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The effects of disposing china clay wastes off the Cornish coast

by

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INTRODUCTION

The mining of china clay has taken place in Cornwall for more than 150 years, and within the last 30 the industry has undergone a period of rapid expansion. The clay is washed out of the ground by means of high pressure hoses and the usable fractions are extracted from the resulting suspension. Not all of the suspended material is utilizable and the remainder, consisting mainly of quartz, mica and a certain amount of very fine kaolinite, is the principal waste product of the industry. The larger particles, mainly quartz, are now placed on land, but the mica and fine kaolinite are released into three rivers: the River Fal, the St. Austell or White River and the Par River (Fig. 1).

In 1967 a proposal was made to divert the effluents entering the Fal and the Par and to add them to the material entering the White River. At that time it was not clear where the final point of discharge into the sea would be situated, except that it would probably be necessary to extend the White River by pipe-line to a point in the Mevagissey/St. Austell Bays area. This, combined with further expansion of the industry, would considerably increase the amounts of china clay waste being released into these two bays. Very little was known about the effects that such an increase would have on the marine life and fisheries of the area, and consequently a short programme of research to determine the effects of china clay disposal was begun in 1968. This work has now been completed. Its main conclusions were that most of the clay waste remained in the area of discharge (Portmann 1970) and that, except for unstable zones near the discharge points, the two affected bays supported a rich benthic fauna (Howell and Shelton 1970).

After this work was completed further hydrographic studies were carried out by the china clay industry, and the disposal of the wastes through a pipe-line from Dodman Point (Fig. 1) was considered. It was

therefore decided to make a further survey during September-October 1970 to include the areas likely to be affected by this discharge. At the same time additional exploratory fishing was carried out in St. Austell and Mevagissey Bays.

METHODS

(i) Benthic sampling

Seabed sampling was carried out with a 1/10 m^2 Smith/McIntyre grab at 103 stations. At each station a 500 ml sample of sediment was retained and the remainder was sieved (1.54 mm mesh) and the benthic fauna preserved in 5 per cent formaldehyde for analysis. Positions were fixed by Decca Navigator.

For qualitative sampling of some of the deeper-burrowing species a large naturalist's dredge, as described by Holme (1961), was used. In addition, a small number of hauls was made with the Agassiz trawl.

(ii) Experimental fishing

A programme of experimental fishing, using a small otter trawl, was conducted from a local vessel fishing out of Mevagissey. Mackerel fishing, using feathers, was also carried out from this boat.

(iii) Processing of sediment samples

The sediment samples were wet-sieved using a Fritsch electromagnetic sieving machine fitted with eight sieves. Particle sizes were graded according to the well known Udden-Wentworth scale, except for the three smallest grades which were those of Portmann (1970).

Grade limits (diameter in micrometres)	Description
Above 4 000	Pebbles
4 000–2 000	Granules
2 000–1 000	Very coarse sand
1 000– 500	Coarse sand
500– 250	Medium sand
250– 125	Fine sand
125– 63	Very fine sand
63– 45	Silt
45– 37	Fine silt
37– 0.45	Clay

RESULTS

(i) The sediments

The distribution of the major components of the bottom deposits is shown in Figures 2-4. Offshore, the sediments consist mainly of muddy sand and gravel, with a number of patches in which the proportion of fine material exceeds 20 per cent (Fig. 2); inshore, within the 40 metre contour, cleaner sand and gravel predominate.

Tidal currents in the area are generally low (up to 0.9 knots), and higher velocities occur off Dodman Point only during spring tides. The widespread occurrence of fine deposits is therefore to be expected. The predominance of coarser materials inshore probably reflects the influence of wave-induced currents.

St. Austell and Mevagissey Bays contain high deposits of china clay waste (Portmann 1970), while Veryan Bay and the area offshore is still comparatively unaffected. However, water containing suspended china clay waste does occasionally flow westwards past Dodman Point and it is therefore possible that some of this material has been deposited off Veryan Bay, where patches with more than 20 per cent of fine deposits were found (Fig. 2).

(ii) The fauna

Three groups of four stations were selected as representative of the inshore and offshore conditions and of areas where over 20 per cent fine deposits occurred in the sediment (referred to below as 'clay' areas). The four stations in each group were matched for depth and sediment composition.

The fauna retained by a 1.54 mm mesh was classified to a point where all species were separated, though not individually identified. Details, together with the physical characteristics of each station, are shown in Table 1. In selected groups, namely the Decapod Crustacea, Mollusca and Echinodermata, identification was taken to specific level (Table 2). Unfortunately, due to shortage of available time, no detailed identification could be made of polychaete worms, for this group yielded by far the most species and individuals.

