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The Benthic Ecology of Carmarthen Bay

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Submitted to the University of Wales in fulfillment of the requirements for the
Degree of Doctor of Philosophy

University of Wales Swansea

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Summary

Carmarthen Bay, an extensive, shallow embayment off the south coast of Wales, UK, encompasses a wide range of rich and diverse coastal and marine habitats. Carmarthen Bay is an internationally important wintering ground for the Common Scoter duck, *Melanitta nigra* (Linnaeus).

An extensive survey of the macrofauna revealed that Carmarthen Bay is dominated by the *Tellina* sub-group of Petersen's *Venus* community characterized by the polychaetes *Spiophanes bombyx*, *Magelona* spp. and *Spio* spp., the amphipods *Perioculodes longimanus*, *Pontocrates arenarius* and *Bathyporeia* spp., and the bivalves *Fabulina fabula*, *Mysella bidentata* and *Chamelea gallina*. Spatial patterns of species abundance and richness are shown to be strongly influenced by hydrodynamic and sedimentary gradients.

A wholly multivariate correlative technique to identify species or groups of species sensitive to environmental gradients was developed. Gradients of depth, proportion of mud in the sediment, median phi grain size, flood current velocity and wave height were all shown to elicit a macrofaunal community response in the Carmarthen Bay *Tellina* sub-community. The application of these techniques to environmental monitoring and ecological research are discussed.

The population dynamics, size structure and growth parameters of *F. fabula* were determined and predictive models of abundance and distribution were developed. These provide evidence of an ontogenetic niche shift in *F. fabula* representing a novel optimal foraging strategy for sessile deposit feeding invertebrates.

A study of the temporal variability in the *Tellina* sub-community redundancy revealed that it was subject to recruitment driven short-term variability in the abundance and dominance of commonly occurring r-selected taxa. Levels of structural redundancy and a successional process involving the numerically abundant taxa suggest that functionally equivalent taxa may be able to compensate for this variability. These results are discussed in the context of functional diversity and the role of biodiversity in ecosystem processes. An assessment of the Carmarthen Bay *Tellina* sub-community's persistence and resilience to perturbation is made.

Declaration

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

Signed. .... (candidate)

Date. 6/10/03 ......

Statement 1

This thesis is the result of my own investigations, except where otherwise stated. Other sources are acknowledged by footnotes giving explicit references. A bibliography is appended.

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I hereby give consent for my thesis, if accepted, to be available for photocopying and for inter-library loan, and for the title and summary to be made available to outside organizations.

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Date. 6/10/03 ......

This thesis is dedicated to the memory of my father, Peter James Woolmer

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Glossary

AONB

Area of Outstanding Natural Beauty.

CCW

The Countryside Council for Wales is the Government's statutory adviser on sustaining natural beauty, wildlife and the opportunity for outdoor enjoyment in Wales and its inshore waters. The national wildlife conservation authority.

FISAT

The FAO-ICLARM Stock Assessment Tools is a fisheries stock assessment software package developed for the detailed analysis of length-frequency data and related analyses.

GIS

Geographical Information System.

MDS

Multidimensional scaling (MDS) is a data analysis technique that displays the structure of distance-like (similarity) data as a geometrical plot.

MLWS

Mean Low Water Spring.

PCA

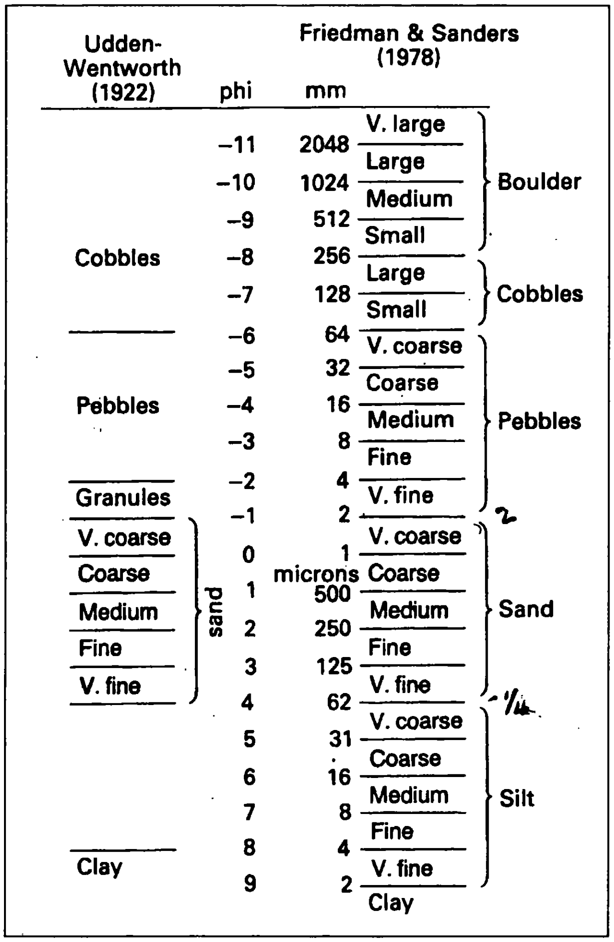
Principal Component Analysis.

Phi Grain Size

Relation between phi units and diameter D in mm is:

phi = - log_2 (D) or D = 2^(-phi)

Size scales of sediment classification methods (after Tucker, 1988).



Udden-Wentworth (1922)	phi	mm	Friedman & Sanders (1978)	
			V. large	Boulder
	−11	2048		
			Large	
	−10	1024		
			Medium	
	−9	512		
			Small	
Cobbles	−8	256		
			Large	Cobbles
	−7	128		
			Small	
	−6	64		
			V. coarse	Pebbles
	−5	32		
			Coarse	
Pebbles	−4	16		
			Medium	
	−3	8		
			Fine	
	−2	4		
Granules			V. fine	
	−1	2		
V. coarse (sand)			V. coarse	Sand
	0	1		
Coarse (sand)		microns	Coarse	
	1	500		
Medium (sand)			Medium	
	2	250		
Fine (sand)			Fine	
	3	125		
V. fine (sand)			V. fine	
	4	62		
			V. coarse	Silt
	5	31		
			Coarse	
	6	16		
			Medium	
	7	8		
			Fine	
	8	4		
Clay			V. fine	
	9	2		
			Clay	

PRIMER

Plymouth Routines in Multivariate Ecological Research software (Clarke & Gorley, 2001).

SAC

Special Area of Conservation.

SPA

Special Protected Area.

STA

Sediment Trend Analysis.

TBT

Tri-Butyl Tin.

THC

Total hydrocarbon concentration.

UWS

University of Wales Swansea.

VBLF

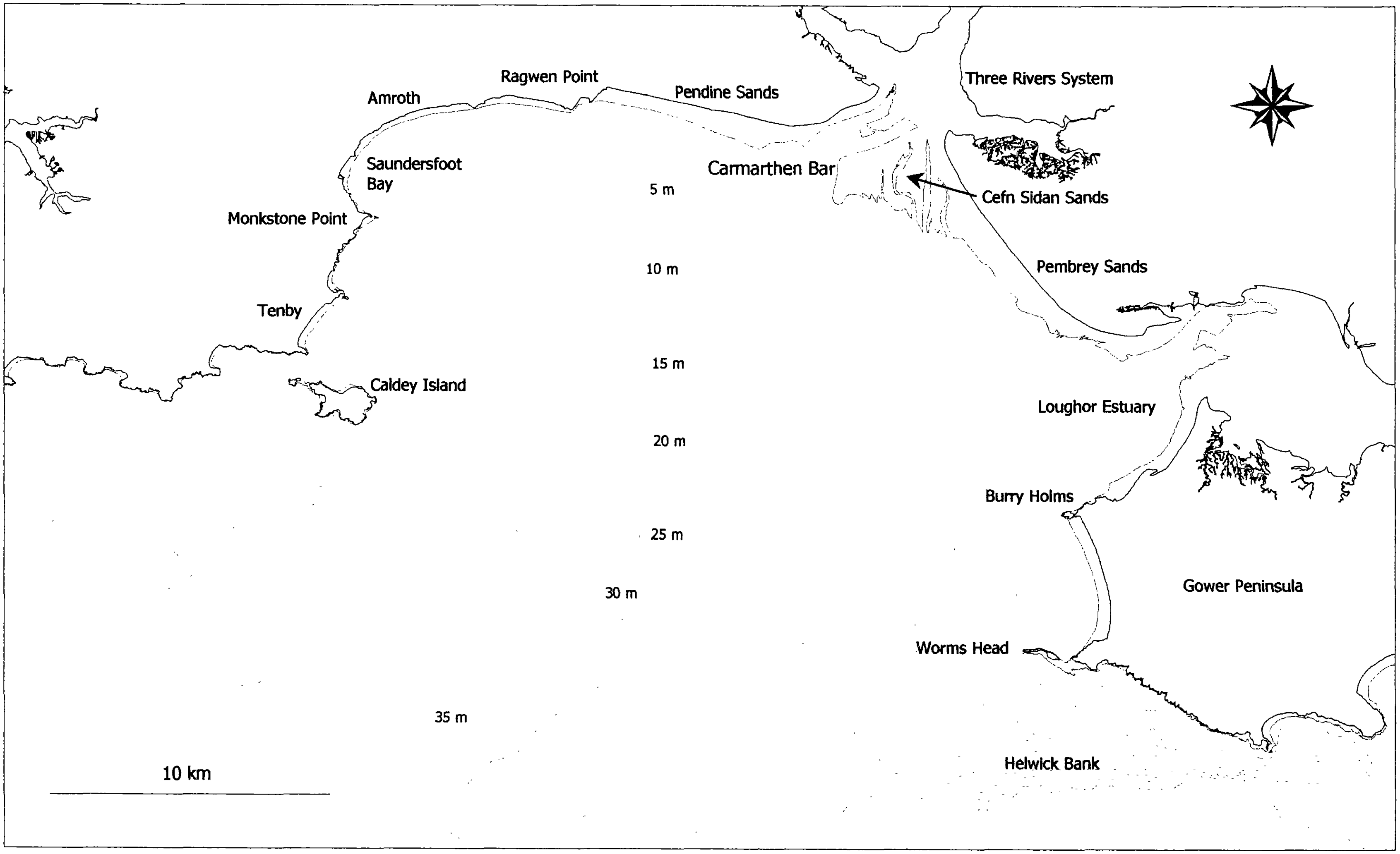
von Bertalanffy Growth Function is the most commonly used growth model for aquatic (gill-breathing) animals. It is a mathematical description or representation of the rate at which an animal approaches their asymptotic length ($L\infty$) at different sizes or ages.

Chapter 1: General Introduction

Carmarthen Bay is an broad, shallow embayment on the south coast of Wales (Figure 1.1). Incorporating elements of the Pembrokeshire Coast National Park, the Gower AONB, the ecologically important wetlands of the Three Rivers system and the Burry Inlet, and the offshore Helwick Sandbank, Carmarthen Bay encompasses a wide range of rich and diverse coastal and marine habitats and consequently is a candidate Special Area of Conservation (cSAC). Carmarthen Bay is an internationally important wintering ground for the Common Scoter duck (*Melanitta nigra* (Linnaeus), and is widely regarded as the most important such site in the UK (Hughes. B., Sanderson, W.G., pers comm. 1999) causing it to be proposed as a Special Protected Area (pSPA) under the EC birds directive.

This project commenced on 1 June 1998 stimulated by concern for the Carmarthen Bay macrofaunal communities, on which the wintering population of the Common Scoter depend, following the *Sea Empress* oil spill of February 1996. On 15th February 1996 the tanker '*Sea Empress*' went aground on rocks off St Annes Head at the mouth of the Milford Haven waterway. Over the subsequent week an estimated 72,000 tonnes of Forties blend light crude oil and 360 tonnes of heavy fuel oil were released. The magnitude of the spill rated it as the third largest to have occurred in the UK and among the top twenty worldwide. The western shores of Carmarthen Bay, from Tenby to Pendine, were heavily oiled over the period 24 – 29th February 1996. Offshore and in the bay, extensive slicks were reported and an oil sheen spread rapidly over a wide area. Over the ensuing weeks hundreds of thousands of dead and moribund molluscs, crustaceans and echinoderms were washed ashore around the whole of the bay, including at sites on the eastern side, such as Rhossili and the Burry Inlet, which had not been directly affected by heavy oiling.

Figure 1.1 Carmarthen Bay



Post-spill surveys of soft sediment shores reported mass strandings of dead and moribund cockles *Cerastoderma edule* (Linnaeus), razor shells *Ensis siliqua* (Linnaeus) and *Pharus legumen* (Linnaeus), wedge shells *Donax vittatus* (da Costa), trough shells *Mactra stultorum* (Linnaeus), masked crabs (*Corystes cassivelaunus* (Pennant) and various starfish and ophiuroids, but these were inadequately documented by the survey methodologies employed (Moore, 1996). Diving surveys of the entire area affected by the spill included eight stations in Carmarthen Bay (Rutt et al., 1998). Enhanced THC levels were recorded in sediments within the bay in March 1996, with a significant decrease in October 1996, but there were no discernible effects on benthic communities. It was noted by Rutt et al. (1998) that this was at variance with the massive invertebrate strandings recorded on all shores of the bay. It is probable that the greatest damage occurred inshore. Common Scoter recovered in the weeks after the spill were found to have ingested quantities of *P. legumen*, a deep-burrowing bivalve not normally accessible to the ducks, which could only have become available following narcotization of infaunal populations (Hughes et al., 1997; Rutt et al., 1998).

Even had the scale of the damage to the benthic communities been quantified, evaluation of its significance would have been limited by the lack of background data on the macrofaunal communities of Carmarthen Bay. At that time the only useful information concerning the macrofaunal communities in the bay was provided by an Institute for Marine Environmental Research (IMER) survey of the Bristol Channel and the Severn Estuary which included the outer part Carmarthen Bay (Warwick & Davies, 1977) and a survey of the soft-sediment shores of the south Wales coast (Withers, 1977). The need for accurate baseline data highlighted by these events was given further impetus by the importance of the macrofaunal communities as the food resource for the over-wintering Common Scoter population.

Throughout their range, Common Scoter are commonly observed feeding over areas of shallow sandy seabed containing fauna characteristic of Petersen's *Venus* community (Petersen, 1914). Common Scoter are able to descend to depths of more than 20 m during foraging dives searching for benthic prey. In reviews of diet studies both Hughes et al. (1998) and Fox (in press) concluded that although prepared to take a variety of benthic macrofaunal taxa, Common Scoter prey mainly on bivalve molluscs. The dominant bivalve prey species was dependant on the study, and hence site, examined. This local predominance suggests that common scoter take those bivalve species that are locally most abundant, demonstrating that they utilize different species at different locations depending on the composition of the macrofaunal community. Determination of the distribution and composition of the potential prey species in Carmarthen Bay was considered to warrant urgent attention to provide insight into the feeding ecology of the Common Scoter and in order to assess the status and vulnerability of these communities.

There is currently an increase in the demand for areas of shallow soft sediment seabed, like those characteristic of Carmarthen Bay and other sites in the Bristol Channel, for use by offshore developments. These developments include aggregate extraction and the siting of offshore structures for oil exploration, windfarms and other renewable energy developments, which by the size and nature of such projects have the potential to give rise to significant environmental effects (CEFAS, 2001). Expanding fisheries, particularly those for bivalve molluscs, also represent significant potential impacts on these soft sediment habitats (Gaspar, 1994; Lindeboom & de Groot, 1998; Robinson & Richardson, 1998; Tuck et al., 2000;

Kaiser & de Groot, 2001). In many cases the siting of these developments have raised conservation concerns for the potential impact on diving duck populations and the communities containing their benthic prey species in Wales (Sanderson & Cole-King, in press) and elsewhere (Guillemette, 1999; Guillemette, 2002). For example, in the last two years there have been three proposals for windfarm developments in the shallow coastal waters of Wales. The first of these proposals has now gained necessary consents and is likely to be built in 2003. The other two windfarms are also likely to be granted the necessary consents with construction to follow (S. Wood, CCW pers comm. 2002). There is, therefore, a need for the development of new methods and techniques adequately to predict and map the extent of sensitive sea duck prey species, and also to assess and predict impacts of such developments on associated communities. These would provide invaluable tools for scientists studying the birds' feeding ecology, and for conservation managers involved in the licensing and siting of offshore structures and aggregate extraction enabling them to avoid sensitive areas of seabed by pinpointing sensitive areas.

While there has been a number of studies correlating bivalve distribution and abundance with pre- and post-settlement processes (e.g. Commito et al., 1995; Olafsson et al., 1994), these have tended to focus on intertidal populations and there is therefore a lack of information concerning the processes determining the distribution and abundances of sublittoral bivalve populations. The distribution of macrofauna has often been found to reflect the local hydrodynamic regime, whereas the relationship with the sediment is often secondary (Snelgrove & Butman, 1994). *Fabulina fabula* (Gmelin) was the predominant bivalve taxon in the baseline survey samples and therefore was considered the most likely to be important as Common Scoter prey. The distribution and abundance of *F. fabulina* has previously been linked to the prevailing hydrodynamic regime in the southern North Sea (Creutzberg, 1986). It was anticipated that the quantification of the effects of physical environmental hydrodynamic and sedimentary factors on abundance would, by the application of GIS mapping and spatial modeling techniques, enable the production of accurate spatial models. These models were considered to represent practical tools which would provide insight into the ecology of *F. fabula* and more broadly, other sublittoral infaunal bivalve species.

Material cost is often an overriding consideration in marine monitoring and assessment due to the logistical difficulties in working in the marine environment. These factors often lead to the use of indicator species in such studies; the abundance, condition, or some other characteristic, measured or observed, associated with a single species is assumed to act as a proxy for conditions in the environment too costly or difficult to measure. The identification of indicator species is often subjective, reliant on the expertise of the ecologist involved to indicate groups of species characterizing various stages of response to a gradient (see Pearson and Rosenberg, 1978). Patterns in composition, richness and diversity of sessile benthic communities have often been shown to reflect clines of abiotic environmental factors (e.g. Rakocinski et al., 1993; Bell & Barnes, 2000, 2000; Brown et al., 2000; DeFelice & Parrish, 2001; Barnes & Brockington, 2003). Patterns observed at the community level are often reflected in the distribution and abundance of individual member taxa. It was considered that by exploiting the correspondence between patterns an objective means of determining indicator species or groups of species could be possible.

Soft sediment communities are recognized to be subject to variability of species composition and relative species abundance at a variety of temporal and spatial scales (Morrisey et al., 1992). It has been suggested that inherently unstable (variable) communities may be more resilient to disturbance than stable ones as they contain species adapted to variable environmental conditions. By determining the nature and temporal scales of variation, and therefore the stability, within the Carmarthen Bay macrofaunal communities it was anticipated that an assessment of its resistance and resilience to disturbance would be possible.

It has been suggested that the level of functional redundancy, the interchangeability of functionally equivalent species, in a community could be a useful determinant of its resilience to perturbation (Chapin et al., 1995; Johnson, 2000) or as a measure of the potential for functional compensation within it (Menge et al., 1994; Rosenfeld, 2002). It may be possible to infer the potential for functional redundancy and functional compensation in a community from an investigation of their levels of structural redundancy (Clarke & Warwick, 1998).

Chapter 2: The Macrofaunal Communities of Carmarthen Bay

2. 1 Introduction

The need for a comprehensive baseline survey of the macrofaunal communities of Carmarthen Bay became a priority for government agencies such as the Countryside Council for Wales in the wake of the *Sea Empress* oil spill of February 1996. The western half of Carmarthen Bay was heavily oiled over the period 24 - 29 February 1996. Subsequent strandings of macrofaunal species such as the bivalves *Ensis siliqua* (Linnaeus), *Pharus legumen* (Linnaeus), *Donax vittatus* (da Costa), and *Mactra stultorum* (Linnaeus), the masked crab *Corystes cassivelaunus* (Pennant) and a number of starfish and ophiuroids were recorded on the shores of the bay (Dyrynda, 1996; Rutt et al., 1998). The timing, degree and high hydrocarbon content detected in those specimens analyzed suggested that the strandings were as a result of the oil spill. The lack of background information on the benthic environment of Carmarthen Bay made quantifiable assessment of impact on the macrofaunal communities impossible. Prior to the oil spill the only useful information concerning the macrofaunal communities in the bay was provided by an Institute for Marine Environmental Research (IMER) survey of the Bristol Channel and the Severn Estuary which included Carmarthen Bay (Warwick & Davies, 1977) and a survey of the soft-sediment shores of the south Wales coast including five sites in the bay (Withers, 1977). Subsequent to the *Sea Empress* oil spill a series of nine stations were sampled in Carmarthen Bay as part of a broader monitoring program for the Environment Agency by OPRU (Hobbs & Smith, 1998).

Warwick and Davies (1977) used a Day grab and a naturalist dredge to sample seven stations in the centre and around the southern periphery of the bay. They described the presence of a *Tellina* subgroup of Petersen's *Venus* community (Petersen, 1914; Jones, 1950) inhabiting the fine sand which characterizes the majority of the seabed of

Carmarthen Bay from Caldey Island to Worms Head. The mixed sediments in the centre of the bay were thought to support a *Modiolus* community and in the muddy sand at the southern extent of the bay, a community dominated by *Abra alba* (Wood) and *Nucula nitidosa* (Winckworth). The *Tellina* sub-community dominating the inner part of the bay was characterized by the infaunal polychaetes *Magelona papillicornis* (*mirabilis/johnstoni*) (Fiege, Licher & Mackie), *Pectinaria* (*Lagis*) *koreni* (Malmgren) and *Tharyx* (*Aphelochaeta*) *marioni* (Saint-Joseph), the cumacean *Iphinoe trispinosa* (Goodsir), the amphipods *Bathyporeia guilliamsoniana* (Bate) and *Pontocrates arenarius* (Bate) and the bivalves *Fabulina fabula* (Gmelin), *Pharus legumen* (Linnaeus) and *Donax vittatus* (da Costa).

Withers (1977) described the presence of taxa typical of the *Tellina* sub-community extending inshore to MLWS in samples throughout the bay from Tenby, Saundersfoot, Pendine, Llangennith and Rhossili. These included the polychaetes *Spiophanes bombyx* (Claparède) and *Owenia fusiformis* (Chiaje), the amphipods *P. arenarius* and a number of *Bathyporeia* species, and the bivalve *F. fabula*.

Hobbs and Smith (1998) sampled nine stations outside of those areas investigated by Warwick and Davies (1977) with a Day grab on three occasions over the period of a year, five stations in the north-west of the bay off Tenby, Saundersfoot and Pendine and the remainder to the west of the Gower peninsula. These stations were characterized by taxa characteristic of the *Tellina* sub-community: The polychaetes *M. filiformis*, *Chaetozone setosa* (Malgren) and *S. bombyx*, the amphipod taxon *Pontocrates/Synchelidium* spp. and the bivalve *F. fabula*.

Although in combination these previous surveys give a broad description of the communities in Carmarthen Bay they do not provide the high spatial resolution and detailed description of species abundance and distributions necessary for them to act as yardsticks to measure any future change against.

The status of Carmarthen Bay as an internationally important over-wintering site for Common Scoter provides further impetus for a detailed survey of the macrofaunal communities in the bay. In a review of the winter diet of Common Scoters (including three studies from Carmarthen Bay) Hughes et al. (1997) showed that while they were catholic in their prey choice, taking 43 taxa in total, bivalves made up the largest proportion in all studies. The difference in dominant bivalve prey species between studies was interpreted as an indication of the non-specific nature of the scoter diet, their prey choice reflecting local abundance of prey species. The paucity of detailed information on the extent and nature of potential common scoter prey resources in Carmarthen Bay was highlighted and was considered to warrant urgent attention.

The aim of this survey then, was twofold: to describe quantitatively the nature and distribution of the macrofaunal communities in Carmarthen Bay thus providing a baseline to assess any future environmental impacts against and to assess the distribution and density of potential Common Scoter food resources in an internationally important over-wintering site.

Large mobile epifauna play an important part in structuring macrofaunal communities. Epibenthic predators have a significant role in determining both density and distribution of soft bottom benthos. Cropping of siphons and tails has demonstrable effects on growth and survival of bivalves and polychaetes (Irlandi & Mehlich, 1996; Lindsay & Woodin, 1996). Post settlement predation and associated physical disturbance also has a marked effect on the recruitment of infaunal species (Bonsdorff et al., 1995; Aarnio et al., 1998). A brief, qualitative beam trawl survey was also included in the baseline study in order to describe the epifauna present in Carmarthen Bay.

A prerequisite to the interpretation of the community and species distributions is an understanding of the physical environment acting upon them. The physical environmental information collected during the current survey was supplemented by an extensive sedimentary and hydrodynamic dataset for Carmarthen Bay produced as part of the 'Bristol Channel Marine Aggregates: Resources and Constraints Research Project' (ABP-Research, 2000). This dataset was reanalyzed and reinterpreted in the context of soft-sediment community ecology.

2. 2 Methods

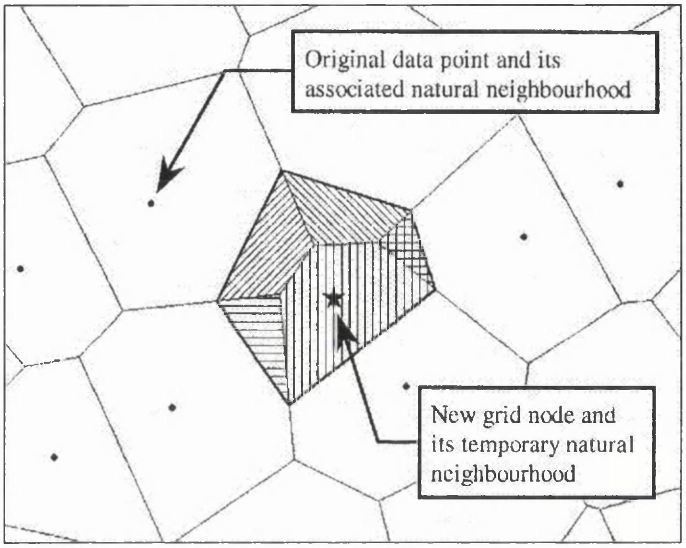
2. 2. 1 Interpretation and mapping of ABP Environmental Data

To aid interpretation of the macrofauna data, contour maps illustrating the physical environment of the bay were produced from a large sedimentary and environmental dataset made available by the Planning Division of the Welsh Assembly. This dataset was produced by Associated British Ports Research and Consultancy Ltd as part of the 'Bristol Channel Marine Aggregates: Resources and Constraints Research Project' (ABP-research, 2000). The sedimentary dataset consisted of 1574 samples spaced on a hexagonal grid with a sample spacing of 1km that encompassed the majority of the macrofauna survey area from the current study. These samples had been collected only 3 months before the present macrofaunal survey and were analyzed for their complete grain-size distribution using a very accurate Malvern 2600L laser particle sizer. Hydrodynamic data; ebb and flood tidal current velocity, residual tidal current velocity, peak wave height and wave period were determined from a hydrodynamic model in the form of a grid of 900m covering the macrofauna survey area.

2. 2. 1. 1 Data Interpolation and Data mining

The interpolated grid files which form basis of the contour plots of hydrographic and sedimentary environment of Carmarthen Bay were produced using the Natural Neighbour interpolation method (Sibson, 1981). The Natural Neighbour method is a geometric estimation technique that uses regions, "natural neighbourhood", generated around each point in the data set to construct a Voronoi diagram (Figure 2.1). Subsequently, a new Voronoi cell is created about the interpolation point. If there are n natural neighbours of the interpolation point, the overlap of the new Voronoi cell with the original cells creates n new cells. In this study the interpolated grid value was determined by averaging the extrapolated slope of each surrounding natural neighbour region and the area weighted according to the area that is encompassed by the temporary natural neighbour Voronoi cell (Figure 2.1).

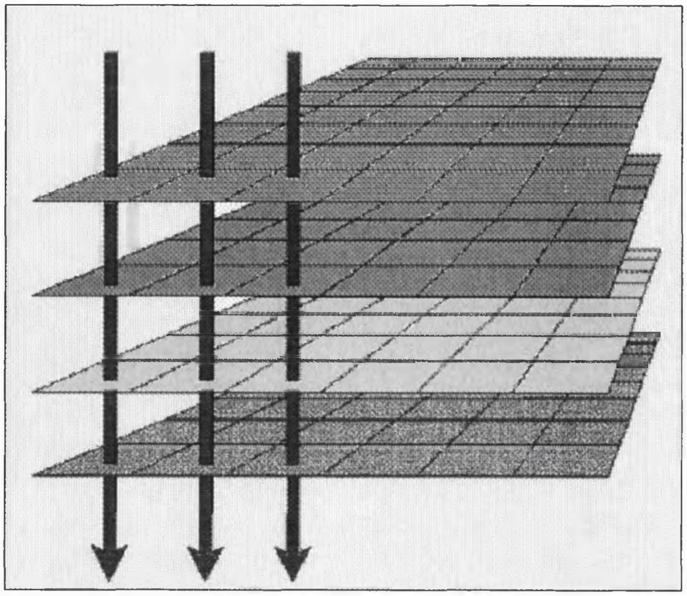
Figure 2.1 Natural Neighbour Voronoi Diagram (after Northwood-Geoscience, 2000)



This method is considered particularly effective for dealing with highly linear distributions such as the ABP survey layout (Abramov, in press; Northwood Geoscience, 2000). Local minimum and maximum values in the original dataset were respected to prevent the production of high or low overshoot values and thereby producing accurate surface models (grid files).

The resulting grid files can be interrogated on a point basis to provide environmental data for use in subsequent analysis of the macrofauna survey data. By examining spatially distinct points, in this case the grab sample stations, and 'drilling down' through each grid a new table of point specific data is produced (Figure 2.2).

Figure 2.2 Point Inspection of Interpolated Environmental Data



All interpolation, map plotting and analysis was done at UWS using Vertical Mapper 2.5 contour modeling and display software (Northwood-Geoscience, 2000) running in MapInfo 5.5 GIS software (MapInfo-Corp., 1999) on a personal computer.

2. 2. 2 Macrofauna Sampling

The baseline survey of Carmarthen Bay was carried out from 1 – 3 June 1998 using the RV *Prince Madog* (School of Ocean Sciences, University of Wales Bangor). This stratified survey consisted of 29 quantitative (3 replicate grabs sieved through a 0.5 mm mesh) and 31 qualitative (single grab sieved through a 1.0 mm mesh) stations (Figure 2.3). A further eight qualitative beam trawls were taken to assess populations of large epifauna (Figure 2.4). Station coordinates and descriptions are presented in the summarized field log (Appendix 2.1).

Figure 2.3 Carmarthen Bay Baseline Survey Grab Stations

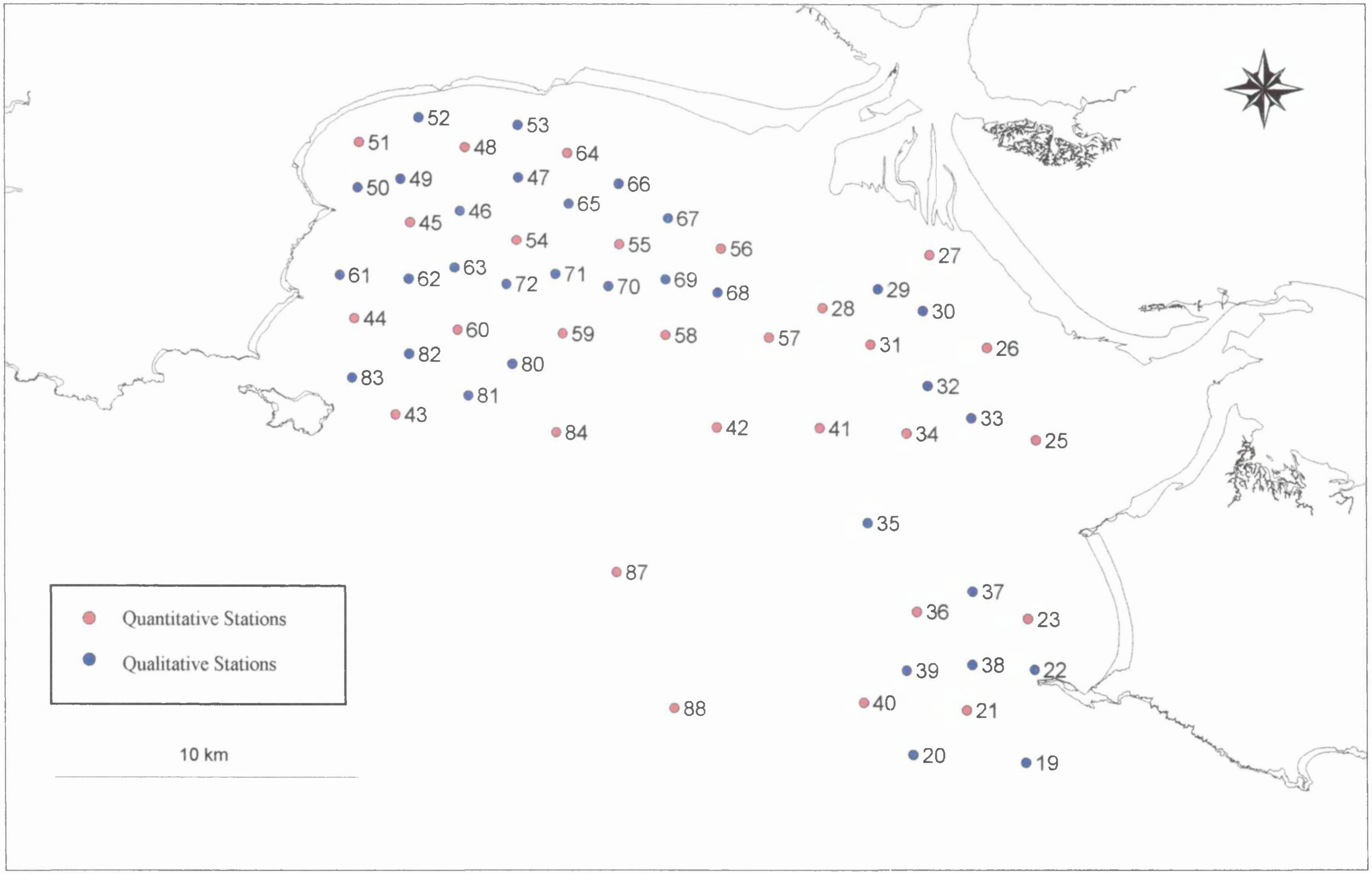
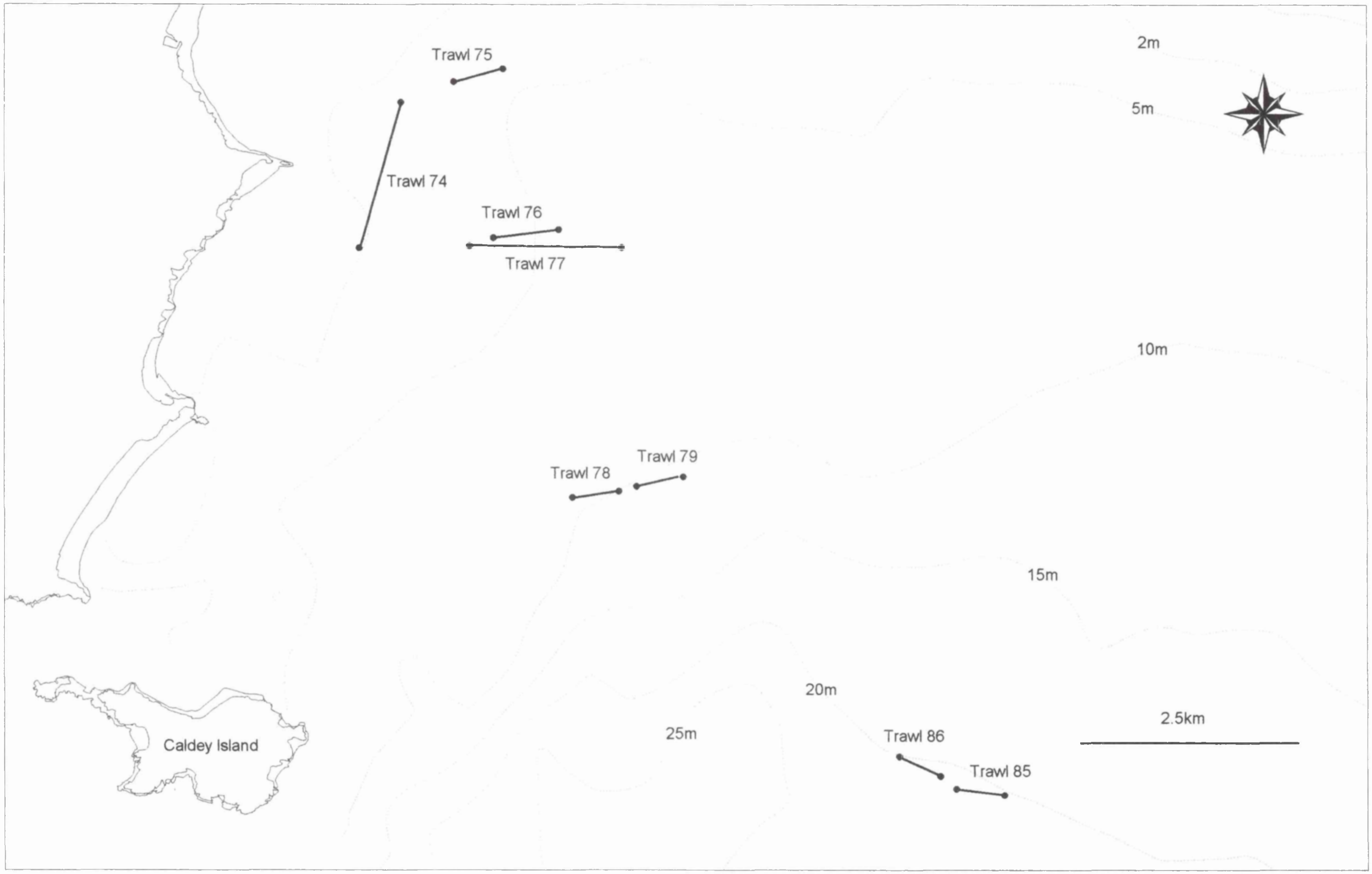


Figure 2.4 Carmarthen Bay Baseline Survey Beam Trawl Stations



2. 2. 2. 1 Grab Sampling

Sampling was carried out using a heavy (85-95 kg) modified long-armed continuous warp-rigged Van-Veen grab with a sample area of $0.1 m^2$ (Mackie, in prep.). This type of grab was considered to be the most effective in obtaining good penetrative samples (~ 80mm) on harder sediments such as those encountered in Carmarthen Bay (Mackie, 1981; Riddle, 1984, 1989). Three replicate grabs were taken at each quantitative station; the two of larger volume were sieved for macrofauna, a sediment sample was taken from the remaining one. A sample was considered valid if the volume of sediment collected was in excess of 4 litres and there was no leakage on retrieving the grab. Two replicates using a grab of this type have been shown to be sufficient for classification analysis and the calculation of diversity indices (Riddle, 1984; Kingston & Riddle, 1989). Single grabs only were taken at qualitative stations. The quantitative grabs allow the accurate description of community type and composition. The qualitative grabs were taken to identify boundaries between communities and enable more accurate interpolation between them in the construction of a community map.

2. 2. 2. 2 Beam Trawls

Eight trawl stations were worked using a 3m beam trawl equipped with two tickler chains. Sampling consisted of two replicate trawls of approximately 500 m on the 5, 10 and 20 m isobaths and two longer trawls of approximately 1700 m parallel to, and across the 5 m isobath. All trawls were taken in the western part of the bay starting off Tenby and working out to 6 km east of Caldey Island (Figure 2.4).

2. 2. 3 Sample Treatment

The sample treatment closely follows those procedures used by the Department of Biodiversity and Systematic Biology of the National Museum and Galleries of Wales Procedures in surveys of the Irish Sea and on the macrofaunal survey of Welsh sandbanks (Mackie, 1994; Mackie et al., 1995; Darbyshire et al., 2002).

Samples were emptied from the grab into large fish boxes and covered with seawater, keeping the samples cool while assisting the gentle break-up of the sediment. Samples were decanted into a large (20 liter) plastic graduated fermenting bin allowing an accurate estimate of volume. Each bin was transferred to a purpose built wooden washing box and the sample softly washed with seawater allowing the excess water containing fine suspended sediment to overflow into the box. When the box was half to three quarters full, the water was released though the exit chute into the sieve. This was repeated, continually breaking up the sediment, until there remained little or no mud and suspended material. This fraction contained the majority of the small polychaetes, crustaceans and small bivalves but very little sediment. The benefits of doing this initial washing are twofold: time is saved later during sorting of the samples in the laboratory and importantly the animals are subjected to less mechanical damage and therefore are in a better condition for identification. The fraction remaining in the box usually contained the coarser sediments and the larger animals, and so could be sieved with more force. Fractions were placed in labeled containers, constituting a single sample, and fixed in 8% formaldehyde (equivalent to 20% formalin) in seawater. The formalin was strongly stained with Rose Bengal to assist laboratory sorting. The stain has the effect of making the animals contrast more sharply against pale sediment or a white sorting tray consequently few are missed and go unrecorded.

After two days fixation, the sieved samples were gently, but thoroughly, washed in freshwater. This removed the formalin and salt, preventing the former from dissolving the shells of delicate molluscs. This washing stage was carried out in the open air to reduce exposure to formaldehyde fumes. The samples were then preserved in 80% alcohol containing 5% Propylene glycol.

2. 2. 4 Laboratory Analysis

In the laboratory the specimen-rich washing fractions were sorted into phyla under a dissecting microscope. The remaining fractions, containing large volumes of sediment, were sorted into phyla by eye using a well-lit white tray and pliable stork-billed forceps.

For each sample all specimens were identified to the highest taxonomic resolution possible using the taxonomic literature available. Specimens were retained to be accessioned into the biodiversity reference collection at the National Museums and Galleries of Wales Cardiff.

2. 2. 5 Sediment Analysis

Sediment samples were taken from the smallest of the three grabs at quantitative stations. These were double wrapped in polythene bags, labeled both internally and externally and frozen on board ship.

The samples were processed following Buchanan (1984). Sub-samples were taken and oven dried at 60°C for between 24-48 hours. These were then individually sieved on a graduated sieve stack using an electric shaker for a period of 20 minutes. Separate fractions were then weighed on an electronic balance and recorded.

2. 2. 5. 1 Organic Content Determination

An estimate of the amount of organic matter in the sediment was also determined by the Difference-On-Ignition (DOI) method standardized by (Luczak et al., 1997). 3 replicate 2g samples of oven dried sediment from each quantitative station were heated to 500°C for 6 hours. The samples were immediately weighed on an electronic balance and the difference calculated.

2. 2. 6 Data Analysis

Analysis of the macrofauna data from this study closely followed the non-parametric multivariate strategy for analyzing multispecies patterns described by Field et al. (1982) and also Clarke and Warwick (2001). These methods have become commonplace in marine environmental assessment and monitoring programs. Multivariate methods of this type are acknowledged as being more sensitive than univariate or simple descriptive measures for the discrimination of sites (Gray et al., 1990; Warwick and Clarke, 1991) and have been recommended as the first step of data exploration in a monitoring study (Gray et al., 1988).

2. 2. 6. 1 Classification and Ordination

For the purposes of multivariate analysis both quantitative and qualitative datasets were separately subjected to identical analyses. The quantitative replicate data were pooled to remove any variance in species abundance due to small scale (<1.0m) patchiness. Taxa sampled only qualitatively, such as colonial hydroids and encrusting bryozoans, were removed from both datasets. A $\log_{10}(x+1)$ transformation was used to increase the influence of the less common taxa and limit the influence of the superabundant ones. Two complementary multivariate methods were used to investigate relationships within the data; cluster analysis and non-metric multidimensional scaling (MDS).

All analyses were performed by the PRIMER (Plymouth Routines in Multivariate Ecological Research) software version 5.1.2 (Clarke & Gorley, 2001) on a personal computer.

2. 2. 6. 2 Cluster Analysis and Non-metric Multidimensional Scaling (MDS)

Cluster analysis is a technique linking samples sequentially according to their similarity (or dissimilarity). The Bray-Curtis similarity coefficient (Bray & Curtis, 1957) is the basis of the cluster analysis:

$$S_{jk} = 100 . \frac{\Sigma_{i=1}^{p} \left(y_{ij} - y_{ik} \right)}{\Sigma_{i=1}^{p} \left(y_{ij} + y_{ik} \right)}$$

Where S_{jk} is the similarity between the *j*th and *k*th samples, y_{ij} the abundance to the *i*th species at site J and y_{ik} the abundance of the *i*th species at site K.

A ranked similarity matrix is produced and after group average clustering the results are plotted in a dendrogram displaying linked groups and levels of similarity.

MDS is a data analysis technique that displays the structure of distance-like data (Bray-Curtis similarities) as a map or ordination. Using the rank order of pairwise similarity between samples, MDS plots these in space while preserving the rank order of pairwise distances. The goodness of fit of the resulting ordination is measured by the stress value, for two dimensional plots a stress value of below 0.1 is good, below 0.2 is useful, but above 3.0 is little better than a random pattern.

2. 2. 6. 3 SIMPER Analysis

The SIMPER function of the PRIMER software package computes the average dissimilarity between all pairs of inter-assemblage samples and subsequently breaks this average down into the separate contributions from each species. The ratio of the individual species contribution to the standard deviation of its contribution gives a useful measure of its utility as a discriminating species. The species are displayed ranked by their average contribution to the total average dissimilarity. Results are given for both inter-assemblage and between assemblage comparisons.

2. 2. 6. 4 Species Clustering and MDS

Construction of a species similarity matrix from the original dataset can show similarities between species. Two species are defined as similar if their abundance tend to fluctuate in parallel across stations.

Following the recommendations in Clarke &Warwick (1994), the number of species in the dataset was decreased, retaining those that accounted for more than 4% of the total abundance at any one site. Species that occurred only as high numbers of juveniles at single stations were also excluded. The resulting similarity matrix was entered into a cluster analysis and MDS ordination.

2. 2. 6. 5 Linking of Community Structure to Environmental Variables

Environmental variables were examined to find those that were highly correlated with each other (pairwise correlations of >0.95). Any pair of variables showing high positive or negative coefficients were identified and the variable least likely to be biologically important removed from the dataset, one substituted for the other without effective loss of information.

Sediment variables, %Gravel, Sand and Mud were log10 transformed to remove skewness in the data.

Using the BIOENV program in the PRIMER software package it is possible to define an optimal subset of environmental variables which 'best explains' the distribution of macrofaunal assemblages identified by the classification and ordination process. This procedure identifies the subset of environmental variables that maximizes the rank correlation (ρ) between the macrofaunal and environmental (dis)similarity matrices underlying the MDS ordinations.

Environmental variables used were: Depth, % Gravel, % Sand, % Mud, Median Phi, % Organics, Flood Velocity, Tidal Residual, Wave Height and Wave Period .

2. 2. 6. 6 Species Diversity

A variety of univariate descriptive variables was calculated from pooled data for each quantitative sampling station. Pooled data were used to maintain continuity with the multivariate analysis and with other macrobenthic studies using similar sampling methods and sample sizes. Unless indicated, all univariate indices were calculated using the DIVERSE function in the PRIMER software package. A full review of species diversity indices is presented by (Magurran, 1988) from which much of the information is drawn.

Fisher's α

$$\alpha = \frac{S}{\log e\left(1 + \frac{N}{\alpha}\right)}$$

Fisher's α was proposed as a descriptive species diversity index by Fisher *et al.* (1943) and is recognized as the first attempt to describe mathematically the relationship between number of species and their relative abundance. Fisher's α is derived from an underlying theoretical species abundance model, the logarithmic series model. It has been shown that this index is analogous to the Q statistic of Kempton and Taylor (1976, 1978), a model not influenced by extremes of abundance being calculated from species data within the middle two quartiles of a range.

Margalef's d

$$\mathrm{d} = \frac{S-1}{\log eN}$$

Margalef's d index is a commonly used species richness measure. This index is a relatively simple species abundance ratio providing some measure of relative abundance of species. This index is sensitive to samples size.

Brillouin H

$$\mathrm{H} = \frac{\log e\, N! - \Sigma \log e\, ni!}{N}$$

The Brillouin H index is the first of the two information measures of diversity calculated here. It was developed from the information theory of mathematics which, when applied to species diversity, treats diversity in a natural system to be analogous to the information in a code or message. The Brillouin H index was deemed the most theoretically satisfactory of the two information measures of diversity by Laxton (1978).

Shannon-Wiener H′

$$\mathrm{H}' = -\Sigma \frac{ni}{N} \log 2 \frac{ni}{N}$$

Shannon-Wiener H′ is the most widely used information diversity measure in marine macrobenthic studies and has become almost standard. Log_2 was used in calculating H′ in this study although any log base can be used. The Shannon-Wiener H′ may be useful in the comparison of surveys as it has been shown to remain stable in combinations of two or more grabs (Kingston & Riddle, 1989) and to be relatively unaffected by mesh size (0.5 or 1.0mm) (Levell et al., 1989).

Simpson D

$$\mathrm{D} = 1 - \Sigma \frac{ni(ni-1)}{N(N-1)}$$

Simpson D index is generally referred to as a dominance measure. The Simpson D index is strongly weighted towards the most abundant species in the sample at the same time as being less sensitive to species richness. The index represents the probability of any pair of individuals randomly taken from the sample belonging to different species.

Berger-Parker Index

$$\mathrm{d} = \frac{N\max}{N}$$

The Berger-Parker index is both conceptually and mathematically simple; it expresses the proportion of the total sample that is due to the dominant species. This index is independent of species richness but may be influenced by sample size. May (1975) asserts that this index is one of the most satisfactory diversity measures.

Pielou J

$$\mathrm{J} = \frac{H'}{\log 2\, S}$$

The Pielou J evenness measure represents the ratio of observed diversity to maximum diversity calculated using the Shannon-Wiener H' as the diversity measure. Values for J range from 0 - 1.0, where 1.0 represents a sample where all species are equally abundant. The Pielou J index is the most commonly used evenness measure in macrobenthic studies and so is included here.

Heip E

$$\mathrm{E} = \frac{2^{H'} - 1}{S - 1}$$

A further evenness index the Heip E been shown to be theoretically superior to other evenness measures (Heip, 1974).

Hurlbert Rarefaction (ES)

$$\mathrm{ES} = \Sigma\left\{1 - \left[\left(\frac{N - N_1}{n}\right) \Big/ \left(\frac{N}{n}\right)\right]\right\}$$

Hurlbert rarefaction calculates the expected number of species in a sample of a standard size. This allows the comparison of samples of a different size, a technique first used by Saunders (1968) and modified by Hurlbert (1971).

2. 2. 6. 7 Determination of numerically dominant taxa

The numerically dominant taxa at each station were ranked according to the percentage they contributed to the total number of individuals. This provides a useful means of identifying the more common or characteristic taxa in the community and aids inter-station comparison. The percentage contributions of the 25 most abundant taxa were summed.

2. 2. 6. 8 Principal Component Analysis of Environmental Variables

Principal component analysis (PCA) is a mathematical procedure that transforms a number of (possibly) correlated variables into a (smaller) number of uncorrelated variables called principal components. The purpose of principal component analysis is to reduce the dimensionality (number of environmental variables) of the dataset but retain most of the original (between station) variability in the data. The first principal component attempts to account for as much of the variability within the data as possible, and each succeeding component attempts to account for as much of the remaining variability as possible. The resulting ordinations demonstrate the physical differences between station samples.

2. 3 Results

2. 3. 1 Physical Environment

2. 3. 1. 1 Sedimentology

The sediment composition at each quantitative station is presented in Table 2.1 and graphically as individual frequency curves (Figure 2.5) and in the form of sediment trigons using proportions of gravel, sand and mud (Fig 2.6 c-d). The sediments at the quantitative stations were found to be medium or fine sand with a low proportion of mud and gravel content. Median grain size at these stations ranged between 1.50 - 2.82 phi.

Maps of the distribution of individual phi grain sizes in Carmarthen Bay made from reinterpreted ABP Research survey data (ABP Research, 2000) are presented in Appendix 2.2. The ABP sediment data show that the seafloor of Carmarthen Bay consists of wide areas of fine and medium sand interspersed with patches of finer and coarse material (Figure 2.7). Figures 2.6 b and 2.9 demonstrate the dominance of clean sand in the sediments of Carmarthen Bay. Coarse material and hard ground were found in patches in the south of the bay, none north of Caldey Island (Figure 2.8). The mud fraction is shown to be distributed in distinct patches across the bay (Figure 2.10). The inshore areas of Saundersfoot Bay are characterized by muddy fine sand, with an area of decreasing mud content graduating east to Pendine Sands. A further area of muddy sand is shown in the centre of the bay south of the Three River estuary.

Table 2.1 Summary of Sediment Characteristics at Each Quantitative Station.

Station	% Gravel	% Sand	% Mud	Median Phi	Skewness	Kurtosis	Sediment Type
21	0.31	99.67	0.02	1.63	-0.10	2.72	Medium Sand
23	0.61	99.20	0.19	1.90	0.20	1.01	Medium Sand
25	0.06	99.90	0.03	2.61	-0.20	7.30	Fine Sand
26	0.15	99.52	0.33	2.82	0.00	1.04	Fine Sand
27	2.56	97.26	0.17	2.74	-0.90	18.99	Fine Sand
28	1.32	98.10	0.58	2.66	0.00	0.77	Fine Sand
31	0.06	99.56	0.38	2.81	0.10	0.95	Fine Sand
34	0.56	98.96	0.48	2.74	-0.10	1.44	Fine Sand
36	1.48	98.35	0.17	2.20	0.00	1.38	Fine Sand
40	0.19	99.77	0.04	1.63	0.10	1.22	Medium Sand
41	3.09	96.49	0.41	2.62	-0.30	4.75	Fine Sand
42	7.86	91.63	0.50	2.40	-0.40	5.43	Fine Sand
43	0.07	99.92	0.01	2.15	-0.10	0.98	Fine Sand
44	15.78	84.03	0.18	2.38	-0.40	1.21	Fine Sand
45	0.34	99.18	0.48	2.45	-0.30	5.15	Fine Sand
48	0.40	98.85	0.75	2.50	0.00	0.89	Fine Sand
51	0.12	97.26	2.62	2.30	0.10	6.89	Fine Sand
54	0.48	99.09	0.43	2.40	0.00	3.31	Fine Sand
55	2.30	97.38	0.32	2.60	-0.40	5.12	Fine Sand
56	2.92	96.08	1.00	2.68	-0.50	6.18	Fine Sand
57	1.17	98.34	0.49	2.74	-0.70	22.54	Fine Sand
58	4.19	95.32	0.49	2.50	0.50	18.85	Fine Sand
59	2.41	97.50	0.09	2.00	0.00	3.66	Medium Sand
60	0.32	99.22	0.46	2.50	-0.70	0.00	Fine Sand
64	0.20	99.44	0.37	2.80	0.10	1.73	Fine Sand
84	0.58	99.37	0.06	1.60	0.00	0.98	Medium Sand
87	0.72	99.25	0.03	1.50	0.00	2.09	Medium Sand
88	0.05	99.74	0.21	1.55	-0.10	1.29	Medium Sand

Figure 2.5 Phi Grain Size Unique Frequency Curves

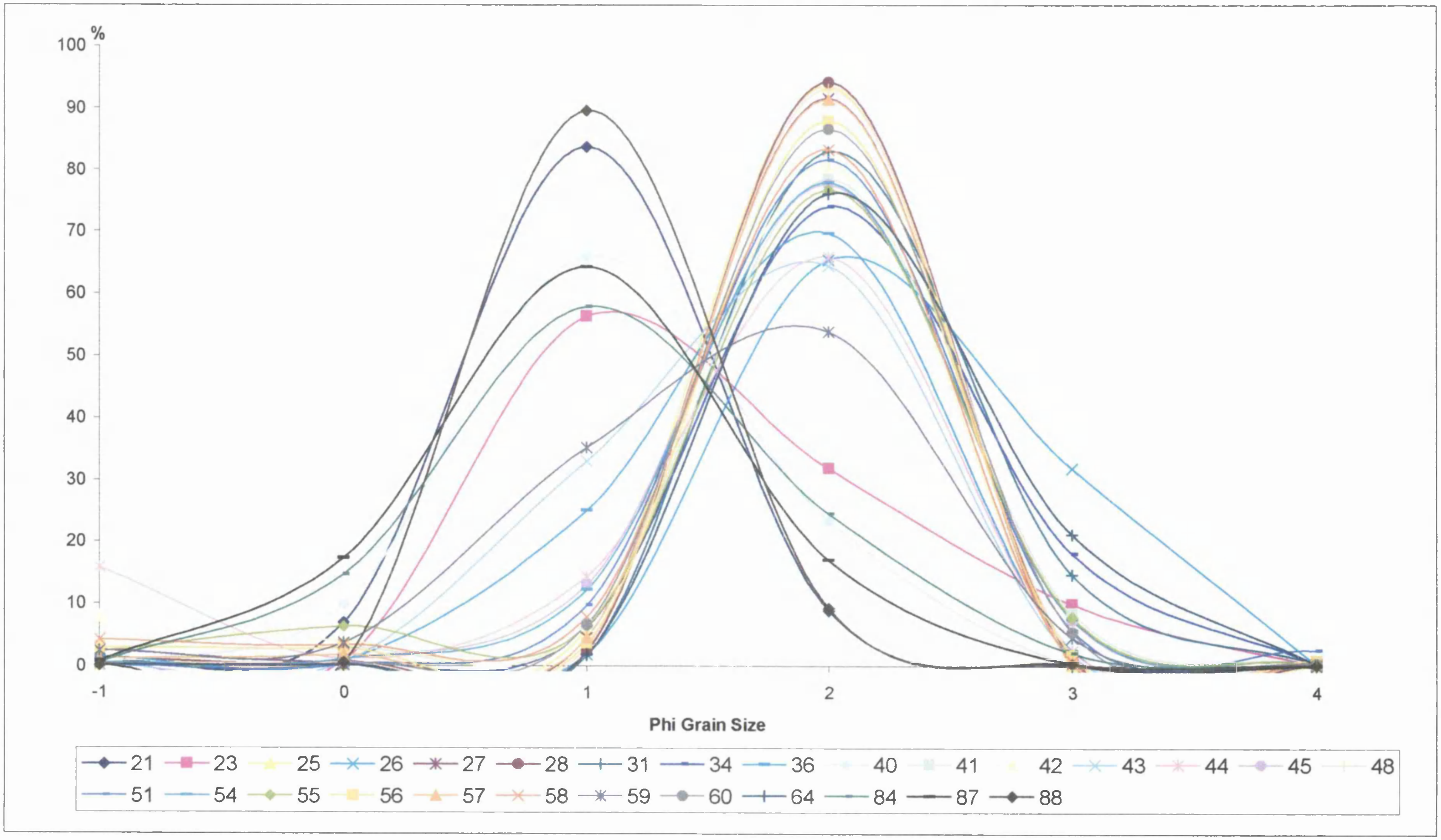


Figure 2.6 Sediment Characterization Trigons. a. Key (after Buchanan, 1971).
b. ABP Sediment Stations. c & d. Quantitative Stations Sediments.

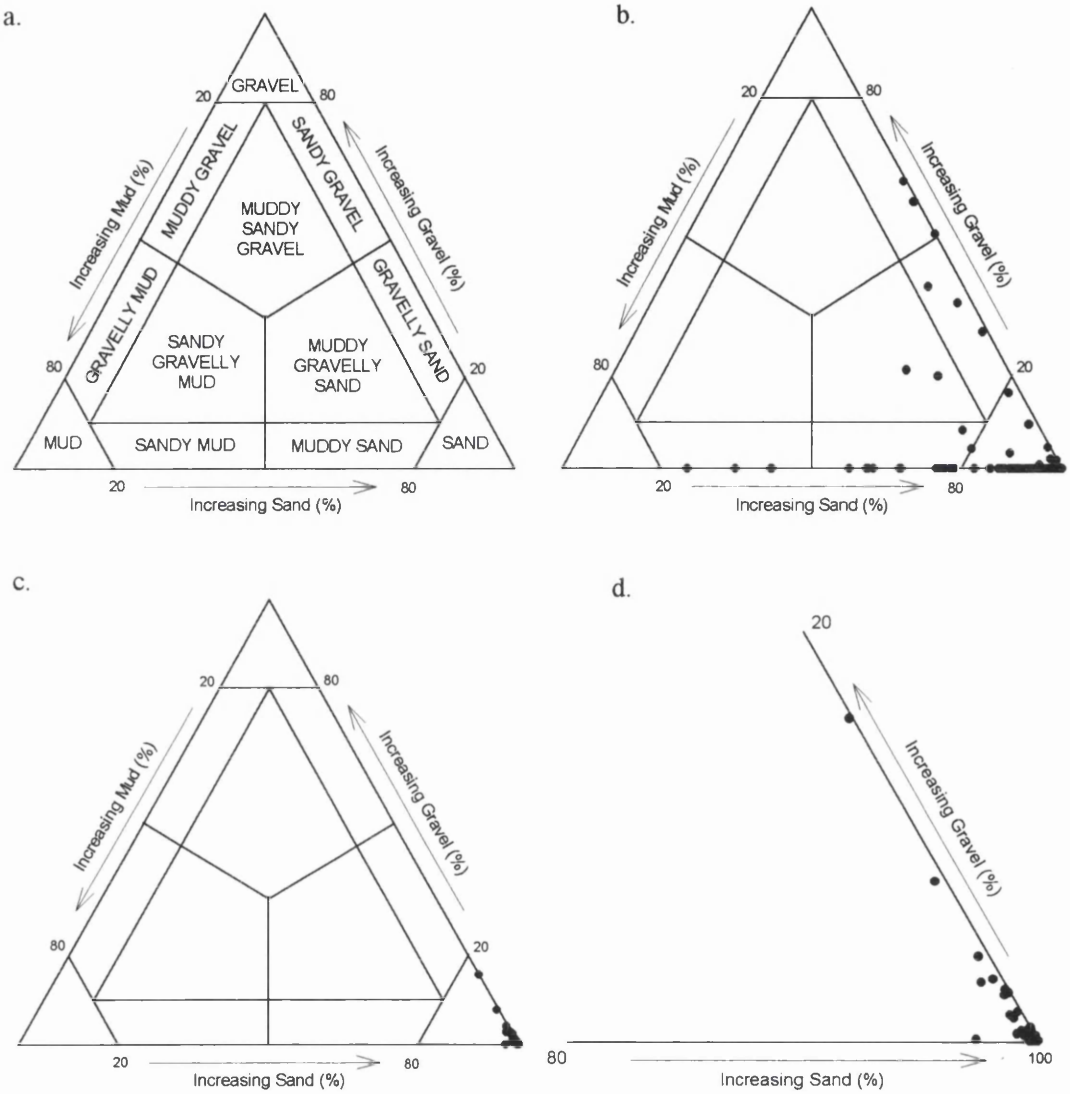


Figure 2.7 Carmarthen Bay Median Phi Grain Size Distributions Derived From Interpolated ABP Sediment Data

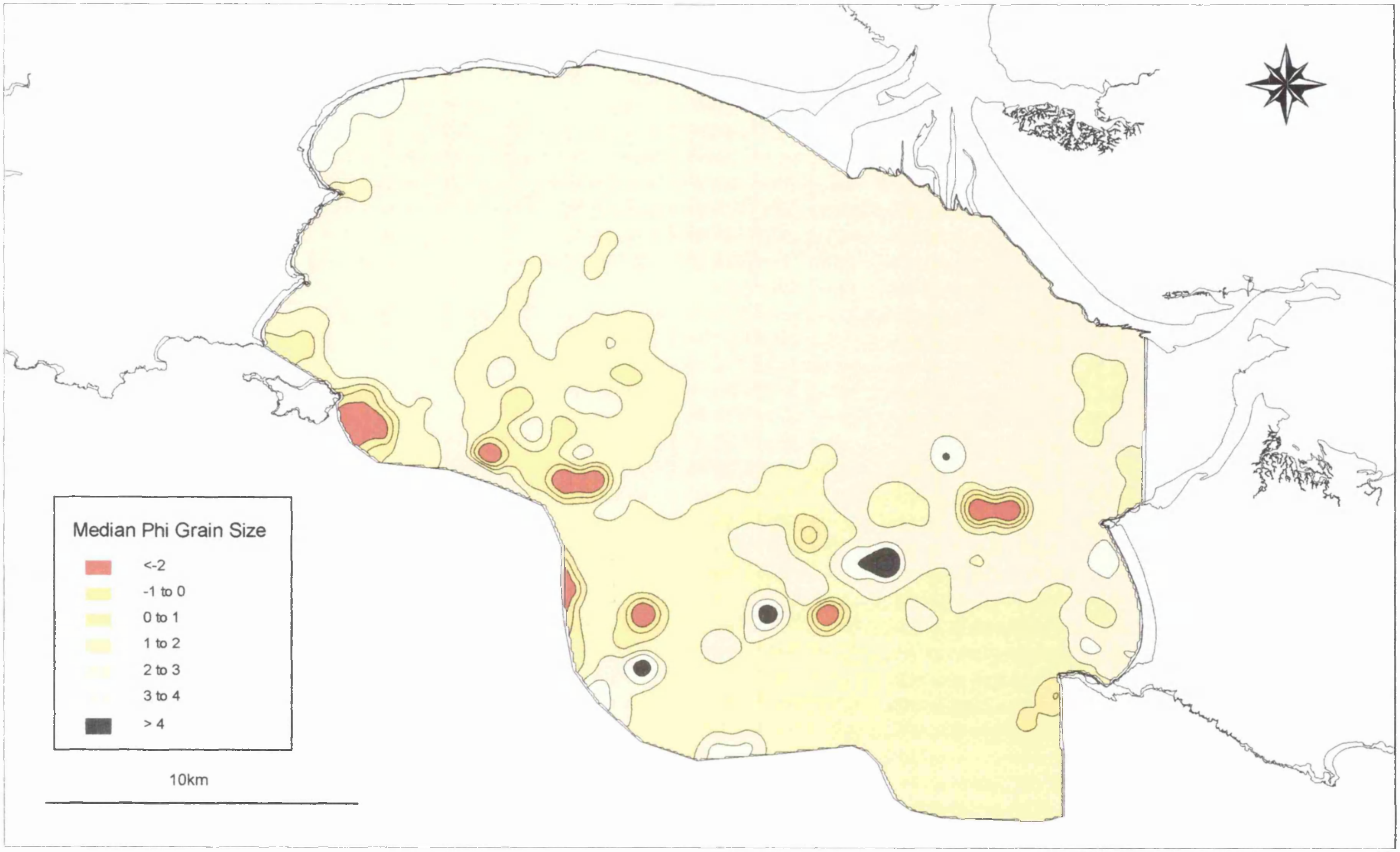


Figure 2.8 Carmarthen Bay Gravel Distribution Derived From Interpolated ABP Sediment Data

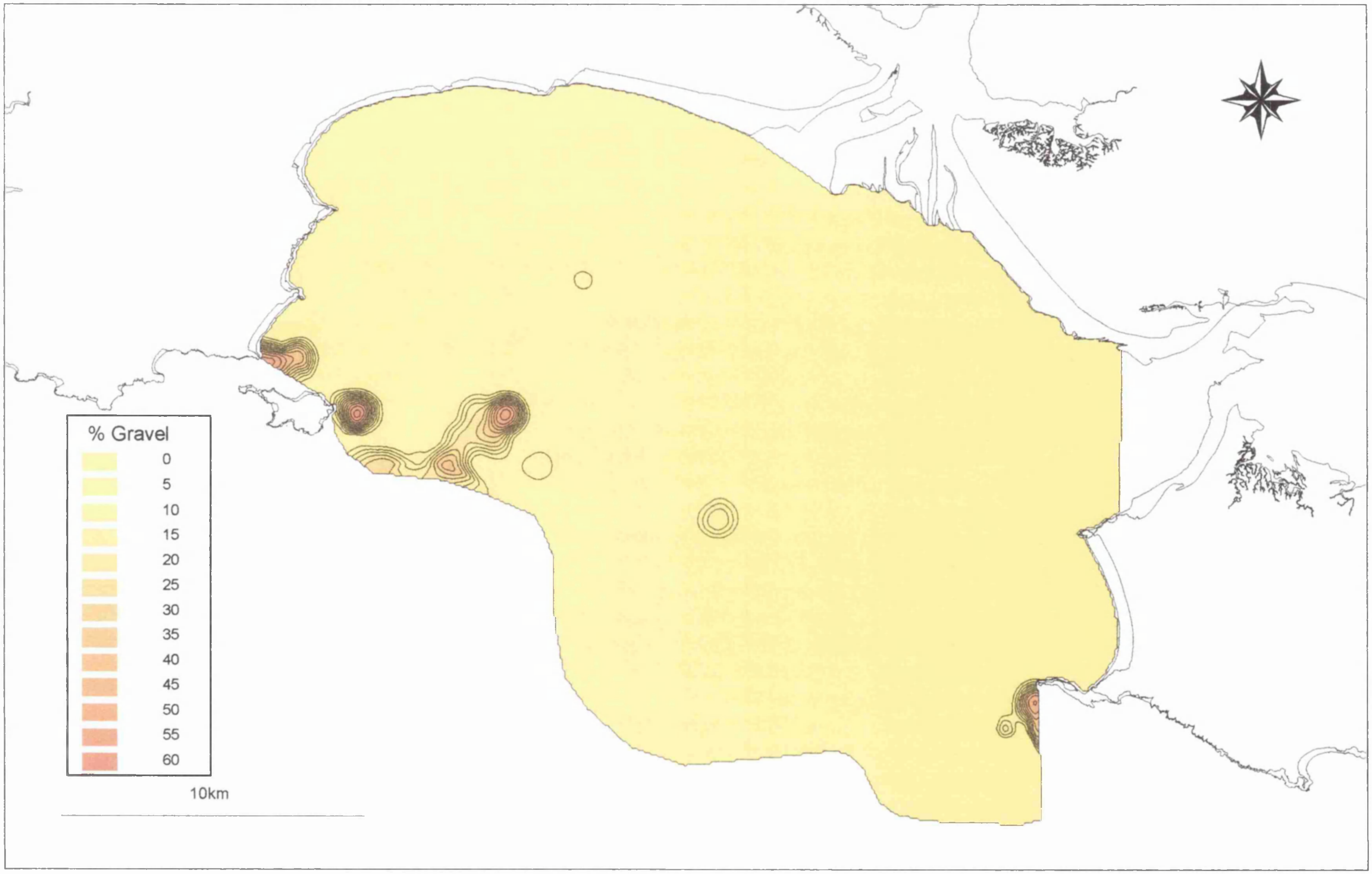


Figure 2.9 Carmarthen Bay Sand Distribution Derived From Interpolated ABP Sediment Data

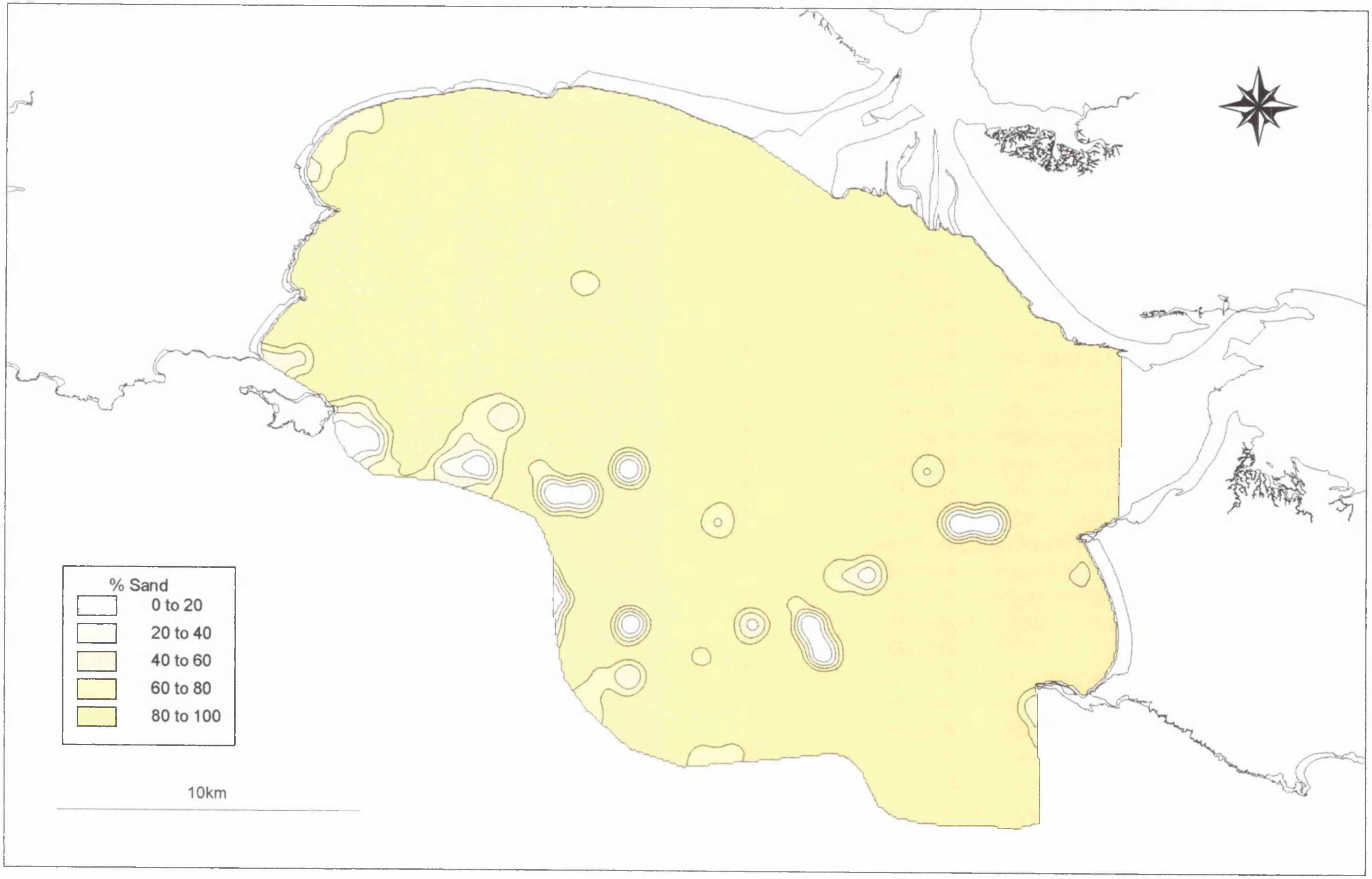
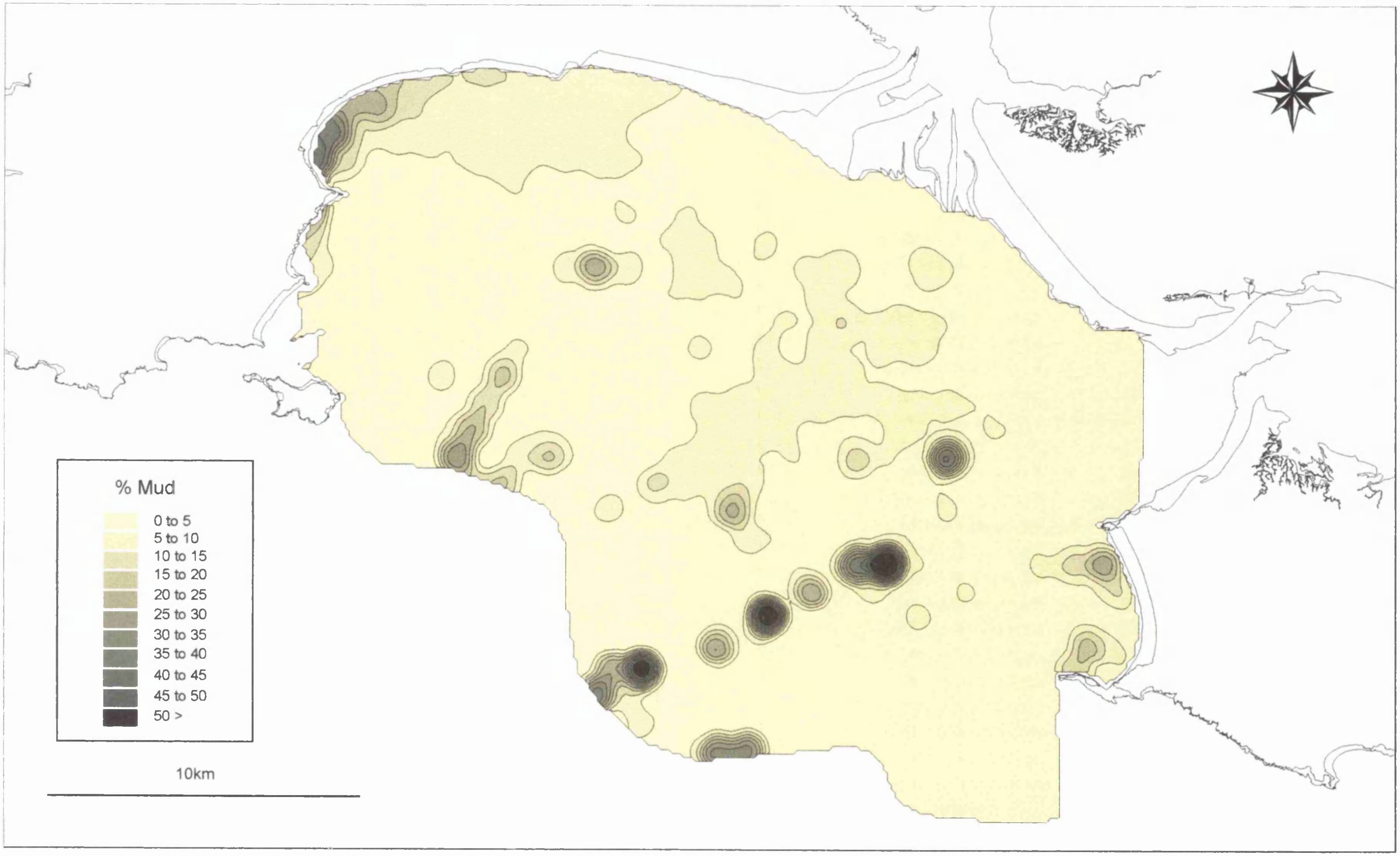


Figure 2.10 Carmarthen Bay Mud (Silt/Clay) Distributions Derived From Interpolated ABP Sediment Data



2. 3. 1. 2 Bathymetry

Depth data from the ABP sampling stations were corrected to chart datum (CD) for each sample date and time and plotted to provide an accurate bathymetry map of the bay (Figure 2.11). Depth data for each quantitative sample station were corrected to CD for use in the PCA and community analysis.

The seabed down to the 10 m isobath stretches from Worms Head in the east around to Caldey Island in the west, seemingly unaffected by the river channels of the Loughor and the Three River system at this scale of resolution. The westernmost part of the Helwick Bank lies on the edge of the survey area south of Worms Head, its steep sides and shallow summit are clearly apparent. To the immediate east of Caldey Island the seabed descends comparatively steeply into deeper water.

2. 3. 1. 3 Tidal Currents

Flood, ebb and tidal residual velocity (m^{-s}) data from the ABP model were interpolated and plotted as contour maps rather than the conventional vector type map in order to highlight broad areas of contrasting current regimes (Figures 2.12-14). Values for each quantitative station was taken from the interpolated grid files for use in the PCA and community analysis, Table 2.

Flood velocity is broadly seen to increase with depth with its lowest velocity off Saundersfoot Bay and highest at the periphery of the bay. Shoreline features such as headlands and river mouths are seen to enhance current flow along the stretch of coastline from Ragwen Point east to the edge of the bay. The northern half of the bay away from these near shore features is subject to flood velocities below 0.46 m^{-2}. Residual currents are negligible in the centre of the bay. Outside of these areas, at the mouths of the Loughor and Three River estuaries, an area off Tenby and in Rhossili Bay are all shown to be subject to some residual currents.

2. 3. 1. 4 Wave Heights and Period

Wave height (m) and period (s) data from the ABP model were interpolated and plotted in the form of contour maps (Figure 2.15 & 2.16). Values for each quantitative station were taken from the interpolated grid files for use in the PCA and community analysis, Table 2.

The interpolated map of wave heights shows the attenuation of wave height as they enter shallow water from the southwest. Changes in wave heights in the bay are seen to broadly reflect corresponding changes in the bathymetry, the area southwest of Rhossili is a good example. The area to the north of Caldey Island and west of the Three River estuary is seen to be protected from the prevailing south westerly swell; mean wave heights in this area are much reduced ranging between 0-1.5 m. Wave period is seen to respond to changes in bathymetry and shelter as the prevailing south westerly swell refracts around Caldey Island into the north of the bay.

