Cah. Biol. Mar. (1988), **29**: 37-49
Roscoff

Infaunal benthic recolonization after dredging operations in La Coruña Bay, NW Spain

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Abstract : In the harbour area of La Coruña Bay (NW Spain) there is a muddy sediment infaunal community dominated by the bivalve *Thyasira flexuosa* and the polychaete *Chaetozone,* sp., whose densities are very high (15 000-20 000 individuals. m^{-2}).

Dredging operations carried out near a recently built dock determined that in this area the original community was reduced to a few species having short life cycles and to newly settled specimens. After the completion of the dredging operations, temporal variation of the affected area was followed during one year, and it is compared with a nearby area unaffected by dredging. Species number, density and biomass increased significantly after the end of the dredging period. On the other hand, similarity between the dredged and the non-dredged areas increased steadily with time. Diversity values increased initially owing to the recruitment of new species, but then decreased because of the great dominance of *Thyasira flexuosa.*

The recovery of the dredged zone is practically attained 6 months after the completion of dredging operations, although biomass takes longer to reach values similar to those of the unaffected area.

Résumé : Dans la zone portuaire de la ria de la Corogne (NO de l'Espagne) existe un peuplement benthique spécifique des sédiments envasés, dominé par le Bivalve *Thyasira flexuoxa* et l'Annélide Polychète *Chaetozone* sp. qui présentent des densités très élevées (15 000-20 000 individus. m^{-2}).

Les opérations de dragage des fonds réalisées dans la zone adjacente à un quai de construction récente ont induit dans cette zone une réduction de la communauté originelle à un très petit nombre d'espèces de cycle vital court et à des formes juvéniles. Après l'achèvement des opérations de dragage, l'évolution temporaire de la zone affectée a été poursuivie pendant un an ; elle est comparée à une zone proche non influencée par le dragage portuaire. Le nombre d'espèces, la densité et la biomasse ont augmenté significativement après la fin des dragages. D'autre part, la similarité entre la station draguée et celle qui ne l'est pas augmente régulièrement avec le temps. La diversité croît initialement de par l'accroissement du nombre d'espèces, mais elle diminue ensuite à cause de la dominance croissante de *Thyasira flexuosa.*

La reconstruction du peuplement de la zone draguée est presque achevée, six mois après la fin des dragages portuaires, mais la biomasse n'atteint qu'au bout d'un temps plus long des valeurs du même ordre que celles de la zone non draguée.

INTRODUCTION

Infaunal benthic studies have been carried out in the subtidal area of La Coruña Bay since 1982. The spatial distribution of benthic communities in relation to the sedimentary environment was described in a previous paper (López-Jamar & Mejuto, 1985). In the harbour area of the bay, the sediment has a very high organic content and high concentration of hydrocarbons and heavy metals. The dominant species in this area are the bivalve mollusc *Thyasira flexuosa* and the polychaete *Chaetozone* sp., occuring in very high densities: 19 000 and 14 500 individuals. m^{-2}, respectively.

Dredging operations carried out in the harbour area (Fig. 1) determined that the original community was reduced to very few species having short life cycles and also newly settled juveniles. Data on the community structure and biomass during the dredging period were available, and thus postdredging recolonization and benthic succession could be followed. Simultaneously, temporal variation of a nearby station apparently unaffected by dredging was studied with comparative purposes.