Ranked species/abundance curves for the total fauna and for the polychaetes of the three areas are shown in Figures 5 and 6. Diversity indices (α), calculated according to the method of Williams (1947), are shown alongside each curve, with the total number of individuals and species. It would be unwise, with such comparatively small samples, to do more than discuss these results in general terms. It does seem,

though, that whereas the fauna (all species and polychaetes) of the inshore and offshore areas is relatively diverse, in the clay areas variety is reduced. The lower diversity index observed in the clay areas is due to the smaller number of species and the larger number of polychaetes present. One species, Polydora caulleryi Mesnil, although particularly abundant in the clay, is so far unrecorded from this part of the English Channel, though it occurs off the French coast. In terms of variety, the fauna of the inshore area is the most distinctive, and resembles the gravel association of Jones (1950). Typical species present included Nucula hanleyi, Glycymeris glycymeris, Venus fasciata, Venus ovata, Venerupis rhomboides, Gari tellinella and Echinocyanus pusillus, and, with the exception of the last-named, none appeared in either the offshore or the clay areas. Six species were found exclusively in the clay area, of which three, Cultellus pellucidus, Amphiura filiformis and Cucumaria elongata, are typical of muddy sand communities. The offshore area was distinguished mainly by the occurrence of the burrowing decapod Upogebia deltaura, a species which burrows too deep for the grab but which was abundant in anchor dredge samples. However, the fauna of both the clay and offshore areas was clearly less distinct than the inshore fauna.

(iii) Experimental fishing

The programme of experimental trawling was designed to compare the distribution and types of fish present in St. Austell and Mevagissey Bays, which are grossly affected by china clay, with those from the comparatively unpolluted Veryan Bay. There were two interesting differences; on the china clay ground, young dabs, Limanda limanda, were considerably more abundant than in Veryan Bay, and like all the fish from the clay areas were of an abnormally pale coloration. The solenette, Buglossidium luteum, was restricted entirely to the clay areas. This latter observation was confirmed by a beam trawl survey carried out in May 1971 by J. D. Riley (personal communication). Apart from these two differences, catches from the two areas were similar and showed no obvious differences which could be attributed to the presence of china clay.

Using hand-lines with feathered hooks, mackerel, Scomber scombrus, could be taken both from water containing suspended china clay (the so-called 'white water') and from unaffected water. However, the number of observations was too small for quantitative comparisons to be made. As with other species, mackerel from the clay zones were abnormally pale.

An interesting observation was made on the behaviour of a shoal of whitebait (immature herring, Clupea harengus), an important prey of the mackerel. A shoal observed visually and by echo-sounder clearly avoided the edge of an advancing mass of white water. This avoidance has been reported before by fishermen but this was the first time that such behaviour had been observed locally by scientists.

DISCUSSION

Hydrographic considerations indicated that if the wastes now being released into the River Fal and St. Austell and Mevagissey Bays were collected and discharged from a pipe-line sited off Dodman Point, the sea bed in Veryan Bay and offshore would undergo a considerable change.

In the immediate area of the point of discharge, the benthos is likely to be markedly impoverished as a result of local instability of sediments. Further away, however, the presence of stable clay areas would probably lead to an increase in the numbers of certain species, especially of some of the sedentary polychaetes, such as Melinna palmata, Polydora caulleryi and Notomastus latericeus. Nevertheless, because of adverse effects on suspension feeding forms, the diversity of the fauna is likely to be reduced.

Away from the discharge point, the sea bed may become more suitable for trawling as the china clay waste covers rocky outcrops. Also, the area would probably be improved as a nursery ground for the dab and possibly other flatfish.

On the debit side, the unstable zone might represent a hazard to trawling as a result of large quantities of soft clay filling the net. Although mackerel did not appear to be adversely affected by the suspended clay, the whitebait observations suggest that at least some species actively avoid it. In addition, the covering of rocky ground by clay might reduce the value of the area for crab and lobster fishing.

Since this investigation was made, better techniques have been developed for the separation of finely suspended material, and the quantities of clay entering Cornish rivers will be substantially reduced. A pipe-line will therefore no longer be required when the new arrangements come into operation. It will be interesting to note what changes take place in the composition of the sea bed, and of the benthos.