Figure 2.11 Carmarthen Bay Bathymetry Derived From Interpolated ABP Bathymetry Data

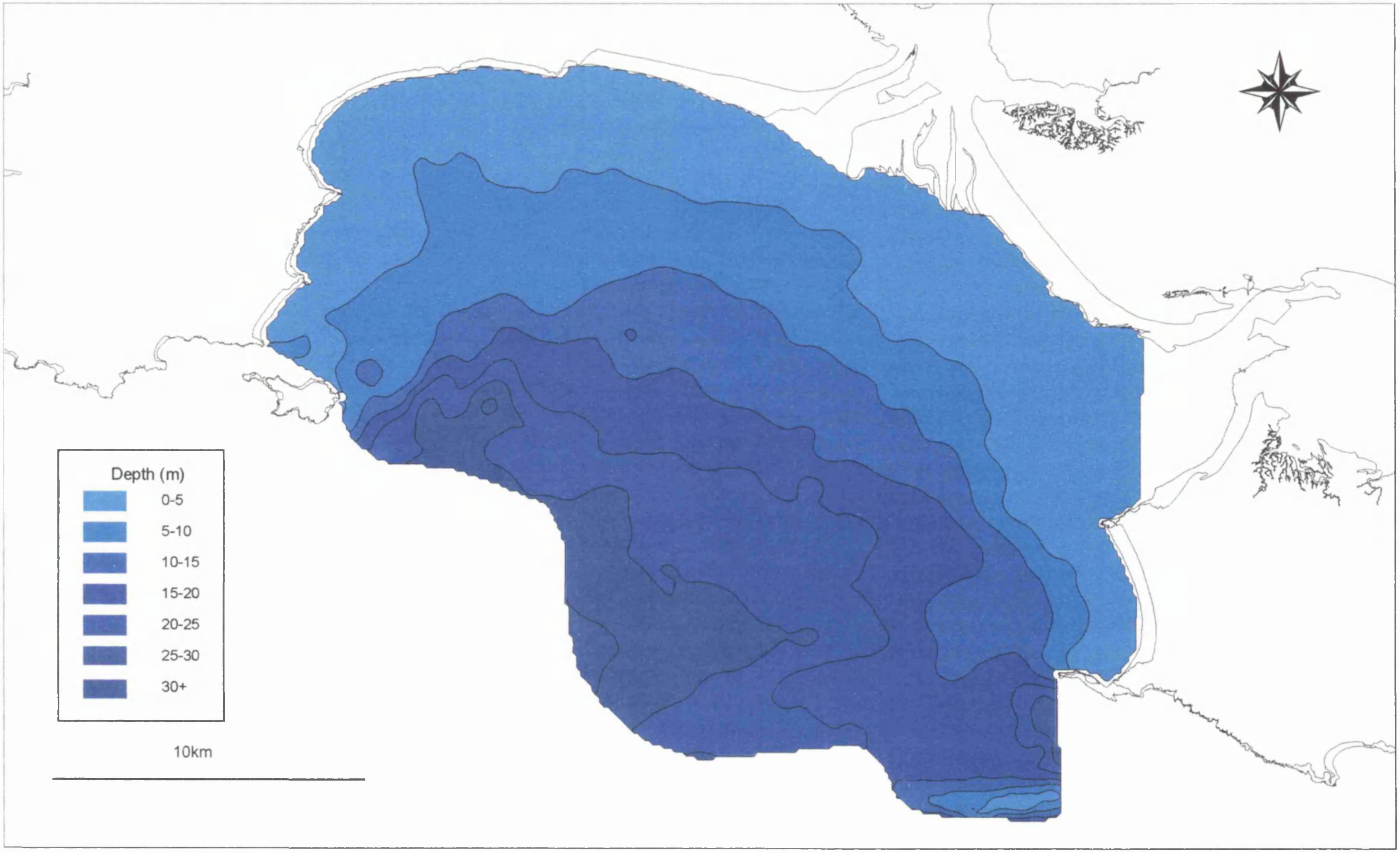


Figure 2.12 Carmarthen Bay Flood Velocity ($m\ s^{-1}$) Derived From Interpolated ABP Tidal Model Data

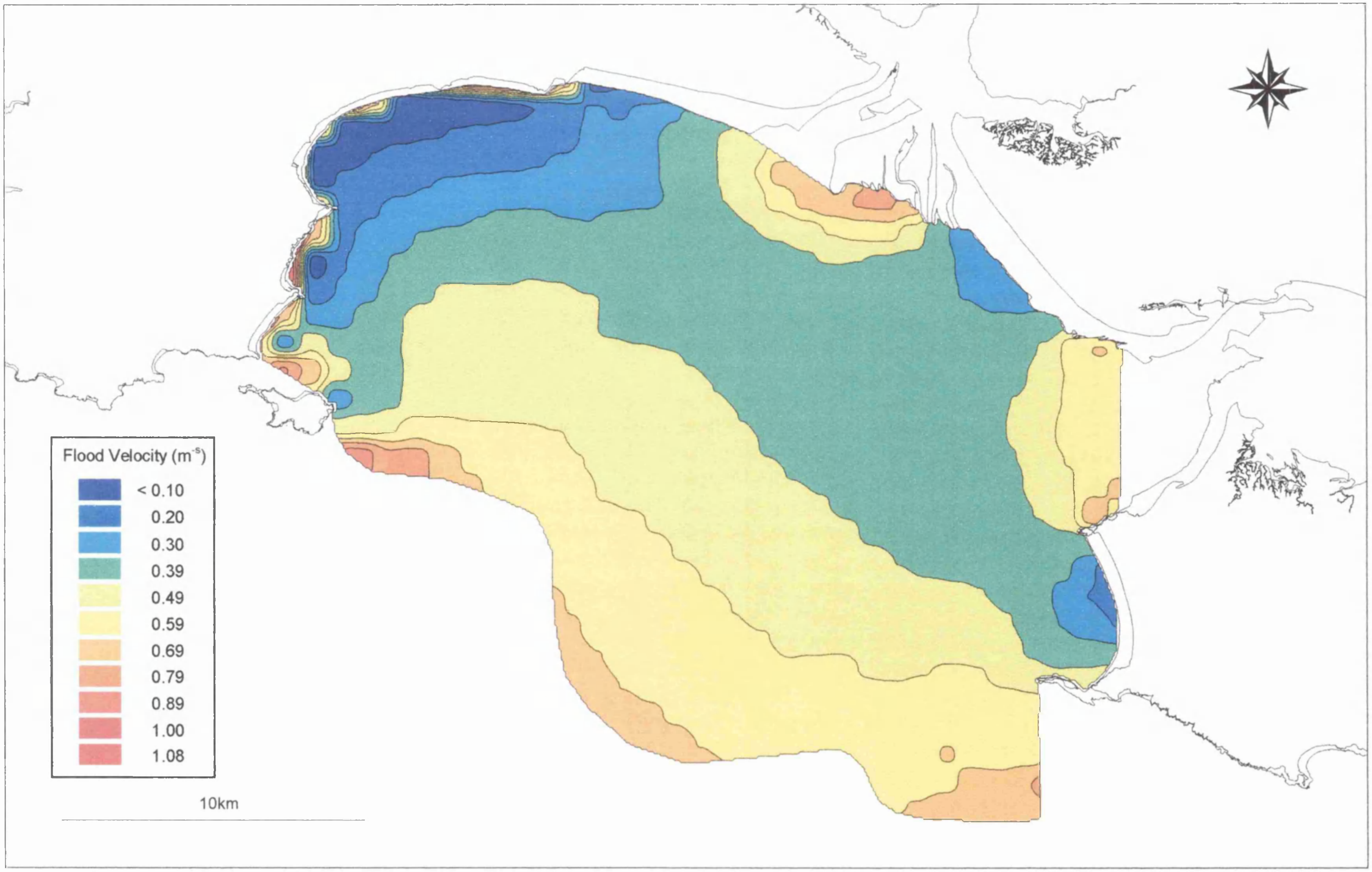


Figure 2.13 Carmarthen Bay Ebb Velocity (m s^{-1}) Derived From Interpolated ABP Tidal Model Data

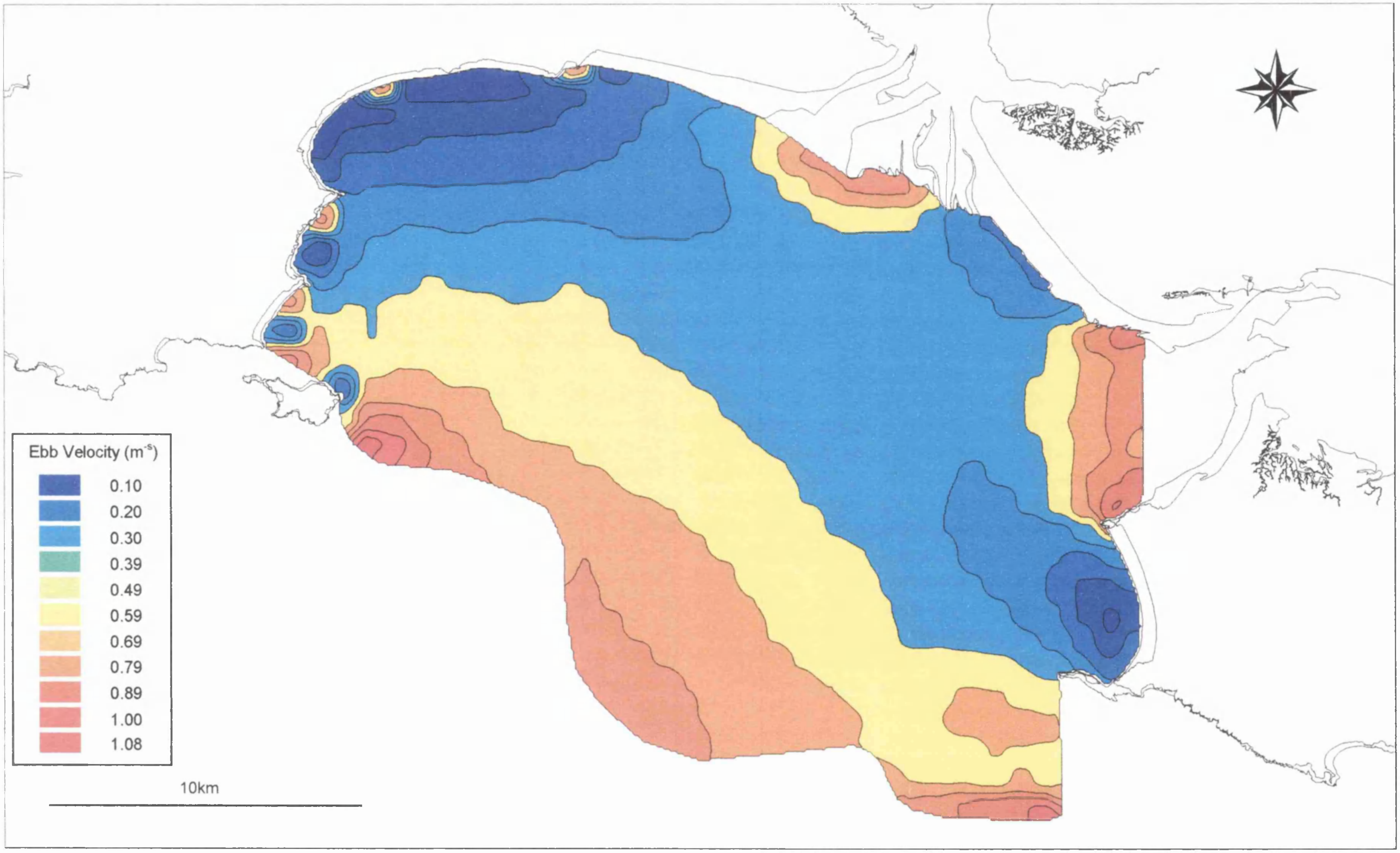


Figure 2.14 Carmarthen Bay Tidal Residual Velocity (m s^{-1}) Derived From Interpolated ABP Tidal Model Data

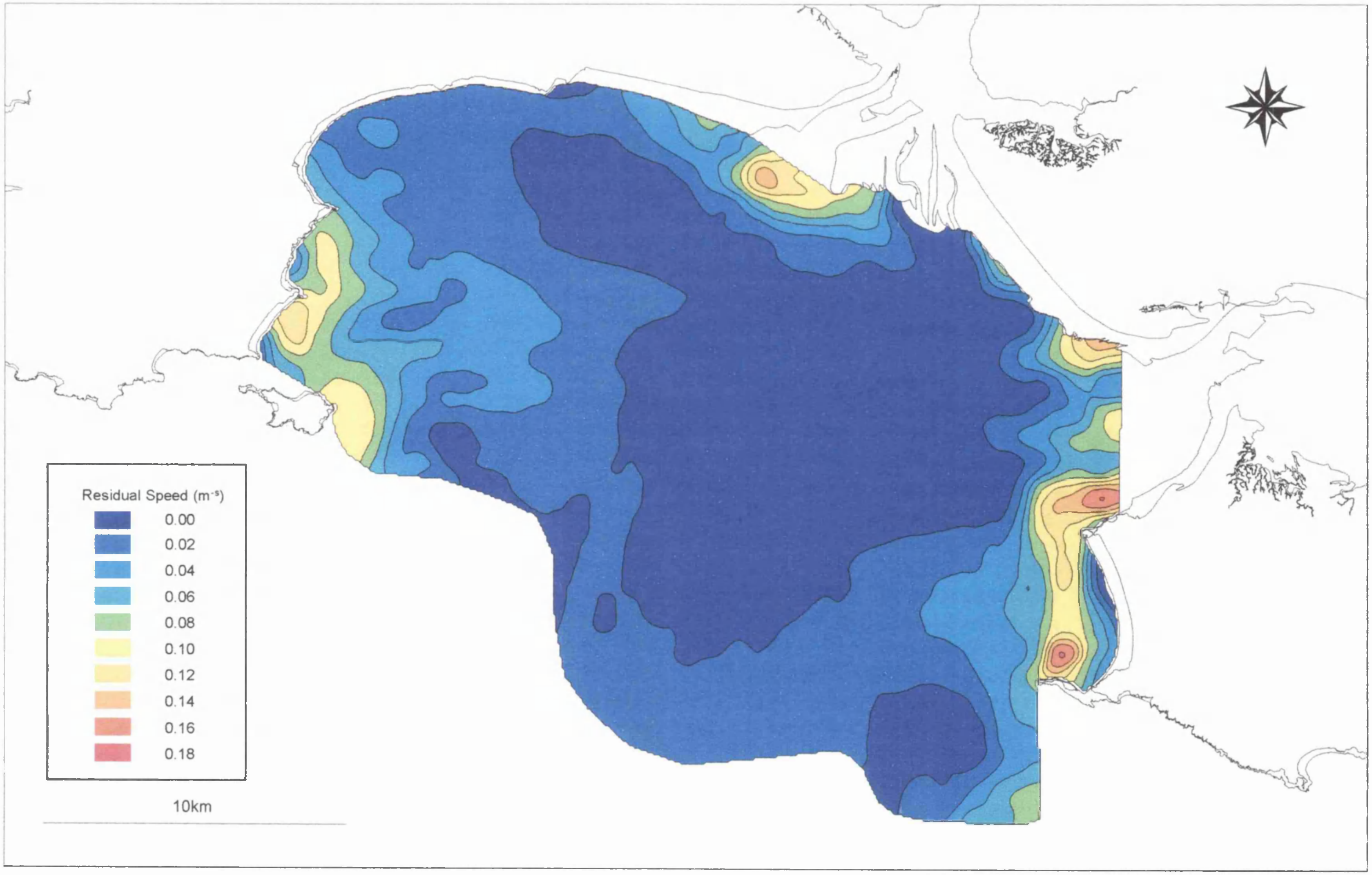


Figure 2.15 Carmarthen Bay Wave Height (m) Derived From Interpolated ABP Wave Climate Model Data

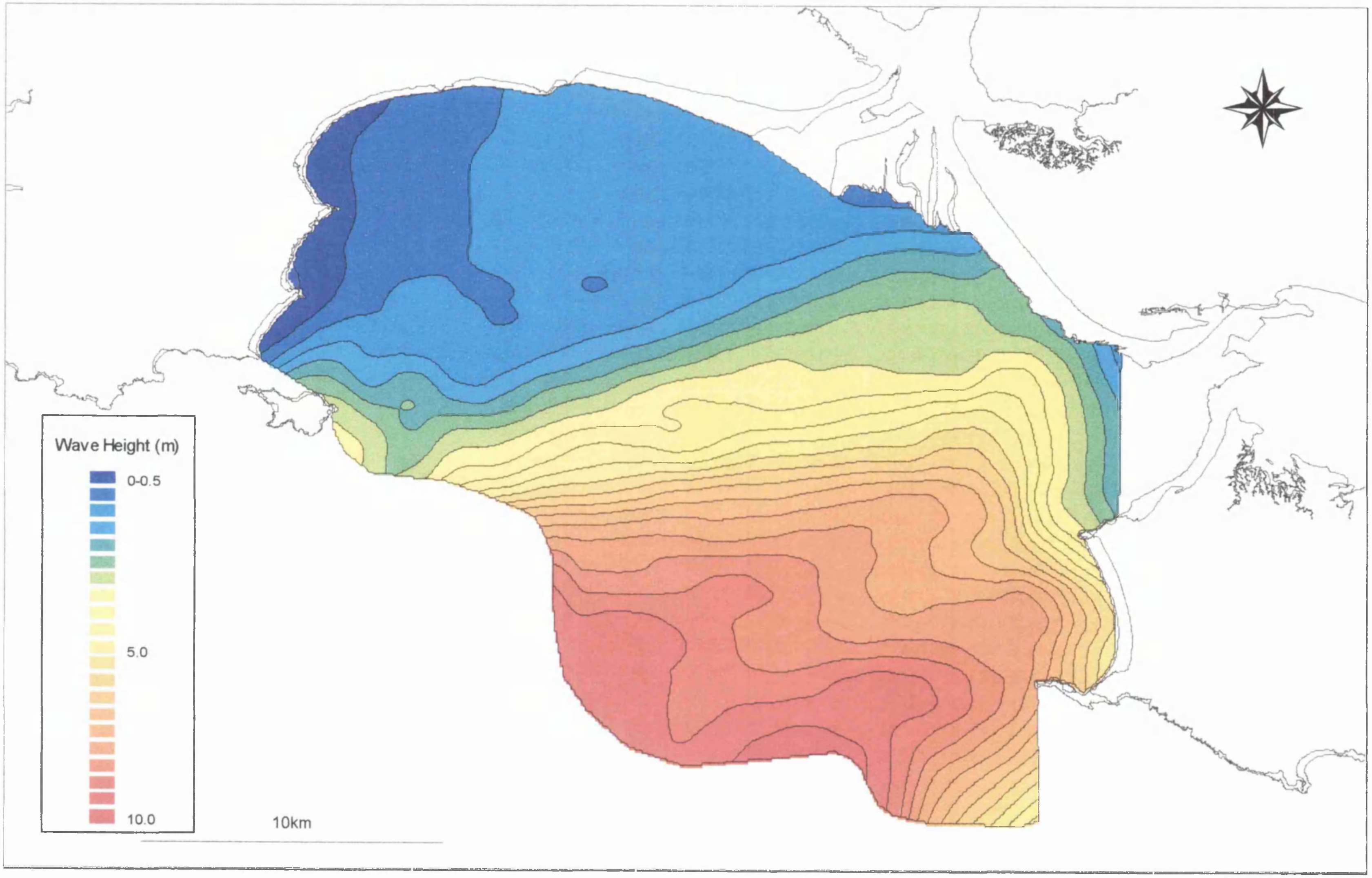


Figure 2.16 Carmarthen Bay Wave Period (s) Derived From Interpolated ABP Wave Climate Model Data

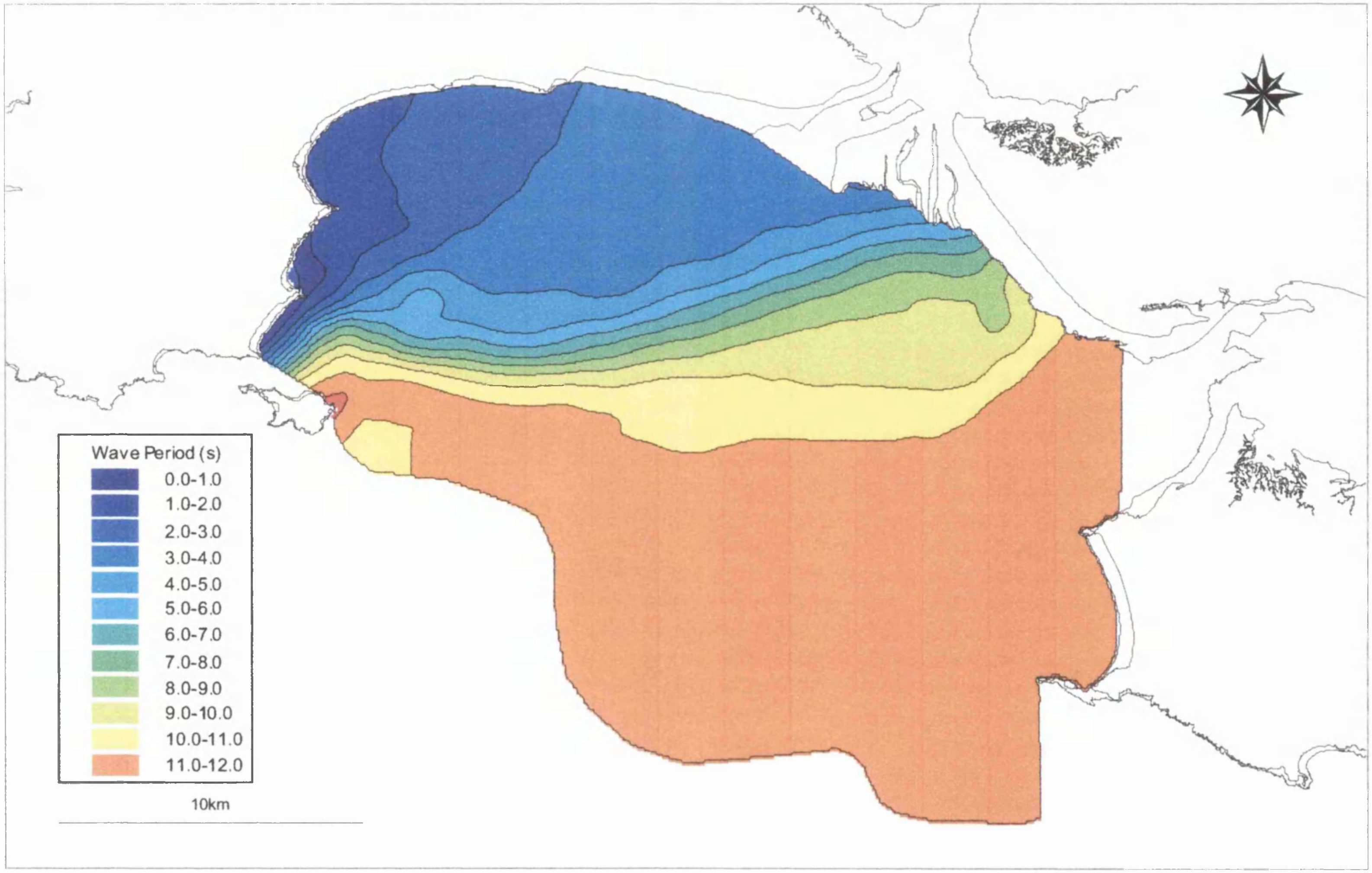


Table 2.2 Environmental Variables used in PCA and Community Analysis.

Station	**Depth (m)**	**% Gravel**	**% Sand**	**% Mud**	**Median Phi**	**% Organics**	**Flood (m s^{-1})**	**Residual (m s^{-1})**	**Wave Height (m)**	**Wave Period (s)**
21	19	0.31	99.67	0.02	1.63	0.66	0.62	0.02	8.70	11.60
23	19	0.61	99.20	0.19	1.90	0.46	0.41	0.07	8.00	11.60
25	0	0.06	99.90	0.03	2.61	0.93	0.52	0.05	4.00	11.60
26	4	0.15	99.52	0.33	2.82	0.89	0.39	0.01	4.10	10.40
27	4	2.56	97.26	0.17	2.74	1.18	0.38	0.02	2.60	8.10
28	7	1.32	98.10	0.58	2.66	0.91	0.39	0.01	2.90	8.70
31	8	0.06	99.56	0.38	2.81	0.85	0.39	0.01	3.50	9.50
34	11	0.56	98.96	0.48	2.74	0.90	0.39	0.01	5.90	11.10
36	23	1.48	98.35	0.17	2.20	1.09	0.49	0.04	7.80	11.50
40	18	0.19	99.77	0.04	1.63	0.75	0.59	0.02	9.60	11.60
41	15	3.09	96.49	0.41	2.62	1.29	0.42	0.00	4.10	10.40
42	15	7.86	91.63	0.50	2.40	1.40	0.47	0.00	4.80	11.00
43	17	0.07	99.92	0.01	2.15	1.21	0.44	0.06	2.50	11.00
44	4	15.78	84.03	0.18	2.38	0.76	0.39	0.07	1.30	7.30
45	6	0.34	99.18	0.48	2.45	1.70	0.28	0.04	0.80	2.30
48	3	0.40	98.85	0.75	2.50	1.35	0.14	0.03	1.00	2.60
51	1	0.12	97.26	2.62	2.30	1.67	0.04	0.04	0.70	2.00
54	7	0.48	99.09	0.43	2.40	1.28	0.41	0.03	1.10	3.70
55	8	2.30	97.38	0.32	2.60	1.17	0.39	0.01	1.10	3.70
56	9	2.92	96.08	1.00	2.68	1.34	0.40	0.01	1.40	4.50
57	10	1.17	98.34	0.49	2.74	0.52	0.41	0.01	3.50	9.50
58	15	4.19	95.32	0.49	2.50	1.03	0.45	0.01	2.20	8.10
59	14	2.41	97.50	0.09	2.00	0.74	0.50	0.04	1.40	6.10
60	13	0.32	99.22	0.46	2.50	0.73	0.52	0.05	1.30	6.20
64	5	0.20	99.44	0.37	2.80	1.37	0.26	0.01	1.20	3.10
84	20	0.58	99.37	0.06	1.60	0.27	0.57	0.04	3.90	11.10
87	26	0.72	99.25	0.03	1.50	0.84	0.61	0.02	8.60	11.40
88	26	0.05	99.74	0.21	1.55	0.75	0.66	0.02	9.50	11.50

2. 3. 1. 5 Principal Component Analysis (PCA)

Principal component analysis was carried out on the selected and transformed environmental variables and an ordination plotted, Fig 12a. Three components (PC 1-3) had eigenvalues greater than one and explained close to 80% of the total variance between quantitative stations.

Table 2.3 Principal Component Analysis Eigenvalues

PC	**Eigenvalues**	**%Variation**	**Cum.%Variation**
1	4.74	47.4	47.4
2	1.69	16.9	64.3
3	1.29	12.9	77.2
4	0.76	7.6	84.9
5	0.49	4.9	89.7

Major contributors to PC1 were Median Phi, log$_{10}$ Mud, % Total Organics (all +ve) and Flood Velocity, Wave Height, Wave Period (all –ve). Log$_{10}$ Gravel (+ve) and log$_{10}$ Sand (-ve) contribute chiefly to PC2. Finally, PC3 contrasts Residuals (-ve) with a combination of log$_{10}$ Mud, Wave Height and Median Phi (all +ve) although the contributions of these variables are relatively low.

Table 2.4 Principal Component Analysis Contributors

Variable	**PC1**	**PC2**	**PC3**	**PC4**	**PC5**
Depth	**-0.384**	0.113	0.144	**-0.446**	-0.170
Log$_{10}$ Gravel	0.101	**0.700**	0.109	-0.100	0.007
Log$_{10}$ Sand	-0.127	**-0.665**	0.195	0.002	-0.143
Log$_{10}$ Mud	**0.352**	0.056	**0.286**	-0.145	**-0.670**
Median Phi	**0.359**	-0.001	**0.218**	**0.568**	0.130
% Organics	**0.327**	-0.134	0.087	**-0.524**	**0.640**
Flood Velocity	**-0.400**	0.148	0.102	0.123	0.141
Residuals	-0.088	-0.007	**-0.827**	0.013	-0.142
Wave Height	**-0.393**	-0.027	**0.257**	-0.128	-0.027
Wave Period	**-0.380**	0.105	0.183	**0.375**	0.187

A further series of 2D PCA ordinations were produced with environmental variables superimposed to illustrate their contributions to PC1 and PC2 (Figure 2.17 b-k).

Figure 2.17 Principle Component Analysis Ordinations with Environmental Factors Overlaid. a. Quantitative Stations. b. Depth. c. % Gravel. d. % Sand. e. % Mud. f. Median Phi. g. % Organics. h. Flood Velocity. i. Residual Velocity. j. Wave Height. K. Wave Period.

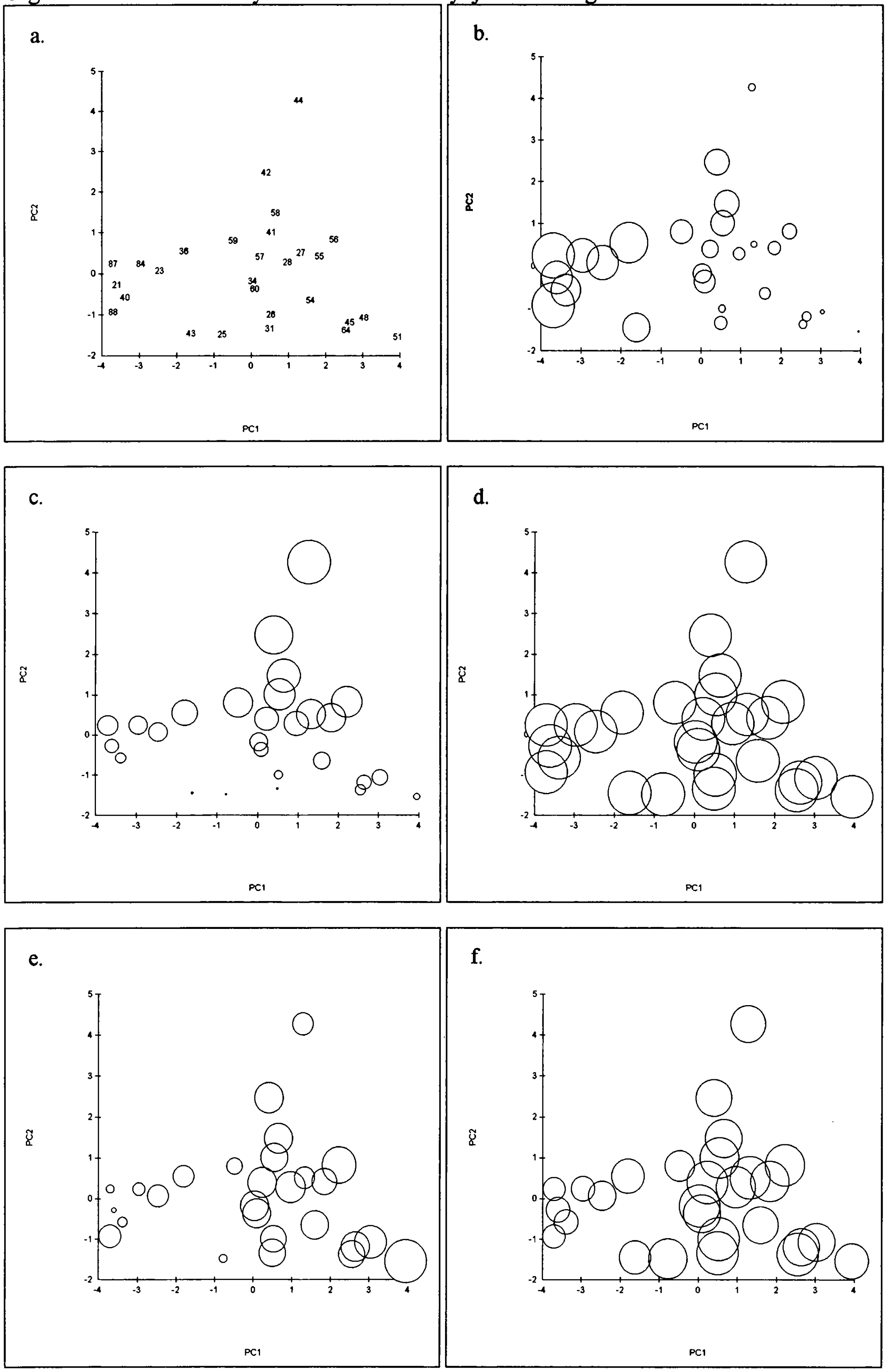
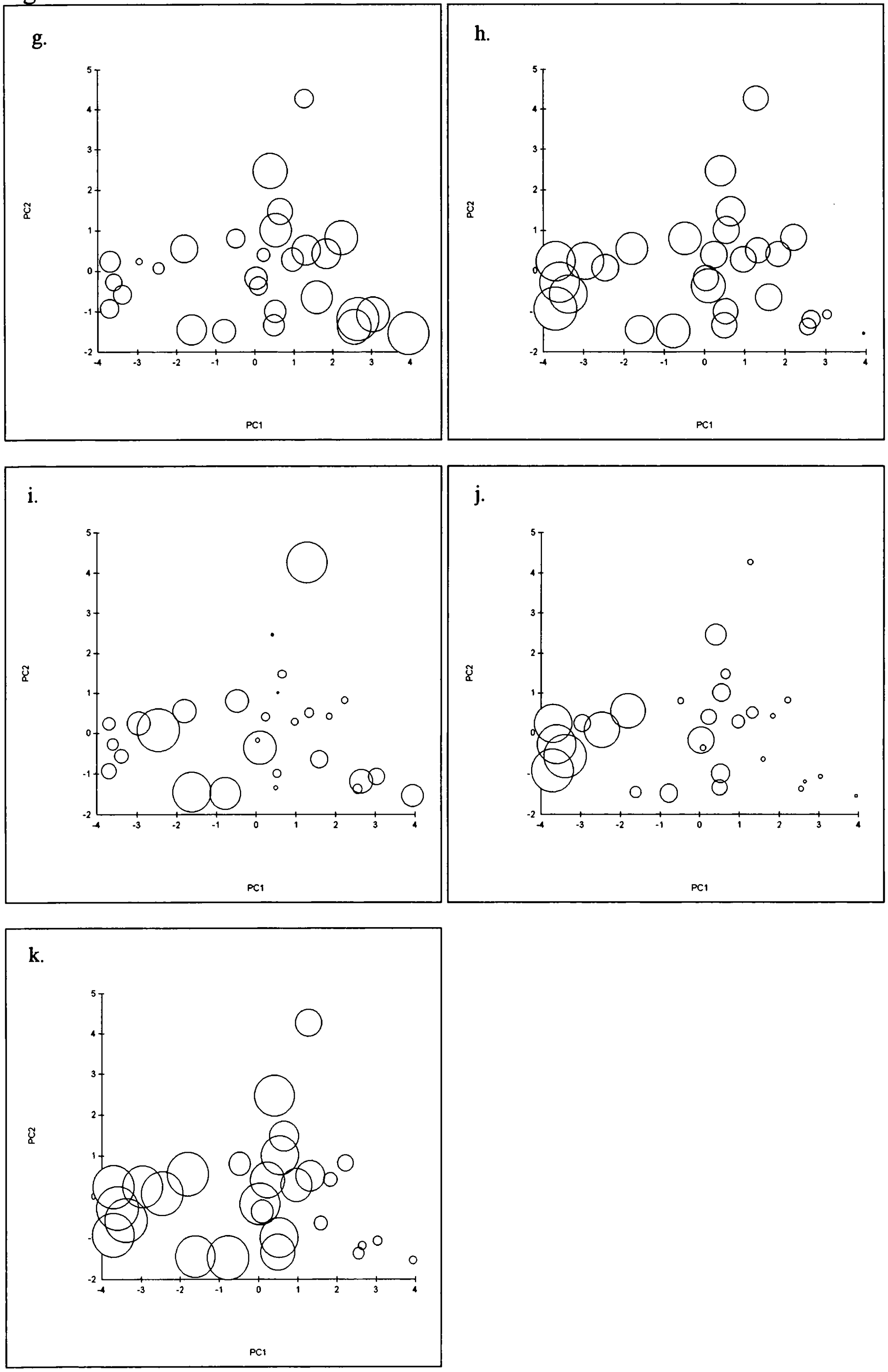


Figure 2.17 Continued



2. 3. 2 Benthic Macrofauna

During the course of the macrofaunal survey a total of 62 grab stations was worked. Twenty nine quantitative stations were sieved to 0.5 mm and 33 qualitative stations to 1 mm. Full species x station macrofauna matrix is presented in Appendix 2.3. Eight qualitative beam trawls were also taken in order to sample the epibenthos.

Table 2.4 Grab Sampling Effort

Station Type	Stations	Samples	Sediment Volume (l)
Quantitative	29	58	290
Qualitative	33	33	165
Totals	62	91	355

Quantitative Stations

A total of 26,206 individuals from 150 taxa was recorded at the quantitative stations. The fauna was dominated by the Polychaeta both in abundance and richness accounting for 63% of the individuals collected and 39% of the taxa identified. The Mollusca were the second most abundant group and the Crustacea the second richest (Table 2.5).

Qualitative Stations

A total of 6,944 individuals from 116 taxa was recorded at the qualitative stations. Again, the fauna was dominated by the Polychaeta both in abundance and richness accounting for 78.5% of the individuals collected and 54% of the taxa identified. The Mollusca were the second richest and abundant group. Crustacea abundance and richness were much reduced in the qualitative samples probably due to the small sized animals passing through the larger 1mm sieve.

Table 2.5 Totals of Major Group Abundance and Richness in Whole Survey

	Quantitative Stations		**Qualitative Stations**	
	N	**S**	**N**	**S**
Polychaeta	15758	52	5225	59
	(63.4%)	*(39.4%)*	*(78.3%)*	*(54.1%)*
Crustacea: Cumacea	1525	7	17	4
	(6.1%)	*(5.3%)*	*(0.3%)*	*(3.7%)*
Crustacea: Amphipoda	1271	21	157	8
	(5.1%)	*(15.9%)*	*(2.4%)*	*(7.3%)*
Crustacea: Others	38	11	32	6
	(0.2%)	*(8.3%)*	(0.5%)	(5.5%)
Mollusca: Bivalves	5742	15	1025	13
	(23.1%)	*(11.4%)*	*(15.4%)*	*(11.9%)*
Mollusca: Others	170	9	28	7
	(0.7%)	*(6.8%)*	*(0.4%)*	*(6.4%)*
Echinodermata	105	5	71	6
	(0.4%)	*(3.8%)*	*(1.1%)*	*(5.5%)*
Others	259	12	115	6
	(1.0%)	*(9.1%)*	*(1.7%)*	*(5.5%)*
Total	**24868**	**132 (+17)**	**6670**	**109 (+6)**

2. 3. 2. 1 Polychaeta

The polychaetes were the numerically dominant component of the Carmarthen Bay fauna composed of 52 species (39.4% of the recorded taxa). The polychaetes were the numerically dominant class at all but 4 of the 29 quantitative stations. Figure 2.18 shows highest numbers of polychaetes occurred at a group of stations in the centre of the bay off Pembrey Sands between the mouths of the Three Rivers and Loughor estuaries; Station 41 (5840m^{-2}), Station 57 (5715m^{-2}) and Station 31 (5340m^{-2}). Polychaetes occurred in low abundance at the southernmost stations in the sample area and at Station 25 at the mouth of the Loughor estuary.

Of the 15,758 individual polychaetes recorded, 6749 were accounted for by the Spionid *Spiophanes bombyx* (Claparede) making it both the most abundant polychaete and taxon overall. *Spiophanes bombyx* was the most abundant taxon at 14 out of the 29 quantitative stations, highest numbers were recorded at Station 41 (3960m^{-2}), Station 57 (3545m^{-2}) and Station 36 (2760m^{-2}) in the centre off the bay in an area off the mouths of the Loughor and the Three River estuary (Figure 2.19). Abundance of *S. bombyx* at the stations in an area of the bay falling to the north of a line between Caldey Island and Cefn Sidan Sands range between 880m^{-2} at Station 59 and 2160m^{-2} at Station 56. *Spiophanes bombyx* abundance was lowest at the deeper, southern stations and at the shallow, inshore stations in the east of the bay at the mouth of the Loughor Estuary.

The second most abundant polychaete group was the genus *Magelona* (F Müller), 3810 individuals were recorded in the quantitative samples. Owing to large numbers of small individuals and time constraints, it was impractical to quantify this group to species level. The four species recorded were *M. alleni* (Wilson), *M. filiformis* (Wilson), *M. mirabilis* (Johnston) and *M. johnstoni* (Fiege, Licher & Mackie).

Magelonids were the numerically dominant taxon at 4 of the 29 stations; Station 26 (1100m^{-2}), Station 27 (585m^{-2}), Station 28 (2780m^{-2}) and Station 64 (1140m^{-2}). The most abundant sites for this taxon were Station 28 (2780m^{-2}), Station 57 (1265 m^{-2}) and Station 34 (1250m^{-2}) situated off Cefn Sidan Sands between the mouths of the Loughor and the Three River estuary (Figure 2.20). Two further Magelonid dominated stations were situated in the north of the bay; Station 51 off Amroth and Station 64 off Ragwen Point. Magelonid species were recorded in relative low numbers or were absent at stations in the south of the bay.

The third most abundant polychaete group was the Spionid genus *Spio* (Fabricius), the recorded species complex is made up of two unidentified species (A.S.Y. Mackie pers. comm. 2002). *Spio* species were the numerically dominant taxa at Station 23 Rhossili Bay with 365m^{-2}. *Spio* species were most abundant at stations 34 (1030m^{-2}), 60 (730m^{-2}) and 31 (695m^{-2}). Stations 31 and 34 are situated off Pembrey Sands between the mouths of the Loughor and the Three River estuary, Station 60 is situated on the opposite side of the bay north of Caldey Island and east of The Yowan rocks (Figure 2.21). *Spio* species were found in relatively low abundance at the southernmost stations being absent from Station 41 and Station 87 and distributed at higher numbers across the bay inshore of these stations.

Nephtys juveniles were conspicuous components of the polychaete fauna at the majority of stations and were the numerically dominant taxon at Station 25 (159m^{-2}) at the mouth of the Loughor. *Nephtys* juveniles occurred in highest numbers at the inshore stations and were reduced in number in the centre and south of the bay (Figure 2.22). The highest abundance, 240m^{-2}, was recorded at stations 44 and 64. Adult *Nephtys* species, *Nephtys assimilis* (Oersted), *Nephtys cirrosa* (Ehlers) and *N. hombergii* (Savigny), were recorded at stations throughout the bay.

Nephtys cirrosa was the numerically dominant taxon at Station 21 south-west of Worms Head with a recorded abundance of 150m^{-2}. In general, the highest numbers of adult *Nephtys* species were recorded at the southern and easternmost stations, the highest abundance recorded off Rhossili Bay at Station 36 (225m^{-2}) (Figure 2.23).

Lanice conchilega was recorded in relative low numbers across the bay but was the numerically dominant taxon at Station 34 off Pembrey Sands at the mouth of the Loughor estuary with an abundance of 1435m^{-2}, a large proportion of these being small individuals (Figure 2.24). A scaled density of 5350m^{-2} was recorded at the qualitative station 33 also off Pembrey Sands. The second highest abundance of *L. conchilega* was recorded at Station 36 off Rhossili Bay.

Figure 2.18 Polychaete Distribution and Abundance (m^{-2})

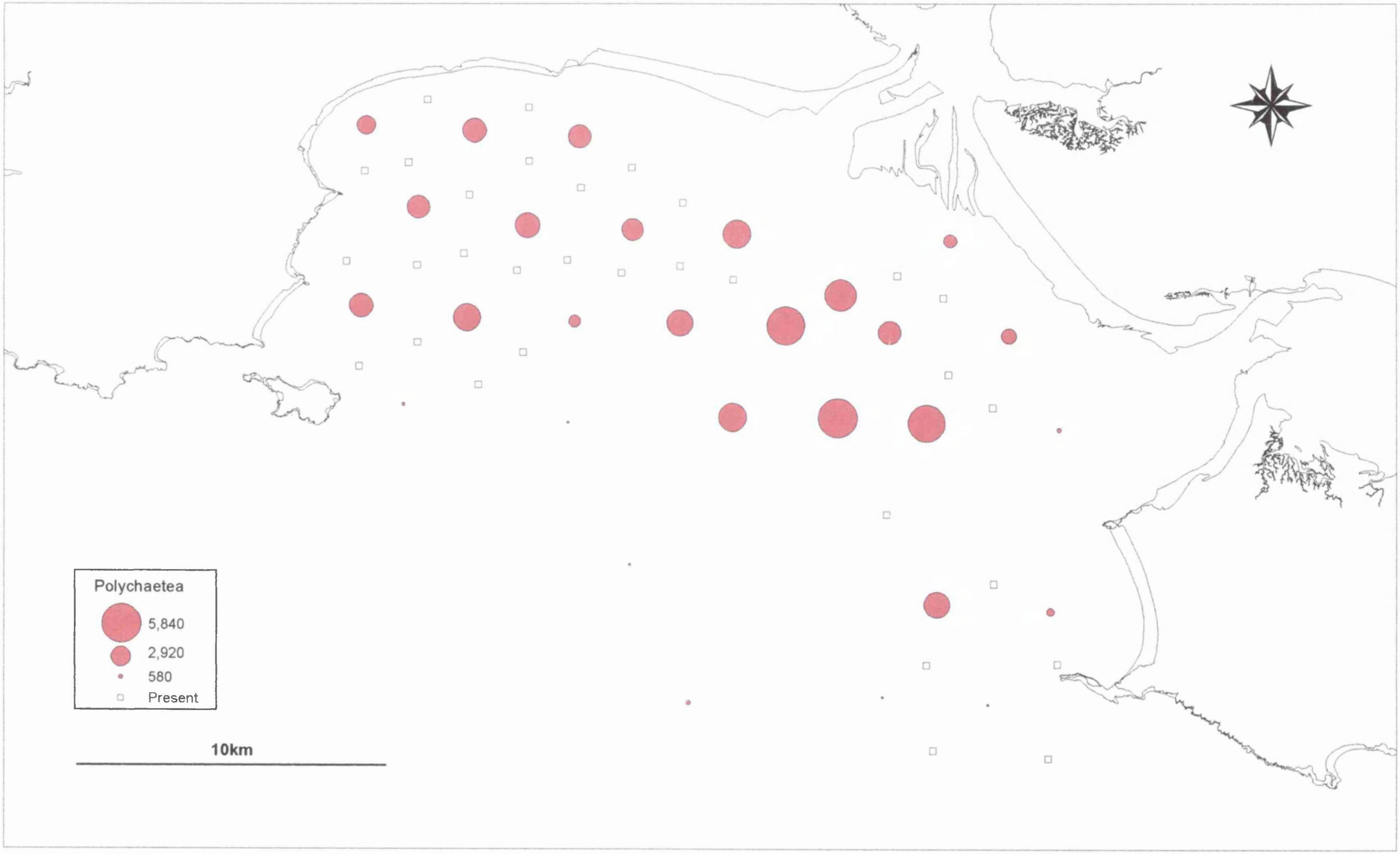


Figure 2.19 *Spiophanes bombyx* Distribution and Abundance (m^{-2})

Figure 2.20 *Magelona* spp. Distribution and Abundance (m^{-2})

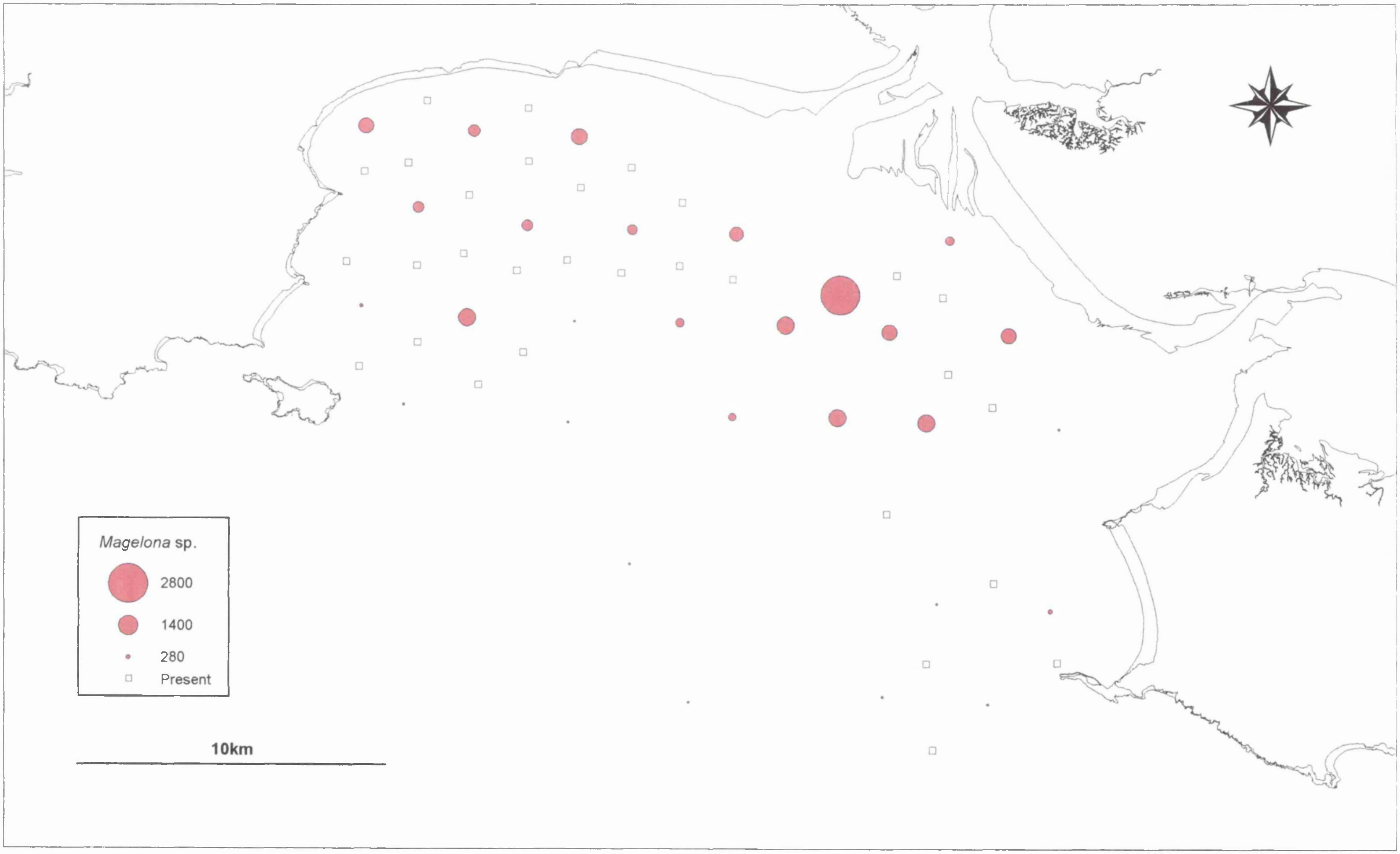


Figure 2.21 *Spio* spp. Distribution and Abundance (m^{-2})

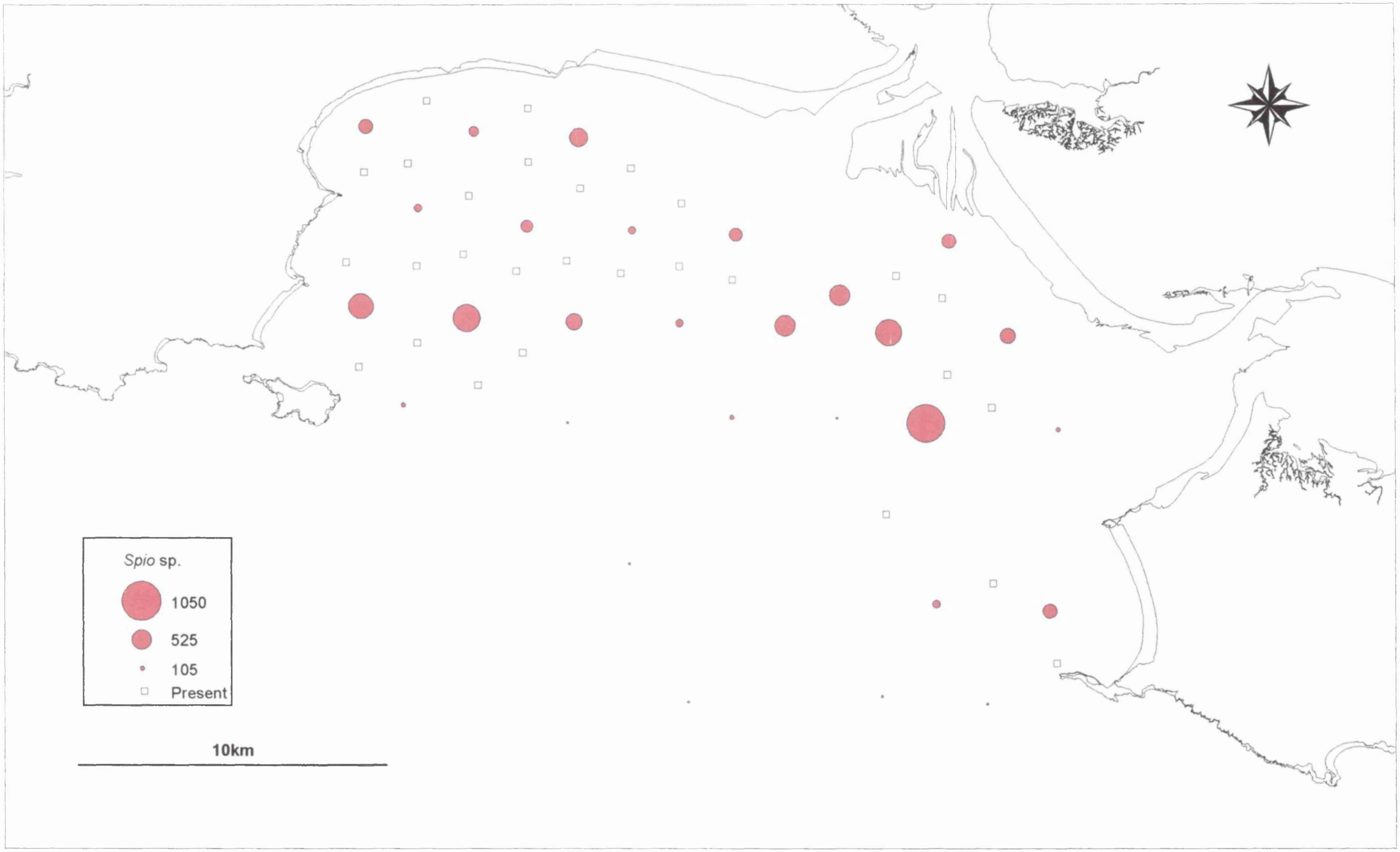


Figure 2.22 *Nephtys* Juveniles Distribution and Abundance (m^{-2})

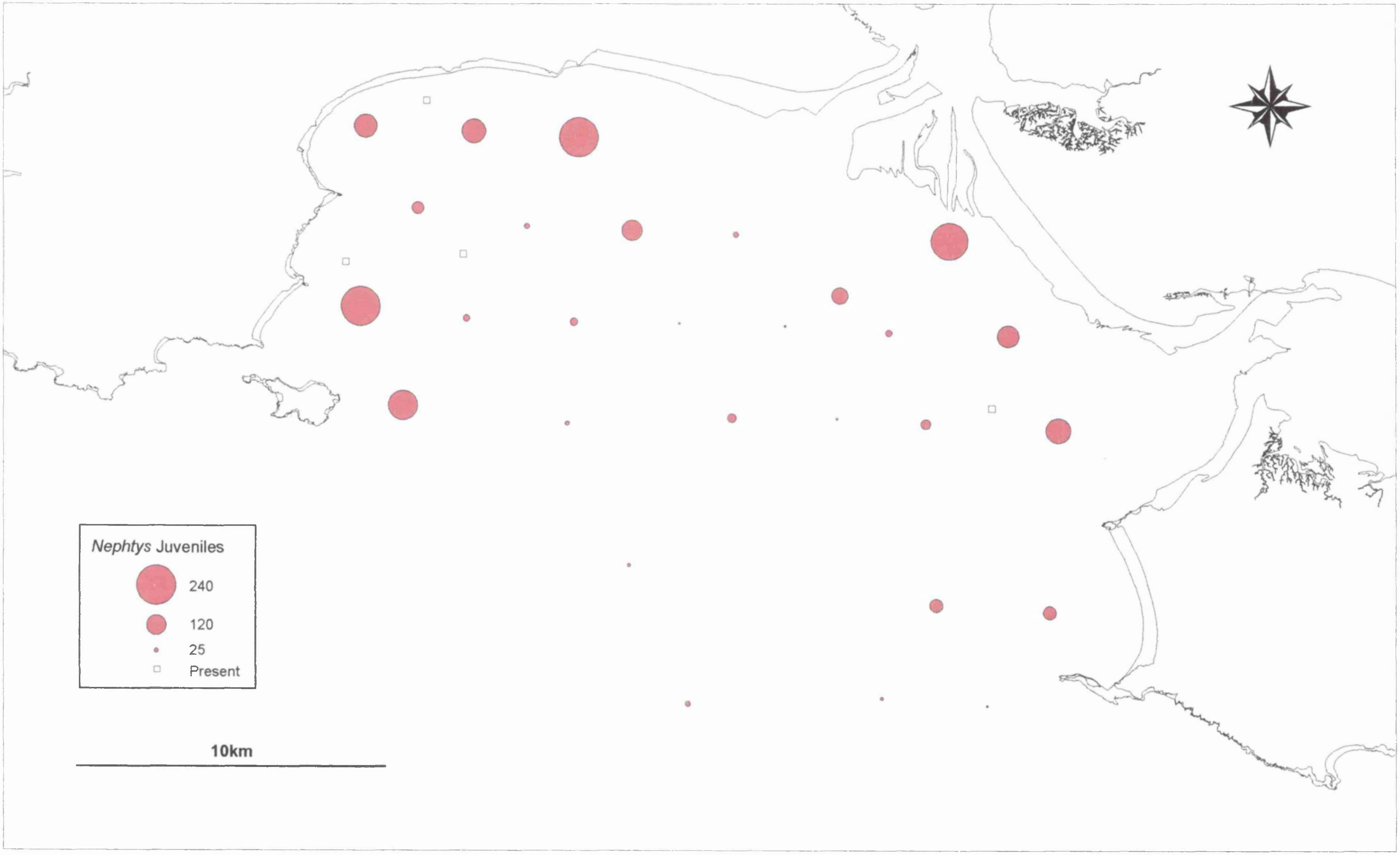


Figure 2.23 Adult *Nephtys* spp. Distribution and Abundance (m^{-2})

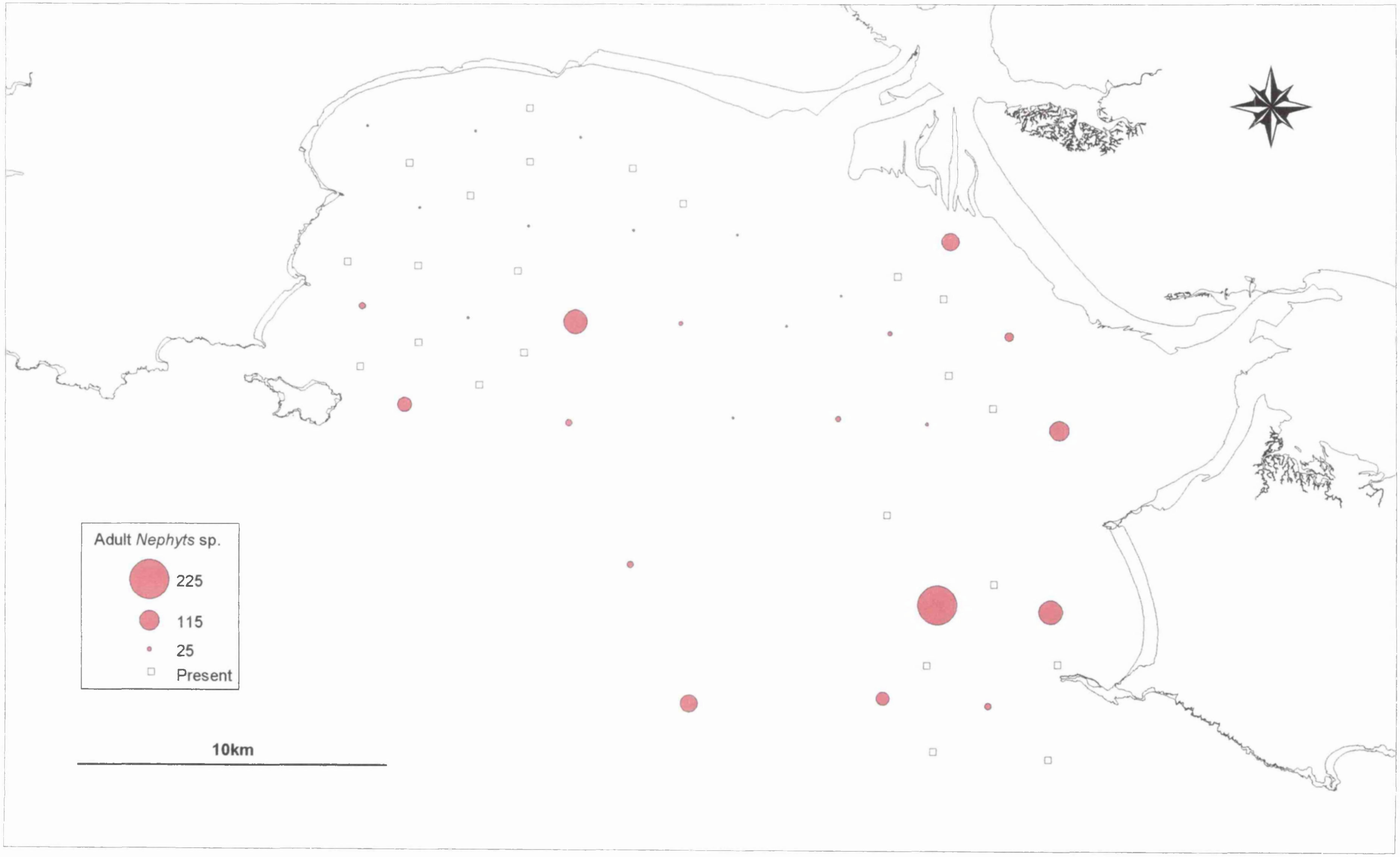
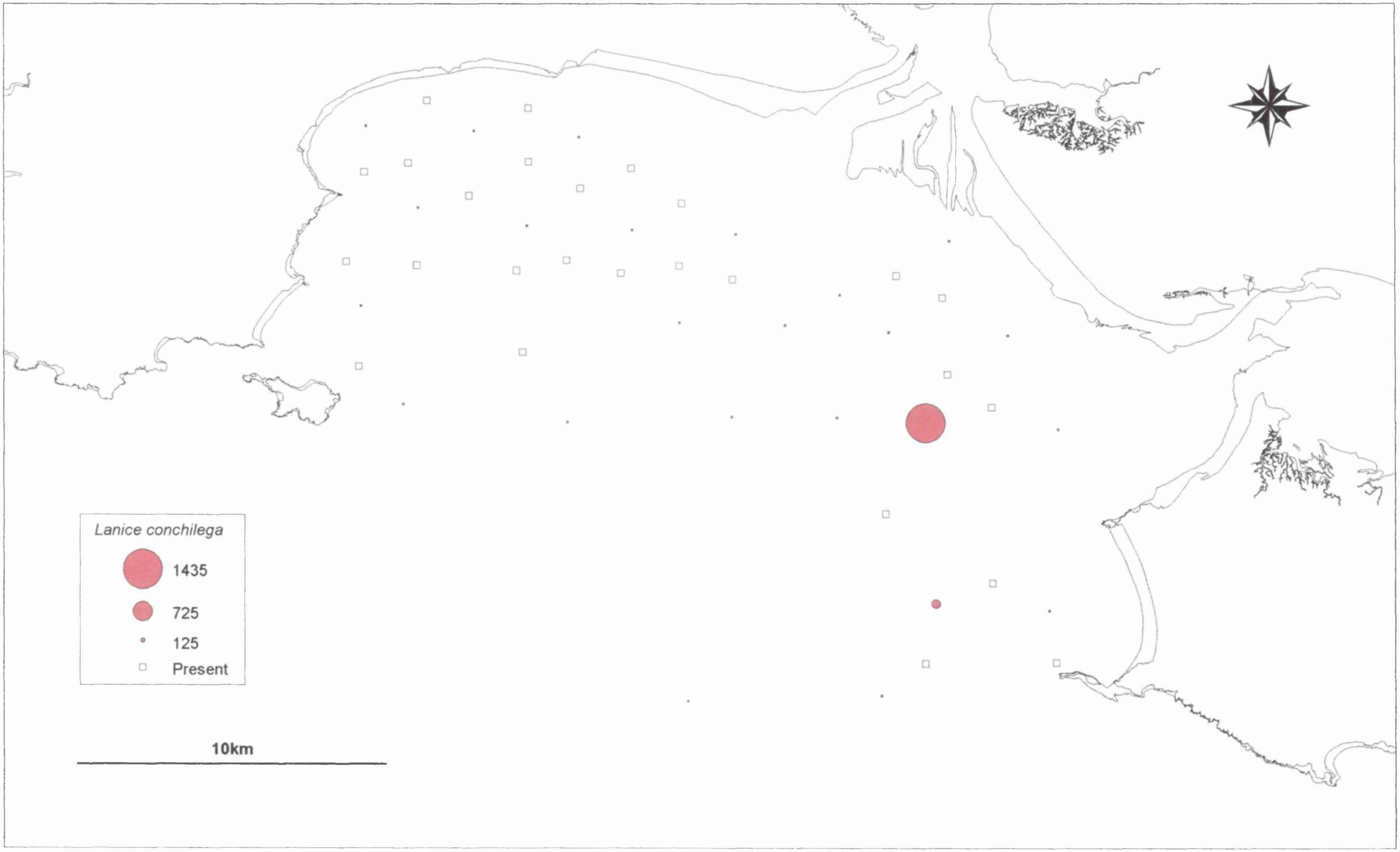


Figure 2.24 *Lanice conchilega* Distribution and Abundance (m^{-2})



2. 3. 2. 2 Crustacea

A total of 1854 individual crustaceans was recorded, these provided 11.4% of the survey total. Thirty nine crustacean taxa were identified, 29.5% of the total taxa recorded in the survey. The Cumacea and the Amphipoda were the most conspicuous of the crustacean groups, the remainder comprised primarily of larger, more solitary individuals. Of these only the burrowing crab *Corystes cassivelaunus* could be considered a conspicuous component of the fauna (Figure 2.25). Excluded from these totals were the ostracods and benthic copepods, these were considered meiofauna and sampled only qualitatively. Crab larvae were excluded for the same reason.

2. 3. 2. 3 Cumacea

The Cumacea were the most numerous crustacean group with 1525 individuals; 6.1% of the survey total. The cumacean fauna was made up of 7 species. By far the most numerous species was *Pseudocuma longicornis* (Bate) with 1407 individuals (92% of the total cumaceans recorded). Figure 2.26 shows that the distribution of the Cumacea in Carmarthen Bay, is virtually indistinguishable from that of *P. longicornis* (Figure 2.27). *Pseudocuma longicornis* was the numerically dominant taxon at 4 stations in Carmarthen Bay; Station 40 (125m^{-2}), Station 43 (130m^{-2}), Station 84 (625m^{-2}) and Station 87 (515m^{-2}). Highest numbers were recorded at Station 84 (625m^{-2}), 28 (555m^{-2}) and 64 (535). Figure 2.27 shows a lack of a coherent general distribution pattern for *P. longicornis* in the bay.

The cumacean species *Iphinoe trispinosa* (Goodsir) was present at a number of stations although in relatively low numbers (Figure 2.28). The highest number of *I. trispinosa*, 190m^{-2}, occurred at Station 51 in Saundersfoot Bay.

Figure 2.25 *Corystes cassivelaunus* Distribution and Abundance (m^{-2})

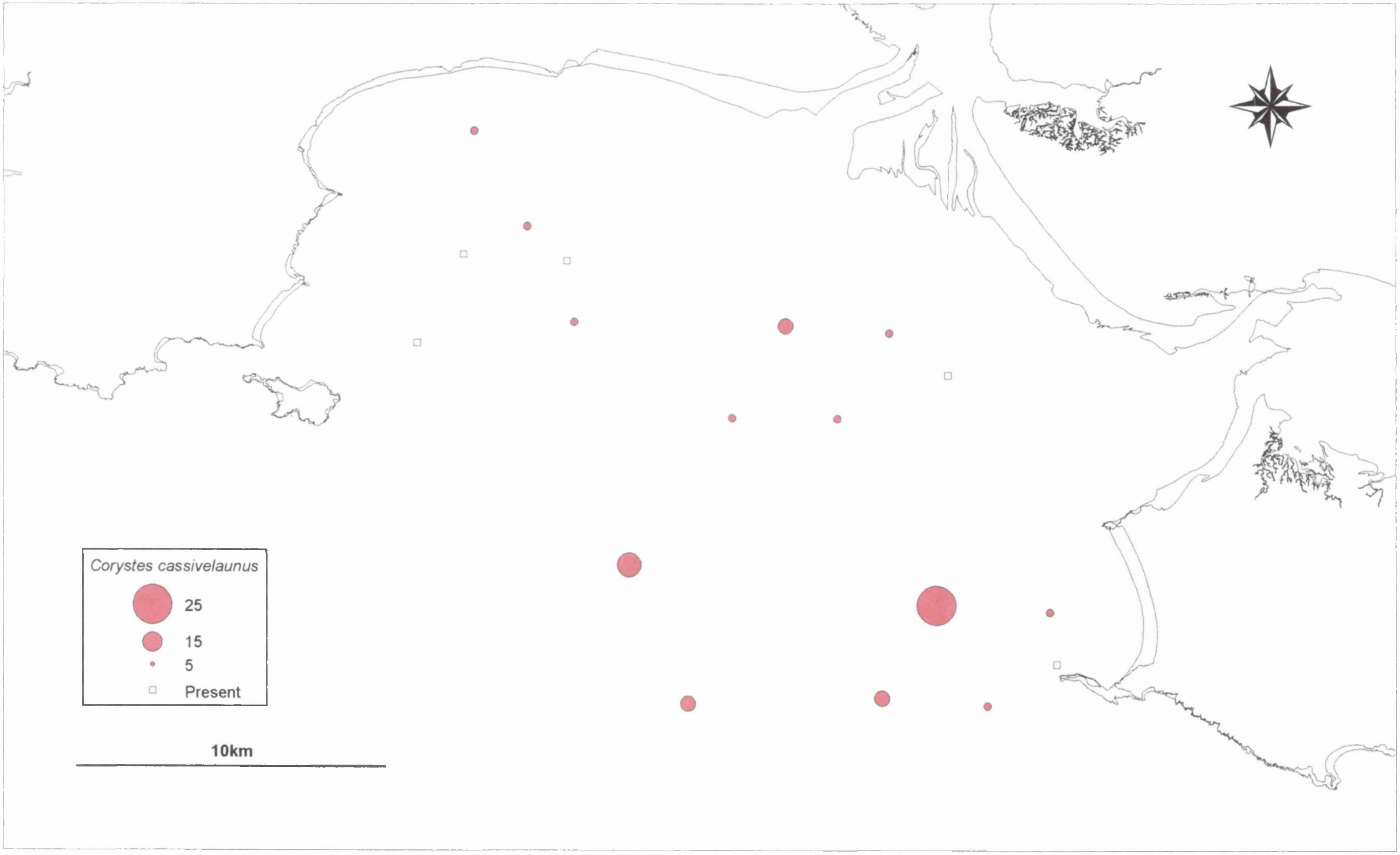


Figure 2.26 Cumacea Distribution and Abundance (m^{-2})

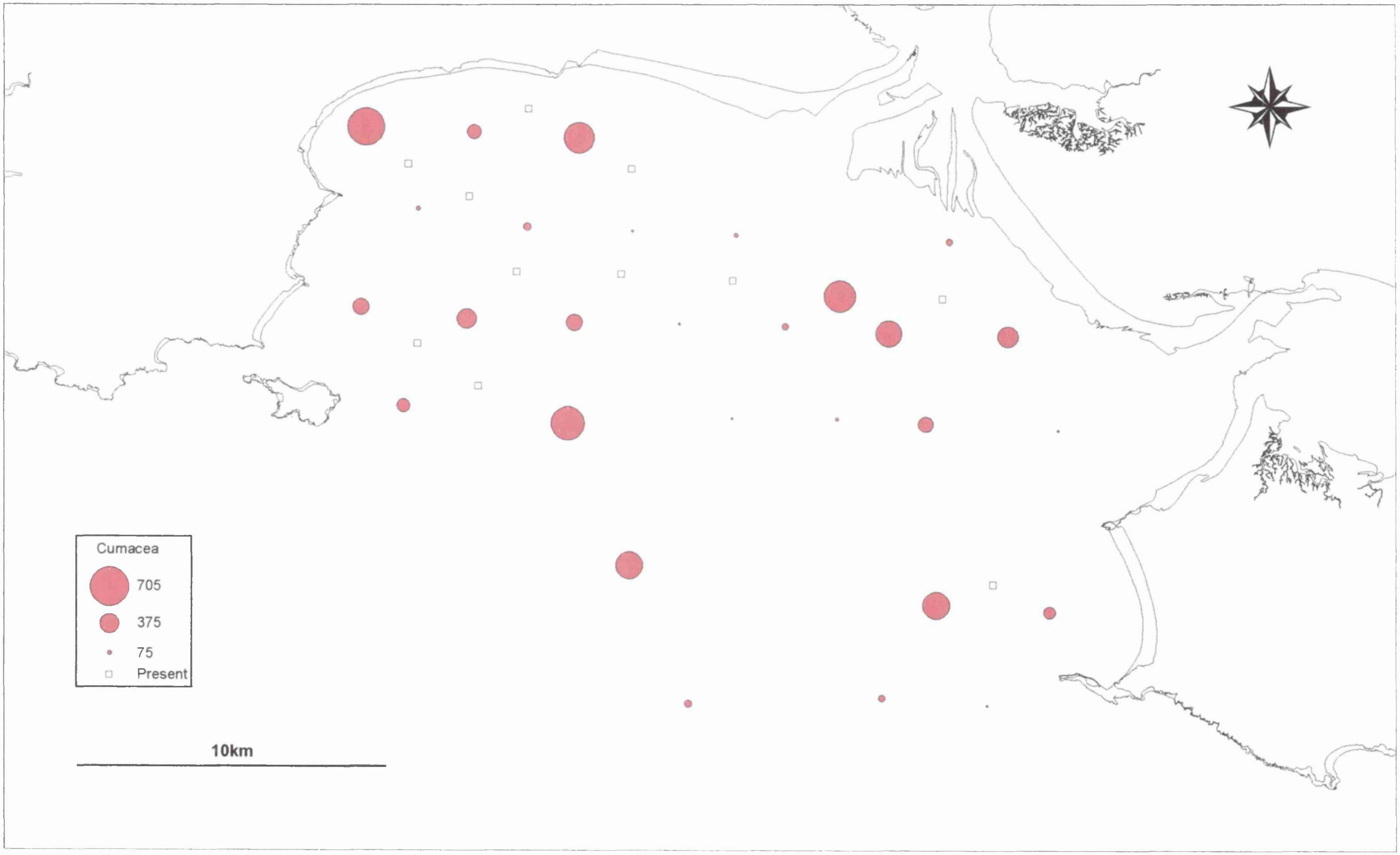


Figure 2.27 *Pseudocuma longicornis* Distribution and Abundance (m^{-2})

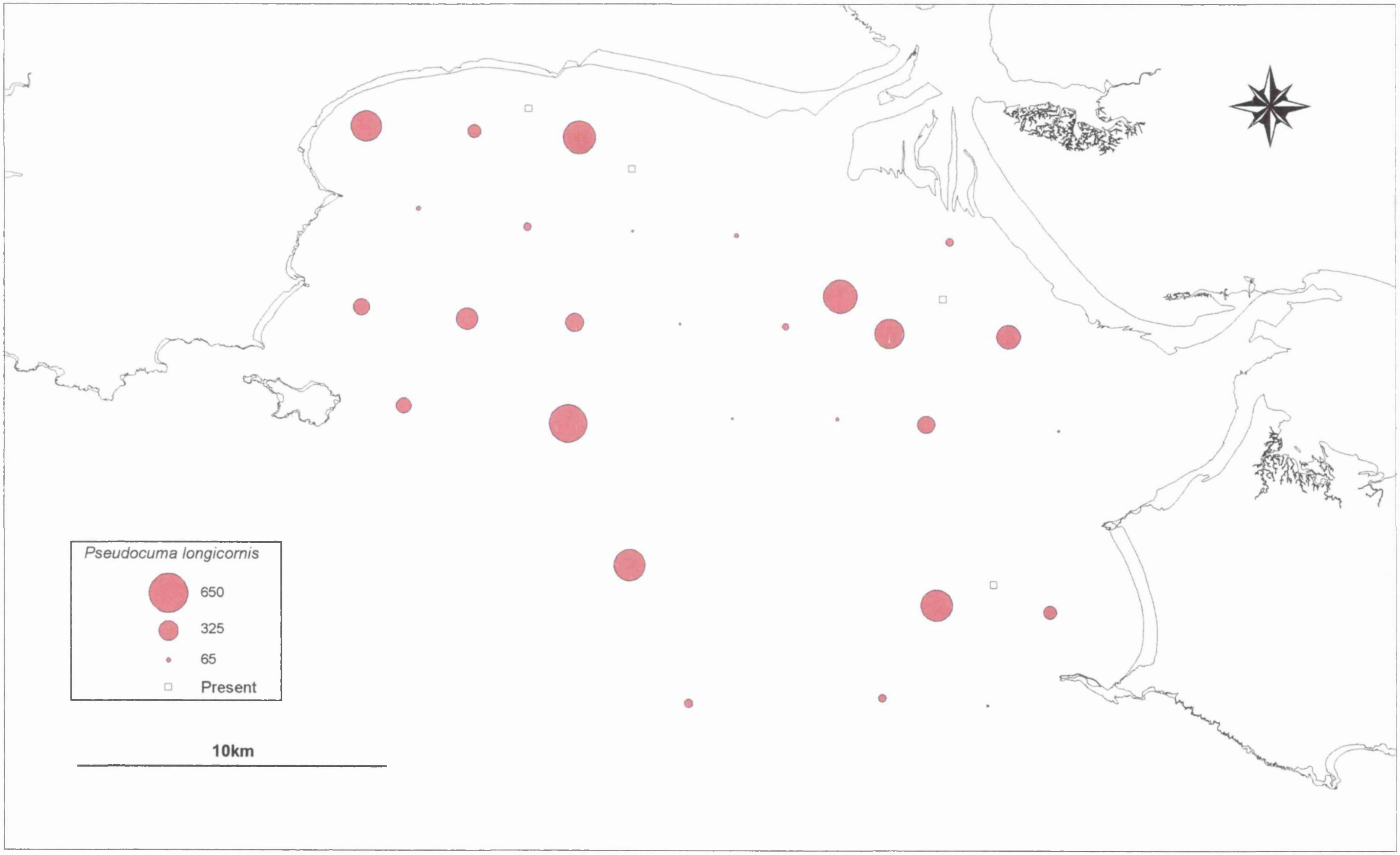
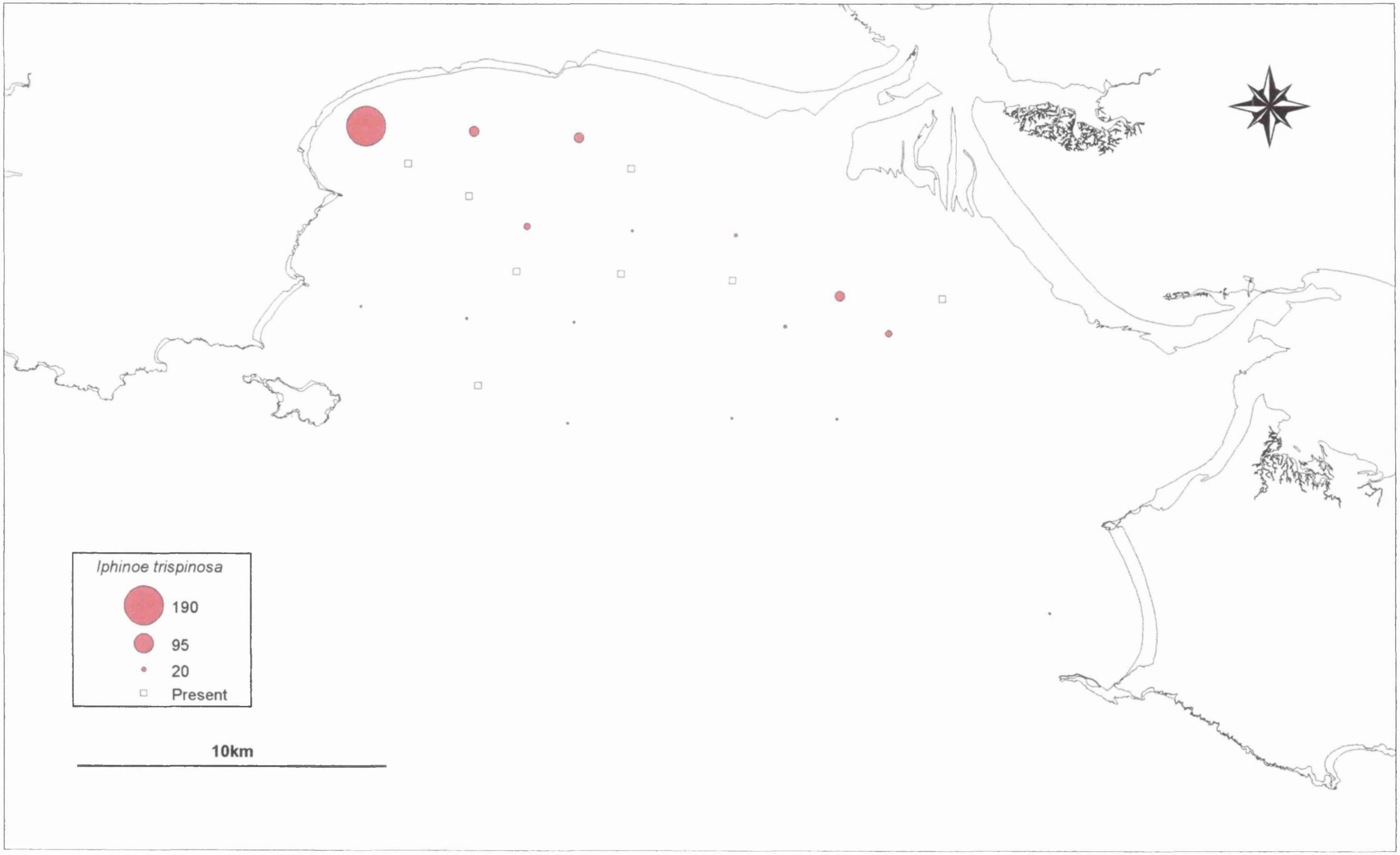


Figure 2.28 *Iphinoe trispinosa* Distribution and Abundance (m^{-2})



2. 3. 2. 4 Amphipoda

The Amphipoda were the most species rich crustacean group with 21 species recorded at the quantitative stations. Amphipods accounted for 1271 individuals at these stations; 5.1% of the survey total. Highest numbers were recorded at Station 44 (605m^{-2}), Station 48 (470m^{-2}) and Station 45 (435m^{-2}); all three situated in the west of the bay Northeast of Caldey Island. Figure 2.29 suggests a gradient of abundance from relatively low numbers of individuals at the outer southernmost stations to higher numbers inshore and to the west of the bay. The amphipod family Oedicerotidae is the predominant amphipod taxon supplying the three highest ranked species; *Perioculodes longimanus* (Bate and Westwood), *Pontocrates arenarius* (Bate) and *Synchelidium maculatum* (Sars).

Perioculodes longimanus was the most abundant amphipod species in Carmarthen Bay. Highest numbers were recorded at Station 51 (315m^{-2}), Station 48 (285m^{-2}) and Station 45 (215m^{-2}). Station 51 was situated in Saundersfoot Bay and stations 45 and 48 are immediately to the south and east respectively. Figure 2.30 shows the distribution of *P. longimanus* in Carmarthen Bay to be highest at the stations in and around Saundersfoot Bay, gradually decreasing in number at stations to the south and east. *Perioculodes longimanus* was absent at stations 21, 25, 27, 40, 43 and 88, occurring only singly at stations 23, 26 and 87. These stations are all on the southern periphery of the sample area with the exception of Station 25 at the mouth of the Loughor.

Pontocrates arenarius was recorded at highest abundance of 215m^{-2} at Station 31 off Pembrey Sands between the mouths of the Three River and Loughor estuaries. In general *P. arenarius* was most prevalent at those stations off Pembrey Sands and with the exception of stations 59 and 60 present in only low numbers in the opposite side of the bay (Figure 2.31).

The highest abundance of *S. maculatum* was recorded at stations 44 ($90m^{-2}$), 45 ($90m^{-2}$), 59 ($86m^{-2}$) and 56 ($80m^{-2}$). Stations 44 and 45 lay to the northeast of Caldey Island, Station 59 is in the centre of the bay south of Ragwen Point and Station 56 is south of Pendine Sands and the Carmarthen Bar. Figure 2.32 demonstrates the distribution of *S. maculatum*, the highest numbers occurred in the area of the bay north of Caldey Island and west of the Three River estuary. *S. maculatum* was absent from the stations off Pembrey Sands and occurred in relatively low numbers in the south and east of Carmarthen Bay.

The Haustorid amphipods *Bathyporeia elegans* (Watkin) and *Bathyporeia tenuipes* (Meinert) were conspicuous members of the amphipod fauna in Carmarthen Bay. Juveniles were also recorded but due to their small size could not be confidently identified to species level. *Bathyporeia elegans* was recorded mainly in the east of the bay off Pembrey Sands (Figure 2.33), the highest number was recorded at Station 25 ($150m^{-2}$) at the mouth of the Loughor estuary, the exceptions being stations 43 and 44 close to Caldey Island. *Bathyporeia tenuipes* was more widely distributed across the bay, with highest numbers occurring in the west of the bay at stations 44 ($140m^{-2}$) and 48 ($110m^{2}$) (Figure 2.34). Juvenile *Bathyporeia* species were recorded at stations in the western half of the bay and at three stations (23,25, and 26) on the opposite side (Figure 2.35). Highest abundance was recorded at Stations 60 ($85m^{-2}$) and 44 ($40m^{-2}$) to the north of Caldey Island.