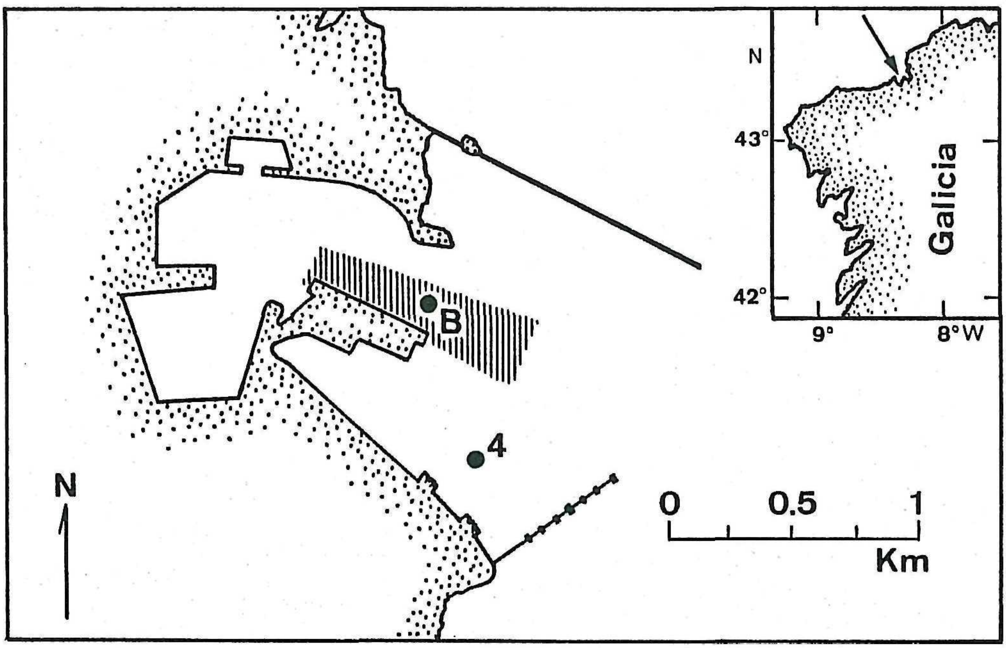

Fig. 1 - Location of the sampling stations. The shaded area corresponds to the dredged zone,

MATERIAL AND METHODS

Benthic samples were collected at two stations in La Coruña Bay: station B (16 m deep), located in the centre of the dredged area, and station 4 (14 m deep), outside the dredged area (Fig. 1). We have used a Bouma box corer of 0.018 m^2 sampling area; sediment penetration was never under 20 cm deep. Minimum sample size for each station was estimated, resulting in 5 samples for station B and 6 for station 4. Sediment was sieved (0.5 mm mesh size) and the fraction retained was treated with menthol as anaesthesic and preserved with 5 % buffered formaldehyde previously stained with rose-bengal to facilitate sorting of organisms.

Sediment samples were also collected for grain-size analysis and organic matter estimations. Sediment size analysis was carried out by a combination of dry sieving and sedimentation techniques (Buchanan & Kain, 1971). Organic content of sediment was estimated as the loss in weight of dried material (100° C, 24 h) after combustion (500° C, 24 h).

During the dredging period two samplings were performed (July and November 1982). After the completion of dredging operations (November 1982) sampling was carried out monthly or bimonthly until November 1983.

The Morisita index (Morisita, 1959) modified by Horn (1966) was used to indicate similarity between samples. This index is quite sensitive to changes in the abundance of the dominant species, and thus it is particularly suitable for our purposes. Only species accounting for more than 1 % in number or biomass were included in this analysis. The inclusion of "rare species", which often occur very randomly, would add a 'background noise" that would obscure the results.

Diversity was calculated using abundance data with the Shannon function (Shannon & Weaver, 1963). Evenness was also estimated as defined by Pielou (1966).

Biomass was estimated weighing preserved organisms after blotting, and it is expressed as ash-free-dry-weight (AFDW) by means of conversion factors previously estimated.

RESULTS

SEDIMENT CHARACTERISTICS

Both stations have a sediment consisting of pure mud or slightly sandy mud, with a clay content of 10 to 15 %. Mean diameter at station B remains relatively constant (18 to 27 μm) except in November 1982, when the sediment is more sandy (77 μm) ; this fact is probably due to the intensification of the dredging operations resulting in a reduction of the surface layer of the sediment (Fig. 2).

At station 4, located outside of the dredged area, mean diameter is very constant during the study period, ranging from 17 to 27 μm, (Fig. 2).

Organic content of sediment in both stations displays a higher variation. At station 4 it varies from 10.40 % to 15.55 % without any discernible pattern. Nevertheless, station B has a relatively low organic content during the dredging period (7.38 % and 5.19 % in July and November 1982, respectively), but increases steadily after the completion of dredging, reaching similar values to those of station 4 (Fig. 2).