ACKNOWLEDGEMENTS

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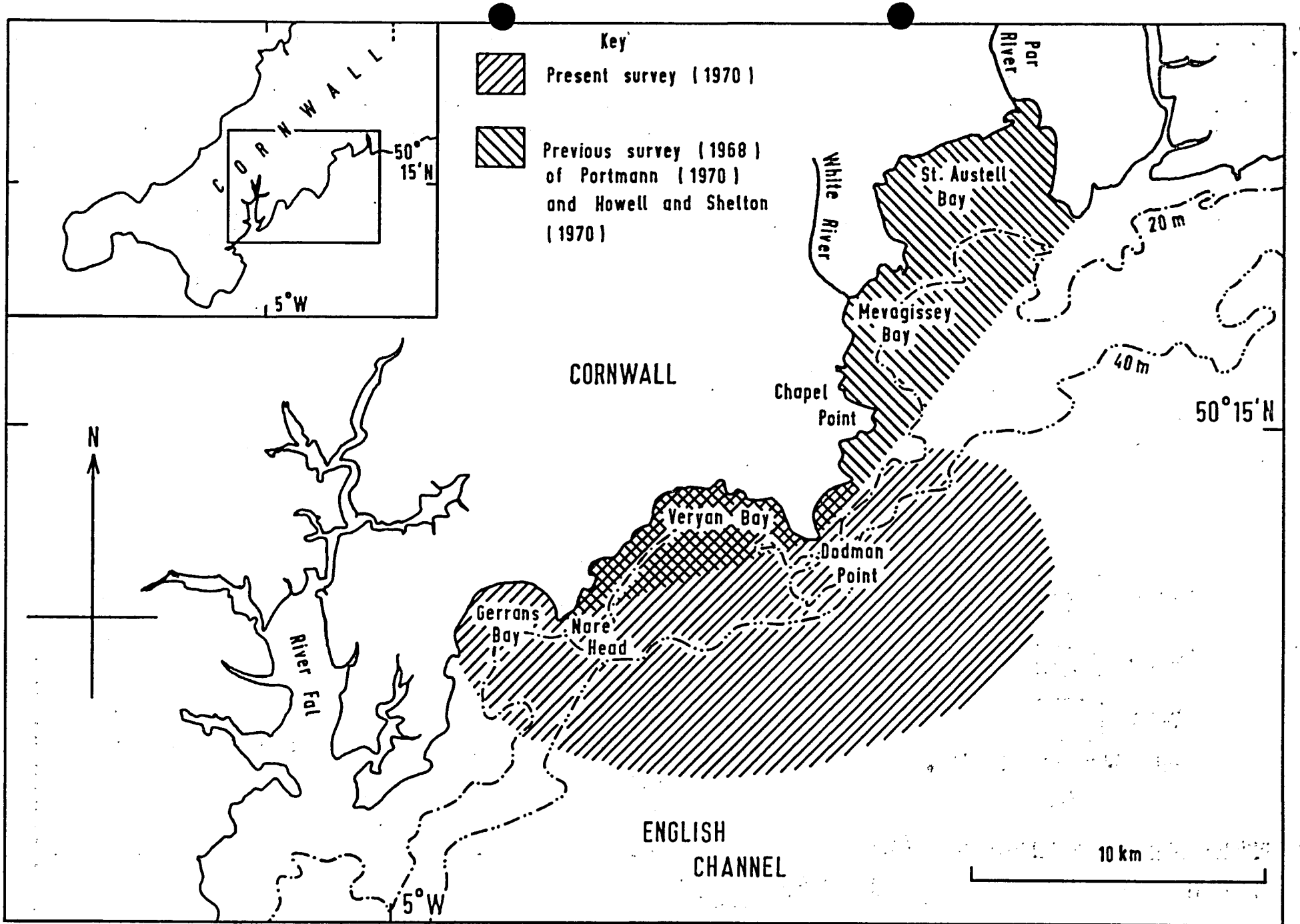

Fig. 1 Location of survey area

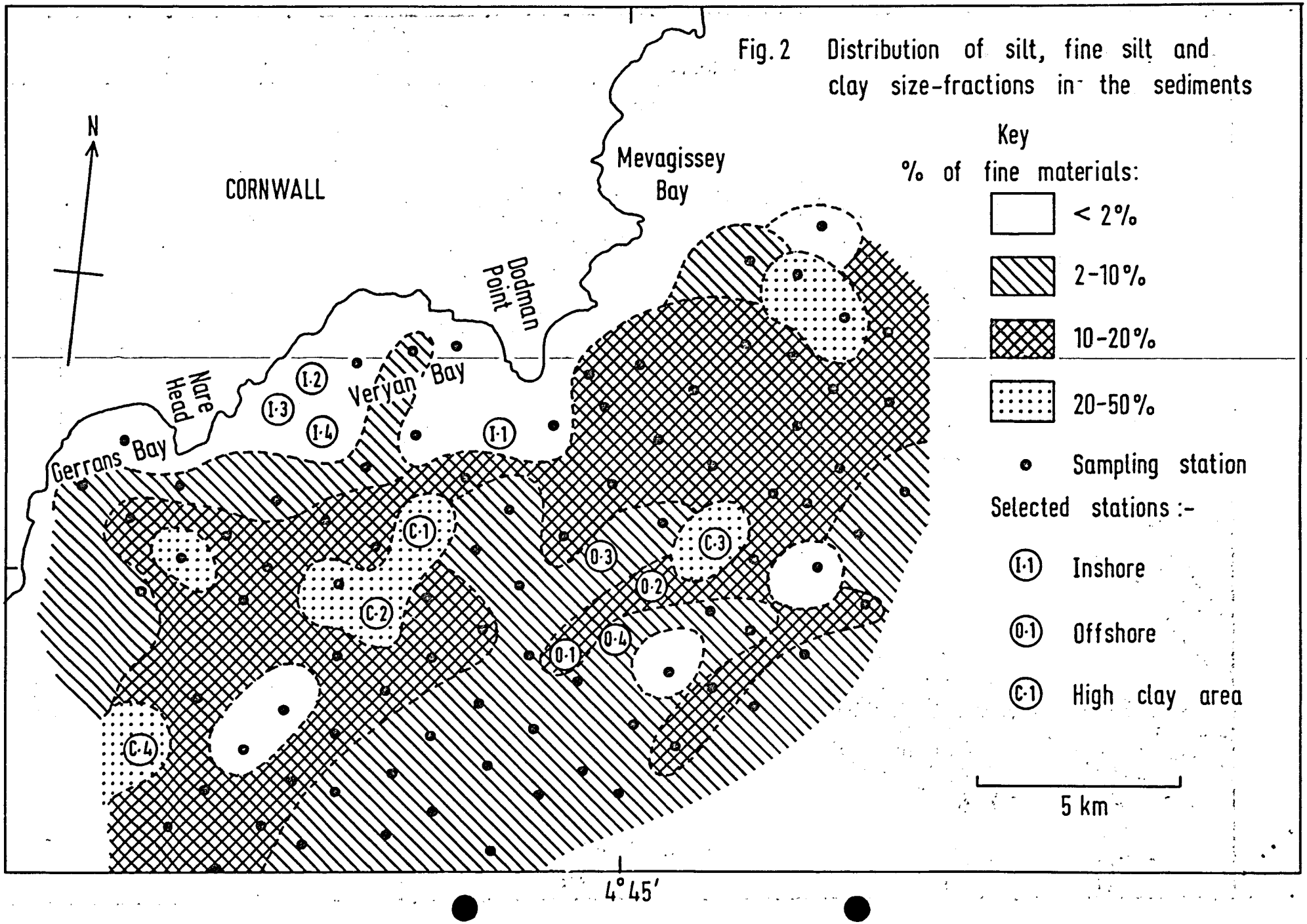
Fig. 2 Distribution of silt, fine silt and clay size-fractions in the sediments
Key
% of fine materials:
< 2%
2-10%
10-20%
20-50%
Sampling station
Selected stations :-
I·1 Inshore
0·1 Offshore
C·1 High clay area
5 km
N
CORNWALL
Mevagissey Bay
Dodman Point
Veryan Bay
Nare Head
Gerrans Bay
I·2
I·3
I·4
I·1
C·1
C·2
C·3
C·4
0·1
0·2
0·3
0·4
50°10′
4°45′