Figure 2.29 Amphipoda Distribution and Abundance (m^{-2})

Figure 2.30 *Perioculodes longimanus* Distribution and Abundance (m^{-2})

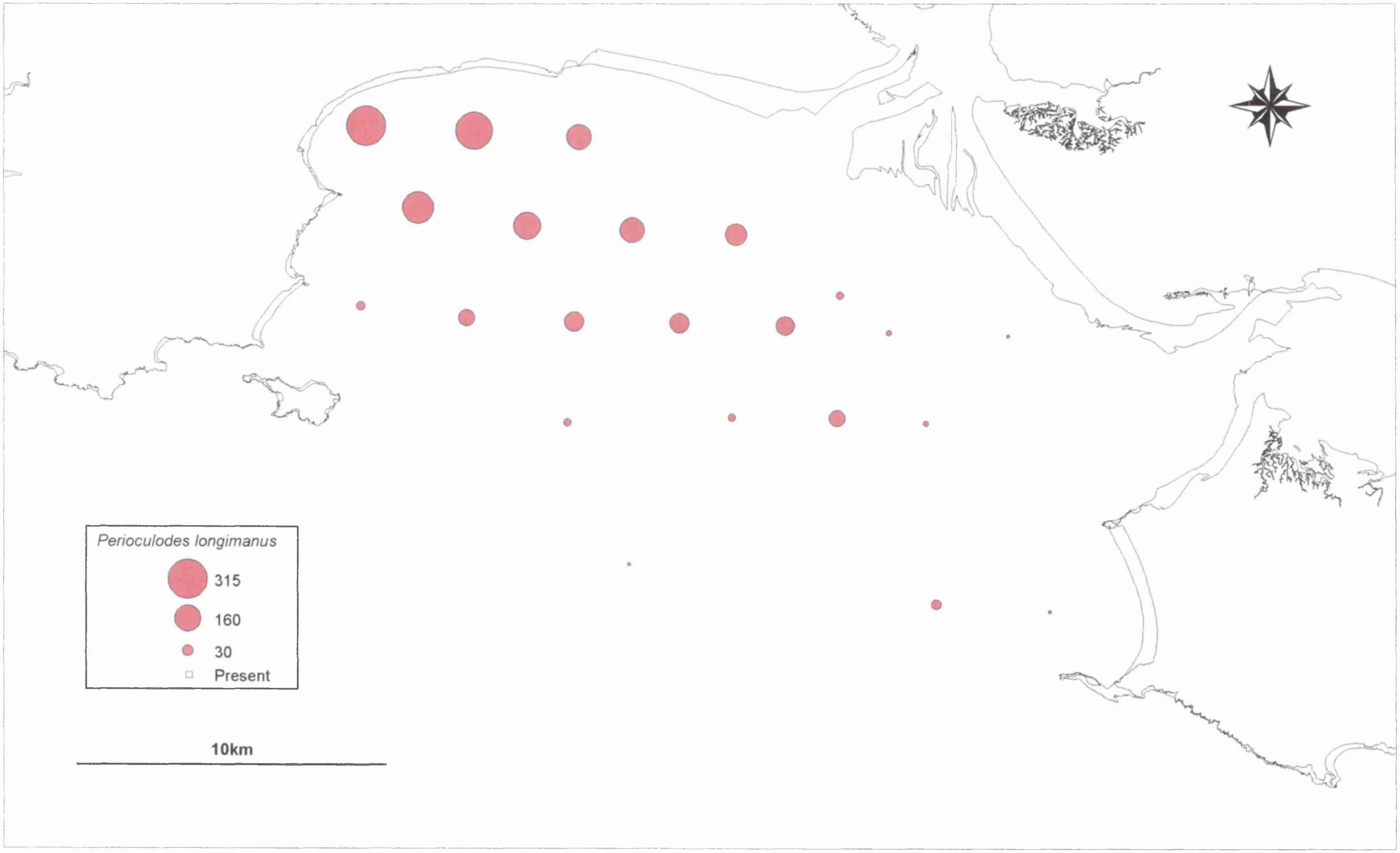


Figure 2.31 *Pontocrates arenarius* Distribution and Abundance (m^{-2})

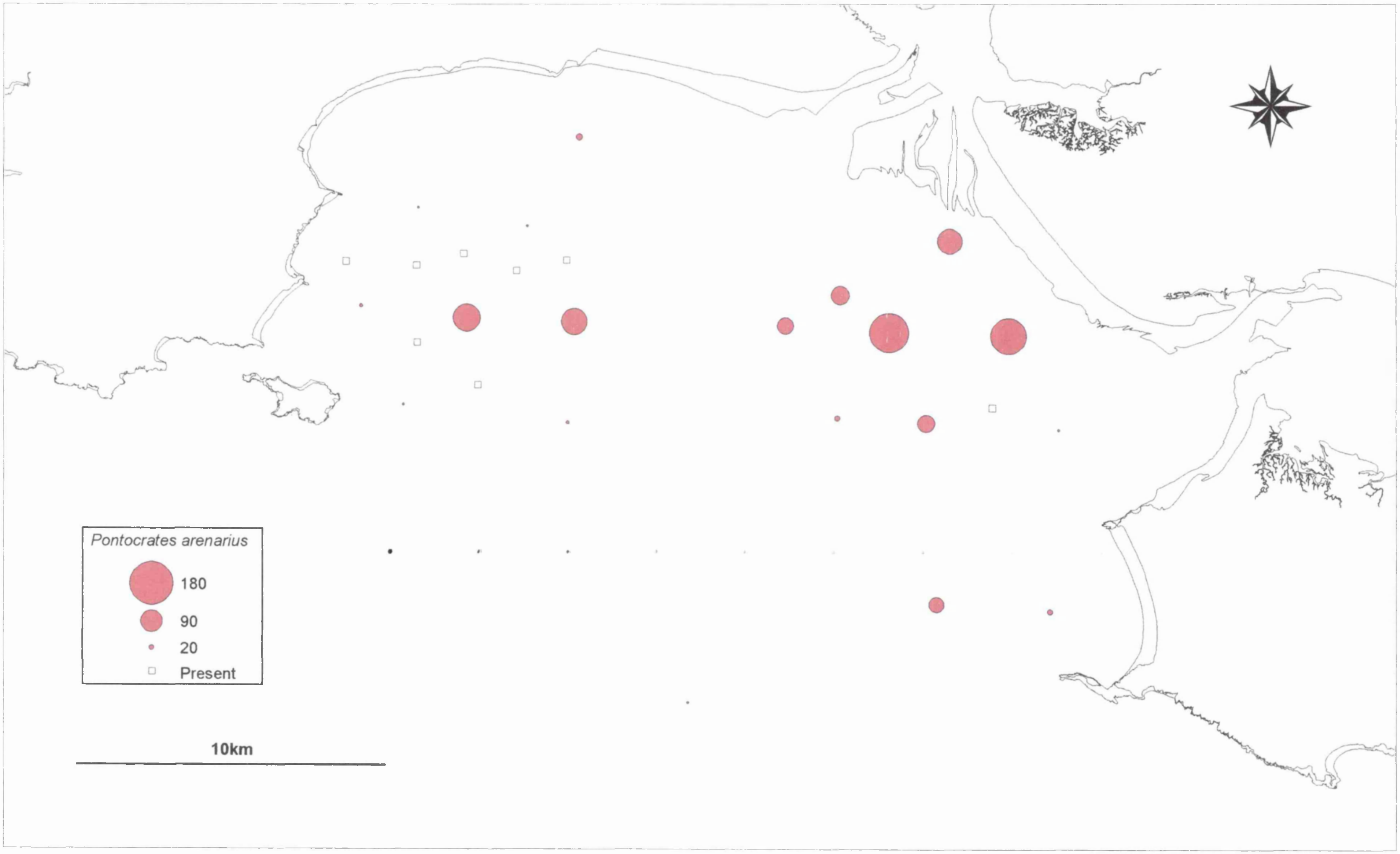


Figure 2.32 *Synchelidium maculatum* Distribution and Abundance (m^{-2})

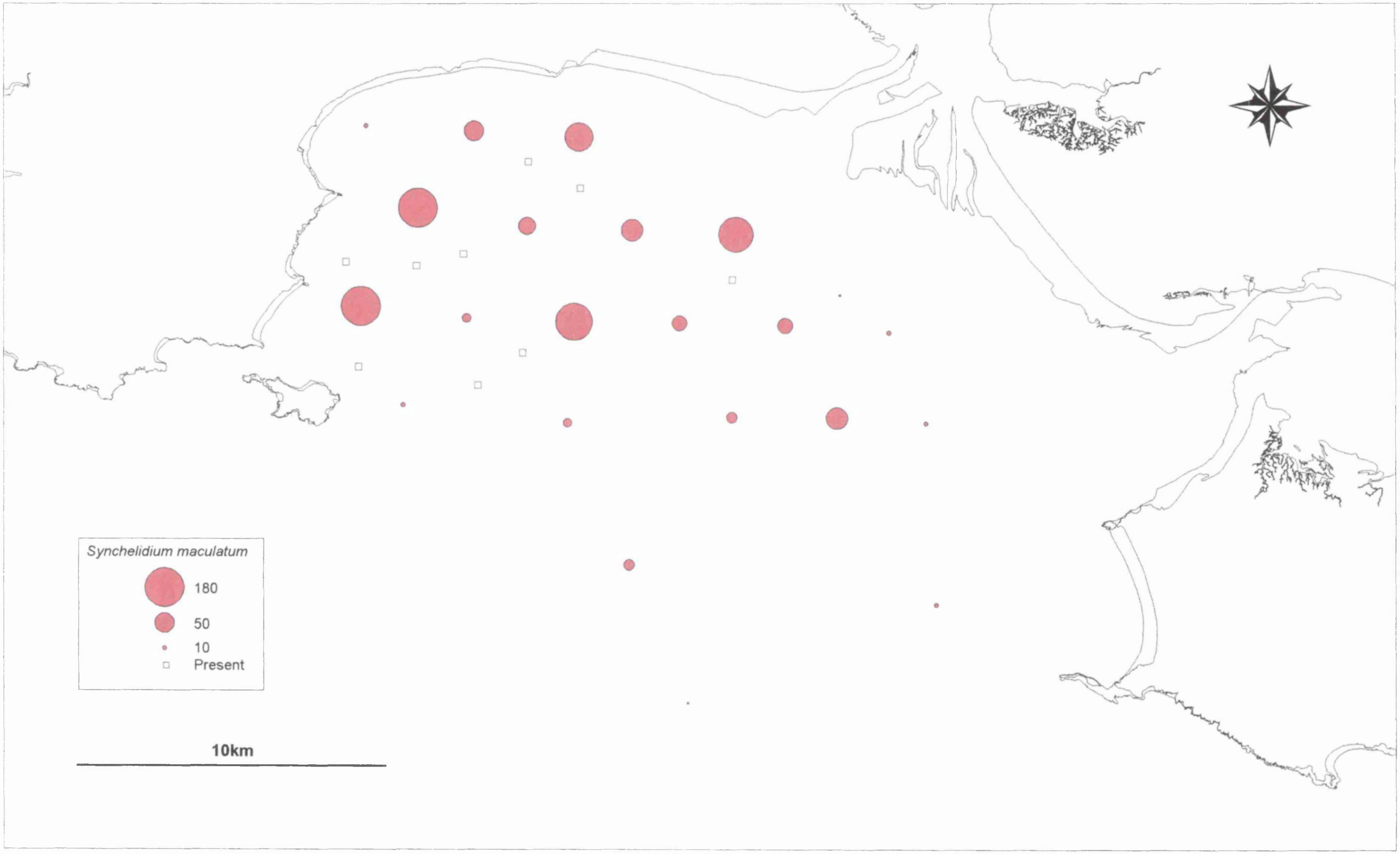


Figure 2.33 *Bathyporeia elegans* Distribution and Abundance (m^{-2})

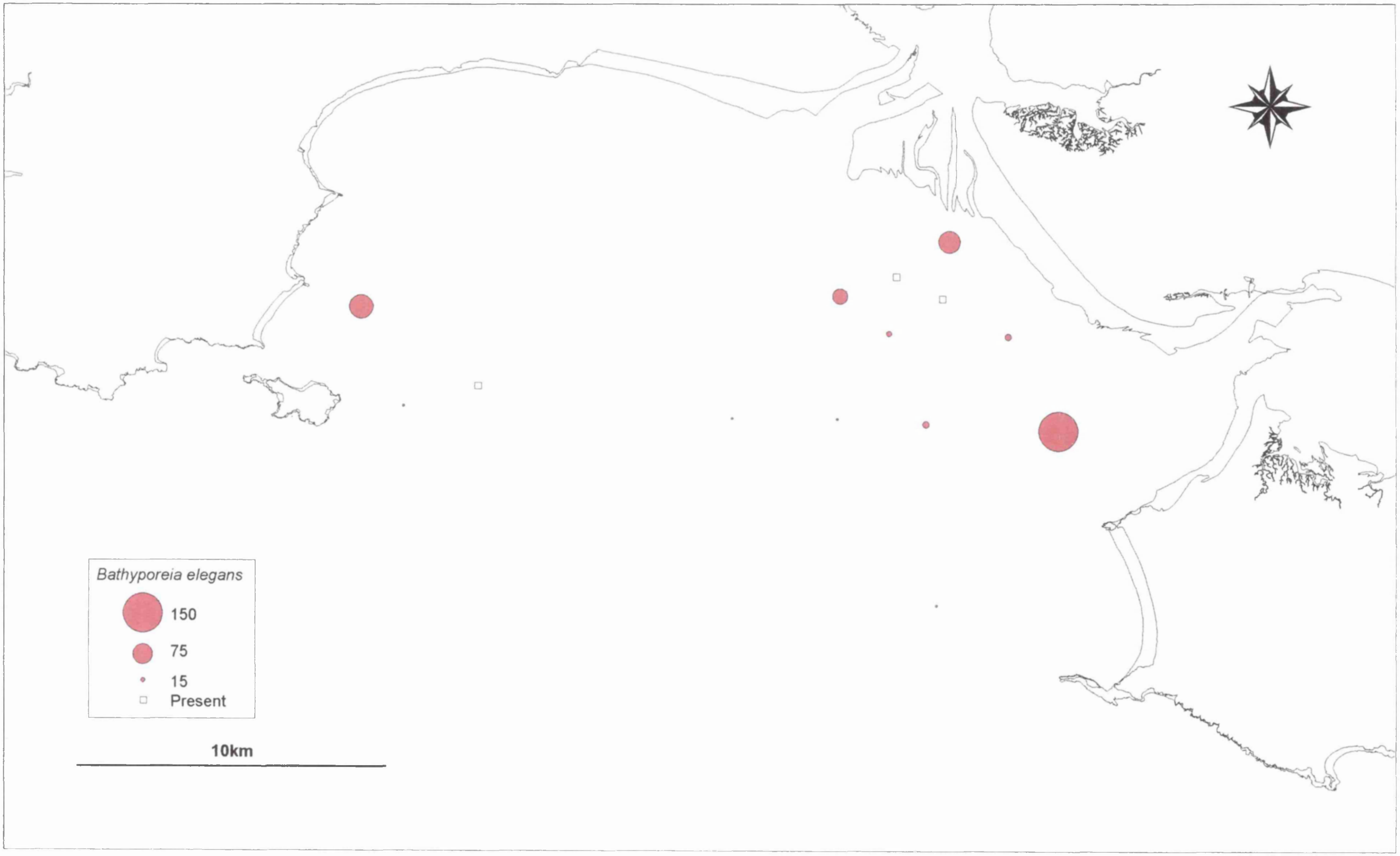


Figure 2.34 *Bathyporeia tenuipes* Distribution and Abundance (m^{-2})

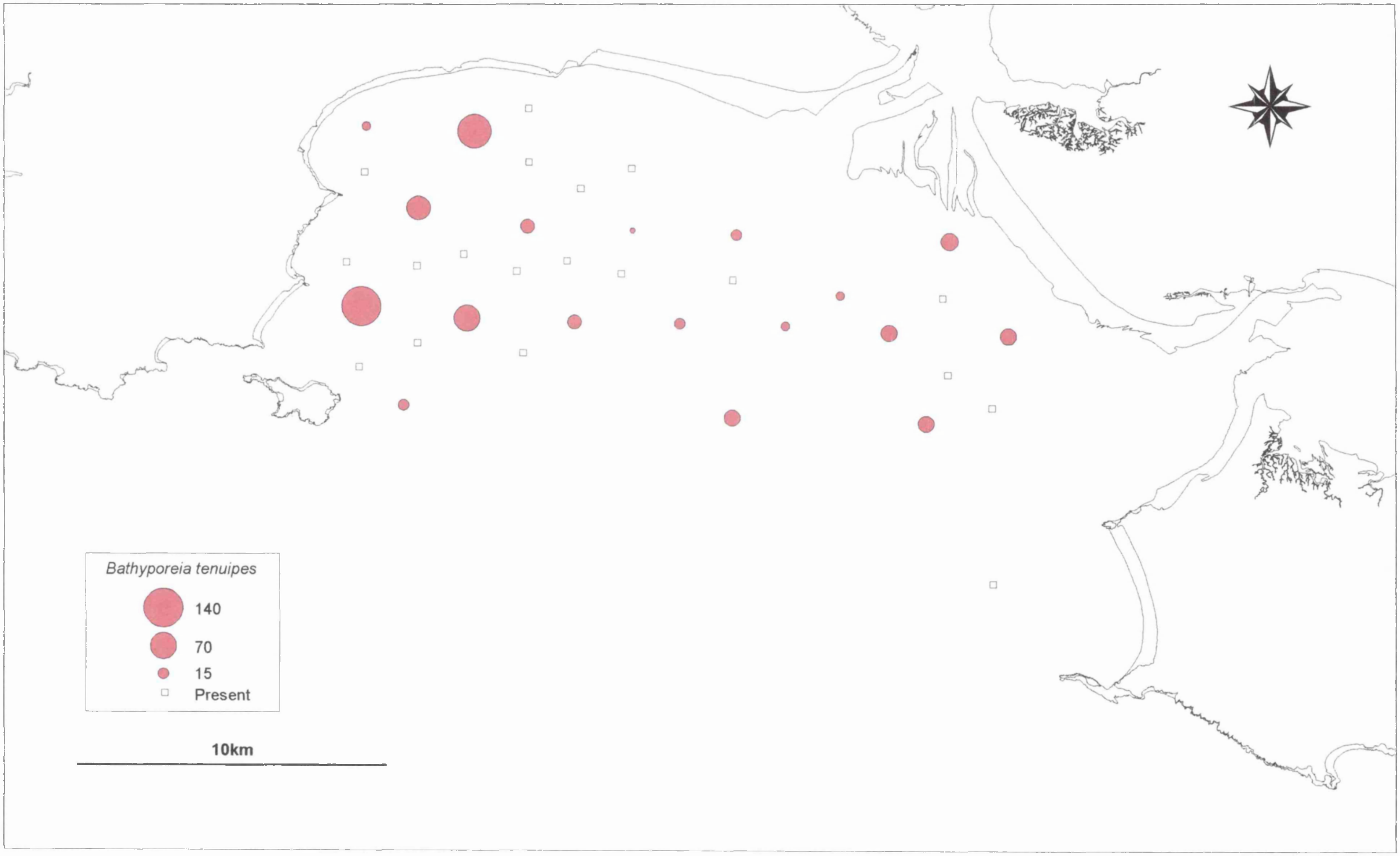
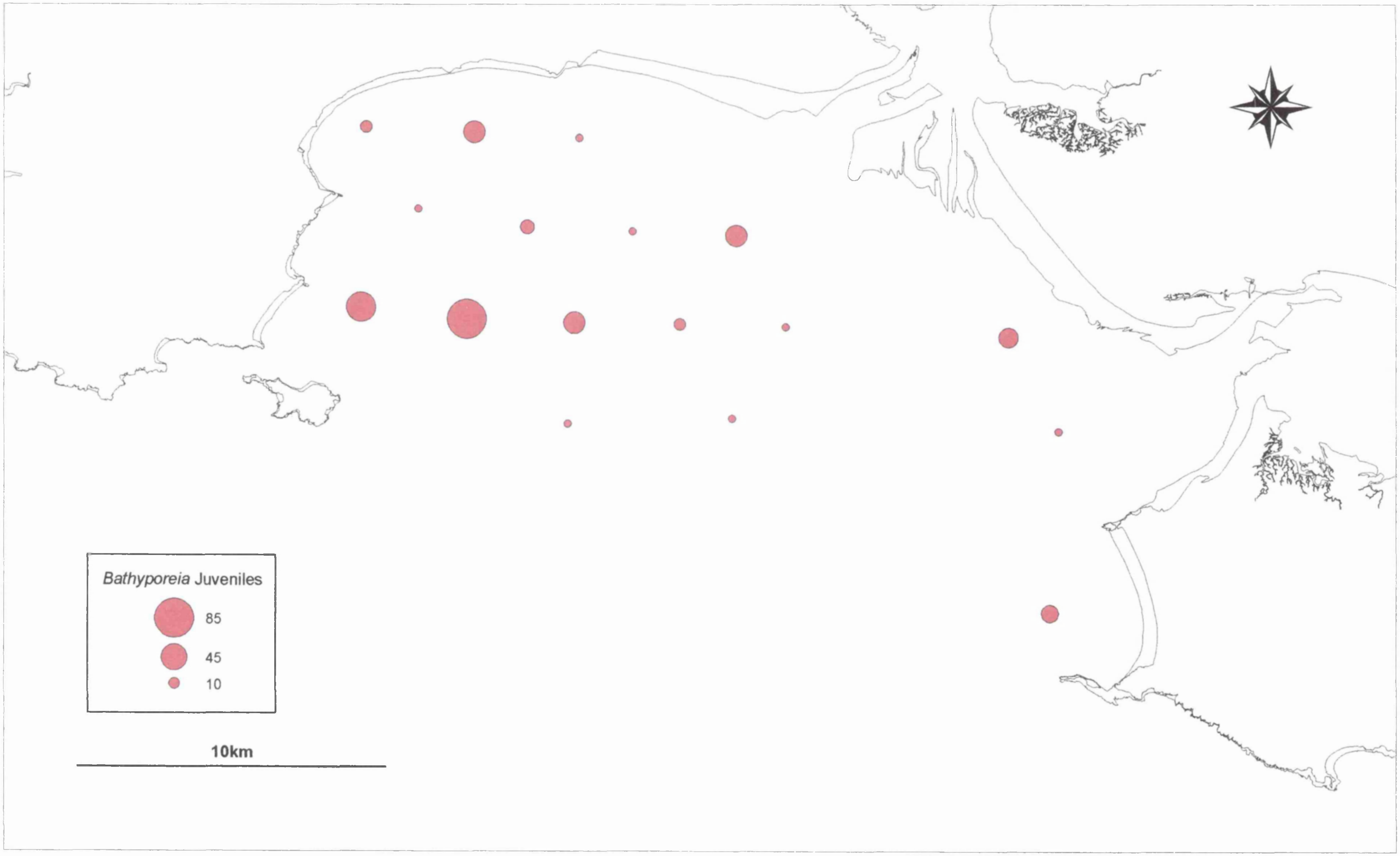


Figure 2.35 *Bathyporeia* Juveniles Distribution and Abundance (m^{-2})



2. 3. 2. 5 Mollusca

The molluscan fauna of Carmarthen Bay was characterized by high numbers of bivalves. Bivalves were shown to be both numerically dominant and species rich, Table 3. Only one gastropod and one opisthobranch species were conspicuous in Carmarthen Bay.

2. 3. 2. 6 Gastropoda

The gastropod *Turbonilla lactea* (Linnaeus) was recorded at highest numbers at stations north of Caldey island; Station 44 (65m^{-2}), Station 45 (45m^{-2}) and Station 48 (40m^{-2}). Figure 2.36 displays the occurrences of *T. lactea* at stations to the north of Caldey Island west to the centre of the bay south of the Carmarthen Bar. *T. lactea* was absent from stations in the south and east of the bay.

2. 3. 2. 7 Opisthobranchia

The opisthobranch *Cylichna cylindracea* (Pennant) was recorded at 12 stations in Carmarthen Bay (Figure 2.37). *C. cylindracea* was most abundant at Station 42 (90m^{-2}) in the centre of the bay directly south of the Carmarthen Bar. This species was distributed at stations in the centre and west of the bay, and absent from stations in the south and east.

Figure 2.36 *Turbonilla lactea* Distribution and Abundance (m^{-2})

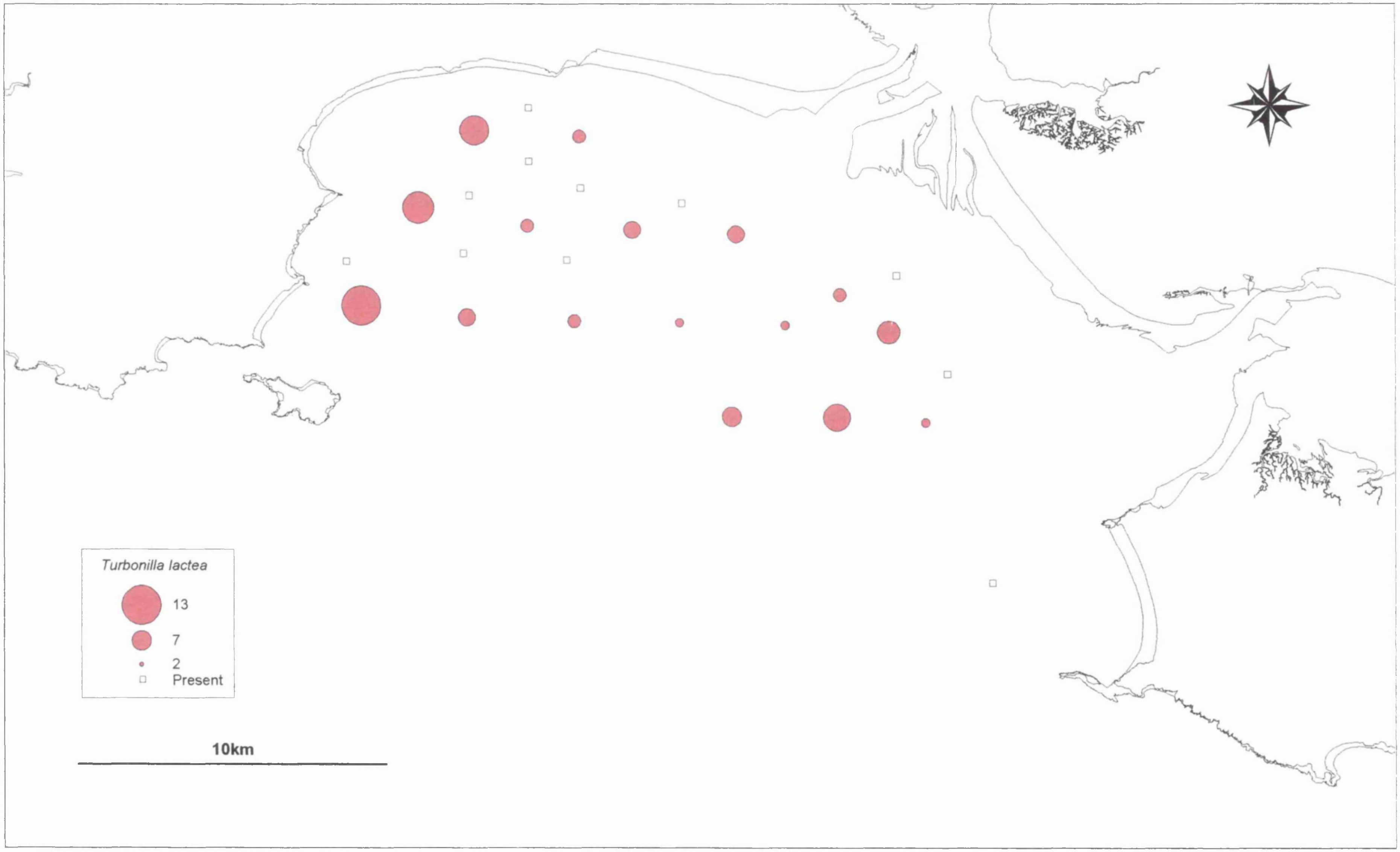
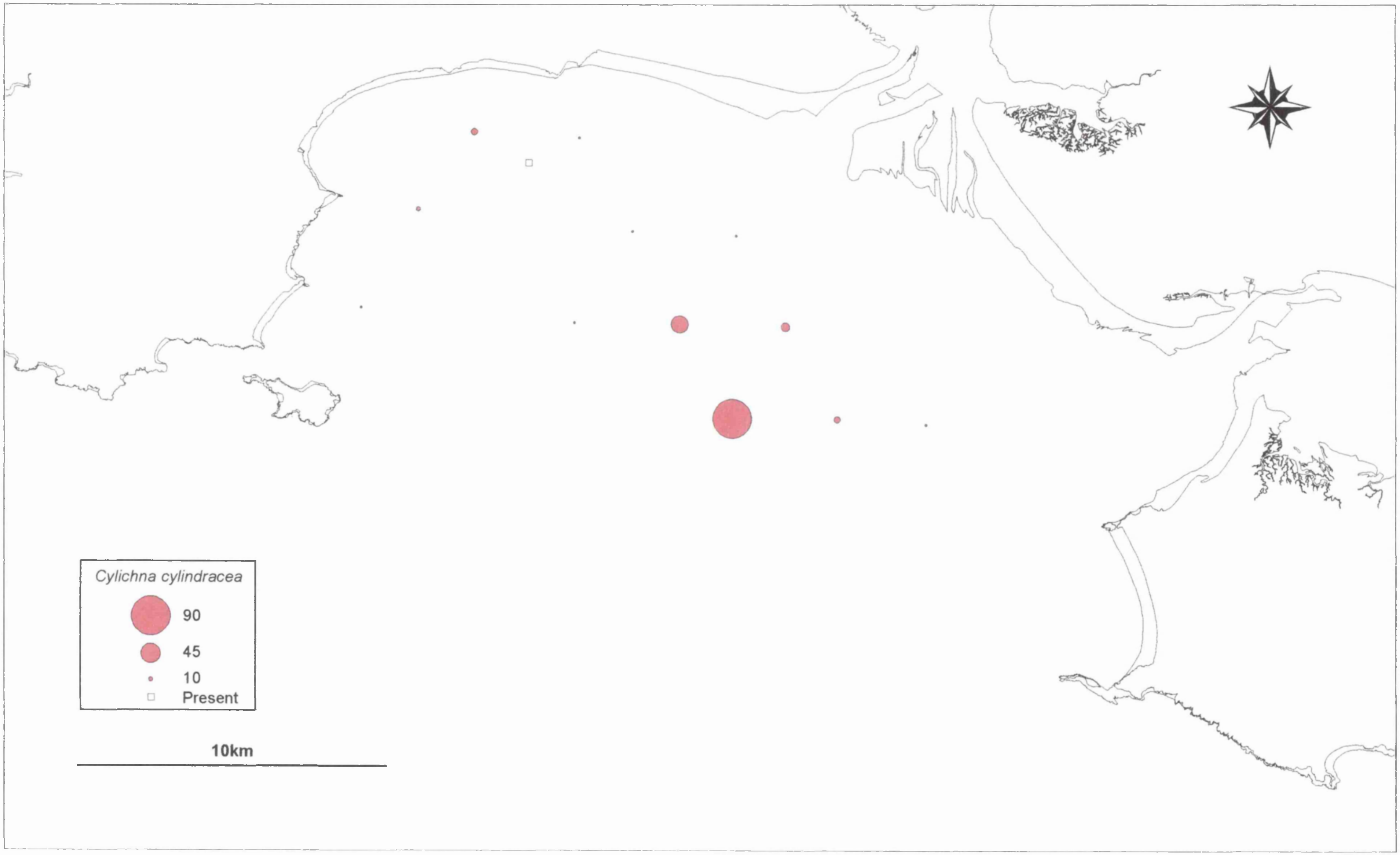


Figure 2.37 *Cylichna cylindracea* Distribution and Abundance (m^{-2})



2. 3. 2. 8 Bivalvia

The molluscan fauna of Carmarthen Bay was dominated by the bivalves, both in terms of numbers of individuals and numbers of species; 5742 individual bivalves were recorded in 15 taxa. In general, the highest numbers of bivalves were recorded in the area of Carmarthen Bay north of Caldey Island and west of Cefn Sidan Sands (Figure 2.38). Low numbers of individuals were recorded at the remaining southernmost stations and those west of Rhossili Bay/Worms Head. Highest numbers of bivalves were recorded at Station 54 (2580m^{-2}) south of Ragwen Point, Station 51 (2330m^{-2}) in Saundersfoot Bay, Stations 58 (2145m^{-2}) and 56 (2010m^{-2}) both south of the Carmarthen Bar at the mouth of the Three River estuary. The high abundance of bivalves at these stations was due to large numbers of small post larvae and juvenile animals.

The most abundant species was *Fabulina fabula* (Gmelin). Highest numbers of this species were recorded at stations 54 (1230m^{-2}), 56 (1025m^{-2}) and 58 (1000m^{-2}), all in the centre of the bay south of Ragwen Point and the Carmarthen Bar. *Fabulina fabula* was absent at Station 21 off Worms Head and Station 25 at the mouth of the Loughor estuary and was recorded in comparatively low numbers at stations 40, 43, 84, 87 and 88 all situated on the southern edge of the survey area (Figure 2.39). Within the area of high *F. fabula* abundance, north of Caldey Island and west of Pembrey Sands, there is a distinct patchiness in abundance. Abundance in this area ranges from 195m^{-2} to 1230m^{-2}.

Mactra stultorum (Linnaeus) were recorded at all stations with the exception of station 25, 60 and 64. Highest abundance was recorded at stations 56 (400m^{-2}), 54 (390m^{-2}), 51 (310m^{-2}) and 55 (285m^{-2}), all in the north of the bay between Saundersfoot Bay and the mouth of the Three Rivers estuary. While the stations of highest abundance are situated in the north of the bay. Figure 2.40 demonstrates the absence of a coherent pattern of distribution for the remainder; low numbers are recorded at stations around Caldey Island, west of Worms Head and off Pembrey Sands.

Highest numbers of *Thracia phaseolina* (Lamarck) were recorded at stations 51 ($620m^{-2}$), 45 ($600m^{-2}$) and 48 ($490m^{-2}$) in and around Saundersfoot Bay. Figure 2.41 describes a gradient of *T. phaseolina* abundance from Saundersfoot Bay southeast towards Worms Head. *T. phaseolina* was absent from stations immediately off Pembrey Sands and Rhossili Bay, and from the southernmost stations of the sample area.

Juveniles of *Phaxas pellucidus* (Pennant) were a conspicuous component of the bivalve fauna in Carmarthen Bay, and were absent from only three stations; 21, 25 and 87. Highest numbers were recorded in an area north of Tenby and west of the Carmarthen Bar (Figure 2.42). The most abundant stations were Station 54 ($635m^{-2}$) in the centre of the bay south of Ragwen Point, Station 28 ($330m^{-2}$) south of Cefn Sidan Sands and Station 45 ($235m^{-2}$) west of Monkstone Point.

High numbers of *Mysella bidentata* (Montagu) were recorded at stations 58 ($740m^{-2}$) and 42 ($710m^{-2}$) in the centre of the bay south of Pendine Sands and at Station 44 ($500m^{-2}$) north of Caldey Island. *M. bidentata* was present at the majority of stations in the bay but were absent at the southern stations 21, 23,40,43, 84 and 87 and Station 64 off Ragwen Point (Figure 2.43).

Chamelea gallina (Linnaeus) was a conspicuous member of the bivalve fauna recorded at 16 stations in Carmarthen Bay. *Chamelea gallina* was distributed north of Caldey Island and west of Pembrey Sands (Figure 2.44). Highest abundance was recorded at Station 57 ($320m^{-2}$) in the centre of the bay south of the Carmarthen Bar.

Figure 2.38 Bivalvia Distribution and Abundance (m^{-2})

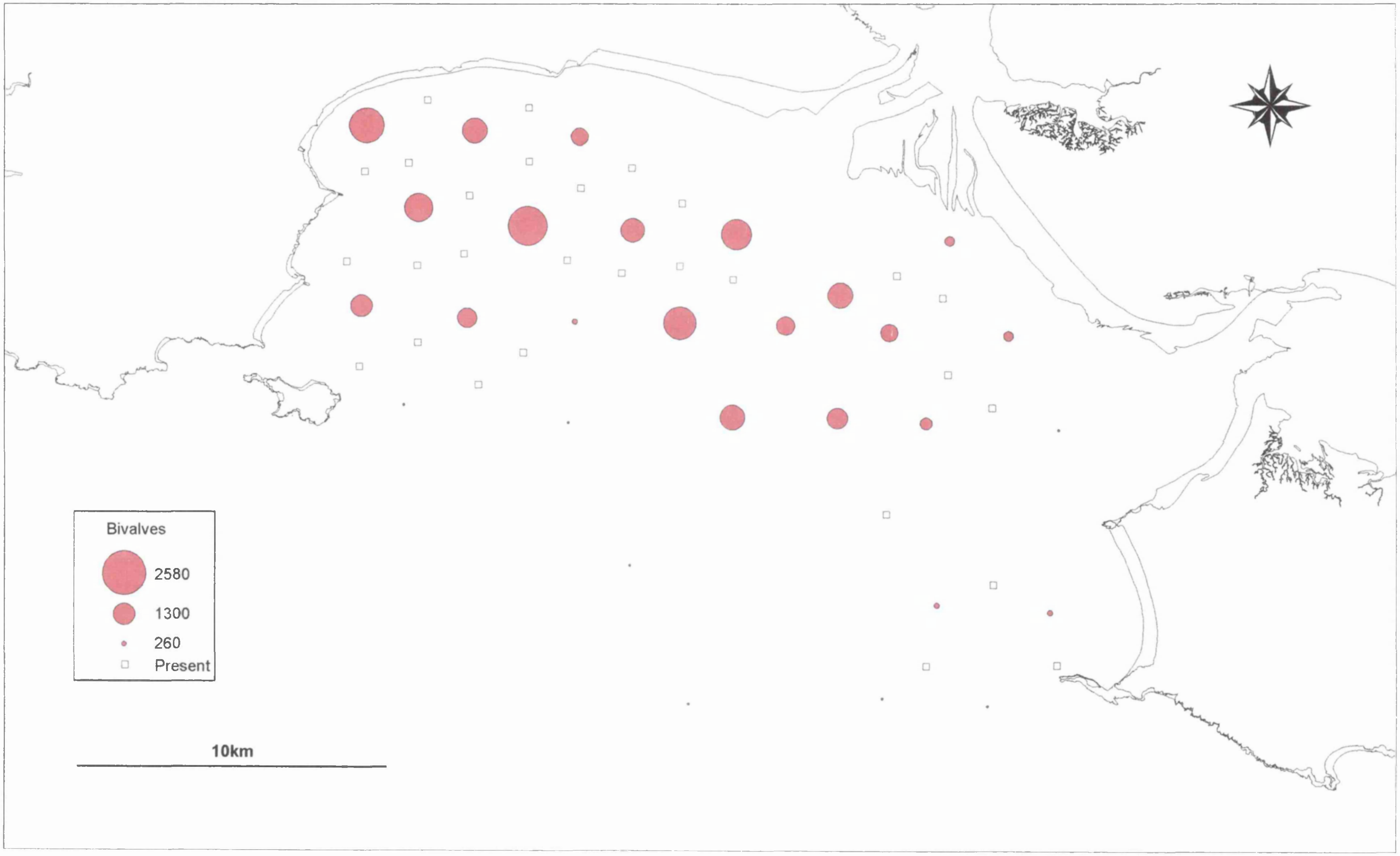


Figure 2.39 *Fabulina fabula* Distribution and Abundance (m^{-2})

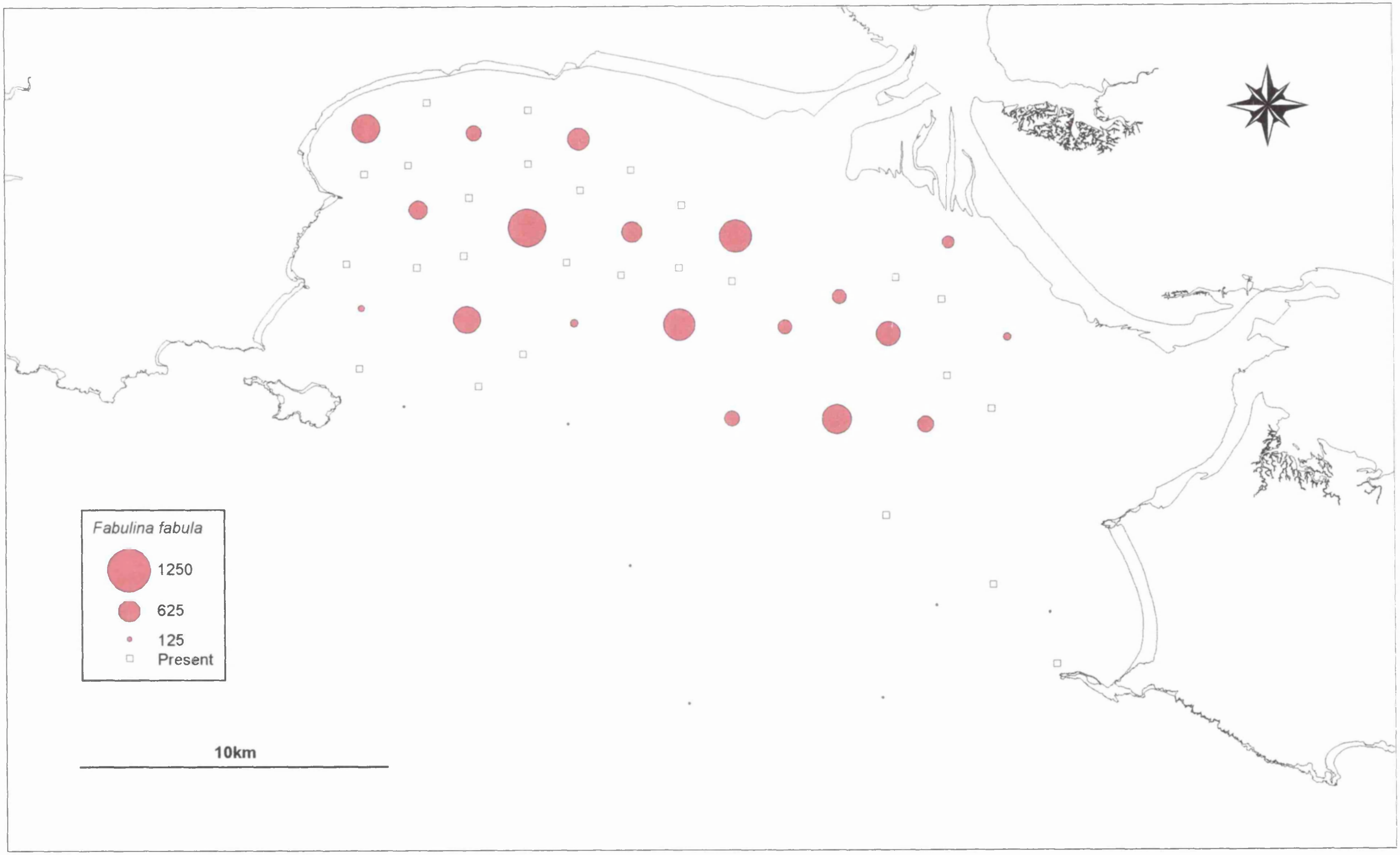


Figure 2.40 *Mactra stultorum* Distribution and Abundance (m^{-2})

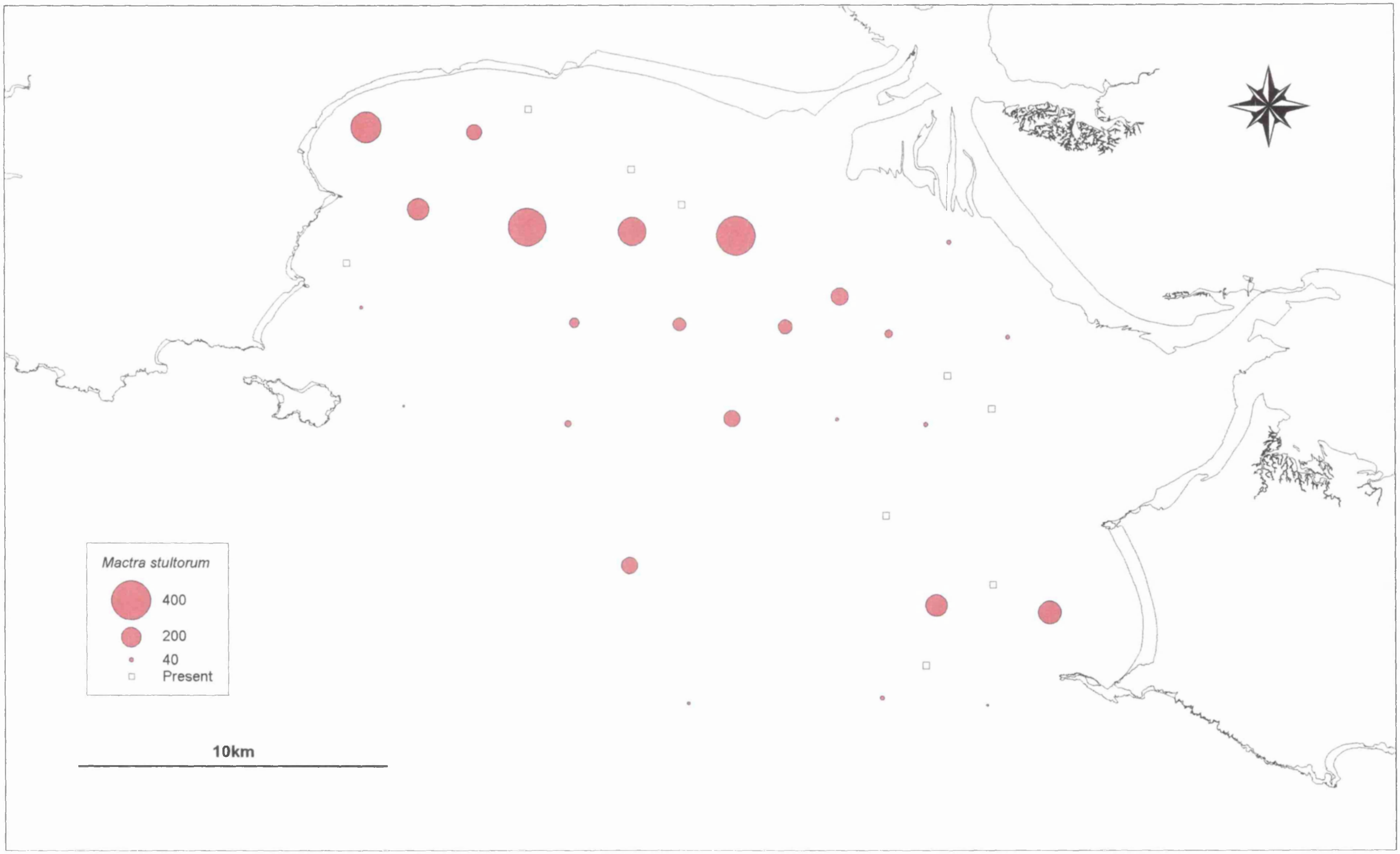


Figure 2.41 *Thracia phaseolina* Distribution and Abundance (m^{-2})

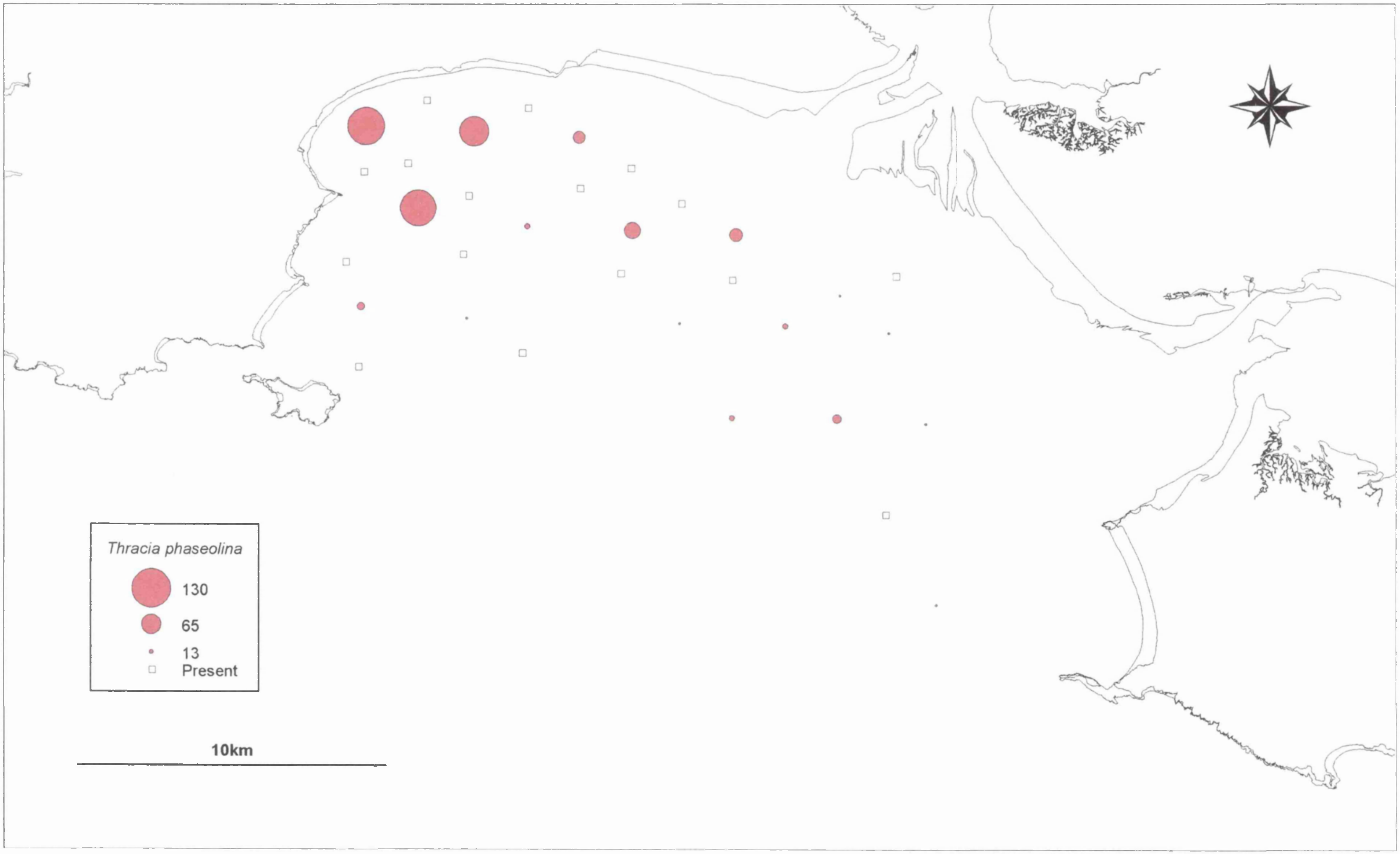


Figure 2.42 *Phaxas pellucidus* Distribution and Abundance (m^{-2})

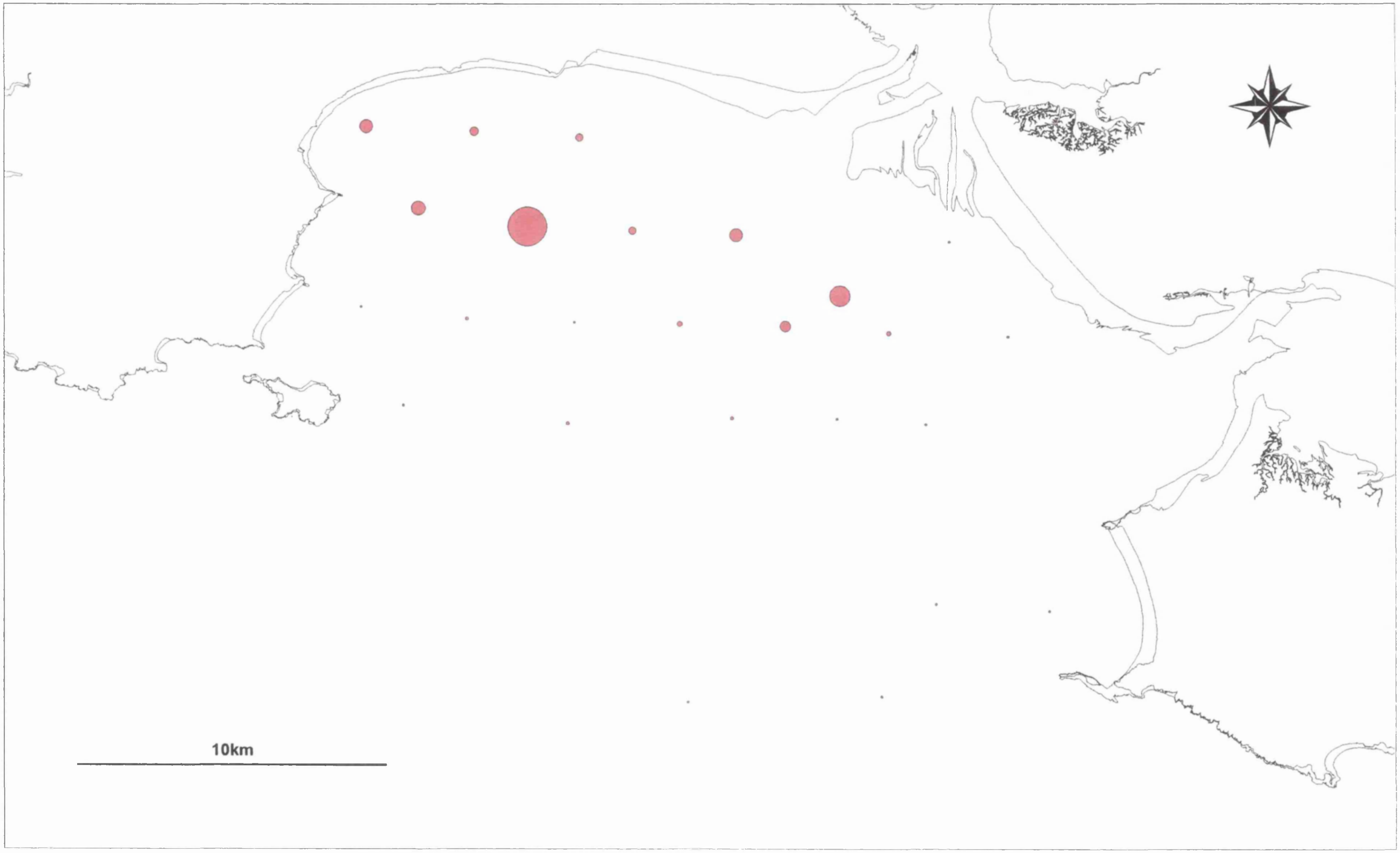


Figure 2.43 *Mysella bidentata* Distribution and Abundance (m^{-2})

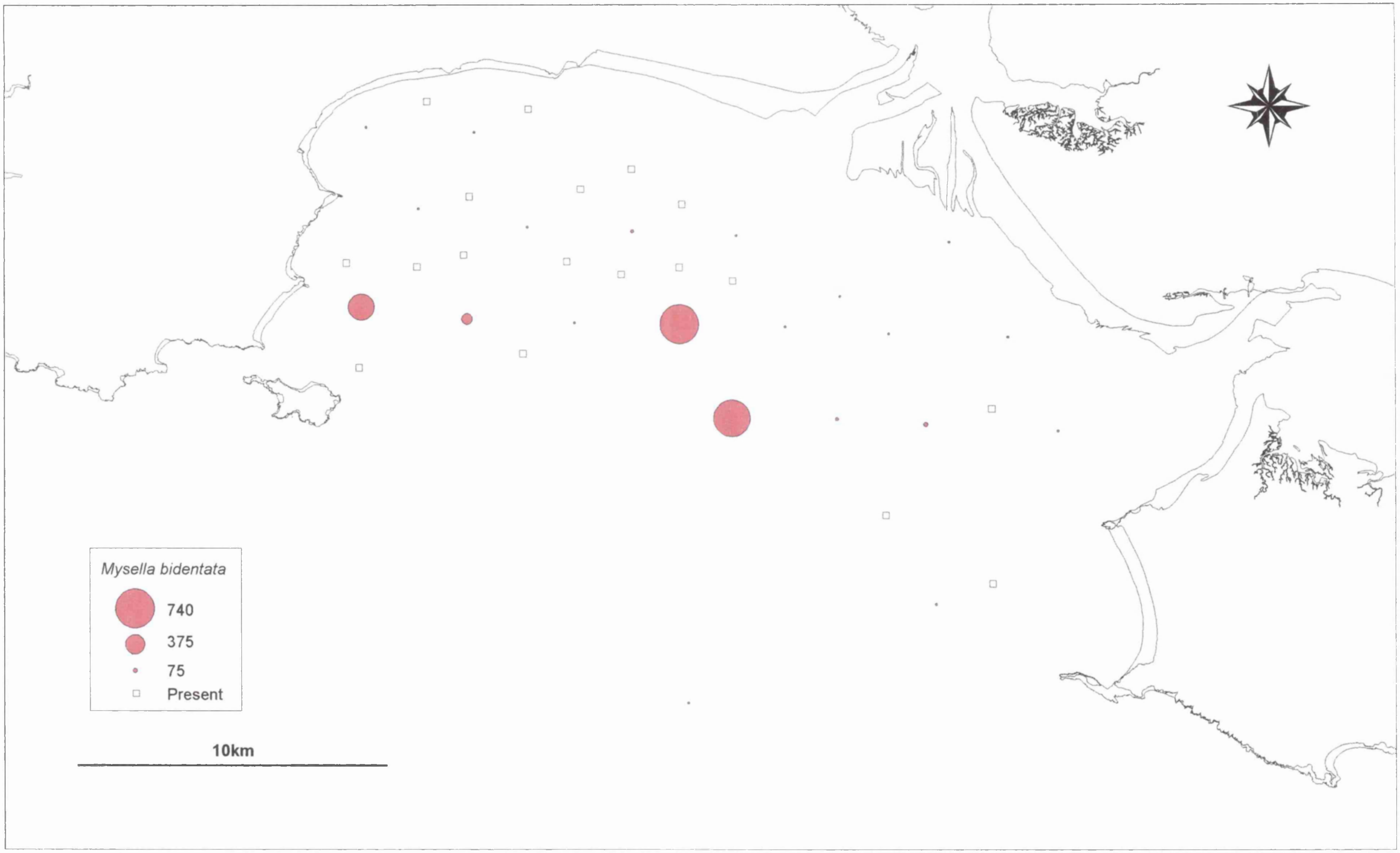
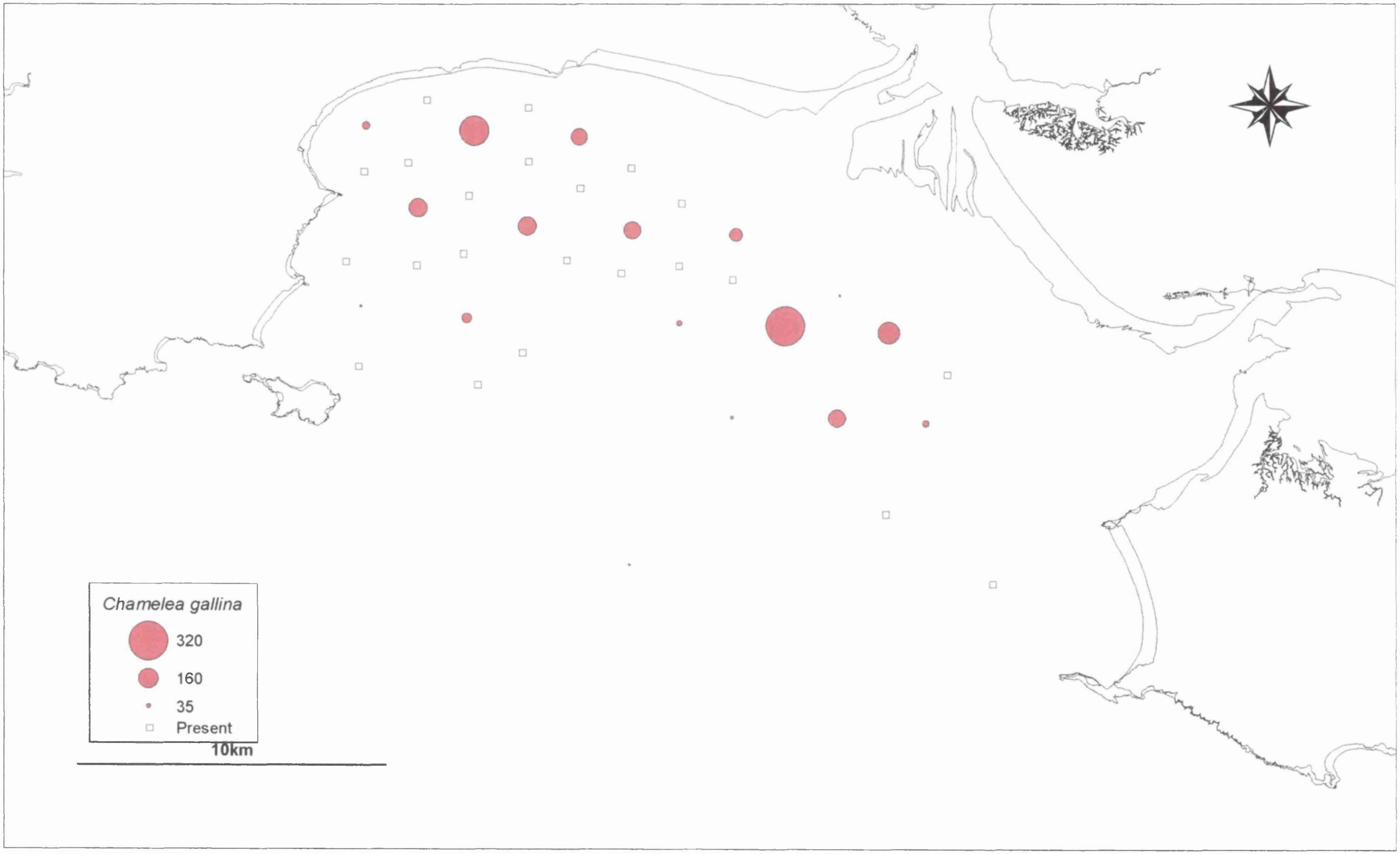


Figure 2.44 *Chamelea gallina* Distribution and Abundance (m^{-2})



2. 3. 2. 9 Echinodermata

A total of 105 individuals from 5 echinoderm taxa was recorded from the quantitative samples. In general, echinoderms were recorded in low numbers (Figure 2.45). Most abundant were the brittlestar *Amphiura brachiata* (Montagu) and the heart urchin *Echinocardium cordatum* (Pennant).

Counting only disks, *A. brachiata* was recorded at 12 stations in Carmarthen Bay (Figure 2.46). It was noted during sorting that arms of *A. brachiata* were present in samples in the absence of disks The most abundant stations were stations 58 ($90m^{-2}$) and 42 ($65m^{-2}$) situated in the centre of the bay south of Pendine Sands and the Carmarthen Bar.

Echinocardium cordatum are relatively widely distributed in Carmarthen Bay (Figure 2.47). Highest numbers were recorded from Station 26 ($25m^{-2}$) off Pembrey Sands and Station 42 ($15m^{-2}$) in the centre of the bay south of the Carmarthen Bar.

Figure 2.45 Echinodermata Distribution and Abundance (m^{-2})

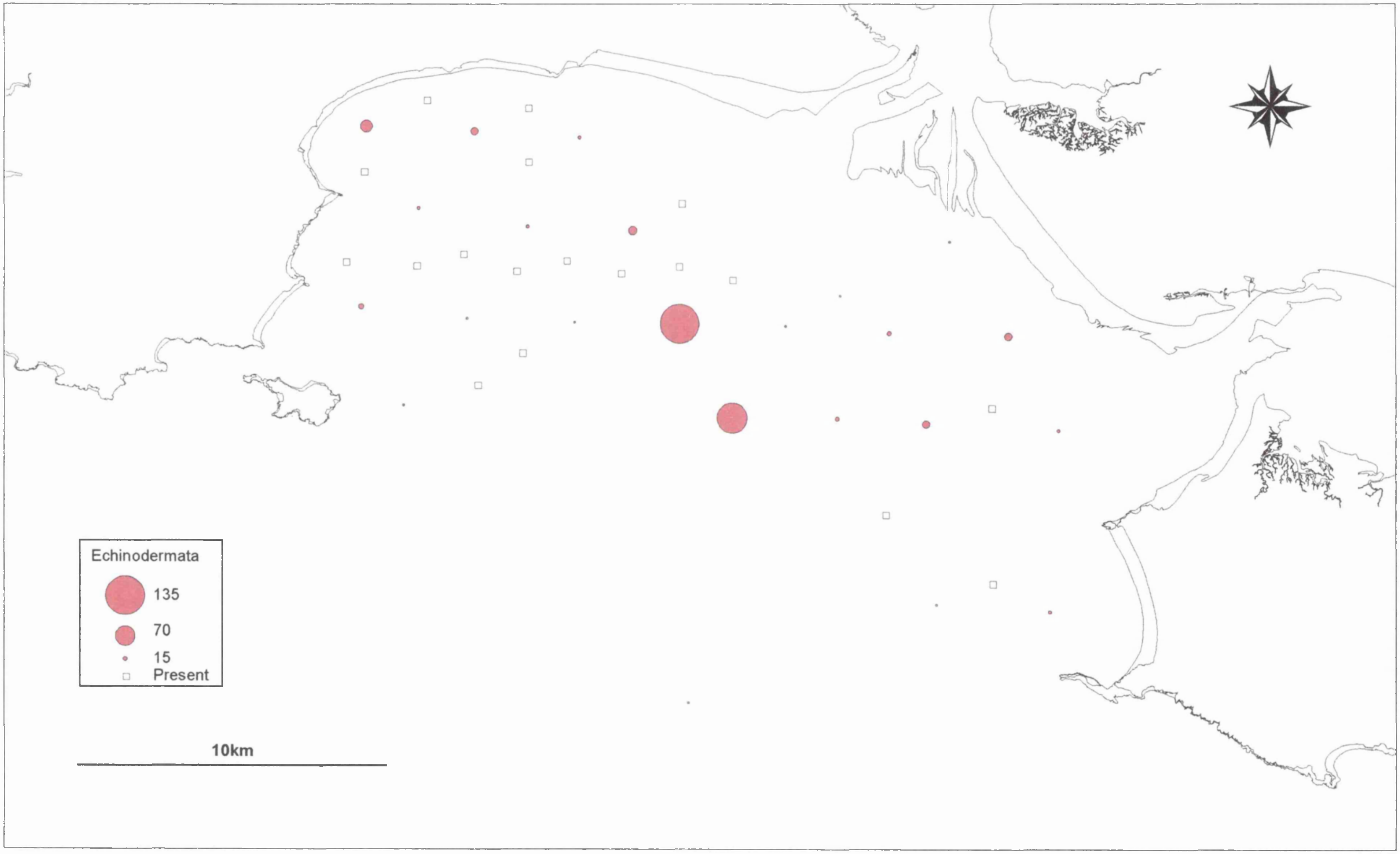


Figure 2.46 *Amphiura brachiata* Distribution and Abundance (m^{-2})

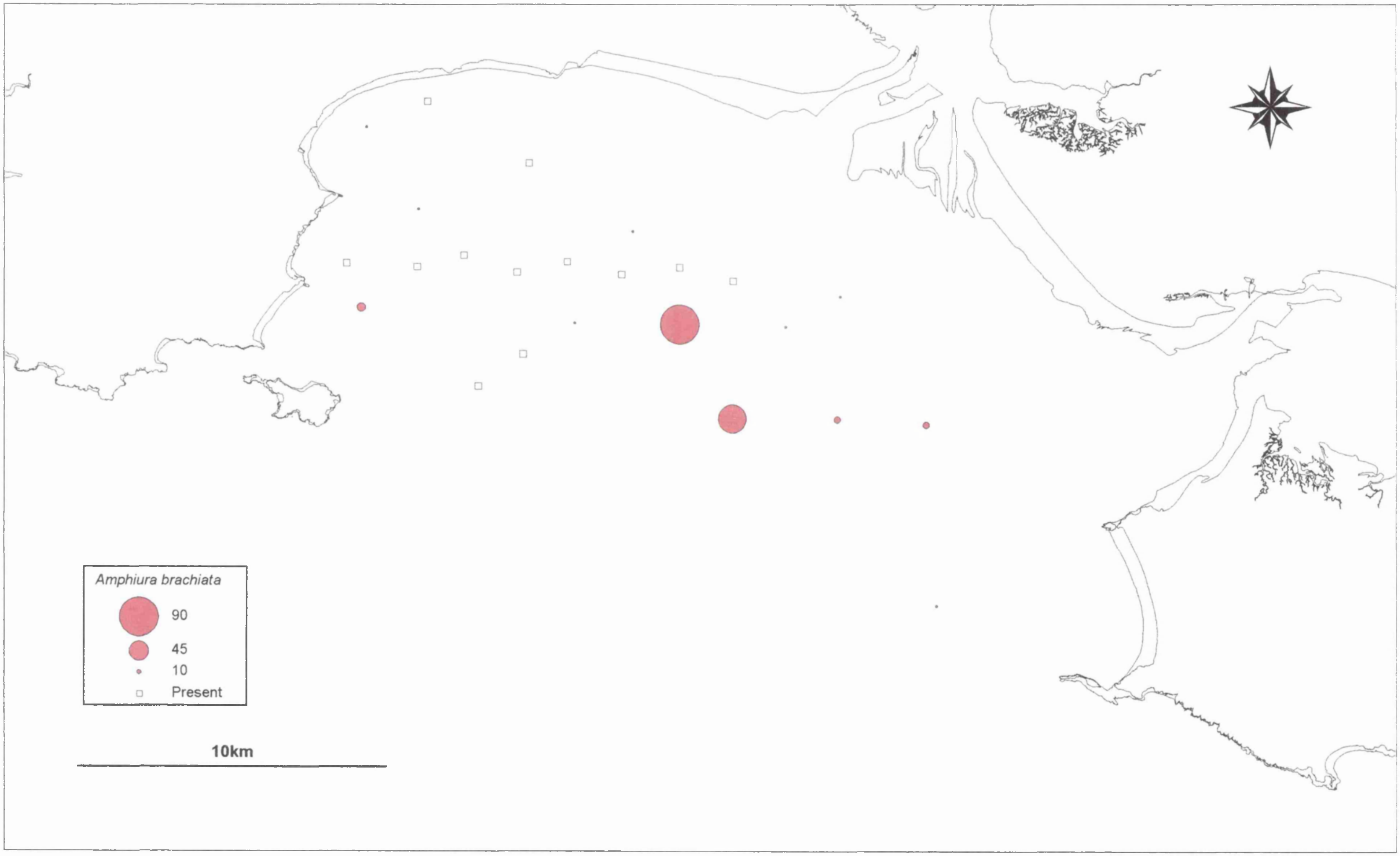
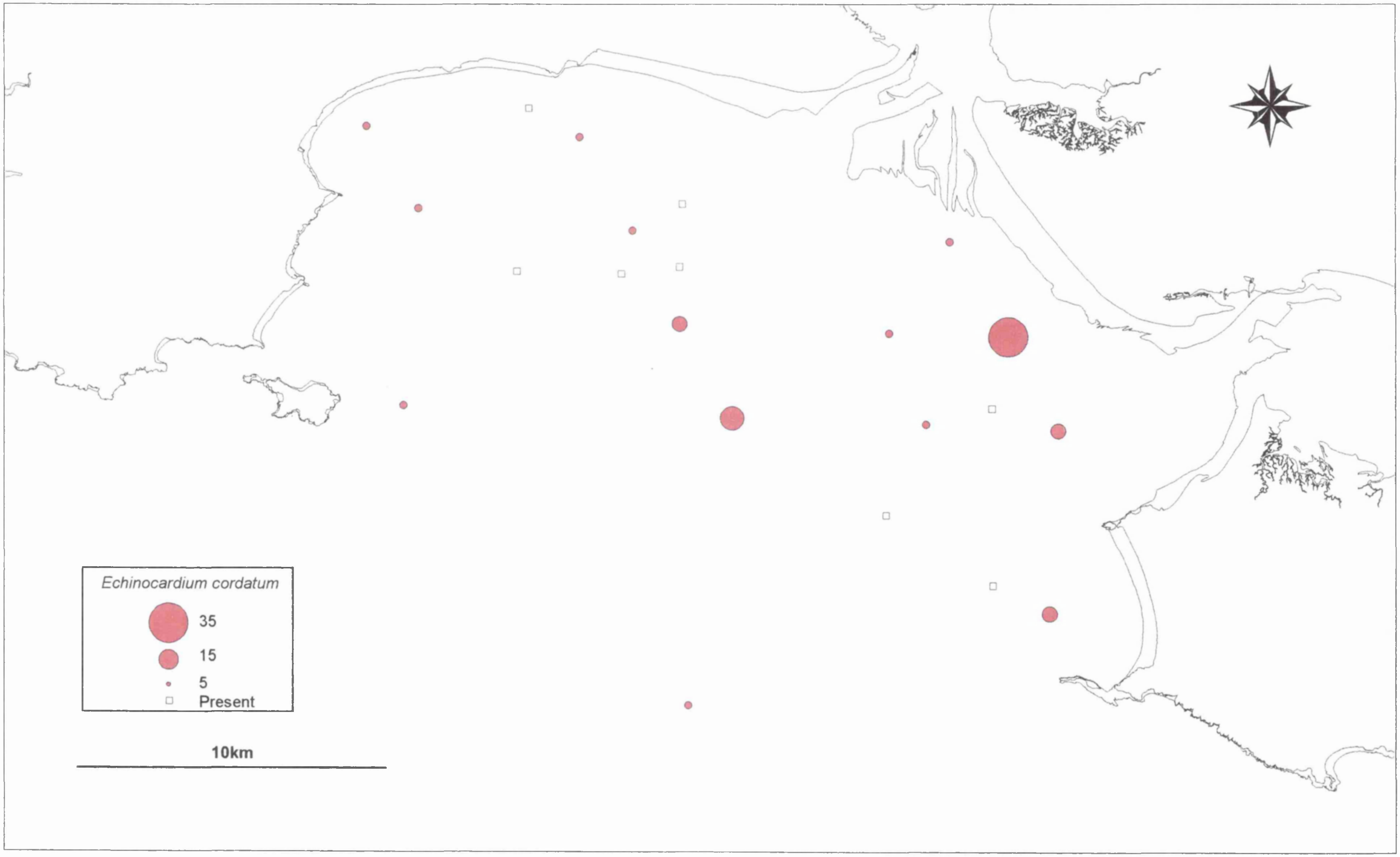


Figure 2.47 *Echinocardium cordatum* Distribution and Abundance (m^{-2})



2. 3. 3 Classification and Ordination

2. 3. 3. 1 Cluster Analysis and Non-metric Multidimensional Scaling (MDS)

Similarities between stations were generally high with all but three values of under 50%. The dendrogram produced from quantitative data showed two main macrofaunal assemblages, A and B, with a single outlier (Station 21: Figure 2.48) Further structure was apparent within Assemblage B and was consequently segregated at the 60% level into B_1 and B_2.

The cluster analysis of the qualitative data revealed similar results to the quantitative cluster analysis. Similarities between qualitative stations were generally high with all but six values of under 50%. The dendrogram produced from the qualitative data showed two main macrofaunal assemblages A and B (Figure 2.50). The further structure apparent within assemblage B in the quantitative data was also apparent in the qualitative cluster analysis and was again categorized as B_1 and B_2.

Table 2.6 Member Stations of Assemblages

	Assemblage A	Assemblage B_1	Assemblage B_2
Quantitative Stations	21, 25, 40, 43, 84 , 87 , 88	31, 34, 41, 42, 45, 48, 51, 54, 55, 56, 57, 58, 60, 64	23, 26, 27, 28, 36, 44, 59
Qualitative Stations	19, 20, 39	37, 46, 47, 49, 52, 53, 61, 62, 63, 65, 66, 67, 68, 71, 83,	22, 29, 30, 32, 33, 35, 50, 69, 70, 72, 80, 81, 82

The MDS ordinations of the quantitative data confirmed the presence of the two main assemblages A and B identified in the cluster analysis (Figure 2.49). The low stress value of 0.08 indicates a good ordination. Assemblage A is shown as a disparate group of stations between the outlier Station 21 and Assemblage B. The internal structure of Assemblage B implied by the cluster analysis was portrayed as a closely allied group of stations (B_1) surrounded by a series of more disparate ones (B_2), although the boundary between B_1 and B_2 was not obvious, station 28 seemingly a member of B_1. The fine structure of Assemblage B was better demonstrated in a 3D MDS plot of communities (Figure 2.50). The nucleus of stations constituting Assemblage B_1 was shown surrounded by the outlying stations of Assemblage B_2 including Station 28 which was shown to be higher in the MDS 3 (Z) axis than the stations of Assemblage B_1.

The MDS ordination (Figure 2.52) of the qualitative data demonstrates a clear difference between the stations of Assemblage A and those of Assemblage B identified by the cluster analysis (Figure 2.52). The low stress value of 0.08 indicates a good ordination. The stations of Assemblage A were shown to be clearly separate from those of Assemblage B. The fine internal structure of Assemblage B was apparent at a nucleus of tightly allied stations surrounded by more disparate stations. The boundary between assemblages B_1 and B_2 was not obvious. A 3D MDS plot more clearly demonstrates the fine internal structure of Assemblage B (Figure 2.53).

Figure 2.54 describes the distributions of these assemblages in Carmarthen Bay. Assemblage A is distributed along the southern edge of the bay, around the peripheral headlands and at the mouth of the Loughor estuary. Assemblage B_1 is distributed in the sheltered north of Carmarthen Bay and in an area south of the Three River estuary and west of Pembrey Sands. Assemblage B_2 is distributed in two areas of clean fine sand on either side of Carmarthen Bay separated by the extension of Assemblage B_1 in the centre of the bay.

Figure 2.48 Cluster Dendrogram of Quantitative Stations

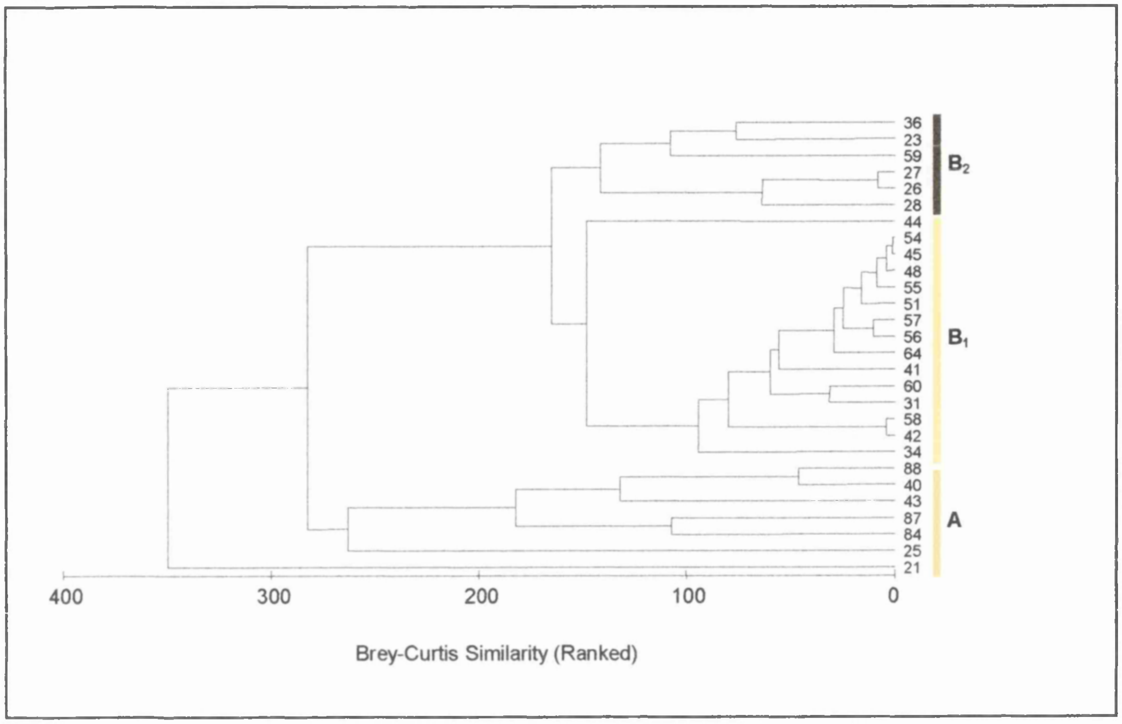


Figure 2.49 MDS Ordination of Quantitative Stations

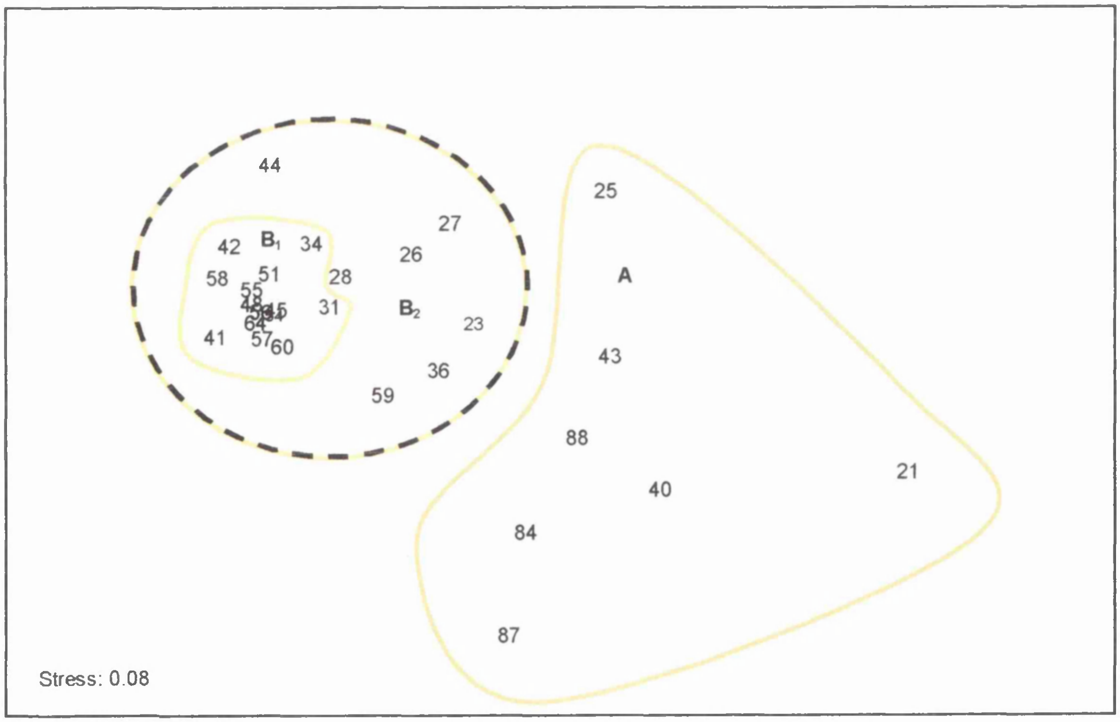


Figure 2.50 3D MDS Plot of Quantitative Stations

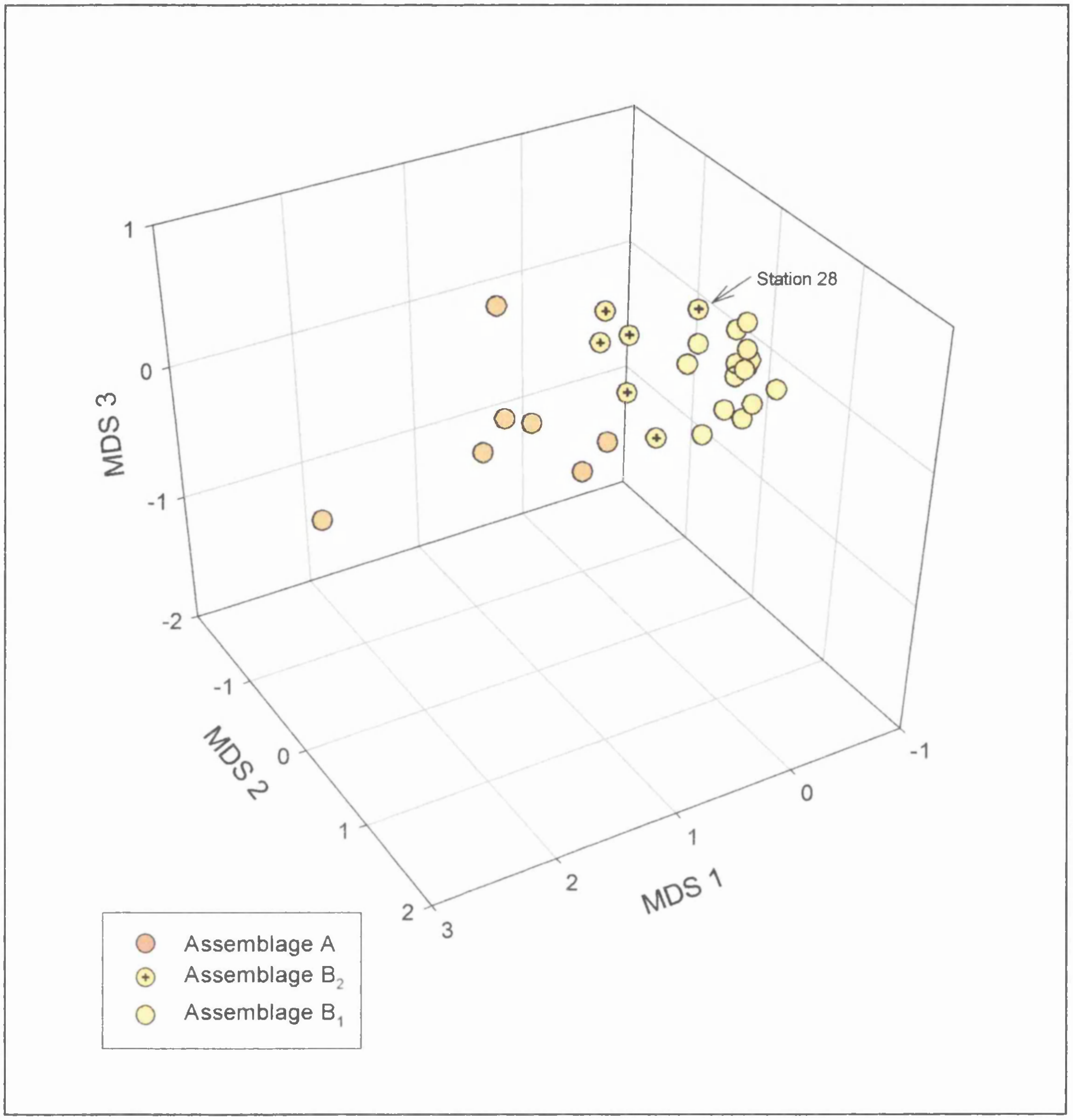


Figure 2.51 Cluster Dendrogram of Qualitative Stations

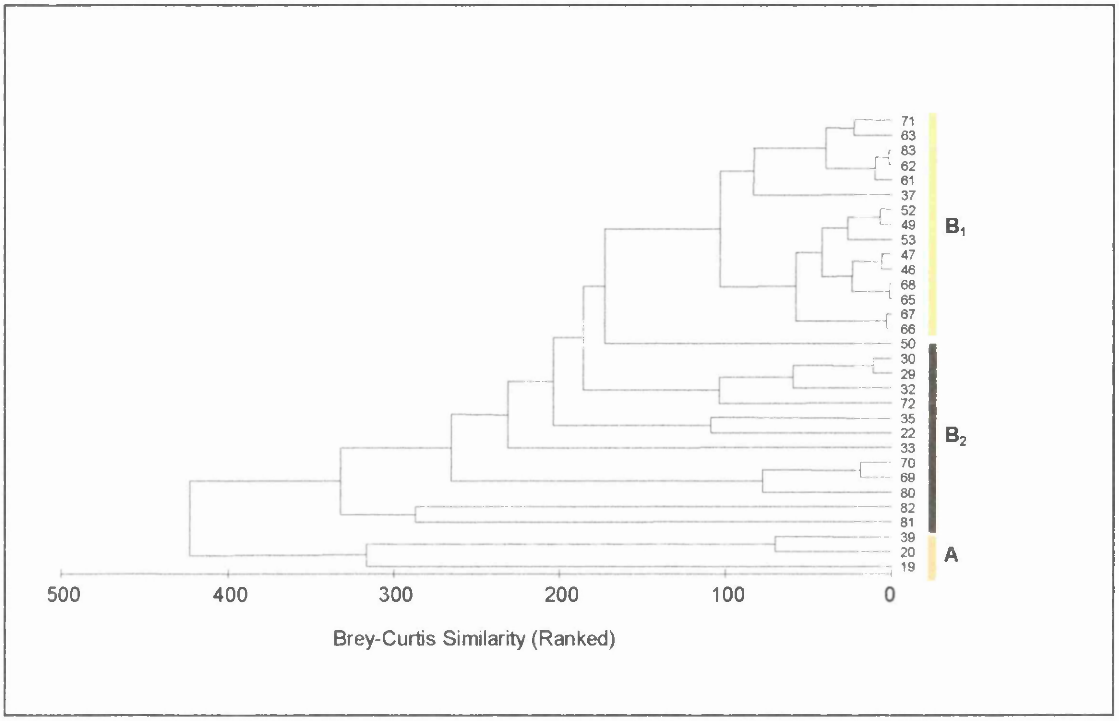


Figure 2.52 MDS Ordination of Qualitative Stations

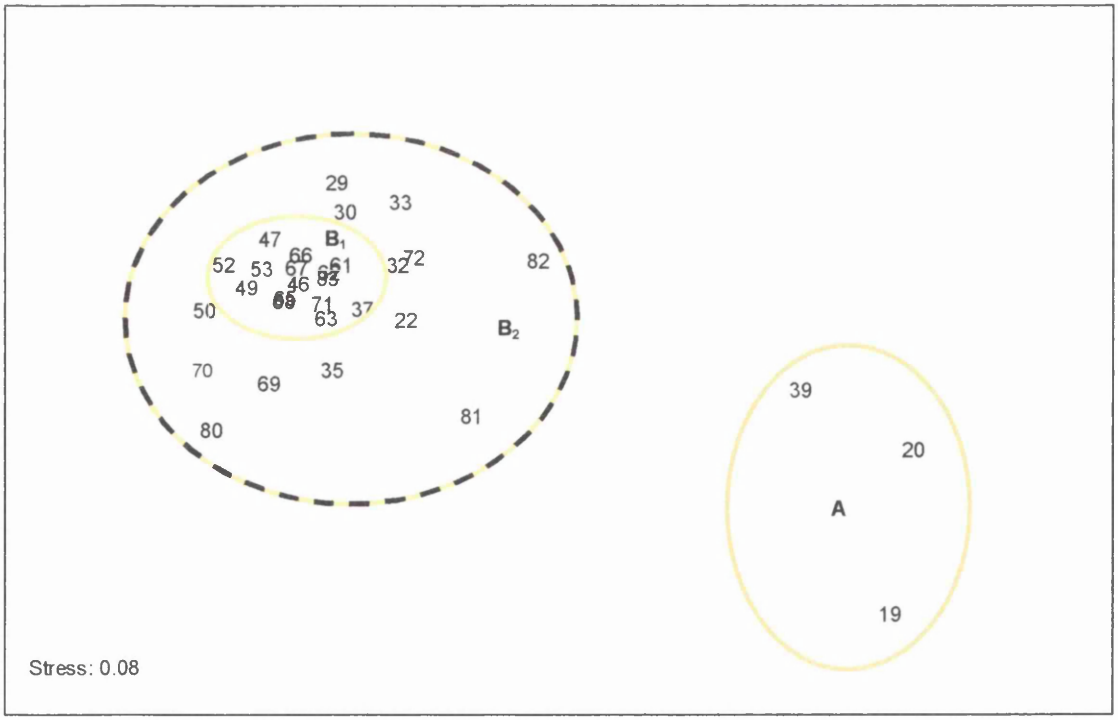


Figure 2.53 3D MDS Plot of Qualitative Stations

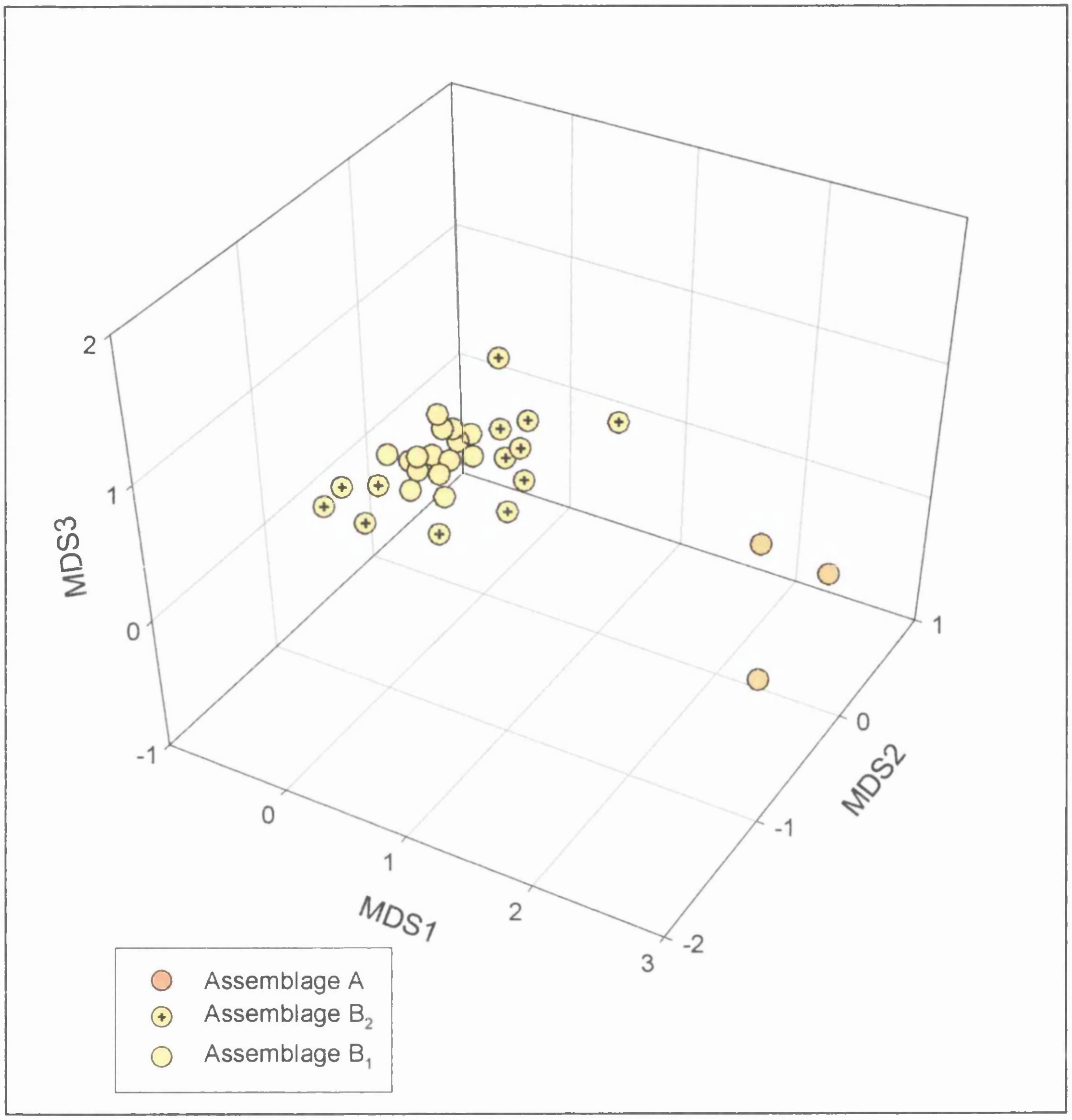
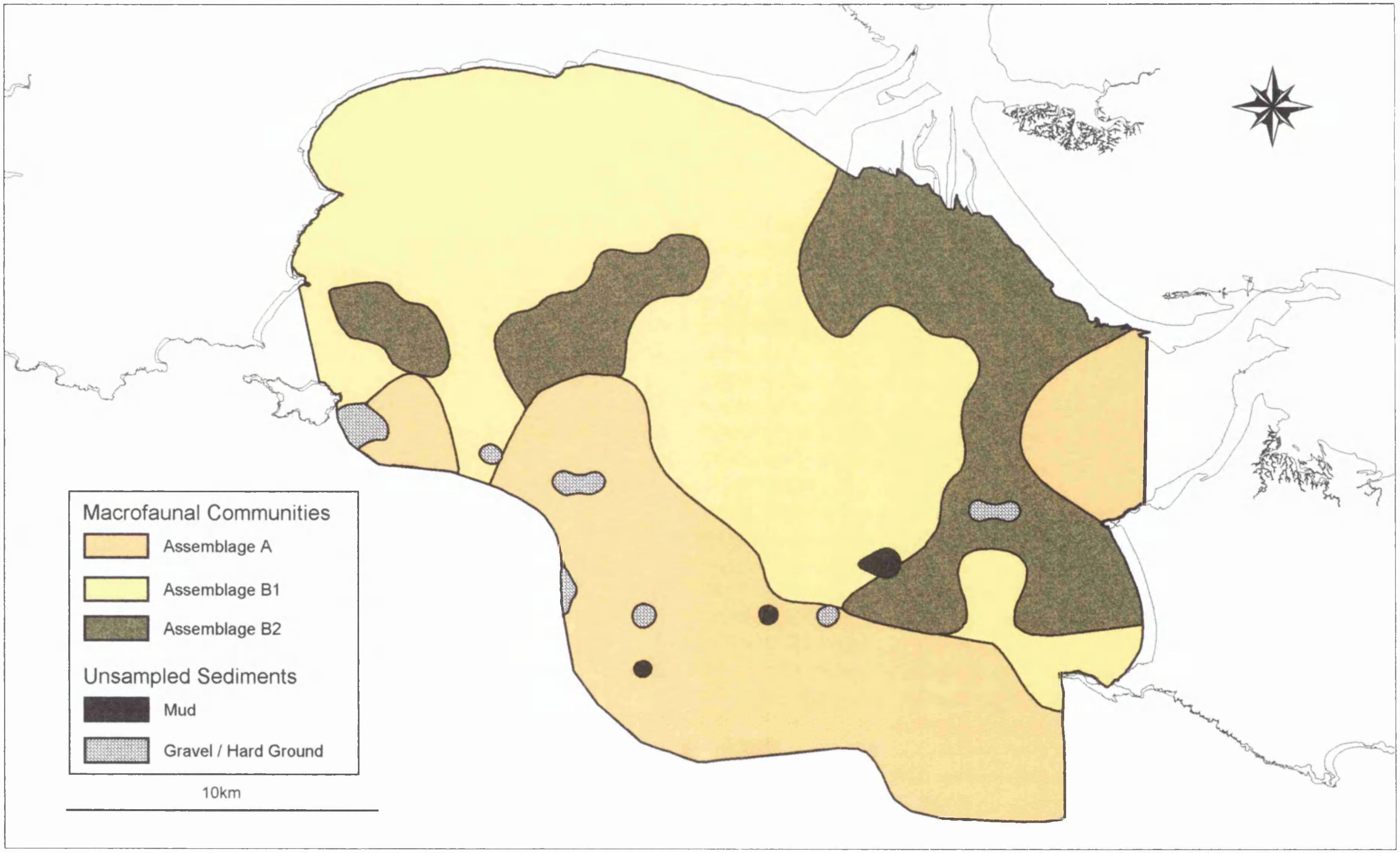


Figure 2.54 Map of Macrofaunal Communities



2. 3. 3. 2 SIMPER Analysis

The faunal assemblages A, B_1 and B_2 identified by the cluster analysis of the quantitative and qualitative data were further examined by the similarity percentage breakdown procedure (SIMPER) which established the taxa principally responsible for differences between assemblages.