TEMPORAL VARIATION OF THE INFAUNAL COMMUNITY

Tables 1 and 2 indicate the abundance of the dominant species in both stations during the study period. The complete list of species is available from the authors.

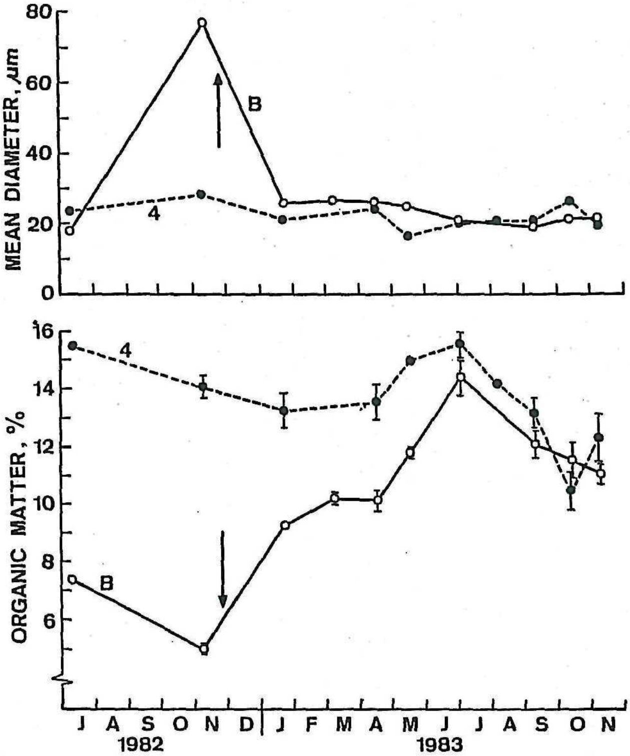

Fig. 2 - Temporal variation of mean diameter and organic content of the sediment in both stations. The arrow indicates the completion of the dredging operations. Vertical bars are standard deviations.

At station 4 total number of species in each sampling ranged from 28 to 43. Species number at station B is much lower during the dredging period (13 to 15), but it increases after the end of dredging (21 to 31) (Fig. 3).

Total abundance is very high at station 4 (14 339 to 30 363 individuals. m^{-2}). Nevertheless, abundance at station B is much lower during the dredging period (1 093 to 3 173 individuals . m^{-2}) but it increases progressively in the postdredging period (3 985 to 17 314 individuals . m^{-2}) (Fig. 3).

Temporal evolution of the community in both stations can be evaluated by an analysis of the similarity of the successive samplings. Similarity values between the first sampling of station 4 and the rest of the samplings of the same station are very high, ranging from 81 to 98 % (except an isolated value of 56 %) and they do not display a clear temporal pattern. However, similarity values referring to station B show a very distinct decrease of the similarity in relation to time : 59 % to 7 %. This means that, whereas at station 4, species composition and community structure remain practically constant during the study period, at station B, a progressive change of the community can be discerned after the completion of dredging operations (Fig. 4).

