



International Council for the Exploration of the Sea

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## 1 INTRODUCTION

The Study Group on Spatfall and Recruitment in Bivalve Stocks was installed during the Statutory Meeting of 1993 and was the follow-up of two workshops on spatfall and recruitment of mussels and cockles held in Yerseke, The Netherlands, in 1992 and 1993. During the Statutory Meeting it was decided that, whereas the scope of the workshops had been restricted to mussels and cockles (after a period of recruitment failure in 1990–1993), the scope of the study group should encompass all bivalve species, including participation from the United States and Canada. During the Council Meeting in 1994, Dr C.H. Peterson was appointed co-chairman.

Unfortunately, the copies of the 1994 report of the Study Group were lost before the meeting in St Johns. The country reports of 1994 are now included in this report.

## 2 MEMBERSHIP IN 1995

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## 3 PROGRAM AND ACTIVITIES

In 1994 there were five contributions to the Study Group report from Canada, Spain, Germany, the Netherlands, and Denmark, mainly country reports. In 1995, there were only 3 contributions: from the United States, Canada, and the Netherlands. In order to decide on future work for the Study Group, members considered the following proposal submitted by C.H. Peterson.

### 3.1 Goals of the Study Group in 1996

The Study Group on Spatfall and Recruitment in Bivalve Stocks proposes to the Shellfish Committee that it work hard in the next year to produce a formal and comprehensive review of what is known about the biological determinants of recruitment of commercially important bivalve stocks. This would involve the compilation of a review of sufficient scope and excellence to be published in the peer-reviewed literature, e.g., the *Annual Reviews of Oceanography and Marine Biology*.

To achieve this goal, the Study Group would need a commitment of active help by members of each ICES country to assemble, reproduce, and deliver to the co-chairmen copies of all relevant unpublished literature and management agency reports relevant to this topic. Much valuable information is unavailable in the published literature, so the ICES format could be wonderfully effective in assembling such information to allow a comprehensive review by the Study Group. This review will aid in formulating and modifying management strategies on a global scale.

#### 3.1.1 Format and outline of the review

A review of the status of each of several currently popular and logically viable hypotheses that relate recruitment in bivalves to adult densities is proposed. Each of the hypotheses specified below plus others identified by members of the Study Group would be evaluated for a number of ecologically and taxonomically different groups of bivalves: (1) infaunal clams; (2) mussels; (3) scallops; and (4) oysters. The hypotheses to be initially considered are as follows.

#### 3.1.2 Hypothesis 1

On a large scale commensurate with the dispersal of their pelagic larvae, recruitment in bivalve mollusc populations can become limited by reduction in abundance of spawning stock. Such "recruitment limitation" must necessarily occur at some low level of spawner density but the question of whether spawner stock densities are ever reduced far enough to invoke this effect is not well answered. The classic view held by shellfisheries managers is that adult shellfish produce so many eggs per capita that there is no relationship between spawner stock and recruitment. This assumption is coming under re-examination, and a review of the status of this hypothesis as it applies to the four separate groups of harvestable bivalves is justified.

#### 3.1.3 Hypothesis 2

On a smaller spatial scale of an individual shellfish bed, recruitment is depressed at high adult density by negative adult larval interactions because adult suspension-feeding bivalves consume invading larvae. This hypothesis can be addressed indirectly by examining the degree of overlap of spatial distributions of separate year classes within a population or it can be addressed more directly by evaluating whether larvae are ingested and killed by ingestion.

### 3.1.4 Hypothesis 3

On a local scale, recruitment of bivalve larvae is enhanced by the presence of adults either because larvae are induced to settle by detecting the presence of adults or because adults provide or modify habitats in ways that promote postlarval survival. This hypothesis seems most relevant to oysters, which create the hard substrate upon which larvae can and do settle, but it may also apply more broadly because the presence of adults could serve as a reliable clue that the habitat is suitable for maturation and survival.

### 3.1.5 Hypothesis 4

The disturbance of the habitat associated with harvest of adult bivalves or with harvest of other fisheries species degrades the habitat and depresses recruitment success of the bivalves. This issue applies especially to bivalves that inhabit vegetated habitats because such vegetation is so readily harmed by bottom-disturbing harvest practices. Nevertheless, even sedimentary structures can be altered by harvest disturbance and harvest of adults can also have direct negative effects on juvenile bivalves.

To complete a thorough review of these and other processes by which adults may influence recruitment in bivalves, the Study Group requests that the Shellfish Committee grant permission to request submission of necessary literature from each ICES Member Country, transmitted by its representative on our Study Group. The chairmen will attempt an initial synthesis, followed by circulation to and review by the full Study Group.

## 4 PRINCIPAL ITEMS IN THE 1994 REPORT

### 4.1 Country Reports and Research Contributions

### 4.1.1 The Netherlands

#### 4.1.1.1 Stocks, spatfall and recruitment of mussels and cockles in 1994

**Mussels *Mytilus edulis***

In the spring of 1993, an assessment was made of the size of the stock of mussel seed and half-grown mussels in the western part of the Wadden Sea. A preliminary survey showed that mussel seed beds of any significance were present only in this area. Storms in winter 1993/1994 had decimated the mussel seed stock, formed by the good 1992 spatfall in the Wadden Sea. Of the entire mussel stock in this area, 95% appeared to be 1992 recruits. In total 43 000 (gross) tonnes of mussel seed were found in the area, of which about 34 000 would be fishable. The average percentage of tare (shell debris, byssus, sand, sillt) was 51%. The mussel fishery industry decided in its 1993 fishing scheme to refrain from fishing on the intertidal flats and in the eastern part of the Wadden Sea. In total, 15 000 tonnes of seed were distributed over the mussel growers. The usual autumn fishery for mussel seed was cancelled in view of the poor stocks.

Spatfall of mussels, after a long (November–March), but not very cold winter of 1993/1994, was considered to be profuse in August 1993, although mortality is still possible before an autumn fishery. A stock survey is being planned for autumn 1994.

**Cockles *Cerastoderma edule***

The regular survey of the adult stock in the spring of 1993 (Dijkema, 1992; 1993) revealed in the Oosterschelde a biomass of 33 000; in the Westerschelde 10 000; and in the Wadden Sea 170 000 tonnes of cockles (fresh weight). This means that 3 800, 2 400 and 17 000 tonnes, respectively, were in harvestable densities (> 50/$m^2$). The survey in the spring of 1994 gave significantly lower biomass figures: 32 000, 6000, and 92 000 tonnes wet weight total biomass in the Oosterschelde, the Westerschelde, and the Wadden Sea, respectively.

Cockle recruitment in 1992 was poor. The spatfall of 1994, however, appears to be good to very good at first sight (July 1994) in the Wadden Sea, the Oosterschelde, and the Westerschelde, as well as along the southern North Sea coast.