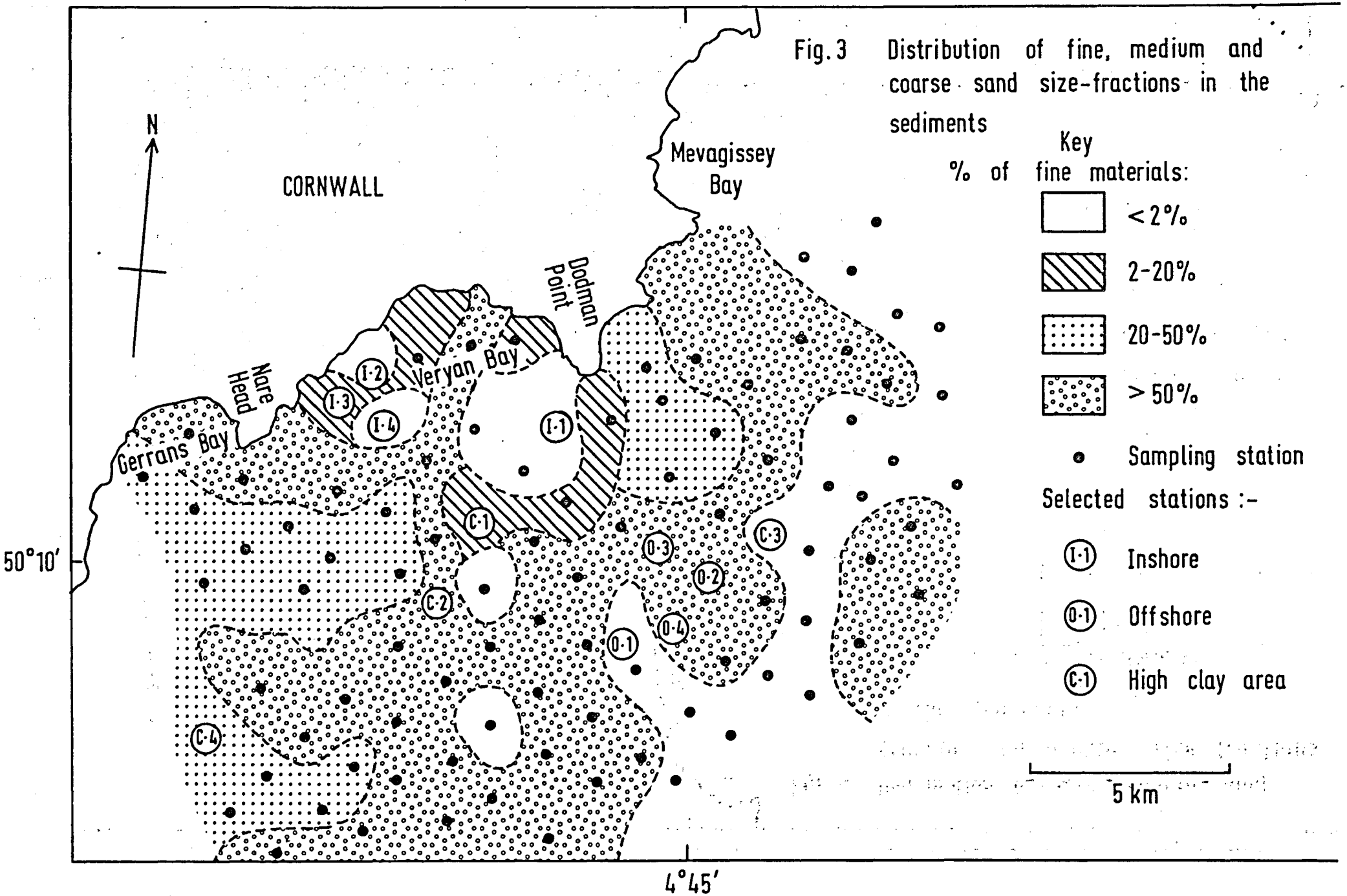

Fig. 3 Distribution of fine, medium and coarse sand size-fractions in the sediments