Assemblage A was a relatively loosely allied group of stations with an average similarity of 44.88 (Table 2.7). The species accounting for the largest proportion of total similarity in Assemblage A were the errant polychaete *N. cirrosa* (17.35%), the cumacean *P. longicornis* (16.27%), the most abundant species in this assemblage and the polychaete *S. bombyx* (13.55%). Assemblage B_1 was the most coherently grouped series of stations with an average similarity of 65.78 (Table 2.8). The taxa accounting for the largest proportion of the similarity in Assemblage B_1 were the polychaete *S. bombyx* (8.86%), the polychaete *Magelona* sp.(7.84%) and the bivalve *F. fabula*. *Spiophanes bombyx* was the most abundant taxon in this assemblage. Assemblage B_2 was a relatively closely grouped series of stations with an average similarity of 59.86 (Table 2.9). Taxa accounting for the largest proportion of the similarity in Assemblage B_2 were the polychaete *Spio* sp. (10.19%), the cumacean *P. longicornis* (9.41%) and the polychaete *Magelona* sp. (9.05%). The polychaete was again the most abundant taxon in this assemblage.

The greatest difference calculated was between Assemblage A and Assemblage B_1 with a dissimilarity of 71.73 (Table 2.11). Taxa accounting for the largest proportion of dissimilarity between assemblages A and B_1 were the bivalve *F. fabula* (4.62%) and the polychaetes *Magelona* sp. (4.47%) and *S. bombyx* (3.74%). The second ranked difference between assemblages was between Assemblage A and Assemblage B_2 with a dissimilarity of 59.77 (Table 2.10). Taxa accounting for the largest proportion of dissimilarity between assemblages A and B_2 were the polychaete *Magelona* sp. (5.66%), the bivalve *F. fabula* (4.98%) and the polychaete *Spio* sp. (4.73%). The least different assemblages were B_1 and B_2 with a dissimilarity of 46.39 (Table 2.12). Species accounting for the largest proportion of dissimilarity between assemblages B_1 and B_2 were the bivalve *T. phaseolina* (3.79%), the bivalve *C. gallina* (3.72%) and the errant polychaete *N. cirrosa* (3.20%)

Table 2.7 Simper Results Table Assemblage A. Average Similarity 44.88

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Nephtys cirrosa	13.57	7.79	4.39	17.35	17.35
Pseudocuma longicornis	48.57	7.30	2.11	16.27	33.62
Spiophanes bombyx	16.29	6.08	2.39	13.55	47.18
Nephtys JUV.	12.71	5.56	4.42	12.39	59.57
Mactra stultorum	9.29	3.44	1.21	7.66	67.23
Spio sp.	8.29	2.76	1.00	6.15	73.38
Scolelepis bonnieri	4.14	2.06	0.87	4.60	77.97
Lanice conchilega	2.71	1.36	0.88	3.03	81.01
Fabulina fabula	1.57	1.19	0.88	2.65	83.65
Magelona sp.	7.71	1.04	0.50	2.33	85.98
Corystes cassivelaunus	1.14	0.97	0.61	2.17	88.15
Glycera tridactyla	1.86	0.78	0.57	1.74	89.89
Synchelidium maculatum	1.71	0.76	0.58	1.70	91.59

Table 2.8 Simper Results Tables Assemblage B_1. Average Similarity 65.78

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Spiophanes bombyx	381.93	5.83	8.12	8.86	8.86
Magelona sp.	183.73	5.16	5.75	7.84	16.70
Fabulina fabula	144.27	4.88	6.24	7.41	24.11
Spio sp.	83.60	3.57	2.28	5.43	29.55
Pseudocuma longicornis	42.80	2.86	2.93	4.34	33.89
Chamelea gallina	24.60	2.76	3.24	4.20	38.08
Chaetozone setosa	28.00	2.72	3.21	4.13	42.22
Phaxas pellucidus	28.67	2.49	2.62	3.78	46.00
Thracia phaseolina	39.87	2.48	2.35	3.77	49.77
Perioculodes longimanus	23.60	2.35	2.42	3.57	53.33
Mactra stultorum	31.87	2.18	1.50	3.31	56.64
Owenia fusiformis	14.87	2.05	3.15	3.12	59.76
Sigalion mathildae	9.60	1.81	2.48	2.76	62.51
Synchelidium maculatum	8.73	1.79	3.14	2.73	65.24
Glycera tridactyla	8.93	1.77	3.00	2.69	67.93
Mysella bidentata	33.87	1.69	1.64	2.56	70.49
Nephtys JUV.	16.33	1.68	1.47	2.56	73.05
Lanice conchilega	26.47	1.50	1.73	2.28	75.33
Capitella sp.	7.40	1.42	1.60	2.15	77.49
Phoronis sp.	4.80	1.33	2.86	2.03	79.51
Bathyporeia tenuipes	7.33	1.10	1.35	1.67	81.18
Turbonilla lactea	4.13	1.03	1.74	1.57	82.75
Eteone longa	5.13	1.01	1.27	1.53	84.28
Iphinoe trispinosa	5.60	0.82	1.12	1.25	85.53
Pariambus typicus	5.00	0.73	0.97	1.12	86.64
OLIGOCHAETA	4.73	0.71	0.81	1.07	87.72
Bathyporeia sp.	3.40	0.59	1.05	0.89	88.61
Tellimya ferruginosa	6.13	0.56	0.62	0.85	89.46
Pontocrates arenarius	7.20	0.56	0.58	0.85	90.31

Table 2.9 Simper Results Table Assemblage B_2. Average Similarity 59.86

Species	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Spio sp.	77.67	6.10	9.08	10.19	10.19
Pseudocuma longicornis	70.83	5.63	7.06	9.41	19.60
Magelona sp.	166.67	5.42	5.61	9.05	28.64
Spiophanes bombyx	151.00	5.09	4.17	8.51	37.15
Fabulina fabula	49.50	4.75	7.25	7.93	45.08
Nephtys JUV.	22.00	3.98	7.52	6.65	51.73
Mactra stultorum	27.50	3.97	3.73	6.64	58.37
Pontocrates arenarius	19.33	3.68	5.16	6.15	64.52
Nephtys cirrosa	19.83	2.61	1.18	4.35	68.87
Owenia fusiformis	21.00	2.35	1.37	3.93	72.80
Phaxas pellucidus	15.17	2.19	2.37	3.66	76.46
Lanice conchilega	15.83	1.43	1.02	2.39	78.85
Glycera tridactyla	7.50	1.35	1.23	2.26	81.11
Capitella sp.	16.33	1.20	0.75	2.00	83.11
Perioculodes longimanus	5.17	0.98	1.07	1.63	84.74
Mysella bidentata	2.50	0.90	1.11	1.50	86.24
Bathyporeia elegans	6.00	0.84	0.74	1.41	87.65
Tellimya ferruginosa	16.00	0.82	0.48	1.37	89.02
Bathyporeia tenuipes	3.33	0.82	0.73	1.36	90.38

Table 2.10 Simper Results Table Groups A and B_2 Average Dissimilarity 59.77

Species	**Av.Abund (A)**	**Av.Abund (B_2)**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Magelona sp.	7.71	166.67	3.38	1.93	5.66	5.66
Fabulina fabula	1.57	49.50	2.97	2.99	4.98	10.64
Spio sp.	8.29	77.67	2.82	2.27	4.73	15.36
Owenia fusiformis	0.14	21.00	2.40	1.69	4.01	19.37
Pontocrates arenarius	1.00	19.33	2.40	2.57	4.01	23.38
Spiophanes bombyx	16.29	151.00	1.97	1.16	3.30	26.68
Capitella sp.	0.29	16.33	1.78	1.28	2.97	29.65
Phaxas pellucidus	2.00	15.17	1.64	1.66	2.74	32.40
Tellimya ferruginosa	1.29	16.00	1.64	1.01	2.74	35.14
Mactra stultorum	9.29	27.50	1.63	1.35	2.73	37.86
Lanice conchilega	2.71	15.83	1.54	1.19	2.58	40.44
Bathyporeia elegans	4.43	6.00	1.41	1.28	2.35	42.80
Pseudocuma longicornis	48.57	70.83	1.39	0.97	2.32	45.12
Glycera tridactyla	1.86	7.50	1.27	1.43	2.12	47.24
Perioculodes longimanus	0.71	5.17	1.23	1.19	2.06	49.30
Scolelepis bonnieri	4.14	0.33	1.17	1.47	1.96	51.27
Nephtys JUV.	12.71	22.00	1.17	1.75	1.95	53.22
Bathyporeia tenuipes	0.43	3.33	1.09	1.24	1.83	55.05
Nephtys cirrosa	13.57	19.83	1.09	1.53	1.83	56.88
Acanthocardia echinata	0.14	19.50	1.08	0.72	1.80	58.68
Synchelidium maculatum	1.71	3.33	0.98	1.05	1.63	60.31
Bathyporeia sp.	0.29	2.50	0.96	1.08	1.60	61.91
Mysella bidentata	0.57	2.50	0.93	1.50	1.56	63.47
Chaetozone setosa	0.00	5.50	0.86	0.63	1.44	64.91
Nephtys assimilis	0.14	2.17	0.84	1.17	1.41	66.32
Megaluropus agilis	2.29	1.33	0.83	0.83	1.39	67.71
Pontocrates altamarinus	0.71	1.83	0.83	1.09	1.38	69.09
Eteone longa	0.00	2.17	0.79	1.17	1.33	70.42
Donax vittatus	0.00	2.83	0.74	0.69	1.24	71.66
Sigalion mathildae	0.00	1.67	0.71	1.19	1.20	72.86
Phyllodoce rosea	0.00	2.17	0.69	0.89	1.15	74.01
Corystes cassivelaunus	1.14	1.17	0.68	1.29	1.14	75.15
Phyllodocidae JUV.	3.57	0.00	0.67	0.65	1.12	76.27
Phyllodocidae sp.	0.29	2.33	0.65	0.78	1.08	77.35
Lagis koreni	0.00	1.50	0.65	0.96	1.08	78.43
Echinocardium cordatum	0.57	1.33	0.64	1.03	1.07	79.50
Corymorpha nutans	1.14	0.83	0.63	0.91	1.06	80.56
Molgula occulta	0.00	3.33	0.61	0.44	1.02	81.58
Iphinoe trispinosa	0.14	2.00	0.59	0.84	0.99	82.57
Ophelia borealis	1.00	0.17	0.51	0.89	0.86	83.43
Pariambus typicus	0.43	0.67	0.46	1.00	0.78	84.21
OLIGOCHAETA	2.14	0.00	0.38	0.40	0.63	84.84
Harmothoe imbricata	0.00	0.67	0.37	0.59	0.62	85.46
Bodotria arenosa	0.71	0.00	0.36	0.62	0.60	86.07
Mysta picta	0.14	0.67	0.36	0.57	0.60	86.67
Turbonilla lactea	0.00	0.67	0.35	0.68	0.58	87.25
Amphiura brachiata	0.00	0.50	0.34	0.96	0.57	87.82
Urothoe poseidonis	0.00	1.17	0.34	0.44	0.57	88.39
Orbinia latreillii	0.14	0.50	0.33	0.76	0.55	88.94
Diogenes pugilator	0.14	0.67	0.33	0.56	0.55	89.49
Lumbrineris gracilis	0.00	0.50	0.32	0.67	0.53	90.02

Table 2.11 Simper Results Table Groups A and B_1 Average Dissimilarity 71.73

Species	**Av.Abund (A)**	**Av.Abund (B_1)**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Fabulina fabula	1.57	144.27	3.31	3.73	4.62	4.62
Magelona sp.	7.71	183.73	3.21	2.35	4.47	9.09
Spiophanes bombyx	16.29	381.93	2.68	2.41	3.74	12.83
Chaetozone setosa	0.00	28.00	2.46	3.27	3.43	16.26
Thracia phaseolina	0.00	39.87	2.46	2.58	3.42	19.68
Chamelea gallina	0.14	24.60	2.37	3.06	3.30	22.99
Spio sp.	8.29	83.60	2.16	1.95	3.01	26.00
Perioculodes longimanus	0.71	23.60	2.01	2.20	2.81	28.80
Nephtys cirrosa	13.57	0.47	1.91	3.62	2.66	31.46
Phaxas pellucidus	2.00	28.67	1.90	1.95	2.65	34.11
Owenia fusiformis	0.14	14.87	1.85	2.80	2.57	36.69
Mysella bidentata	0.57	33.87	1.76	1.63	2.45	39.14
Sigalion mathildae	0.00	9.60	1.71	2.80	2.38	41.52
Mactra stultorum	9.29	31.87	1.40	1.50	1.95	43.48
Capitella sp.	0.29	7.40	1.37	1.95	1.90	45.38
Phoronis sp.	0.00	4.80	1.28	2.69	1.79	47.17
Bathyporeia tenuipes	0.43	7.33	1.21	1.57	1.69	48.85
Eteone longa	0.00	5.13	1.19	1.63	1.66	50.51
Lanice conchilega	2.71	26.47	1.18	1.21	1.65	52.16
Synchelidium maculatum	1.71	8.73	1.15	1.59	1.61	53.77
Glycera tridactyla	1.86	8.93	1.14	1.52	1.59	55.36
Pseudocuma longicornis	48.57	42.80	1.12	1.22	1.56	56.92
Turbonilla lactea	0.00	4.13	1.11	2.05	1.55	58.47
OLIGOCHAETA	2.14	4.73	1.05	1.23	1.47	59.94
Iphinoe trispinosa	0.14	5.60	1.03	1.35	1.44	61.37
Pontocrates arenarius	1.00	7.20	1.00	1.04	1.40	62.77
Tellimya ferruginosa	1.29	6.13	1.00	1.08	1.39	64.16
Nephtys JUV.	12.71	16.33	0.96	1.44	1.34	65.50
Pariambus typicus	0.43	5.00	0.93	1.27	1.30	66.80
Scolelepis bonnieri	4.14	0.47	0.92	1.35	1.29	68.09
Podarkeopsis capensis	0.00	4.20	0.78	1.03	1.08	69.17
Bathyporeia sp.	0.29	3.40	0.76	1.10	1.06	70.23
Euclymene oerstedii	0.00	9.20	0.75	0.73	1.04	71.27
Cylichna cylindracea	0.00	2.87	0.73	1.16	1.01	72.28
Bathyporeia elegans	4.43	2.07	0.71	0.82	0.98	73.27
Megaluropus agilis	2.29	1.67	0.70	1.01	0.97	74.24
Amphiura brachiata	0.00	3.00	0.63	0.92	0.88	75.12
Phyllodoce rosea	0.00	3.07	0.61	0.82	0.86	75.98
Modiolus modiolus	0.14	8.87	0.59	0.65	0.82	76.80
Phyllodocidae JUV.	3.57	0.53	0.59	0.71	0.82	77.62
Galathowenia sp.	0.00	1.53	0.53	0.97	0.74	78.36
Lumbrineris gracilis	0.00	2.93	0.53	0.72	0.74	79.10
Sagartia troglodytes	0.00	1.40	0.53	1.05	0.74	79.84
Microjassa cumbrensis	0.00	3.00	0.52	0.65	0.72	80.56
Ophiura ophiura	0.00	1.60	0.51	0.93	0.71	81.27
Nephtys assimilis	0.14	1.13	0.46	0.98	0.64	81.91
Corystes cassivelaunus	1.14	0.47	0.46	1.22	0.64	82.54
Corymorpha nutans	1.14	0.60	0.45	0.77	0.63	83.17
Nephtys hombergii	0.00	1.07	0.45	0.97	0.62	83.80
Orbinia latreillii	0.14	1.13	0.44	1.04	0.62	84.41
Phyllodocidae sp.	0.29	1.00	0.43	0.86	0.60	85.02
Acanthocardia echinata	0.14	1.20	0.42	0.87	0.59	85.61
Poecilochaetus serpens	0.00	1.33	0.42	0.64	0.58	86.19
Ophelia borealis	1.00	0.00	0.39	0.80	0.54	86.73
Scoloplos armiger	0.14	1.60	0.38	0.64	0.52	87.25
Echinocardium cordatum	0.57	0.73	0.36	1.10	0.51	87.76
Donax vittatus	0.00	1.00	0.35	0.74	0.49	88.26
Malmgrenia marphysae	0.00	1.07	0.35	0.70	0.49	88.74
Scalibregma inflatum	0.71	0.40	0.35	0.84	0.48	89.23
Nucula sp.	0.00	1.00	0.31	0.64	0.44	89.66
Pholoe sp.	0.00	0.73	0.28	0.77	0.40	90.06

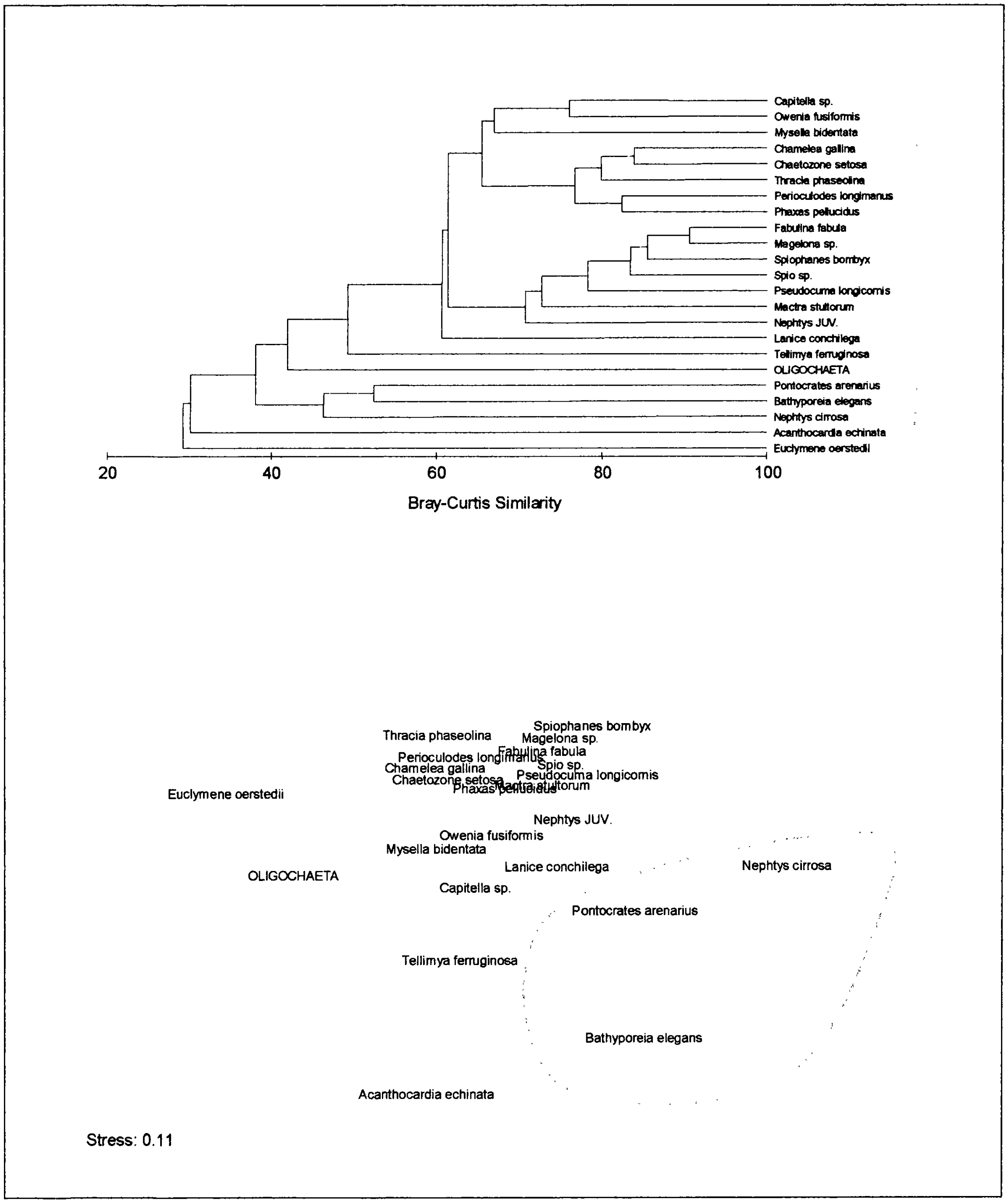
Table 2.12 Simper Results Table Groups B_1 and B_2 Average Dissimilarity 46.39

Species	Av.Abund (B_1)	Av.Abund (B_2)	Av.Diss	Diss/SD	Contrib%	Cum.%
Thracia phaseolina	39.87	0.33	1.76	2.29	3.79	3.79
Chamelea gallina	24.60	0.67	1.73	2.58	3.72	7.52
Nephtys cirrosa	0.47	19.83	1.48	1.76	3.20	10.72
Chaetozone setosa	28.00	5.50	1.48	1.80	3.18	13.90
Pontocrates arenarius	7.20	19.33	1.09	1.65	2.34	16.24
Spiophanes bombyx	381.93	151.00	1.07	1.57	2.31	18.55
Perioculodes longimanus	23.60	5.17	1.06	1.58	2.28	20.83
Tellimya ferruginosa	6.13	16.00	1.04	1.29	2.24	23.07
Mysella bidentata	33.87	2.50	1.03	1.33	2.23	25.29
Synchelidium maculatum	8.73	3.33	0.97	1.88	2.08	27.38
Sigalion mathildae	9.60	1.67	0.92	1.64	1.98	29.36
Lanice conchilega	26.47	15.83	0.91	1.28	1.97	31.33
Phoronis sp.	4.80	0.17	0.91	2.36	1.96	33.30
Capitella sp.	7.40	16.33	0.88	1.49	1.91	35.20
Phaxas pellucidus	28.67	15.17	0.87	1.68	1.87	37.08
Owenia fusiformis	14.87	21.00	0.80	1.55	1.73	38.80
OLIGOCHAETA	4.73	0.00	0.79	1.21	1.70	40.51
Acanthocardia echinata	1.20	19.50	0.78	0.96	1.68	42.19
Fabulina fabula	144.27	49.50	0.78	1.49	1.67	43.86
Bathyporeia elegans	2.07	6.00	0.77	1.28	1.66	45.53
Mactra stultorum	31.87	27.50	0.74	1.10	1.59	47.12
Magelona sp.	183.73	166.67	0.72	1.46	1.56	48.67
Iphinoe trispinosa	5.60	2.00	0.72	1.37	1.55	50.23
Turbonilla lactea	4.13	0.67	0.70	1.56	1.51	51.74
Bathyporeia tenuipes	7.33	3.33	0.69	1.27	1.49	53.22
Nephtys JUV.	16.33	22.00	0.68	1.13	1.46	54.69
Eteone longa	5.13	2.17	0.67	1.39	1.45	56.14
Pseudocuma longicornis	42.80	70.83	0.67	1.34	1.45	57.59
Pariambus typicus	5.00	0.67	0.67	1.31	1.44	59.03
Glycera tridactyla	8.93	7.50	0.66	1.40	1.41	60.45
Bathyporeia sp.	3.40	2.50	0.63	1.41	1.35	61.80
Euclymene oerstedii	9.20	0.00	0.59	0.73	1.27	63.07
Phyllodoce rosea	3.07	2.17	0.56	1.09	1.21	64.28
Podarkeopsis capensis	4.20	0.33	0.56	1.02	1.20	65.48
Donax vittatus	1.00	2.83	0.55	1.01	1.18	66.66
Cylichna cylindracea	2.87	0.17	0.53	1.12	1.14	67.80
Spio sp.	83.60	77.67	0.50	0.74	1.07	68.87
Phyllodocidae sp.	1.00	2.33	0.49	1.04	1.05	69.92
Pontocrates altamarinus	0.00	1.83	0.48	1.09	1.04	70.96
Nephtys assimilis	1.13	2.17	0.48	1.27	1.03	71.98
Megaluropus agilis	1.67	1.33	0.47	0.83	1.01	72.99
Lumbrineris gracilis	2.93	0.50	0.46	0.92	0.99	73.99
Amphiura brachiata	3.00	0.50	0.46	0.99	0.99	74.98
Modiolus modiolus	8.87	0.00	0.43	0.56	0.92	75.90
Galathowenia sp.	1.53	0.00	0.41	0.98	0.89	76.79
Sagartia troglodytes	1.40	0.00	0.41	1.06	0.88	77.67
Microjassa cumbrensis	3.00	0.00	0.40	0.65	0.86	78.53
Lagis koreni	0.47	1.50	0.40	1.29	0.85	79.38
Ophiura ophiura	1.60	0.00	0.40	0.92	0.85	80.24
Echinocardium cordatum	0.73	1.33	0.38	1.15	0.83	81.06
Poecilochaetus serpens	1.33	0.50	0.38	0.78	0.81	81.88
Urothoe poseidonis	0.60	1.17	0.35	0.84	0.76	82.63
Orbinia latreillii	1.13	0.50	0.35	1.10	0.75	83.39
Molgula occulta	0.00	3.33	0.34	0.44	0.73	84.12
Corystes cassivelaunus	0.47	1.17	0.34	0.97	0.73	84.86
Nephtys hombergii	1.07	0.33	0.33	1.07	0.72	85.58
Corymorpha nutans	0.60	0.83	0.33	0.83	0.71	86.29
Scoloplos armiger	1.60	0.17	0.29	0.65	0.64	86.92
Malmgrenia marphysae	1.07	0.00	0.27	0.70	0.58	87.51
Harmothoe imbricata	0.33	0.67	0.26	0.73	0.56	88.07
Mysta picta	0.33	0.67	0.25	0.63	0.53	88.60
Nucula sp.	1.00	0.00	0.24	0.63	0.53	89.12
Harmothoe glabra	0.47	0.33	0.24	0.91	0.52	89.64
Sthenelais limicola	0.40	0.33	0.23	0.92	0.49	90.13

2. 3. 3. 3 Species by Species Cluster Analysis and MDS Ordination

Species by species cluster analysis of the quantitative data was used to identify the presence of faunal assosiations in the commuity and reveals a closely associated group of taxa at the 60% level (Figure 2.55). Outside of this association there is an additional, albeit weaker association around the 45% level. The MDS ordination illustrates these associations.

Figure 2.55 Species by Species Cluster Analysis & MDS Ordination



2. 3. 4 Environmental Influences (BIOENV Analysis)

The BIOENV function of the PRIMER software identified the combination of environmental variables whose MDS ordination best matched that of the macrofaunal MDS ordination.

The combination of environmental variables best matching the macrofaunal samples was that of Depth-Mud-Wave Height returning a harmonic rank correlation (ρ_w) of 0.795, judged 'very good' by Clarke & Ainsworth (1993). These three variables are also ranked the highest single environmental variables (Table 2.13). These variables were plotted superimposed on the macrofaunal MDS (Figure 2.56 a-k). The patterns highlighted by these plots illustrate the environmental gradients acting across the stations.

Table 2.13 BIOENV Best Variable Combinations

n.	(ρ_w)	Best variable combinations
1	0.665	%Mud
1	0.620	Median Phi
1	0.471	Wave Height
2	0.792	%Mud-Median Phi
2	0.743	%Mud-Wave Height
2	0.727	Depth-%Mud
3	**0.795**	**%Mud-Median Phi-Wave Height**
3	0.775	Depth-%Mud-Median Phi
3	0.745	Depth-%Mud-Wave Height
4	0.778	Depth-%Mud- Median Phi-Wave Height
4	0.770	Gravel-%Mud Median Phi-Wave Height
4	0.743	%Mud-Median Phi-Residuals-Wave Height
5	0.761	Depth-%Gravel %Mud-Median Phi-Wave Height
5	0.746	Depth-%Mud-Median Phi-Residuals-Wave Height
5	0.733	Depth-%Sand-Median Phi-Wave Height

Figure 2.56 a-k MDS Ordinations with Individual Environmental Variables Graduated to Relative Size Superimposed.

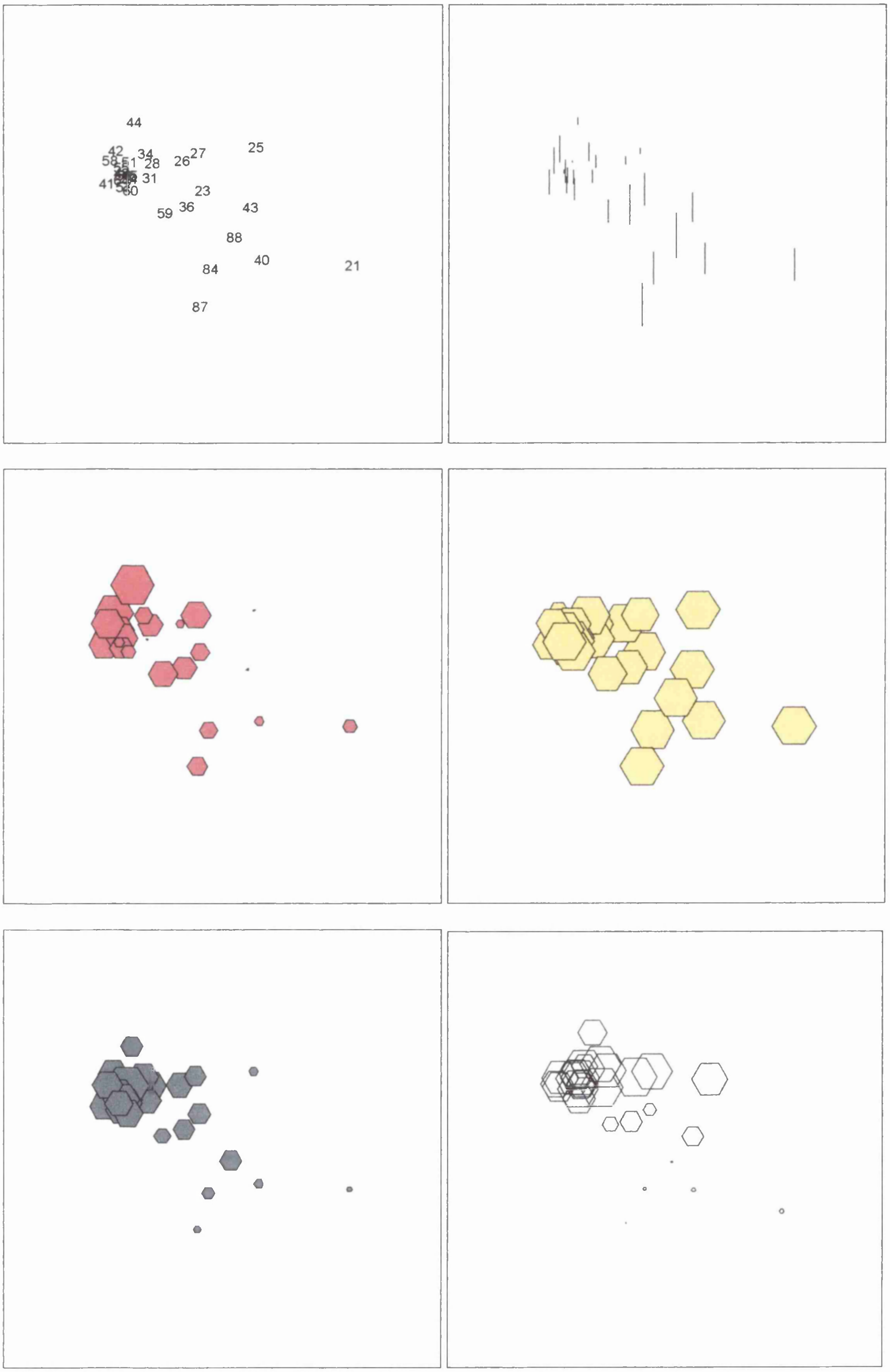
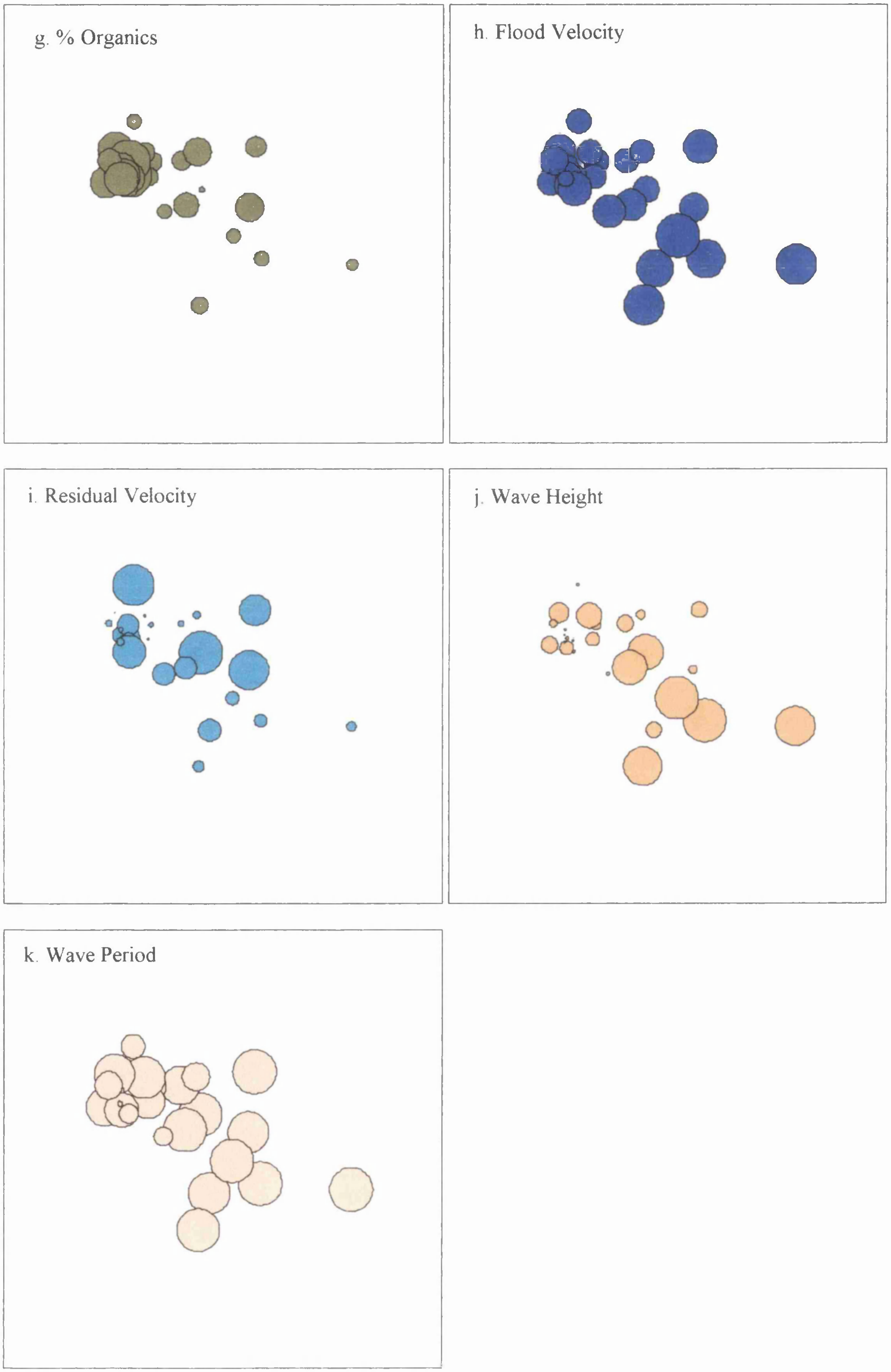


Figure 2.56 continued g-k MDS Ordinations with Superimposed Environmental Variables Graduated to Relative Size.



g. % Organics

h. Flood Velocity

i. Residual Velocity

j. Wave Height

k. Wave Period

3. 3. 5 Species Diversity

A variety of univariate community description variables were calculated from pooled data for each quantitative sampling station. Numbers of individuals (N) are scaled to individual per square metre to aid interpretation.

Table 2.14 Station Diversity Indices. Highest values in **bold**.

Station	**S**	**N**	**α**	**d**	**H**	**H'**	**J**	**E**	**D**	**1 / d**	**ES(100)**
21	**10**	**120**	6.44	**2.83**	**1.55**	2.84	**0.85**	**0.68**	0.86	3.57	-
23	27	1950	6.59	4.36	2.44	3.68	0.77	0.45	0.90	5.41	17.77
25	22	980	6.36	3.98	2.37	3.67	0.82	0.56	0.90	**6.60**	18.02
26	31	3560	6.61	4.57	2.39	3.56	0.72	0.36	0.86	3.24	18.70
27	31	3010	6.92	4.69	2.63	3.93	0.79	0.48	0.91	5.15	20.98
28	40	7125	7.64	5.37	2.30	3.39	0.64	0.24	0.82	2.57	18.28
31	37	5290	7.46	5.17	2.25	3.33	0.64	0.25	0.86	4.54	16.41
34	47	7045	9.36	6.34	2.38	3.52	0.63	0.23	0.87	4.92	18.50
36	32	4940	6.33	4.50	1.73	**2.57**	0.51	0.16	**0.66**	**1.82**	**14.15**
40	15	440	**5.20**	3.13	1.89	3.05	0.78	0.52	0.84	3.60	15.00
41	41	**7570**	7.77	5.46	1.75	2.58	**0.48**	**0.12**	0.68	1.94	15.07
42	53	6335	11.18	7.28	2.35	3.49	0.61	0.20	0.80	2.45	21.93
43	25	880	7.96	4.64	2.01	3.16	0.68	0.33	0.84	3.45	18.10
44	**68**	6355	**15.36**	**9.37**	**2.99**	**4.44**	0.73	0.31	**0.92**	4.81	**27.56**
45	46	5960	9.51	6.35	2.53	3.75	0.68	0.28	0.87	3.43	21.27
48	44	6160	8.91	6.04	2.63	3.89	0.71	0.32	0.88	3.72	21.72
51	48	6250	9.91	6.59	2.76	4.09	0.73	0.34	0.91	5.85	22.51
54	47	6850	9.43	6.37	2.40	3.54	0.64	0.23	0.85	3.44	19.13
55	45	5360	9.51	6.31	2.39	3.55	0.65	0.24	0.83	2.84	20.72
56	44	6785	8.70	5.96	2.34	3.46	0.63	0.23	0.84	3.14	18.85
57	46	7380	9.01	6.17	1.93	2.86	0.52	0.14	0.73	2.08	16.26
58	49	6520	10.06	6.69	2.47	3.66	0.65	0.24	0.85	3.21	21.83
59	33	2895	7.59	5.03	2.34	3.51	0.70	0.33	0.86	3.30	18.15
60	35	6270	6.68	4.77	2.25	3.31	0.65	0.26	0.85	3.67	16.43
64	41	5460	8.41	5.72	2.46	3.65	0.68	0.29	0.88	4.79	18.85
84	24	1170	6.70	4.22	1.81	2.82	0.61	0.26	0.70	1.87	18.04
87	22	1160	5.97	3.86	1.92	2.98	0.67	0.33	0.77	2.25	17.14
88	24	830	7.70	4.50	2.20	3.45	0.75	0.43	0.87	4.49	19.29
Max	68	7570	15.36	9.37	2.99	4.44	0.85	0.68	0.92	6.60	27.56
Min	10	120	5.20	2.83	1.55	2.57	0.48	0.12	0.66	1.82	14.15

Table 2.15 Assemblage Diversity Indices

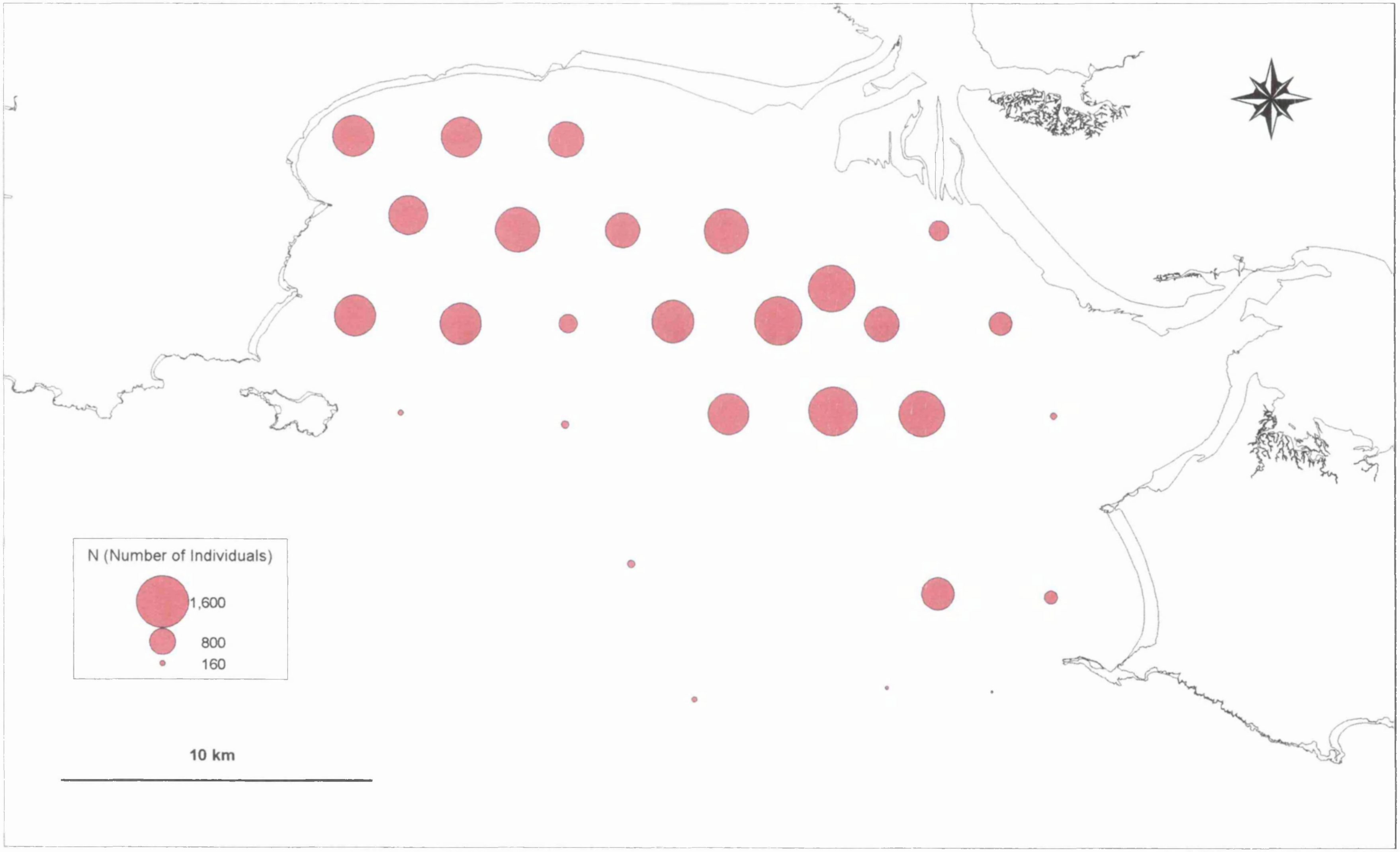
Assemblage	**S**	**N**	**α**	**d**	**H**	**H'**	**J**	**E**	**D**	**1 /d**	**ES(100)**
Mean A	21	802	7.00	4.01	2.00	3.20	0.74	0.45	0.83	3.69	17.04
Mean B_1	47	6396	9.60	6.41	2.40	3.56	0.64	0.25	0.84	3.66	19.98
Mean B_2	33	3943	7.21	4.90	2.33	3.48	0.69	0.34	0.84	3.58	18.45

3. 3. 5. 1 Abundance of Individuals (N)

Numerical abundance of macrofauna varied widely between sites and assemblages with numbers of individuals ranging from 120m^{-2} at Station 21 to 7570m^{-2} at Station 41. In general, the lowest numbers of individuals were recorded at the deeper, southern stations and at the eastern, inshore stations between the Cefn Sidan Sands and Rhossili Bay (Figure 2.57). The stations to the north and west of these are more numerically abundant. Highest abundances were recorded at Stations 28, 34, 41, 57 and 58 in an area west of Pembrey Sands and south of Pendine Sands.

The lowest average abundance of individuals was recorded from Assemblage A with a mean of 802m^{-2}, the highest average abundance was recorded from Assemblage B_1 with a mean of 6396 m^{-2}, Assemblage B_2 averaged 3943m^{-2}.

Figure 2.57 Abundance of Individuals (N)



3. 3. 5. 2 Species Richness

149 taxa were recorded at the quantitative stations. Species richness in Carmarthen Bay ranged from 10 taxa at Station 21 to 68 taxa at Station 44. The general pattern of species richness follows closely that of numerical abundance (Figure 2.58). Low numbers of taxa were recorded at stations in the south and east of the bay, whereas higher numbers were recorded at stations in the centre and west of the bay. To elucidate the association between numerical abundance and species richness a plot of them was produced. This plot of species richness to numerical abundance of the fauna shows a parallel increase in species richness in Assemblage A. Assemblage B_1 and Assemblage B_2 show a corresponding increase in species richness with numerical abundance but to a lesser extent than Assemblage A.

Comparison of rank abundance plots for each community reveals subtle differences between them. Assemblage A exhibits a steep curve comprised of a rapidly declining number of taxa. Assemblages B_1 and B_2 show similarly shaped curves, the disparity between them due mostly to the difference in abundance of the intermediate ranked taxa.

Assemblage A was the least species rich community averaging 20 taxa per station and a range of 12-25. The most species rich was the Assemblage B_1 averaging 46 taxa (range 35-68) while Assemblage B_2 averaged 32 taxa (range 28-41).

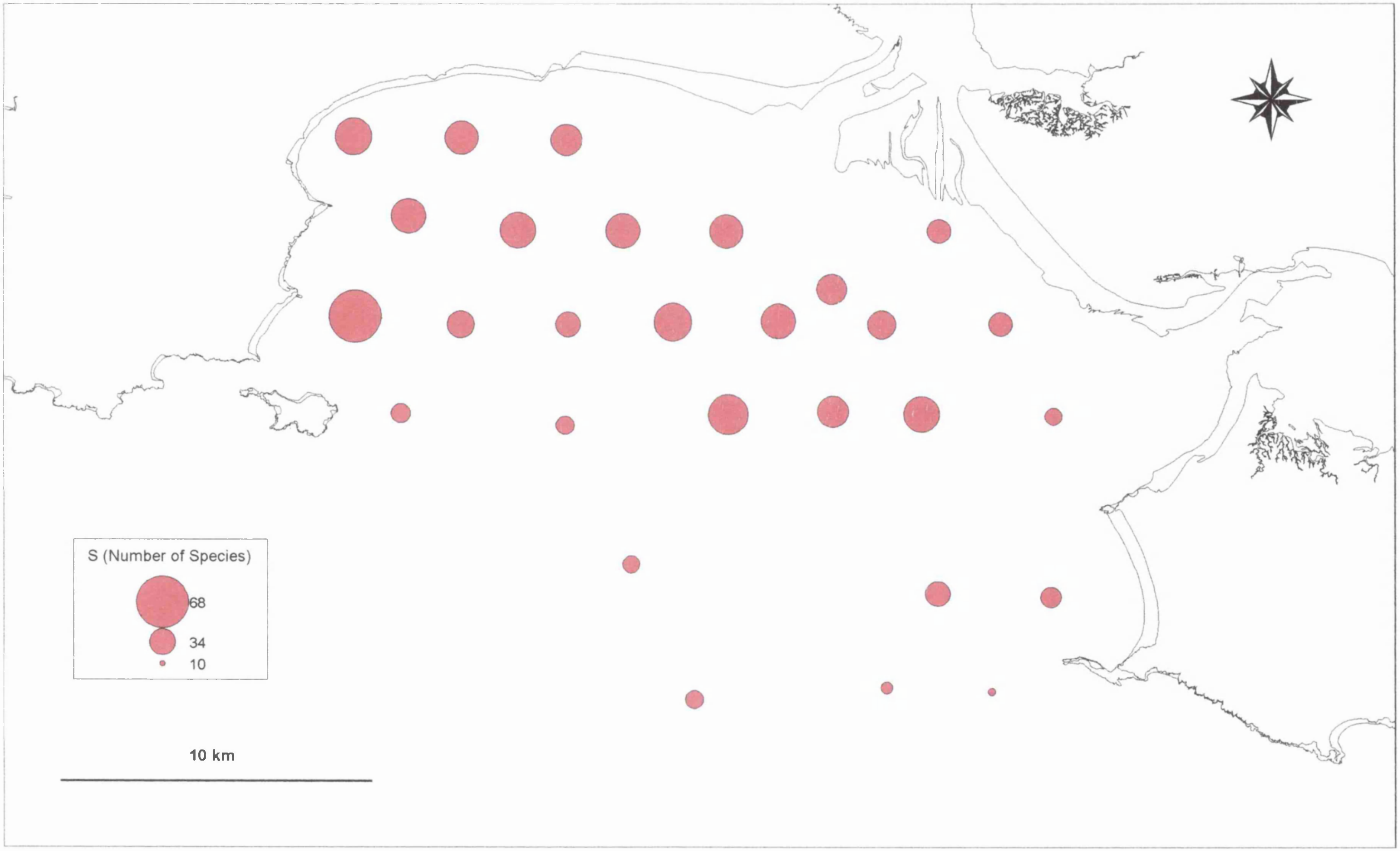


Figure 2.58 Species Richness (S)

Figure 2.59 Relationship of Species Richness / Number of Individuals

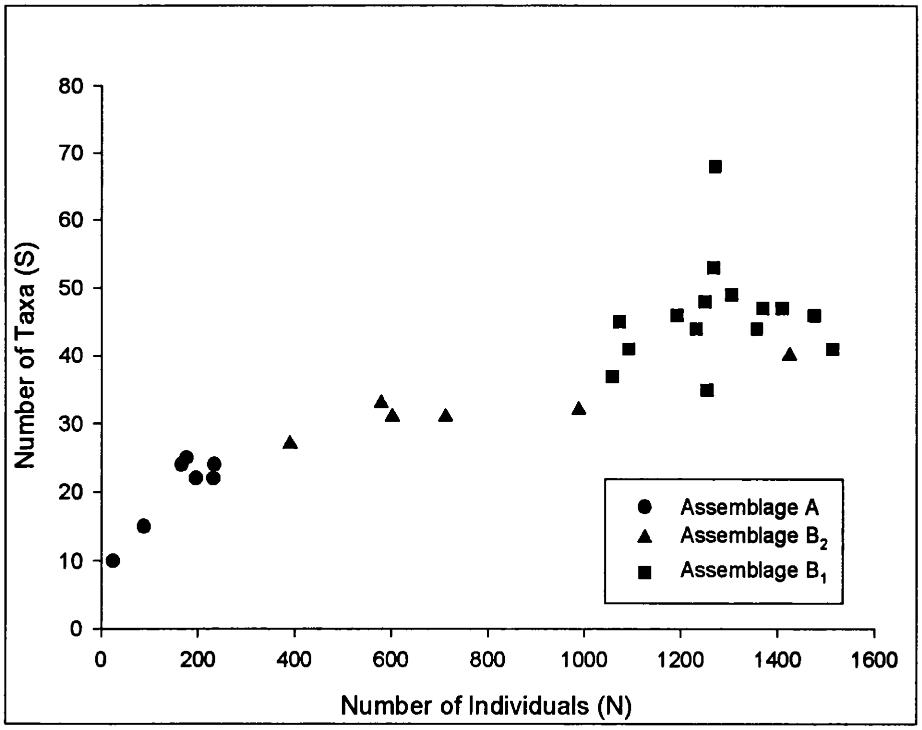
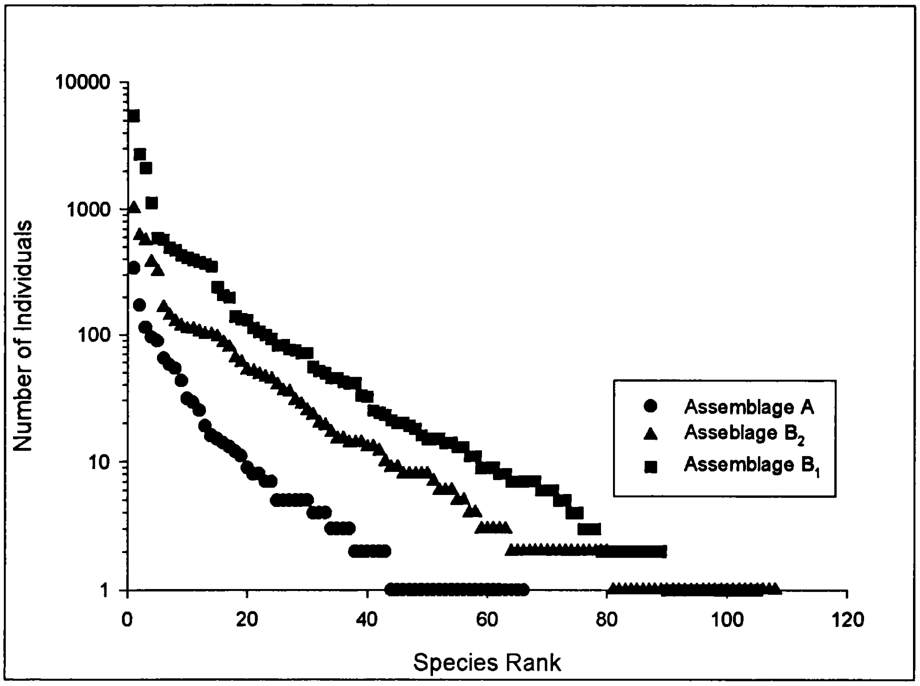


Figure 2.60 Species Dominance Curves



3. 3. 5. 3 Diversity

When plotted, similar classes of diversity measures gave rise to similar patterns of diversity. Both the Margalef's d and Fishers α indices show bias towards species richness in their calculation and therefore demonstrate a similar distribution to that of species richness (Figures 2.61 & 2.62). Both these indices show Station 44 to be the most diverse station. These indices reveal an area of relative high diversity stretching in an arc from the centre of the bay south of the Three River Estuary to Saundersfoot Bay and Tenby. Stations 21 and 40, west of Worms Head, were calculated to be the least diverse stations by Margalef's d and Fishers α respectively. The area of lowest diversity was shown by both measures to be the southernmost stations and those stations in the east of the bay around the mouth of the estuaries.

Both Margalef's d and Fishers α indices demonstrate Assemblage B_1 to be the most diverse on average, Table 2.15. Assemblage A had the lowest average diversity for both indices.

The heterogeneity indices Shannon-Wiener H′ and Brillouin H take both evenness and species richness into account in their calculation, this is reflected in the difference in their distributions relative to the previous species richness biased indices (Figures 2.63 & 2.64). The most diverse station recorded by both indices was Station 44 in a corresponding area of high relative diversity stretching from the north of Caldey Island around Saundersfoot Bay to Ragwen Point. Areas of low diversity are shown west of Worms Head and in the centre of the bay at stations 41 and 57. These stations are low in both species richness and, in the case of stations 41 and 57, evenness. Intermediate values are recorded outside of these areas.

Both indices show Assemblage B_1 to be most diverse with a mean Shannon-Wiener H′ value of 3.56 and a mean Brillouin H value of 2.40. Assemblage A returned the lowest mean value for both Shannon-Wiener H′ and Brillouin H indices.

Figure 2.61 Patterns of Species Diversity (Margalef d)

Figure 2.62 Patterns of Species Diversity (Fishers α)

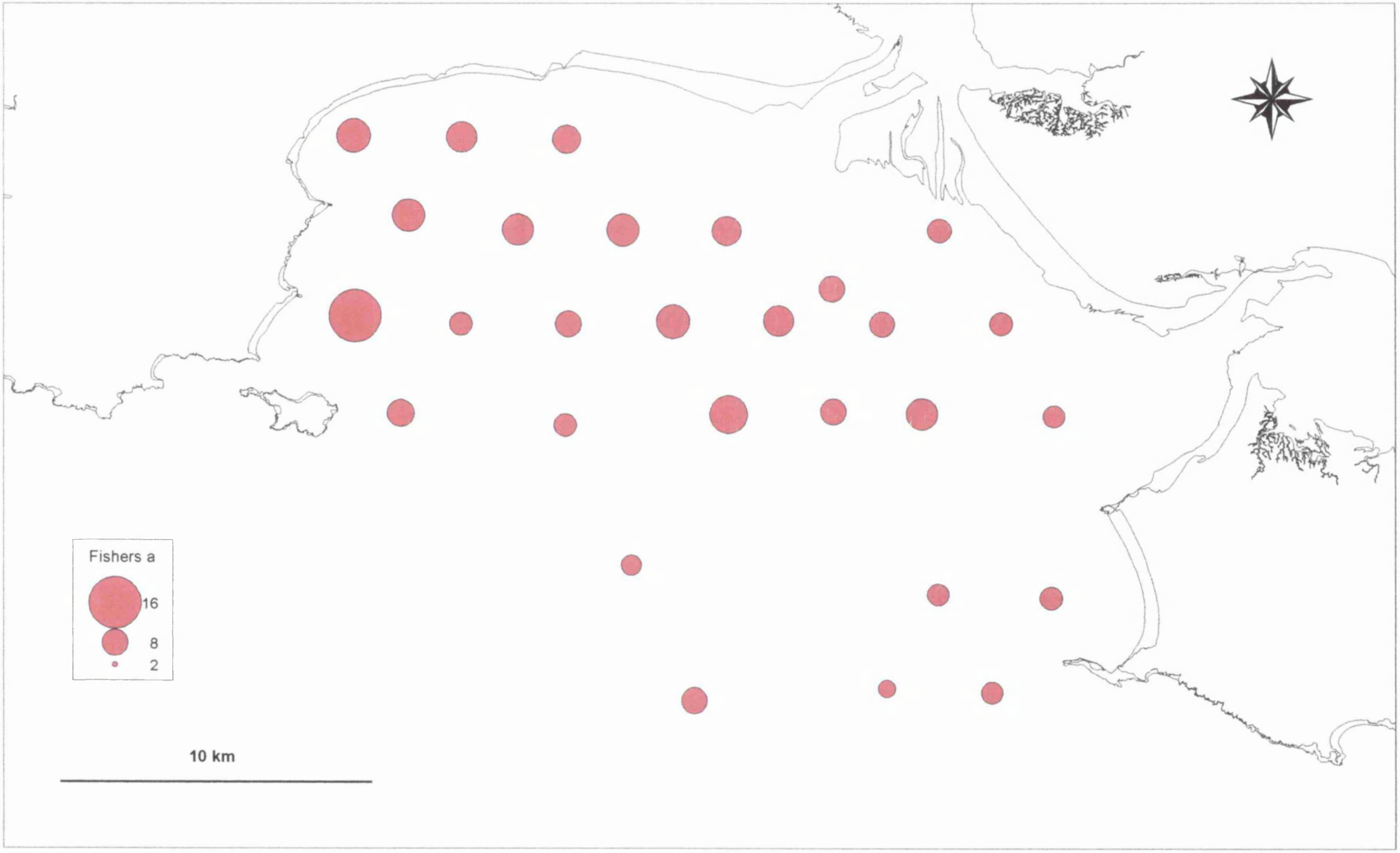
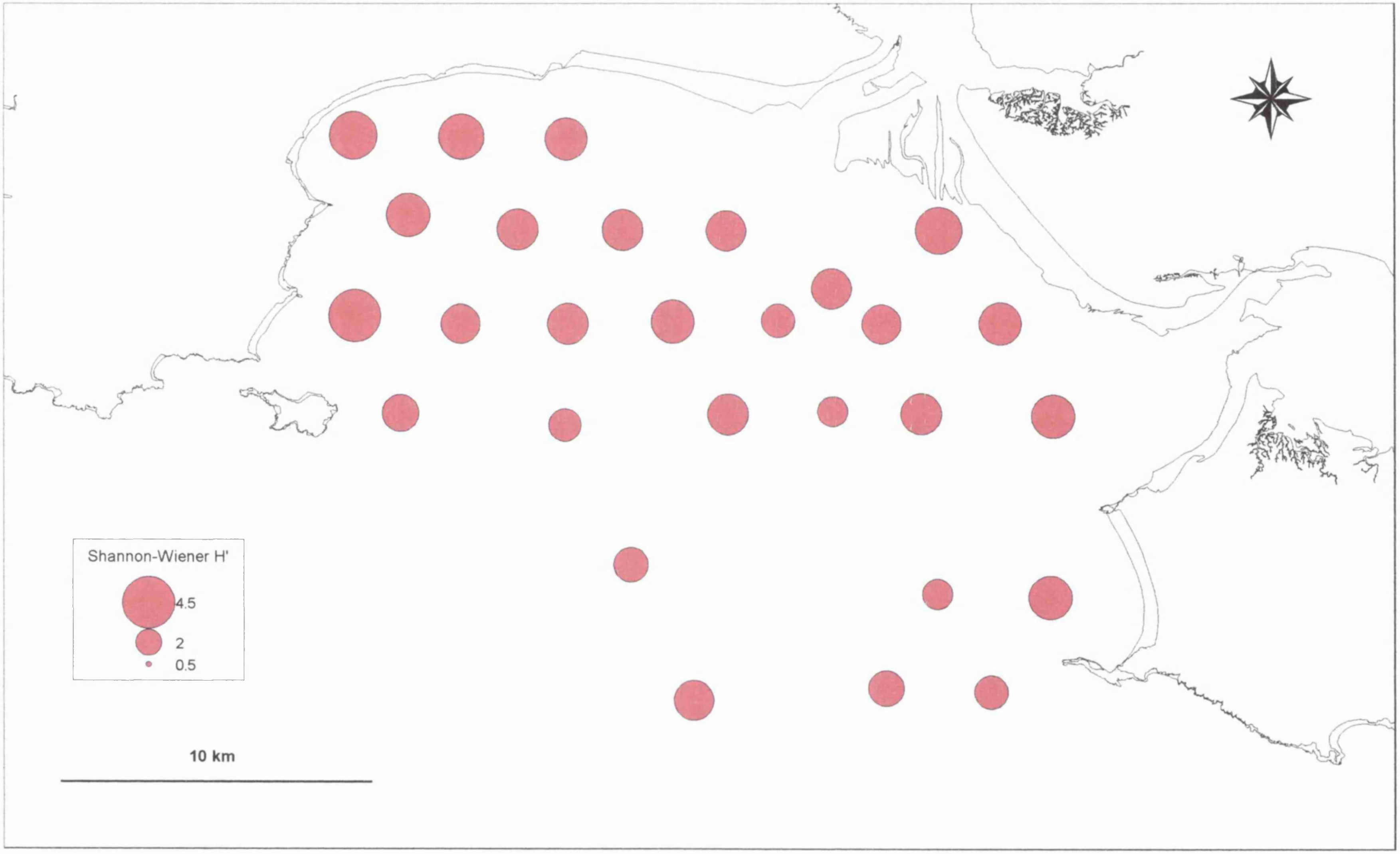


Figure 2.63 Patterns of Species Diversity (Brillouin H)

Figure 2.64 Patterns of Species Diversity (Shannon-Wiener H')



3. 3. 5. 4 Dominance

A measure of dominance at each station is given by Simpson's D and the Berger-Parker indices. Simpson's D is heavily weighted to the abundance of the commonest species in the sample. Figure 2.65 shows that the stations in the north of Caldey Island around Saundersfoot Bay and directly off Pembrey Sands in the east to be the least dominated by abundant species. A gradient of increasing dominance with its focus in the centre of the bay between Caldey Island and Burry Holms is also apparent. This area defined by stations 41, 42, 57, and 84.

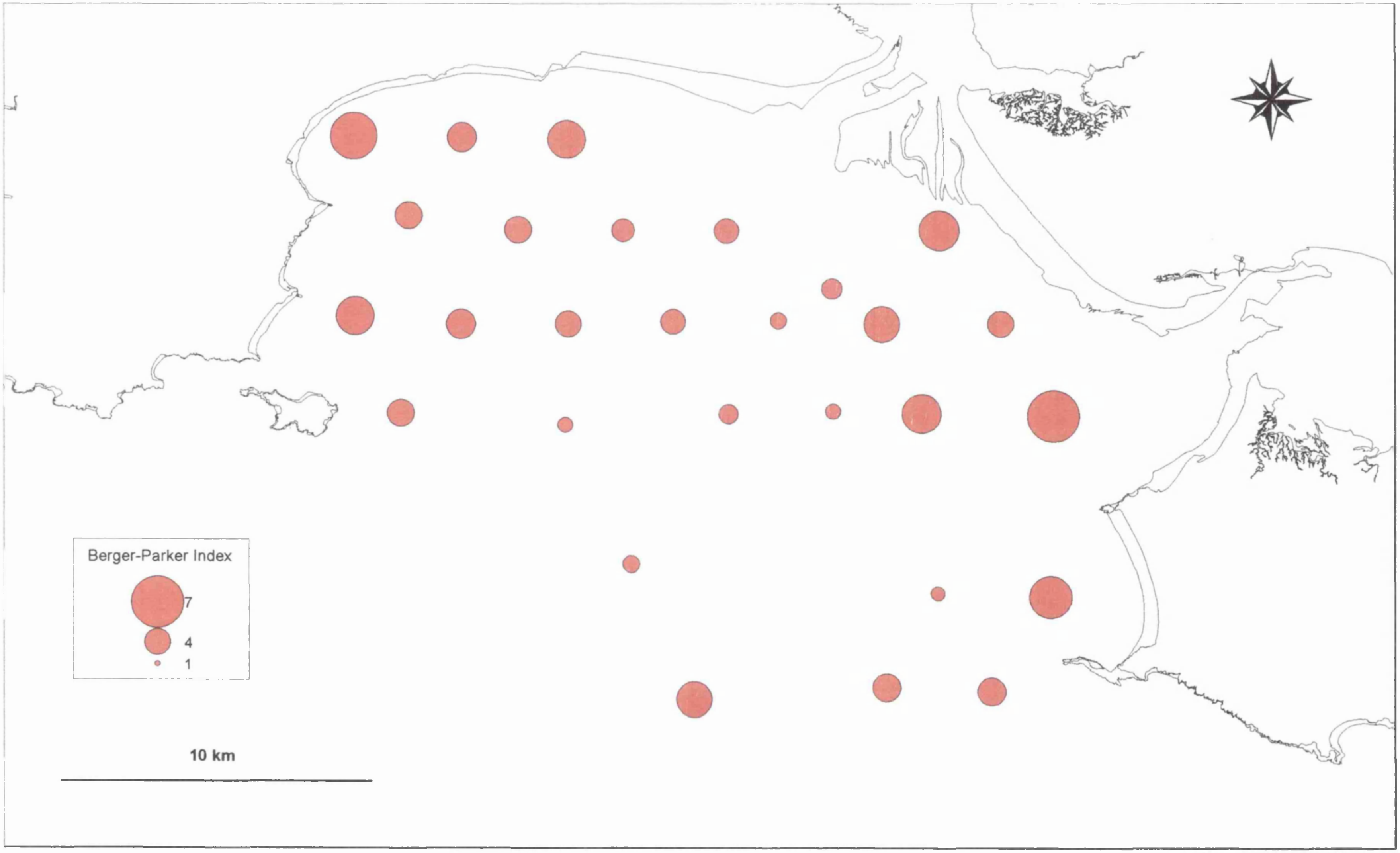
On an assemblage level there is very little difference between the mean Simpson's D values, ranging from 0.84 – 0.86, the combined samples masking any detectable dominance.

The Berger-Parker index gives a measure of how single-species-dominated a site is. Figure 2.66 shows that a large proportion of the bay is dominated numerically by single species. Lowest values were recorded at stations in the centre of the bay and highest in Saundersfoot Bay and at the mouth of the Loughor estuary. On a whole relatively low values were recorded for the whole bay.

On an assemblage level there is very little difference between the mean Berger-Parker values, ranging from 0.84 – 0.86, the combined samples masking any detectable dominance.

Figure 2.65 Patterns of Species Dominance (Simpsons D)

Figure 2.66 Patterns of Species Dominance (Berger-Parker Index)



3. 3. 5. 5 Evenness

The Heip evenness index was shown to have a higher level of discrimination than the Pielou J index with ranges between 0.12-0.68 and 0.48-0.85 respectively. Distributions of the evenness measures J and E correspond roughly those described for the dominance measures (Figures 2.68 & 2.69). Relatively low evenness values were recorded for stations in the centre of the bay off Pembrey Sands and across the bay in the direction of Saundersfoot Bay. The areas of highest evenness are shown to be stations in Saundersfoot Bay and at the stations in the south and east of the bay.

The stations returning the highest evenness values were stations with reduced species richness. The apparently linear relationship is shown in Figure 2.67.

Figure 2.67 The Relationship of Species Richness and Evenness

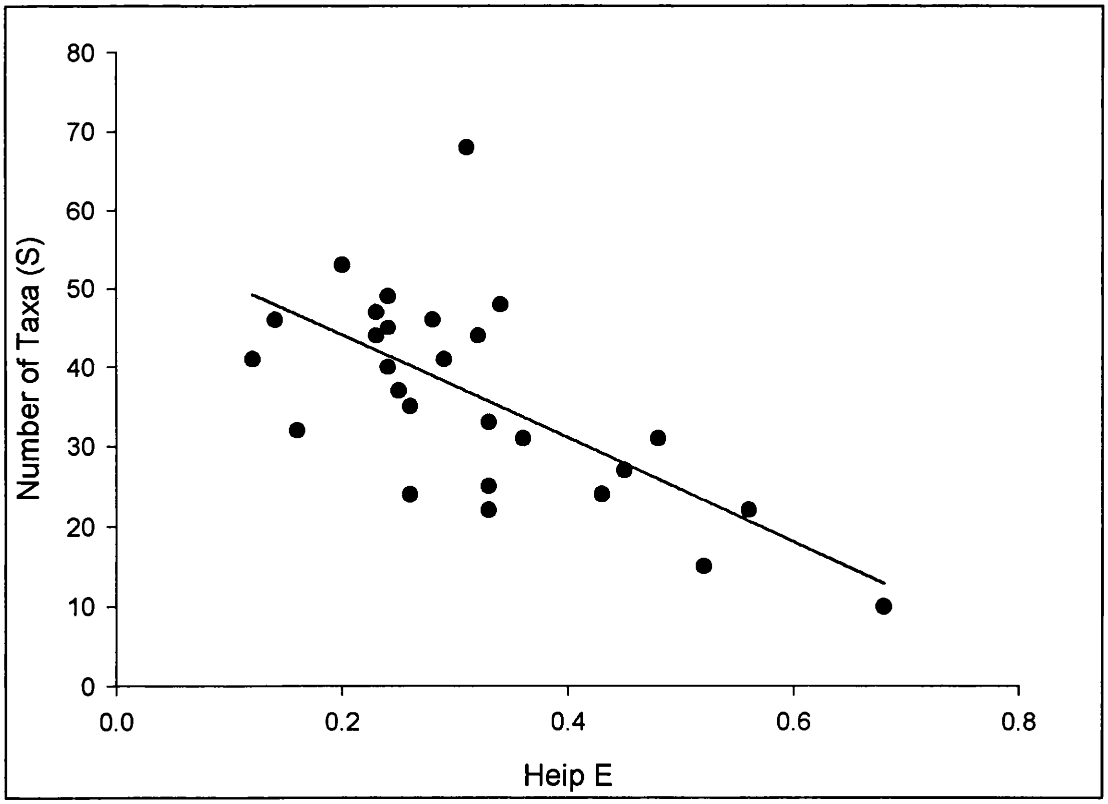


Figure 2.68 Patterns of Species Evenness (Pielou J)

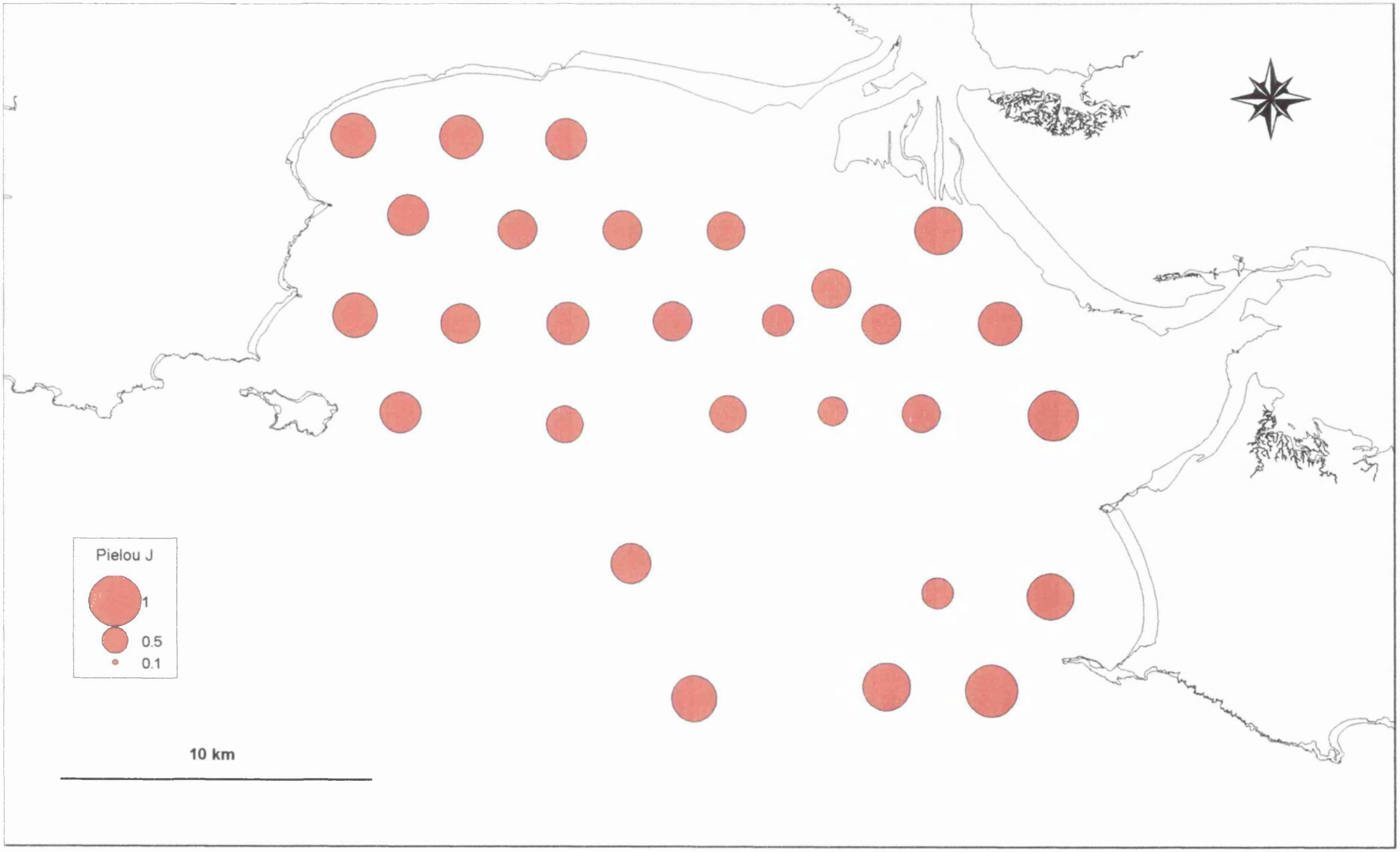


Figure 2.69 Patterns of Species Evenness (Heip E)

3. 3. 5. 6 Hurlbert Rarefaction

Plotting the upper and lower Hurlbert rarefaction curves for each assemblage revealed apparent difference between assemblages (Figure 2.70). The curves of Assemblage A are truncated due to low richness and abundance. Assemblage B_2 shows markedly shorter and shallower curves than the corresponding curves of B_1. Station 44 was treated as an outlier in this analysis being both the most abundant and rich station.

More useful for the comparison of stations was the index ES100, the estimated number of species per 100 individuals. Figure 2.71 demonstrates the pattern of distribution of this index across the bay. The highest values were calculated for stations in the area north of Caldey Island, off Tenby and Saundersfoot and the lowest values at stations west of Worms Head and in the centre of the bay south of the Carmarthen Bar.

Average ES100 figures for the assemblages showed Assemblage A to be the least diverse and Assemblage B_1 to be the most, Assemblage B_2 falling between them both.

Figure 2.70 Hurlbert Rarefaction Curves

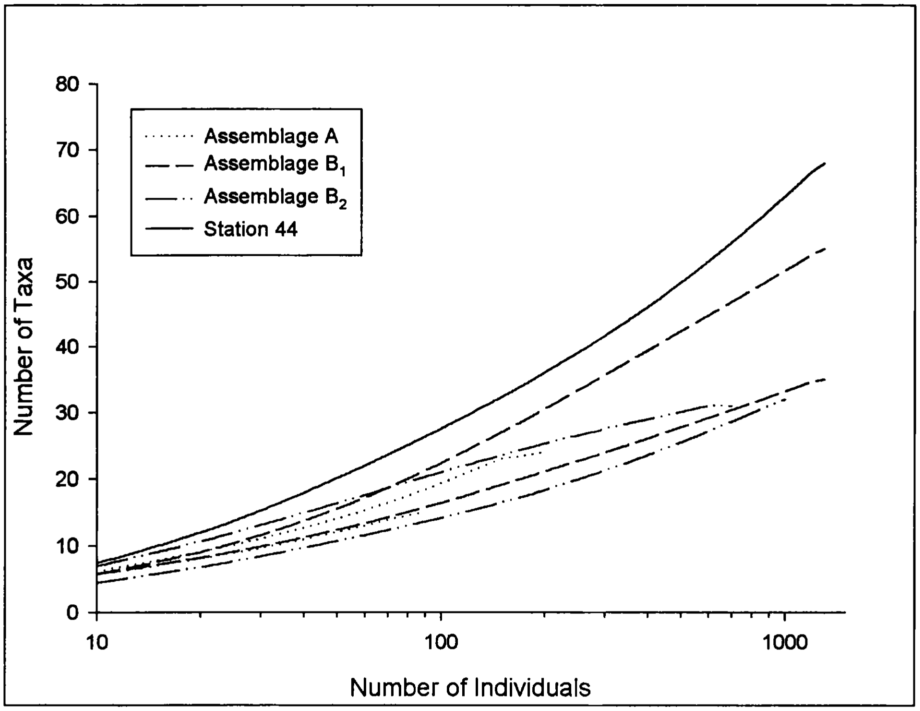


Figure 2.71 Patterns of Hurlbert Rarefaction (ES 100)

3. 3. 6 Epifauna (Beam Trawls)

Table 2.15 Beam Trawl Results Standardized Epifauna Results (% of all Trawls)

Taxa	**ST 74**	**ST 75**	**ST 76**	**ST 77**	**ST 78**	**ST 79**	**ST 85**	**ST 86**	**% All Trawls**
Aphrodita aculeata	-	0.15	0.15	-	0.31	-	0.23	-	0.85
Crangon crangon	-	-	0.08	-	-	-	-	-	0.08
Pagurus bernhardus	-	-	-	0.08	0.39	-	0.31	0.15	0.92
Maja squinado	0.08	0.08	0.23	-	-	-	-	-	0.39
Macropodia sp.	-	-	-	0.08	-	0.08	-	-	0.15
Corystes cassivelaunus	-	-	-	-	0.08	-	-	-	0.08
Liocarcinus sp.	-	-	-	-	-	0.08	-	-	0.08
Liocarcinus holsatus	-	-	0.08	-	-	-	-	-	0.08
Necora puber	-	-	-	-	-	-	-	0.08	0.08
Sepiola sp.	-	-	-	-	-	-	-	0.15	0.15
Buccinum undatum	0.77	-	0.31	-	0.62	0.39	0.15	-	2.23
Hinia sp.	0.39	-	0.39	-	-	-	-	-	0.77
Philine aperta	5.62	7.70	0.77	0.08	0.08	0.08	0.31	-	14.64
Asterias rubens	0.08	3.85	1.54	2.31	0.77	0.77	0.77	0.62	10.71
Ophiura ophiura	44.99	2.31	0.08	1.93	-	-	-	-	49.31
Echinocardium cordatum	-	-	-	0.08	-	-	-	-	0.08
Astropecten irregularis	0.77	-	0.77	0.08	0.15	0.15	0.62	0.39	2.93
Raja microocellata	-	-	-	-	-	-	0.08	0.15	0.23
Raja montagui	-	-	-	-	-	-	0.08	-	0.08
GADIFORMES	-	-	-	-	0.39	-	-	-	0.39
Merlangius merlangus	-	-	-	0.08	-	-	0.08	-	0.15
Syngnathus rostellatus	-	-	0.08	-	-	-	-	-	0.08
Eutrigla gurnardus	-	-	-	-	-	-	-	0.15	0.15
Trigla lucerna	-	-	0.08	0.08	-	-	-	-	0.15
Callionymus lyra	-	-	-	-	-	-	0.08	-	0.08
Gobiidae	0.08	0.08	0.08	0.08	-	0.08	0.08	-	0.46
Scophthalmus rhombus	-	-	-	-	0.08	-	-	-	0.08
Limanda limanda	-	-	0.23	0.77	0.39	0.39	0.08	0.08	1.93
Pleuronectes platessa	0.39	0.08	0.31	0.39	0.39	0.39	0.46	0.23	2.62
Buglossidium luteum	2.31	0.08	1.16	1.16	0.77	0.77	0.08	0.77	7.09
Solea solea	0.77	0.08	0.39	0.77	0.39	0.39	0.08	0.15	3.00
% All Trawls	56.24	14.41	6.70	7.94	4.78	3.54	3.47	2.93	100

Large hauls of single species such as the brittlestar *Ophiura ophiura* required that some samples were recorded proportionally as percentage of haul rather than counted. Results presented here are proportional, percentage per individual trawl (Figure 2.72) and percentage of total trawls (Figure 2.73); this allows comparison of unequal trawl lengths and sample size.