**References**

Kesteloo-Hendrikse, J.J. 1993. Het kokkelbestand in de Oosterschelde, de Westerschelde, de Waddenzee en de Voordelta in 1993. Preliminary report. RIVO-DLO.

Kesteloo-Hendrikse, J.J. 1994. Het kokkelbestand in de Oosterschelde, de Westerschelde, de Waddenzee en de Voordelta in 1994. Preliminary report. RIVO-DLO.

Van Stralen, M.R., and Schol-Brand, C.M.. 1993. Het mosselbestand in de Westelijke Waddenzee in het voorjaar van 1993. Preliminary report. RIVO-DLO.

#### 4.1.1.2 Settlement of mussels *Mytilus edulis* in the western Dutch Wadden Sea

by Cees de Vooys, DLO Institute for Forestry and Nature Management (IBN-DLO)

Settlement of mussels has been moderate to poor in the last six years. In the years 1989 and 1990 settlement was very poor, it was better in 1991 and 1993, and appears poor again in 1994. Most winters have been mild in this

period. It is well known that after a severe winter huge mussel spatfalls occur often. In contrast, after very mild winters with little or no frost, no spatfall at all has been found. Very severe or very mild winters, however, seldom occur. Experience shows that after 'normal' winters spatfall is very variable. The factors that cause this variability are not known and have scarcely been investigated. In the propagation of mussels three stages can be distinguished.

Stage 1 begins when gametogenesis is finished and the gametes are ripe. Spawning should be timed as much as possible at the same time to guarantee maximal fertilizing of the eggs. After spawning a pelagic larva stage occurs for one month. The 'trigger' for the spawning could be a temperature shock.

Stage 2. When the larvae are completely developed (pediveliger stage), they will attach themselves on thread from substrates, on which they metamorphose. From their numbers, an assessment can be made on the survival of the larvae.

Stage 3. After metamorphosis the small mussels detach and become pelagic again floating in the water column with a thread. When they find a suitable substrate they will settle.

In the western Dutch Wadden Sea observations have been made on the concentration of larvae in the water and the metamorphosis of mussel larvae over several years. Many of these samples still have to be counted and analysed. The spawning peaks of larvae can be correlated with temperatures of the upper water layer to investigate if there exists a 'trigger' effect of temperature. The number of metamorphosing larvae can be compared between years, and matched to the number of larvae found in the same year. On settlement and the period between the settlement and the spat stage hardly any research has been carried out (spat stage is defined here as young mussels less than one year old, larger than 1 cm occurring in autumn). However, survival in this period could be an important factor in determining the amount of spat available for fishermen and birds. From the time of spawning, the following factors could negatively influence the mass of spat:

(1) few eggs;

(2) bad quality of eggs (i.e., little reserve food);

(3) few larvae;

(4) too little food for larvae;

(5) heavy predation of larvae;

(6) low salinities at the time of settlement;

(7) heavy predation after settlement;

(8) effects of storms.

As for (1), the number of eggs will not soon be limiting. In 1992 in the west Dutch Wadden Sea, an extreme low parent stock produced enough eggs to give a moderate spatfall. The condition of the adult mussel will determine the quality of the eggs, and the number of eggs and larvae per mussel. It is desirable to match the occurrence of the phytoplankton with that of the larvae, to see which phytoplankton species are important as food for the larvae, and its influence on larval survival. Especially at the time of settling, larvae can be directly predated by adult mussels or other bivalves. When a large settlement occurs this probably will not be a problem, but it can be when relatively few larvae are present with a large adult stock. In addition to predation, other factors mentioned which can influence settlement and the survival till the spat stage should be matched to the mortality and the amount of surviving spat. Especially important for the western Dutch Wadden Sea are predation, salinity, storms, and sediment stability.

### 4.1.2 Denmark

### 4.1.2.1 Stocks and recruitment of bivalves in Danish waters 1993/1994

by Per Sand-Kristensen, Danish Institute for Fisheries and Marine Research, Charlottenlund

**Survey of Danish mussel stocks**

In 1993, a comprehensive survey on the mussel *Mytilus edulis* stocks in Limfjorden and the Danish Wadden Sea was carried out (Hofman, 1993; Kristensen, 1994a). Stock densities in Limfjord varied between 0 and 416 g per $m^2$ of total wet weight.

The stock in Limfjord in 1993 consisted of up to 5 different year classes. The dominating year class in the Wadden Sea in 1993 was a very strong 1987 cohort.

**Recruitment**

In 1993, the spatfall of mussels has been poor in most Danish waters.

The spatfall has only been good in one area in Limfjord. In April 1994, a comprehensive spatfall took place in a limited area in Lovns Bredning of Limfjord (Figures 1 and 2). Thousands of small mussels per $m^2$ (shell length 0.25–1.5 cm) had settled on older mussels, algae, and the sand tubes of *Korenii* sp. (Kristensen, 1994b).

There is no information from 1993 or 1994 on the spatfall in the Little Belt and the other mussel fishing areas (Table 1).

| Mussel fishing area | Spatfall |
|---|---|
| Limfjord | Generally poor, but exellent in Lovns |
| Little Belt | Unknown |
| Wadden Sea | Poor |
| Isefjord | Unknown |

*Table 1: Danish mussel fishing areas and the spatfall in 1993/1994.*

**Survey of mussel stocks**

In May 1994 a comprehensive survey of the mussel stocks in the Kattegat area (ICES area IIIc (22) was initiated. The three most important fjords, i.e., Kolding, Vejle and Horsens fjords, will be investigated the first year (Figure 1). Other areas will be investigated during the following years by standard survey techniques (Van Veen sampling (water depth <3 m) and swept area analyses (water depth > 3m).

#### 4.1.2.2 Cockles *Cerastoderma edule*

**Recruitment**

In 1993 the recruitment of cockles in the Danish Wadden Sea was very poor. The mussel survey in Limfjord in April 1994 revealed large cockle stocks in the westernmost parts of the fjord which may be commercially exploitable, and which had settled in 1991.

#### 4.1.2.3 *Spisula solida*

**Fishery**

In 1993 and 1994 around 1000 tonnes of *Spisula solida* have been landed annually from the North Sea (Kristensen, 1994a).

**Recruitment**

There is no information on spatfall of *Spisula solida* in 1993 or 1994.

#### 4.1.2.4 Oysters *Ostrea edulis*

In 1993 around 100 000 pieces of European flat oysters (*O. edulis*) were landed from Limfjord. The new comprehensive stock was established around 1990. There is, at this moment, no knowledge about stock size or distribution of individuals in the stock.

#### 4.1.2.5 References

Hofmann, E. 1993. Blåmuslingebestanden i Limfjorden 1993. DFH rapport nr. 465a. 78 pp.