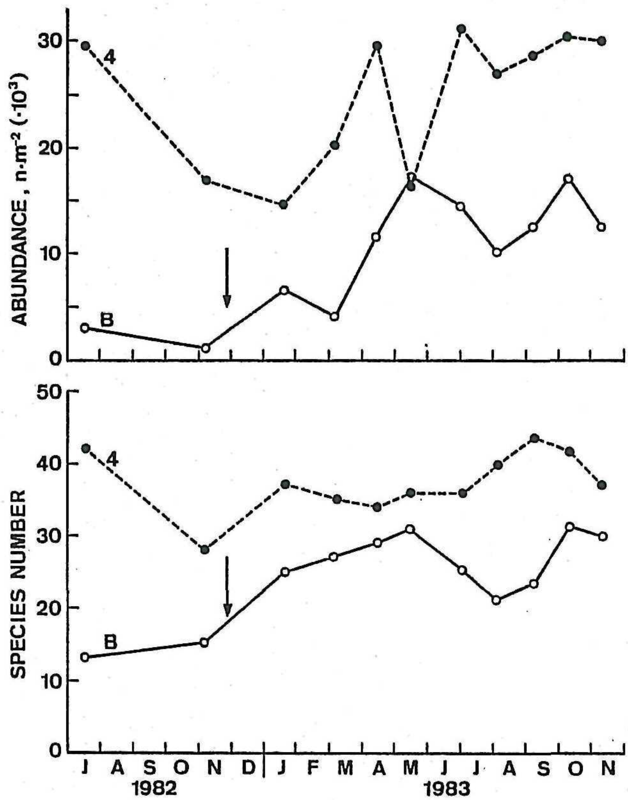

Fig. 3 - Temporal variation of total abundance (thousands . m^{-2}) and of species number in both stations.

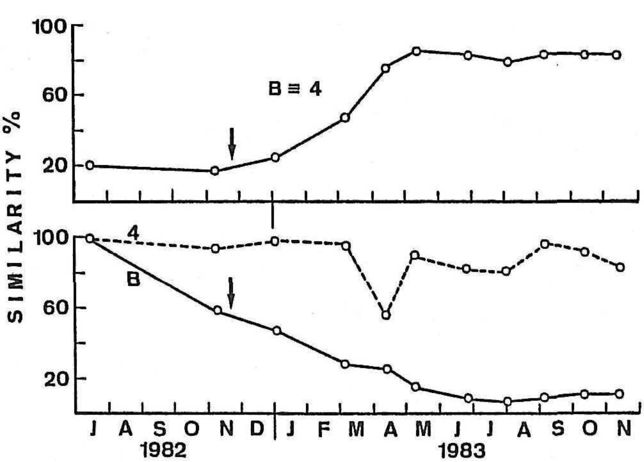

Fig. 4 - Temporal variation of the similarity, B = 4: mean similarity between station 4 ant the successive samples of B. 4: similarity between samples of station 4 and the first sample of this station. B: similarity between samples of station B and the first samples of this station.

On the other hand, similarity between station 4 and the successive samplings of station B increases steadily with time : the initial similarity between both stations is low (17 % to 21 %), but after the end of dredging it becomes progressively higher (25 % to 84 %). This means that the species composition and the community structure of the dredged station (B) change with time, becoming more and more similar to those of station 4. This being so, the station affected by dredging can be considered practically recovered 6 months after the end of dredging operations.

It is also interesting to observe the variation of diversity in both stations. At station 4, unaffected by dredging, diversity variation is not high (from 2.09 to 2.92), and the same happens with evenness (0.39 to 0.56). In contrast, at station B, diversity increases initially at the beginning of the postdredging period, reaching a maximum value of 3.76, but then decreases gradually to much lower values. Evenness follows a similar pattern, having relatively high values just after the completion of dredging (up to 0.79) and decreasing thereafter to lower figures (Fig. 5).

RECOLONIZATION OF THE DOMINANT SPECIES

We have considered until now the recovery of the area affected by dredging in a comprehensive way. However, recolonization does not take place at the same rate for every species, as it depends on many different factors : spawning period, larval development, growth strategy, inter and intraspecific competition, etc.

If we observe the temporal variation of the abundance of the dominant species at the dredged station, very different patterns can be distinguished. There are some species apparently unaffected by dredging, such as *Capitella capitata* and *Chaetozone* sp., whose abundance is relatively high both during and after dredging (Fig. 6 A). Several species that can be considered as "opportunistic" display a very fast increase just after the end of dredging, but then decrease and remain at relatively low densities. This is the case of the polychaetes *Scolelepis fuliginosa* and *Pseudopolydora* sp. (Fig. 6 B). The dominant species of the original community inhabiting the harbour area, such as the bivalve *Thyasira flexuosa* and the hesionid polychaete *Ophiodromus flexuosus,* present a steady increase and thereafter remain at high densities. *T. flexuosa* increases exponentially soon after the end of dredging, and it reaches a similar density to that of the unaffected area (10 000-12 000 individuals . m^{-2}). *O. flexuosus* follows a similar pattern, but the recovery starts later (Fig. 6 C). The only species that is more abundant during the dredging period than after dredging is the small polychaete *Ophryotrocha* sp. (Fig. 6 D).