The echinoderms make up 63% of the total combined trawls. A large haul of *O. ophiura* at Station 74 alone accounts for 45% of the combined total. *O. ophiura* were present at the other shallow stations 75-77 but at greatly reduced numbers (Table 2.15), and were absent thereafter. The large starfish *Asterias rubens* and *Astropecten irregularis* were represented in reasonable proportions at all stations, *A. rubens* accounting for 25% and 30% of the trawls at stations 75 and 77 respectively.

The molluscs account for nearly 18% of the combined total fauna, with the small opisthobranch *Philine aperta* accounting for 14%. *Philine aperta* was present in proportionally high numbers at stations 74 and 75 but at much lower numbers at subsequent stations. The common whelk *Buccinium undatum* and the dog whelk *Hinia* sp. accounted for the remainder of the shelled molluscs. A pair of cuttlefish, *Sepiola* sp. were caught at station 86.

Fish species make up just over 16% of the combined total fauna with 11 species. The bulk of these fish are accounted for by the Solenette (*Buglossidium luteum*) at just over 7% of the combined total. The sole (*Solea solea*), plaice (*Pleuronectes platessa*) and dab (*Limanda limanda*) were present in similar proportions of between 2-3% of the total fauna. The remainder of the fish species were found only singly or in pairs at one or two stations.

When combined, replicate stations show a decrease in abundance with an increase in depth (Figure 2.74). Almost 60% of the total fauna in the replicate trawls occurred around the 5m isobath, with 23% at 10m and 18% at 20m. The 5m stations are characterised by the high proportions of molluscs and echinoderms, particularly high numbers of the opisthobranch *P. aperta*. The 10m and 20m stations are characterised by the increased proportion of fish species, accounting for over 50% of the 10m trawls and over 40% at 20m (Table 8). The molluscs show a decline at these stations, with no large hauls of *P. aperta*. The echinoderms remain important throughout, represented by *A. rubens* and *A. irregularis* at these stations; no *O. ophiura* were present.

Table 2.16 Major Groups at Isobaths

	5m	**10m**	**20m**
Polychaetes	1.68	3.23	3.33
Crustaceans	3.14	7.01	8.39
Molluscs	37.66	13.78	9.30
Echinoderms	39.21	22.72	37.11
Fish	18.31	53.26	41.87

Figure 2.72 Proportion of Major Phyla in Individual Beam Trawls

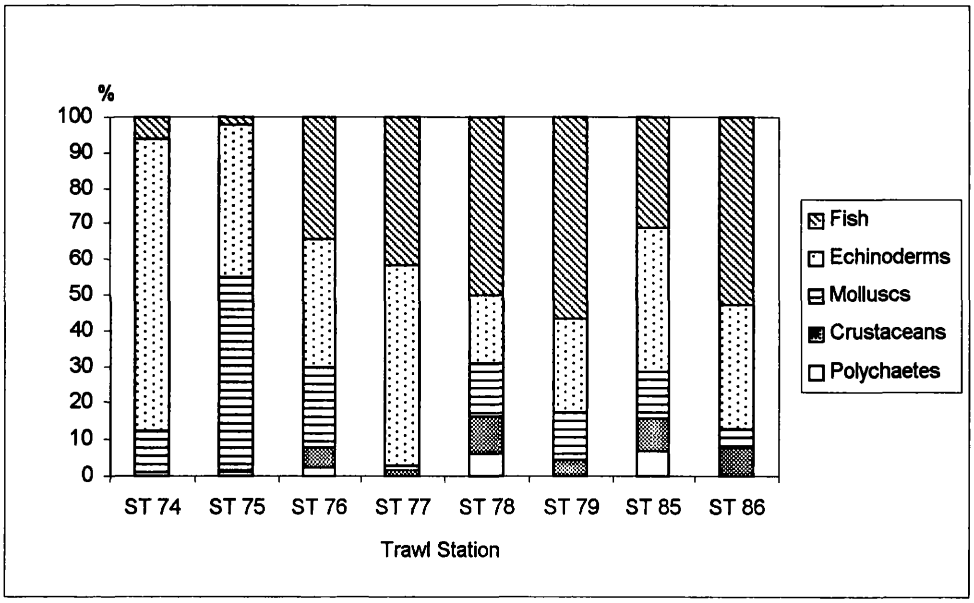


Figure 2.73 Proportions of Major Phyla of Beam Trawl Total

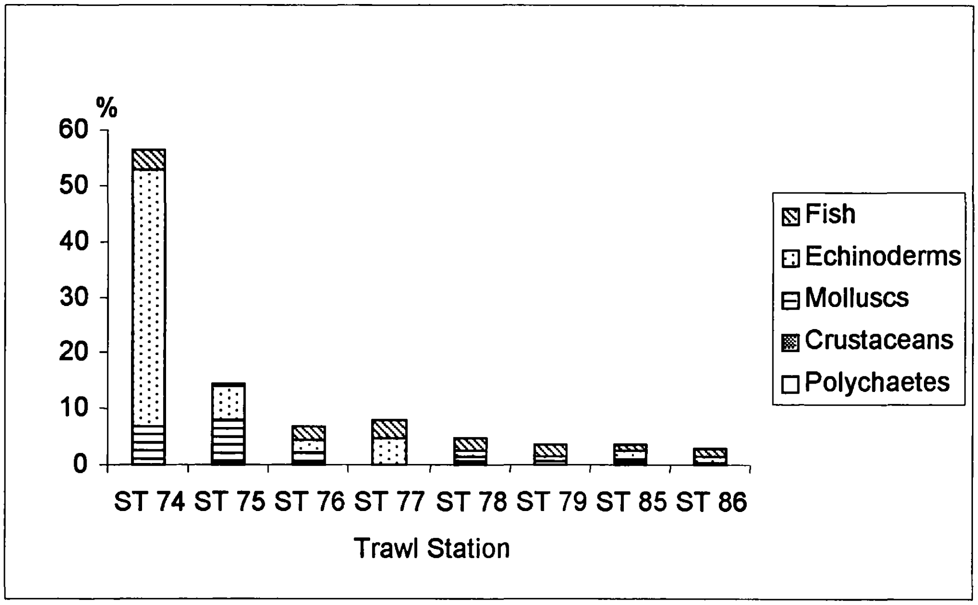
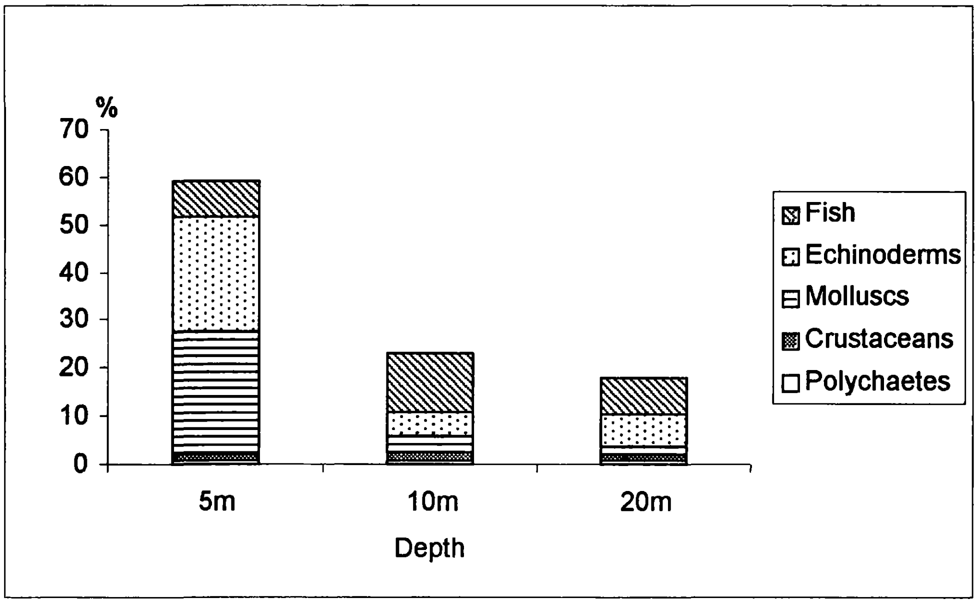


Figure 2.74 Proportion of Major Phyla at 5m Interval Isobaths



2. 4 Discussion

2. 4. 1 Physical Environment

The maps produced from the ABP data (Figures 2.7 – 2.16) demonstrate that the physical environment of Carmarthen Bay is subject to strong hydrodynamic and sedimentary gradients.

The amphitheatric shape of the seabed imposes a bathymetric gradient from the deep centre of the bay to the shore (Figure 2.11). This basin is only interrupted by a pair of infilled drowned river valleys described by North (1955) in the east of the bay off Rhossili Bay, the channels of which are generally 5m deeper than the adjacent seabed, these are represented by an area raised seabed sperating them extending southwest from Rhossili Bay.

The hydrodynamic environment of Carmarthen Bay, dictated by the prevailing wave and tidal regimes, displays an emergent energy gradient following an arc from Saundersfoot Bay southwards across the bay with its focus around Caldey Island (Figures 2.12 – 2.13). The wave climate of Carmarthen Bay is dominated by the open fetch to the North Atlantic, any locally generated waves arriving from the west/south-west being duration limited (ABP-Research, 2000). The region of the bay to the north of Caldey Island is not subject to the direct force of the predominantly south westerly swell and shows a corresponding reduction in wave height and period in comparison to other more west-facing areas of the bay. Situated in the lee of the Pembrokeshire land mass, waves entering this area originate when the south westerly swell is refracted around Caldey Island. Wave height and period is reduced as wave energy is attenuated by its action on the gently shoaling seabed and consequently, as the wave period shortens, water particles change from orbital paths to a more horizontally-orientated translational path which is likely to have a significant transport effect on macrofauna and sediments. In contrast, the eastern side of Carmarthen Bay is open to the full force of the prevailing southwesterly swell, notably Rhossili Bay and the approaches to Pendine.

The tidal currents describe a similar arc of increasing velocity from a minimum in Saundersfoot Bay to the outer southern limit of the bay (Figures 2.12 & 2.13). Tidal velocity is seen to increase around coastal features such as headlands and the mouths of estuaries, these were considered by ABP Research to be relatively localized anomalies attributed to local circulation cells (ABP-Research, 2000). Whilst the ebb velocity dominates, the same areas of the bay are subject to extremes of current velocity irrespective of state of tide, it is unsurprising then that these two environmental variables were found to be strongly correlated. Tidal residual currents occur in areas of ebb-flood asymmetry such as those around the river mouths of the Loughor and the Three River System, and the headlands of Worms Head and Caldey Island (Figure 2.14). Conversely, there is negligible residual current in the centre of Carmarthen Bay. Residual current circulation has been implicated in the structuring of macrofaunal communities by the retention of larvae or drifting post-larvae (Thiebaut et al., 1998).

Sediment grades in Carmarthen Bay display a broadly corresponding pattern of distribution to the wave and tidal gradients. With the focus around Caldey Island, an arc of increasing median grain size is evident, from the finest in Saundersfoot Bay increasing to coarsest sediments in the southern periphery of the survey area (Figure 2.7). The relationship between hydrodynamic forces and sediment distribution is particularly clear when comparing the distribution of mud in the north of the bay (Figure 2.10); the strong west-east mud gradient strongly mirrors the corresponding gradients of ebb and flood velocities (Figure 2.12 & 2.13). The exceptions to this pattern are the patches of muddy sediment in the east of the bay, the drowned river valleys seemingly acting as a sink for fine material. The PCA of the quantitative stations demonstrates the coupling of hydrodynamic and sedimentary data. PC1 explains close to 50% of the variance between stations, a strong inverse relationship between sediment variables Median Phi, Log_{10} Mud, and %Organics and the hydrodynamic variables Flood Velocity, Wave Height and Wave Period. The authors of the ABP project concluded that, generally within the Bristol Channel, 'areas of higher tidal shear stress correspond to areas of bedrock, gravel and sands and areas of low shear stress corresponding to areas of fine sediment' and that in the nearshore zone waves heavily influence the bed shear stress (ABP-Research, 2000). In Carmarthen Bay then, a combination of wave and tidal forces maintain, through continual sediment reworking, a gradient of fine to coarse sediment around the bay from Saundersfoot Bay in the west to its margins south of Worms Head in the east.

The three assemblages, A, B_1 and B_2, isolated by the multivariate cluster analysis and MDS ordination are seen to be compositionally very similar. All three assemblages can be attributed to the *Tellina* sub-community of Petersen's Shallow *Venus* community (Petersen, 1914) similar to that described by both Warwick and Davies (1977) and Hobbs and Smith (1998). This community corresponds to Thorson's *Venus gallina* community (Thorson, 1957) and Jones (1950), relating communities to environmental factors, referred to this community as the Boreal offshore sand association and later (Jones, 1951) the Boreal offshore fine sand association. There is a prevalence of characteristic species of this community at all stations; the polychaetes *S. bombyx*, *Magelona* spp. and *Spio* spp., the amphipods *P. longimanus*, *P. arenarius* and *Bathyporeia* spp. and the bivalves *F. fabula*, *M. bidentata* and *C. gallina*. The uniformity in component species between assemblages suggests that they represent a series of states within the *Tellina* sub-community. SIMPER analysis supports this assertion, showing that distinctions between macrofaunal assemblages A, B_1 and B_2 are largely due to changes in dominance and in abundance of ubiquitous species.

(Thorson, 1957) noted variation in species composition within the *Venus* community in response to sand grain size and sediment stability, the *Tellina* sub-community showing a propensity for clean, fine, compact sands, whereas the sister *Spisula* sub-community displays a preference for more mobile, coarser sediments. There is firm evidence that the prevailing environmental gradients in Carmarthen Bay play an important role in structuring the macrofaunal community. An indication of this is provided by the faunal MDS ordinations (Figures 2.49 & 2.52) where there is a strong resemblance of the placement of stations in the MDS ordinations to their true geographic distribution of stations in the bay. This resemblance suggests that broad scale physical processes affect community composition and abundance. The BIOENV procedure identified a combination of '%Mud-Median Grain Size-Wave Height' as best 'explaining' the faunal MDS ordinations of individual stations with a 'very good' correlation of ρ_w 0.795. A clear illustration of the relationship between these environmental factors and the composition and abundance of the community is provided by the MDS ordinations with these factors superimposed (Figure 2.56).

Stations of Assemblage A were found in medium sand along the southern edge of the bay, around the peripheral headlands and at the mouth of the Loughor estuary (Figure 2.54). The distribution of Assemblage A corresponds to areas of stronger tidal flows, increasing wave height and corresponding coarser, cleaner sediments. Assemblage A represents a reduced form of the *Tellina* sub-community. Reduced species richness and abundance are characteristic at these stations, as is a generally low species diversity. In comparison to other areas of the bay, sedentary members of the *Tellina* sub-community such as the thin-shelled *F. fabula* and the fragile tube-dwelling polychaete *S. bombyx,* although present are much reduced in numbers. These stations are characterized by the dominance of more motile fauna such as *N. cirrosa* and *P. longicornis*. SIMPER analysis revealed the errant polychaete *N. cirrosa* to be the most regularly occurring and consequently characteristic taxon of this assemblage. Clark (1960, 1961) found *N. cirrosa* to be indicative of mobile, clean sediment environments and to be morphologically adapted to such sediments. The cumacean *P. longicornis* was the most abundant taxon at stations in this assemblage, occurring almost as regularly as *N. cirrosa*. This cumacean is an active burrower in the upper few centimeters of sediment and is highly mobile undertaking diel vertical migrations into the water column, making it well adapted to a mobile sand habitat. The paucity of fauna at Station 21 to the southwest of Worms Head suggests that this station is closely allied to the reduced communities found on the Helwick Bank, most recently described by Darbyshire et al. (2002) and previously by Tyler & Shackley (1980). Assemblage A represents a transition between the richer, shallower, more sheltered fine sand *Tellina* sub-community and the more exposed, mobile sediment, *Spisula* sub-community recorded offshore in the Bristol Channel by Warwick & Davies (1977) and Tyler & Shackley (1980). Indeed, Warwick and Davies (1977) described the *Spisula* sub-community found in deeper water in the central Bristol Channel as being unstable, and characterized by the absence of delicate species. Degraer et al. (1999) described a similar *N. cirrosa* dominated, low diversity community on the western Belgian Coastal Banks in the North Sea.

Both assemblages B_1 and B_2 strongly resemble the *Tellina* sub-community previously described in Carmarthen Bay by Warwick and Davies (1977) and Hobbs and Smith

(1998). These assemblages are characterized by high abundance and dominance of the deposit-feeding polychaetes *S. bombyx*, *Spio* sp. and *Magelona* sp. and bivalve *F. fabula*. *Pseudocuma longicornis*, ubiquitous among stations, is common in both assemblages. The dissimilarities between the two assemblages, and illustrated by the cluster analysis and MDS ordination, is attributed primarily to the significant differences in abundance and richness between them. Assemblage B_1 is distributed in the sheltered north of Carmarthen Bay and in an area south of the Three River estuary and west of Pembrey Sands. These stations are found in fine sand containing a small percentage of mud, a comparison of the distribution of Assemblage B_1 with that of areas containing fine material and mud shows a strong correspondence in distribution (Figure 2.10 and Figure 2.54). Assemblage B_2 is distributed in two areas of clean fine sand on either side of Carmarthen Bay separated by the extension of Assemblage B_1 in the centre of the bay (Figure 2.54).

Similar communities have been variously described in fine sand habitats around the British coasts: Mackie et al. (1995) described a variety of similar assemblages at a number of stations locally in Cardigan Bay and southwest of Anglesey in the Irish Sea, the composition of which was shown to vary with sediment type. Ford, (1923) reported a number of muddy fine sand stations containing a mixture of members of the *Abra* community and *Tellina* sub-community off Plymouth. McIntyre & Eleftheriou (1968) described a very similar community at Firemore Bay in Loch Ewe on the west coast of Scotland, here high abundances of *Magelona* spp., *Spio* spp., *Chaetozone* spp., *B. elegans* and *F. fabula* were reported. The physical environment of Firemore Bay, the high degree of shelter and fine sand substratum, closely resembles that of the northwest of Carmarthen Bay around Saundersfoot Bay highlighting the importance of these factors in the structuring of this community.

To conclude, the *Tellina* sub-community, characterized by high abundances the polychaetes *Magelona* spp., *Spio* spp., *S. bombyx*, *Chaetozone* spp., the amphipods *P. longimanus*, *P. arenarius* and *Bathyporeia* spp. and the bivalves *F. fabula*, *M. bidentata* and *C. gallina*, inhabits areas of sheltered, fine clean sands. This community has been descrbed by various authors and is also recognised by Connor et al. in the 1997 version of the 'Marine Biotopes Classification for Britian and Ireland', which is currently under revision. The composition and relative abundance of taxa is seen to change in response to a combination of hydrodynamic and sedimentary environmental gradients: Species abundance and richness decrease with an increase in hydrodynamic energy and associated sediment grain size and mobility. As the sediments become finer and muddier and hydrodynamic stress decreases the *Tellina* community grades into the *Abra* community previously reported by Warwick & Davies (1977).

2. 4. 3 Potential Areas of Importance for Common Scoter

There are a number of considerations in identifying those areas of Carmarthen Bay likely to be important as Common Scoter feeding grounds.

Although bivalve species are generally considered to be the most important prey species in Common Scoter diet (Hughes et al., 1997; Fox, in press), the importance of other taxa may have been overlooked. There is evidence that the bill of the Common Scoter is adapted for handling small prey items; the American ornithologist John James Audubon (1840) presented a clear description of the bill: 'The roof of the mouth is very concave and broad, with a median ridge, on which there are six papillae towards the base. There are about 25 large lamellae on each side of the upper mandible, besides a number of smaller ones anteriorly; about 40 on each side of the lower mandible'. These lamellae are spaced approximately 1mm apart (pers. obs.) and are likely to function in the selection and handling of small prey (Jean-Pierre L. Savard pers. comm.). Common Scoter, in addition to tactile foraging for bivalve prey, may be able to switch to feeding in a manner described in other water fowl, sucking water and sediment in through the open bill tip, filtering the mixture through the bill lamellae and so trapping small prey items.

There can be significant bias in gut content analysis of diving ducks; smaller easily digested items may be under-represented and conversely the proportion of highly calcified organisms such as bivalves and gastropods overestimated (Swanson & Bartonek, 1970). This bias is compounded by post-mortem digestion if the gut contents come from long-dead birds such as those recovered after oil spills or drowning in fishing nets, which is often the case in such Common Scoter diet studies (e.g. Moyse & Thomas, 1977; Stempniewicz, 1986; Hughes et al., 1997).

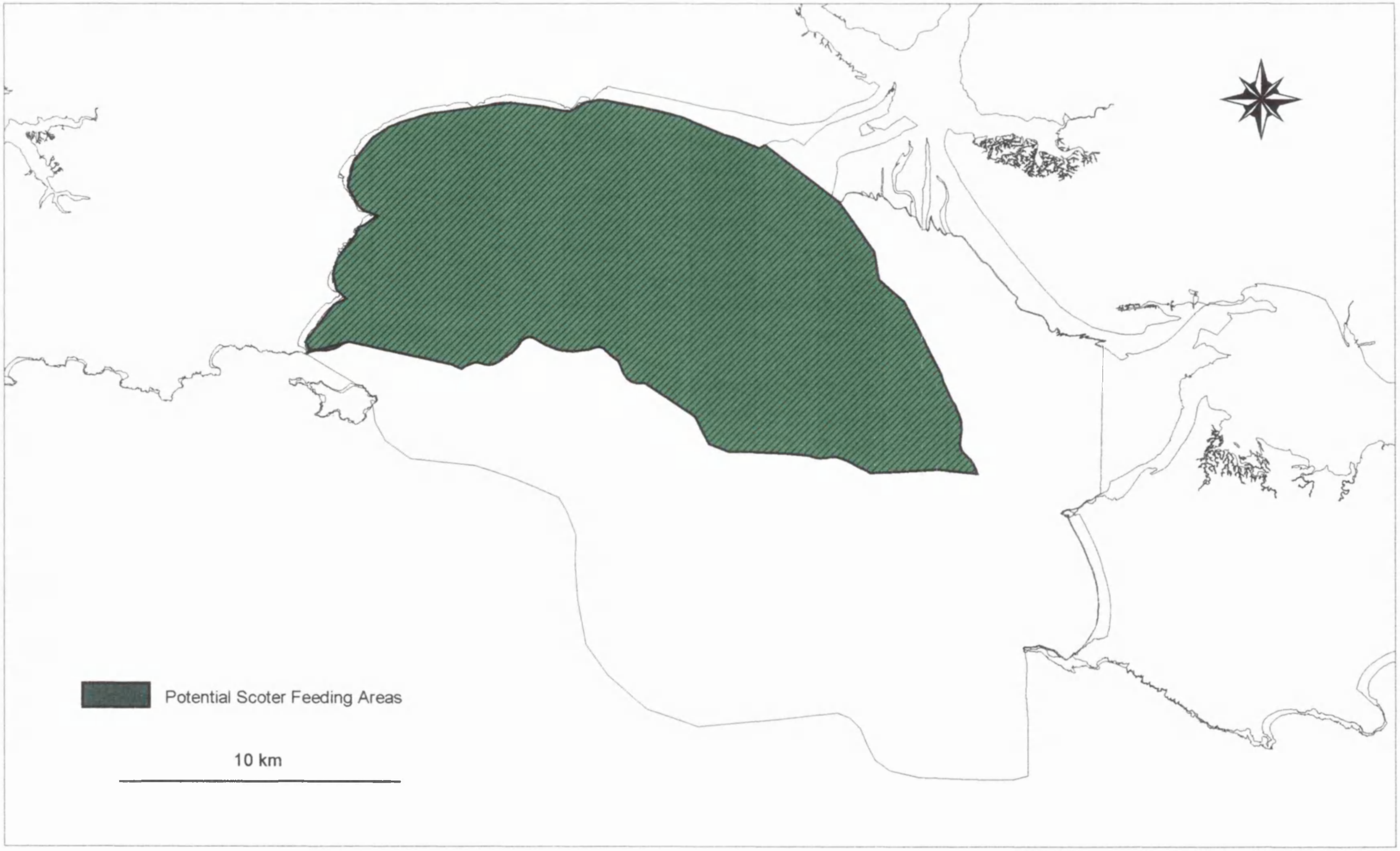
There are also energetic reasons why high abundances of taxa other than bivalves may be equally important prey resources for Common Scoter. It is likely that Common Scoter are able to vary their foraging strategy in relation to water depth, prey abundance and possibly prey type. Diving is energetically costly and so the depth of water is likely to be an important consideration, in addition to prey density, to a diving bird (Boyd, 1997; Halsey et al., 2003). Common Scoter have been reported to dive for extended periods and are able dive to depths in excess of 20 m (Fox, in press). In order for a dive to be energetically profitable there is a trade-off between the energy expended foraging and handling the prey and the energy obtained from that resource (Mori, 1998; Mori et al., 2002). Areas containing high abundances of prey at greater depths may therefore be equally profitable at lower abundance in shallow water areas. The probability of encountering a prey item during a dive is also an important consideration; sparsely distributed high energy items such as large bivalves may be less important than dense aggregations of small lower energy items (juvenile bivalves or other taxa) if a number of dives it required to locate them.

The profitability of feeding in certain areas of the bay is also likely to be affected by the large tidal range (~ 9 m), feeding would only become energetically viable to feed from at certain periods of diel and lunar tidal cycles.

Taking these factors into account, areas likely to be important as Common Scoter feeding grounds are those areas of the seabed accessible to the birds when diving and having sufficient densities of individuals, irrespective of taxa, in order to make foraging profitable. Using these criteria an area of seabed from the intertidal to intermediate depths (<15m) stretching from Saundersfoot Bay to south of the Three River estuary can be identified as being of importance for Common Scoter feeding (Figure 2.76) This area is characterized by stations of high abundance of individuals, including the bivalves *F. fabula*, *M. stultorum* and *C. gallina* and also dense aggregations of smaller taxa such as the sessile polychaetes *S. bombyx* and *L. conchilega*.

A proviso should be added here: This estimation is base upon a single survey and there is currently insufficient data to assess the spatiotemporal variability of likely prey distributions.

Figure 2.76 Potential Common Scoter Feeding Areas



Chapter 3: Growth, Abundance and Spatial Models of the Tellinacean Bivalve *Fabulina fabula* (Gmelin, 1791) Population in Carmarthen Bay

3.1 Introduction

The tellinacean bivalve *Fabulina fabula* (Gmelin) inhabits fine to medium sand from the lower shore to the shallow sublittoral. The geographical range of this species stretches from the Norway and Baltic Sea in the north, south to the Iberian peninsular, the Mediterranean, the Black Sea and the Atlantic coast of Morocco. *Fabulina fabula* was attributed as a character species of the *Venus striatula* community by Petersen (1914), and has been shown to be one of the dominant species of this community accounting for up to 8% of its total biomass (Stripp, 1969 in Salzwedel, 1979). The importance of *F. fabula* as a component of the Carmarthen Bay benthos is heightened owing to the likelihood of its role of food resource of the Common Scoter *Melanitta nigra* (Linnaeus). Investigation of its ecology will provide information useful in the conservation and management of both species.

A variety of biotic and abiotic factors affect the distribution and abundance of sessile marine invertebrates. There have been a number of studies correlating bivalve distribution and abundance with pre- and post-settlement processes (Commito et al., 1995; Legendre et al., 1997; Norkko et al., 2001; Garland et al., 2002). In the main, these studies have tended to concentrate on intertidal populations, most notably *Macoma balthica* (Linnaeus) (Seitz & Lipcius, 2001; Seitz et al., 2001; Strasser et al., 2001; Azouzi et al., 2002; Hiddink et al., 2002; Richards et al., 2002). There is however a paucity of information concerning the processes determining the distribution and abundances of sublittoral bivalve populations. The extensive biological sampling undertaken in this study and the extensive concurrent physical dataset produced by ABP Research as part of the 'Bristol Channel Marine

Aggregates: Resources and Constraints' research project (ABP-Research, 2000) present an unique opportunity to assess these processes.

The life history of *F. fabula* makes it an ideal model animal for this study; it has a dispersive planktotrophic larval stage which, at metamorphosis, develops into a competent pediveliger prior to benthic plantigrade and post-larval juvenile stages (Salzwedel, 1979; Webb, 1986). *Fabulina fabula* cohorts have been reported to be subject to synchronized development with corresponding heavy mass recruitment (Bosselmann, 1988); broad scale post-settlement effects are therefore likely to be detected at a population wide scale.

Olafsson (1994) concluded that larval supply is rarely limiting and therefore, in sedimentary habitats at least, is probably not a major determinant of patterns of species distribution and abundance. Hydrodynamic processes are however important factors in dictating the density and distribution of initial larval settlement (Butman, 1987; Snelgrove & Butman, 1994; Metaxas, 2001). Patterns of distribution and abundance of adult bivalves are influenced by a variety of pre- and post-settlement processes (e.g. Baker & Mann, 1997; Gosselin & Qian, 1997; Hunt & Scheibling, 1997; Hunt & Mullineaux, 2002).

Newly settled post-larval invertebrates are typically subject to high rates of mortality. Thorson (1966) calculated that fewer then 1.4% of bivalves settling on subtidal mudflats might survive long enough to attain a size of 2 mm. The causes of post-larval mortality in marine invertebrates are manifold: inter- and intraspecific predation, competition, physical and biological disturbance, physiological stress, incomplete metamorphosis and congenital complications have all been implicated (Gosselin & Qian, 1997). Density-dependent effects on the distribution of year classes caused by the ingestion of post-larvae by conspecifics, or larval avoidance of conspecifics have been widely reported (Olafsson, 1986; Thrush et al., 1992; Thrush et al., 1996; David et al., 1997; Richards et al., 2002)

The relationship between animal distributions and sediment has often been found to be secondary, reflecting the local hydrodynamic regime (Snelgrove & Butman, 1994). The ultimate distribution and abundance of adult bivalves may not be solely due to location and density of initial larval settlement, but by also in a large part to post–larval redistribution and migration (Baker & Mann, 1997). These redistributions are forced and entrained by the dynamic sedimentary and hydrodynamic environment (Butman, 1987). Many bivalves have post-metamorphic stages that are functionally distinct from the late juvenile or adult stages, the plantigrade and the pelagic post-larvae are post-larval stages most often implicated in post-larval redistribution and migration (Emerson & Grant, 1991; Cummings et al., 1993; Baker & Mann, 1997). Byssal drifting is reported in other members of the Tellinacea (Sigurdsson, 1976) and is widely studied in varying scales in the intertidal *Macoma balthica* (Linnaeus) (Beukema & Devlas, 1989; Armonies, 1992; Armonies & Hellwig-Armonies, 1992; Armonies, 1996; Garrison & Morgan, 1999; Hiddink et al., 2002). These post-larval redistributions often result in differential distribution of year classes and the spatial separation of juveniles and adults.

In addition to distribution and abundance, the growth rate and longevity of *F. fabula* is of interest. Salzwedel (1979) provided growth parameters for *F. fabula* populations from two sites in the German Bight. Similar growth parameters for the Carmarthen Bay *F. fabula* population were reported by Warwick (1978), these animals were shown to be slower growing and longer living than the German Bight animals. This disparity between growth parameters and longevity was considered erroneous by

Salzwedel. The clarification of growth parameters for *F. fabula* in Carmarthen Bay is a useful addition to this study.

3. 2 Methods

3. 2. 1 Specimen Processing

Individuals of *F. fabula* were separated from the baseline survey samples at time of identification (see Chapter 2). Additionally, individuals for use in the growth analysis were separated from samples collected at Station 49 where time-series sampling was conducted (see chapter 5). These samples were collected in November 1998, April 1999, September and November 1999, May and November 2000. The RV Nicola (University of Wales Swansea) was used on all occasions except one (April 1999) when the RV Skamley (Skomer MNR) was used. Total shell lengths were measured to the nearest 0.1 mm using either a microscope fitted with an eyepiece graticule or, in the case of larger individuals, vernier calipers.

3. 2. 2 Data Analysis

3. 2. 2. 1 Population Structure

Data from all stations in the baseline survey were pooled to provide a representative sample of the total Carmarthen Bay population. Length frequency distributions of 1 mm size classes were calculated and length frequency histograms were plotted.

3. 2. 2. 2 Determination of Year Class Sizes

Bhattacharya's method (Bhattacharya, 1967) was applied to the pooled length-frequency sample using the FISAT software package (Gayanilo & Pauly, 1997). The Bhattacharya method attempts to separate normal distributions, each representing a year class, from the composite pooled distribution. Once the first normal distribution has been determined it is removed from the total distribution and the same procedure is repeated as long as it is possible to separate normal distributions from the total distribution. A full description of this method is presented in Sparre and Venema (1998).

The resulting modal lengths calculated for each year class were used to identify the abundance and distribution of each year class from individual station length frequency data. This information was plotted onto charts using MapInfo GIS software.

3. 2. 2. 3 Determining Physical Environmental Factors on Year Class Abundance and Distribution

Using the environmental dataset from the baseline survey (Chapter 2) and a similarity matrix was produced from Log_{10} transformed year class distribution data, the multivariate BIOENV procedure of the PRIMER package was used to identify the combination of environmental factors 'best explaining' the distribution of year classes. This method, while not able to provide predictive statistics, is a useful method of highlighting important environmental factors in the determination of distribution and abundance of *F. fabula*.

Stepwise multiple regression models (Sokal & Rohlf, 1981) were used to determine which environmental variables best accounted for the variance in the abundance of year class 0 and adult animals. These analyses were done by the Essential Regression add-in for MS Excel 97 (Stebben et al. 1998). The variables selection procedure used the stepwise auto-selection option, with a selection threshold of 5%. The Durbin Watson statistic was used to assess autocorrelation of predictor variables.

3. 2. 2. 4 Prediction of Year Class Distribution

Spatial models of post-larval and adult distributions were produced by the application of the step-wise multiple regression model to the spatially distinct ABP-Research

(ABP-Research, 2000) environmental dataset previously described in Chapter 2. Interpolation of these points using the Natural Neighbor method described in Chapter 2 was carried out using Vertical Mapper 2.6 software and displayed as detailed contour plots in MapInfo charts.

3. 2. 2. 5 Determination of Growth

The Von Bertalanffy Growth Function (VBGF) has been widely applied to growth studies in marine bivalves, often the prerequisite age data is obtained from the counting of visible annual shell growth rings or determined from acetate peels (e.g. Richardson, 1993). Due to the small size of the animals and to assess a more time efficient method, the growth parameters from the VBGF of the population were assessed using length-frequency analysis methods commonly used in the assessment of tropical fish stocks (Gayanilo & Pauly, 1997; Sparre & Venema, 1998), and previously applied to bivalve populations (Zeichen et al., 2002).

VBGF growth parameters asymptotic length ($L\infty$) and growth coefficient (K) were estimated by applying the Response Surface Analysis and Scan of K-Value functions of the ELEFAN (Electronic Length Frequency Analysis) routine of the FiSAT software package (Gayanilo & Pauly, 1997) to the year class data resulting from the Bhattacharya analysis.

Time-series length-frequency replicate data at each sampling date were pooled to provide a representative sample of Station 49. Length frequency distributions were calculated for 1 mm size classes and plotted. Due to the absence of older year classes growth parameters were not calculated for Station 49 but were used in the graphical assessment of growth models produced from the baseline data.

3. 3 Results

3. 3. 1 Population Size Structure

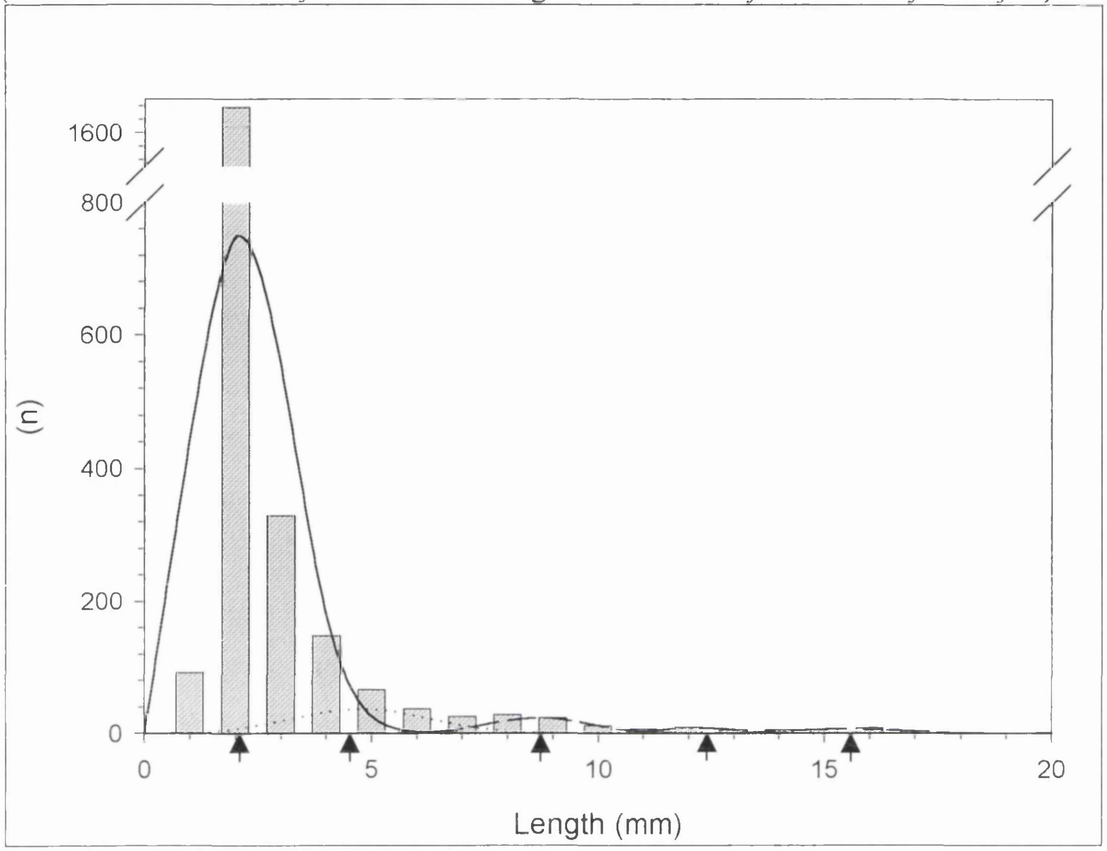
3. 3. 1. 1 Pooled Baseline Data

Length frequency data for the baseline survey are presented in Appendix 3.1. Figure 3.1 illustrates the length frequency distributions of the Carmarthen Bay *F. fabula* population sampled on the 1st June 1998. Small, <5 mm individuals were shown to be numerically dominant and the 2 mm size class the most abundant size class overall (1674 individuals). Isolation of year classes by the Bhattacharya method revealed a series of 5 year classes (Table 3.1). A separation index (si) value >2 indicates a good level of separation between year classes. Juvenile animals of year class 0 with a mean shell length of 2 mm were numerically dominant, whereas larger animals of the older year classes with a mean over 5 mm were more rare in the samples.

Table 3.1. Bhattacharya analysis statistics

Year Class	**(n)**	**Mean (mm)**	**SD**	**si**
0	2095	2.01	1.109	-
1	138	4.66	1.491	2.836
2	65	8.57	1.098	2.89
3	18	12.10	0.842	3.576
4	22	15.34	1.342	2.964

Figure 3.1 Length Frequencies With Year Class Normal Distributions Superimposed (Arrows indicate mean year class shell length determined by Bhattacharya analysis)



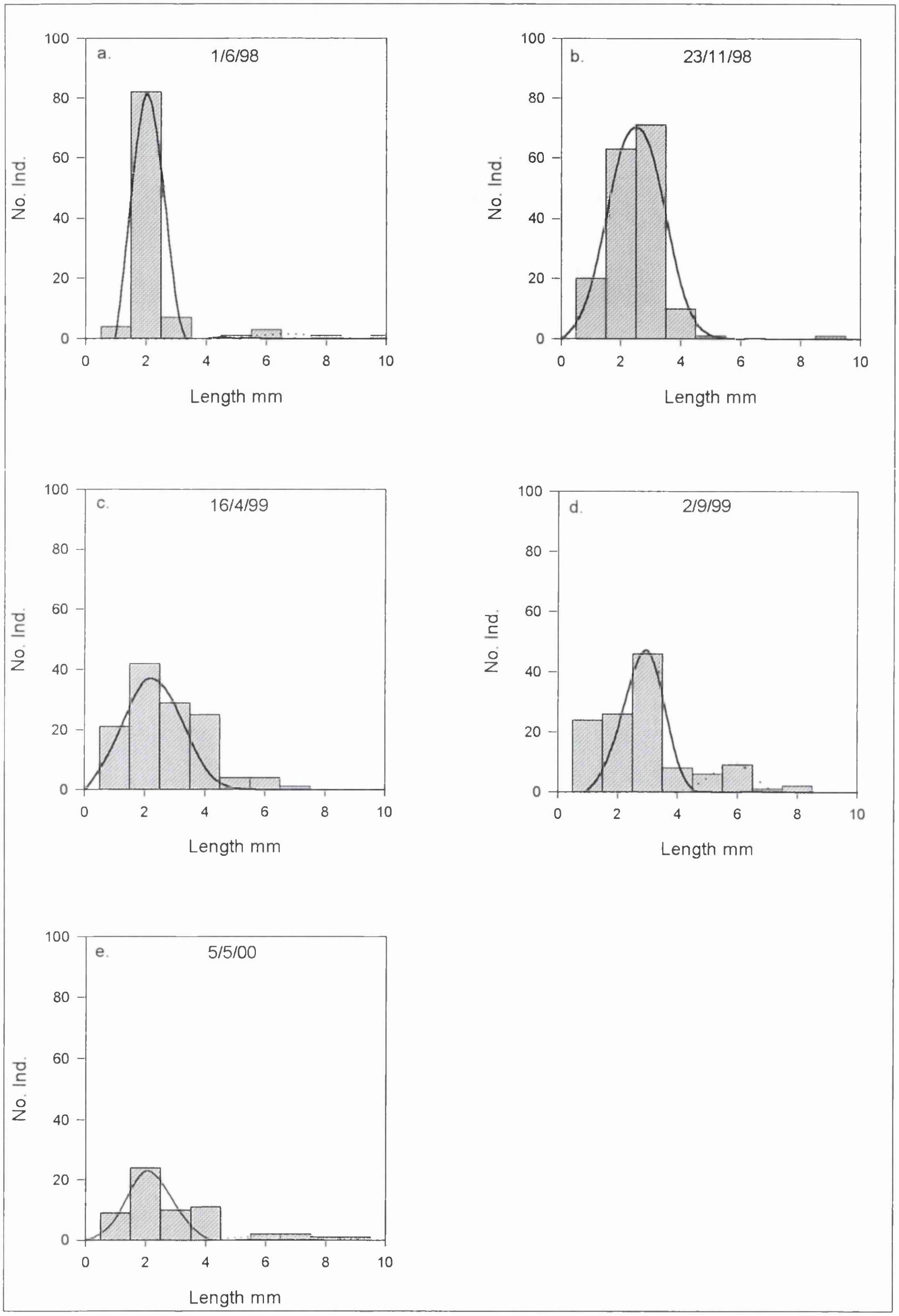
3. 3. 1. 2 Time Series Data

Length-frequency data for the Time Series Station 49 are presented in Appendix 3.2. Figure 3.2 illustrates the length frequency distribution of *F. fabula* at the time station 49. Small animals (<5 mm) were numerically dominant at all sampling times. Larger animals were less abundant, the very largest size classes only represented by single animals.

Bhattacharya method was used for the identification of separate year classes. Two year classes were identified in June 1998, September 1999 and May 2000 samples, but not in the November 1998 or April 1999 samples where only single classes were present. Distributions of these are superimposed on the length frequency histograms in Figure 3.2 a-e.

Comparison of time series and Carmarthen Bay population length frequency histograms show that the animals at the time series station repeat the pattern of abundant small size classes and rare large individuals from year to year. The time series station was characterized by the generally small size of individuals. The largest individual at the time series station measured 10 mm, half the length of the largest individual in the Carmarthen Bay population sampled in the baseline survey. The absence of older size classes was also apparent only two of the five year classes were recorded at the time series station; juvenile year class 0 was present in all samples and year class 2 was recorded on three occasions.

Figure 3.2 a-e Length Frequency Histograms of *Fabulina fabula* at Time Series Station 49.



3. 3. 1. 3 Spatial Distribution of Year Classes

Individual station data from the baseline survey (Chapter 2) were separated into individual year classes using the mean shell length determined by the Bhattacharya method. Abundances of individual year classes at each quantitative station are presented in Table 3.2 and plotted spatially in Figures 3.3 – 3.7.

Individuals of year class 0 were nearly ubiquitous at quantitative stations; only absent at stations 21 and 25, at Worms Head and the mouth of the Loughor estuary. Highest abundances were recorded in an area in the centre of the bay, south of Ragwen Point stretching east towards Burry Holms (Figure 3.3). Highest abundances of year class 0 were Stations 54 (204 ind. 0.2 m^{-2}), Station 58 (181 ind. 0.2 m^{-2}) and Station 41 (175 ind. 0.2 m^{-2}). Lowest abundances of year class 0 were found at the southern stations of the survey area.

Individuals of year class 1 were present at all but four quantitative stations; stations 40, 43, 87 and 88, all on the southern periphery of the survey area. There was no discernible general pattern of abundance for year class 1. Highest abundances were recorded at Station 51 (90 ind. 0.2 m^{-2}) in Saundersfoot Bay and at station 60 northeast of Caldey Island (Figure 3.4).

Year class 2 shows a marked reduction in overall abundance although individuals were present at all but eight quantitative stations. An area of relatively high abundance of this year class is apparent south of Pendine Sands; highest abundances were recorded at Station 56 (16 ind. 0.2 m^{-2}), Station 55 (10 ind. 0.2 m^{-2}) and Station 64 (10 ind. 0.2 m^{-2}) (Figure 3.5). Year class 2 was absent from stations in the south of the bay.

Year class 3 was the least abundant year class and was present at under half the quantitative stations. Year class 3 was mainly concentrated in the north west of the bay inshore of Caldey Island (Figure 3.6). The highest abundance was recorded in Saundersfoot Bay at Station 51 (7 ind. 0.2 m^{-2}).

Year class 4 was present at seven quantitative stations all situated in the north west of the bay inshore of Caldey Island (Figure 3.7). The highest abundance was again as Station 51 in Saundersfoot Bay.

Table 3.2 Individual Year Class Abundance (ind. 0.2 m^{-2})

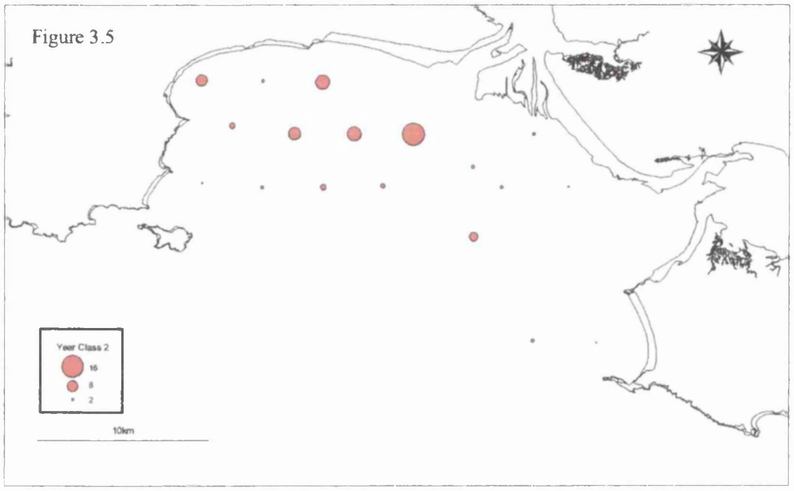
Station	**23**	**26**	**27**	**28**	**31**	**34**	**36**	**40**	**41**	**42**	**43**	**44**	**45**	**48**	**51**	**54**	**55**	**56**	**57**	**58**	**59**	**60**	**64**	**84**	**87**	**88**
Year 0	7	35	70	50	120	78	13	1	175	99	3	21	92	87	71	204	108	148	76	181	36	102	88	1	1	4
Year 1	5	16	8	41	35	20	2	-	11	2	-	17	24	10	90	24	9	45	6	19	4	67	44	2	-	-
Year 2	1	1	2	2	2	-	2	-	6	-	-	1	4	2	8	9	10	16	-	3	4	2	10	-	-	-
Year 3	-	3	-	1	-	-	-	-	1	-	-	1	4	1	7	2	5	-	-	2	-	1	4	-	-	-
Year 4	-	-	-	-	-	-	-	-	-	-	-	2	-	-	11	1	-	2	-	-	1	9	3	-	-	-

Figures 3.3 – 3.7 Distribution of *Fabulina fabula* Year Classes in Carmarthen Bay (ind. 0.2 m^{-2}).

Figure 3.3

Figure 3.4

Figure 3.5



Figures 3.6 & 3.7

Figure 3.6

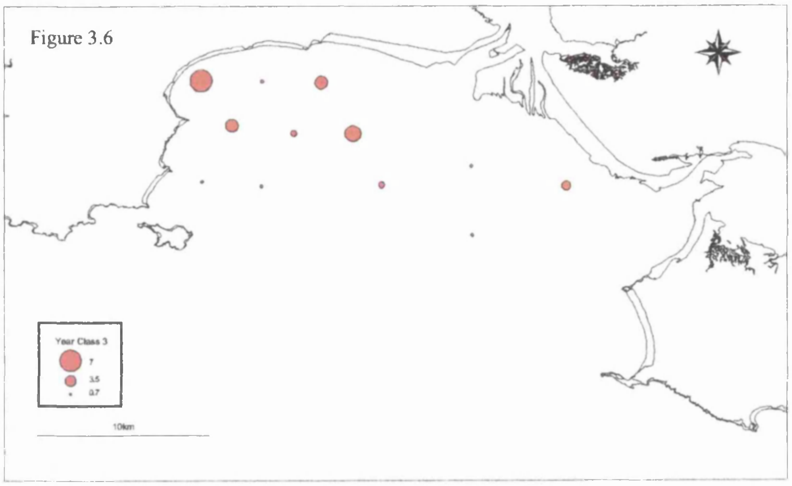
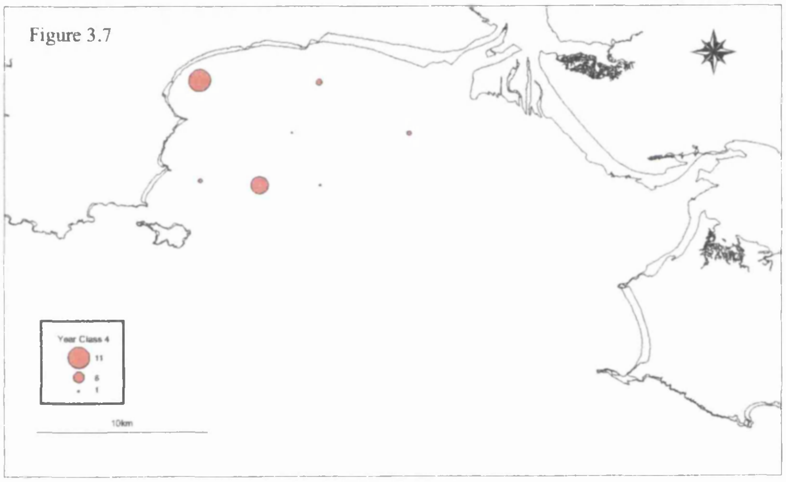


Figure 3.7



3. 3. 2 Linking Environmental Factors to Year Class Distribution

3. 3. 2. 1 BIOENV Results

BIOENV analysis revealed that the combination of environmental variables best matching the year class samples was that of '%Mud-Median Phi-Wave Height' returning a harmonic rank correlation (ρ_w) of 0.841, a very good level of similarity. These three variables are also ranked among the highest single environmental variables (Table 3.3).

Correlation of individual year classes with environmental variables identified by the BIOENV analysis revealed a general pattern of positive correlation with '% Mud' and 'Median Phi' and a corresponding negative correlation with 'Wave Height' and 'Depth' across year classes. The strength of these correlations reduced with age of year class (Table 3.4).

Table 3.3 BIOENV Harmonic Rank Correlations (ρ_w) of Best Variable Combinations

n.	(ρ_w)	Best variable combinations
1	0.692	Median Phi
1	0.653	%Mud
1	0.522	Depth
1	0.504	Wave Height
2	0.800	%Mud-Median Phi
2	0.792	%Mud-Wave Height
2	0.742	Depth-%Mud
3	**0.841**	**%Mud-Median Phi-Wave Height**
3	0.796	Depth-%Mud-Median Phi
3	0.779	Depth-%Mud-Wave Height
4	0.817	Depth-%Mud- Median Phi-Wave Height
4	0.807	%Mud-Median Phi-Residuals-Wave Height
4	0.796	%Gravel-%Mud-Median Phi-Wave Height
5	0.809	Depth-%Mud-Median Phi-Residuals-Wave Height
5	0.746	Depth-%Mud-Median Phi-%Organics-Wave Height
5	0.733	Depth-%Gravel %Mud-Median Phi-Wave Height

Table 3.4 Pearson Correlation Matrix for Year Class and Environmental Factors
P values classified as Extremely significant***, Very Significant**, Significant*.

	Depth	% Gravel	% Mud	Median Phi	% Organics	Residuals	Wave Height
Year Class 0	-0.391	0.257	0.621	0.616	0.488	-0.468	-0.537
P value (two-tailed)	*0.053*	*0.206*	$<0.001^{***}$	$<0.001^{***}$	0.011^{*}	0.016^{*}	0.005^{**}
Year Class 1	-0.540	-0.207	0.651	0.412	0.372	0.002	-0.519
P value (two-tailed)	0.004^{**}	*0.312*	$<0.001^{***}$	0.037^{*}	*0.061*	*0.991*	0.007^{**}
Year Class 2	-0.415	0.136	0.471	0.368	0.546	-0.233	-0.530
P value (two-tailed)	0.035^{*}	*0.507*	0.015^{*}	*0.065*	0.004^{**}	*0.253*	0.005^{**}
Year Class 3	-0.559	-0.166	0.485	0.292	0.569	-0.053	-0.509
P value (two-tailed)	0.003^{**}	*0.419*	0.012^{*}	*0.148*	0.002^{**}	*0.797*	0.008^{**}
Year Class 4	-0.307	-0.191	0.414	0.087	0.235	0.282	-0.379
P value (two-tailed)	*0.128*	*0.350*	0.036^{*}	*0.673*	*0.248*	*0.164*	*0.056*

3. 3. 3 Predictive Models of *F. fabula* Abundance and Distribution

3. 3. 3. 1 Predictive Model of Year Class 0 *F. fabula* Abundance

Using stepwise multiple regression it was demonstrated that over 65% of the variance in *F. fabula* year-class 0 abundance could be accounted for by the combination of environmental variables: Depth, Log_{10} %Mud, Residual Currents and Wave Height ($F_{4\text{-}21}$=9.876; $R^2 = 0.653$; p= 0.0001). Partial R^2 values revealed that the mud content of the sediment was the most important predictor variable followed by tidal residual current, maximum wave height and depth (See table 5 for model predictor statistics). Due to the likelihood of sampling error incurred in the correction of depth sounder readings to chart datum, depth was included as a predictor variable in the model although the p value was marginally outside of the normally accepted maximum of 0.05. The value of the Durbin Watson statistic was 2.524 indicating no autocorrelation of predictor variables. The adequacy of the model is plotted in Figure 3.8.

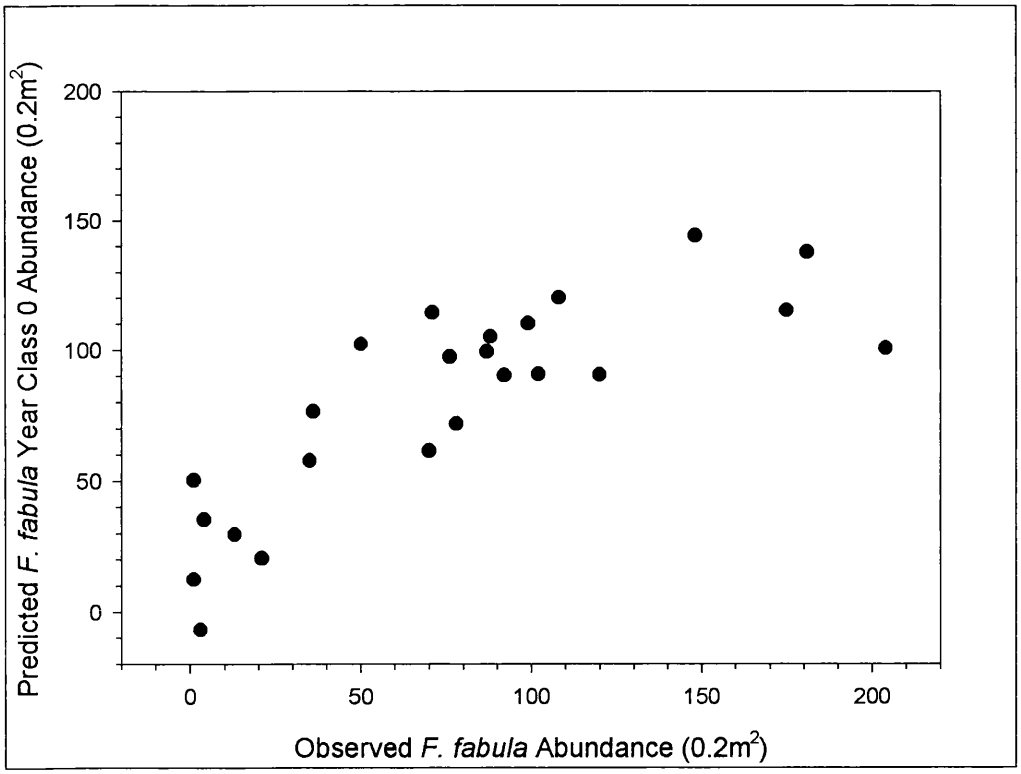
Table 3.5. Model predictor statistics

Predictor	**Partial R^2**	**P Value**	**Coefficient**
Log_{10} %Mud	0.385	0.0205	50.776
Wave Height	0.087	0.0025	-15.325
Residuals	0.114	0.0099	-1255.7
Depth	0.067	0.0568	3.900

Equation 3.1 Predictive Model of Year Class 0 *Fabulina fabula* Abundance in Carmarthen Bay

$$\boxed{\textbf{Year Class 0 Abundance} = 144.82 + (50.776 * \text{Log10 \% Mud}) + (-15.325 * \text{Wave Height}) + (-1255.7 * \text{Residuals}) + (3.900 * \text{Depth})}$$

Figure 3.8 Performance of the Stepwise Regression



3. 3. 3. 2 Predictive Model of Adult *F. fabula* Year Class Abundance

Stepwise multiple regression showed that over 56% of the variance in abundance of adult (>1year) *F. fabula* year-classes could be accounted for by the combination of two environmental variables: Log10 %Mud and Wave Period ($F_{2\text{-}23}$=14.604; R^2 = 0.559; p= <0.0001). Partial R^2 values revealed that the mud content of the sediment was the most important predictor variable followed by wave period (s^{-1}) (Table 6. Model Predictor Statistics). The Durbin Watson statistic was 2.386, indicating no autocorrelation between the predictor variables. The model's adequacy is plotted in Figure 3.9.

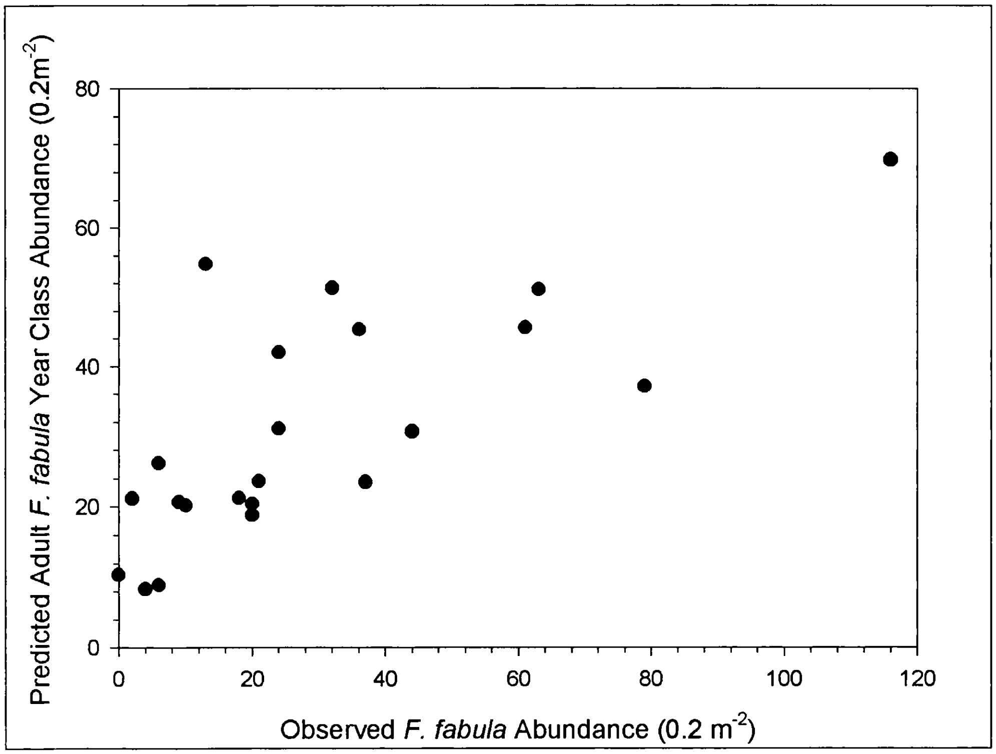
Table 3.6 Model predictor statistics

Predictor	**Partial R^2**	**P Value**	**Coefficient**
Log_{10} %Mud	0.434	0.01753	23.80
Wave Period	0.125	0.01762	-3.507

Equation 3.2 Predictive Model of Adult *F. Fabula* Year Classes Abundance in Carmarthen Bay.

$$\boxed{\textbf{Adult Year Classes} = 66.88 + (23.80 * \text{Log}_{10}\ \%\ \text{Mud}) + (-3.507 * \text{Wave Period})}$$

Figure 3.9 Performance of the Stepwise Regression.



3. 3. 4 Spatial Models of *F. fabula* Year Classes in Carmarthen Bay

3. 3. 4. 1 *F. fabula* Year Class 0

The application of the abundance model for year class 0 *F. fabula* (Equation 3.1) to a spatially distinct environmental dataset produced a spatial model of year class 0 *F. fabula* distribution in Carmarthen Bay. This model is presented as a contour map of predicted densities and distributions (Figure 3.10).

An extensive area of low year class 0 abundance is predicted in the east of the bay stretching from the Loughor estuary, south to the western tip of the Helwick sandbank. Further areas of low abundance (0-300 ind. m^{-2}) are predicted in an area around Caldey Island and at the mouth of the Three River estuary. There are three foci of high abundance (>900 ind. m^{-2}); two in the centre of the bay south of Pendine Sands and one to the east of Caldey Island. These high abundance areas are concurrent with a broad tongue of intermediate abundance (400-800 ind. m^{-2}) stretching southeast from Saundersfoot Bay to an area south of Pendine Sands and west of Burry Holms, representing in total 245 km^2 of seabed.

3. 3. 4. 2 *F. fabula* Adult Year Classes

The application of the abundance model for adult *F. fabula* (Equation 3.2) to the spatially distinct environmental dataset produced a spatial model of adult *F. fabula* distribution in Carmarthen Bay. The model is presented as a contour map of predicted densities and distributions (Figure 3.11).

The distribution of adult year classes is distinct from that of the year class 0 animals. There is a clear gradient of abundance in the model from peak numbers (450 ind. m^{-2}) in Saundersfoot Bay southeast to an area of low and zero values off Worms Head. The area of relative high abundance (>250 ind. m^{-2}) represents an area of 170km^2, covering an area from Pembrey Sands in the east to Tenby in the West. Areas of low abundance are exclusively situated in the south of the bay and around the mouth of the Loughor Estuary.

Figure 3.10 Predictive Model of Year Class 0 *F. Fabula* Abundance and Distribution in Carmarthen Bay

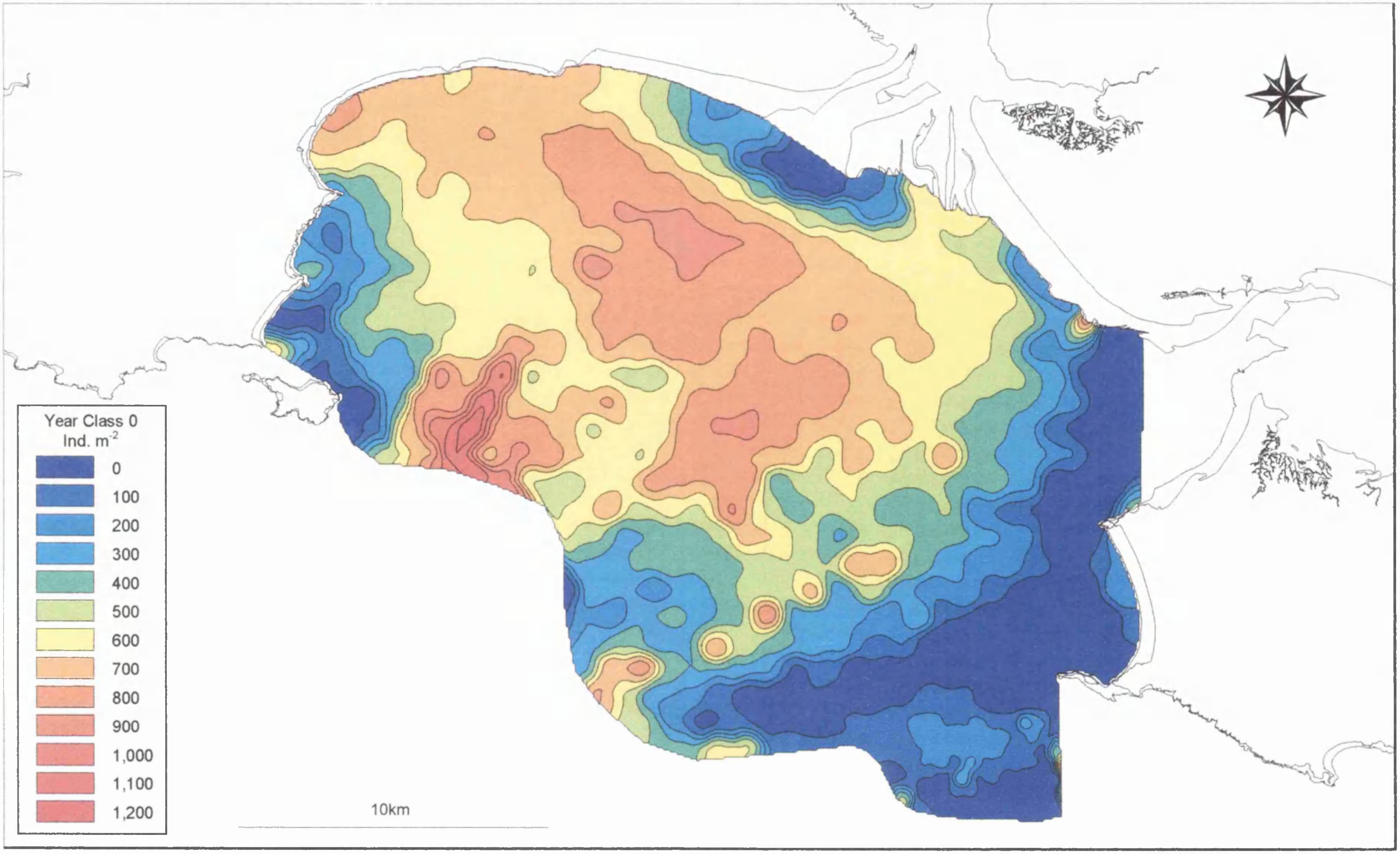
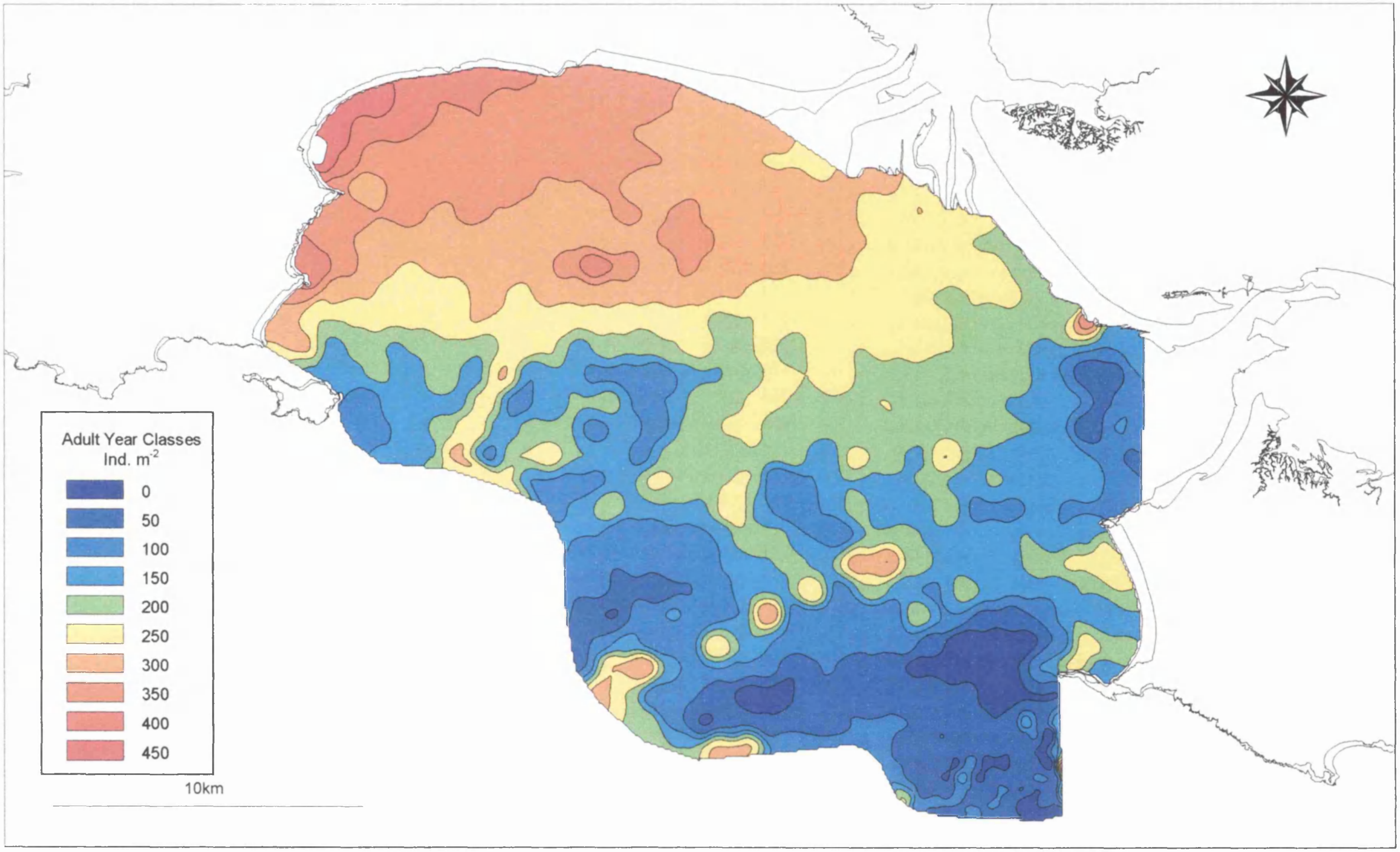


Figure 3.11 Predictive Model of Adult *F. fabula* Abundance and Distribution in Carmarthen Bay



3. 3. 5 Growth Parameters

As only two year classes were recorded at the time series station, growth was calculated using data from the baseline survey year classes.

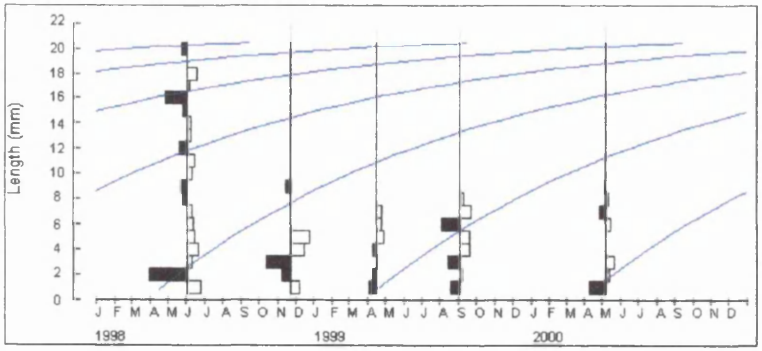
Von Bertalanffy growth parameters asymptotic length, $L\infty = 21.53$, and growth coefficient, $K = 0.670$, were estimated by the Response Surface Analysis and Scan of K-Value (Figure 3.12) functions in the ELEFAN routine of the FISAT software. The growth curve was superimposed on length frequency data plotted using restructured frequencies (Figure 3.12 a). For comparison, Von Bertalanffy growth parameters from a previous study in Carmarthen Bay (Warwick et al., 1978) and two sites in the German Bight (Salzwedel, 1979) are presented in Table 3.7. These parameters were superimposed as growth curves on Carmarthen Bay length frequency data plotted using restructured frequencies (Figures 12 a-d). Growth curves calculated for animals from the current survey are shown to be similar to those calculated by Salzwedel (1979) for German Bight animals, but markedly different than those calculated from the Warwick (1978) length at age data. $L\infty$ calculated for the 1998 Carmarthen Bay population ($L\infty = 21.53$) falls between the two values calculated for the German Bight populations ($L\infty = 17.85$ & $L\infty = 23.28$) and is 20% less than that calculated for the 1974 Carmarthen Population ($L\infty = 26.53$). K calculated for the 1998 Carmarthen Bay population ($K = 0.670$) was lower than both German Bight stations but much higher than the value calculated for the 1974 Carmarthen Population ($K = 0.195$).

Table 3.7 Comparison of VBGF Parameters

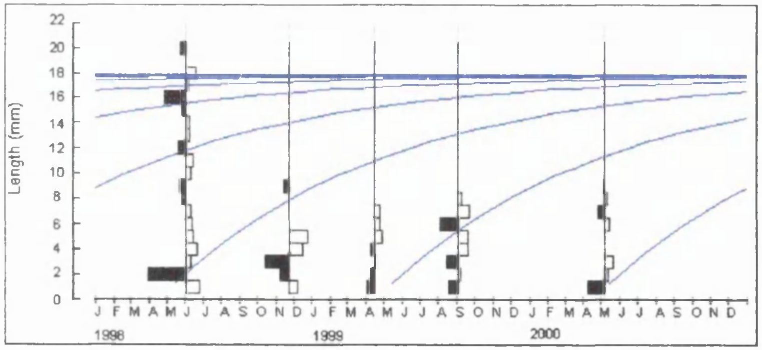
Site	$L\infty$	K
Carmarthen Bay 1998 Survey	21.53	0.670
'Tellinagrund' (Salzwedel, 1979)	17.85	0.966
'Sand Station' (Salzwedel, 1979)	23.28	0.766
Carmarthen Bay (Warwick 1978)	26.5	0.195

Figure 3.12 a-d VBGF Curves Superimposed On Restructured Length Frequency Histograms Of 1998 Carmarthen Bay Survey Data

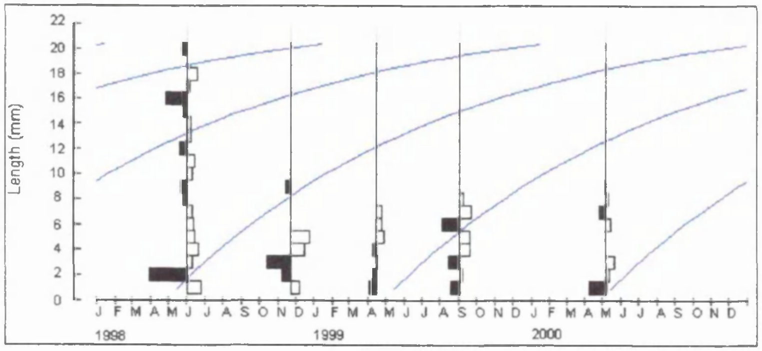
a. 1998 Carmarthen Bay



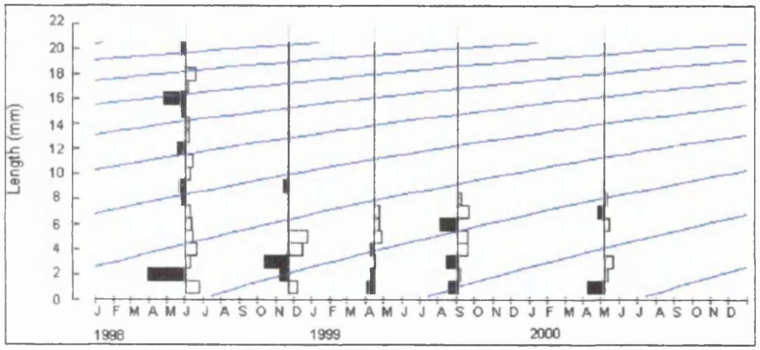
b. 'Tellinagrund' (Salzwedel, 1979)



c. Sand Station (Salzwedel, 1979)



d. Carmarthen Bay (Warwick, 1978)



3. 4 Discussion

The population structure of the Carmarthen Bay *F. fabula* population was characterized by five classes each likely to represent the recruits of five consecutive years, 1992-96 (Table 3.1 and Figure 3.1). In response to differences in individual growth and mortality rates in young animals the length of recruits from multiple settlements 'catch up' which has the effect of flattening the modal groups and results in the detection of single year classes by the length frequency analysis rather than detecting multiple cohorts within each year.

Fabulina fabula has been reported to continually spawn throughout the summer months (Rachor and Salzwedel 1976, Salzwedel, 1979), and larvae have been reported in the plankton until November (Bosselmann, 1988), therefore, each size class represent the recruits of a number of spawning events and settlements. The most abundant year class, year class 0, was defined by high numbers of recently recruited post-larval animals with shell lengths of less than 5 mm. The growth curve calculated for the Carmarthen Bay population (Figure 3.12 a.) suggests that the largest proportion of these animals would have been spawned from late February/early March onwards. Furthermore, using size at metamorphosis as size at settlement of ~0.36 mm (Webb, 1986), it is probable that the first recruits settled to the benthos in early April.

The Von Bertalanffy growth parameters for the Carmarthen Bay population (calculated by the ELEFAN application) and estimated life span are in broad agreement with those calculated for two German Bight populations by Salzwedel (1979); *Fabulina fabula* live for around 4 years, reaching a maximum shell length of approximately 21.5 mm, with a VBLF K = 0.670. Warwick (1978) provided growth parameters for the Carmarthen Bay *F. fabula* population based upon length at age data calculated by counting shell growth rings. These animals were shown to live for up to 7 years and approached their asymptotic length (L∞) much more slowly (K = 0.195) than found in the present and the German Bight study. This disparity between growth parameters was considered erroneous by Salzwedel who suggested the counting of seasonal shell rings as annual was responsible. The results presented here, derived from length frequency analysis , confirm that there is a difference between methods, but without a direct comparison it would be unwise to conclude either one is erronous. The mean shell length of year classes identified by the Bhattacharya method in this study are slightly less than those reported by Salzwedel (1979), for corresponding year classes in the German Bight established using a combination of growth ring counts and shell measurements. Whether this is due to biological differences between populations, Carmarthen Bay animals being generally smaller, environmental differences between sites, habitat, some aspect of their biogeography or inaccuracies in the LFA/Bhattacharya method is not clear. The length frequency analysis method used in this study has a disadvantage in its reliance on the arbitrary birth date, 1st June, given to length size classes due to the lack of information on the timing of spawning or settlement in proceeding years and so may result in a small error in the estimation of length at age.

Length frequency histograms of *F. fabulina* at time series station 49 again show that small post-larval year class 0 animals were most abundant (Figure 3.2). These newly settled recruits were present in all samples throughout the year from as early as April through to late November. By applying the growth curve calculated for the Carmarthen Bay population to the April 1999 sample (Figure 3.12 a) it is estimated that a proportion of them would have settled in late January or early February, mid-winter, of that year. Extended spawning throughout the winter has been reported for other tellinacean bivalves (Stead et al., 2002). Stead et al. (2002) suggested the extended spawning throughout the winter by *Semele solida* (Gray) was a consequence of its ability, like that of *F. fabula*, to feed on bottom deposits when food in suspension was low. Continuous reproduction is most common in deep sea and tropical species, but uncommon in temperate bivalves (Sastry, 1979). Temperature is a major factor in regulating both feeding behaviour and reproductive events in marine bivalves (Sastry, 1979). The low winter temperatures reported by Salzwedel (1979) in the German Bight and Muus (1973) in the Øresund area of the Baltic may act to inhibit reproduction and may account for the absence of winter recruits at those locations, whereas the average winter temperature in Carmarthen Bay of around 7°C may allow some low level of wintertime reproduction and recruitment (Environment Agency data). Deposit feeding activity has been demonstrated to increase at low temperatures in *M. balthica* (de Wilde, 1975) and was suggested as the reason for increased soft tissue production in *F. fabula* during midwinter by Salzwedel (1979) and demonstrated experimentally in *M. balthica* by Honkoop and Beukema (1998) (Honkoop & Beukema, 1998). A corresponding increase in deposit feeding in the Carmarthen Bay *F. fabula* population during winter may provide sufficient resources to allow some level of reproductive output during this time. It is equally possible that these animals are late autumn recruits whose growth having been retarded during the winter months, subsequently joined the size class of the succeeding years recruits. A seasonal pattern of winter dormancy and summer activity of organisms is characteristic in temperate seas, temperature is often suggested as the main cause for winter dormancy owing to its direct effect on the rate of chemical reactions and its indirect effect on other physical parameters of the environment (Coma et al., 2000). As the biogeographic range of *F. fabula* extends from Norway and the Baltic Sea in the north, south to the Iberian peninsular, the Mediterranean, the Black Sea and the Atlantic coast of Morocco, it is likely to be adapted to a temperature range from ~3°C to ~20°C. Carmarthen Bay winter temperatures fall somewhere at the bottom end of the scale which could conceivably affect winter productive output.

Older year classes were conspicuously absent as were animals larger than 10 mm (year class 2). The absence of older larger animals suggests that significant post-settlement factors are affecting the size structure of *F. fabula* at Station 49, the nature of these are discussed below.

The post-settlement effects of mortality, and more specifically predation, is a major influence on the patterns of distribution and abundance of adult bivalves and are likely to be an important factor in determining the distribution of *F. fabulina* in Carmarthen Bay, at least on the small scale <100 m. On a larger scale > 1 km however, the effect of predation may become confounded by the broad scale physical effects and recruitment patterns (Fernandes, 1999).

The distribution and abundance of *F. fabula* year classes in Carmarthen Bay were shown to be strongly influenced by physical environmental factors. Multivariate analysis by the BIOENV procedure showed that the distribution of a combination of environmental variables '% Mud-Median Phi-Wave Height' strongly matched the distribution of the year classes. Correlation of individual year classes with physical environmental variables revealed a significant positive correlation between percentage of mud and abundance of all year classes and a corresponding significant negative correlation between peak wave height and all year classes. The negative relationship with high hydrodynamic energy, represented by peak wave height, and the converse positive relationship with the mud fractions, which commonly occur in areas of low hydrodynamic energy, suggested that the distribution of *F. fabula* year classes in

Carmarthen Bay is dictated by gradients in the local hydrodynamic regime. The results from the stepwise multiple regression models of year class 0 and adult year class abundance provide compelling evidence to support this: 65.3% of the variance in year class 0 abundance was accounted for by the combination of depth, percentage of mud, strength of residual currents and peak wave height. Again, there is a positive relationship between abundance and percentage mud and a negative one between variables representing hydrodynamic energy (peak wave height and residual tidal current speed).

The stepwise multiple regression model of adult year class abundance showed that 56% of the variance in the abundance was accounted for by a combination percentage mud (43%) and length of wave period (13%). As in the year class 0 model, percentage mud was the most important environmental factor in predicting abundance. Wave period values entered into the model probably reflect a general level of wave energy at those sites, wave height and period is reduced as wave energy is attenuated by its action on the seabed.

The direct linkage between the prevailing hydrodynamic processes and the distribution of *F. fabula* in Carmarthen Bay is illustrated by the year class 0 spatial model. The position in the bay of the areas of high year 0 abundance predicted by the abundance and distribution models were found to closely resemble the equi-distant pattern of distribution of sediment parting zones reported by (McLaren, 1999) (Figures 3.14 & 3.15). Sediment Trend Analysis (STA) (McLaren & Bowles, 1985; McLaren, 2001) of Carmarthen Bay revealed a series of transport pathways emanating from three major sediment parting zones and converging at three major meeting zones (McLaren, 1999). STA is a technique that enables patterns of net sediment transport to be determined by relative changes in grain-size distributions of all naturally occurring sediments. Additionally, STA can determine the dynamic behavior of bottom sediments with respect to erosion, accretion or dynamic equilibrium.