Kristensen, P.S. 1994a. *Spisula solida*/Tykskallet trugmusling. Fordkomst og udbredelse i den Dansks del af Nordsoen syd for Horns Rev. DFH-rapport nr. 472. 21. pp.

Kristensen, P.S. 1994b. Blåmuslingebestander i Vadehavet og fiskeriets effekt (1991–1993), DFH rapport nr. 476-94. 56 pp.

Kristensen, P.S. 1994c. Blåmuslingebestander i Limfjorden 1994. DFH rapport (preliminary report). 31 pp.

### 4.1.3 Spain

**Interannual Variability in Mussel Spat Abundance in the Ría de Arousa using Artificial Collectors**

by J. Molares, J. Fuentes, and A. Villalba, Centro de Investigaciónes Mariñas, Conselleria de Pesca, Marisqueo e Acuicultura, Xunta de Galicia, Spain

#### 4.1.3.1 Introduction

Mussel cultivation in Galicia relies on the availability of wild seed suitable for growth in rafts placed in protected areas inside the Rías. Traditionally, two different procedures have been used by the mussel farmers to obtain seed for growing: collection of young mussels (1–2 cm long) from the intertidal exposed rocky shores and collection of mussels directly settled on ropes hung from the culture rafts. In order to know the spatial and temporal variability of recruitment of this species in the Ría de Arousa, a monitoring program of mussel spat abundance on rocky shores and collector ropes was started in 1990. Data from 1990, 1991, and 1992 are reported here.

#### 4.1.3.2 Materials and methods

Collectors used to monitor the recruitment on ropes and their location in the Ría de Arousa are described in Fuentes and Molares (1994). Collectors used to monitor the recruitment on rocky shore are pieces of jute material (18x12 cm in size) mounted on PVC plates by means of plastic frames. These collectors were attached to the substratum by stainless steel bolts at 1.5 m above mean lower low water (MLLW) in an exposed rocky shore in the middle of the Ría de Arousa (Figure 3). One month after placing, collectors were removed and new ones were put in place. The treatment of the samples is described in Fuentes and Molares (1994).

#### 4.1.3.3 Results and discussion

Recruitment of *Mytilus galloprovincialis* in the Ría de Arousa was restricted to the March–September period; in this period, there was high interannual and spatial variability. Recruitment of mussel was more abundant in rocky shore than in culture rafts (Figure 4), and the raft in the inner zone obtained the lowest recruitment in the

Ría. Similar results were found by Cáceres-Martínez *et al.* (1993) in the Ría de Vigo.

Recommendations related to the management of mussel spat collection in the Ría de Arousa are as follows: (1) rope collectors should be hung from the rafts in April in order to make full use of the main peak of recruitment; (2) collectors should be placed in the outer and middle parts of the Ría; (3) the farmers should remove the mussel seed from intertidal beds from January to March because in this period young mussels have suitable size to be tied onto ropes, and thus rocks will remain clean to accept new mussel settlement.

#### 4.1.3.4 References

Cáceres-Martínez, J., Robledo, J.A.F., and Figueras, A. 1993. Influencia de factores ambientales en la fijación del mejillón *Mytilus galloprovincialis* de Galicia. Actas IV Congreso Nac. Acuicult.: 377–382.

Fuentes, J., and Molares, J. 1994. Settlement of the mussel *Mytilus galloprovincialis* on collectors suspended from rafts in the Ría de Arousa (NW of Spain): annual pattern and spatial variability. Aquaculture, 122: 55–62.

### 4.1.4 Canada

by Marcel Fréchette, Institut Maurice-Lamontagne, Mont-Joli, Quebec

His field of research is mainly in biomass-dependence of bivalves in general, particularly focusing on the blue mussel *Mytilus edulis* and the giant scallop *Placopecten magellanicus*. He is presently carrying out a study on the critical spawner density for successful fertilization in natural populations of the giant scallop. This work involves coupling a biological model of fertilization with a physical model of the dispersal of gametes of both sexes.

### 4.1.5 Germany

by Maarten Ruth, Institut für Meereskunde, Universität Kiel

He reported on mussel recruitment in the Schleswieg-Holstein area of the Wadden Sea. There seems to be a difference between subtidal and intertidal recruitment. Recruitment seems to show a distinct pattern in both regions. The last more "global" recruitment occurred in 1987. In the following years, the recruitment in the intertidal region was restricted to single tidal stream systems. Within these systems, some beds showed "good" recruitment, resulting in expansion of the area covered with mussels. Settlement took place in the vicinity of existing beds, mainly in dense stocks of *Zostera noltii*. From 1990 onwards, he observed beds showing this behaviour in different tidal stream systems.

On the other hand, there was no clear spatial or year by year difference in numbers of recruits per biomass of adults in the core zones of existing beds (areas covered with adults). From this point of view, the **intertidal** recruitment could be classified as follows:

| | |
|---|---|
| 1987: | good |
| 1988: | medium, |
| 1989: | poor (hardly any results could be found) |
| 1990: | medium |
| 1991: | medium |
| 1992: | medium |
| 1993: | medium |

As the recruitment success in the intertidal region can not be estimated before autumn 1994, there is no information on the influence of the moderate cold winter 1993/1994 on the recruitment success in 1994 up to the present.

There are no existing long-term subtidal beds in the Schleswieg-Holstein region. Recruitment takes place at predictable sites, but it is not predictable whether a certain site in a certain year is settled by spat or not. Some sites have a higher potential than others. Recruitment can take place within some weeks, as in 1990, or within several months, as in 1993/1994. For this reason, the temporal occurrence of subtidal recruitment could be defined as the date when fishery for spat started. No fishery for subtidal small spat means poor subtidal recruitment, fishery for only some days means medium recruitment, and sufficient spat supply means good recruitment in the subtidal area. Following these categories, **subtidal** recruitment showed the following temporal pattern:

| | |
|---|---|
| 1987: | good |
| 1988: | medium |
| 1989: | poor |
| 1990: | good (with one additional star!) |
| 1991: | medium |
| 1992: | poor |
| 1993: | medium |
| 1994: | good |

One interesting observation can be added: The most important spatfall area, called "Vortrapp Tief", showed settlement of larvae from spring 1993 onwards, but no increase in medium length of the 0-group. This process continued until May 1994, even in winter. From April 1994 onwards, the cohort showed sudden rapid growth. The 1994 settlers reached the length of the 1993 settlers within some weeks. At the moment, there are about 150 ha covered with 15 mm medium-length mussels, and the fishery will be able to stock most of the culture lots. In contrast to 1990, the "Vortrapp Tief" seems to be the only area with significant recruitment success.