TEMPORAL VARIATION OF BIOMASS

As we have stated before, species composition and community structure of the dredged area are practically recovered 6 months after the completion of dredging operations. Nevertheless it is likely that biomass will last longer to reach values similar to those of the original community.

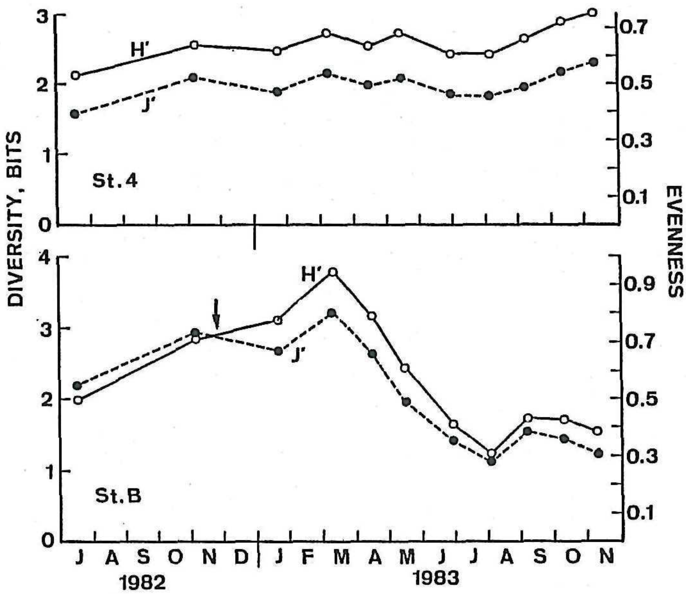

Fig. 5 - Temporal variation of diversity (H') and evenness (J') in both station.

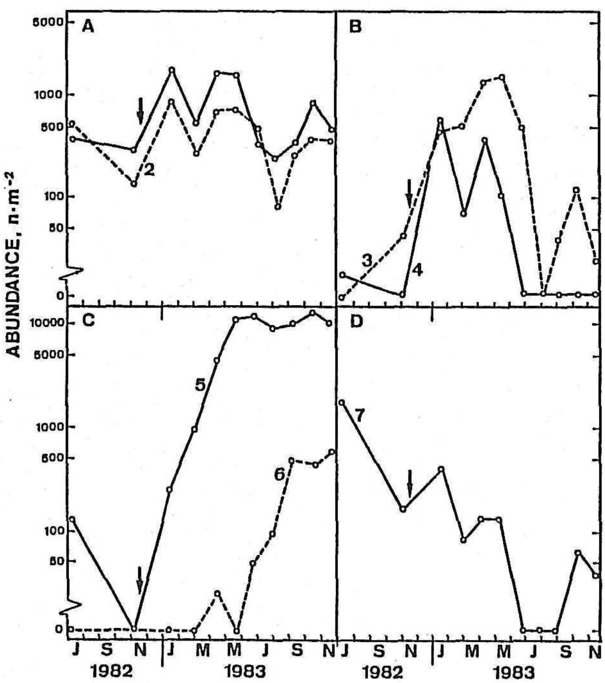

Fig. 6 - Temporal variation of the abundance of the dominant species in station B. 1 : *Capitella capitata* ; 2 : *Chaetozone* sp. ; 3 : *Pseudopolydora* sp. ; 4 : *Scolelepis fuliginosa* ; 5 : *Thyasira flexuosa* : 6 : *Ophiodromus flexuosus* ; 7 : *Ophryotrocha* sp.