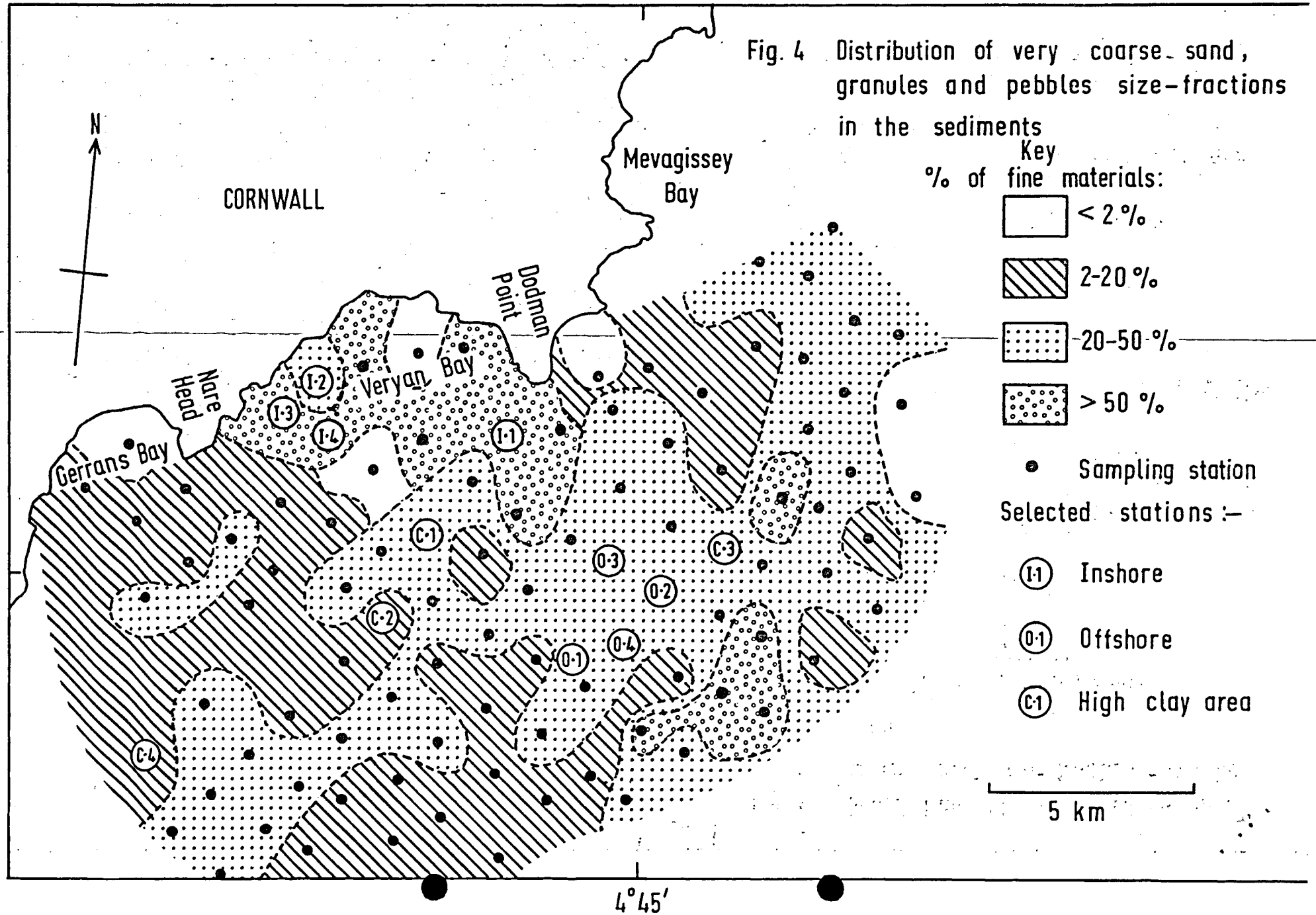

Fig. 4 Distribution of very coarse sand, granules and pebbles size-fractions in the sediments