# 5 REPORT FOR 1995

## 5.1 The Netherlands

by Renger Dijkema, Netherlands Institute for Fisheries Research (RIVO-DLO)

### 5.1.1 Mussels *Mytilus edulis*

**Autumn Survey 1994**

A mild winter 1993/1994 yielded a rich spatfall of mussels in the Wadden Sea and, for the first time in many years, spatfall also occurred in the Oosterschelde (SW Netherlands). A qualitative estimate of the stock was made in September 1994. An aerial survey was made to localize seedbeds, and a number of beds and areas found not to contain mussels from the air was surveyed on foot in order to calibrate these observations. All seedbanks appeared to be clearly visible from the air, and in areas which appeared "empty" from the air, no mussels were found afterwards. In shallow areas with clear water, mussel banks could be localized on sight from small boats. In addition to this survey, fishing trips were made with mussel dredging ships (towed dredge), which is the traditional method used by the mussel industry to estimate the amounts of wild mussel seed prior to the seed fishery. Dense banks were found in the intertidal area off the islands of Terschelling and Ameland, generally occurring in closed mats with densities over 5 kg seed/$m^2$.

The "guesstimated" amounts of mussel seed, originating from spatfall 1994, were (gross weight, about 40% of tare): 100 000–200 000 metric tonnes of seed in the subtidal area, and 100 000–150 000 metric tonnes in the intertidal area. A fishing quota of 30 000 metric tonnes for the Wadden Sea was fixed by the Dutch government. The stock of seed in the Oosterschelde (Vuilbaard area) was assessed using a Van Veen grab sampling and a towed sampling cage dredge. The estimated fresh biomass was 4200 metric tonnes, the seed densities were up to 1–2 kg/$m^2$.

**Spring Survey 1995**

In the subtidal areas an assessment was made with a specially adapted hydraulic cockle dredge, using a narrowed cutting blade. Transects were made through areas with mussel seed, and the amount of seed caught was quantified. Subsamples yielded information on size, age, and species composition of the catch. The stocks in the intertidal areas were assessed on foot. The periphery of the banks was mapped using hand-held GPS equipment (Figure 5). In transects across the beds, core samples were taken, making quantitative estimates of biomass, size distribution,and species composition possible.

Winter storms in winter 1994/1995 appeared to have decimated the mussel seed stocks in the very exposed and locally shallow Wadden sea, both in the intertidal and in the subtidal areas. This could be ascribed to wave action in the tidal area and current scouring in the tidal channels. The subtidal stock was found to be 26 700 metric tonnes net fresh weight, of which 23 400 tonnes were mussel seed, the remainder were half-growns. In the intertidal area, a stock of 4500 metric tonnes of seed and 400 tonnes of half-grown mussels had survived the winter storms.

In the Oosterschelde, the area of "Vuilbaard" still appeared to contain a fair stock of mussel seed which originated from previous spatfall. This area has a sheltered lie and in general the only cause of mortality are starfishes *Asterias rubens*. The estimated mussel seed stock was 1800 metric tonnes net fresh weight.

#### 5.1.1.1 Cockles *Cerastoderma edule*

Wild stocks of cockles, mussels *Mytilus edulis* and the Baltic tellin *Macoma balthica* were assessed in the intertidal area of the Wadden Sea, the Oosterschelde, and the Westerschelde, using the hand-held scooping device, described in earlier reports. Spatfall 1994 appeared to have been good in the Westerschelde, moderate to poor in the Oosterschelde, and good again in the Wadden Sea. As yet, no exact data on the amounts of recruits and older cockles are available. The total biomass of cockles was (provisional data) approximately 30 000, 6000, and 60 000 metric tonnes fresh weight, respectively. Amounts of *Macoma balthica* were 100, 1300, and 32 000 metric tonnes fresh weight in the Oosterschelde, the Westerschelde (Western Scheldt), and the Wadden Sea, respectively.

### 5.1.2 Spatfall and recruitment of mussels in the Dutch Wadden Sea

by C. de Vooys, Institute for Forestry and Nature Management (IBN-DLO), Texel

Settlement of mussels has been moderate or poor in the Wadden Sea since 1988. It is well known that often after a severe winter (e.g., 1978/1979 and 1986/1987) huge mussel spatfall occur. In contrast, after very mild winters with little or no frost, no spatfall at all was found. Very severe or very mild winters, however, seldom occur. Experience shows that in 'normal' winters spatfall is very variable. The factors that cause this variability are not known and have scarcely been investigated to date.

In the western Dutch Wadden Sea observations were made on the concentration of larvae in the water and the metamorphosis of mussel larvae over several years. The majority of larvae and spat result from cultivated mussels, which are reared on plots along channels at a

depth of 3–10 m. Larvae are counted in samples of 100 l water filtered through plankton gauze. The samples were taken from the jetty of the Netherlands Institute for Sea Research in the Marsdiep, which has a depth of 10–20 m and connects the main basin of the western Dutch Wadden Sea with the North Sea. Metamorphosing, just-settled larvae were collected from petticoat gauze that was hung from the jetty stretched on a frame. Both free larvae and metamorphosing larvae were sampled two times per week.

Spawning of mussels generally is a mass phenomenon. The spawning could be triggered by a significant rise in water temperature in a short time. Vugts and Zimmerman (1975) demonstrated a relationship between the tidal cycle and a rise in the temperature of the daily water-temperature cycle. At high tide the tidal flats are flooded, which means an increase in water surface area by 30% for the western Dutch Wadden Sea. This causes a periodical change in the surface area, through which solar radiation penetrates and heat is absorbed. When high tide occurs at noon, the situation for a warming up of the water is maximal, when high tide occurs at midnight, it is minimal. This mechanism could provide a 'temperature shock' that could trigger mass spawning of mussels. This hypothesis was tested by comparing the times of spawning over five years, measured as larvae peaks at the jetty, with the nearest time when high tide occurs at noon. The differences between these times, in six out of eight cases, show a significant relationship.

When the times of occurrence of peaks in abundance of larvae are compared over five years, a distinct pattern appears. In three years, only one larval peak occurs: twice in May and once in June. In the two other years, two peaks occur each year. In one year, peaks occur in April and May, the other year in May and June. In four years, not only have peaks in abundance of larvae in the water been obtained, but peaks in abundance of metamorphosing larvae on gauze as well.

When the position of the latter peaks over four years are compared, at least one peak in June appears every year. In two out of the four years, two peaks of metamorphosing mussels are found in June, and in one year, one is also found in July. This pattern resembles the one found for larvae in the water. When the difference in time between the peaks in abundance of larvae in the water and those in metamorphosing larvae on gauze are compared, a difference of 24–37 days is found, with a mean of 31 days. This is in agreement with the time of the pelagic larval period as reported in the literature.

A preliminary comparison between the peak height of pelagic and metamorphosing larvae shows that the ratio can be very different in various years.