Figure 3.14 Sediment Parting and Meeting Zones (After McLaren, 1999)

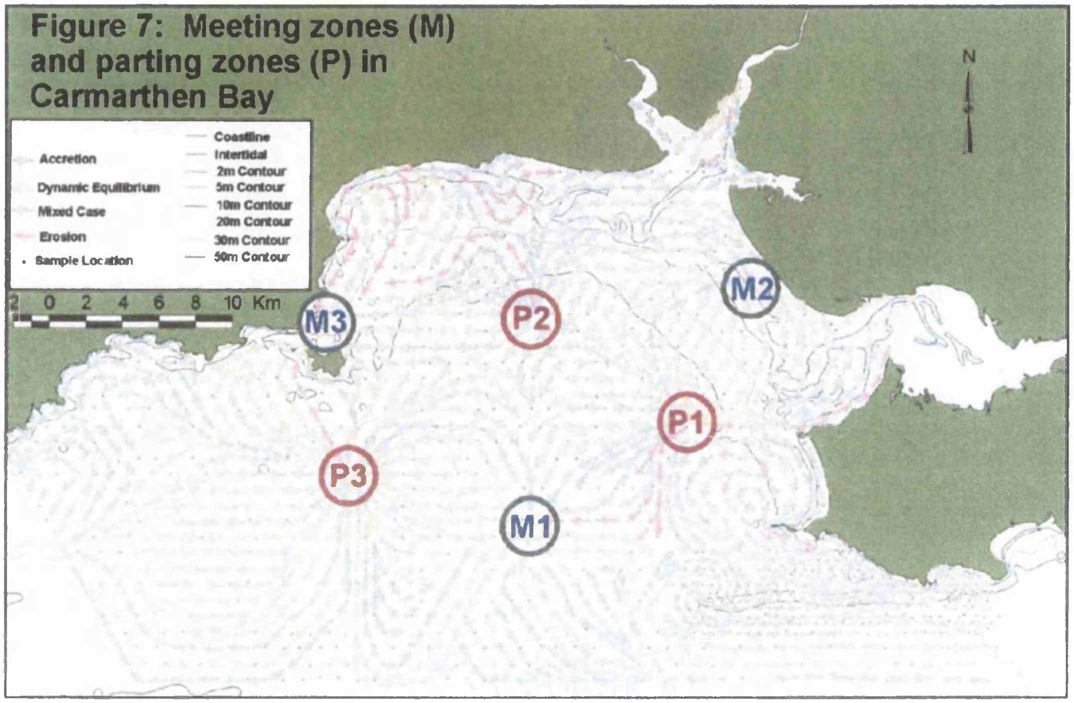
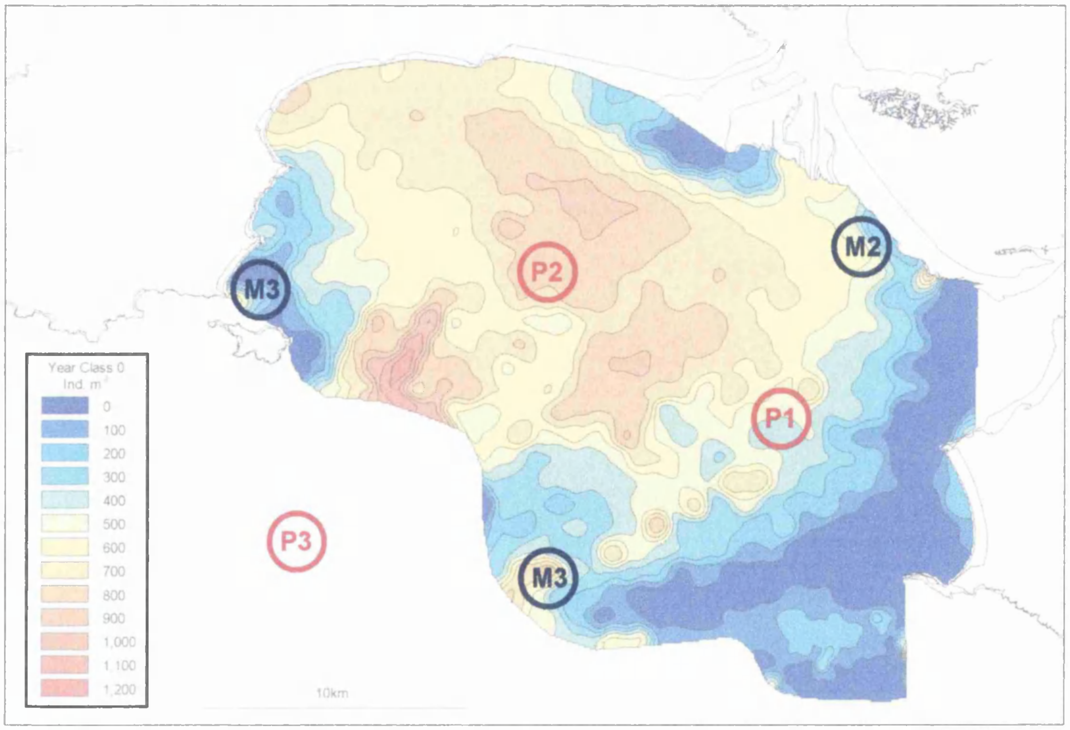


Figure 3.13 Sediment Parting and Meeting Zones Superimposed on Year Class 0



McLaren (1999) postulated that extreme events (the example given, a storm surge acting together with spring tides) act to load the parting zones with sediment, after which regular transport processes proceed to produce the derived transport patterns, returning the build up of sediment to the meeting zones. The equi-spaced positioning of these parting and meeting zones was accounted for by resonance features produced by the prevailing tidal, wave and wind driven hydrodynamics. As part of the same study, wave generated bedload currents were reported to be the key hydrodynamic force implicated in sediment transport in Carmarthen Bay, bed shear velocities for waves and currents were shown to have values up to 50 times greater than for currents alone (ABP-Research, 2000). Additionally, tidally driven residual currents were considered to be of importance in the net transport of solutes and fine material, and although considerably weaker than storm driven residual currents, were considered to have a significant long-term contribution to their overall distribution (ABP-Research, 2000). It seems likely that processes similar to those involved in the loading of sediment to the parting zones act upon the juvenile animals, although at a lower magnitude, transporting them as passive particles to similar positions in the bay.

It is suggested that the distribution of juvenile *F. fabula* in Carmarthen Bay is due to the combination of passive accumulation of competent larvae and the subsequent post-larval redistribution by the action of wave and tidal induced currents. The importance of hydrodynamics in the supply of larvae to the substratum has been well studied and, at least at small spatial scales, well understood (Butman, 1987; Snelgrove & Butman, 1994; Metaxas, 2001). The prevailing current regime has been shown to be the prevailing factor in the regulation of horizontal larval transport at broad spatial scales of 1000-10000km (Scheltema, 1986) and at smaller 100-1000km scales in cross shelf transport (Shanks, 1995). The scales of transport operating within

Carmarthen Bay are likely to be in the region of 10s of kilometres. At these scales a number of additional processes have been identified in the regulation of larval distribution including wind stress, tidal currents and salinity fluxes resulting from the outflow of estuaries (Eggleston et al., 1998; Xie & Eggleston, 1999; Epifanio & Garvine, 2001). Given the importance of wave and tidal current driven processes in the sorting and redistribution of sediments and their implication in the distribution of post-larval *F. fabula*, it is reasonable to assume they have a corresponding role in the fate of larval stages. Areas of low wave and tidal current flow have been long demonstrated to be areas where competent larvae, acting as passive particles, may be entrained, enter the benthic boundary layer and ultimately settle (Hannan, 1984; Shanks, 1995). This process of passive settlement, entrained by the prevailing hydrodynamic conditions was found to be responsible for the distribution of a *F. fabula* population in the southern North Sea (Creutzberg, 1986) and may be responsible for the concentration of larvae, particularly competent larvae, in those areas of the bay corresponding to the areas of high juvenile abundance.

Both the passive and active redistribution and migration of the post-larval stages of bivalve is widely reported in the intertidal (Baker & Mann, 1997). Many bivalves have post-metamorphic stages that are functionally distinct from the late juvenile or adult stages. The plantigrade and the pelagic post-larvae are post-larval stages most often implicated in post-larval redistribution and migration (Baker & Mann, 1997). The plantigrade of *F. fabula* is likely to be of too small a size to enable it to bury in the sediment, and is forced to crawl through the top few millimetres of the substratum or the interstitial spaces between sediment grains. The limitation in its vertical distribution in the substratum makes the plantigrade vulnerable to hydrodynamic processes acting on the surface of the sediment. Plantigrade post-larvae and young juvenile bivalves have been shown to be subject to limited redistribution by tidal or wave current induced bedload transport (Emerson & Grant, 1991; Cummings et al., 1993). This mode of redistribution may transport animals tens to hundreds of metres over a tidal cycle or storm event (Beukema, 1993). The process is not a solely passive one, there is evidence that post-larval *M. balthica* utilize the everted foot as a functional drogue and actively enter the water column at periods of tidally induced bedflow to redistribute themselves (Armonies, 1992). It is conceivable that similar behaviour, in conjunction with prevailing hydrodynamic conditions act in part to concentrate or entrain the post-larvae and small juvenile *F. fabulina* into the foci of high abundance identified in this study.

A second mode of post-larval transport, acting on wider spatial and temporal scales, may also be implicated in the redistribution or migration of the Carmarthen Bay *F. fabula* population. Post-larval drifting by means of a byssal thread or hyaline mucus string is the most regularly reported means of post-larval transport (Sigurdsson, 1976; Baker & Mann, 1997; Wang & Xu, 1997; Hiddink et al., 2002). Byssal drifting stages have been reported in other members of the Tellinacea (Sigurdsson, 1976) but not previously recorded in *F. fabula*. Byssal drifting has been widely studied in the intertidal *M. balthica* (Beukema & Devlas, 1989; Armonies, 1992; Armonies & Hellwig-Armonies, 1992; Armonies, 1996; Garrison & Morgan, 1999; Hiddink et al., 2002). Population wide redistributions, taking place over a longer period of days and weeks, have been reported in this species at distances of over 15km in the Wadden Sea (Beukema & Devlas, 1989). The function of a prolonged byssal drifting stage in *F. fabula* may not be solely one of dispersal, but may provide the animal with the capacity to perform an ontogenetic habitat shift. This type of population wide redistribution may explain the disparity between predicted distributions of juvenile and adult animals shown in the spatial models.

The ontogenetic niche was defined by Werner and Gilliam (Werner & Gilliam, 1984) as 'the patterns in an organism's resource use that develop as it increases in size from birth to its maximum'. Salzwedel (1979) described an ontogenetic shift in resource use from an obligate suspension feeding in small <3-5 mm juveniles of *F. fabula* to facultative deposit and suspension feeding in larger animals. This was supported by the application of Hughes's (1973) linear model of inhalant aperture to shell length in *Abra tenuis* (Montgu) to shell length data for *F. fabula*, Salzedel (1979) revealing that small (<3.3 mm) animals could not ingest sediment of the modal size (188 μm) in which they were found. In Carmarthen Bay the adult year classes are seen to occur in sediments containing a higher percentage of mud than that of the juveniles of the population. Muddy sediments are often strongly correlated with high organic content, a unit volume of smaller particles has been shown to contain a higher organic nitrogen than one of larger particles (Longbottom in Hughes, 1980), and therefore represent an energetically more profitable food resource for deposit feeding animals. Examination of the time series length frequency data provides evidence that may support the ontogenetic habitat shift hypothesis. The largest animal recorded during the whole sampling period at the time series station measured 10 mm, at the majority of sampling times animals >8 mm had disappeared, either failing to grow to size or being removed by predation or, as proposed, by redistribution. The concept of optimal foraging is probably so important to the survival of bivalves that extant forms may be living close to their preferred optima (Hughs, 1980). Due to their sedentary nature, the foraging strategies of bivalve deposit feeders are mainly a function of ingestive and digestive processes; the regulation of feeding rates, particle selection and gut retention times (Taghon and Jumars, 1984). *Fabulina fabula* in Carmarthen Bay may add to these strategies by, upon reaching a critical size of around 5 mm, undertaking a redistribution in search of more profitable sedimentary habitats resulting in the distribution patterns described by this study.

This ontogenetic habitat shift may also act as a process whereby adult animals are kept separate from settling and newly settled post-larvae. By using Hughes's (1973) linear shell length/inhalant aperture diameter model for the deposit feeding tellinacean *A. alba*, and assuming that a similar relationship exists in *F. fabula*, it is seen that a deposit feeding adult with a shell length of 7-8 mm could ingest post-larvae at the <0.4 mm size at settlement given by Webb (1986).

Chapter 4: Macrofaunal Response Groups: a Multivariate Method for Isolating Indicator Species Along Environmental Gradients.

4. 1 Introduction

An indicator species was defined by Landres et al. (1988) as an organism whose characteristics (e.g., presence or absence, population density, dispersion, reproductive success) are used as an index of attributes too difficult, inconvenient, or expensive to measure for other species, or as an index of environmental conditions of interest. Due to the logistical difficulties and expense associated with working in the marine environment one or more of these criteria often apply and therefore the use of indicator species in marine monitoring is commonplace. Indicator species have been used in the assessment of anthropogenic impacts such as hydrocarbon contamination (Moore, 1991; Gaston et al., 1998), eutrophication (Rygg, 1985; Blackstock et al., 1986; Corbera and Cardell, 1995) industrial discharges (Olsgard and Rytter-Hasle 1993; Ward and Hutchings, 1996; Corfield, 2000), TBT contamination (Meador, 1993; Minchin et al., 1997; Dahllof et al., 2001) and recently the effects of fishing (Kaiser, 1996; Ramsay et al., 2000; Ramsay et al., 2001).

Patterns in composition, richness and diversity of sessile benthic communities have often been shown to reflect clines of abiotic environmental factors (Rakocinski et al., 1993; Bell and Barnes, 2000; Brown et al., 2000; DeFelice and Parrish, 2001). Patterns of distribution and abundance of individual member taxa similarly reflect these environmental clines. The identification of sub-groups or individual taxa of a community responding to environmental clines may be an important first step in ecological studies.

Often the methods employed in the isolation of indicator species are subjective, reliant on the expertise of the ecologist involved to indicate groups of species characterising various stages of response to a gradient (see Pearson and Rosenberg, 1978). Other less subjective methods rely on the a priori selection of a species or group of species and subsequent laboratory or field manipulation experiments to assess the utility or suitability of a species as an indicator of a particular pollutant or environmental factor (Parry et al., 1997; Fichet et al., 1998). An objective, statistical, framework for the isolation of indicator species was presented by Gray and Pearson (1982) and Pearson et al. (1983). This method detects deviations from a log normal distribution of individuals among species caused by structural changes within a community affected by pollution and has been widely used in ecological studies and pollution impact studies where it is also used as a measure of disturbance (e.g. Hall et al., 1997; Harvey et al., 1998; Mucha and Costa, 1999; Koutsoubas et al., 2000; Rizzo and Amaral, 2000; Pagola-Carte and Saiz-Salinas, 2001; Pohle et al., 2001; Vopel and Thiel, 2001).

The non-parametric multivariate strategy for analysing multispecies patterns described by Field et al. (1982) and also Clarke and Warwick (2001) has become commonplace in marine environmental assessment and monitoring programs e.g. Olsgard and Rytter-Hasle (1993); Olsgard and Gray (1995); Ward and Hutchings (1996); Saiz-Salinas (1997); Morris and Keough (2002). Multivariate methods of this type are acknowledged as being more sensitive than univariate or simple descriptive measures for the discrimination of sites (Gray et al., 1990; Warwick and Clarke, 1991) and have been recommended as the first step of data exploration in a monitoring study (Gray et al., 1988). Urkiaga-Alberdi et al. (1999) employed a combination of multi- and univariate techniques in the identification of sessile hard substratum species sensitive to anthropogenic disturbance.

A multivariate measure of the degree to which a community (faunal) change conforms to a linear sequence, the Index of Multivariate Seriation (IMS), was suggested by Clarke et al. (1993) in their examination of the effects of dredging on the structure of coral communities using the RELATE procedure, a non-parametric Mantel test (Mantel, 1967). Somerfield (2002) used RELATE to detect a macrofaunal response along distance gradients around drilling platforms, but indicated that this procedure is applicable to any ecological or monitoring study in which a faunal response to a gradient may occur. In the current study the RELATE procedure is used to provide a multivariate measure, the Index of Community Response (ICR) (directly analogous to the IMS of Clarke et al. (1993)), of the degree to which a community (faunal) change conforms to that of the environmental gradient. Somerfield et al. (2002) demonstrated the enhanced sensitivity of the RELATE procedure in comparison to the multivariate categorical ANOSIM technique (Clarke and Green, 1988; Clarke, 1993) in the detection of spatial gradients in macrofaunal community data. The use of categorical techniques in the detection of a response to environmental variables may not be appropriate. Sample stations must be classified into arbitrary groupings, for example a series of depth soundings could be split into three categories, shallow, medium and deep stations, the thresholds for which may not correspond to those responsible for a detectable biological change.

A stepwise multivariate technique, BVSTEP, has been previously applied to quantify structural redundancy in ecological communities represented by sub-groups of the community (Clarke and Warwick, 1998). In the current study, BVSTEP was employed to define subsets of the community whose patterns of occurrence and abundance reflect those of the selected environmental variable. Clarke and Warwick (1998) used the term ‘Response Unit’ to refer to sub-groups representing structural redundancy within a community. To avoid confusion, the term ‘Response Group’ is used here to refer to subgroups of a community that demonstrate a response to an environmental factor.

The aim of the current study is to provide a wholly multivariate correlative technique to identify species or groups of species (response groups) sensitive to abiotic environmental gradients. The isolation of these response groups in the first stages of community analysis may help direct later analysis and interpretation.

The dataset analysed in this study was produced during an investigation of the benthic ecology of Carmarthen Bay, South Wales UK. The fine sand substratum of Carmarthen Bay is dominated by fauna of Petersen's (1914) *Tellina* sub-community. The physical environment of Carmarthen Bay is subject to strong hydrodynamic and sedimentary gradients which affect the extent and distribution of the community and individual taxa (Chapter 2).

4. 2 Materials and Methods

The macrofauna data used in this study, station/species data from 28 quantitative stations, were produced during a 1998 survey of Carmarthen Bay. The species abundance data were initially reduced to those taxa representing more than 0.1% of the total fauna count, removing those taxa occurring at few or single stations which were found to produce spurious results in the BVSTEP procedure. An additional benefit of this action is to substantially reduce the computation time of this procedure. Species abundance data were log (x+1) transformed so that during the ensuing multivariate analysis, patterns in variation of less abundant taxa were accounted for by reducing the influence of the more abundant ones. Environmental data came from two sources; sedimentary and depth data were collected during the same survey whereas tidal and wave height data were derived from hydrodynamic models developed by ABP Research (ABP, 2000) (Table 4.1). Sediment data, % Gravel, % Sand and % Mud were log (x+1) transformed to reduce skewness and stabilise the variance. Also included in the environmental dataset were the first two principal components (PC1 and PC2) resulting from a Principal Component Analysis (PCA) of the environmental variables, the PC1 accounted for 47% of the variation in the original PCA and consequently represents a strong composite environmental gradient.

The Bray-Curtis (Bray and Curtis, 1957) similarity coefficient was used to produce the macrofaunal between-station similarity matrices central to the multivariate statistical procedures used in this study. This coefficient is often used for species counts, being unaffected by zero counts common in these types of data (Field et al., 1982) and has been used previously in RELATE and BVSTEP analyses (Clarke et al. 1993; Clarke and Warwick, 1998). A more suitable (Clarke and Warwick, 2001) between station Euclidian distance matrix was calculated for each of the environmental variables.

The degree to which changes in the ecological data corresponded to those in environmental variable was assessed by calculating the ICR using the RELATE procedure. The ICR is defined as a Spearman rank-correlation coefficient (ρ), adjusted for tied ranks (Kendall, 1970) calculated between the corresponding members of 2 triangular matrices of 'dissimilarities': the first being the Bray-Curtis similarity matrix and the second the environmental Euclidian distance matrix. A nonparametric rank-correlation coefficient is an appropriate method of assessing the degree of agreement between similarity matrices derived from different methods of construction and having different units, species counts of the macrofaunal matrix and distances in the model matrix, their common denominator is the relative ordering of dissimilarities within each matrix. If the changes in the ecological data correspond exactly with the ranking in the environmental distance matrix, then the ICR will equal 1 and conversely, if the there is no discernible correspondence the ICR will be near zero.

A test for statistical significance of the ICR is provided by a Monte Carlo permutation procedure (Hope, 1968) which tests the H_0: The dissimilarities among samples from the ecological matrix are not (non-parametrically) correlated with the corresponding distances in the environmental matrix. The alternative hypothesis being H_1: The sample dissimilarities are correlated to the distances in the environmental matrix. For a full description and discussion of these procedures see Clarke et al. (1993).

A linear regression model was used to provide a univariate comparison and some measure of sensitivity of the RELATE procedures in the detection of a macrofaunal response to an environmental factor. The Shannon-Wiener diversity index H' ($\log_2$) was employed to represent the macrofaunal data in the correlations as normality of this index can be assumed (Magurran, 1988), making its use appropriate under standard general linear model theory (Sokal and Rohlf, 1981). The environmental data were transformed as necessary to provide constant variance across the stations and to allow an assumption of normality.

The BVSTEP procedure was used to isolate those subsets of taxa (response groups) sensitive to the environmental gradients found to elicit a response in the community. This subset selection procedure attempts to maximise a Spearman rank correlation coefficient (ρ) calculated with a standard adjustment for tied ranks (Kendall, 1970) between the corresponding entities in two triangular matrices of between-sample similarities: the Bray-Curtis similarities of the ecological matrix and Euclidean distances of the environmental matrix. As Clarke and Warwick (1998) indicate, a search of the full space of $2^t - 1$ possible subsets, where t is the total number of taxa, is computationally impractical and therefore a stepwise procedure is utilized. Analogous to stepwise multiple regression, this subset selection process progressively selects the taxon which most increases ρ at each iterative stage for addition to the existing subset. A deselection step also occurs at each stage removing a member from the subset in response to an increase in ρ. This selection procedure continues until a minimal-size subset is found meeting the selection criteria, $\rho > 0.95$, or there is no improvement of a minimal amount in ρ ($\delta\rho = 0.001$). Due to the large number of possible subsets (in this study $2^{63} - 1$) BVSTEP is not guaranteed to find all of the optimal subsets, it is therefore desirable to repeat the stepwise procedure several times with randomly selected starting points. Following the example of Clarke and Warwick (1998) 40 such random starts were run on an initial subset of 10% of the full taxa dataset, giving each taxon the independent probability of 0.1 of being selected for the initial subset. The subset containing the smallest number of taxa and that maximizes ρ was designated the 'response group' best matching the distribution of the environmental variable. An additional BVSTEP analysis was run using a composite environmental similarity matrix made up of % Mud, Median Phi and Wave Height as these have been found to be the best matched environmental variables in a BIOENV (Clarke and Ainsworth, 1993) analysis of the full macrofaunal dataset (see Chapter 2). Non-metric MDS ordinations of individual response groups with superimposed measures of the corresponding environmental variable provide a clear illustration of their relationships.

All multivariate calculations and procedures were undertaken using PRIMER v5 analysis software (Clarke and Gorley, 2001) on a desktop PC.

4. 3 Results

The RELATE procedure revealed that dissimilarities among samples from 6 of the 12 environmental matrices were significantly correlated with the distances in the macrofauna matrix (Table 4.2) rejecting the H_0: The dissimilarities among samples from the ecological matrix are not (non-parametrically) correlated with the corresponding distances for the Depth, % Mud, Median Phi grain size, Peak Flood Current, Peak Wave Height and PC1 gradients. The highest ICR values were recorded along the Median Phi (ρ 0.624) gradient and the composite PC1 (ρ 0.62) gradient. Significant correlations were calculated for the Depth, Median Phi, Peak Flood Current, Peak Wave Height variables, with ICR values ranging from 0.322 – 0.473. The % Gravel, Residual Current and PC2 distance matrices showed no significant correlation with the macrofaunal similarity matrix and were therefore rejected as showing no meaningful macrofaunal response.

The BVSTEP procedure isolated subsets of taxa whose between-pair Bray-Curtis similarity best correlated with values in a Euclidian distance matrix of each environmental variable found to exhibit a macrofaunal response in the RELATE procedure. Individual taxa lists for each response group are presented in Table 4.3.

The univariate comparisons provided by the general regression models of H′ response to individual environmental gradients are broadly in agreement with the RELATE procedure (Table 4.2). Significant linear relationships were found between H′ and each of the environmental factors, with the exception of the Median Phi, whose gradients were found to elicit a macrofaunal response by the RELATE procedure. However, the strength response, represented by the ICR and r^2 in the RELATE and regression analysis respectively, when ranked, show no concurrence; Median Phi was responsible for the highest ICR whereas Depth returned the highest significant r^2

value, the lowest significant ICR was returned for the Flood Current gradient and % Mud the lowest significant r^2.

Non-metric MDS ordination of individual response groups with superimposed measures of the corresponding environmental variable provide a clear illustration of the linear nature of the macrofaunal responses (Figure 4.1). These linear relationships are demonstrated in the arc-like arrangement of samples in ordinations of single factors % Mud and Flood Current and in the composite PC1 and BIOENV response groups.

Table 4.2 Results of the RELATE Analysis
An Index of Community Response (ICR) ρ value of 1 indicates a perfect correlation between community and environmental data, a value of near zero indicates no such relationship. Results of linear regressions of Shannon-Wiener diversity index H' are presented for comparison. Significant responses from either procedures in **bold**.

Environmental	**RELATE**		**Regression**	
Gradient	**ICR (ρ)**	**P**	**r^2**	**P**
Depth	**0.46**	**0.001**	**0.433**	**>0.001**
% Gravel	-0.047	0.65	0.007	0.666
% Sand	-0.006	0.457	**0.152**	**0.040**
% Mud	**0.381**	**0.001**	**0.144**	**0.047**
Median Phi	**0.624**	**0.001**	0.107	0.089
% Organics	0.092	0.16	0.113	0.080
Flood Current	**0.322**	**0.007**	**0.313**	**0.002**
Residuals Current	0.077	0.205	0.060	0.209
Wave Height	**0.473**	**0.001**	**0.263**	**0.005**
Wave Period	0.117	0.072	**0.293**	**0.003**
PC1	**0.62**	**0.001**	**0.349**	**>0.001**
PC2	0.023	0.35	0.003	0.777

Table 4.3 Response Groups Identified by the BVSTEP Procedure.
A Spearman rank correlation (ρ) value of > 0.95 indicates a perfect correlation between response group and environmental similarity matrices.

Environmental Gradient	ρ	No. Taxa	Response Group
Depth	0.614	15	*Sigalion mathildae*, *Autolytus* sp., *Lumbrineris gracilis*, *Scoloplos armiger*, *Scolelepis bonnieri*, *Capitella* sp., *Iphinoe trispinosa*, *Bathyporeia elegans*, *Bathyporeia tenuipes*, *Modiolus modiolus*, *Acanthocardia echinata*, *Donax vittatus*, *Turbonilla lactea*
% Mud	0.689	6	*Podarkeopsis capensis*, *Nephtys cirrosa*, *Scoloplos armiger*, *Capitella* sp., *Pontocrates arenarius*, *Turbonilla lactea*
Median Phi	0.76	16	*Sigalion mathildae*, *Nephtys* JUV., *Nephtys assimilis*, *Scoloplos armiger*, *Scolelepis bonnieri*, *Capitella* sp., *Euclymene oerstedii*, *Bathyporeia elegans*, *Bathyporeia tenuipes*, *Mysella bidentata*, *Tellimya ferruginosa*, *Donax vittatus*, *Thracia phaseolina*, *Phoronis* sp.
Peak Flood Current	0.563	11	*Nephtys assimilis*, *Nephtys cirrosa*, *Lumbrineris gracilis*, *Scoloplos armiger*, *Scolelepis bonnieri*, *Owenia fusiformis*, *Lanice conchilega*, *Pontocrates arenarius*, *Bathyporeia tenuipes*, *Modiolus modiolus*, *Donax vittatus*
Peak Wave Height	0.631	13	*Nephtys* JUV., *Nephtys assimilis*, *Chaetozone setosa*, *Iphinoe trispinosa*, *Perioculodes longimanus*, *Pontocrates arenarius*, *Bathyporeia* sp., *Bathyporeia elegans*, *Bathyporeia tenuipes*, *Microjassa cumbrensis*, *Tellimya ferruginosa*, *Acanthocardia echinata*
PC1	0.817	15	*Sigalion mathildae*, *Nephtys assimilis*, *Nephtys cirrosa*, *Lumbrineris gracilis*, *Scoloplos armiger*, *Capitella* sp., *Pontocrates arenarius*, *Bathyporeia elegans*, *Bathyporeia tenuipes*, *Modiolus modiolus*, *Tellimya ferruginosa*, *Acanthocardia echinata*, *Donax vittatus*, *Thracia phaseolina*, *Turbonilla lactea*
BIOENV (%Mud-Median Phi-Wave Height)	0.694	11	*Glycera tridactyla*, *Nephtys assimilis*, *Nephtys cirrosa*, *Scoloplos armiger*, *Capitella* sp., *Iphinoe trispinosa*, *Pontocrates arenarius*, *Bathyporeia elegans*, *Bathyporeia tenuipes*, *Donax vittatus*, *Turbonilla lactea*

Tables 4.4 – 4.10. Distribution of Response Group Taxa Along Environmental Gradients

Depth Response Group	**25**	**51**	**48**	**26**	**27**	**44**	**64**	**45**	**28**	**54**	**31**	**55**	**56**	**57**	**34**	**60**	**59**	**41**	**42**	**58**	**43**	**40**	**21**	**23**	**84**	**36**	**87**	**88**
Sigalion mathildae	-	12	24	3	1	5	16	12	5	18	8	1	10	7	5	1	1	12	5	8	-	-	-	-	-	-	-	-
Autolytus sp.	-	-	-	-	-	65	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lumbrineris gracilis	-	-	-	-	-	12	-	-	-	-	-	-	1	-	-	2	2	2	12	15	-	-	-	-	-	1	-	-
Scoloplos armiger	-	13	8	-	-	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-
Scolelepis bonnieri	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	1	-	2	3	2	5	-	-	10	1	3	9
Capitella sp.	2	4	4	6	38	12	-	11	49	26	5	8	-	4	8	7	-	8	4	10	-	-	-	5	-	-	-	-
Iphinoe trispinosa	-	38	9	-	-	2	10	-	10	6	6	2	3	3	-	2	1	2	1	-	-	-	-	1	1	-	-	-
Bathyporeia elegans	30	-	-	5	17	18	-	-	12	-	4	-	-	-	5	-	-	2	2	-	1	-	-	-	-	2	-	-
Bathyporeia tenuipes	-	2	22	6	7	28	-	12	2	5	6	1	3	2	6	14	5	-	6	3	3	-	-	-	-	-	-	-
Modiolus modiolus	-	7	21	-	-	100	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Acanthocardia echinata	-	8	-	-	10	-	3	2	107	2	-	-	1	-	-	1	-	1	-	-	1	-	-	-	-	-	-	-
Donax vittatus	-	6	2	8	9	2	3	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbonilla lactea	-	-	8	-	-	13	2	9	2	2	5	3	3	1	1	3	2	7	4	1	-	-	-	-	-	-	-	-

% Mud Response Group	**43**	**21**	**25**	**87**	**40**	**84**	**59**	**27**	**36**	**44**	**23**	**88**	**55**	**26**	**64**	**31**	**41**	**54**	**60**	**34**	**45**	**57**	**58**	**42**	**28**	**48**	**56**	**51**
Podarkeopsis capensis	-	-	-	-	-	-	1	-	-	8	-	-	-	1	1	-	3	1	1	-	1	5	21	20	-	2	-	-
Nephtys cirrosa	15	7	22	8	15	8	27	15	45	5	28	20	-	4	-	1	-	-	-	1	-	-	-	-	-	-	-	-
Scoloplos armiger	-	-	-	-	1	-	-	-	1	1	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	8	-	13
Capitella sp.	-	-	2	-	-	-	-	38	-	12	5	-	8	6	-	5	8	26	7	8	11	4	10	4	49	4	-	4
Pontocrates arenarius	1	-	2	-	-	3	24	23	14	3	5	1	-	33	6	36	5	1	25	16	1	15	-	-	17	-	-	-
Turbonilla lactea	-	-	-	-	-	-	2	-	-	13	-	-	3	-	2	5	7	2	3	1	9	1	1	4	2	8	3	-

Median Phi Response Group	**87**	**88**	**84**	**21**	**40**	**23**	**59**	**43**	**36**	**51**	**44**	**42**	**54**	**45**	**48**	**58**	**60**	**55**	**25**	**41**	**28**	**56**	**27**	**34**	**57**	**64**	**31**	**26**
Sigalion mathildae	-	-	-	-	-	-	1	-	-	12	5	5	18	12	24	8	1	1	-	12	5	10	1	5	7	16	8	3
Nephtys JUV.	4	7	5	3	4	16	9	36	16	28	48	10	7	14	29	2	8	25	30	-	20	6	45	12	-	48	8	26
Nephtys assimilis	-	-	-	-	-	-	1	1	-	1	2	1	-	-	1	2	-	1	-	4	2	-	5	-	1	-	4	5
Scoloplos armiger	-	-	-	-	1	-	-	-	1	13	1	-	-	1	8	-	-	-	-	-	-	-	-	-	-	1	-	-
Scolelepis bonnieri	3	9	10	-	5	-	1	2	1	-	1	2	-	1	-	3	-	-	-	-	-	-	-	-	-	-	-	-
Capitella sp.	-	-	-	-	-	5	-	-	-	4	12	4	26	11	4	10	7	8	2	8	49	-	38	8	4	-	5	6
Euclymene oerstedii	-	-	-	-	-	-	-	-	-	10	8	43	2	-	1	72	-	2	-	-	-	-	-	-	-	-	-	-
Bathyporeia elegans	-	-	-	-	-	-	-	1	2	-	18	2	-	-	-	-	-	-	30	2	12	-	17	5	-	-	4	5
Bathyporeia tenuipes	-	-	-	-	-	-	5	3	-	2	28	6	5	12	22	3	14	1	-	-	2	3	7	6	2	-	6	6
Mysella bidentata	-	2	-	-	-	-	1	-	4	8	100	142	9	4	6	148	41	13	2	11	5	5	1	18	2	-	1	4
Tellimya ferruginosa	-	-	-	-	-	-	-	-	-	13	-	23	-	7	-	23	7	10	9	-	22	1	24	7	-	-	1	50
Donax vittatus	-	-	-	-	-	-	-	-	-	6	2	-	-	-	2	-	-	-	-	-	-	1	9	-	-	3	1	8
Thracia phaseolina	-	-	-	-	-	-	-	-	1	124	27	17	17	120	98	6	2	53	-	29	1	42	-	2	18	39	4	-
Phoronis sp.	-	-	-	-	-	-	-	-	1	2	1	8	5	11	2	7	2	10	-	8	-	2	-	3	6	2	3	-

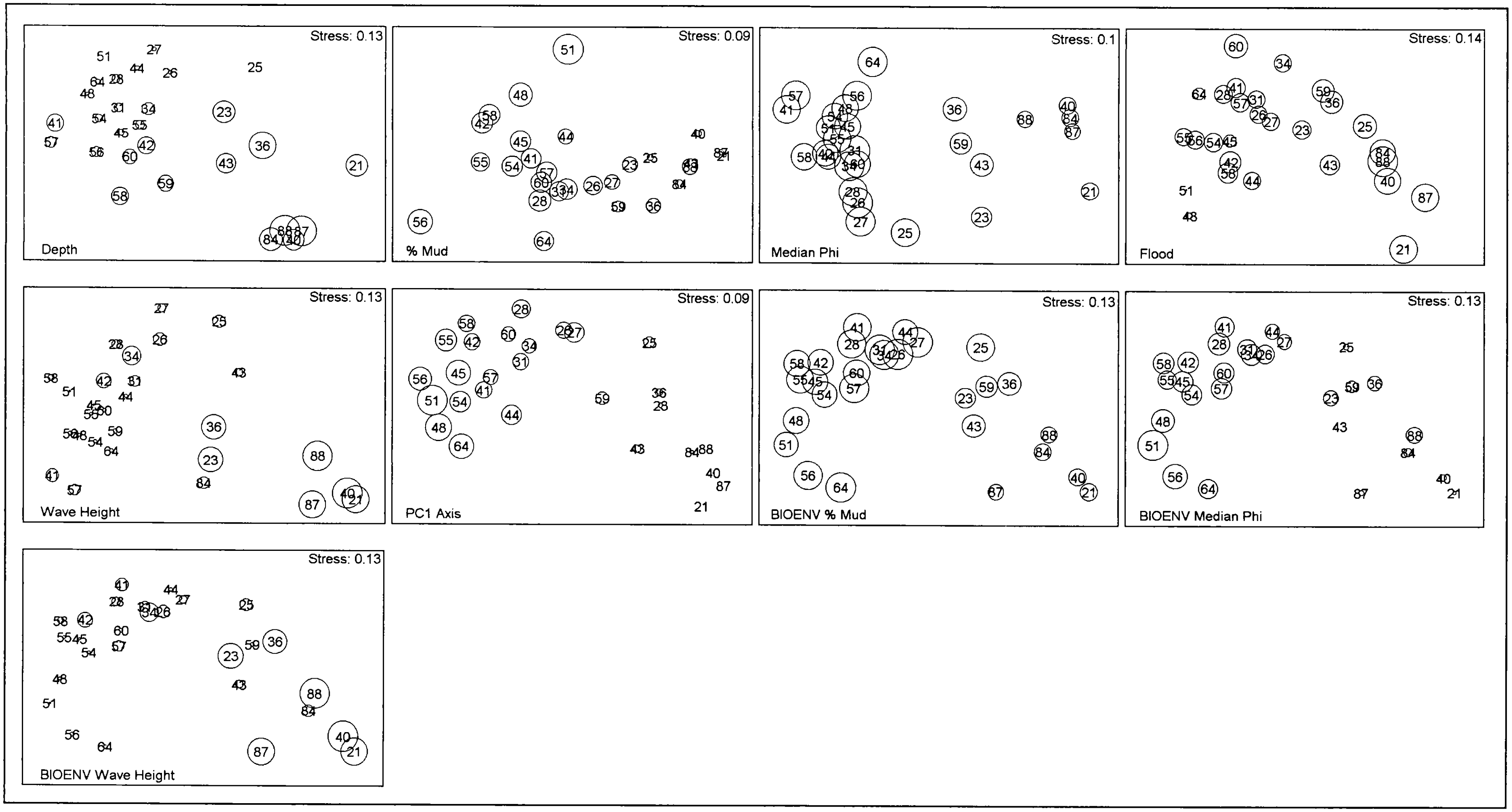
Tables 4.4 – 4.10 continued.

Flood Response Group	**51**	**48**	**64**	**45**	**27**	**55**	**44**	**26**	**34**	**31**	**28**	**56**	**57**	**54**	**23**	**41**	**43**	**58**	**42**	**36**	**59**	**60**	**25**	**84**	**40**	**87**	**21**	**88**
Nephtys assimilis	1	1	-	-	5	1	2	5	-	4	2	-	1	-	-	4	1	2	1	-	1	-	-	-	-	-	-	-
Nephtys cirrosa	-	-	-	-	15	-	5	4	1	1	-	-	-	-	28	-	15	-	-	45	27	-	22	8	15	8	7	20
Lumbrineris gracilis	-	-	-	-	-	-	12	-	-	-	-	1	-	-	-	2	-	15	12	1	2	2	-	-	-	-	-	-
Scoloplos armiger	13	8	1	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-
Scolelepis bonnieri	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	2	3	2	1	1	-	-	10	5	3	-	9
Owenia fusiformis	27	5	13	12	49	13	17	40	1	4	16	65	8	13	19	9	1	21	11	1	1	4	-	-	-	-	-	-
Lanice concheleaga	3	1	2	7	6	3	19	16	287	15	1	10	8	8	4	16	1	6	12	68	-	-	11	2	2	-	-	3
Pontocrates arenarius	-	-	6	1	23	-	3	33	16	36	17	-	15	1	5	5	1	-	-	14	24	25	2	3	-	-	-	1
Bathyporeia tenuipes	2	22	-	12	7	1	28	6	6	6	2	3	2	5	-	-	3	3	6	-	5	14	-	-	-	-	-	-
Modiolus modiolus	7	21	-	-	-	-	50	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Donax vittatus	6	2	3	-	9	-	2	8	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Wave Height Response Group	**51**	**45**	**48**	**54**	**55**	**64**	**44**	**60**	**56**	**59**	**58**	**43**	**27**	**28**	**31**	**57**	**84**	**25**	**26**	**41**	**42**	**34**	**36**	**23**	**87**	**21**	**88**	**40**
Nephtys JUV.	28	14	29	7	25	48	48	8	6	9	2	36	45	20	8	-	5	30	26	-	10	12	16	16	4	3	7	4
Nephtys assimilis	1	-	1	-	1	-	2	-	-	1	2	1	5	2	4	1	-	-	5	4	1	-	-	-	-	-	-	-
Chaetozone setosa	9	44	66	37	21	19	27	55	15	27	8	-	-	6	12	2	-	-	-	51	40	14	-	-	-	-	-	-
Iphinoe trispinosa	38	-	9	6	2	10	2	2	3	1	-	-	-	10	6	3	1	-	-	2	1	-	-	1	-	-	-	-
Perioculodes longimanus	63	43	57	34	29	29	5	14	23	19	19	-	-	4	2	17	4	-	1	13	4	2	6	1	1	-	-	-
Pontocrates arenarius	-	1	-	1	-	6	3	25	-	24	-	1	23	17	36	15	3	2	33	5	-	16	14	5	-	-	1	-
Bathyporeia sp.	2	1	6	3	1	1	10	17	6	6	2	-	-	-	-	1	1	1	5	-	1	-	-	4	-	-	-	-
Bathyporeia elegans	-	-	-	-	-	-	18	-	-	-	-	1	17	12	4	-	-	30	5	2	2	5	2	-	-	-	-	-
Bathyporeia tenuipes	2	12	22	5	1	-	28	14	3	5	3	3	7	2	6	2	-	-	6	-	6	6	-	-	-	-	-	-
Microjassa cumbrensis	2	-	-	-	-	1	-	-	9	-	5	-	-	-	-	1	-	-	-	-	-	27	-	-	-	-	-	-
Tellimya ferruginosa	13	7	-	-	10	-	-	7	1	-	23	-	24	22	1	-	-	9	50	-	23	7	-	-	-	-	-	-
Acanthocardia echinata	8	2	-	2	-	3	-	1	1	-	-	1	10	50	-	-	-	-	-	1	-	-	-	-	-	-	-	-

PC1 Response Group	**88**	**87**	**21**	**40**	**84**	**23**	**36**	**43**	**25**	**59**	**34**	**60**	**57**	**42**	**31**	**26**	**41**	**58**	**28**	**44**	**27**	**54**	**55**	**56**	**64**	**45**	**48**	**51**
Sigalion mathildae	-	-	-	-	-	-	-	-	-	1	5	1	7	5	8	3	12	8	5	5	1	18	1	10	16	12	24	12
Nephtys assimilis	-	-	-	-	-	-	-	1	-	1	-	-	1	1	4	5	4	2	2	2	5	-	1	-	-	-	1	1
Nephtys cirrosa	20	8	7	15	8	28	45	15	22	27	1	-	-	-	1	4	-	-	-	5	15	-	-	-	-	-	-	-
Lumbrineris gracilis	-	-	-	-	-	-	1	-	-	2	-	2	-	12	-	-	2	15	-	12	-	-	-	1	-	-	-	-
Scoloplos armiger	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	1	8	13
Capitella sp.	-	-	-	-	-	5	-	-	2	-	8	7	4	4	5	6	8	10	49	12	38	26	8	-	-	11	4	4
Pontocrates arenarius	1	-	-	-	3	5	14	1	2	24	16	25	15	-	36	33	5	-	17	3	23	1	-	-	6	1	-	-
Bathyporeia elegans	-	-	-	-	-	-	2	1	30	-	5	-	-	2	4	5	2	-	12	18	17	-	-	-	-	-	-	-
Bathyporeia tenuipes	-	-	-	-	-	-	-	3	-	5	6	14	2	6	6	6	-	3	2	28	7	5	1	3	-	12	22	2
Modiolus modiolus	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100	-	5	-	-	-	-	21	7
Tellimya ferruginosa	-	-	-	-	-	-	-	-	9	-	7	7	-	23	1	50	-	23	22	-	24	-	10	1	-	7	-	13
Acanthocardia echinata	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	1	-	107	-	10	2	-	1	3	2	-	8
Donax vittatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	8	-	-	-	2	9	-	-	1	3	-	2	6
Thracia phaseolina	-	-	-	-	-	-	1	-	-	-	2	2	18	17	4	-	29	6	1	27	-	17	53	42	39	120	98	124
Turbonilla lactea	-	-	-	-	-	-	-	-	-	2	1	3	1	4	5	-	7	1	2	13	-	2	3	3	2	9	8	-

Figure 4.1 Non-metric MDS ordinations of Response Groups identified by the BVSTEP procedure. Bubbles represent the corresponding environmental variables demonstrating the extent to which the abundance patterns of response group fauna follow that of the environmental gradient. The composite BIOENV response group is overlayed by its component environmental variables.



4. 4 Discussion

The significant ICR values calculated by the RELATE procedure for 6 of the 12 environmental datasets represent a community response to an environmental factor. The sensitivity of the RELATE procedure in the detection of community response to distance gradients, shown previously by Somerfield et al. (2002), is reflected here in the detection of a community response to individual environmental factors. The strongest significant responses were recorded for Median Phi sediment grain size (ICR ρ 0.624) and PC1 gradients (ICR ρ 0.62). Sedimentary factors have been identified as important in structuring the Carmarthen Bay *Tellina* community (Chapter 2) and the PC1 gradient, a composite of all 10 environmental variables is likely to have a broad variety of effects on a greater number of taxa and consequently would be expected to return a high ICR.

Those environmental clines where no significant relationship was found by either uni- or multivariate method, % Gravel, Residual current speed and PC2, may be below a threshold level necessary to elicit a biological response in this community. % Gravel was the largest eigenvector (coefficient in the linear combinations of variables making up PCs in Principal Component Analysis) of the PC2 axis. Deposits of shell material generally accounted for the small proportion of coarse material represented by % Gravel in the fine sand of Carmarthen Bay. The proportion and type of material does not reflect a radical change in habitat type as would be expected if it were a lithic gravel deposit and so may explain the lack of detectable macrofaunal response. Both the Residual current speed and % Organics are likely to have sufficiently weak gradients across stations as not to trigger any detectable macrofaunal response within the *Tellina* community.

The linear models of H′ for each environmental variable showed significant linear relationships corresponding to all but one of those found in the RELATE procedure. Although this general concurrence of the uni- and multivariate techniques would seem to validate the results from the RELATE procedure, there remains a difference in the ranked strength of response represented by ICR and r^2, suggesting a difference in the type of response detected by these methods. The H′ index is a measure of species diversity calculated from species abundance and richness, however as no account of constituent taxa is considered, it is perfectly possible to return equal measures for communities containing quite different fauna. As the presence and abundances of individual taxa are fundamental in the calculation of the underlying macrofaunal similarity matrix used in the calculation of the ICR, it may be the case that the RELATE procedure is more sensitive to changes in abundance of individual species in response to clines in the environmental factor.

The BVSTEP procedure isolated response groups for each of the environmental factors found to elicit a linear macrofaunal response by the RELATE procedure. The strength of these responses is indicated by the relatively strong Spearman rank correlations between faunal similarity and environmental distance matrices ranging from ρ 0.563 – ρ 0.817. The strength of correlation between response group and environmental variable similarity matrices is likely to be linked to the range and severity of effects the environmental factor has on the members of the macrofaunal community. The PC1 gradient, a composite of all 10 environmental variables and therefore more likely to have a broad variety of effects on a greater number of taxa, returned the highest correlation (ρ 0.817) in the BVSTEP procedure with a response group of 15 taxa. The best correlation between an individual environmental variable and its response group of 16 taxa was $\rho = 0.76$ calculated for Median Phi sediment grain size. Although a secondary factor in the structuring of soft sediment communities, other factors such as the hydrodynamic environment or the sediment chemistry being more likely primary driving forces (Snelgrove and Butman, 1994), grain size may act as a surrogate correlate for a variety of environmental factors which would account for the high ρ value.

The MDS ordinations of individual response groups indicate the linear nature of many of these responses represented by arch or 'horseshoe' effect (Figure 4.1). Further evidence of the linear nature of response represented by the response groups was found by rearranging station/species data for each response group in rank order of the corresponding environmental variable (Tables 4.4 – 4.10). These tables reveal a general pattern of increasing abundance and occurrence at the ends of this simulated gradient, becoming reduced or absent towards the other, indicating a series of approximate linear responses by individual taxa. These patterns seem to validate the inclusion of these taxa in their respective response groups by the BVSTEP procedure, but do they reflect ecologically meaningful processes?

Using the % Mud response group as an example, there was a higher incidence and general abundance of the hesionid polychaete *Podarkeopsis capensis* (Day) at the muddier end of the gradient whereas at the opposite end there was a greater incidence and abundance of the errant nephtyd *Nephtys cirrosa* (Ehlers). Both polychaetes, although motile carnivores of soft sediments, have been previously recorded as showing preference to different sediment grades, *Podarkopsis* species are found in fine sand and muddy grounds (Hartmann-Schröder, 1996) and *N. cirrosa* in clean, coarse sediments (Rainer, 1991). The remaining members of this response group show an increase in incidence and abundance toward the muddier end of the gradient and, with the exception of the ectoparasite *Turbonilla lactea* (Linneaus), have been previously described as showing a preference for muddy sand habitats (*Scoloplos* *armiger* (O F Müller) (Oug, 2001); *Pontocrates arenarius* (Bate & Westwood) (Beare & Moore, 1996)), or organically enriched sites (the proportion of mud in a sediment is often correlated with proportion of organic matter) *Capitella* sp. (e.g. Pearson and Rosenburg, 1978; Holte and Oug, 1996; Cardell et al., 1999). *Turbonilla lactea* is a non-specific ectoparasite of sedentary bivalves and polychaetes, an increased abundance and diversity of such host animals in the fine sand stations (Chapter 2) is likely account for the presence of *T. lactea* in this response group. It would seem reasonable then, that these animals should be included in the % Mud response group. The other response groups demonstrate similarly ecologically meaningful inclusions, such as the absence of the fragile Cirratulid *Chaetozone setosa* (Malmgren) at the exposed end of the Wave height gradient. The distribution of the polychaete *Owenia fusiformis* (Chiaji) is reported to be determined by local hydrodynamics (Thiébaut et al., 1992; Thiebaut et al., 1994; Barnay et al., 2003) which may account for its occurrence at the low velocity end of the Flood current gradient.

There is however a certain level of duplication of species within groups. This is again thought to be due to a degree of surrogacy between environmental factors. For example, Wave Period and Height can be expected to be related to Depth and a similar relationship would be envisaged between the sedimentary factors, % Mud or % Sand, and the prevailing hydrodynamic regime represented by Flood current. This should not detract from the effectiveness of these multivariate methods in isolating meaningful response groups of fauna, but care should be taken in their interpretation; do these response groups represent a macrofaunal response to the tested environmental gradient or to some other, untested or unmeasured factor?

Although the example given here dealt with environmental clines arising within a distinct embayment these methods are applicable at wider spatial and temporal scales.

Current key research areas to which these methods may be applied include the study of latitudinal gradients in species diversity and the study of the impact of climate change. Recent evidence suggests that environmental factors such as temperature and sediment grain-size diversity have dominant roles in the determination of patterns of regional-scale species richness (Gray, 2002). Multivariate methods such as those presented here may further our understanding of the functional pathways along which these patterns are formed. Similarly, the isolation of response groups sensitive to changes in climate-linked environmental factors, such as increased disturbance due to increases in wave height or incidence of stormy weather (Grevemeyer et al., 2000; Debernard et al., 2002) may allow the assessment of the magnitude of these impacts and focus their future monitoring. The results from this study will form part of a study into the long term persistence and resilience of the *Tellina* community in Carmarthen Bay.

Chapter 5: Temporal Variability, Structural Redundancy and the Long-Term Persistence of the Carmarthen Bay *Tellina* Community

5. 1 Introduction

The potential resilience of a community to disturbance can be inferred by an assessment of the levels of variability within it, a number of studies have demonstrated that unstable communities are more able than stable ones to return to their previous structure and composition after some form of disturbance (Pickett & White, 1985). Holling (1974) considered unstable communities to be more resilient to disturbance than stable communities because they contain species adapted to variable environmental conditions. Turner et al. (1995) gave 4 definitions of stability in addition to stability in its strictly mathematical sense. Persistence stability; the constancy in a parameter (e.g. the number of species, taxonomic composition or the size of a population) measured over time. Variability; the degree to which a parameter fluctuates over time. Resilience; the ability of a system to recover and continue functioning after disturbance. Resistance; the ability of a system to withstand or resist such a perturbation in the first place. Understanding the nature and temporal scales of variation, and therefore the stability, within the Carmarthen Bay *Tellina* community will provide an assessment of its resistance and resilience to future perturbations.

Soft sediment macrofaunal communities have long been recognized to be subject to variability of species composition and relative species abundance (Morrisey et al., 1992). Variability in community structure occurs at a variety of temporal and spatial scales. Causes of this variability are a variety of biological and physical disturbances occurring at varying frequencies and intensities.

The temporal scales at which these variations occur range from differences in abundance of taxa over a tidal cycle to decadal changes in community composition. The variability in composition and abundance of crustacean fauna entering the water column from soft sediments over tidal cycles is reported by Saigusa et al. (2001) and Schlacher & Wooldridge (1995). Dauvin et al. (2000) also described significant changes in composition and abundance of suprabenthic fauna above soft-sediment communities in response to diel migration of motile crustacean taxa, notably cumaceans and amphipods, from the sediment. These very short-term changes in community structure tend to reflect behavioral adaptations of fauna to the effects of tidal periodicity such as the change in current flow or, possibly, the redistribution of sediments over the ebb-flow cycle (Warwick & Uncles, 1980).

Short-term changes in community structure on a scale of days-weeks are reported in a number of soft sediment communities. Armonies (2000) describes dramatic changes in community composition over a period of 14 days in a shallow (7-11 m) fine sand community in the southern North Sea. Approximately 50% of the sampled fauna showed spatial changes in abundance within the sampling period roughly equal to the average variation between consecutive years, this was attributed to active migration or drifting of macrofauna. Elsewhere changes in community structure occurring on similar temporal scales have been attributed to stochastic events such as anthropogenic disturbance such as fishing effects and aggregate extraction (Kaiser, 1998; van Dalfsen et al., 2000; Ball et al., 2000; Chícharo et al., 2002) or natural climatologically induced disturbance such as storm events (Glémarec, 1979).

At intermediate temporal scales and especially at temperate latitudes, seasonal variability in community structure in soft sediment communities is likely the most important. The importance of recruitment in structuring macrofaunal communities is long recognized (Olafsson et al., 1994; Miron et al., 1995; Caley et al., 1996) and generally occurs on a seasonal cycle. Typically this variation in species composition and relative abundance is in response to high levels of recruitment and other import processes during the summer months followed by post-settlement processes such as high levels of mortality and redistribution during the subsequent winter (e.g.(Petti & Nonato, 2000; Rueda et al., 2001). Seasonal climatic effects are also important sources of seasonal variability in soft-sediment macrofaunal communities; prolonged periods of low bottom temperatures, hypoxia and even ice scour in the shallow sublittoral are an often cited cause of mortality in high latitudes (Glémarec, 1979; Conlan et al., 1998; Karlson et al., 2002).

Long-term variation in community composition and relative abundance of species generally reflects long-term environmental variability, both natural and anthropogenic. Long-term climatic sources of variability function on different temporal scales and at varying periodicity.

The North Atlantic Oscillation (NAO) is an episodic (an average 7.9 year period) northerly shift in the Azores high pressure system and affects weather patterns in western Europe (see Marshall et al., 2001). The El Niño disruption of the ocean-atmosphere system in the tropical Pacific (periodicity of 2-7 years) has far reaching climatic and oceanographic effects, and has been shown to be a source of variability in soft sediment macrofaunal communities (Zmarzly et al., 1994).

The NAO has been demonstrated to be highly correlated with changes in structure of macrofaunal communities in the German Bight (Kroncke et al., 1998) and the Skagerrak (Tunberg & Nelson, 1998). Kroncke et al. (1998) attributed interannual variability in biomass, abundance and species number of fauna to interannual climate variability. Using a multivariate model, a strong relationship between abundance, species richness and biomass in the spring and the NAO index was demonstrated. The mediator between the NAO and benthos was suggested to be sea surface temperature (SST) in the late winter and early spring; low SST affecting the survival of certain taxa, notably *Fabulina fabula* (Gmelin). Longer period climate variability may be implicated in structuring marine communities on wide geographic scales (de Vooys & van der Meer, 1998; Pearson & Mannvik, 1998; Hall, 2002).

The separation of anthropogenic and natural effects of variation in benthic communities is difficult (Frid & Clark, 2000). Nevertheless a number of studies have demonstrated anthropogenic factors to be significant causes of long-term variability in soft sediment macrofaunal communities notably the effects of fishing (e.g. Jennings & Kaiser, 1998; Frid et al., 1999; Jennings et al., 2001; Jennings et al., 2001) and eutrophication (Josefson & Rosenberg, 1988; Bonsdorff et al., 1997) and also see the review by (Karlson et al., 2002).

The most important source of fishing-related variation to soft-sediment communities are the long term effects of trawl or dredge disturbance. The disturbance of mobile fishing gear on the community structure of macrofaunal communities is well documented (Dayton et al., 1995; Jennings & Kaiser, 1998; Lindeboom & De Groot, 1998; Hall, 1999; Collie et al., 2000; Jennings et al., 2001) and has been demonstrated to be a source of variability in community structure of soft sediment macrofauna communities over long temporal scales (Frid et al., 200l; McConnaughey et al., 2000; Jennings et al., 2001; Kaiser & Spence, 2002).

Despite the variety in scales and intensity of temporal variability in community structure, soft-sediment communities are often seen to be persistent over a variety of temporal scales (Buchanan et al., 1986; Turner et al., 1995; Carrasco, 1997; Posey & Alphin, 2002). Two soft-sediment communities sampled bi-weekly for a period of 4 years in North Inlet, North Carolina by Service (1992) demonstrated long-term stability in abundance despite short-term (seasonal) and high year-to-year variability. It was reported that although abundances varied considerably between seasons or years only 9 of 22 taxa analyzed showed a directional change in abundance. The community composition at these stations was also shown to remain stable over the period. In a comparison of a 4 year series of samples with earlier surveys Thiebaut et al. (1997) demonstrated a degree of long-term (15 years) persistence of the *Abra* community in the Bay of Seine despite significant inter-annual variation of dominant bivalve abundance.

The study of variability and the persistence of soft bottom macrofaunal communities requires the production of detailed time-series datasets. A number of studies at sites in European waters of *Tellina* communities similar to the one present in Carmarthen Bay provide detailed information of the variety of scales and sources of variation likely to occur there and provide useful comparisons to results of the current study. Bosselmann (1988, 1991) sampled a German Bight *Tellina* Community monthly for 2 years in an investigation of the role of recruitment in community structure reporting large intra-annual variations in individual species abundance. Ziegelmeier, (1978) described a 25 year biannual (spring and autumn) sampling program at 9 fine sand stations in a *Tellina* community in the eastern German Bight reporting variability in species abundance and composition at intra- and inter-annual scales. A *Tellina* community in La Coruña Bay, north western Spain was the subject of a 12 year monitoring program (López-Jamar et al., 1986, 1995). The La Coruña Bay *Tellina* community, although subject to intra- and inter-annual variation in species abundance and relative dominance, was found to be stable in composition.

Two previous studies were used as sources of the long-term data used in the current study. Warwick et al. (1978) sampled a station in Carmarthen Bay at regular intervals between February 1974 and March 1975 in an investigation into the production of a Venus (*Tellina*) community. Hobbs & Smith (1998) sampled 9 stations in

Carmarthen Bay on three occasions between March 1996 and April 1997 to monitor the impact of the *Sea Empress* oil spill. These provide a baseline of community composition and abundance in addition to the seasonal variability of certain taxa.

The aim of the present study is to assess the variability in species abundance and composition of the Carmarthen Bay *Tellina* community on a variety of temporal scales. The results of this, with reference to studies at other sites, will enable an assessment of the stability and therefore the resilience and resistance of the Carmarthen Bay *Tellina* community to the impact of future disturbance.

In addition to the analysis of time-series data, analysis of the structural redundancy of the *Tellina* community was also undertaken. Recent studies into the roles species play in ecosystem processes (McCann, 2000) and particularly the role of biodiversity and ecosystem function (Chapin et al., 2000; Petchey & Gaston, 2002) have developed a consensus that communities with high species richness and functional diversity are likely to be relatively stable and resilient to disturbance (McCann, 2000). It has been suggested that the level of functional redundancy, the interchangeability of functionally equivalent species, in a community could be a useful determinant of its resilience to perturbation (Chapin et al., 1995; Johnson, 2000) or as a measure of the potential for functional compensation within it (Menge et al., 1994; Rosenfeld, 2002). The determination of the precise functional role of each taxon within the community requires extensive manipulative studies and was outside the scope of the present study. An assessment of structural redundancy in the Carmarthen Bay *Tellina* community was however possible, from which it may be possible to infer the potential for functional redundancy and functional compensation in the community. Structural redundancy can be considered the extent that the overall community pattern, in response to temporal or environmental variability, is reflected by smaller subsets of taxa. A method for the quantification of the structural redundancy of ecological communities was developed by Clarke and Warwick (1998). High levels of structural redundancy have been found in marine macrofaunal communities by Clarke and Warwick (1998) and were assessed as likely to be resilient to environmental and temporal variability. Using the same methodology Mistri et al. (2001) calculated low levels of structural redundancy in lagoonal habitats in the Adriatic highlighting the vulnerability of these habitats. Whereas previous studies have applied these methods to temporally distinct data (Clarke and Warwick, 1998) or a combination of temporally and spatially distinct data (Mistri et al., 2001), the current study applies them to the spatially distinct data from the baseline survey (Chapter 2). The level of structural redundancy within the *Tellina* community is therefore estimated by the detection of subgroups of taxa that reflect the overall community pattern of response to environmental variability within the fine sand habitat of Carmarthen Bay.

5. 2 Methods

5. 2. 1 Sampling for Short-Term Variability Study

In order to assess the seasonal variation within the *Tellina* community sampling took place in November 1998, April 1999, September and November 1999, May 2000 and November 2000. The *RV Nicola* (University of Wales Swansea) was used on all occasions except one (April 1999) when the *RV Skamley* (Countryside Council for Wales) was used. Sampling was carried out using a heavy (90 kg) long-armed continuous warp-rigged Van Veen grab with a sample area of $0.1m^2$. Five grabs were taken at each station, the four largest were retained for macrofaunal samples and the fifth was used as a sediment sample. The four faunal replicates at four stations in the *Tellina* community were considered to be adequate to assess whether spatial variation was greater than temporal variability (Thrush et al., 1994; Armonies, 2000). Samples were washed through a 0.3 mm mesh to ensure that recent recruits and small juvenile animals were accurately sampled. Samples were processed as described in Chapter 1.

Initially, 4 time-series stations were selected from the baseline survey, stations 48 and 49 off Amroth and stations 23 and 37 in Rhossili Bay, and were sampled on all occasions. Unfortunately a number of crucial sample containers were lost from the sample store at the University of Wales Swansea. These containers contained the initial sample washings and therefore contained large numbers of small and juvenile animals. The only set of station samples with a reasonable time series were those from Station 49; November 1998, April 1999, September 1999 and May 2000 (November 1999 and November 2000 were missing). This station has been used to assess seasonal variation in the *Tellina* community in the present study.

5. 2. 2 Data Analysis for Long-term variability Study

A long-term macrofaunal dataset was produced by amalgamating data from two previous studies in Carmarthen Bay; Warwick et al. (1978), Hobbs & Smith (1998) and the current study. Because the macrofaunal data stem from three different surveys and were produced by different workers there were differences in taxonomic interpretation and resolution. A lengthy process of rationalization involved the amalgamation of a number of taxa to equal taxonomic resolution where taxonomic uncertainty existed. This usually led to the amalgamation to family level. The resulting dataset was scaled to 0.1m^2, the size of the grab used in all surveys, for ease of interpretation.

A single sample station (CB20) from the Hobbs and Smith (1998) study is used in the calculation of univariate statistics and production of summary tables as a representative of the *Tellina* community. This station is similar in terms of physical environment and the closest (~ 1 km) geographically to Station 49 of the current study. Station 126 from the Warwick et al. (1978) study was more distant (~10 km), but in similar sediments and at a similar depth. It was thought that despite the large spatial separation any gross changes, such as change in species composition, would be detectable over time.

Diversity indices for each sampling occasion were calculated: species number (S); abundance (N); Margalef species richness (d); Shannon-Weiner diversity index ($H' \log_2$); Pielou evenness (J). Rarefaction curves were also produced and plotted.

Multivariate statistical methods similar to those used in Chapter 2 were utilized in the analysis of the amalgamated time-series macrofaunal data. The underlying Bray-Curtis similarity matrix was produced from the standardized and 4th root transformed amalgamated time-series dataset. Standardization of the macrofaunal data serves to changing it into compositional data, this was necessary to account for the differences in of sample volume taken at each sampling time. This difference in sample volume is the result of the use of different samplers with different penetration characteristics (Knudsen sampler and the Day and Van Veen Grabs) and different numbers of replicates being taken at each sampling time. Species abundance data were 4th root transformed so that during the ensuing multivariate analysis, patterns in variation of less abundant taxa were accounted for by reducing the influence of the more abundant ones.

Cluster analysis dendrograms and multi-dimensional scaling (MDS) ordinations were plotted.

5. 2. 3 Data Analysis for Short-term Variability Study

Seasonal time-series replicate data from Station 49 were analyzed separately with similar methods used to assess long-term variability.

In addition to the multivariate cluster analysis and MDS ordination used in the analysis of the long-term data the SIMPER procedure was used to identify taxa responsible for the dissimilarity between sampling times, those whose abundance demonstrates variability over time. Those taxa responsible for up to 50% of the dissimilarity between any sampling times were plotted to aid interpretation.

Summary tables for the major taxonomic groups were produced and plotted.

5. 2. 4 Structural Redundancy Analysis

The structural redundancy in the Carmarthen Bay *Tellina* community was assessed by the application of the BVSTEP procedure of Clarke and Warwick (1998) to the baseline survey macrofauna data presented in Chapter 2. The BVSTEP procedure isolates sub-groups of taxa, termed 'response units' by Clarke and Warwick (1998), by attempting to maximize a Spearman rank correlation coefficient (ρ) between the corresponding entities in two triangular matrices of between-sample similarities: the Bray-Curtis similarities of the full macrofaunal matrix and Bray-Curtis similarities of the subset macrofaunal matrix produced in a stepwise manner by BVSTEP. Once a response unit is isolated the members are removed from the full macrofaunal matrix and the BVSTEP procedure is re-run. This sequence is repeated, successively peeling response units from the full dataset. See Chapter 3 for a full explanation of the BVSTEP procedure.

the current study applies them to the spatially distinct data from the baseline survey (Chapter 2). The level of structural redundancy within the *Tellina* community is therefore estimated by the detection of subgroups of taxa that reflect the overall community pattern of response to environmental variability within the fine sand habitat of Carmarthen Bay.

The baseline macrofauna dataset (see Chapter 2) was utilized for this analysis rather than the single station short-term time series data because it contained a larger pool of species from which response units could be drawn. The baseline macrofaunal dataset was reduced to those animals representing >0.1% of the total abundance, those taxa occurring at few or single stations which were found to produce spurious results in the BVSTEP procedure. An additional benefit of this action is to substantially reduce the computation time of this procedure. This reduced dataset was log (x+1) transformed so that during the ensuing multivariate analysis, patterns in variation of less abundant taxa were accounted for by reducing the influence of the more abundant ones.

5. 3 Results

5. 3. 1 Long-term Variability Study

5. 3. 1. 1 Long-term Variability in Community Abundance and Composition

A full composite species x station matrix containing macrofaunal data from previous studies by Warwick et al. (1974) and Hobbs and Smith (1998) along with that those from the current study is presented in Appendix 5.1.

The numerically abundant taxa at each sampling time are presented in Tables 5.1 a-h. No single taxon is ubiquitous within the ten most numerically dominant taxa at all stations/sampling times. A group of taxa composed of the polychaetes *Spiophanes bombyx* (Claparéde), *Spio* sp., *Chaetozone setosa* (Malmgren) and the bivalves *Donax vittatus* (da Costa) and *F. fabula*, are commonly among the numerically dominant taxa at most sampling times. Other taxa are seen to occasionally occur in high abundances, e.g. *Owenia fusiformis* (Chaije), *Bathyporeia tenuipes* (Bate), *Perioculodes longimanus* (Bate & Westwood) and *Abra alba* (Wood).

Table 5.2 shows the ubiquitous and commonly occurring taxa of the combined macrofaunal data. Ten taxa are seen to occur in all studies; the Nemerteans, the polychaetes *Sigalion malthidae* (Audouin & Milne-Edwards), *Spio* sp., *S. bombyx* and *C. setosa*, the cumacean *Iphinoe trispinosa* (Goodsir), and the bivalve molluscs *Mysella bidentata* (Montagu), *F. fabula*, *A. alba* and *Chamelea gallina* (Linnaeus). These taxa and those occurring in >50% of the samples also account for the majority of individuals in the samples indicated by their ranked total abundance in all samples. The 40 taxa that are present in >50% of samples include each of the top 25 ranked abundant taxa.

The relative proportions of taxa in the February 1974 survey sample show a marked difference from samples taken in subsequent years (Table 5.1). The most dominant taxa in this sample, *Magelona mirablis* (Johnston), accounts for 58% of all individuals whereas the proportion the most dominant taxa accounts for in any subsequent survey ranges between 14% - 25%.

The general pattern drawn from the numerically dominant taxa is one of variable relative abundance but relatively stable composition.

Table 5.1 a-h Summary Tables of Abundant Taxa at Each Sampling Time
All abundances scaled to 0.1m^2.

a. February 1974	Density	%	Cum. %
Magelona mirablis	243.60	58.09	58.09
Spiophanes bombyx	92.30	22.01	80.10
Glycera alba	13.90	3.31	83.41
Pharus legumen	11.70	2.79	86.20
Fabulina fabula	8.00	1.91	88.11
Donax vittatus	6.70	1.60	89.71
Bathyporeia guilliamsoniana	6.40	1.53	91.23
Pontocrates arenarius	5.90	1.41	92.64
Nephtys hombergi	4.90	1.17	93.81
Iphinoe trispinosa	4.70	1.12	94.93

b. March 1996 (CB20)	Density	%	Cum. %
Chaetozone setosa	29.00	17.68	17.68
Spiophanes bombyx	27.00	16.46	34.15
Fabulina fabula	20.00	12.20	46.34
Magelona filiformis	18.00	10.98	57.32
Glycera tridactyla	8.00	4.88	62.20
Bathyporeia tenuipes	7.00	4.27	66.46
NEMERTEA	6.00	3.66	70.12
Spio sp.	6.00	3.66	73.78
Nephtys hombergi	4.00	2.44	76.22
Abra alba	4.00	2.44	78.66

c. October 1996 (CB20)	Density	%	Cum. %
Abra alba	103.00	20.79	20.79
Perioculodes longimanus	86.67	17.50	38.29
Chaetozone setosa	54.67	11.04	49.33
Spio sp.	44.67	9.02	58.34
Magelona filiformis	39.00	7.87	66.22
Pseudocuma sp.	23.67	4.78	71.00
Tubulanus polymorphus	19.33	3.90	74.90
Iphinoe trispinosa	19.00	3.84	78.73
Fabulina fabula	16.67	3.36	82.10
Sigalion mathildae	13.33	2.69	84.79

d. April 1997 (CB20)	Density	%	Cum. %
Magelona filiformis	37.33	20.78	20.78
Chaetozone setosa	29.33	16.33	37.11
Cirratulidae unident.	19.67	10.95	48.05
Fabulina fabula	16.33	9.09	57.14
Perioculodes longimanus	10.67	5.94	63.08
Chamelea gallina	6.67	3.71	66.79
Tubulanus polymorphus	5.67	3.15	69.94
Magelona mirablis	4.67	2.60	72.54
Sigalion mathildae	3.67	2.04	74.58
Spio sp.	3.67	2.04	76.62

e. November 1998 (Station 49)	Density	%	Cum. %
Chaetozone setosa	43.75	13.73	13.73
Fabulina fabula	37.00	11.61	25.33
Magelona filiformis	35.00	10.98	36.31
Donax vittatus	31.25	9.80	46.12
Spiophanes bombyx	27.50	8.63	54.75
Spio sp.	24.00	7.53	62.27
Bathyporeia tenuipes	18.75	5.88	68.16
Abra alba	18.75	5.88	74.04
Modiolus modiolus	8.50	2.67	76.71
Thracia phaseolina	6.75	2.12	78.82

f. April 1999 (Station 49)	Density	%	Cum. %
Magelona filiformis	83	22.71	22.71
Chaetozone setosa	65.5	17.92	40.63
Modiolus modiolus	54.5	14.91	55.54
Spiophanes bombyx	32.25	8.82	64.36
Fabulina fabula	27.5	7.52	71.89
Spio sp	11	3.01	74.90
Bathyporeia tenuipes	10.5	2.87	77.77
Thracia phaseolina	9	2.46	80.23
Donax vittatus	8.75	2.39	82.63
Sigalion mathildae	6.25	1.71	84.34

g. September 1999 (Station 49)	Density	%	Cum. %
Chaetozone setosa	260.5	25.10	25.10
Magelona filiformis	162	15.61	40.70
Spiophanes bombyx	146.25	14.09	54.79
Spio sp	52.75	5.08	59.87
Owenia fusiformis	51.5	4.96	64.84
Donax vittatus	39.5	3.81	68.64
Perioculodes longimanus	33.5	3.23	71.87
Magelona johnstoni	27.5	2.65	74.52
Fabulina fabula	26.5	2.55	77.07
Abra alba	26	2.50	79.58

h. May 2000 (Station 49)	Density	%	Cum. %
Chaetozone setosa	161.75	21.93	21.93
Spiophanes bombyx	132.5	17.97	39.90
Magelona filiformis	126.5	17.15	57.05
Pseudocuma longicornis	39.75	5.39	62.44
Spio sp	35.5	4.81	67.25
Thracia phaseolina	26	3.53	70.78
Ophiura ophiura	23	3.12	73.90
NEMERTEA	22.75	3.08	76.98
Nephtys sp.	18.75	2.54	79.53
Bathyporeia tenuipes	17.75	2.41	81.93

Table 5.2 Taxa Occurring in >50% of Samples (* = Present)

Taxon	**CB20 Feb-74**	**CB20 Mar-96**	**CB20 Oct-96**	**St 49 Apr-97**	**St 49 Nov-98**	**St 49 Apr-99**	**St 49 Sep-99**	**May-00**	**Ranked Abundance**
NEMERTEA	*	*	*	*	*	*	*	*	19
Sigalion mathildae	*	*	*	*	*	*	*	*	12
Spio spp.	*	*	*	*	*	*	*	*	5
Spiophanes bombyx	*	*	*	*	*	*	*	*	3
Chaetozone setosa	*	*	*	*	*	*	*	*	2
Iphinoe trispinosa	*	*	*	*	*	*	*	*	17
Mysella bidentata	*	*	*	*	*	*	*	*	26
Fabulina fabula	*	*	*	*	*	*	*	*	6
Abra alba	*	*	*	*	*	*	*	*	8
Chamelea gallina	*	*	*	*	*	*	*	*	20
Nephtys hombergi	*	*	*	*		*	*	*	25
Magelona filiformis		*	*	*	*	*	*	*	4
Perioculodes longimanus		*	*	*	*	*	*	*	7
Bathyporeia tenuipes		*	*	*	*	*	*	*	11
Donax vittatus	*	*	*		*	*	*	*	9
Phoronis sp.	*		*	*	*	*	*	*	36
Etone longa	*	*			*	*	*	*	48
Orbinia latreillii	*		*		*	*	*	*	52
Scoloplos armiger			*	*	*	*	*	*	24
Magelona alleni		*	*	*	*		*	*	53
Magelona mirablis	*	*	*	*		*	*		1
Pontocrates arenarius	*		*	*	*	*		*	27
Cylichna cylindracea		*	*	*	*	*	*		49
Glycera tridactyla		*			*	*	*	*	23
Owenia fusiformis				*	*	*	*	*	13
Synchelidium maculatum				*	*	*	*	*	39
Pariambus typicus	*		*	*			*	*	40
Tellimya ferruginosa	*			*		*	*	*	45
Ensis spp.			*		*	*	*	*	59
Thracia phaseolina				*	*	*	*	*	16
SIPUNCULA					*	*	*	*	31
Nephtys spp. juv.			*	*			*	*	28
Magelona johnstoni					*	*	*	*	15
Galathowenia spp.					*	*	*	*	46
Nucula spp.					*	*	*	*	47
Modiolus modiolus					*	*	*	*	10
Mactra stultorum					*	*	*	*	41
Pharus legumen	*				*	*	*		18
Ophiura ophiura	*				*		*	*	22
Echinocardium cordatum	*		*	*			*		64

5. 3. 1. 2 Long-term Variability in Diversity Indicies

Diversity indices were calculated for each sample time from data averaged and scaled to 0.1 m^{-2} (Table 5.3).

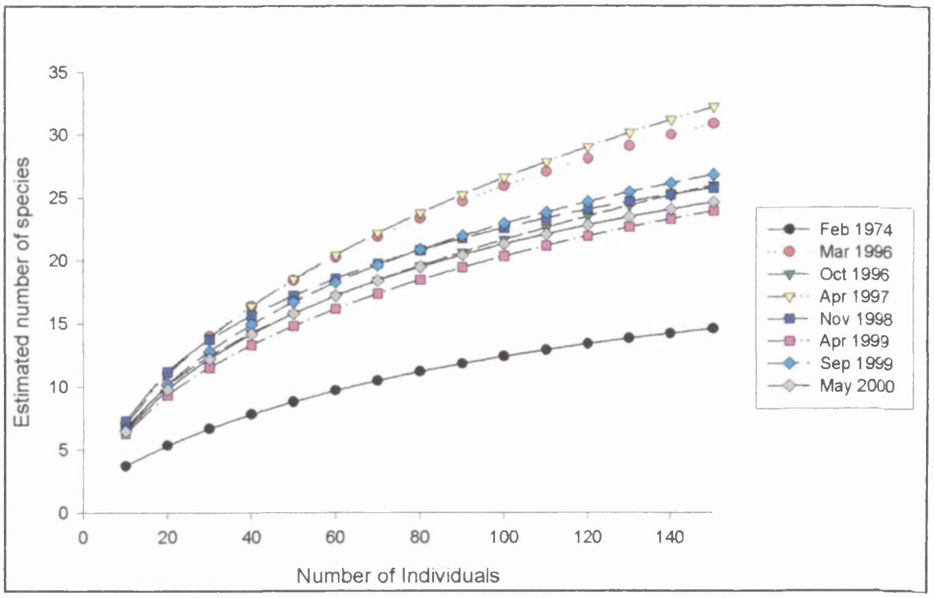
Species richness (S) is seen to range between 32 – 57 taxa. The highest number of taxa recorded in October 1996 and September 1999, and the lowest in March 1996. The number of individuals (N) showed a large range of variability from 164 in March 1996 – 1036 in September 1999. Margalef's index (d) was relatively consistent at all times ranging from 7.12 in April 1999 - 9.82 in April 1997. The Shannon-Wiener diversity index H' lowest in the February 1974 sample (2.21) and highest in the November 1998 sample (4.18), correspondingly evenness (Pielou J) was also lowest in the February 1974 sample.

Hurlbert rarefaction calculates an expected number of species from a standard sample size, ES(n), and provides a useful graphical comparison of species diversity and richness. Figure 5.1 shows that using this method, the February 1974 data describes the shallowest curve and is, according to this method, the least diverse sample. The steepest curves are described by data from the most diverse samples March 1996 and April 1997.

Table 5.3 Diversity Indices

Date	S	N	d	H'(log2)	J'	ES(50)
February 1974	52	419	8.45	2.21	0.39	8.78
March 1996	32	164	6.08	4.00	0.80	18.42
October 1996	57	495	9.02	3.91	0.67	15.79
April 1997	52	180	9.82	4.14	0.73	18.50
November 1998	49	320	7.81	4.18	0.76	17.20
April 1999	43	366	7.12	3.71	0.68	14.80
September 1999	60	1038	8.07	3.91	0.67	16.71
May 2000	47	737	6.97	3.79	0.68	15.77

Figure 5.1 Hurlbert Rarefaction Curves of Long-Term Data



5. 3. 1. 2 Multivariate Analysis of Long-term Variability Study Data

A Bray-Curtis similarity matrix was produced from averaged and standardized species x station data and cluster analysis and MDS plots were produced (Figures 5.2 & 5.3). The cluster analysis dendrogram (Figure 5.2) reveals 4 distinct groupings; the seasonal samples from the current study at Station 49 are grouped around the 70% level, the OPRU/EA survey samples from March 1996 (with the exception of Station CB23) were grouped around the 50% level and the October and April 1997 samples were grouped together at around the 60% level. The February 1974 Station 126 was not grouped with any of the subsequent surveys at a level of over 30%.

The MDS ordination (Figure 5.3) illustrates the cluster analysis groupings, the stress value of 0.12 indicates that the plot is a fairly good ordination. On examination of the MDS ordination it appeared that samples were grouped according to survey or study rather than by season or year. This suggested that the between stations difference or some factor of the sampling methodology employed by the three workers was acting to confound the discernment of a temporal pattern.

Re-labeling the samples with sampling effort, the number of replicates taken at each time, and re-plotting the MDS ordination revealed that similarities between sampling times are likely due to sampling effort rather than any temporal change (Figure 5.4). No further statistical analysis was thought to be worthwhile although qualitative comparisons between sampling times was still possible.

Figure 5.2 Cluster Analysis Dendrogram of Long-Term Macrofauna Data

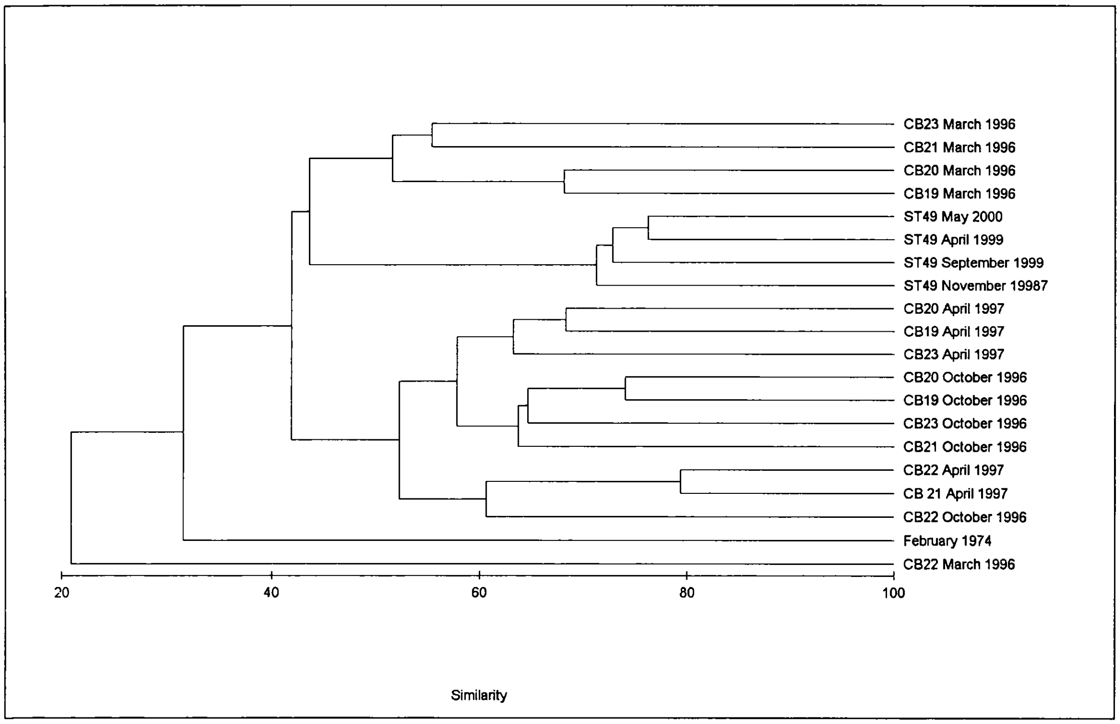


Figure 5.3 MDS Ordination of Long-Term Macrofauna Data

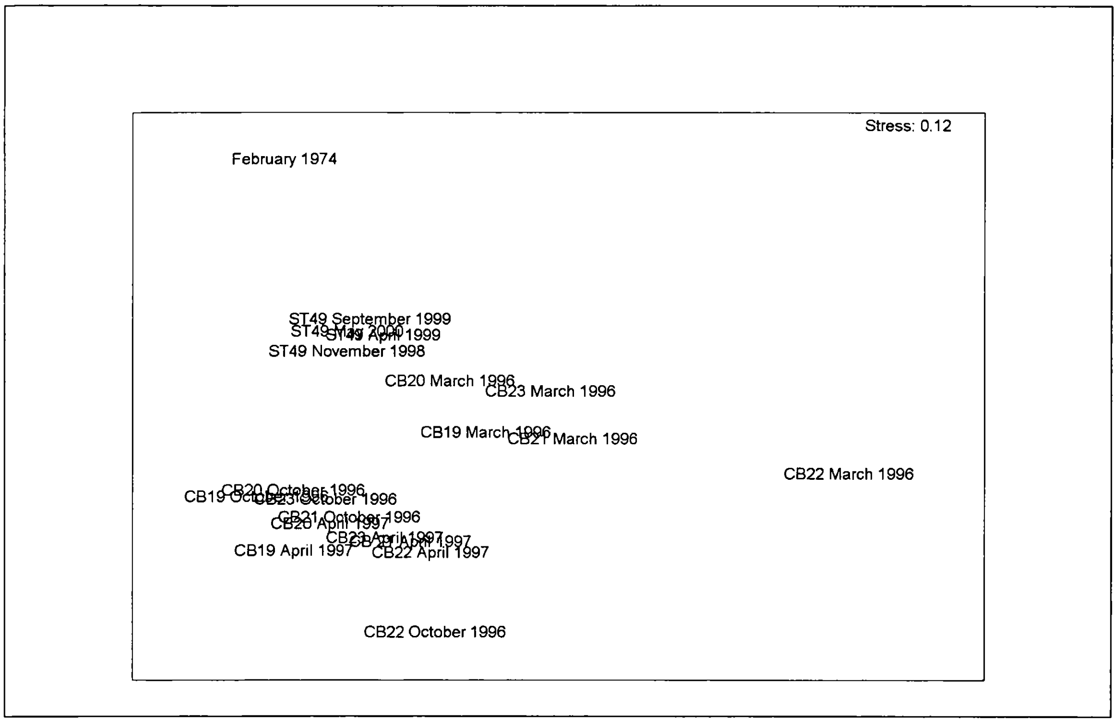
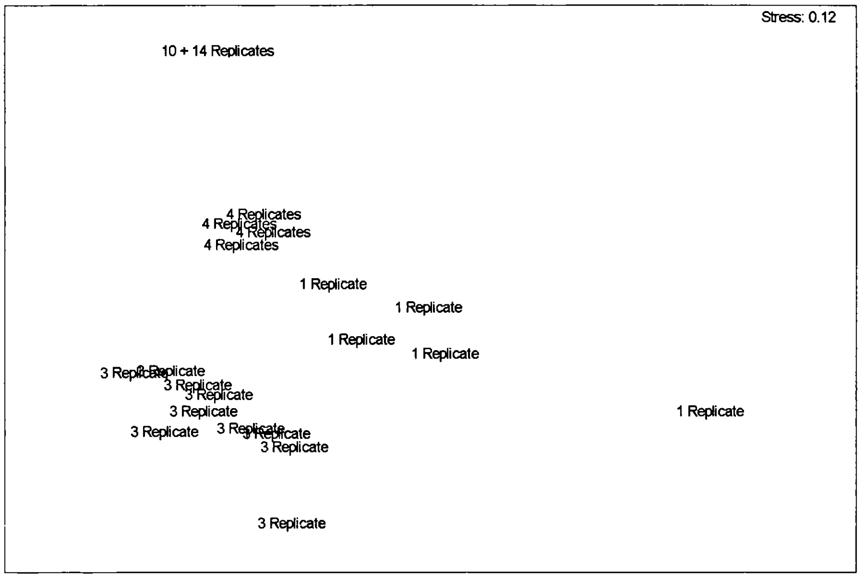


Figure 5.4 MDS Ordination of Long-Term Macrofauna Data Re-Labelled With Sampling Effort



5. 3. 2 Short-term variability Study (Station 49)

5. 3. 2. 1 Short-term Variability in Community Abundance and Composition

Abundance and richness of taxa was seen to vary between short-term samples ranging from 1280 ind. $0.4m^{-2}$ in November 1998 to 4152 ind. $0.4m^{-2}$ in September 1999. A corresponding maximum species richness of 60 species $0.4m^{-2}$ was also recorded in the September 1999 sample, but the lowest species richness, 43 taxa, occurred in the April 1999 samples. There was a relatively small amount of variability in diversity indices between sampling times at Station 49 (Table 5.3). Evenness J′ values were also seen to stay relatively stable between sampling times.