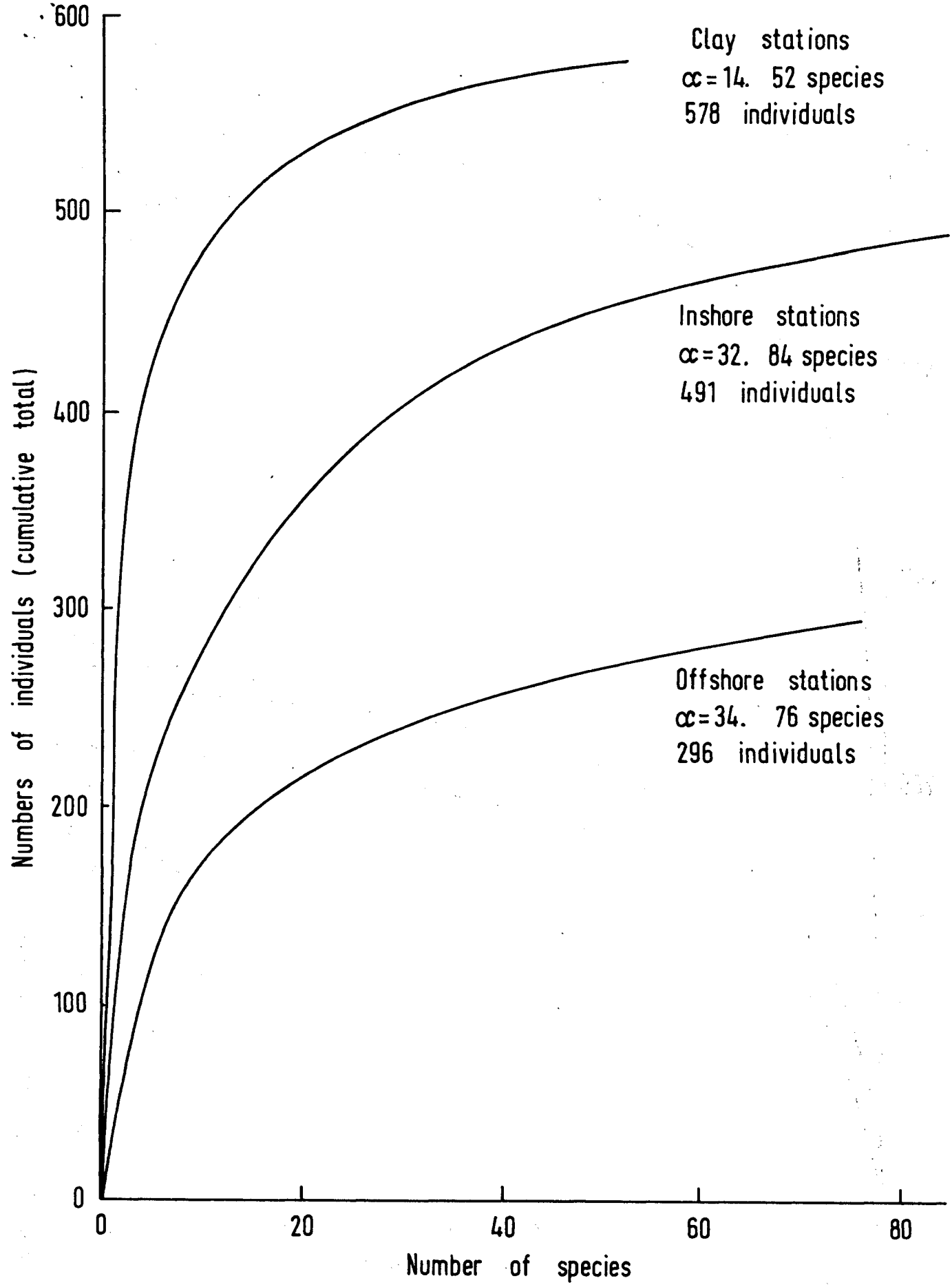

Fig. 5 Ranked species/abundance curves (all animals)