The investigations, of which the first results are given here, have not been finished yet. To obtain a more definitive interpretation, the final results will be correlated with meteorological data and the mass of spat obtained from estimates of fishery research. In 1995 investigations have started on newly formed intertidal mussel beds. After a good spatfall in 1994 the development of the juvenile mussels will be followed. Emphasis will be laid on the factors which are responsible for the survival of spat >1 cm. There is still insufficient knowledge of the factors responsible for the survival of spat between settlement and the first winter. We hope to propose a project to the EU-FAIR programme in December 1995. Interested parties are requested to contact us at the IBN. Telephone: +31-2220-69700. Telefax: +31-2220-19235.

### 5.2 United States

by C.H. (Pete) Peterson, Institute of Marine Sciences, University of North Carolina

There has been intense recent interest and research activity in the USA in several generic issues relative to the recruitment of bivalve molluscs. Emphasis has centered on: (1) the question of whether recruitment limitation plays any role in affecting the population size and, thus, management of bivalve mollusc stocks; (2) the importance of maintaining and restoring habitat quality for promoting recruitment of oysters; (3) the implications of bottom-disturbing fishing practices on recruitment of bivalve molluscs; and (4) application of aquaculture technology to enhance recruitment of depressed stocks of commercially important bivalves.

Evaluation of the question of recruitment limitation as a control on adult population size has been an active area of research interest among scientists studying reef fish populations in particular but also among those investigating bivalve molluscs. Work by Summerson and Peterson on bay scallops has provided some evidence that for species with limited transport of larvae and distinct subpopulations only weakly connected by larval emigration, such as some estuarine stocks including bay scallops, there is reason to recognize these subdivisions in management. Specifically, management units should be defined by the reproductive subpopulations. This recognition leads to the adoption of spawner transplantation into isolated areas in which stocks have been grossly depressed as a means of resource restoration. This transplantation of adult bay scallops seems responsible for restoration of bay scallop populations in a coastal lagoon in North Carolina and may well permit restoration of this species along much of the east coast of the USA.

There is also intense effort in the USA to evaluate the role of maintaining oyster reef habitat as a means of sustaining recruitment, growth, and production of oysters. The oyster creates a biogenic reef habitats,

which is sensitive to damage during harvest but which is necessary for successful recruitment of subsequent generations of oysters. Much legislation exists to protect vegetated aquatic habitats such as seagrass and saltmarsh, but oyster reefs enjoy no such protection. Research efforts in the Chesapeake Bay and in North Carolina's Pamlico Sound are actively evaluating the role of reef habitat conditions in affecting oyster recruitment success. These studies are being conducted by Heral, Rothschild, Paynter, and Newell in the Chesapeake Bay and by Peterson and Lenihan in the Pamlico Sound.

An international concern about the impacts of bottom-disturbing fishing practices is evident also in the USA. One of the concerns about harvest practices involves whether bottom habitat alteration reduces the quality of the habitat for settlement and survival of larval shellfish. Various research programs nationwide are evaluating this question and assessing whether some alternative gears and methods might better preserve bottom habitat quality.

The tremendous and widespread success of artificial propagation of many species of bivalve molluscs worldwide has now lead to the question of whether this technology can be applied to restoration and management of wild stocks of bivalves. This approach of selective breeding of disease-resistant strains of some shellfish stocks, especially oysters, is being actively evaluated in the Chesapeake Bay region and in the mid-Atlantic states. Furthermore, the question of whether aquaculture of native species results in a benefit of providing and releasing larvae to help populate public bottom is being tested in some regions. On the other hand, there is also concern over and research on the question of whether non-native stocks of aquacultured bivalves can truly be prevented from spawning and therefore prevented from invading the wild ecosystem. Finally, questions of the bioeconomic viability of reseeding depleted shellfish beds with nursery raised seed are being further investigated.

## 5.3 Canada

by Marcel Frechette, Institute Maurice-Lamontagne, Mont-Joli, Quebec

### 5.3.1 Growth and survival of giant scallop spat in collector bags

An expensive step in scallop aquaculture and restocking operations is intermediate culture in pearl nets. In an attempt to obtain scallops of suitable size for bottom sowing without using pearl nets, the fishermen in Iles-de-la-Madeleine, Quebec, have left naturally collected spat to grow in collector bags for a whole year. The goal of this study was to assess whether growth and survival of spat in "intermediate culture" collectors are competition-dependent, and if so, at which density level this would occur.
Since initial density in bags cannot be controlled experimentally, competition is inferred from the relationship between biomass and density in the bags. Without competition, this relationship is linear, with positive slope. When competition is present, the biomass-density relationship is curved downward, toward zero slope, or the relationship is negative. The latter case is interpreted as reflecting self-thinning. Preliminary analysis suggests that after one year in the collector bags, spat growth and survival are competition-independent for population densities lower than about 500 individuals per bag.

### 5.3.2 Intensity of giant scallop spat collection as an early index of natural recruitment

Intensity of scallop spatfall on artificial spat collectors has been monitored since 1986 in Iles-de-la-Madeleine, Quebec, along with adult stock abundance, in order to assess whether spatfall would be a reliable early index of future recruitment. In addition, drifting buoys and vertical plankton net tows have been used to study larval drift. Preliminary results suggest that the intensity of spatfall is closely linked to variations in wild broodstock.

### 5.3.3 Study of spawning success as a function of spawner density

A study on the critical spawner density for successful fertilization of gametes in natural populations of the giant scallop is under way. This work involves coupling a biological model of fertilization with a physical model of the dispersal of gametes of both sexes.

### 5.3.4 Giant scallop spat collection: influence of various structural components of spat collectors

The influence of various structural components of spat collectors was studied in field experiments. Giant scallop spat were more abundant in collectors made with intermediate mesh size bags (0.4 X 0.5 cm) containing low densities of monofilament than in other types of collectors. Abundance did not vary significantly with spatial arrangement, diameter, or heterogeneity of monofilament.