The short-term variability in total abundance and richness was reflected in the abundances and richness of the major taxonomic groups (Figures 5.5 & 5.6). The polychaetes were the most abundant and species rich group at Station 49 on each occasion. Bivalves and amphipods were the second and third most abundant and species rich groups respectively. The relative proportions of major groups were seen to shift in favour of the polychaete fraction over the sampling period (Table 5.4 and Figure 5.7). The polychaetes accounted for 49% of the total abundance in the November 1998 samples, this rose to 76% in September 1999 before falling back to 71% in the May 2000 samples.

Figure 5.5 Abundance of Major Groups in Short-Term Samples

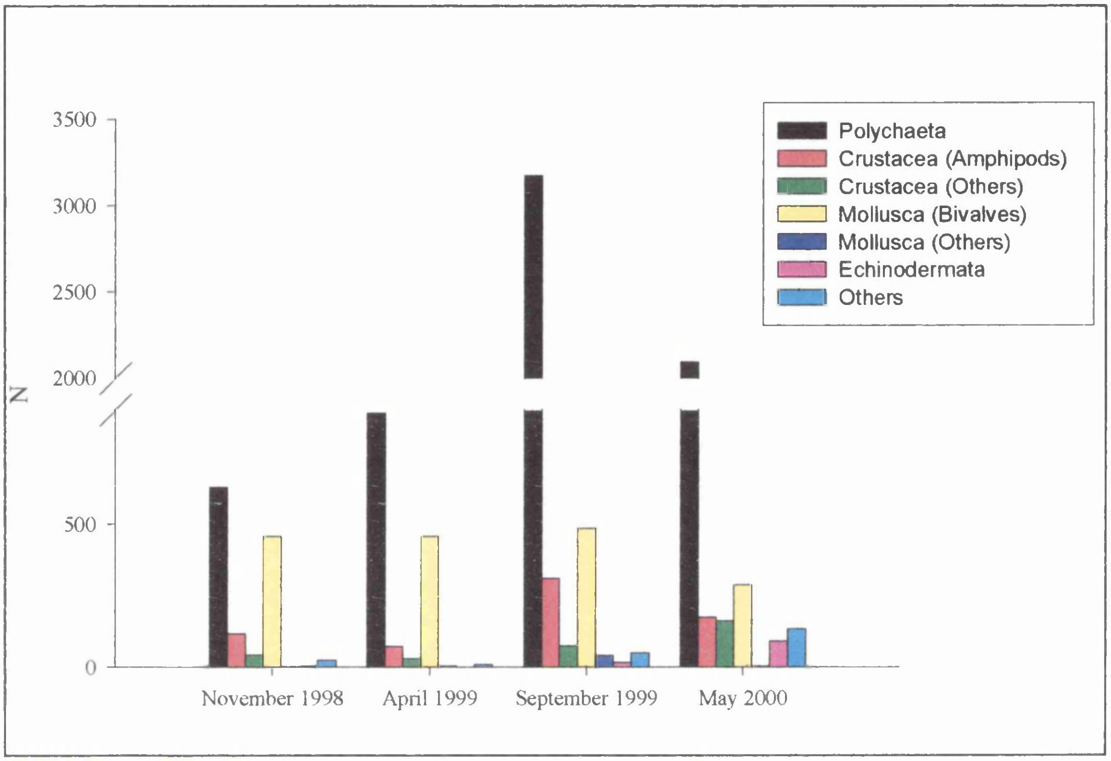


Figure 5.6 Species Richness of Major Groups in Short-term Samples

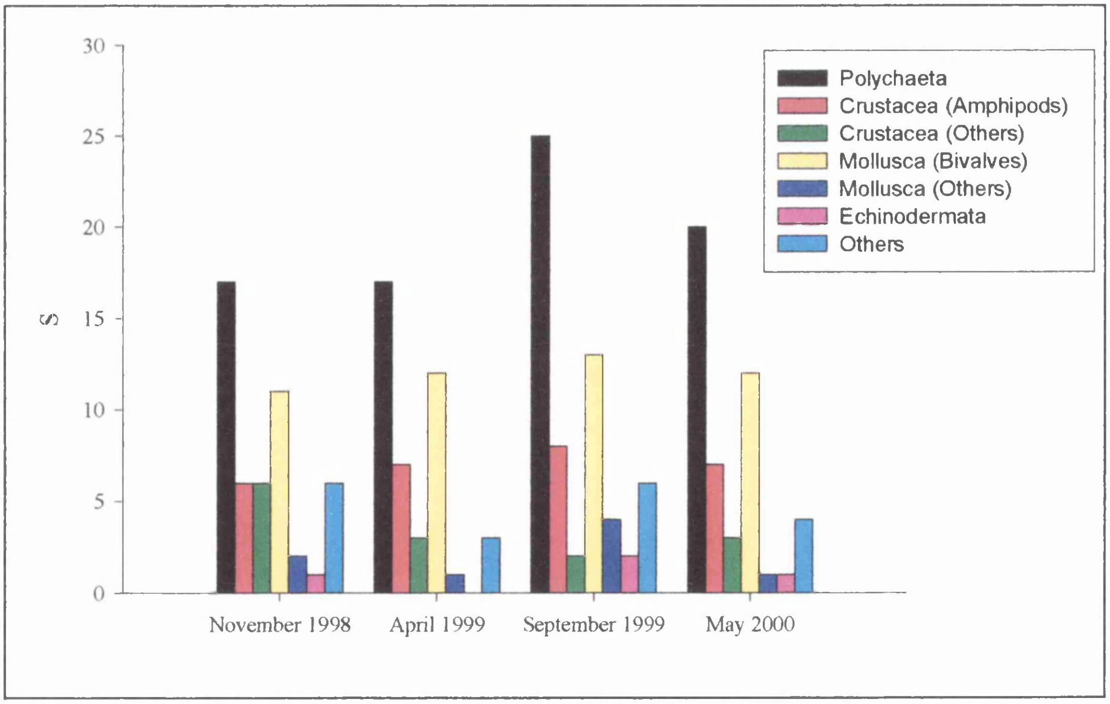
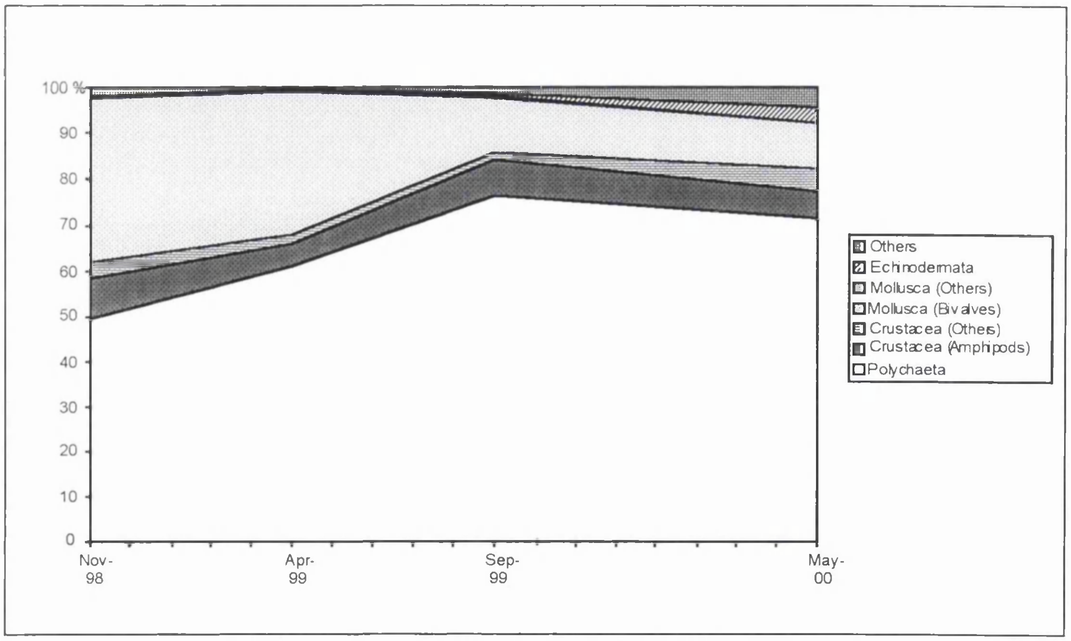


Table 5.4 Pooled Abundance of Major Groups at Each Sample Time

	November 1998		April 1999		September 1999		May 2000	
	N	**S**	**N**	**S**	**N**	**S**	**N**	**S**
Polychaeta	630	17	887	17	3172	25	2094	20
	49.2%	*34.7%*	*60.7%*	*39.5%*	*76.4%*	*41.7%*	*71%*	*41.7%*
Crustacea (Amphipods)	117	6	73	7	311	8	175	7
	9.1%	*12.2%*	*5%*	*16.3%*	*7.5%*	*13.3%*	*5.9%*	*14.6%*
Crustacea (Others)	43	6	30	3	75	2	163	3
	3.4%	*12.2%*	*2.1%*	*7%*	*1.8%*	*3.3%*	*5.5%*	*6.3%*
Mollusca (Bivalves)	458	11	458	12	485	13	288	12
	35.8%	*22.4%*	*31.3%*	*27.9%*	*11.7%*	*21.7%*	*9.8%*	*25%*
Mollusca (Others)	3	2	4	1	42	4	4	1
	0.2%	*4.1%*	*0.3%*	*2.3%*	*1%*	*6.7%*	*0.1%*	*2.1%*
Echinodermata	4	1	0	0	17	2	92	1
	0.3%	*2%*	*0%*	*0%*	*0.4%*	*3.3%*	*3.1%*	*2.1%*
Others	25	6	10	3	50	6	134	4
	2%	*12.2%*	*0.7%*	*7%*	*1.2%*	*10%*	*4.5%*	*8.3%*
TOTAL	1280	49	1462	43	4152	60	2950	48

Figure 5.7 Proportions of Total Abundance of Major Groups



5. 3. 2. 2 Polychaetes

The most abundant polychaete taxa at Station 49 were *C. setosa*, *M. filiformis*, *M. johnstoni*, *S. bombyx*, *Spio* sp., *O. fusiformis* and *Sigalion mathildae* (Audouin & Milne-Edwards) (Table 5.5 and Figure 5.8). The relative dominance of these was seen to be highly variable (Figure 5.8). *Chaetozone setosa* was the numerically dominant polychaete taxon on three of the four sampling occasions, *M. filiformis* was numerically dominant in the April 1999 samples.

The number of individuals of abundant polychaetes varied greatly between sampling occasions; *C. setosa* ranged from 44 to 260 ind. 0.1m^{-2}, *M. filiformis* from 35 to 162 ind. 0.1m^{-2}, *M. johnstoni* from 5 to 28 ind. 0.1m^{-2}, *S. bombyx* from 28 to 146 ind. 0.1m^{-2}, *Spio* sp. From 11 to 52.75 ind. 0.1m^{-2}, *O. fusiformis* 3 to 52 ind. 0.1m^{-2} and *S. mathildae* from 6 to 25 ind. 0.1m^{-2}.

Species composition of the polychaete fauna generally remained stable with 12 taxa occurring at all sampling times. Other, rarer, species such as *Phyllodoce rosea* (McIntosh) and *Lanice conchilega* (Pallas) were found in the samples only singly.

Figure 5.8 Variability of Ubiquitous Polychaete Taxa at Station 49
Error bars indicate standard deviation

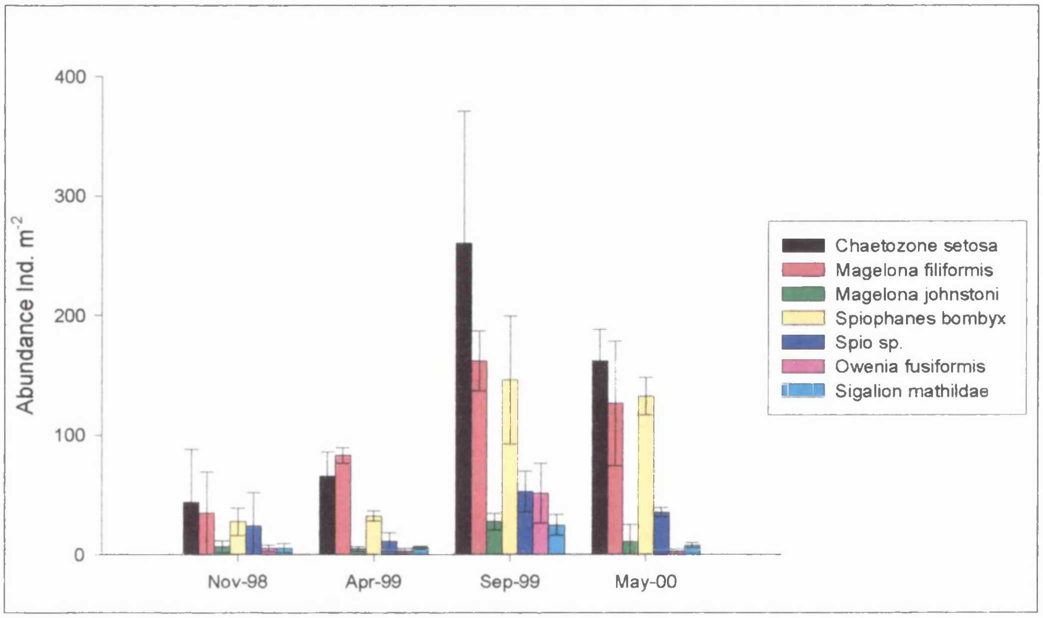


Table 5.5 Polychaete Abundance 0.1m^{-2} at Station 49

	November 1998		April 1999		September 1999		May 2000		Total	
Polychaete Taxa	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Aphelochaeta sp.	0	0	0	0	10.5	6.4	0	0	10.5	21
Caulleriella zetlandica	0.25	0.5	0	0	0.	0	0	0	0.25	0.5
Chaetozone setosa	43.75	44.27	65.5	20.31	260.5	110.64	161.75	26.41	531.5	397.36
Eteone longa	0.50	0.58	1.25	0.5	1.75	1.71	1.5	1.29	5	2.16
Euclymene oerstedii	0	0	0	0	0.5	1	0	0	0.5	1
Eumida bahusiensis	0.25	0.5	0.75	1.5	2.75	3.5	0	0	3.75	4.99
Galathowenia sp.	0.25	0.5	1.25	0.5	3	3.46	1.75	0.96	6.25	4.57
Glycera sp.	0.50	1	0	0	0	0	0	0	0.5	1
Glycera tridactyla	1.25	1.5	2.5	1.29	16.5	6.35	4	3.65	24.25	28.19
Harmothoe glabra	0	0	0	0	0	0	0.25	0.5	0.25	0.5
Heteroclymene robusta	0	0	0	0	0	0	0.25	0.5	0.25	0.5
Lanice congilega	0	0	0	0	0.25	0.5	0	0	0.25	0.5
Magelona alleni	0.50	1	0	0	0.75	0.96	0.5	1	1.75	1.26
Magelona filiformis	35.00	34.47	83	6.68	162	24.91	126.5	52.16	406.5	219.69
Magelona johnstoni	6.50	4.93	4.75	2.06	27.5	6.86	10.75	14.41	49.5	41.57
Magelona mirabilis	0	0	0.25	0.5	1	1.41	0	0	1.25	1.89
Malmgrenia andreapolis	0	0	0	0	0.25	0.5	0	0	0.25	0.5
Nephtys assimilis	0.25	0.5	0	0	0	0	0	0	0.25	0.5
Nephtys hombergii	0	0	2	1.15	5.25	2.87	1.75	2.06	9	8.76
Nephtys sp.	0	0	0	0	0.75	0.96	18.75	3.59	19.5	37.03
Orbinia latreillii	1.25	1.26	0.5	0.58	0.5	0.58	0.5	0.58	2.75	1.5
Owenia fusiformis	5.50	2.65	3.25	2.22	51.5	25.11	2.5	2.08	62.75	95.64
Paranaitis kosteriensis	0	0	0.5	0.58	0	0	0	0	0.5	1
Pholoe sp.	0	0	0	0	14.5	13.53	0	0	14.5	29
Phyllodoce groenlandica	0	0	0	0	0	0	0.25	0.5	0.25	0.5
Phyllodoce rosea	0	0	0.5	1	0.75	0.5	12	2.83	13.25	23.2
Podarkeopsis helgolandica	0	0	0	0	0.25	0.5	0	0	0.25	0.5
Poecilochaetus serpens	0	0	0	0	0.25	0.5	0	0	0.25	0.5
Scoloplos armiger	4.75	4.99	6.25	0.96	8.25	1.71	4.5	2.65	23.75	6.9
Sigalion mathildae	5.5	3.7	6.25	0.96	24.75	8.77	7.75	1.89	44.25	36.69
Spio sp.	24	28.01	11	7.35	52.75	16.88	35.5	3.7	123.3	70.89
Spiophanes bombyx	27.5	11.56	32.25	4.27	146.25	53.46	132.5	15.76	338.5	253.99
Sthenelais sp.	0	0	0	0	0	0	0.25	0.5	0.25	0.5

The amphipod element of the crustacean fauna are presented separately to provide a clearer picture of their temporal variability.

5. 3. 2. 3 Crustacea (excluding amphipods)

The most abundant and consistently occurring non-amphipod crustaceans were the cumacean species (Table 5.6 and Figure 5.9). The largest abundance of nearly 40 0.1 m^{-2} was recorded for *Pseudocuma longicornis* in the May 2000 samples. *Iphinoe trispinosa* was ubiquitous in all samples with an abundance ranging from 1 to 11 ind. 0.1 m^{-2}. The relative dominance of these species varied between the two sampling times.

Other crustacean taxa were recorded more sporadically, 3 species of mysid shrimp *Gastrosaccus spinifer*, *Paramysis arenosa* and *Schistomysis spiritus* were recorded in the November 1998 sample but were absent subsequently. The masked crab *Corystes cassivelaunus* was recorded in the April 2000 sample but not before then.

5. 3. 2. 4 Amphipods

The amphipod taxa at Station 49 were characterized by the numerical dominance of *Perioculodes longimanus* and *Bathyporeia tenuipes* (Table 5.7 and Figure 5.10), *B. tenuipes* was the dominant amphipod in the November 1998, April 1999 and May 2000 samples, *P. longimanus* dominated the September 1999 sample. Species composition remained relatively stable over the sampling times, all taxa occurred in more than one sample. The main type of variability in the amphipod fauna was in changes in relative abundance, *B. tenuipes* ranged from 11 – 19 ind. 0.1 m^{-2}, *P. longimanus* from 5 – 34 ind. 0.1 m^{-2} and *Ampelisca brevicornis* from 0 - 12 ind. 0.1 m^{-2}.

Figure 5.9 Variability of Crustacean Taxa (Excluding Amphipods) at Station 49
Error bars indicate standard deviation

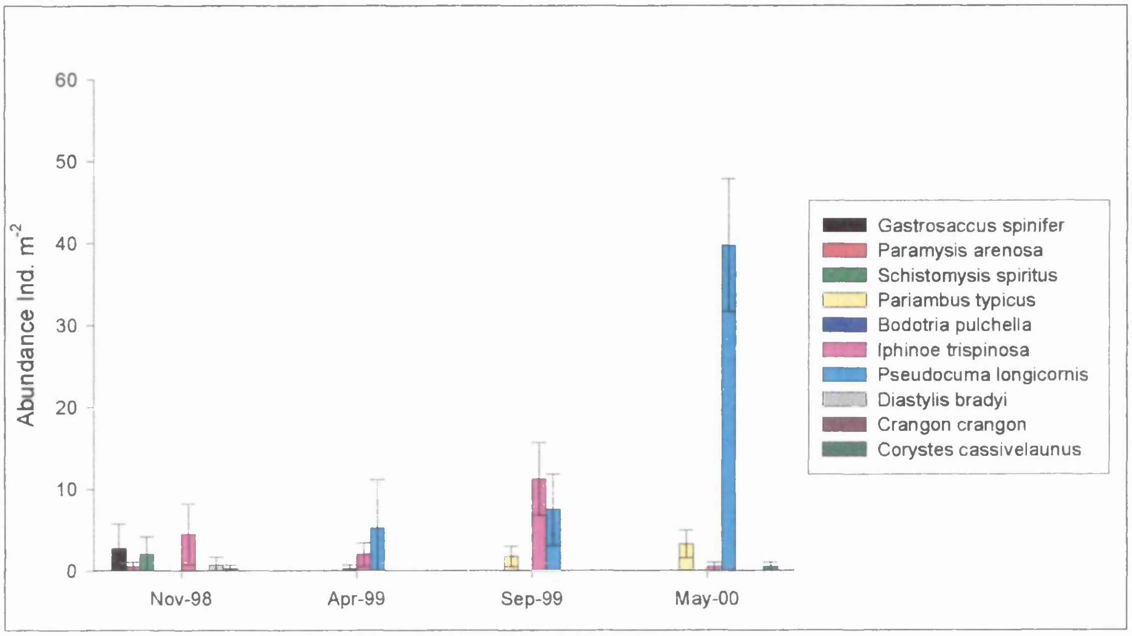


Table 5.6 Crustacean Taxa (Excluding Amphipods) Abundance at Station 49

	November 1998		April 1999		September 1999		May 2002		Total	
Crustacean (Other) Taxa	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Gastrosaccus spinifer	2.75	2.99	0	0	0	0	0	0	0.69	1.49
Paramysis arenosa	0.5	0.58	0	0	0	0	0	0	0.5	0.29
Schistomysis spiritus	2	2.16	0	0	0	0	0	0	2	1.08
Pariambus typicus	0	0	0	0	1.75	1.26	3.25	1.71	2.56	0.88
Bodotria pulchella	0	0	0.25	0.5	0	0	0	0	0.25	0.25
Iphinoe trispinosa	4.5	3.70	2	1.41	11.25	4.43	0.5	0.58	17.88	1.83
Pseudocuma longicornis	0	0	5.25	5.91	7.50	4.36	39.75	8.06	22.69	3.41
Diastylis bradyi	0.75	0.96	0	0	0	0	0	0	0.75	0.48
Crangon crangon	0.25	0.50	0	0	0	0	0	0	0.25	0.25
Corystes cassivelaunus	0	0	0	0	0	0	0.5	0.58	0.13	0.29

Figure 5.10 Variability of Amphipod Taxa at Station 49
Error bars indicate standard deviation

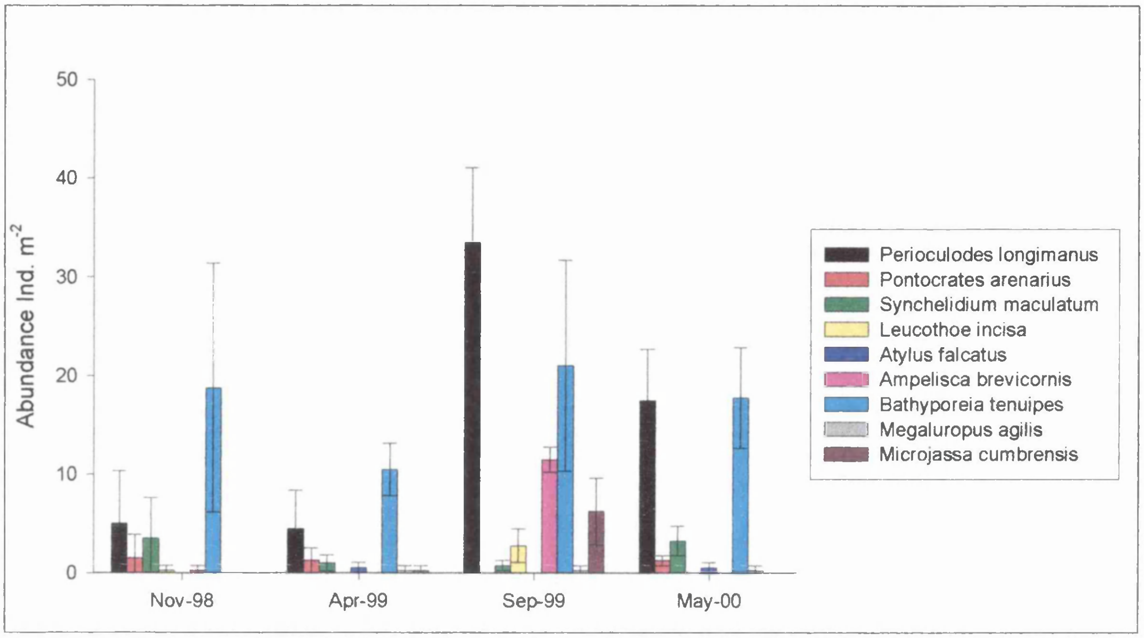


Table 5.7 Amphipod Taxa at Station 49

	23/11/98		16/04/99		02/09/99		05/05/00		Total	
Amphipod Taxa	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Perioculodes longimanus	5	5.35	4.5	3.87	33.5	7.55	17.5	5.2	47.38	1.52
Pontocrates arenarius	1.5	2.38	1.25	1.26	0	0	1.25	0.5	3.06	1.04
Synchelidium maculatum	3.5	4.12	1	0.82	0.75	0.5	3.25	1.5	6.06	1.65
Leucothoe incisa	0.25	0.5	0	0	2.75	1.71	0	0	3	0.81
Atylus falcatus	0	0	0.5	0.58	0	0	0.5	0.58	0.63	0.33
Ampelisca brevicornis	0.25	0.5	0	0	11.5	1.29	0	0	11.75	0.61
Bathyporeia tenuipes	18.75	12.61	10.5	2.65	21	10.68	17.75	5.12	54.69	4.66
Megaluropus agilis	0	0	0.25	0.5	0.25	0.5	0.25	0.5	0.56	0.25
Microjassa cumbrensis	0	0	0.25	0.5	6.25	3.40	0	0	6.5	1.64

5. 3. 2. 5 Bivalves

The bivalve fauna of the Carmarthen Bay *Tellina* community showed very little variability in species composition during the sampling period, of the 14 bivalve taxa recorded 10 occurred at all times (Table 5.8 and Figure 5.11). Those taxa that occurred less often or singly had low abundance.

The bivalve fauna was characterized by relatively high abundances of *F. fabula* (8 - 37 ind. 0.1 m^{-2}), *D. vittatus* (6 – 40 ind. 0.1 m^{-2}) and *A. alba* (1 – 19 ind. 0.1 m^{-2}), the majority of these individuals were noted to be newly settled post-larvae. *Modiolus modiolus* (Linnaeus) post-larvae were also a consistent element of the bivalve fauna and were the numerically dominant species in the April 1999 sample.

Figure 5.11 Variability of Abundant Bivalve Taxa at Station 49
Error bars indicate standard deviation

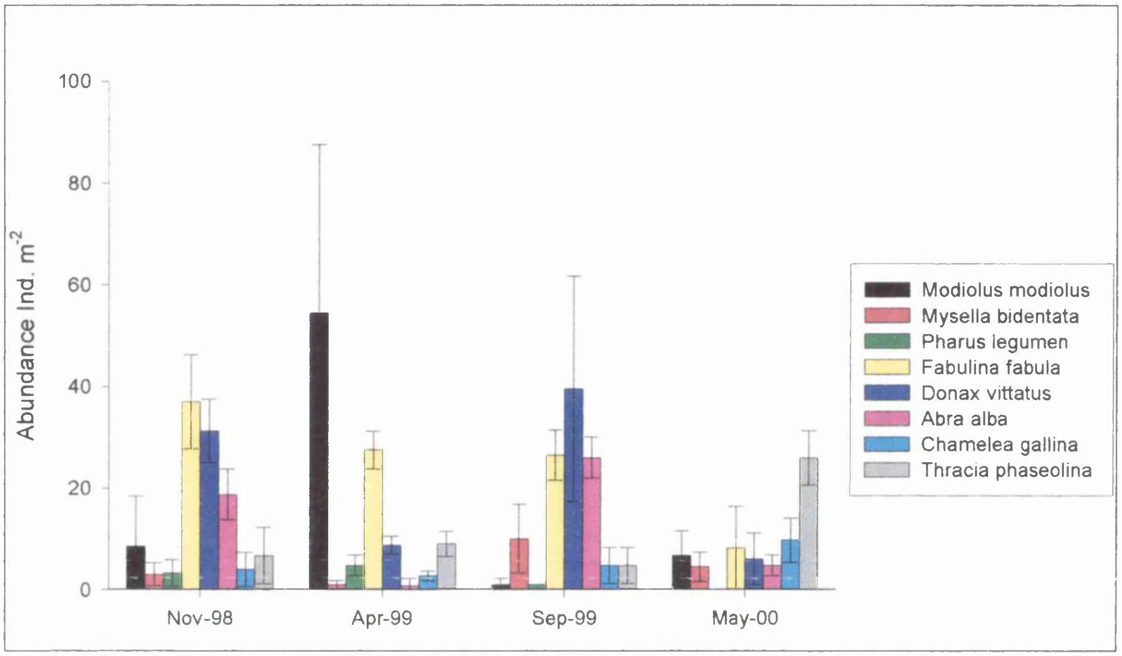


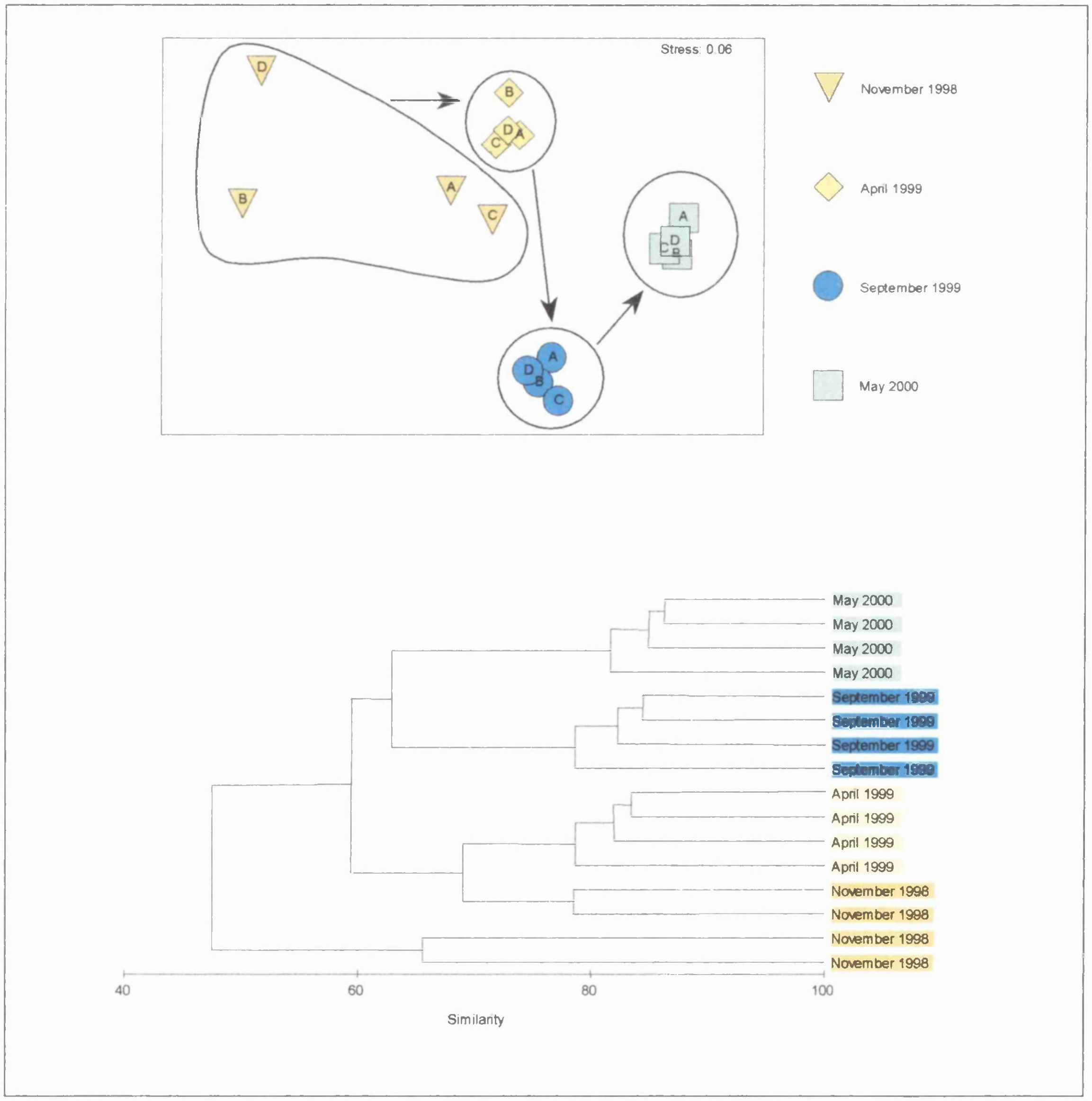
Table 5.8 Bivalve Abundance at Station 49

	November 1998		April 1999		September 1999		May 2002		Total	
Molluscan Taxon	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Nucula sp.	0.75	0.5	0.5	0.58	2.5	1.91	1.75	2.06	1.38	1.54
Modiolus modiolus	8.5	9.88	54.5	33.12	1	1.15	6.75	4.79	17.69	27.09
Tellimya ferruginosa	0	0	3.25	6.5	0.5	1	1.25	1.89	1.25	3.32
Mysella bidentata	3	2.31	1	0.82	10	6.78	4.5	2.89	4.63	4.9
Acanthocardia	0	0	0	0	0	0	0.25	0.5	0.06	0.25
Mactra stultorum	0.75	0.96	1.5	1.73	3	1.83	2	1.41	1.81	1.6
Ensis sp.	0.5	0.58	0.25	0.5	1	0.82	0.75	0.96	0.63	0.72
Pharus legumen	3.25	2.63	4.75	2.06	1	0	0	0	2.25	2.44
Fabulina fabula	37	9.27	27.5	3.7	26.5	4.93	8.25	8.18	24.81	12.39
Donax vittatus	31.25	6.24	8.75	1.71	39.5	22.16	6	5.10	21.38	18.19
Gari fervensis	0	0	0	0	0.25	0.5	0	0	0.06	0.25
Abra alba	18.75	4.99	0.75	1.5	26	4.08	4.75	2.06	12.56	11.02
Chamelea gallina	4	3.37	2.75	0.96	4.75	3.59	9.75	4.35	5.31	4.05
Thracia phaseolina	6.75	5.56	9	2.45	4.75	3.59	26	5.35	11.75	9.41

5. 3. 2. 6 Multivariate Analysis of Short-Term Variability Study Data

The cluster dendrogram and MDS ordination produced from the Bray-Curtis similarity matrix are presented in Figure 5.12. The MDS ordination stress level of 0.06 indicates a meaningful representation of relationships. The MDS ordination highlights the high level of within group similarity of each group of replicates indicating that spatial variability is less than temporal variability. The autumn 1998 samples are an exception being less tightly grouped, showing some degree of separation, this is due to large variability in numbers of polychaetes.

Figure 5.12 MDS Ordination and Cluster Dendrogram of Replicate Samples



The results of the SIMPER analysis of within and between season (dis)similarities are presented in full in Appendix 5.2.

Table 5.9 Within Season Similarity

Date	Average Similarity
November 1998	54.85
April 1999	78.77
September 1999	77.52
May 2000	82.52

The within season analysis reveal taxa that are responsible for the similarity of each group of seasonal replicates. The average similarity values are used here to indicate the fidelity and evenness in abundance of taxa between replicates and therefore also to indicate the degree of spatial variation of the community. The November 1998 replicates showed lowest level of similarity with a coefficient of 54.85 reflecting the pattern seen in the MDS ordination, suggesting a higher level of spatial variability at this sampling time. The other sampling times are shown to be very similar and from this a general low level of spatial variability is inferred.

The pair-wise between-sample comparison tables show that there is a degree of dissimilarity between seasonal sample replicates (Table 5.10). A temporal increase in dissimilarity is apparent, the further apart in time the replicate groups are the more dissimilar they are.

Individual contributions each taxon makes to these between sample dissimilarities are presented in full in Appendix 5.2 Tables e-j. In general, it is the difference in relative abundance of shared taxa which contributes the largest proportion of dissimilarity between seasons and not changes in community composition. The polychaetes *M. filiformis*, *C. filiformis* and *S. bombyx* were the primary contributors to the overall dissimilarity between seasons.

Seasonal abundances of individual taxa contributing the first 50% of the dissimilarity between seasonal samples are shown in Figure 5.13 a-k.

Table 5.10 SIMPER Between season comparisons

Pairwise Comparison	**Dissimilarity**	**1° Contributing Taxa**	**Contribution %**
Nov. 1998 – April 1999	47.99	Magelona filiformis	17.12
Nov. 1998 – Sep. 1999	62.26	Chaetozone filiformis	25.58
Nov. 1998 – May 2000	63.52	Chaetozone filiformis	18.53
April 1999 – Sep. 1999	58.50	Chaetozone filiformis	23.04
April 1999 – May 2000	51.33	Spiophanes bombyx	17.74
Sep. 1999 – May 2000	37.38	Chaetozone filiformis	14.28

Figure 5.13 Abundance 0.1m^{-2} of Taxa Influential in Between-Sample SIMPER Test. Error bars represent within sample standard deviation.

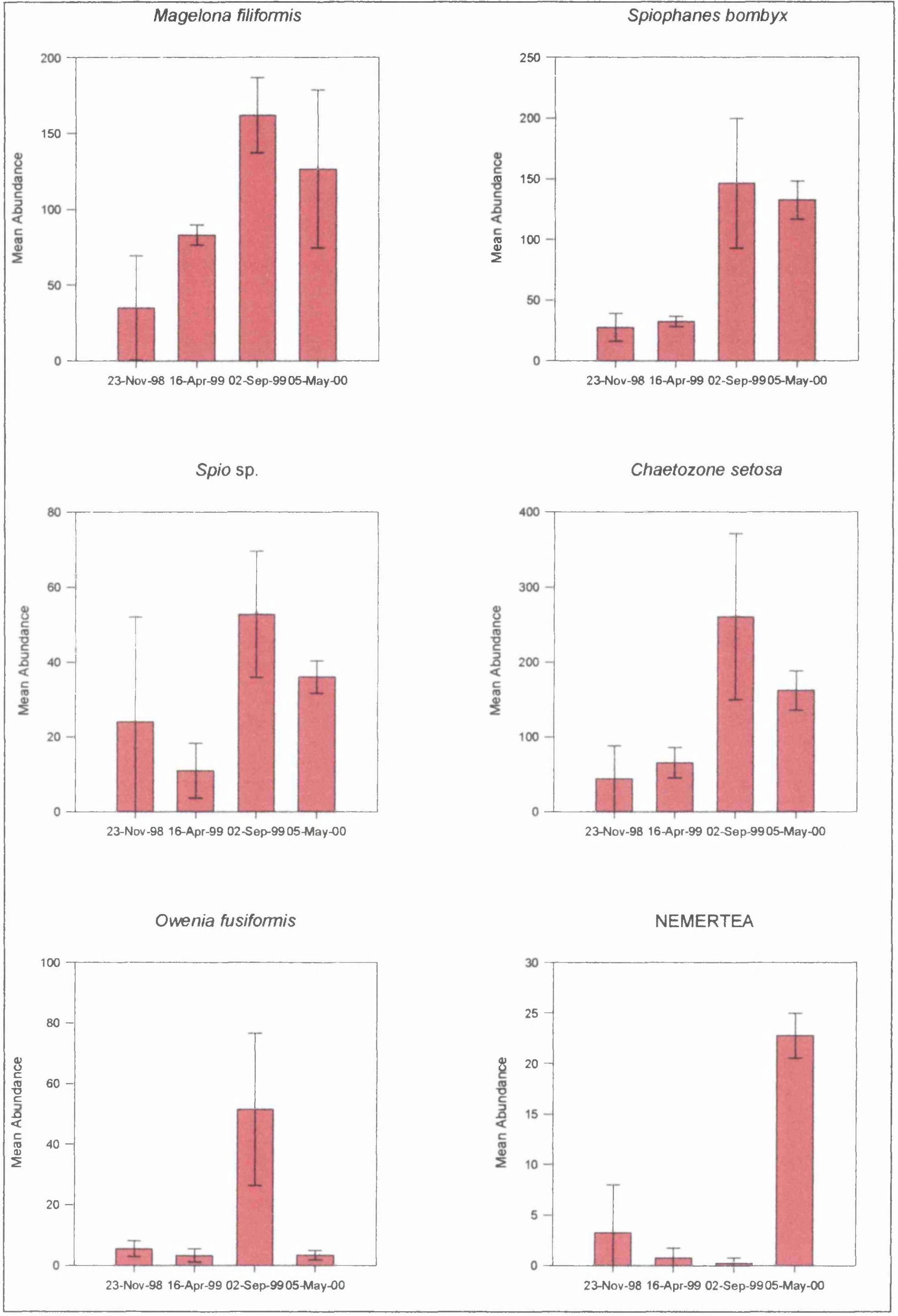
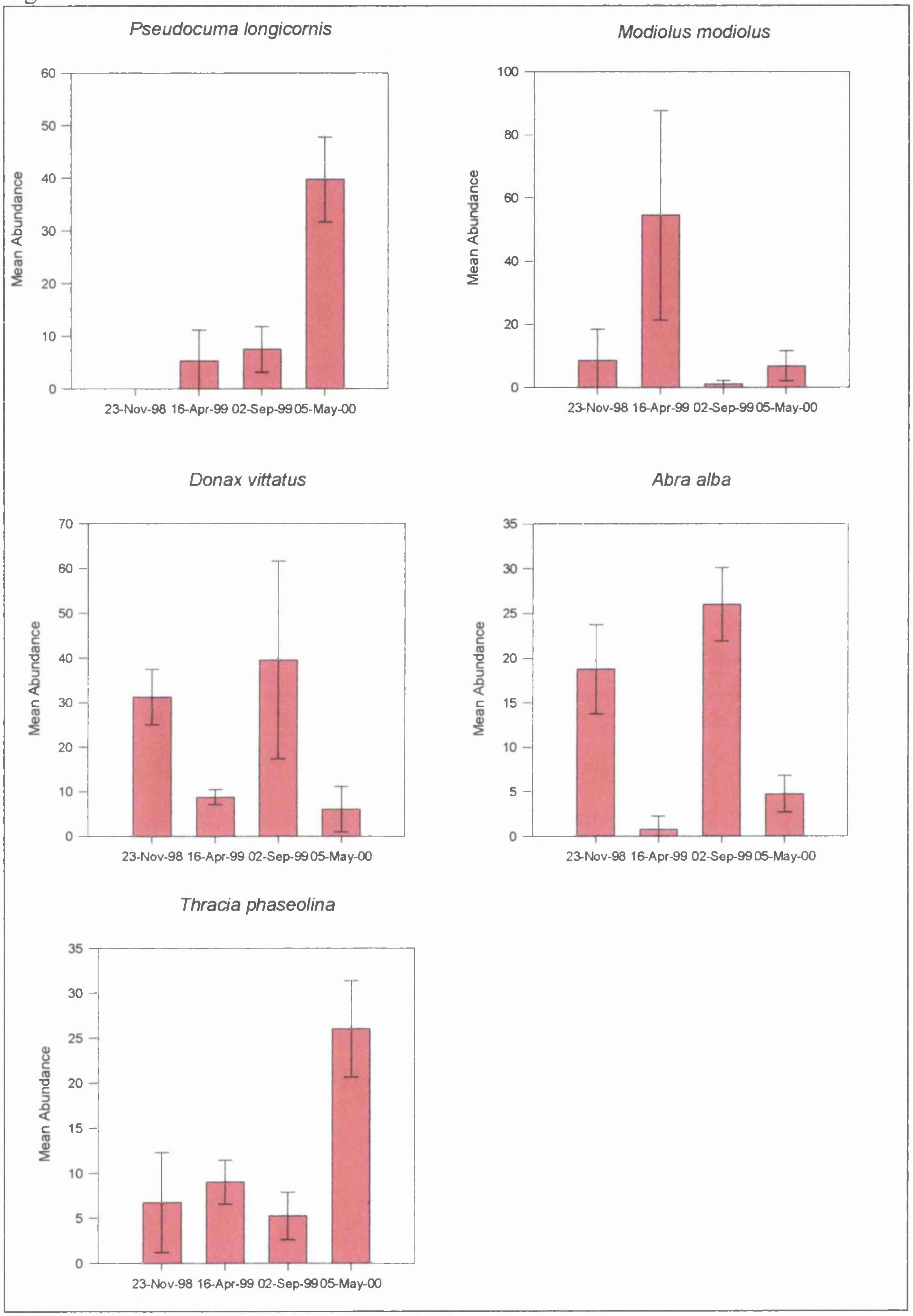


Figure 5.13 Continued



5. 3. 3 Structural redundancy in the Carmarthen Bay *Tellina* community

The BVSTEP procedure isolated 3 sub-groups of macrofauna whose ordination matched that of the full dataset with a Spearman rank-correlation coefficient (ρ) > 0.95 (Figure 5.14 b-d). A further 2 sub-groups with $\rho < 0.95$ were produced during the peeling procedure, one of which produced an ordination resembling that produced from the reduced baseline data set (Figure 5.14 e). The remaining sub-group contained those fauna present only in a reduced number of samples and therefore the resulting ordination could not be considered a convincing match with a $\rho = 0.477$. The reduced data set returned a $\rho = 0.992$ when matched against the full baseline dataset, this indicated that the exclusion of rare taxa (those taxa accounting for < 0.1% of total abundance) had negligible effect on the overall community pattern.

The 3 response units with $\rho > 0.95$ increase in size from 7 taxa in the first response unit, 9 taxa in the second to 15 taxa in the last, a similar pattern found in previous studies by Clarke and Warwick (1998) and Mistri et al. (2001).

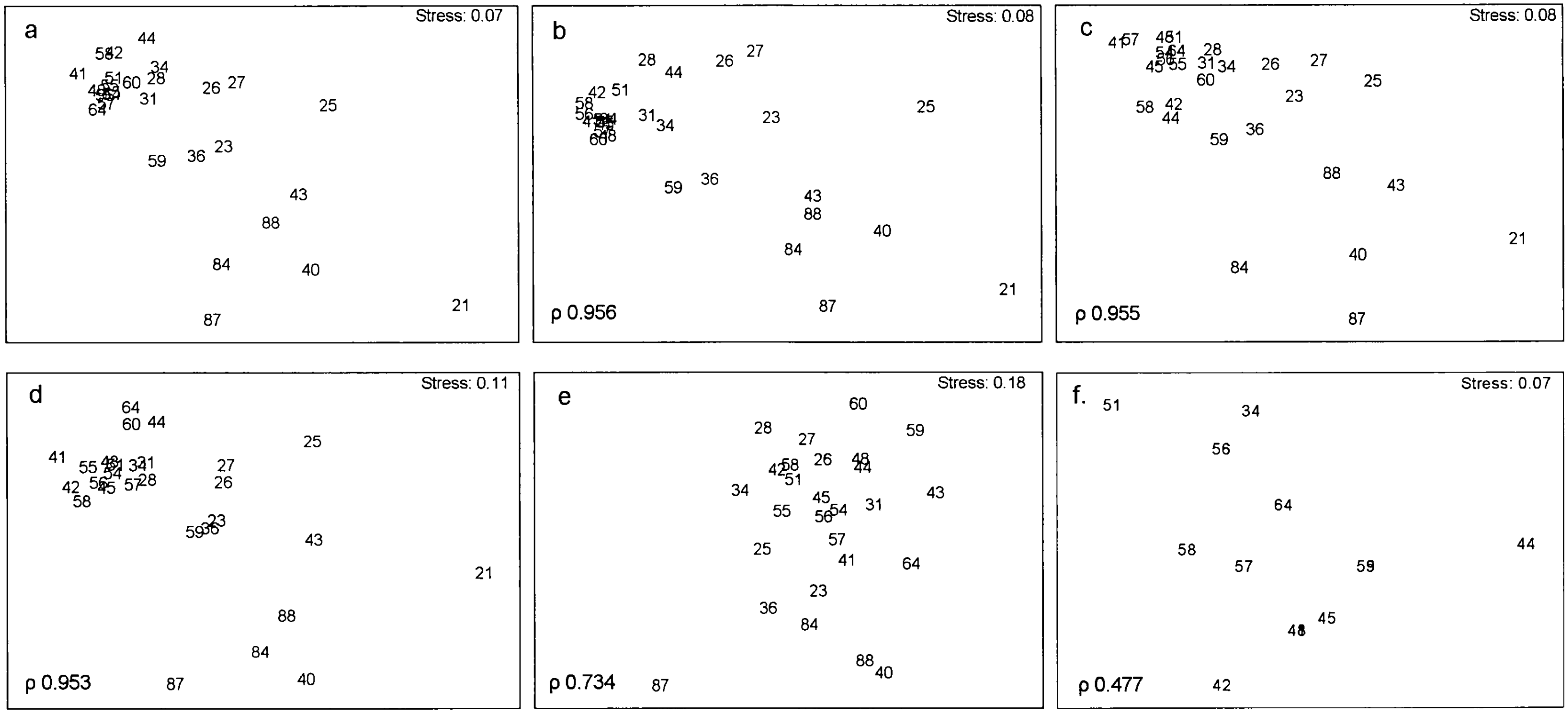
Table 5.11 presents the taxa from the successive peels classified into a simplified taxonomic/functional grouping modified from those used by Clarke and Warwick (1998); sessile polychaetes that are generally deposit feeders, motile polychaetes that are mainly carnivorous, amphipods and cumaceans that are essentially deposit feeders, bivalve molluscs that are a variety of deposit and suspension feeders, other molluscs which in this case are an ectoparasite and a carnivore, the final grouping contains suspension feeding animals not included in the major groups.

Table 5.11 Structural Redundancy Response Units

Major Group	**Response Unit 1 (ρ 0.956)**	**Response Unit 2 (ρ 0.955)**	**Response Unit 3 (ρ 0.953)**	**Response Unit 4 (ρ 0.734)**	**Response Unit 5 (ρ 0.477)**
Polychaetes (Sedentary)	*Spiophanes bombyx* *Owenia fusiformis*	*Magelona* spp. *Scolelepis bonnieri*	*Spio* spp. *Chaetozone setosa* *Capitella* sp. *Autolytus* sp.	*Lanice conchilega* *Euclymene oerstedii* *Podarkeopsis capensis*	
Polychaetes (Motile)	*Nephtys cirrosa* *Lumbrineris gracilis*	*Sigalion mathildae* *Nephtys* JUV.	*Phyllodocidae JUV.* *Eteone longa* *Glycera tridactyla*	*Phyllodoce rosea* *Nephtys assimilis*	
Amphipods and Cumaceans	*Synchelidium maculatum* *Bathyporeia elegans*	*Perioculodes longimanus*	*Pseudocuma longicornis* *Iphinoe trispinosa* *Pontocrates arenarius*	*Pariambus typicus* *Bathyporeia sp.* *Bathyporeia tenuipes*	*Microjassa cumbrensis* *Stenothoe monoculoides*
Molluscs (Bivalves)	*Fabulina fabula*	*Thracia phaseolina,* *Phaxas pellucidus*	*Mactra stultorum* *Mysella bidentata* *Chamelea gallina* *Donax vittatus*	*Tellimya ferruginosa* *Acanthocardia echinata*	
Molluscs (Others)		*Turbonilla lactea*			*Cylichna cylindracea*
Others		*Amphiura brachiata*	*Phoronis* sp.		

Figure 5.14 MDS Ordinations of Individual Redundancy Response Units.

a. Full macrofaunal data, b-f response units 1-5. Matching co-efficient ρ shown in bottom left corner of each plot.



5. 4 Discussion

5. 4. 1 The Effects of Station and Sampling Bias

The most likely factors involved in the masking of long-term variation in the time series data are the spatial separation of stations and sampling bias.

As the data used in the long-term variability study originated from spatially separate stations, a degree of between station dissimilarity could be expected. Station 49 of the present study and station CB20 of the Hobbs and Smith (1998) study were situated within 1km of each other and were similar in terms of physical environment. Station 126 from the Warwick et al. (1978) study was situated further away (~10 km) but in similar fine sediment and at a similar depth. The degree of dissimilarity between these stations due to their spatial separation and any disparity in physical characteristics in habitat may act to confound the detection of long-term variations in he multivariate analysis of community structure.

The patterns of abundance in macrofaunal communities can be strongly influenced by sampling methods, including gear type used, number of replicates taken, sieve mesh sizes and taxonomic resolution used in the analysis (Kingston & Riddle, 1986; Bachelet, 1990; James et al., 1995). The sampling methods used in the 3 surveys amalgamated to produce the dataset analyzed in the current study were different in a number of ways: sampling device, mesh size of sieve and number of replicates taken. Warwick et al. (1978) sampled 14 replicate samples with a Day grab with a bite profile of 0.7 m^2 and 10 replicate samples with a deep penetrating Knudsen sampler, the retained fauna was washed through a 0.5 mm mesh. Hobbs and Smith (1998) used a similar 0.1 m^2 Day grab in March 1996; taking single samples and again washing them through a 0.5 mm mesh. Their subsequent October 1996 and April 1997 samples employed the same methodology with the addition that 3 replicates were taken. The current study used a heavy Van-Veen grab with a bite profile of 0.1 m^2 to take 4 replicate samples which were washed through a 0.3 mm mesh.

A number of studies have shown mesh size to affect estimates of abundance and diversity of marine macrofauna (Bachelet, 1990; Schlacher & Wooldridge, 1996; Tanaka & Leite, 1998; Crewe et al., 2001; Callaway et al., 2002) and to sample taxa according to their body shape (Schlacher & Wooldridge, 1996). The mesh sizes used in the previous surveys of 0.5 mm are likely to have retained the majority of the macrofauna in the *Tellina* community as would the 0.3 mm mesh used in the current survey, with the addition of newly recruited post-larvae and juveniles. The use of the 0.3 mm mesh may have resulted in some changes in the relative abundances of certain taxa caused by the retention of more numerous, smaller size classes.

Members of soft-sediment communities occupy different sediment horizons at different depths in the substratum. This potentially could lead to sampling bias when different sampling methods are employed. The Day grab employed in the Warwick et al. (1974) and Hobbs and Smith (1998) studies has been demonstrated to have a shallower bite profile than that of the type of heavy long-armed Van-Veen grab used in the current study (Riddle, 1984, 1989), whereas the Knudsen sampler can penetrate the sediment to a depth of 30 cm (Barnett, 1969). The improved sampling efficiency of the heavy long-armed Van-Veen grab will be discussed in Mackie (in prep). The shallower bite profile and lighter weight of the Day grab leads to a smaller volume of sediment being retained and the under-sampling of deeper-living taxa. This under-sampling due to smaller volumes and omission of the deeper-living taxa may have lead to a small measure of sampling error.

Figure 5.4 strongly suggests that a significant source of sampling error is sample size represented by the number of replicates taken at each sampling time. The sensitivity of multivariate analysis to sample replication has been demonstrated by Gamito & Raffaelli (1992) where it was shown that MDS ordinations are affected by the number of replicate samples taken. Scaling of the samples to 0.1 m^2 and standardization prior to transformation (log x+1) of the macrofaunal data did not affect the analysis.

5. 4. 2 Long-term Variability in the Carmarthen Bay *Tellina* Community

Due to the confounding effects discussed above, long-term variability can only usefully be discussed qualitatively using the most abundant animals for comparison. It is difficult to identify long term trends in community structure without an appropriate estimate of spatial variability. Variability in even the mere presence or absence of taxa has to be interpreted with caution. An absence of a common taxon from a time series sample may be due either to real temporal variability in its abundance or to spatial variability in its distribution and its absence from the sample due simply to it being missed by the grab.

The results indicate that community composition remains relatively stable when considering the most commonly occurring taxa. A group of 10 taxa was found to be ubiquitous in the combined samples (Table 5.2). These persistent taxa of the Carmarthen Bay *Tellina* community are also reported as commonly occurring in the German Bight and La Coruña Bay *Tellina* communities (Ziegelmeier, 1978; López-Jamar et al. 1995) and are therefore considered characteristic of the *Tellina* community as a whole. Those taxa demonstrating frequent but intermittent occurrence (the polychaete *G. tridactyla* and the amphipod *P. arenarius*) can also be considered characteristic species of the *Tellina* community but are taxa likely to be subject to either significant spatial or temporal variation in abundance.

Carmarthen Bay is not subject to the extreme climatic events such as low bottom temperatures that periodically occur in the German Bight and are cause of long-term perturbations in community (Ziegelmeier, 1978; Kroncke et al., 1998). The north and east of the bay is in the lee of Pembrokeshire and is sheltered from much of the force of the prevailing south westerly wind and swell waves. These factors may provide the basis of the stability of community composition.

The *Sea Empress* oil spill of February 1996 is reported to have caused the mortality of sensitive small crustacean taxa such as amphipods and cumaceans (Rostron, 1997) in the immediate area of the spill and subsequent mass strandings of larger fauna such as the bivalves *P. legumen* and *Mactra stultorum* (Linnaeus) and the burrowing urchin *Echinocardium cordatum* (Pennant) (Dyrynda, 1996). The lack of adequate baseline survey data made accurate assessment of its true impact difficult and prompted the survey presented in Chapter 2. What can be inferred from the subsequent survey data (Hobbs and Smith, 1998; & current study) is that the small crustacean taxa rapidly recovered from any initial impact of the oil spill in Carmarthen Bay. The short generation time and rapid reproductive cycle of these highly r-selected taxa would have enabled rapid re-colonization of the sediments by migration and larval transport from unaffected areas. It is difficult of assess the recovery of the larger, more k-selected taxa such a *P. legumen* and *M. stultorum* as they relatively deep in the sediment and are likely to be undersampled by the methods employed in the current study. These taxa were not found in high densities in any of the samples at either time series Station 49 or during the baseline survey (Chapter 2) and those that did occur were juveniles. Samples taken from sites in Carmarthen Bay in the summer of 2002 contained high abundances of small (<30 mm) *P. legumen* (personal obs.). It may be the case that slower growing and reproducing k-selected fauna such as these may be subject to more lengthy recoveries from perturbations and are dependent on more infrequent annual or longer period recruitment events.

5. 4. 3 Short-term Variability in the Carmarthen Bay *Tellina* Community

The reduced temporal scale resulting from the loss of samples at Station 49 was unfortunate but the remaining data have enabled a brief insight into temporal variability of the Carmarthen Bay *Tellina* community.

Spatial variability in macrofaunal communities is an often cited source of potential error in time series studies (Morrisey, 1992; Armonies, 2000; Ghertsos et al., 2000). The spatial separation of grabs taken at Station 49 were dependent on boat drift and GPS error but is considered to be within a 50 m radius of the sample station. Standard deviations of individual taxa indicate that spatial variability at this scale is generally small. Where spatial variability is indicated, it can be attributed to the patchy settlement of large numbers of juveniles, for example *C. setosa* in the September 1999 samples, or to patchy distributions of motile fauna, such as the amphipod *B. tenuipes*. Spatial variability was indicated by high standard variations for polychaete fauna in the November 1998 samples and this is reflected in the multivariate ordinations of the macrofauna data. The MDS ordination of the Station 49 macrofauna data (figure mds) illustrates the results of the SIMPER analysis showing that dissimilarity within replicates (spatial variation) is less than dissimilarity between sampling times (temporal variation).

The results from the current study at Station 49 showed that the species composition of the *Tellina* community was very stable during the sampling period, although the relative proportions of the numerically dominant taxa were subject to variability. On a community wide scale, changes in the abundance of individuals was the prevailing type of variability. The highest abundance of individuals was recorded in the September 1999 samples, and the lowest in the November 1998 and April 1999 samples. This pattern of variability of abundance can be attributed in part to the increase in abundance of individual polychaete fauna, although a corresponding increase in abundance was recorded across all groups. If the samples are considered representative of seasons; November 1998 and April 1999 as autumn and winter samples and May 2000 and September 1999 as summer samples, a seasonal source of this variation can be inferred; highest abundances occurring in the summer and the lowest in the autumn and winter. The most likely sources of seasonal variability of abundance in a macrofaunal community at this latitude are seasonal recruitment events and subsequent post-settlement mortality and redistribution processes. This would be in agreement with the results of Bosselman (1991) and López-Jamar et al. (1986, 1995) from *Tellina* communities in the German Bight and La Coruña Bay where monthly sampling revealed that short-term seasonal variations in abundance was due to the variable recruitment of juveniles. A sampling period on a finer scale, monthly or shorter, would have identified the timing of these recruitments from peaks of super abundance of single taxa. There are a number of such peaks in abundance that suggest sampling from the current study coincided with such recruitments, the peak abundance of the polychaete *C. setosa* and the amphipod *P. longimanus* in the September 1999 samples are good examples.

The community structure, when considered in context of relative proportions of major groups, was also seen to be subject to recruitment induced variability over the sampling period. The relative proportion the polychaete fauna increased from 49% in the November 1998 samples to a peak of 76 % in September 1999 samples. The results suggest that this shift in relative abundance towards the polychaete fauna can be accounted for not by a loss of fauna from other groups but by the import and recruitment of polychaetes in the period April – September 1999.

SIMPER multivariate analysis revealed a pattern of increasing dissimilarity between sampling occasions with increasing time, also suggesting a successional process affecting the structure of the community. The SIMPER between-season comparisons show that the resulting dissimilarities were due to changes in abundance of common shared taxa, often polychaetes, and not to changes in community composition.

The only major group that remained relatively stable in the terms of abundance were the bivalves. López-Jamar et al. (1995) attribute the short-term stability in abundance of some members of a *Tellina* community, including bivalve species, to their longer life-cycles and k-selected reproductive strategies. Seasonal or short-term oscillations in the abundance of these taxa are generally of a longer period and consequently these taxa are likely to show longer period, inter-annual variability.

Community composition remained relatively stable over the sampling period, there was no loss or gain of abundant taxa, only of rarely sampled taxa which usually occurred as single individuals.

5. 4. 4 Structural Redundancy of the Carmarthen Bay *Tellina* Community

Analysis of structural redundancy of the Carmarthen Bay *Tellina* community using the BVSTEP 'peeling' procedure revealed 3 subsets of taxa which correlated to the wider community pattern (from 150 species) with a matching coefficient $\rho > 0.95$. The results show a progressive increase in subgroup size (subgroup 1 = 7 taxa, subgroup 2 = 9 taxa and subgroup 3 = 15 taxa) was also reported by Clarke and Warwick (1998). Clarke and Warwick (1998) hypothesized that the first subgroup, containing key taxa with a strong 'signal to noise' ratio, dictates the overall pattern, and that subsequent subgroups contain taxa with weaker 'signal to noise' ratios and therefore require two or three representatives to mirror the pattern of the preceding subsets. The results indicate that it is not necessary for taxa to be numerically abundant to be considered key species, the ranked abundances in the first group range from 1 - 39 and the second 2 - 42.

Clarke and Warwick (1998) found higher levels of structural redundancy at three sites; the Bay of Morlaix: 4 subsets $\rho > 0.95$ + 1 subset $\rho > 0.90$, Northumberland station P: 3 subsets $\rho > 0.95$ + 1 subset $\rho > 0.90$; Northumberland station M1: 4 subsets $\rho > 0.95$ + 1 subset $\rho > 0.90$. Mistri et al. (2001) reported low levels of structural redundancy in soft-sediment eutrophic lagoon communities in the northern Adriatic; Valli di Comacchio community contained 2 subsets and the Sacca di Goro contained 1 subset. The *Tellina* community of the current study falls between the two; however, as the current study lacked the temporal variability component of the previous studies and in light that Clarke and Warwick (1998) hesitated to define a formal redundancy index based on the number of subsets isolated, a direct comparison between sites may not be appropriate. There does however appear to be a link between species richness and structural redundancy. The current debate on the role of biodiversity in ecosystem function and resilience has developed a consensus that systems with high species richness and functional diversity should be relatively stable and insensitive to perturbations (McCann, 2000).

Apportioning an accurate functional role to each individual taxon within the community is not possible without experimental or observational information and therefore the taxonomic/functional characterization used in the current study was fairly broad. However, these characterizations appear to be appropriate to the Carmarthen Bay *Tellina* community, they contain representatives of all the functional groups that would be expected to occur in a soft-sediment habitat of this type; surface and subsurface deposit-feeders, carnivores and scavengers. The structure of the 3 subgroups is very similar, there is a broad representation of taxonomic/functional groups in the members of each subgroup. Current theories of functional redundancy propose that the decline or removal of a member taxon of a functional group will result in the increase in abundance of a functionally equivalent but redundant taxon (Walker, 1995; Jaksic, 2003). The level of functional redundancy is likely to modulate how community stability and persistence is affected by local species extinction by a process of compensation. The prediction of this compensation process in the Carmarthen Bay *Tellina* community using the structural redundancy subgroups is tempting. A purely hypothetical example could be; the removal of the surface deposit feeding bivalve *F. fabula* may be compensated for by an increase in abundance or production of the deposit feeding bivalve *P. legumen*, however, without accurate information on the true functional role of each taxon and their mutual interaction predictions such as these are best treated with caution. The actual compensation, if any, could equally be an increase in the abundance of a functionally similar deposit feeding polychaete such as *S. bombyx* or a *Magelona* species, as any perturbation likely to affect significantly the abundances of a single taxon are likely to affect other taxonomically and functionally similar taxa. A similar situation was observed immediately after *Sea Empress* oil spill where a significant reduction in sensitive crustacean taxa was reported across a wide taxonomic range (Rostron, 1997).

Further evidence of functional redundancy in the *Tellina* community can be drawn from both the short-term data from Station 49 and the long-term comparisons. The successional process suggested by the results of the SIMPER analysis of the short-term dataset may be an example of the functionally redundant taxa in the community compensating for fluctuation over time. The results demonstrate that changes in relative dominance of taxa are responsible for the increase in dissimilarity between sampling times. It is conceivable that as the abundance of one taxon is reduced, possibly due to recruitment limitation, the abundance of some other functionally similar taxon increases due to reduced competition for space, food or some other limiting resource. Results of the long-term comparison may also be interpreted as representing a similar process. The variable presence of individual taxa among the most abundant taxa and the changes in dominant taxa between sampling times, may also be representative of the interchangeability of functionally similar taxa.

5. 4. 5 Conclusions

In conclusion the Carmarthen Bay *Tellina* community is shown to be subject to recruitment driven short-term variability in relative abundance and dominance of commonly occurring r-selected taxa. A measure of the persistence of the *Tellina* community is provided by the relatively stable community composition over longer time periods. There is may be a dichotomy in levels of resilience of the Carmarthen Bay *Tellina* community; certain longer lived and slower reproducing k-selected taxa may take a number of years to recover from perturbation, whereas rapidly reproducing and short-lived r-selective taxa are likely to recover in a number of months. Levels of structural redundancy suggest that functionally equivalent taxa may be able to compensate for variability in the abundance of individual taxa. This process may maintain certain ecosystem processes of the community but as McCann (2000) points out, simplification of the community is likely to make it unstable and subject to wide variations in both abundance of individuals and community composition. This process of simplification in the Carmarthen Bay *Tellina* community could conceivably arise from a sustained or recurring perturbation of k-selected species such as that presented by the proposed hydraulic shellfish fishery in Carmarthen Bay.

Chapter 6: General Discussion

The baseline macrofaunal survey revealed that Carmarthen Bay is dominated by the *Tellina* sub-group of Petersen's *Venus* community. Although the presence of this type of community had previously been reported at sites in the bay (Warwick & Davies, 1977; Hobbs & Smith, 1998), its distribution and that of its component fauna remained undescribed. The Carmarthen Bay *Tellina* sub-community is characterized by the polychaetes *S. bombyx*, *Magelona* spp. and *Spio* spp., the amphipods *P. longimanus*, *P. arenarius* and *Bathyporeia* spp. and the bivalves *F. fabula*, *M. bidentata* and *C. gallina*. Similar communities are found in inshore shallow sand around the British Isles, in the Irish Sea (Eagle, 1973, 1975; Rees et al., 1976; Mackie et al., 1995; Mackie et al., 2000), north-east coast of England (Buchanan, 1963) and in Scottish sea lochs (McIntyre & Eleftheriou, 1968). In the North Sea, communities sharing taxa characteristic of the *Tellina* sub-community are found further offshore inhabiting shallow coarser sediment sandbank areas (Govaere et al., 1980; Vanosmael et al., 1982; Degraer et al., 1999) whereas more sheltered inshore fine sand areas such as those of the German Bight hold communities with a compositionally comparable faunal (Niermann et al., 1990; Duineveld et al., 1991; Kunitzer et al., 1992). The general trend in the structure of this community, its composition and structure, is known to reflect changes in the prevailing hydrodynamic and associated sedimentary environment. Fine, more sheltered, sands tend to support communities dominated by *Magelona* spp. and *F. fabula*, and coarser, more exposed, sands support communities dominated by *N. cirrosa* and *Spisula* spp. (Thorson, 1957). This pattern is seen on a small spatial scale within Carmarthen Bay: The combination of diurnal tidal and periodic wave induced currents constantly reworking the surficial sediments result in gradients of increasing grain size in an arc from Saundersfoot Bay around to Worms Head. The powerful tidal currents and the prevailing southwesterly swell describe similar patterns of intensity in the bay. The composition and relative abundance of taxa in the Carmarthen Bay *Tellina* community is seen to change in response to the combination of hydrodynamic and sedimentary environmental gradients. Species abundance and richness are seen to correspond to an increase in hydrodynamic energy and associated sediment grain size and mobility, becoming more akin to a reduced *Spisula* community. As the sediments become finer and muddier and hydrodynamic stress decreases, the *Tellina* community grades into Petersen's *Abra* community reported at the southern periphery of the bay by Warwick and Davies (1977).

Determining the mechanistic pathways between the physical environment and community structure and distribution was beyond the scope of this project and as Snelgrove & Butman (1994) affirm, the complexity of soft-sediment communities may defy any simple paradigm relating to any single factor. Nevertheless, the application and utilization of non-parametric multivariate statistical techniques during this study, the use of BVSTEP to isolate 'Response Groups' of species demonstrating a significant correlative relationship with individual environmental clines, may provide a useful starting point. The determination of those taxa sensitive to natural or anthropogenic environmental clines is a prerequisite for more detailed, hypothesis driven experimental studies.

It is possible, however, to speculate on the nature of the interaction between the *Tellina* sub-community and physical environmental gradients. The *Tellina* sub-community is numerically dominated by surface deposit-feeding taxa, for example *S. bombyx*, *Magelona* spp. and *F. fabula*. Spatial patterns of species abundance and richness were shown to be positively correlated to the proportion of mud and fine sand, and negatively correlated with the hydrodynamic factors wave height and tidal flow. As muddy sediments often contain a higher organic content than clean sandy sediment, organic matter tending to be more closely associated with the lighter depositional sediment fraction accumulating in low-energy areas, it is possible to infer a link between food supply and community distribution. These low energy areas are likely to accumulate phytodetritus settling out of the water column and are likely to have thicker surface diatom films than those areas with high current flow (Stewart, 1987; Cahoon et al., 1999). The rapid utilization of this material surface deposit feeders has been recently experimentally demonstrated and quantified (Josefson et al., 2002). The effect of food supply has been demonstrated as having a fundamental role in determining the population dynamics of deposit feeding polychaetes (Rossi et al., 2001; Rossi & Lardicci, 2002) and bivalves (Seitz & Lipcius, 2001) in estuarine habitats, but never in fully marine sublittoral ones. It may be the case that food supply acts as directly as a ‘bottom-up’ control in structuring the Carmarthen Bay *Tellina* sub-community; high availability of organic material resulting in high productivity of the community.

Alternatively, there is evidence that that distributions of some taxa are due to a pre- or post-settlement habitat selection process. Habitat selection by larvae is recognized as an important factor in determining the distribution of many soft-sediment taxa (Butman, 1987; Olafsson et al., 1994; Snelgrove & Butman, 1994; Snelgrove et al., 1998; Huxham & Richards, 2003). A number of habitat selection studies in deposit feeding taxa have presented evidence of sediment selection based upon the organic content (food value) of the sediment (Butman & Grassle, 1992; Grassle et al., 1992; Grassle et al., 1992; Snelgrove et al., 2001). The community structure of soft-sediment communities may be determined in part, by a succession of sediment exploratory stages facilitated by the dispersal and deposition of post-larvae and juveniles (Woodin, 1991; de Montaudouin, 1997; Armonies, 2000; Hunt &

Mullineaux, 2002). Although there is little direct evidence for active habitat selection in species undergoing these migrations, it would explain the non-random, patchy distribution of adults, particularly bivalves (Huxham & Richards, 2003). The spatial models of *F. fabula* in Carmarthen Bay provide evidence for a similar dispersal stage. *Fabulina fabula* may undergo an ontogenetic niche shift, migrating towards muddier, fine sand habitats in response to a change in resource use from obligate suspension feeding as a juvenile to more profitable facultative deposit and suspension feeding as an adult. Taghon & Jumars (1984) considered optimal foraging in deposit feeding to be mainly a function of ingestive and digestive processes: the regulation of feeding rates, particle selection and gut retention times being due to their sedentary nature. Deposit-feeding taxa have many adaptations that improve the efficiency of sediment processing and food absorption and are consistent with the energy maximization principle of optimal foraging theory (Lopez & Levinton, 1987). If migrations of individuals or significant proportions of the population, such as those described for *F. fabula,* are provoked by resource limitation, they may provide represent an additional optimal foraging strategy open to soft-sediment macrofauna.

Prior to any post-settlement redistribution, the initial settlement of larvae from the water column may also be significantly influenced by the hydrodynamic regime in Carmarthen Bay. Hydrodynamic processes have been demonstrated important factors in dictating the density and distribution of larval settlement (Butman, 1987; Snelgrove & Butman, 1994; Metaxas, 2001). Larval supply is a key limitation in the dynamics of adult populations and consequently in the structure of marine benthic communities (Roughgarden et al., 1988; Underwood & Fairweather, 1989; Grosberg & Levitan, 1992). It is possible that the hydrodynamics of Carmarthen Bay act to retain locally produced larvae and post-larvae and act as a sink for those transported in from outside. The results of an analysis of sediment transport pathways in Carmarthen Bay concluded that the bay is largely self-contained with no major exchange paths with the Bristol Channel or Celtic Sea (ABP-Research, 2000). It is feasible that similar processes apply to the exchange of dispersive stages of the *Tellina* community. The spatial model of year 0 *F. fabula* distribution suggests that entrainment of larvae and post-larvae occurs in areas of low residual tidal flow in the central part of the bay. The current debate on the openness of marine populations puts great emphasis on such processes (e.g. Caley et al., 1996; Cowen et al., 2000; Camus & Lima, 2002). Marine populations can be demographically defined as either open or closed according to adult distribution patterns and the scales of larval dispersal (Caley et al., 1996). In coastal zones, many benthic invertebrate taxa undergo a dispersive planktonic larval stage providing the potential for larvae transport on a temporal scale ranging from days to a number of weeks (Eckman, 1996). During this period larvae may be dispersed long distances away from their parent populations. This transport acts to maintain gene flow among spatially isolated local populations within a metapopulation and provides a means of rapid recolonization of habitats following a local extinction. Alternately, local hydrodynamics and biological factors, both behavioural and ontogenetic, may constrain larval dispersal close to their source populations. The regulation of this type of closed population relies only on the local production of offspring that settle in the parental population. Marine populations are generally considered to be open systems due largely to the high levels of larval transport, and to be maintained by outside larval supply from mixed origins (Barnay et al., 2003).

If the hydrodynamics of Carmarthen Bay result in it functioning as a sink for allochthonous recruits, and also able to retain locally produced offspring, the macrofaunal populations in the bay may have the capacity for rapid recovery to local extinctions or mortalities such as those reported immediately following the *Sea Empress* oil-spill. As discussed in Chapter 5, the Carmarthen Bay *Tellina* community is subject to recruitment driven short-term variability in both abundance and dominance. Temporal and spatial variability of larval supply in coastal areas is often dependent on hydrodynamic conditions at the site of release, and subsequent dispersal patterns under control of meteorological and broad-scale hydrodynamic processes (Ellien et al., 2000; Jolly et al., 2003). These sources of variability are likely to be important factors in the success of recruitment and recolonization of k-selected taxa as their lower reproductive output makes them more susceptible to deleterious stochastic factors, such as wind-strength or direction, affecting the probability of the transport of allochthonous propagules into the bay. Populations of r-selected taxa are likely rapidly to recover from perturbation under these conditions due to a higher probability of successful allochthonous recruitment and larger numbers of locally produced recruits. *Pharus legumen* may represent an example of the slow recovery or recolonization of a k-selected species. Subsequent to the mass mortalities reported after the *Sea Empress* oil spill, this species has only recently returned to Carmarthen Bay in something approaching pre-spill abundances (personal obs.). The identification and sensitive management of populations of such taxa outside of Carmarthen Bay necessary to maintain the within bay populations may be of conservation importance.

The long-term stability and persistence of the Carmarthen Bay *Tellina* sub-community composition may be a factor in its importance to Common Scoter as an over-wintering site. Elsewhere, sites at which the most important moulting and over-wintering concentrations of Common Scoter occur are characterized by fine sand bottom types, e.g. the Danish Kattegat south of Læsø, probably the most important moulting and wintering site for the species in the world (Fox, in press). These sites are often characterized by the presence of Petersen's *Venus* community. But as Fox (in press) highlights, the presence of this community type does not automatically guarantee the presence of Common Scoters, suggesting that there are other considerations in their habitat selection than solely benthic community and sediment type. Predictability of food resources are likely to be of importance for migrating birds, particularly as their prey is subject to long- and short-term variability of abundance, and may represent a significant factor in their habitat selection.

To conclude, the *Tellina* sub-community of Carmarthen Bay demonstrates trends in community structure reflecting the strong hydrodynamic and sedimentary gradients in the bay. The mechanistic pathways generating these trends are unclear but are likely to involve, on the broad scale at least, food supply mediated behavioural responses of pre- and post-settlement individuals in site selection. The populations of r-selected taxa are subject to recruitment driven short-term variability in relative abundance and dominance, which has the effect of making them resistant to perturbation. Populations of k-selected taxa are likely to be more vulnerable, taking longer periods to recover. The long-term persistence of the *Tellina* community and stability of its populations may be a factor in the importance of the Carmarthen Bay as an internationally important over-wintering site for Common Scoter. The future persistence of which depends on the sensitive management of not only the communities and populations within the bay, but beyond the bay in the surrounding Bristol Channel.