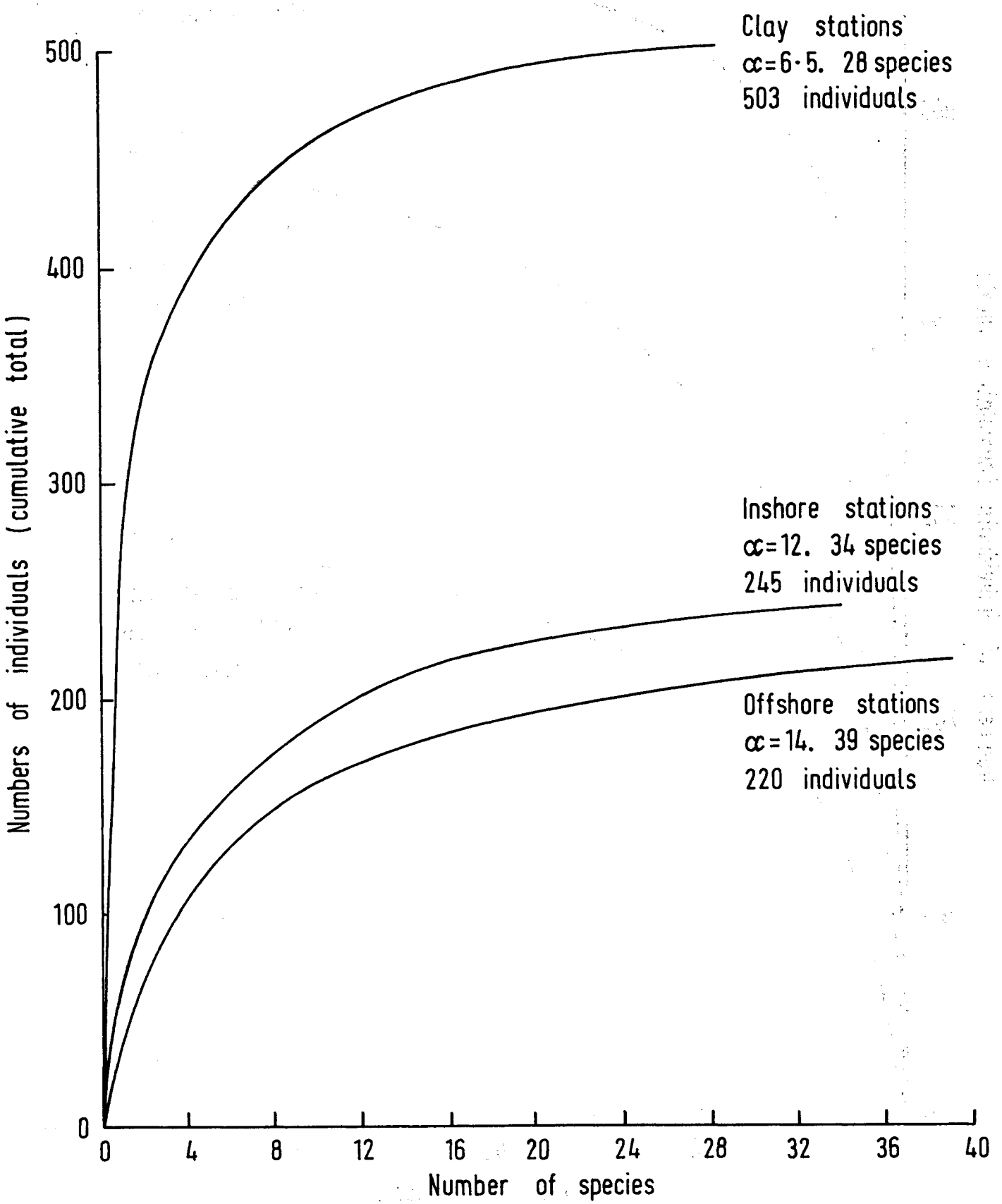

Fig. 6 Ranked species/abundance curves (polychaete worms only)

Table 1 Physical characteristics and benthic fauna found at selected stations

	Clay stations					Inshore stations					Offshore stations				
	C.1	C.2	C.3	C.4	Total	I.1	I.2	I.3	I.4	Total	0.1	0.2	0.3	0.4	Total
Physical characteristics															
Depth (m)	44	50	55	54		24	21	20	26		57	58	60	62	
Distance from shore (km)	4.4	5.9	5.9	4.5		1.4	0.8	0.7	1.9		6.7	5.8	4.6	6.7	
Sediment (%)															
Clay, fine silt and silt	41.2	35.8	30.3	41.1		0.7	0.7	1.6	0.3		15.8	12.6	12.1	12.0	
Fine, medium and coarse sand	19.0	51.3	33.7	47.9		23.5	39.4	1.3	0.5		48.8	57.5	52.1	56.6	
Very coarse sand, granules and pebbles	39.8	12.9	36.0	11.0		75.8	59.9	97.1	99.2		35.4	29.9	35.8	31.4	
Benthic fauna (first number = number of species; second number = number of individuals)															
Coelenterata															
Hydrozoa	-	-	-	-	-	-	-	-	-	-	-	-	-	1- 1	1- 1
Anthozoa	1- 1	-	1- 1	1-27	2- 29	-	-	-	-	-	-	1- 1	-	1- 1	1- 2
Nematoda	-	-	-	-	-	2- 3	3- 4	-	2- 2	3- 9	-	-	-	-	-
Nemertini	-	-	-	-	-	-	1- 2	1- 1	1- 2	1- 5	-	-	-	-	-
Annelida															
Polychaeta	14-336	16-36	14-68	18-63	28-503	13- 72	14-69	21-81	14-23	34-245	20-74	26-70	14-38	18-38	39-220
Sipunculoidea	-	-	1- 1	1- 1	1- 2	-	-	-	-	-	1- 1	-	-	-	1- 1
Arthropoda															
Crustacea															
Isopoda	1- 1	-	-	-	1- 1	1- 2	2- 6	-	1- 2	3- 10	-	-	-	-	-
Amphipoda	-	2- 3	2- 7	2- 3	3- 13	3- 5	3- 7	4-27	6- 7	13- 46	5- 5	7- 9	4- 4	3- 3	12- 21
Decapoda	2- 2	1- 1	2- 5	-	4- 8	2- 4	1- 1	1- 1	1- 3	3- 9	5-19	2- 6	2- 2	-	7- 27
Mollusca															
Loricata	-	-	1- 3	-	1- 3	-	-	-	-	-	1- 1	-	-	1- 2	1- 3
Gastropoda	-	-	1- 1	-	1- 1	1- 1	-	1- 1	2- 3	3- 5	-	-	-	1- 1	1- 1
Lamellibranchia	3- 3	2- 4	-	2- 3	5- 10	11-107	8-18	6- 8	5- 6	18-139	1- 1	1- 1	4- 4	1- 1	6- 7
Echinodermata															
Asteroidea	-	-	-	-	-	-	-	-	1- 1	1- 1	-	-	-	-	-
Ophiuroidea	-	1- 1	1- 1	-	2- 2	2- 2	1- 1	1- 1	2- 2	3- 6	2- 2	3- 6	-	1- 1	4- 9
Echinoidea	-	-	1- 1	-	1- 1	1- 1	1-11	2- 3	1- 1	2- 16	-	1- 1	-	-	1- 1
Holothuroidea	-	1- 1	-	1- 1	2- 2	-	-	-	-	-	1- 1	1- 1	-	1- 1	2- 3
Chordata															
Tunicata	1- 3	-	-	-	1- 3	-	-	-	-	-	-	-	-	-	-
Number of species	22	23	24	25	52	36	34	37	36	84	36	42	24	28	76
Number of individuals	346	46	88	98	578	197	119	123	52	491	104	95	48	49	296
Diversity index (α) -															
for all animals					14					32					34
for Polychaete worms only					6.5					12					14