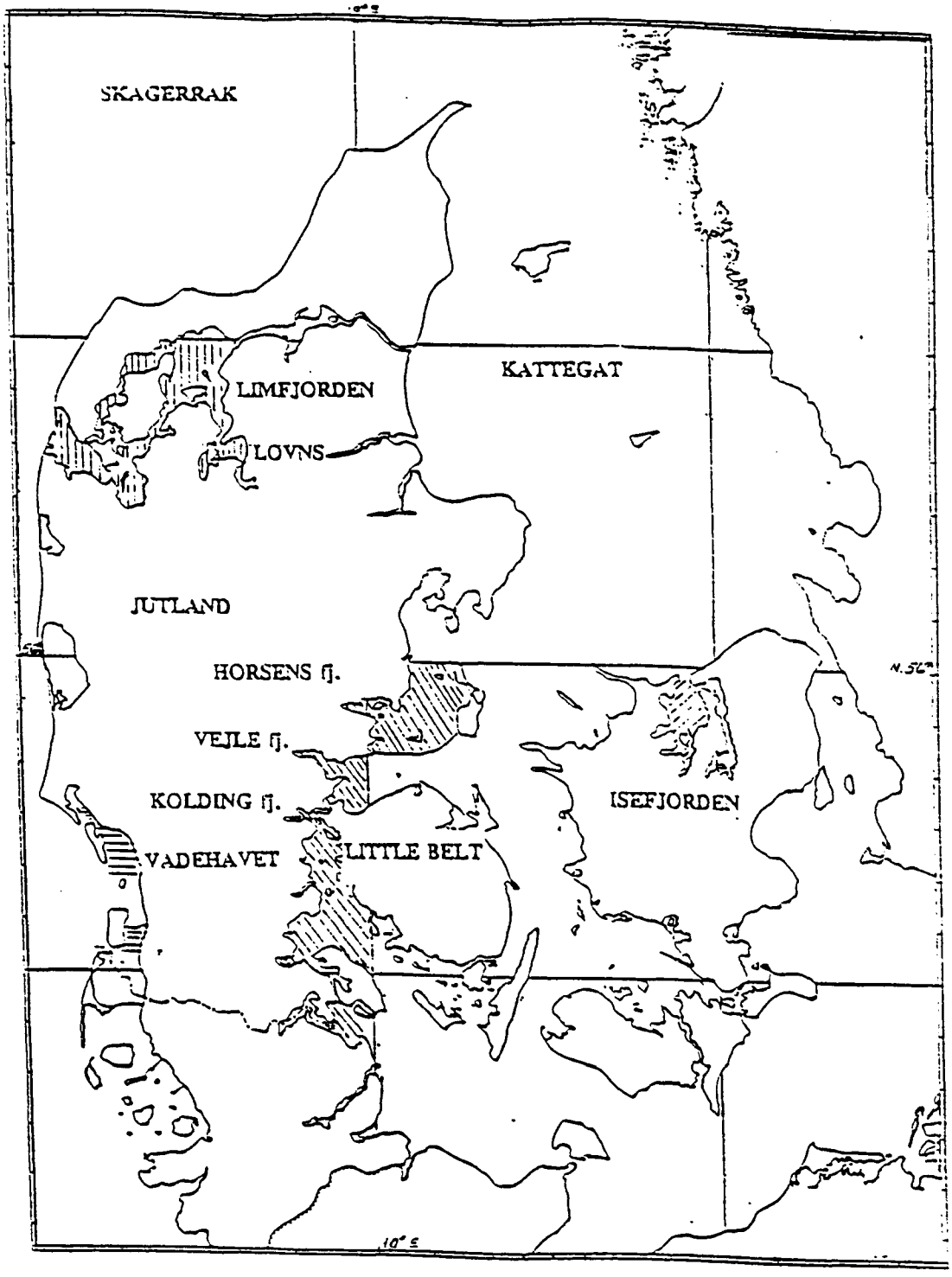


Figure 1. The Danish mussel fishing areas. Limfjord ; Danish Wadden Sea ; Little Belt (ICES area IIIc (22)) ; Isefjord .

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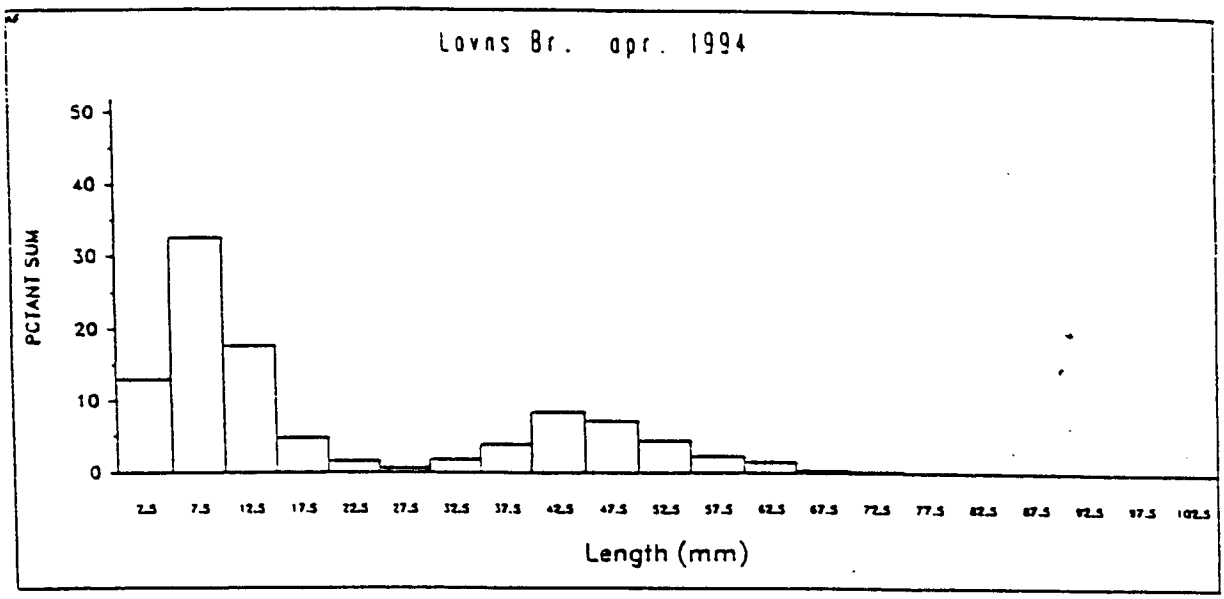