At the control site (station 4) biomass remains relatively high throughout the study period (12.26 - 22.89 g . m^{-2} AFDW). In this station total biomass and the proportion of the different taxonomic groups vary irregularly, although the polychaetes as a group show a tendency to increase their biomass with time (Fig. 7). In general, at station 4, molluscs and polychaetes are the dominant groups in terms of biomass, however the group "others" (nemerteans, hydrozoans, etc.) may occasionally constitute an important fraction of total biomass due to the occurrence of relatively large individuals of *Cerianthus* sp. At this station the dominant species in biomass is the bivalve *Thyasira flexuosa.*

In the dredged area (station B), biomass is very low during the dredging period (<1 g . m^{-2} AFDW) and starts to increase 5 or 6 months after the dredging ended (Fig. 7). This increase is progressive, and one year after the completion of dredging, the biomass reaches similar values to those of the unaffected area. In contrast to station 4, polychaete biomass at station B remains practically stable with time; the biomass increase is mainly due to molluscs, principally *Thyasira flexuosa,* although *Abra alba, Abra nitida* and *Nassarius incrassatus* may also contribute significantly to total biomass. *T. flexuosa* is dominant in number since March 1983 (4 months after the dredging ended), but it becomes dominant in biomass in June of the same year.

DISCUSSION

The main physical effect of the dredging operations carried out in La Coruña Bay was the removing of the superficial layer of the sediment. This results in a change of the sediment which becomes more sandy and with a lower organic content than that of the unaffected area (López-Jamar & Mejuto, 1985). On the other hand, the main biological effect of dredging is the elimination of most of the infaunal organisms.

Dredging operations were performed by means of a dredging ship that operated randomly in the area. Consequently, the period between two successive dredging events at the same point cannot be estimated, but in some cases it can be longer than 10 days. This can explain the fact that the infauna during dredging is formed by newly settled juveniles and also by species having a very short life-cycle (*Capitella capitata, Ophryotrocha* sp., etc.) that can reach a high abundance in a short time. Biomass is very low because of the dominance of juveniles and also small-sized organisms.

During the dredging period, diversity of the dredged area is similar to that of the unaffected area. Although the species number in the dredged station is small, evenness is relatively high because there are no species that clearly dominate. This fact could be expected because the removing of the superficial layer of the sediment prevents the community from reaching some degree of equilibrium. Never-