Table 2 Numbers of Decapod Crustacea, Mollusca and Echinodermata found at selected stations

	Clay stations					Inshore stations					Offshore stations				
	C.1	C.2	C.3	C.4	Total	I.1	I.2	I.3	I.4	Total	0.1	0.2	0.3	0.4	Total
CRUSTACEA															
Decapoda															
Ebalia tuberosa (Pennant)	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-
Eupagurus prideauxi (Leach)	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Eurynome aspera (Pennant)	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1
Galathea intermedia Liljeborg	1	-	4	-	5	-	1	-	3	4	11	5	1	-	17
Galathea strigosa (L.)	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1
Pandalina brevirostris (Rathke)	-	-	-	-	-	3	-	1	-	4	2	-	-	-	2
Porcellana longicornis (L.)	-	-	-	-	-	-	-	-	-	-	4	-	-	-	4
Portunus pusillus Leach	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-
Upogebia deltaura (Leach)	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Unidentified shrimp (damaged)	-	1	-	-	1	-	-	-	-	-	1	-	-	-	1
MOLLUSCA															
Loricata															
Lepidopleurus asellus (Gmelin)	-	-	3	-	3	-	-	-	-	-	1	-	-	2	3
Gastropoda															
Emarginula reticulata J. Sowerby	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Natica alderi (Forbes)	-	-	-	-	-	1	-	1	-	2	-	-	-	-	-
Odostomia sp.	-	-	-	-	-	-	-	-	2	2	-	-	-	-	-
Trivia arctica (Montagu)	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-
Unidentified Opisthobranch	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-
Lamellibranchia															
Abra alba (W. Wood)	-	1	-	1	2	-	-	-	-	-	-	-	1	-	1
Chlamys opercularis (L.)	1	-	-	-	1	9	-	1	-	10	-	-	-	-	-
Chlamys tigerina (Müller)	-	-	-	-	-	8	-	-	-	8	-	-	-	1	1
Chlamys varia (L.)	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Cultellus pellucidus (Pennant)	-	3	-	2	5	-	-	-	-	-	-	-	-	-	-
Dosinia exoleta (L.)	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-
Dosinia lupinus (L.)	-	-	-	-	-	-	2	-	-	2	-	-	-	-	-
Gafrarium minimum (Montagu)	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-
Gari costulata (Turton)	-	-	-	-	-	-	2	-	-	2	-	-	-	-	-
Gari tellinella (Lamarck)	-	-	-	-	-	2	2	-	2	6	-	-	-	-	-
Glycymeris glycymeris (L.)	-	-	-	-	-	-	1	-	1	2	-	-	-	-	-
Laevicardium crassum (Gmelin)	-	-	-	-	-	1	-	-	-	1	1	-	1	-	2
Lima loscombi Sowerby	1	-	-	-	1	1	-	-	1	2	-	-	-	-	-
Lima subauriculata (Montagu)	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-
Lima sp. (soft parts only)	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-
Nucula hanleyi Winckworth	1	-	-	-	1	1	3	-	-	4	-	1	-	-	1
Parvicardium ovale (Sowerby)	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-
Tellina crassa Pennant	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-
Tellina donacina L.	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Venerupis rhomboides (Pennant)	-	-	-	-	-	81	6	3	1	91	-	-	-	-	-
Venus fasciata da Costa	-	-	-	-	-	1	1	1	1	4	-	-	-	-	-
Venus ovata Pennant	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-

Table 2 continued

	Clay stations					Inshore stations					Offshore stations				
	C.1	C.2	C.3	C.4	Total	I.1	I.2	I.3	I.4	Total	0.1	0.2	0.3	0.4	Total
ECHINODERMATA															
Asteroidea															
Henricia sanguinolenta (O. F. Muller)(?juv.)	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-
Ophiuroidea															
Amphiura filiformis (O. F. Muller)	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-
Ophiocomina nigra (Abildgaard)	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1
Ophiothrix fragilis (Abildgaard)	-	-	-	-	-	1	-	-	-	1	-	2	-	1	3
Ophiura albida (Forbes)	-	-	1	-	1	1	-	-	1	2	1	3	-	-	4
Unidentified sp. (juv.)	-	-	-	-	-	-	1	1	1	3	1	-	-	-	1
Echinoidea															
Echinocardium pennatifidum Norman?	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-
Echinocyamus pusillus (O. F. Muller)	-	-	1	-	1	1	11	2	1	15	-	-	-	-	-
Psammechinus miliaris (Gmelin)	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1
Holothuroidea															
Cucumaria elongata Düben + Koren	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-
Cucumaria hyndmani Thompson	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Cucumaria normani Pace	-	-	-	-	-	-	-	-	-	-	1	1	-	-	2
Thyone roscovita Herouard	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-