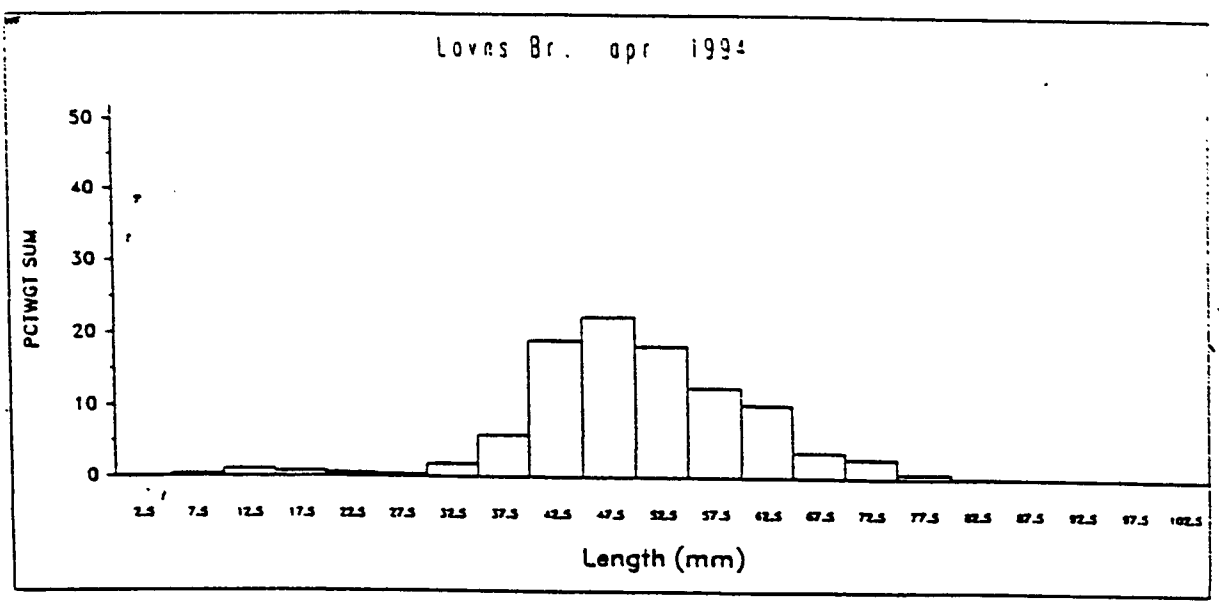


Figure 2. The relative number and weight of mussels in Lovns Bredning in Limfjord in April 1993 (Kristensen, 1994c).

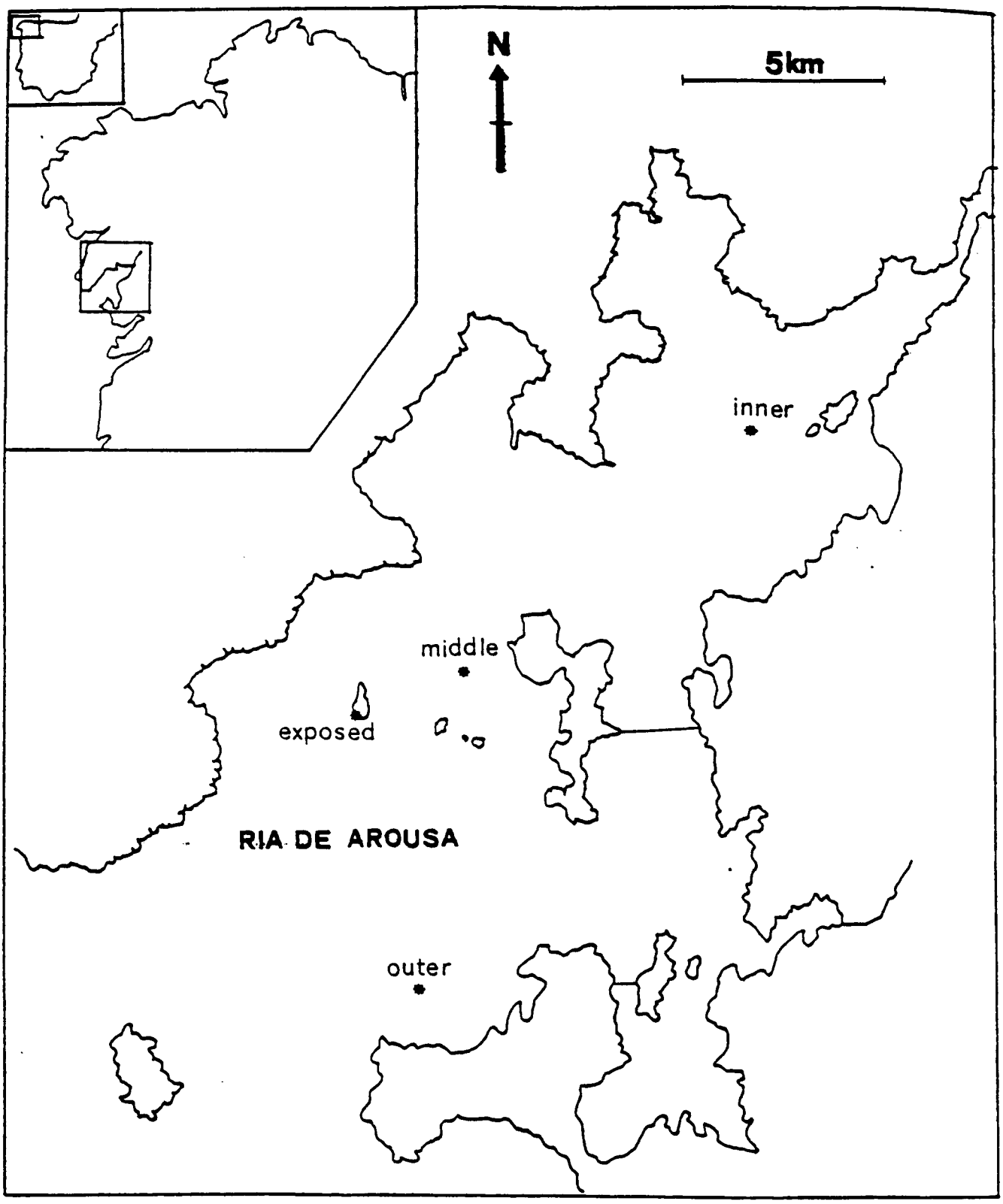


Figure 3. Map of the Ría de Arousa (NW Spain), showing the sites of the study.