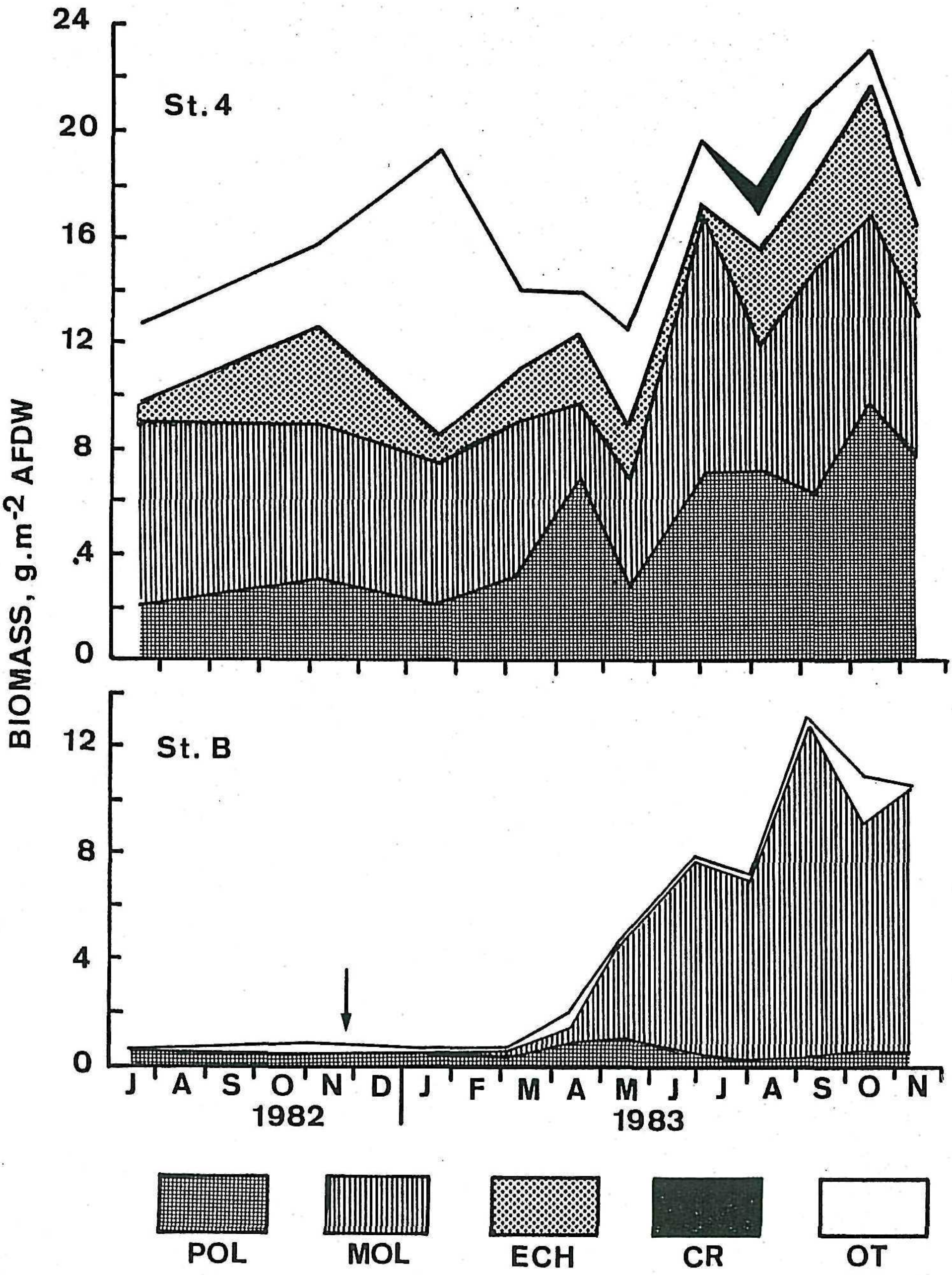

Fig. 7 - Temporal variation of total biomass and of the proportion of the different groups in both stations. POL: polychaetes: MOL: molluscs,; ECH: echinoderms; CR: crustaceans; OT: others.

TABLE 1 : Species composition of station 4 (non dredged). 1982: dredging period, mean of 2 samplings (July and November). 1983: postdredging period, mean of 9 samplings (January-November). Densities are expressed as no. individuals . m^{-2}. Only the species accounting for more than 1 % of total number or biomass are included.

	1982	1983
Polychaetes		
Polydora pulchra Carazzi	119	200
Pseudopolydora sp.	-	76
Prionospio malmgreni Clap.	58	265
Spio filicornis (Müller)	9	232
Chaetozone sp.	2 059	7 002
Tharyx marioni (St.-Joseph)	2 001	1 584
Paradoneis armata Glémarec	79	104
Capitella capitata (Fabricius)	23	168
Mediomastus sp.	1 100	527
Notomastus latericeus Sars	79	283
Brada villosa (Rathke)	366	807
Ampharete acutifrons (Grube)	22	331
Ophiodromus flexuosus (delle Chiaje)	103	152
Gyptis capensis (Day)	45	24
Nephtys cirrosa Ehlers	-	5
Nephtys hombergi Savigny	51	22
Glycera rouxii Aud. & M. Edwards	4	25
Glycera unicornis Savigny	-	5
Pholoe minuta Fabricius	12	45
Neireidae indet.	9	5
Lumbrineris latreilli Aud. & M. Edw.	98	177
Lumbrineris fragilis (O.F. Müller)	4	2
Ophryotrocha sp.	115	37
Molluscs		
Thyasira flexuosa (Montagu)	13 926	10 521
Abra alba (Wood)	10	162
Abra nitida (Müller)	226	102
Mysella bidentata (Montagu)	774	327
Tellina fabula Gmelin	9	39
Philine aperta (L.)	40	22
Nassarius incrassatus (Ström)	19	24
Echinoderms		
Leptosynapta inhaerens (O.F. Müller)	104	137
Crustaceans		
Amphipoda indet.	8	33
Others		
Cerianthus sp.	199	116
Peloscolex sp.	1 369	1 378
Nemerteans indet.	86	108

TABLE 2 : Species composition of station B (dredged). 1982: dredging period, mean of 2 samplings (July and November). 1983: postdredging period, mean of 9 samplings (January-November). Densities are expressed as no. individuals . m^{-2}. Only the species accounting for more than 1 % of total number or biomass are included.