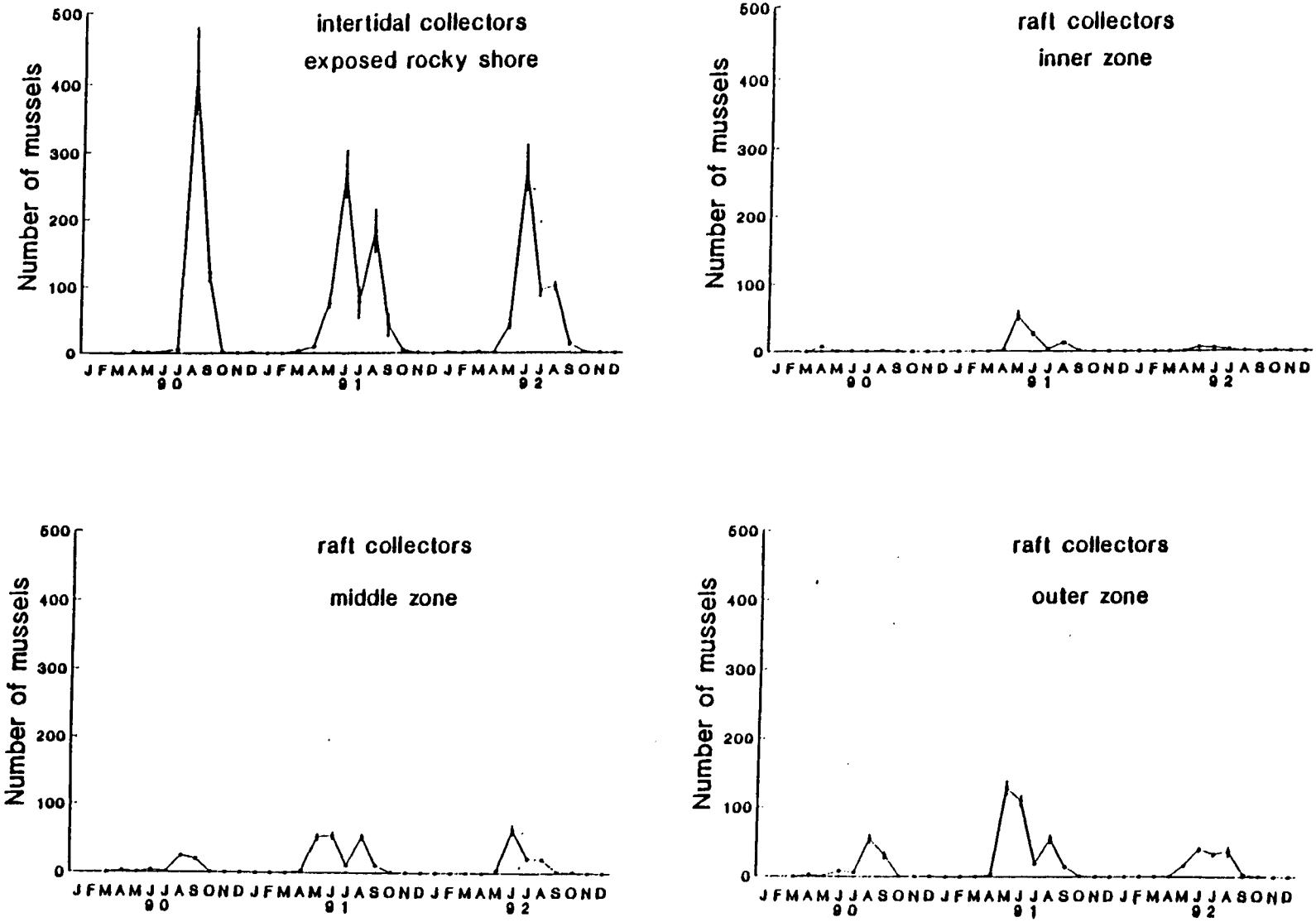


Figure 4. Mean number of mussels per 4 $cm^2$ in collectors placed on rocky shore and on ropes suspended from rafts at three sites in the Ría de Arosa.

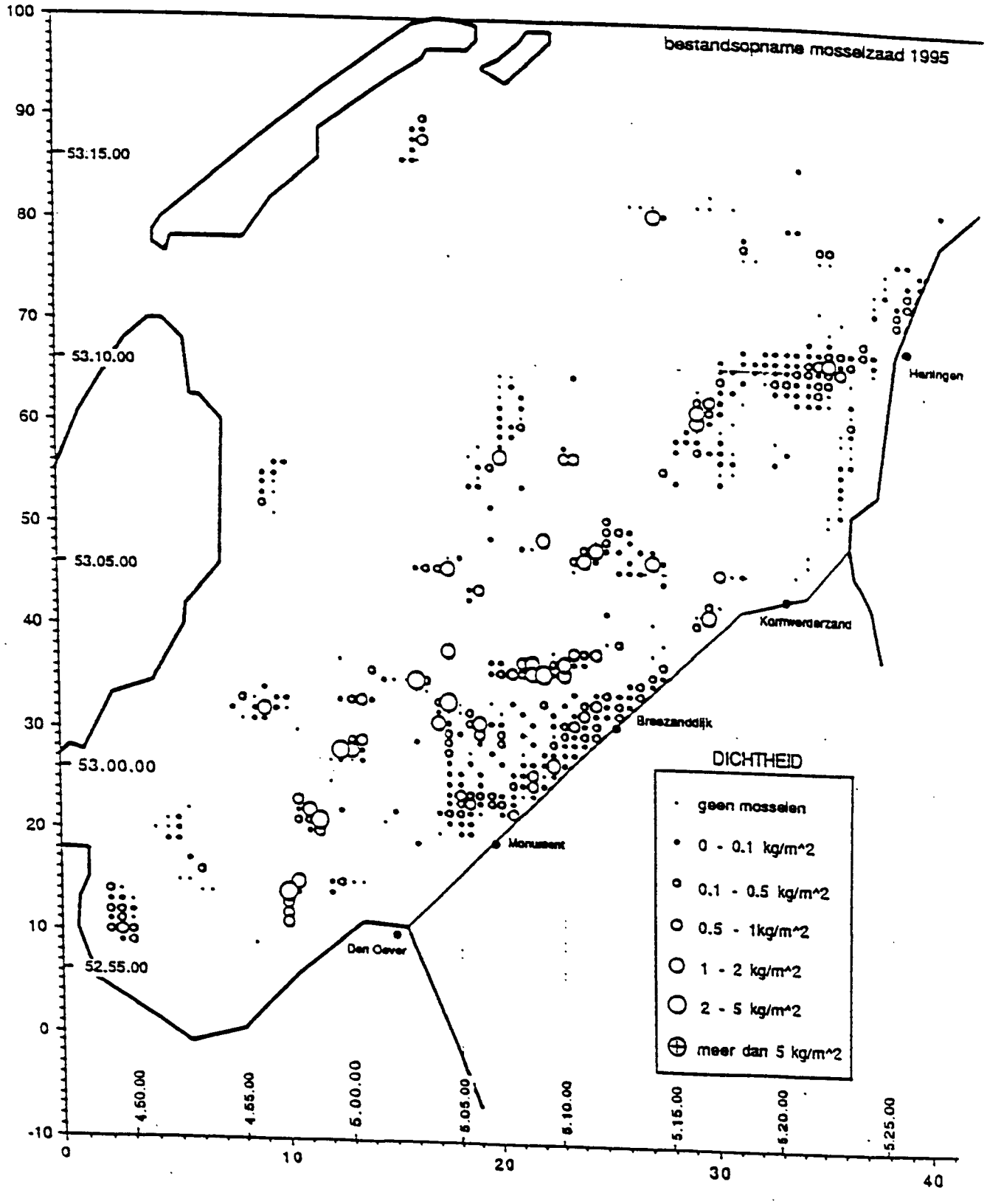


Figure 5. Distribution of the density of the mussel stock (seed + adults) in the western part of the Dutch Wadden Sea, spring survey by RIVO-DLO in 1995.