	1982	1983
Polychaetes		
Pseudopolydora sp.	21	475
Prionospio malmgreni Clap.	-	36
Spio filicornis (Müller)	86	16
Scolelepis fuliginosa (Clap.)	12	170
Chaetozone sp.	433	604
Cirriformia sp.	-	160
Capitella capitata (Fabricius)	445	1 132
Notomastus latericeus Sars	-	124
Brada villosa (Rathke)	4	129
Pherusa plumosa (Müller)	-	8
Ampharete acutifrons (Grube)	-	100
Anaitides lineata (Clap.)	4	133
Ophiodromus flexuosus (delle Chiaje)	-	170
Glycera rouxii Aud. & M. Edwards	66	51
Pholoe minuta Fabricius	-	26
Nereidae indet.	-	2
Lumbrineris latreilli Aud. & M. Edw.	4	231
Lumbrineris fragilis (O.F. Müller)	4	231
Ophryotrocha sp.	898	84
Molluscs		
Thyasira flexuosa (Montagu)	65	7 348
Abra alba (Wood)	8	206
Abra nitida (Müller)	-	109
Tellina fabula Gmelin	-	19
Philine aperta (L.)	33	62
Nassarius incrassatus (Ström)	4	57
Echinoderms		
Leptosynapta inhaerens (O.F. Müller)	-	37
Others		
Cerianthus sp.	-	24
Nemerteans indet.	-	20

theless, a short time after the end of dredging, the diversity of the affected area increases because of the colonization of new species. But 3 or 4 months later diversity decreases progressively due to the increasing dominance of *Thyasira flexuosa.* As soon as the density of this species is stabilized (June-July 1983), diversity and evenness also become quite stable, but with lower values than during the dredging period.

This pattern of evolution of the community agrees with the findings of Santos & Simon (1980) in a Florida estuary. According to these authors, the recovery of benthic infauna after its elimination as a consequence of a periodic anoxia is relatively fast. Similarly to the results of this research, Dauvin (1981) stated that density of *T. flexuosa* increased after the Amoco Cadiz oil spill in the coasts of Britanny. In La Coruña Bay there is an oil terminal close to the study area, and heavy metal and hydrocarbon concentrations in the sediments are very high (Cabanas, personal communication). Thus it is likely that *T. flexuosa* is enhanced by this type of pollution, and its recovery after dredging can be faster than that of other species.

Recolonization after a catastrophic event depends also on the life cycle and spawning period of each species. In La Coruña Bay, the spawning period of *Thyasira flexuosa* starts in January - February, and maximum recruitment takes place during April - May. This can explain the fact that this species has been one of the fastest in colonizing the dredged area, reaching very high densities in a short time. After dredging ended, the number of recently recruited juveniles is about 3 times higher in the dredged area than in the control site, and this is probably due to the little competition in the dredged station.

Currently, benthic studies are being continued in the area affected by dredging in order to assess the long term evolution of the community. However, the high similarity between both the dredged and control stations one year after the completion of dredging, and also the tendency of diversity and biomass to stabilize, seem to indicate that the recovery is practically completed.

ACKNOWLEDGMENTS

We are indebted to the crew of the R/V "Lura" for their collaboration. The identification of several polychaetes was possible thanks to Dr. Brendan O'Connor (Galway University, Ireland) and to Dr. Mary Petersen (Zoological Museum, Copenhagen, Denmark). This research is included in the COST 47 Project on Coastal Ecology.

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