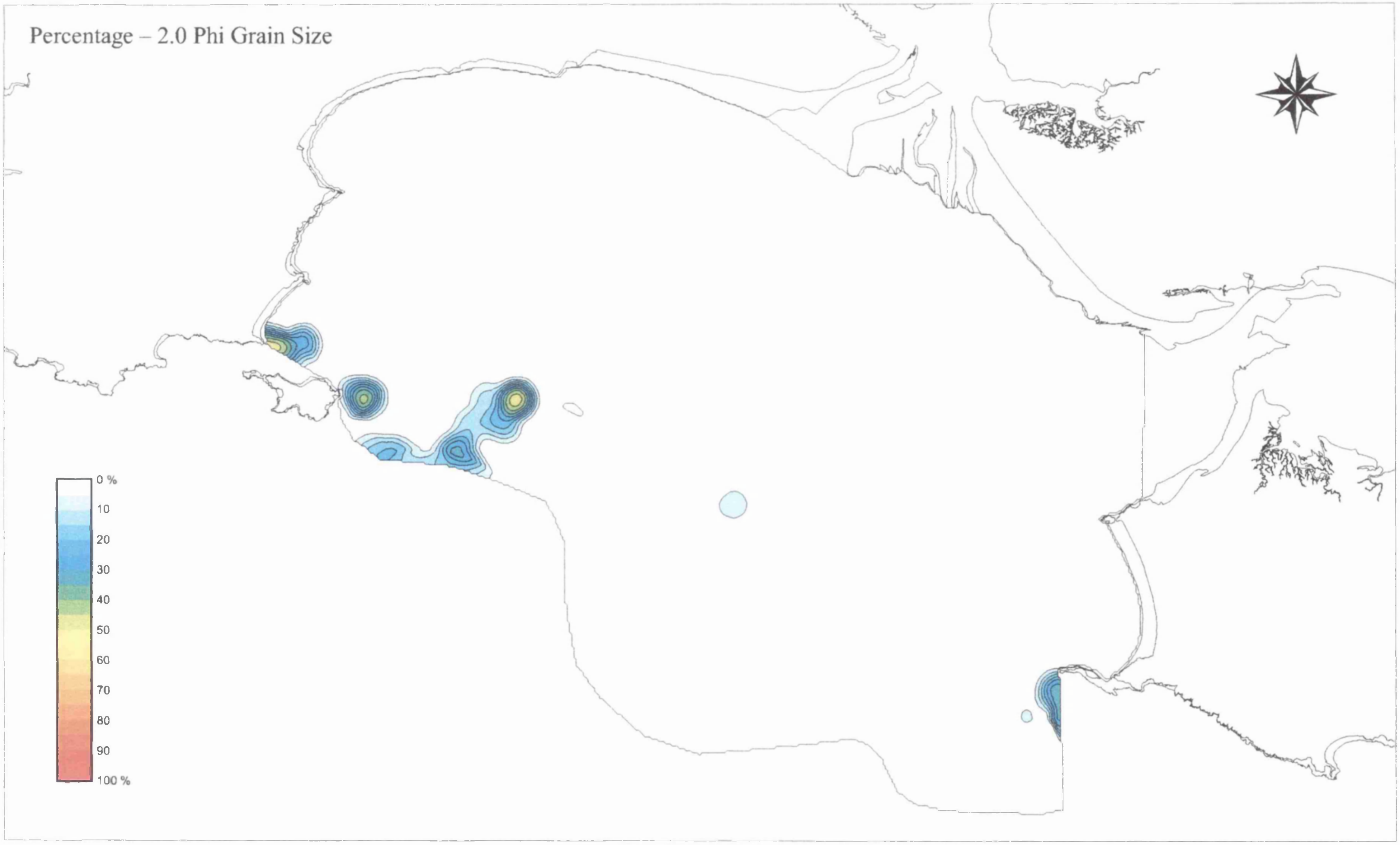
Appendices

Appendix 2.1 Summary of Field Log

Station	Latitude	Longitude	Location	Sediment	Depth (m)	Qualitative	Quantitative
19	51.540833	4.338167	South of Worms Head	Fine Sand / Shell Fragments	24	*	
20	51.542000	4.391833	SW of Worms Head	Fine Sand / Some Gravel	21	*	
21	51.555833	4.367000	SW of Worms Head	Fine Sand	19		*
22	51.568333	4.335333	North of Worms Head	Fine Sand	15	*	
23	51.583333	4.339333	Rhossili Bay	Very Fine Sand	19		*
25	51.636000	4.338000	Middle Channel / Burry Inlet	Very Fine Sand	0		*
26	51.662833	4.362667	Off Pembrey Sands	Very Fine Sand	4		*
27	51.689833	4.391500	South of Cefn Sidan Sands	Very Fine Sand	4		*
28	51.673000	4.441833	SW of Cefn Sidan Sands	Very Fine Sand	7		*
29	51.679167	4.415667	South of Cefn Sidan Sands	Very Fine Sand / Polychaete Tubes / Shell	7	*	
30	51.673167	4.393833	West of Pembrey Sands	Very Fine Sand / Polychaete Tubes / Shell	4	*	
31	51.662667	4.418333	West of Pembrey Sands	Fine Sand / Shell	8		*
32	51.651000	4.390333	West of Pembrey Sands	Fine Sand	7	*	
33	51.641833	4.369167	Off Middle Channel / Burry Inlet	Fine Sand	11	*	
34	51.636667	4.399722	Off Middle Channel / Burry Inlet	Very Fine Sand	11		*
35	51.609833	4.417000	Off Middle Channel / Burry Inlet	Fine Sand / Gravel / Shell	22	*	
36	51.584333	4.392167	Rhossili Bay	Sand / Shell Fragments	23		*
37	51.590833	4.366000	Rhossili Bay	Fine Sand / Shell Fragments	16	*	
38	51.569167	4.365000	West of Worms Head	Fine / Medium Sand	15	*	
39	51.566833	4.396167	West of Worms Head	Fine / Medium Sand	18	*	
40	51.557000	4.416167	West of Worms Head	Medium / Coarse Sand	18		*
41	51.637333	4.441333	Off Middle Channel / Burry Inlet	Sand / Shell	15		*
42	51.636500	4.490667	Middle of Carmarthen Bay	Sand / Large Proportion Shell Fragments	15		*
43	51.636833	4.645000	East of Caldey Island	Fine Sand	17		*
44	51.665000	4.666333	North of Woolhouse Rocks	Sand / Shell Fragments / Mud Globules	4		*
45	51.694167	4.641333	East of Monkstone Point	Fine Sand / Shell	6		*
46	51.698167	4.617667	East of Monkstone Point	Shelly Sand	4	*	
47	51.708667	4.590333	South of Marros	Fine Sand / Shell / Polychaete Tubes	3		
48	51.717000	4.616389	East of Saundersfoot Bay	Hard Fine Sand / Silt	3		*
49	51.707000	4.646667	East of Saundersfoot Bay	Fine Sand / Mud Globules	4		

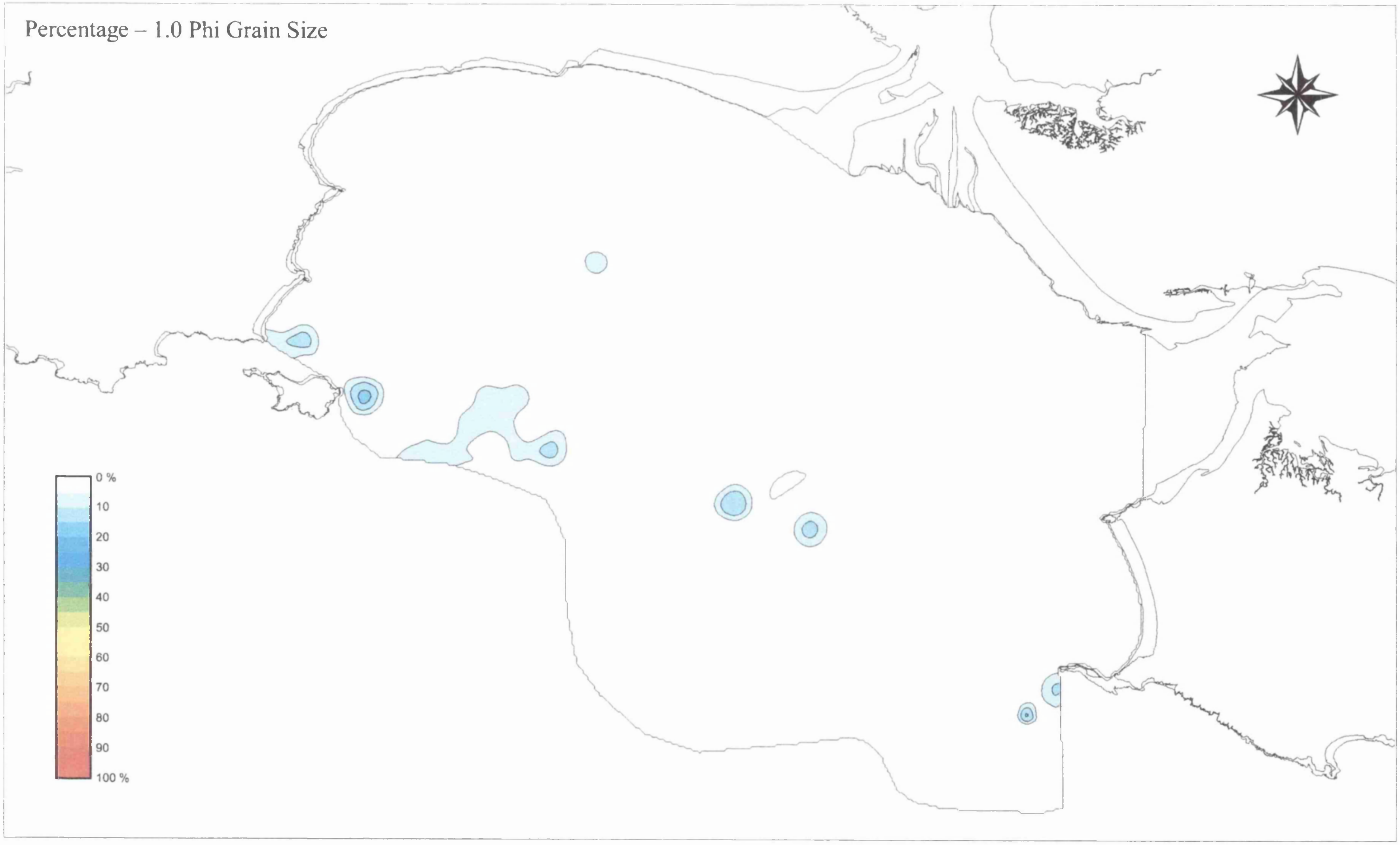
Station	Latitude	Longitude	Location	Sediment	Depth (m)	Qualitative	Quantitative
50	51.704000	4.667000	Saundersfoot Bay	Fine Sand / Mud Globules	4	*	
51	51.717333	4.667000	Saundersfoot Bay	Very Fine Sand / Mud	1		*
52	51.725333	4.639000	SE of Amroth	Very Fine Sand / Mud	2	*	
53	51.724167	4.591333	South of Marros	Very Fine Sand / Shell Fragments	3	*	
54	51.690000	4.590000	East of Monkstone Point	Fine Sand / Mud Globules	7		*
55	51.689833	4.540500	South of Pendine Sands	Sand	8		*
56	51.689667	4.491500	South of Carmarthen Bar	Sand / Shell Fragments	9		*
57	51.663667	4.467000	Middle Carmarthen Bay	Fine Sand / Shell / Mud	10		*
58	51.663333	4.516833	Middle Carmarthen Bay	Find Sand / Shell Fragments	15		*
59	51.662667	4.566333	East of The Yowan	Sand / Shell	14		*
60	51.662667	4.616833	The Yowan	Fine Sand / Silt / Mud	13		*
61	51.677667	4.674000	Tenby Roads	Coarse Sand / Shell	5	*	
62	51.677333	4.641000	East of Tenby Roads	Sand / Shell Fragments	7	*	
63	51.681167	4.619333	East of Tenby Roads	Sand / Silt / Mud	9	*	
64	51.716333	4.567000	South of Ragwen Point	Fine Sand / Silt / Mud	5		*
65	51.701500	4.565500	South of Ragwen Point	Sand / Shell	6	*	
66	51.707833	4.541833	South of Pendine Sands	Fine Sand / Mud	5	*	
67	51.698167	4.517500	South of Carmarthen Bar	Sand / Shell / Polychaete Tubes	7	*	
68	51.676500	4.492500	South of Carmarthen Bar	Fine Muddy Sand	13	*	
69	51.679833	4.517833	South of Carmarthen Bar	Sand / Mud / Shell	12	*	
70	51.677167	4.545000	South of Pendine Sands	Muddy Sand / Shell	13	*	
71	51.680333	4.570833	South of Ragwen Point	Sand / Shell	8	*	
72	51.676833	4.594167	NE of The Yowan	No Record	9	*	
80	51.653167	4.590000	NE of Caldey Island	Muddy Sand / Shell	17	*	
81	51.643333	4.610500	East of Caldey Island	Shelly Sand	20	*	
82	51.655000	4.639500	NE of Caldey Island	Fine Sand	8	*	
83	51.647333	4.666389	NE of Caldey Island	Sand / Shell	11	*	
84	51.633333	4.567833	East of Caldey Island	Medium / Coarse Sand	20		*
87	51.592833	4.536667	SE of Caldey Island	Coarse Sand	26		*
88	51.553500	4.506833	SE of Caldey Island	Medium / Coarse Sand	26		*

Appendix 2.2 Sediment Phi Grain Size Distribution Maps Produced From ABP Research Data (ABP-Research, 2000)

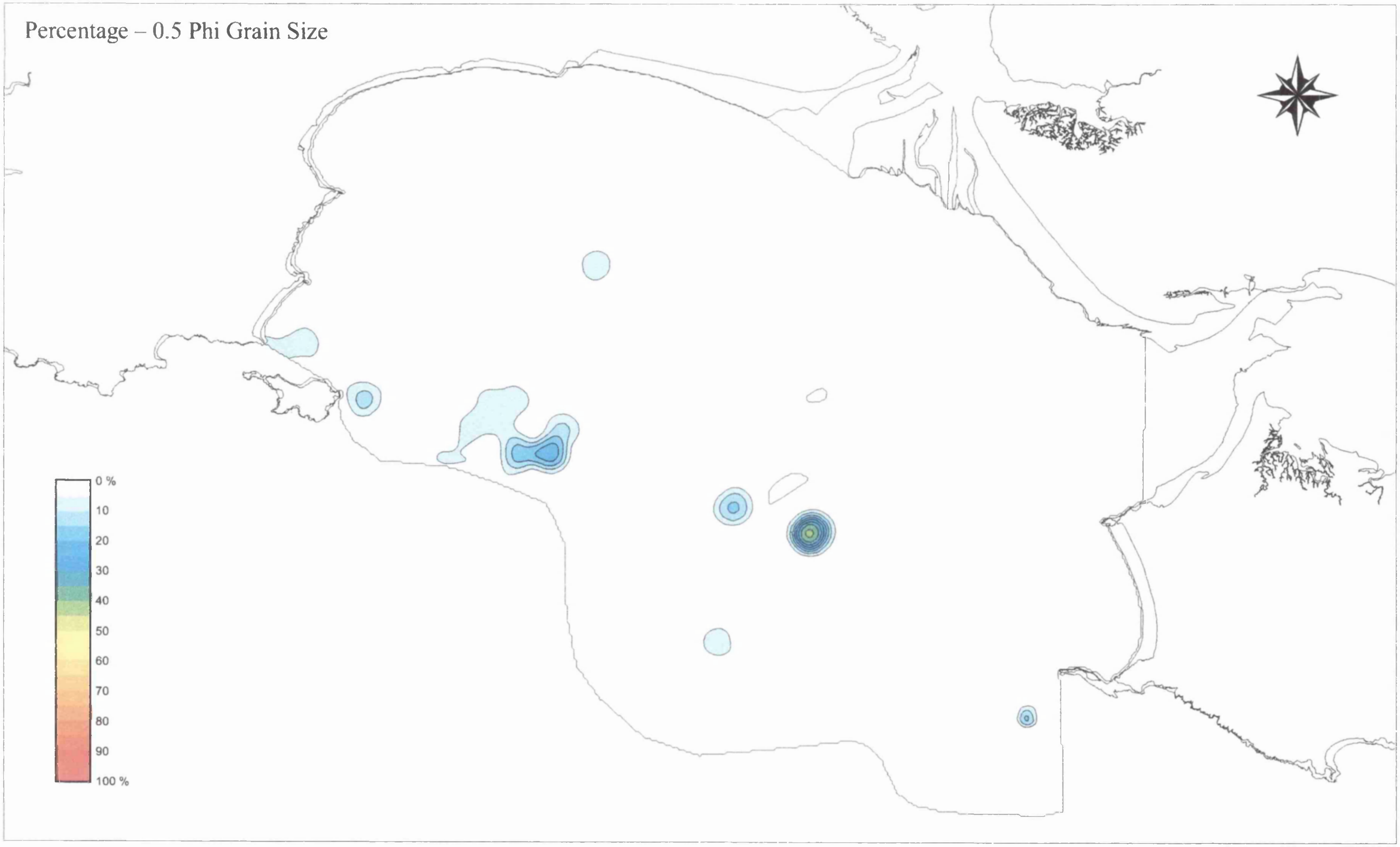


Percentage – 2.0 Phi Grain Size

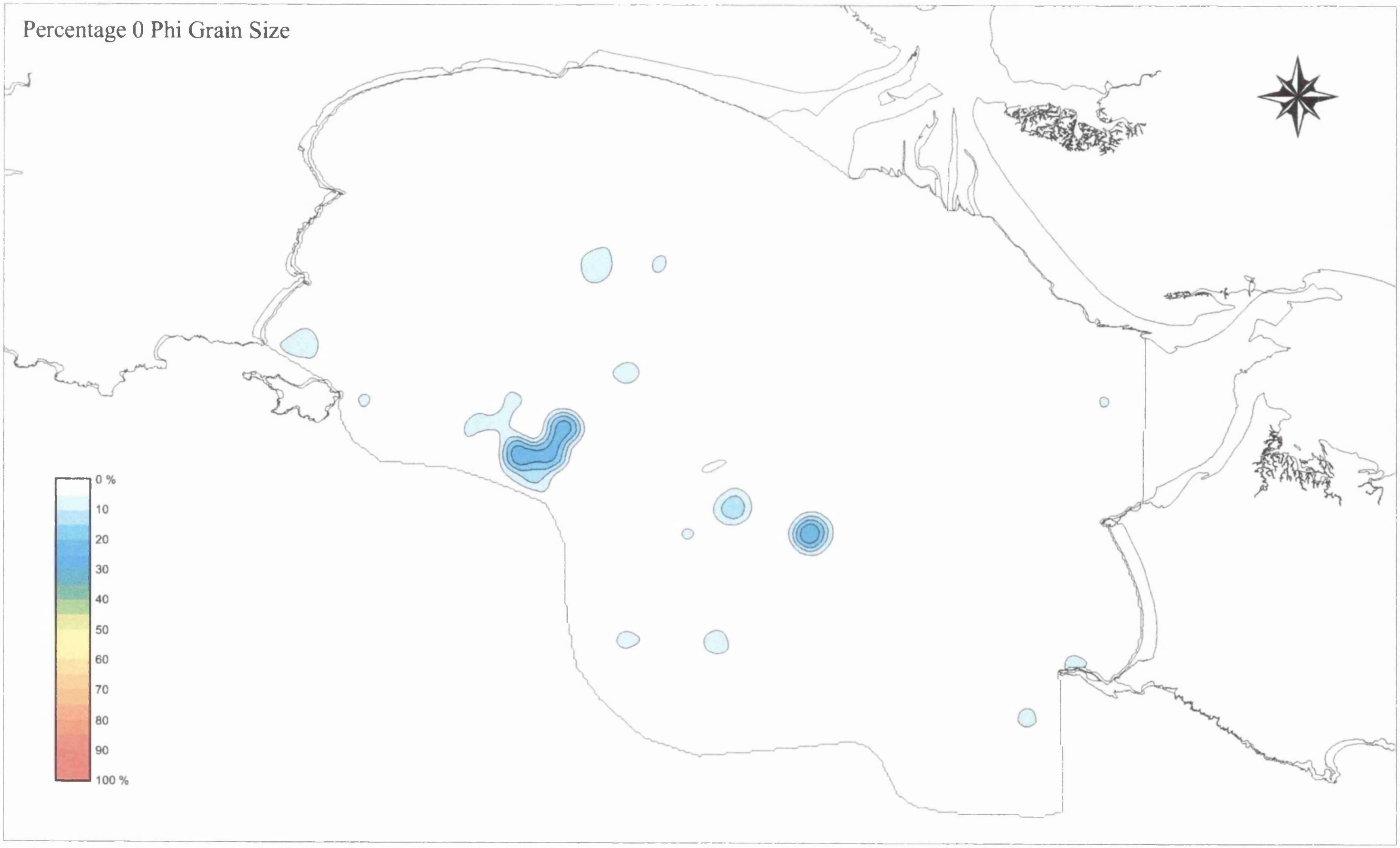
Percentage – 1.5 Phi Grain Size



Percentage – 1.0 Phi Grain Size

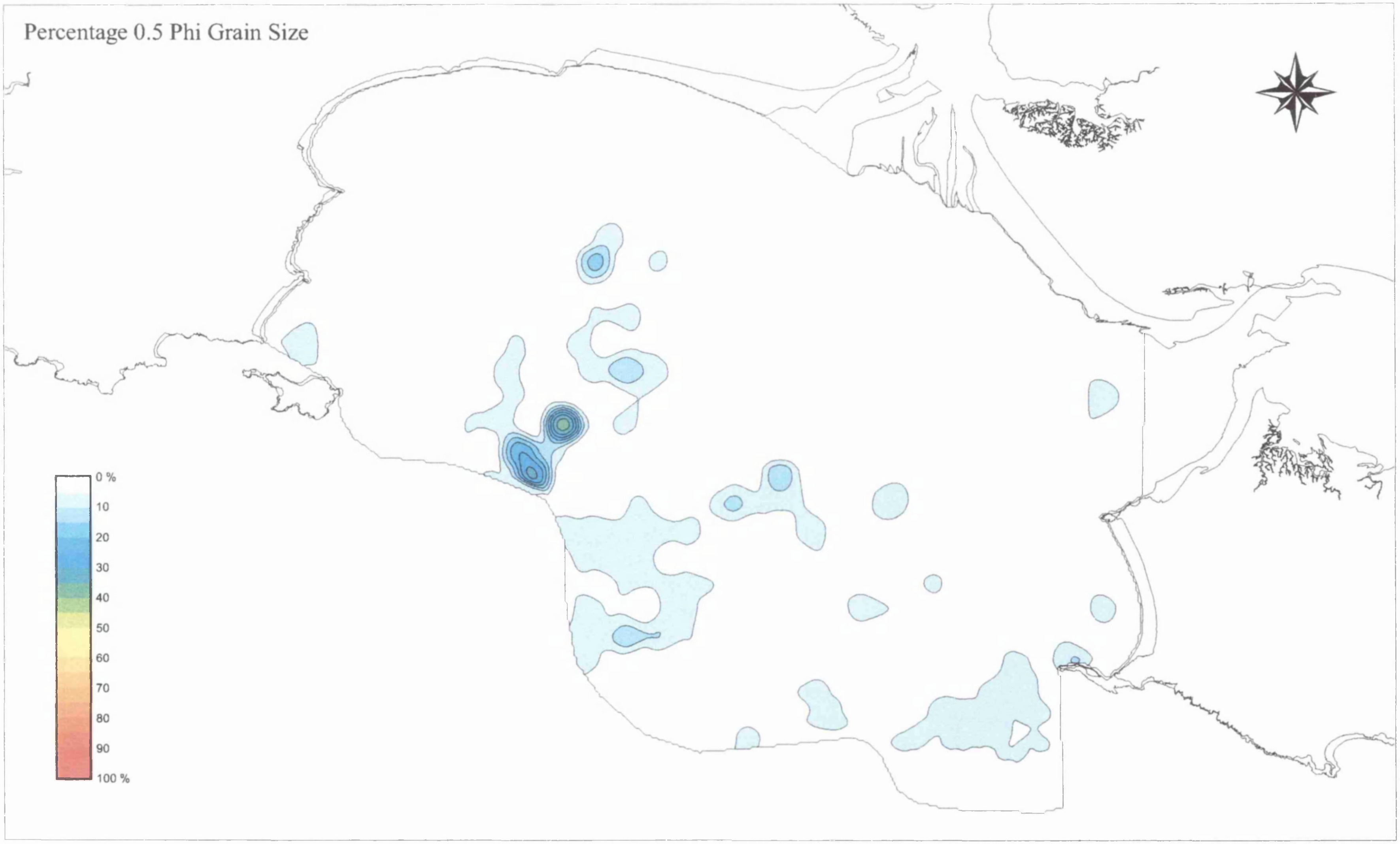


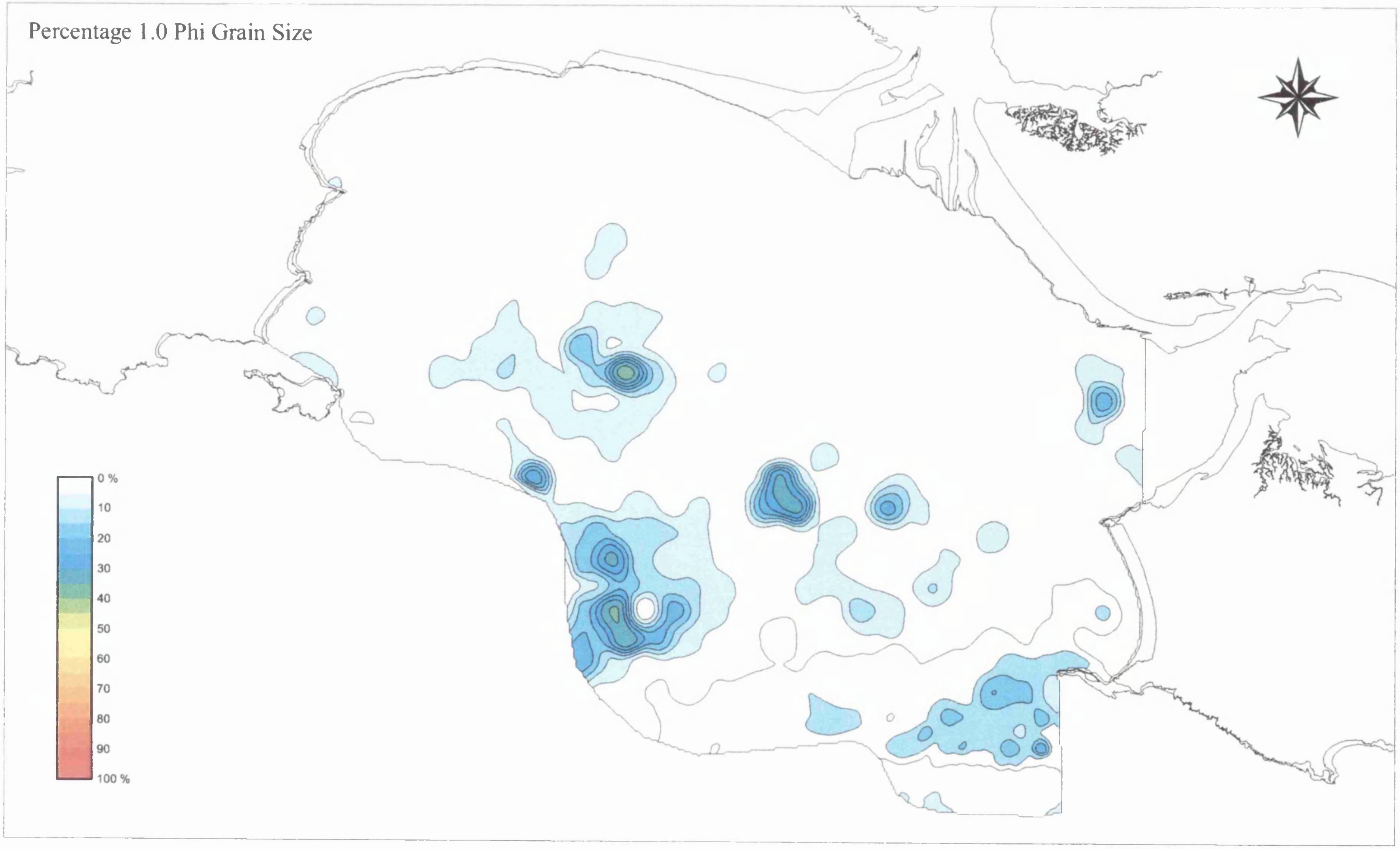
Percentage – 0.5 Phi Grain Size



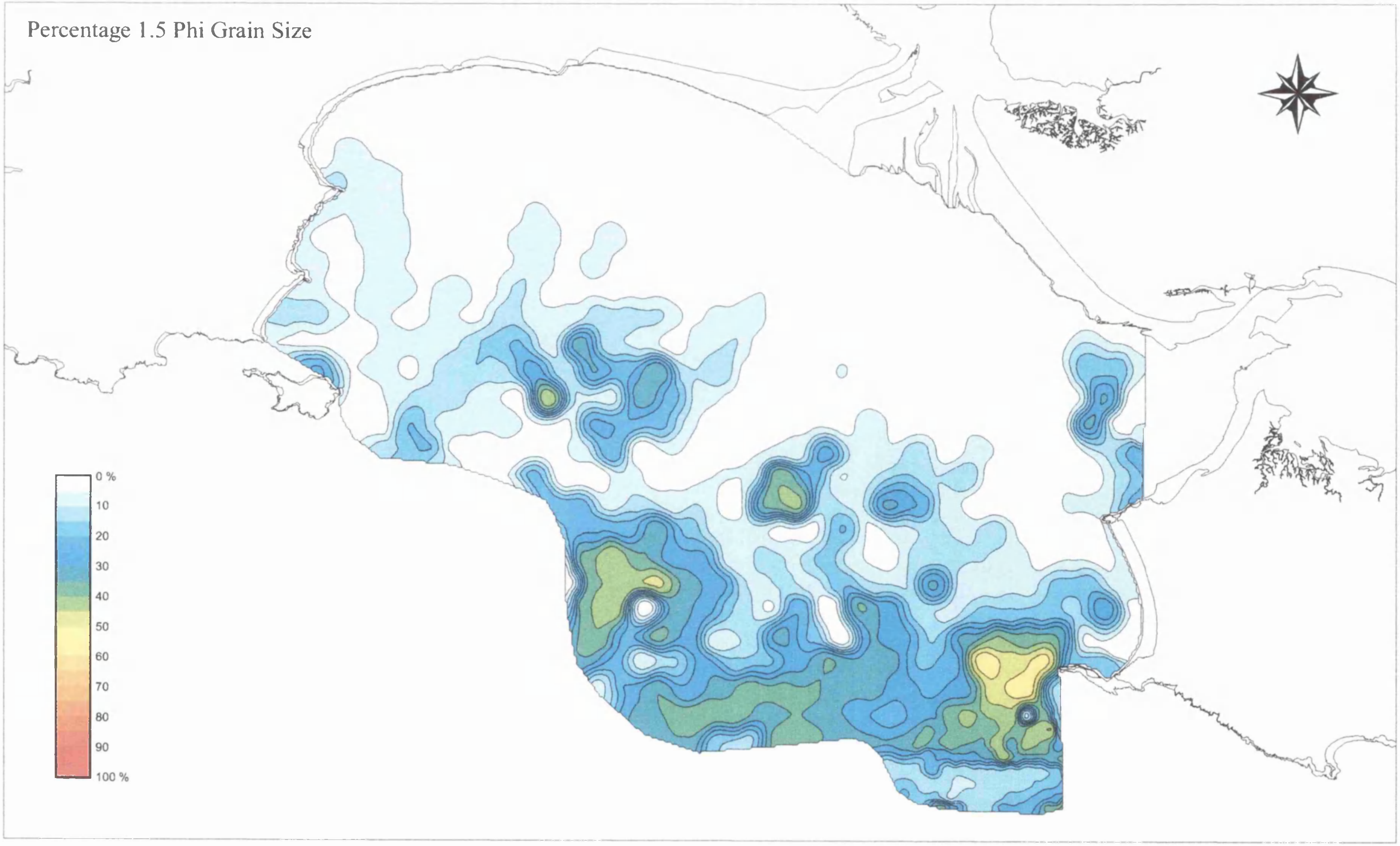
Percentage 0 Phi Grain Size

Percentage 0.5 Phi Grain Size

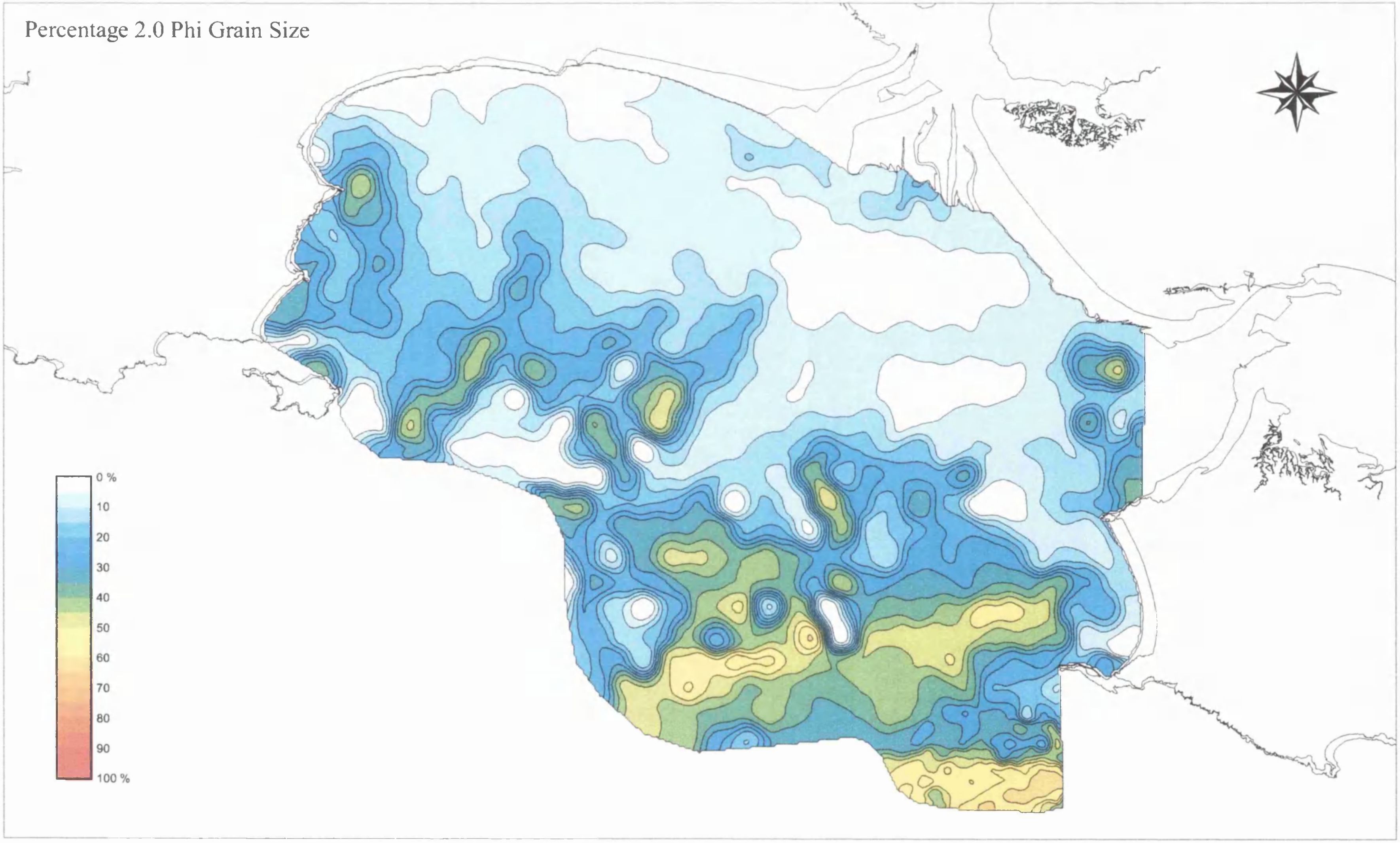


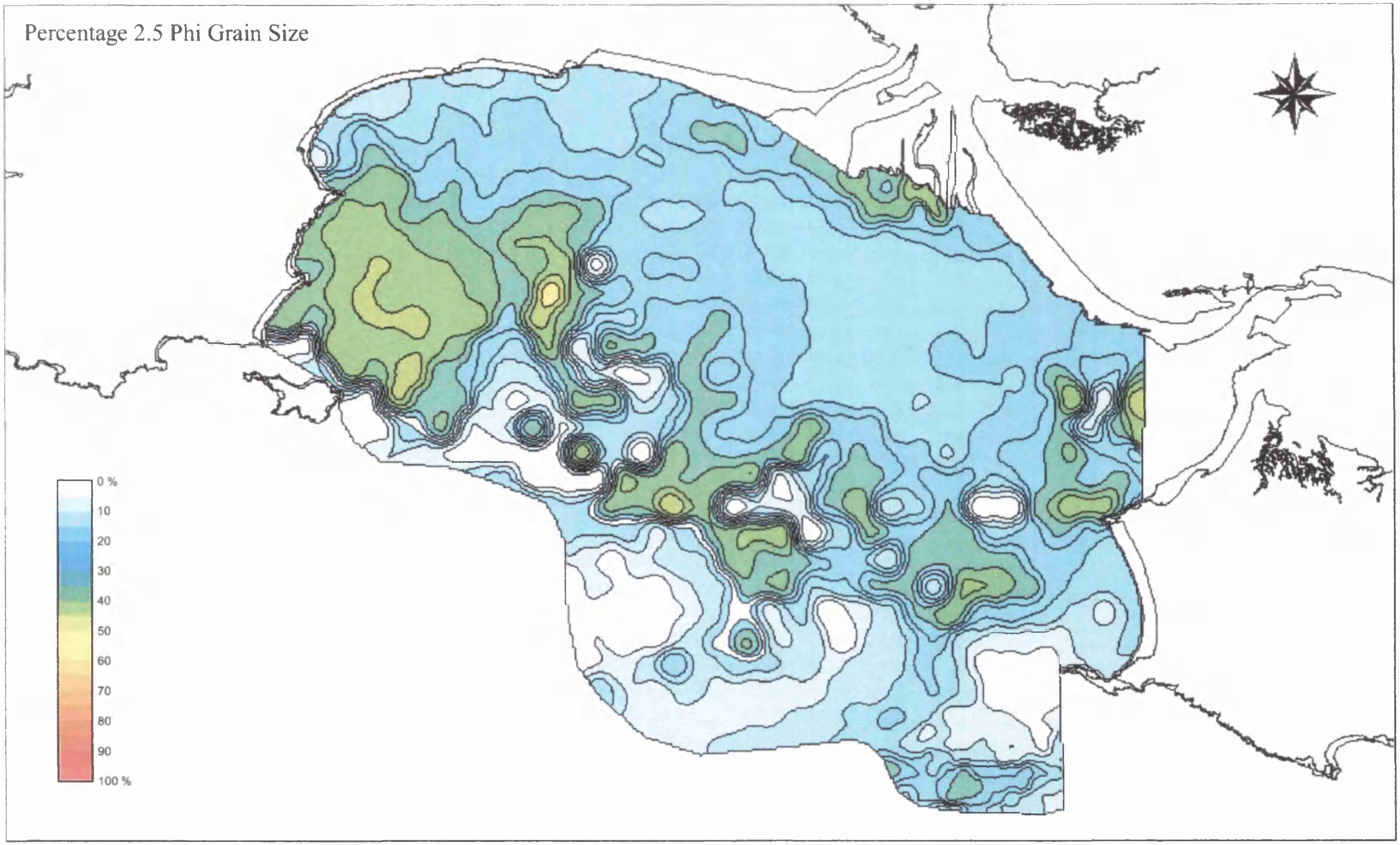

Percentage 1.0 Phi Grain Size

Percentage 1.5 Phi Grain Size

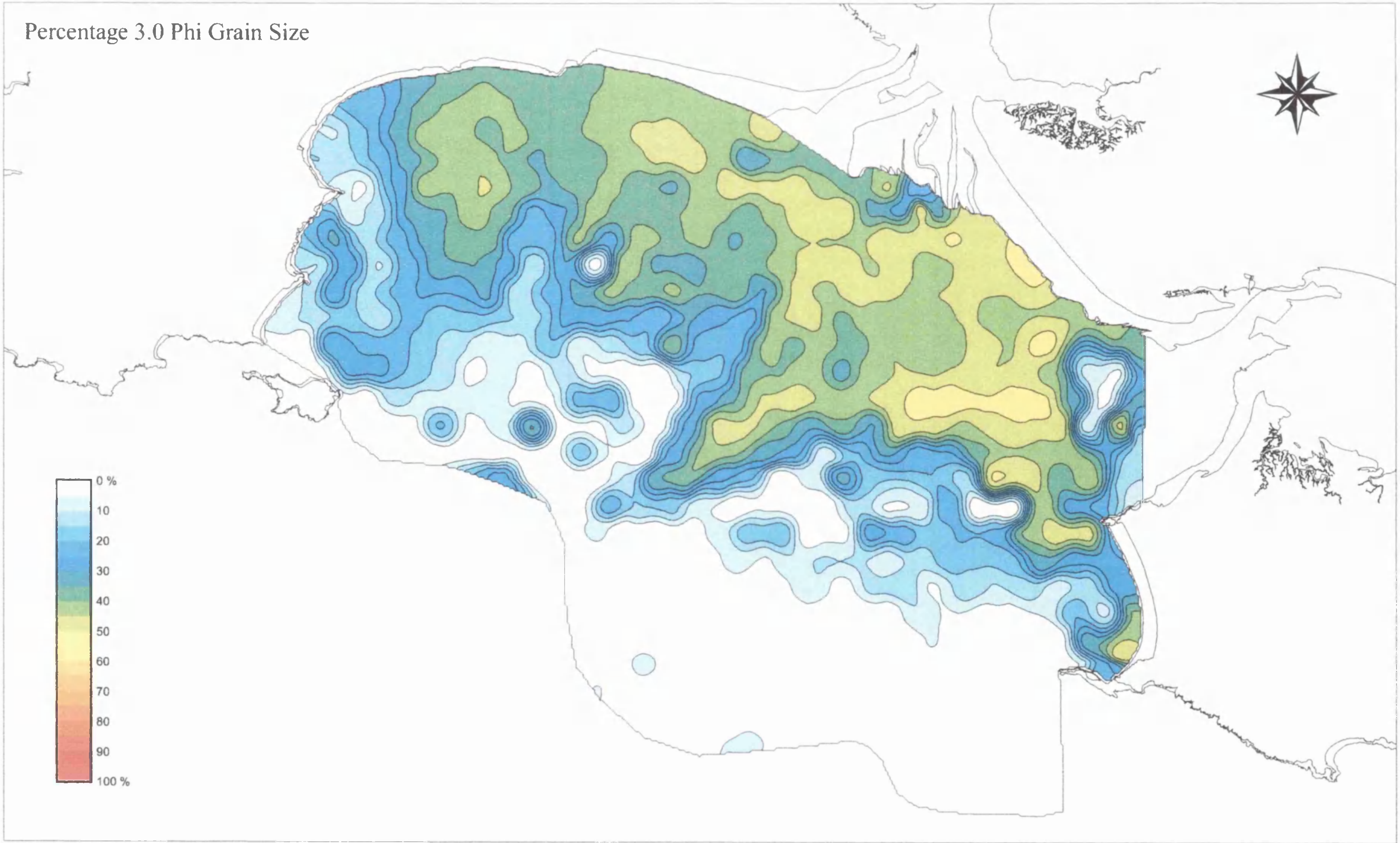


Percentage 2.0 Phi Grain Size



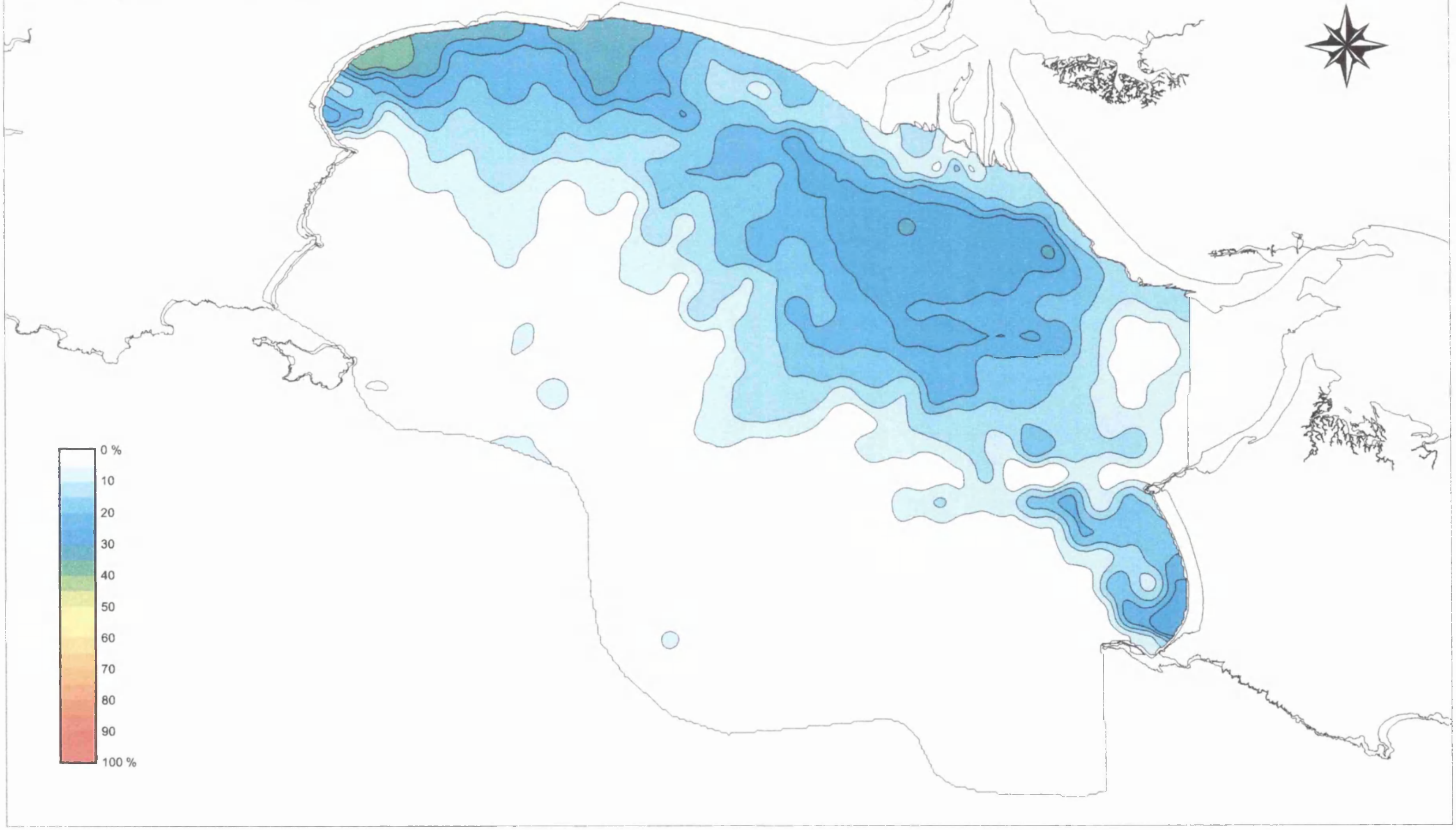


Percentage 2.5 Phi Grain Size



Percentage 3.0 Phi Grain Size

Percentage 3.5 Phi Grain Size



Percentage 4.0 Phi Grain Size

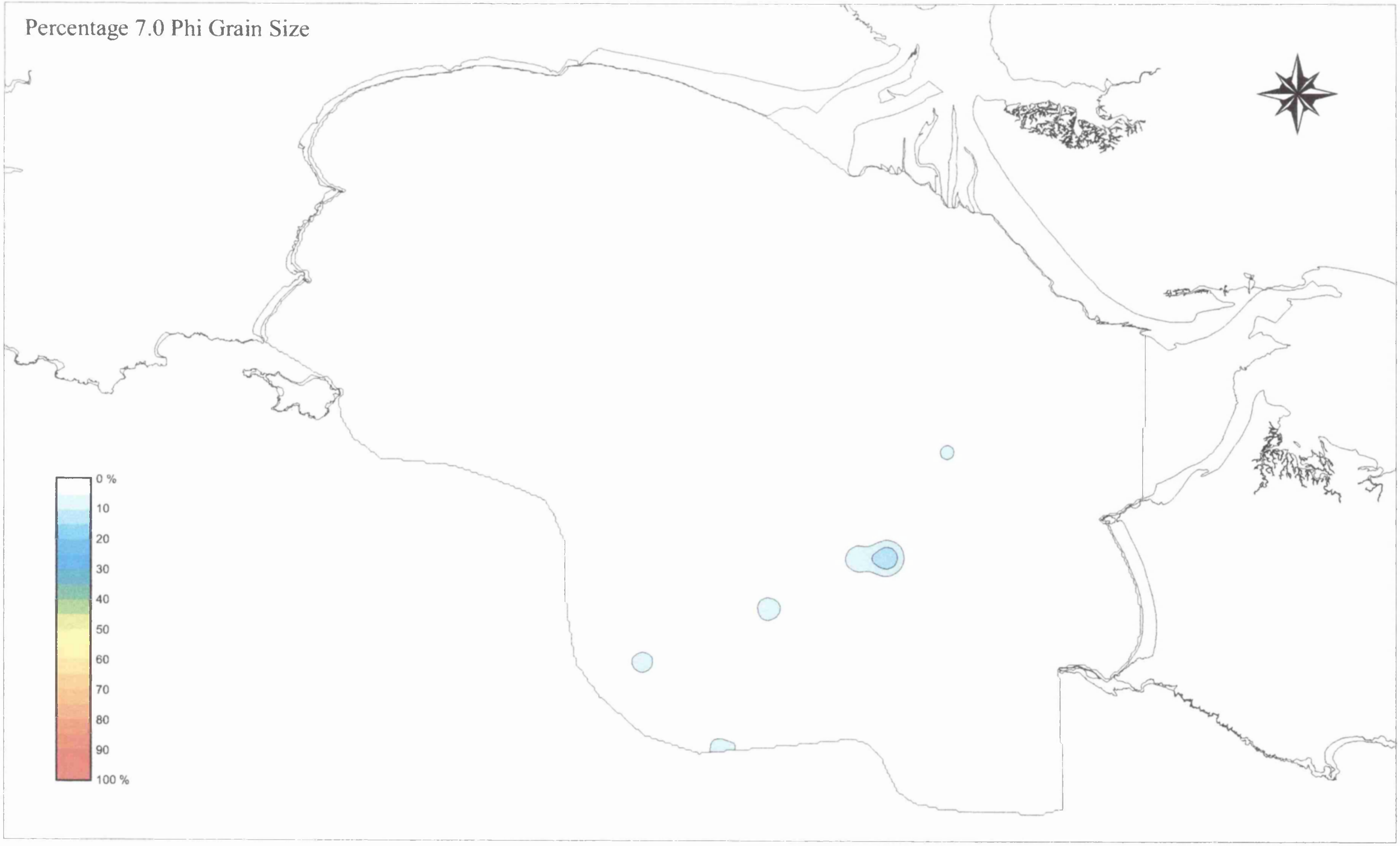
Percentage 4.5 Phi Grain Size

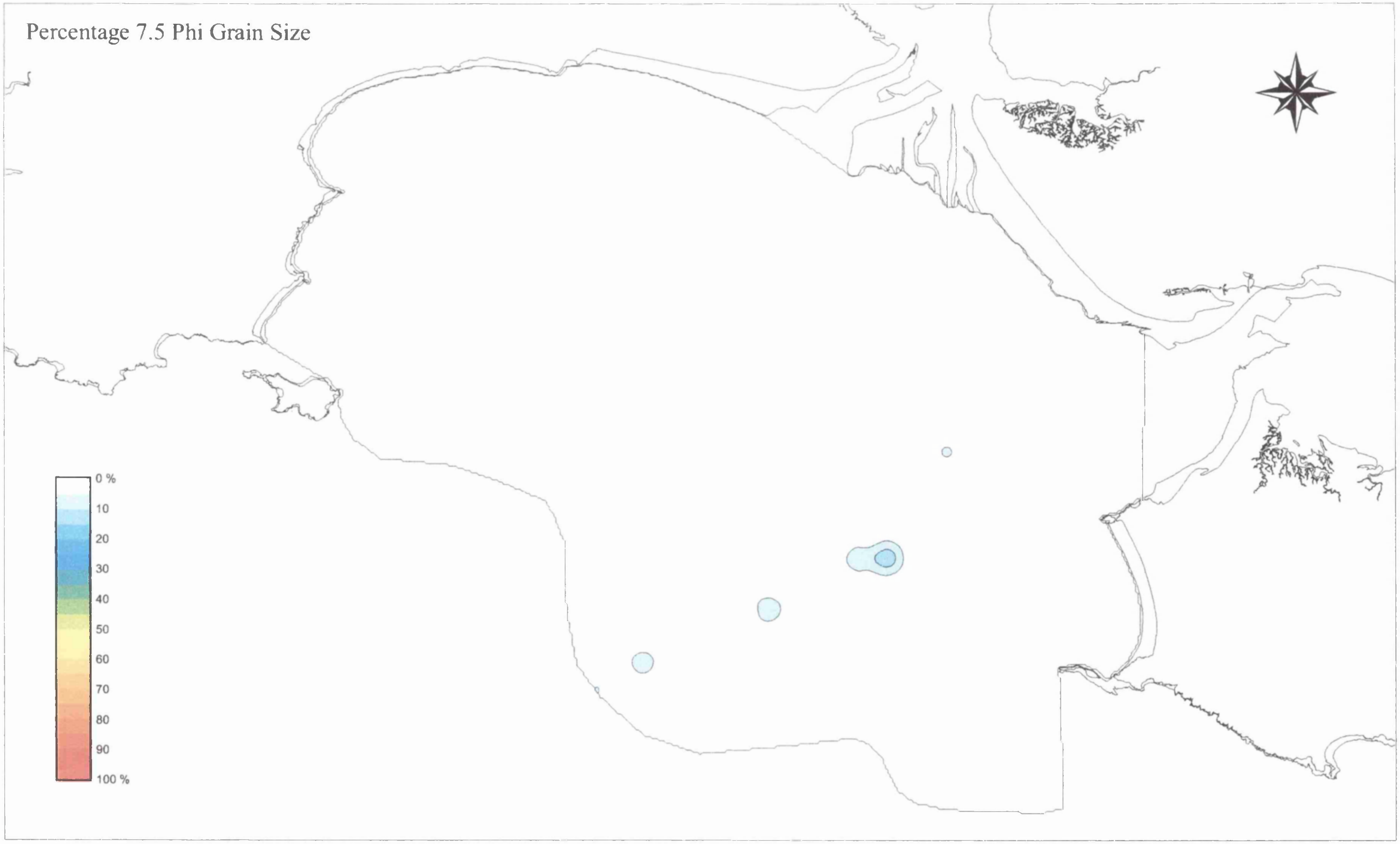
Percentage 5.0 Phi Grain Size


Percentage 5.5 Phi Grain Size

Percentage 6.0 Phi Grain Size

Percentage 6.5 Phi Grain Size


Percentage 7.0 Phi Grain Size


Percentage 7.5 Phi Grain Size

Percentage 8.0 Phi Grain Size

Percentage 8.5 Phi Grain Size

Percentage 9.0 Phi Grain Size

Polygons define areas containing < 5% of this grain size


Percentage 9.5 Phi Grain Size

Polygons define areas containing < 5% of this grain size

Percentage 10.0 Phi Grain Size

Polygons define areas containing < 5% of this grain size

Percentage 10.5 Phi Grain Size

Polygons define areas containing < 5% of this grain size


Percentage 11.0 Phi Grain Size

Polygons define areas containing < 5% of this grain size

Appendix 2.3 Species x Station Matrix Baseline Macrofauna Survey June 1998

MCS Code	Taxon Name	21A	21B	23A	23B	25A	25B	26A	26B	27A	27B	28A	28B	31A	31B
Qualitative Taxa															
D4420	Calycella syringa	-	-	-	-	-	-	-	-	-	-	-	-	-	-
D4570	Lovenella clausa	-	-	3	-	-	-	-	-	-	-	1	1	1	1
D5350	Halecium undulatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-
D6400	Diphasia fallax	-	-	-	-	-	-	-	-	-	-	-	-	-	-
D6530	Hydrallmania falcata	-	-	-	-	-	-	-	-	-	-	-	-	-	-
D6760	Sertularia argentea	-	-	-	-	-	-	-	-	-	-	-	-	-	-
D6960	Campanularia hincksii	-	-	-	-	-	-	-	-	-	-	-	-	-	-
D7030	Clytia hemisphaerica	-	-	-	-	-	-	-	-	-	-	-	-	-	-
D7210	Laomedea calceolifera	-	-	-	-	-	-	-	-	-	-	-	-	-	-
D7300	Obelia dichotoma	-	-	1	-	1	-	1	-	-	-	-	-	-	-
G1	NEMERTEA	-	1	-	5	2	-	-	-	-	-	-	2	8	16
HD1	NEMATODA	2	-	-	-	-	-	8	3	2	-	-	-	-	-
L01	CHAETOGNATHA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R1940	COPEPODA	2	-	1	5	-	-	-	3	-	-	-	44	5	-
R35180	OSTRACODA	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Y2370	Vesicularia spinosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Y6690	Conopeum reticulum	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Y6780	Electra pilosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quantitative Taxa															
D1210	Corymorpha nutans	-	-	-	-	-	-	-	-	3	-	-	-	-	-
D12320	Sagartia troglodytes	-	-	-	-	-	-	-	-	-	-	-	-	-	-
N10	Sipunculidae sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P420	Polynoidae sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P1060	Harmothoe imbricata	-	-	1	2	-	-	-	-	-	-	1	-	-	-
P1160	Malmgrenia andreapolis	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P1190	Harmothoe glabra	-	-	-	-	-	-	-	-	-	-	-	-	-	1
P1210	Malmgrenia marphysae	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P1680	Pholoe sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P1810	Sigalion mathildae	-	-	-	-	-	-	1	2	1	-	3	2	4	4
P1890	Sthenelais limicola	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P2000	Phyllodocidae sp.	-	-	-	-	-	-	-	-	-	-	7	4	3	1
P2000	Phyllodocidae JUV.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P2020	Eteone sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P2050	Eteone longa	-	-	-	1	-	-	-	-	3	-	4	4	2	-
P2240	Mysta picta	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P2830	Eumida bahusiensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P3110	Phyllodoce groenlandica	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P3110	Phyllodoce maculata	-	-	1	-	-	-	-	-	-	-	-	-	-	-
P3110	Phyllodoce mucosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P3110	Phyllodoce rosea	-	-	-	1	-	-	2	1	-	-	6	3	-	-
P4710	Glycera JUV.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P4810	Glycera tridactyla	-	-	1	1	2	3	4	7	4	3	11	12	1	1
P5410	Podarkeopsis capensis	-	-	-	-	-	-	-	1	-	-	-	-	-	-
P5680	Ophiodromus flexuosus	-	-	-	-	1	-	-	-	-	-	-	-	-	-
P7610	Autolytus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P8340	Nereis longissima	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P8670	Nephtys JUV.	-	3	9	7	17	13	10	16	20	25	9	11	3	5
P8675	Nephtys assimilis	-	-	-	-	-	-	2	3	3	2	2	-	3	1
P8700	Nephtys cirrosa	5	2	8	20	12	10	3	1	9	6	-	-	1	-
P8710	Nephtys hombergii	-	-	-	-	-	-	1	-	-	-	-	1	-	-
P10080	Lumbrineris gracilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-

MCS Code	Taxon Name	21A	21B	23A	23B	25A	25B	26A	26B	27A	27B	28A	28B	31A	31B
P11420	Orbinia latreillii	-	-	-	-	-	-	-	1	1	1	-	-	-	-
P11520	Scoloplos armiger	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P12210	Poecilochaetus serpens	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P13120	Pseudopolydora pulchra	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P13230	Scolelepis bonnieri	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P13330	Spio sp.	5	1	52	21	11	13	41	38	32	41	46	65	83	56
P13430	Spiophanes bombyx	1	-	15	14	5	7	13	18	9	5	47	57	94	145
P13610	Magelona sp.	-	-	20	38	11	11	104	116	63	54	237	319	79	145
P13980	Caulleriella zetlandica	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P14030	Chaetozone setosa	-	-	-	-	-	-	-	-	-	-	3	3	4	8
P14280	Aphelochaeta sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P17430	Scalibregma inflatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P13970	Tharyx killariensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P15300	Capitella sp.	-	-	4	1	1	1	5	1	15	23	31	18	1	4
P15620	Notomastus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	1
P16330	Euclymene oerstedii	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P16900	Ophelia borealis	-	1	-	-	-	-	-	-	-	-	-	-	-	-
P18310	Galathowenia sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P18360	Owenia fusiformis	-	-	-	19	-	-	23	17	31	18	14	2	4	-
P18540	Lagis koreni	-	-	1	1	-	-	-	-	1	1	2	3	-	-
P19040	Ampharete sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P20310	Lanice conchilega	-	-	4	-	10	1	8	8	3	3	-	1	7	8
P20810	Proclea graffii	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P24170	OLIGOCHAETA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Q40	Nymphon brevirostre	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Q620	Anoplodactylus petiolatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Q830	Halacaridae sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S370	MYSIDACEA	1	-	-	-	-	-	-	-	-	-	-	-	-	-
S670	Gastrosaccus spinifer	-	-	-	-	-	-	1	-	-	-	-	-	-	-
S2280	Perioculodes longimanus	-	-	-	1	-	-	-	1	-	-	1	3	-	2
S2330	Pontocrates altamarinus	-	-	-	-	3	2	1	-	2	2	1	-	-	-
S2340	Pontocrates arenarius	-	-	3	2	2	-	16	17	15	8	2	15	16	20
S2400	Synchelidium maculatum	-	-	-	-	-	-	-	-	-	-	1	-	-	2
S2810	Amphilochus spencebatei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S3130	Leucothoe incisa	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S3710	Stenothoe monoculoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S4310	Urothoe poseidonis	-	-	-	-	-	-	-	-	6	1	-	-	1	1
S4360	Phoxocephalidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S4640	Lysianassidae sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S4670	Acidostoma obesum	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S6810	Atylus falcatus	-	-	-	-	-	-	-	-	-	-	-	1	-	-
S7400	Bathyporeia sp.	-	-	1	3	-	1	-	5	-	-	-	-	-	-
S7410	Bathyporeia elegans	-	-	-	-	19	11	4	1	10	7	7	5	4	-
S7480	Bathyporeia tenuipes	-	-	-	-	-	-	1	5	2	5	-	2	4	2
S7540	Haustorius arenarius	-	-	-	-	-	5	-	-	-	-	-	-	-	-
S7680	Gammarus sp.	-	-	-	-	-	-	1	1	-	-	-	-	-	-
S7900	Megaluropus agilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S9550	Jassa falcata	-	-	-	-	1	-	-	-	-	-	-	-	-	-
S9630	Microjassa cumbrensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S10220	Corophium bonnellii	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S10840	Pariambus typicus	-	-	-	1	-	-	-	-	-	-	1	-	-	-
S10960	Phtisica marina	-	-	-	-	-	1	-	-	-	-	-	-	-	-
S19940	Vauntompsonia cristata	-	-	-	-	-	-	-	-	-	-	-	-	-	-

MCS Code	Taxon Name	21A	21B	23A	23B	25A	25B	26A	26B	27A	27B	28A	28B	31A	31B
S19999	Bodotria arenosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S20150	Iphinoe trispinosa	-	-	1	-	-	-	-	-	-	-	-	10	4	2
S20720	Pseudocuma longicornis	1	-	5	39	-	7	34	46	14	12	26	85	43	53
S20960	Diastylis bradyi	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S20999	Diastylis rathkei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S21080	Diastyloides serrata	-	-	1	-	-	-	-	-	-	-	-	-	-	-
S21440	Decapod Larvae	4	-	1	3	6	3	2	-	-	-	-	3	-	8
S23001	Processa edulis crassipes	-	-	-	-	-	-	-	-	-	-	-	1	-	-
S23310	Crangon crangon	-	-	-	-	-	-	-	-	-	-	-	1	-	-
S24399	Diogenes pugilator	-	-	-	-	-	1	-	-	3	1	-	-	-	-
S24440	Paguridae sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S25660	Achaeus cranchii	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S26200	Corystes cassivelaunus	1	-	1	-	-	-	-	-	-	-	-	-	1	-
S26330	Thia scutellata	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S26660	Liocarcinus	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W2200	Skenea serpuloides	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W2820	Rissoa lilacina rufilabrum	-	-	-	-	-	1	-	-	-	-	-	-	-	-
W5080	Chrysallida decussata	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W5940	Turbonilla crenata	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W5990	Turbonilla lactea	-	-	-	-	-	-	-	-	-	-	-	2	2	3
W7770	Polinices pulchellus	-	-	-	-	-	-	-	-	1	-	-	-	-	-
W9690	Cylichna cylindracea	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W9790	Philine aperta	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W12370	NUDIBRANCHIA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W16160	Nucula sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W16750	Modiolus modiolus	1	-	-	-	-	-	-	-	-	-	-	-	-	-
W19050	Mysella bidentata	-	-	-	-	2	-	3	1	-	1	2	3	1	-
W19110	Tellimya ferruginosa	-	-	-	-	-	9	24	26	17	7	18	4	-	1
W19690	Acanthocardia echinata	-	-	-	-	-	-	-	-	6	4	83	24	-	-
W19870	Laevicardium crassum	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W19980	Mactra stultorum	1	1	13	34	-	-	1	7	6	3	18	18	6	9
W20220	Ensis sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W20320	Phaxas pellucidus	-	-	7	-	-	-	-	5	1	-	33	33	7	8
W20570	Fabulina fabula	-	-	7	7	-	-	29	22	37	41	37	53	68	84
W20810	Donax vittatus	-	-	-	-	-	-	5	3	5	4	-	-	1	-
W21190	Pharus legumen	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W21890	Chamelea gallina	-	-	-	-	-	-	-	-	-	-	4	-	18	17
W22390	Corbula gibba	-	-	-	-	-	-	-	-	-	-	1	-	-	-
W23510	Thracia phaseolina	-	-	-	-	-	-	-	-	-	-	1	-	2	2
ZA30	Phoronis sp.	-	-	-	-	-	-	-	-	-	-	-	-	1	2
ZB410	Astropecten irregularis	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ZB2850	Amphiura brachiata	-	-	-	-	-	-	-	-	-	-	1	-	-	-
ZB3150	Ophiura ophiura	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ZB4070	Echinocardium cordatum	-	-	2	-	-	2	2	3	-	1	-	-	-	1
ZB4950	Thyone fusus	-	-	-	-	-	-	-	-	-	-	-	-	-	2
ZC10	ENTEROPNEUSTA	-	-	-	-	-	-	-	-	-	-	-	-	-	1
ZD2570	Molgula occulta	-	-	20	-	-	-	-	-	-	-	-	-	-	-

MCS Code	Taxon Name	34A	34B	36A	36B	40A	40B	41A	41B	42A	42B	43A	43B	44A	44B
Qualitative															
D4420	Calycella syringa	-	-	-	-	-	-	-	-	-	-	-	-	-	1
D4570	Lovenella clausa	1	-	1	-	-	-	1	1	-	-	-	-	-	-
D5350	Halecium	-	-	-	-	-	-	-	-	-	-	-	-	-	1
D6400	Diphasia fallax	-	-	-	-	-	-	-	-	-	-	-	-	1	-
D6530	Hydrallmania	-	-	-	-	-	-	-	-	-	-	-	-	-	1
D6760	Sertularia argentea	-	-	-	-	-	-	-	-	-	-	-	-	1	-
D6960	Campanularia	-	-	-	-	-	-	-	-	-	-	-	-	-	-
D7030	Clytia	-	-	-	-	-	-	-	-	-	-	-	-	1	-
D7210	Laomedea	-	-	-	-	-	-	-	-	-	-	-	-	1	-
D7300	Obelia dichotoma	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G1	NEMERTEA	-	-	6	8	2	-	16	10	-	-	-	-	-	-
HD1	NEMATODA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L01	CHAETOGNATHA	-	1	-	-	-	-	-	-	-	-	-	-	-	-
R1940	COPEPODA	-	2	-	15	1	3	-	-	-	4	-	-	7	30
R35180	OSTRACODA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Y2370	Vesicularia spinosa	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Y6690	Conopeum	-	-	-	-	-	-	-	-	-	-	-	-	3	-
Y6780	Electra pilosa	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Quantitative															
D1210	Corymorpha nutans	-	-	2	-	-	-	5	-	-	-	-	-	-	-
D12320	Sagartia troglodytes	3	-	-	-	-	-	-	1	2	2	-	-	-	1
N10	Sipunculidae sp.	-	-	-	-	-	-	-	-	-	3	-	-	-	-
P420	Polynoidae sp.	7	1	-	-	-	-	-	-	1	1	-	-	-	1
P1060	Harmothoe	-	-	-	-	-	-	-	-	-	-	-	-	-	3
P1160	Malmgrenia	-	-	-	-	-	-	-	-	2	-	-	-	-	2
P1190	Harmothoe glabra	-	-	-	-	-	-	-	-	-	1	-	-	-	-
P1210	Malmgrenia	-	-	-	-	-	-	-	1	-	-	-	-	2	-
P1680	Pholoe sp.	-	-	-	-	-	-	-	-	2	1	-	-	-	3
P1810	Sigalion mathildae	5	-	-	-	-	-	2	10	3	2	-	-	-	5
P1890	Sthenelais limicola	-	-	-	-	-	-	-	1	-	-	-	-	-	-
P2000	Phyllodocidae sp.	-	-	2	1	-	-	4	-	-	-	-	-	1	-
P2000	Phyllodocidae JUV.	8	-	-	-	-	-	-	-	-	-	-	-	-	-
P2020	Eteone sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P2050	Eteone longa	4	2	1	-	-	-	-	9	1	-	-	-	-	1
P2240	Mysta picta	-	-	3	1	1	-	3	-	-	-	-	-	-	-
P2830	Eumida bahusiensis	2	1	-	-	-	-	-	-	-	-	-	-	-	-
P3110	Phyllodoce	2	-	-	-	-	-	-	-	-	-	-	-	-	-
P3110	Phyllodoce	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P3110	Phyllodoce mucosa	-	-	-	-	-	-	-	-	-	-	-	-	-	1
P3110	Phyllodoce rosea	25	2	-	-	-	-	-	-	-	-	-	-	-	1
P4710	Glycera JUV.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P4810	Glycera tridactyla	2	4	-	2	-	-	2	2	5	4	2	-	1	-
P5410	Podarkeopsis	-	-	-	-	-	-	1	2	15	5	-	-	3	5
P5680	Ophiodromus	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P7610	Autolytus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	65
P8340	Nereis longissima	-	-	-	-	-	-	-	-	-	1	-	-	1	2
P8670	Nephtys JUV.	7	5	4	12	2	2	-	-	7	3	24	12	21	27
P8675	Nephtys assimilis	-	-	-	-	-	-	3	1	-	1	1	-	1	1
P8700	Nephtys cirrosa	1	-	22	23	10	5	-	-	-	-	4	11	2	3
P8710	Nephtys hombergii	-	3	-	-	-	-	1	1	-	-	-	-	-	-
P10080	Lumbrineris gracilis	-	-	1	-	-	-	2	-	6	6	-	-	5	7

MCS Code	Taxon Name	21A	21B	23A	23B	25A	25B	26A	26B	27A	27B	28A	28B	31A	31B
P11420	Orbinia latreillii	2	-	-	-	-	-	-	-	-	-	-	1	-	2
P11520	Scoloplos armiger	-	-	-	1	1	-	-	-	-	-	-	-	-	1
P12210	Poecilochaetus serpens	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P13120	Pseudopolydora pulchra	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P13230	Scolelepis bonnieri	-	-	1	-	5	-	-	-	-	2	2	-	1	-
P13330	Spio sp.	70	136	14	29	-	1	-	-	13	8	11	13	34	103
P13430	Spiophanes bombyx	172	75	184	368	12	5	412	380	227	292	16	5	154	110
P13610	Magelona sp.	105	145	5	26	-	2	104	142	47	63	-	1	3	42
P13980	Caulleriella zetlandica	-	-	-	-	-	-	-	-	-	-	-	-	1	-
P14030	Chaetozone setosa	10	4	-	-	-	-	26	25	18	22	-	-	8	19
P14280	Aphelochaeta sp.	-	-	-	-	-	-	-	-	-	-	-	-	1	-
P17430	Scalibregma inflatum	1	-	-	-	-	-	-	-	1	-	-	-	-	-
P13970	Tharyx killariensis	-	-	-	-	-	-	-	-	-	-	-	-	1	-
P15300	Capitella sp.	8	-	-	-	-	-	4	4	-	4	-	-	6	6
P15620	Notomastus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P16330	Euclymene oerstedii	-	-	-	-	-	-	-	-	35	8	-	-	3	5
P16900	Ophelia borealis	-	-	-	-	-	-	-	-	-	-	4	-	-	-
P18310	Galathowenia sp.	-	-	-	-	-	-	1	-	1	-	-	-	2	-
P18360	Owenia fusiformis	1	-	1	-	-	-	5	4	3	8	-	1	11	6
P18540	Lagis koreni	1	-	-	-	-	-	-	-	-	-	-	-	-	-
P19040	Ampharete sp.	-	-	-	-	-	-	-	-	1	-	-	-	-	-
P20310	Lanice conchilega	259	28	11	57	1	1	10	6	7	5	-	1	1	18
P20810	Proclea graffii	-	-	-	-	-	-	-	-	-	2	-	-	2	2
P24170	OLIGOCHAETA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Q40	Nymphon brevirostre	-	-	-	-	-	-	-	-	-	-	-	-	-	23
Q620	Anoplodactylus petiolatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Q830	Halacaridae sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	1
S370	MYSIDACEA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S670	Gastrosaccus spinifer	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S2280	Perioculodes longimanus	1	1	3	3	-	-	6	7	4	-	-	-	5	-
S2330	Pontocrates altamarinus	-	-	2	3	-	-	-	-	-	-	-	-	-	-
S2340	Pontocrates arenarius	16	-	12	2	-	-	3	2	-	-	-	1	3	-
S2400	Synchelidium maculatum	2	-	1	1	-	-	7	3	1	4	1	1	9	9
S2810	Amphilochus spencebatei	-	-	-	-	-	-	-	-	-	-	-	-	2	-
S3130	Leucothoe incisa	1	1	-	-	-	-	-	-	-	-	-	-	-	-
S3710	Stenothoe monoculoides	-	-	-	-	-	-	-	-	-	-	-	-	-	35
S4310	Urothoe poseidonis	1	-	-	-	-	-	-	-	-	-	-	-	-	2
S4360	Phoxocephalidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S4640	Lysianassidae sp.	-	-	-	-	-	-	-	-	-	-	1	-	-	-
S4670	Acidostoma obesum	-	-	-	-	-	-	-	-	1	-	-	-	-	-
S6810	Atylus falcatus	-	-	1	-	-	-	-	-	-	-	1	-	-	-
S7400	Bathyporeia sp.	-	-	-	-	-	-	-	-	-	1	-	-	-	10
S7410	Bathyporeia elegans	5	-	2	-	-	-	1	1	2	-	-	1	11	7
S7480	Bathyporeia tenuipes	6	-	-	-	-	-	-	-	-	6	1	2	14	14
S7540	Haustorius arenarius	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S7680	Gammarus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S7900	Megaluropus agilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S9550	Jassa falcata	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S9630	Microjassa cumbrensis	27	-	-	-	-	-	-	-	-	-	-	-	-	-
S10220	Corophium bonnellii	-	-	-	-	-	-	-	-	-	-	-	-	-	1
S10840	Pariambus typicus	23	1	2	-	-	-	1	2	11	6	-	-	-	-
S10960	Phtisica marina	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S19940	Vauntompsonia cristata	-	1	-	-	-	-	-	-	-	-	-	-	1	4

MCS Code	Taxon Name	21A	21B	23A	23B	25A	25B	26A	26B	27A	27B	28A	28B	31A	31B
S19999	Bodotria arenosa	-	-	-	-	1	1	-	-	-	-	-	-	-	-
S20150	Iphinoe trispinosa	-	-	-	-	-	-	1	1	1	-	-	-	2	-
S20720	Pseudocuma longicornis	36	23	32	71	9	16	6	6	1	4	28	23	36	19
S20960	Diastylis bradyi	-	-	-	-	-	-	-	-	1	1	-	-	-	-
S20999	Diastylis rathkei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S21080	Diastyloides serrata	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S21440	Decapod Larvae	6	-	7	2	3	4	3	-	1	3	60	-	4	-
S23001	Processa edulis crassipes	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S23310	Crangon crangon	-	1	-	-	-	-	-	-	-	-	-	-	-	-
S24399	Diogenes pugilator	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S24440	Paguridae sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	1
S25660	Achaeus cranchii	-	-	-	-	-	-	-	-	-	-	-	-	-	1
S26200	Corystes cassivelaunus	-	-	2	3	1	1	1	-	-	1	-	-	-	-
S26330	Thia scutellata	-	-	-	-	-	-	-	-	-	-	1	-	-	-
S26660	Liocarcinus	1	-	-	-	-	-	-	-	-	-	-	-	-	-
W2200	Skenea serpuloides	-	-	1	-	-	-	-	-	-	-	-	-	-	-
W2820	Rissoa lilacina rufilabrum	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W5080	Chrysallida decussata	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W5940	Turbonilla crenata	-	-	-	-	-	-	-	-	-	1	-	-	-	-
W5990	Turbonilla lactea	-	1	-	-	-	-	4	3	3	1	-	-	-	13
W7770	Polinices pulchellus	-	-	-	-	-	-	-	-	-	-	-	-	1	-
W9690	Cylichna cylindracea	-	1	-	-	-	-	1	2	8	10	-	-	1	-
W9790	Philine aperta	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W12370	NUDIBRANCHIA	-	-	-	-	-	-	-	-	-	-	-	-	-	51
W16160	Nucula sp.	-	-	-	-	-	-	1	-	2	2	-	-	-	-
W16750	Modiolus modiolus	-	-	-	-	-	-	-	-	-	-	-	-	-	100
W19050	Mysella bidentata	16	2	2	2	-	-	1	10	79	63	-	-	42	58
W19110	Tellimya ferruginosa	7	-	-	-	-	-	-	-	-	23	-	-	-	-
W19690	Acanthocardia echinata	-	-	-	-	-	-	-	1	-	-	-	1	-	-
W19870	Laevicardium crassum	-	-	-	-	-	-	-	-	-	-	-	-	1	-
W19980	Mactra stultorum	5	3	36	9	2	7	5	2	13	20	1	-	7	-
W20220	Ensis sp.	-	-	-	-	-	-	-	-	-	1	-	-	-	-
W20320	Phaxas pellucidus	4	-	1	6	1	-	2	1	6	4	-	1	1	1
W20570	Fabulina fabula	60	42	5	12	1	-	86	104	51	49	-	2	10	29
W20810	Donax vittatus	-	-	-	-	-	-	-	-	-	-	-	-	2	-
W21190	Pharus legumen	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W21890	Chamelea gallina	9	2	-	-	-	-	11	17	2	4	-	-	-	4
W22390	Corbula gibba	-	-	-	-	-	-	1	-	-	-	-	-	-	1
W23510	Thracia phaseolina	1	1	1	-	-	-	14	15	14	3	-	-	14	13
ZA30	Phoronis sp.	2	1	1	-	-	-	5	3	5	3	-	-	1	-
ZB410	Astropecten irregularis	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ZB2850	Amphiura brachiata	2	1	1	-	-	-	2	1	10	3	-	-	4	-
ZB3150	Ophiura ophiura	-	-	-	-	-	-	-	-	-	1	-	-	-	-
ZB4070	Echinocardium cordatum	1	-	-	-	-	-	-	-	2	1	-	1	-	-
ZB4950	Thyone fusus	1	-	-	-	-	-	-	-	3	1	-	-	-	-
ZC10	ENTEROPNEUSTA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ZD2570	Molgula occulta	-	-	-	-	-	-	-	-	-	-	-	-	-	-

MCS Code	Taxon Name	45A	45B	48A	48B	51A	51B	54A	54B	55A	55B	56A	56B	57A	57B
Qualitative Taxa															
D4420	Calycella syringa	-	-	-	-	-	-	-	-	-	-	-	-	-	-
D4570	Lovenella clausa	1	-	1	-	1	-	1	1	1	1	1	-	-	-
D5350	Halecium undulatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-
D6400	Diphasia fallax	-	-	-	-	-	-	-	-	-	-	-	-	-	-
D6530	Hydrallmania falcata	-	-	-	-	-	-	-	-	-	-	-	-	-	-
D6760	Sertularia argentea	-	-	-	-	-	1	-	-	-	-	-	-	-	-
D6960	Campanularia hincksii	-	-	-	-	-	-	-	-	-	-	1	-	-	-
D7030	Clytia hemisphaerica	-	-	-	-	-	-	-	-	-	-	-	-	-	-
D7210	Laomedea calceolifera	-	-	-	-	-	-	-	-	-	-	-	-	-	-
D7300	Obelia dichotoma	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G1	NEMERTEA	-	-	-	-	-	-	-	1	-	-	-	-	-	-
HD1	NEMATODA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L01	CHAETOGNATHA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R1940	COPEPODA	6	5	-	-	1	2	13	-	10	-	3	4	70	100
R35180	OSTRACODA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Y2370	Vesicularia spinosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Y6690	Conopeum reticulum	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Y6780	Electra pilosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quantitative Taxa															
D1210	Corymorpha nutans	-	-	-	-	-	-	-	-	-	-	-	3	-	1
D12320	Sagartia troglodytes	-	-	2	-	-	-	-	-	2	3	-	-	1	1
N10	Sipunculidae sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P420	Polynoidae sp.	-	-	-	-	-	-	-	-	-	-	-	1	-	-
P1060	Harmothoe imbricata	-	-	-	-	-	-	-	-	-	-	-	-	-	2
P1160	Malmgrenia andreapolis	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P1190	Harmothoe glabra	-	-	-	-	-	-	1	-	-	-	-	-	-	-
P1210	Malmgrenia marphysae	-	-	-	-	-	-	1	-	2	2	-	-	1	-
P1680	Pholoe sp.	-	1	1	-	-	-	1	-	-	-	-	-	-	-
P1810	Sigalion mathildae	4	8	12	12	7	5	10	8	-	1	5	5	6	1
P1890	Sthenelais limicola	-	-	-	1	-	-	-	1	1	-	-	-	-	-
P2000	Phyllodocidae sp.	1	-	-	-	-	-	-	1	-	-	-	-	1	-
P2000	Phyllodocidae JUV.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P2020	Eteone sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P2050	Eteone longa	3	2	5	9	1	2	2	-	2	3	4	9	5	8
P2240	Mysta picta	-	-	-	1	-	-	-	-	1	-	-	-	-	-
P2830	Eumida bahusiensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P3110	Phyllodoce groenlandica	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P3110	Phyllodoce maculata	-	-	1	-	1	-	-	-	-	-	-	-	-	-
P3110	Phyllodoce mucosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P3110	Phyllodoce rosea	1	-	1	2	1	1	-	1	-	-	-	1	-	-
P4710	Glycera JUV.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P4810	Glycera tridactyla	3	5	3	2	13	10	3	4	4	5	9	11	4	2
P5410	Podarkeopsis capensis	1	-	2	-	-	-	1	-	-	-	-	-	4	1
P5680	Ophiodromus flexuosus	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P7610	Autolytus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P8340	Nereis longissima	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P8670	Nephtys JUV.	5	9	10	19	12	16	4	3	15	10	2	4	-	-
P8675	Nephtys assimilis	-	-	-	1	-	1	-	-	1	-	-	-	1	-
P8700	Nephtys cirrosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P8710	Nephtys hombergii	-	-	1	-	1	1	-	-	-	-	-	1	1	-
P10080	Lumbrineris gracilis	-	-	-	-	-	-	-	-	-	-	1	-	-	-

MCS Code	Taxon Name	45A	45B	48A	48B	51A	51B	54A	54B	55A	55B	56A	56B	57A	57B
P11420	Orbinia latreillii	-	3	-	2	3	1	1	-	1	-	-	-	-	-
P11520	Scoloplos armiger	-	1	3	5	3	10	-	-	-	-	-	-	-	-
P12210	Poecilochaetus serpens	1	4	-	-	-	-	-	-	1	-	-	2	-	6
P13120	Pseudopolydora pulchra	1	-	-	-	-	-	-	-	-	-	-	-	-	-
P13230	Scolelepis bonnieri	-	1	-	-	-	-	-	-	-	-	-	-	-	-
P13330	Spio sp.	27	15	16	38	38	36	43	23	35	7	31	39	46	67
P13430	Spiophanes bombyx	152	196	163	168	42	75	210	188	192	186	162	270	304	405
P13610	Magelona sp.	101	61	81	85	117	97	78	73	81	58	76	128	119	134
P13980	Caulleriella zetlandica	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P14030	Chaetozone setosa	20	24	37	29	5	4	20	17	13	8	6	9	-	2
P14280	Aphelochaeta sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P17430	Scalibregma inflatum	-	-	-	-	-	-	1	1	-	-	-	-	-	-
P13970	Tharyx killariensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P15300	Capitella sp.	3	8	3	1	-	4	7	19	1	7	-	-	3	1
P15620	Notomastus sp.	-	-	-	-	-	-	-	-	-	-	-	-	1	-
P16330	Euclymene oerstedii	-	-	1	-	7	3	2	-	2	-	-	-	-	-
P16900	Ophelia borealis	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P18310	Galathowenia sp.	-	-	-	-	1	-	-	-	5	2	1	4	-	1
P18360	Owenia fusiformis	6	6	-	5	8	19	3	10	6	7	22	43	1	7
P18540	Lagis koreni	-	1	-	-	1	-	-	-	1	-	1	-	-	1
P19040	Ampharete sp.	-	1	-	-	-	-	-	-	-	-	-	-	-	-
P20310	Lanice conchilega	4	3	1	-	3	-	7	1	-	3	4	6	4	4
P20810	Proclea graffii	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P24170	OLIGOCHAETA	3	2	-	4	4	2	2	6	6	9	3	2	2	-
Q40	Nymphon brevirostre	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Q620	Anoplodactylus petiolatus	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Q830	Halacaridae sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S370	MYSIDACEA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S670	Gastrosaccus spinifer	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S2280	Perioculodes longimanus	-	43	27	30	31	32	21	13	10	19	4	19	7	10
S2330	Pontocrates altamarinus	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S2340	Pontocrates arenarius	1	-	-	-	-	-	1	-	-	-	-	-	7	8
S2400	Synchelidium maculatum	11	7	5	4	1	1	7	1	7	3	4	12	3	4
S2810	Amphilochus spencebatei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S3130	Leucothoe incisa	-	1	-	-	2	1	-	-	-	-	-	-	-	-
S3710	Stenothoe monoculoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S4310	Urothoe poseidonis	-	-	-	-	1	-	1	1	-	-	1	-	-	-
S4360	Phoxocephalidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S4640	Lysianassidae sp.	-	-	-	-	-	-	1	-	-	-	-	-	-	-
S4670	Acidostoma obesum	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S6810	Atylus falcatus	-	-	-	-	-	-	-	1	-	-	-	-	-	-
S7400	Bathyporeia sp.	-	1	4	2	1	1	3	-	1	-	1	5	-	1
S7410	Bathyporeia elegans	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S7480	Bathyporeia tenuipes	7	5	20	2	1	1	1	4	1	-	3	-	2	-
S7540	Haustorius arenarius	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S7680	Gammarus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S7900	Megaluropus agilis	8	3	-	-	-	-	2	1	-	-	-	1	3	3
S9550	Jassa falcata	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S9630	Microjassa cumbrensis	-	-	-	-	1	1	-	-	-	-	-	9	1	-
S10220	Corophium bonnellii	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S10840	Pariambus typicus	1	2	3	2	1	2	1	1	5	2	1	6	-	2
S10960	Phtisica marina	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S19940	Vauntompsonia cristata	-	-	-	-	-	1	-	-	-	2	-	-	-	-

MCS Code	Taxon Name	45A	45B	48A	48B	51A	51B	54A	54B	55A	55B	56A	56B	57A	57B
S19999	Bodotria arenosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S20150	Iphinoe trispinosa	-	-	3	6	19	19	3	3	-	2	1	2	1	2
S20720	Pseudocuma longicornis	3	12	20	25	38	64	9	16	2	2	2	12	12	9
S20960	Diastylis bradyi	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S20999	Diastylis rathkei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S21080	Diastyloides serrata	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S21440	Decapod Larvae	5	3	5	6	1	3	30	42	-	-	6	18	6	5
S23001	Processa edulis crassipes	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S23310	Crangon crangon	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S24399	Diogenes pugilator	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S24440	Paguridae sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S25660	Achaeus cranchii	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S26200	Corystes cassivelaunus	-	-	1	-	-	-	1	-	-	-	-	-	2	-
S26330	Thia scutellata	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S26660	Liocarcinus	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W2200	Skenea serpuloides	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W2820	Rissoa lilacina rufilabrum	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W5080	Chrysallida decussata	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W5940	Turbonilla crenata	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W5990	Turbonilla lactea	3	6	2	6	-	-	1	1	2	1	3	-	-	1
W7770	Polinices pulchellus	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W9690	Cylichna cylindracea	2	-	2	1	-	-	-	-	1	-	1	-	2	2
W9790	Philine aperta	-	-	-	-	1	-	-	-	-	-	-	1	-	-
W12370	NUDIBRANCHIA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W16160	Nucula sp.	-	-	-	-	4	3	-	2	1	-	-	-	-	-
W16750	Modiolus modiolus	-	-	21	-	7	-	5	-	-	-	-	-	-	-
W19050	Mysella bidentata	2	2	6	-	3	5	6	3	2	11	2	3	1	1
W19110	Tellimya ferruginosa	-	7	-	-	-	13	-	-	-	10	-	1	-	-
W19690	Acanthocardia echinata	2	-	-	-	3	5	2	-	-	-	1	-	-	-
W19870	Laevicardium crassum	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W19980	Mactra stultorum	45	-	30	-	31	31	48	30	30	27	40	40	29	-
W20220	Ensis sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W20320	Phaxas pellucidus	17	30	13	16	19	22	64	63	17	6	12	31	23	11
W20570	Fabulina fabula	50	69	57	42	64	114	116	130	64	65	119	86	89	-
W20810	Donax vittatus	-	-	2	-	4	2	-	-	-	-	-	1	-	-
W21190	Pharus legumen	-	-	-	-	-	-	-	-	-	-	-	1	-	1
W21890	Chamelea gallina	14	17	48	-	8	4	13	17	14	14	10	12	33	31
W22390	Corbula gibba	-	-	-	-	-	-	-	-	-	-	-	1	1	1
W23510	Thracia phaseolina	57	63	98	-	61	63	6	11	35	18	12	30	8	10
ZA30	Phoronis sp.	3	8	-	2	1	1	1	4	5	5	2	-	2	4
ZB410	Astropecten irregularis	-	-	-	-	-	-	-	-	-	1	-	-	-	-
ZB2850	Amphiura brachiata	-	1	-	-	1	-	-	-	-	1	-	-	1	-
ZB3150	Ophiura ophiura	-	-	5	-	3	2	1	1	1	1	-	-	-	-
ZB4070	Echinocardium cordatum	-	1	-	-	-	1	-	-	-	1	-	-	-	-
ZB4950	Thyone fusus	-	-	-	-	1	-	-	-	-	1	-	-	-	-
ZC10	ENTEROPNEUSTA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ZD2570	Molgula occulta	-	-	-	-	-	-	-	-	-	-	-	-	-	-

MCS Code	Taxon Name	58A	58B	59A	59B	60A	60B	64A	64B	84A	84B	87A	87B	88A	88B
Qualitative Taxa															
D4420	Calycella syringa	-	-	-	-	-	-	-	-	-	-	-	-	-	-
D4570	Lovenella clausa	1	1	1	-	1	1	1	1	1	-	1	1	-	-
D5350	Halecium undulatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-
D6400	Diphasia fallax	-	-	-	-	-	-	-	-	-	-	-	-	-	-
D6530	Hydrallmania falcata	-	-	-	-	-	-	-	-	-	-	-	-	-	-
D6760	Sertularia argentea	-	-	-	-	-	-	-	-	-	-	-	-	-	-
D6960	Campanularia hincksii	-	-	-	-	-	-	-	-	-	-	-	-	-	-
D7030	Clytia hemisphaerica	-	-	-	-	-	-	-	-	-	-	-	-	-	-
D7210	Laomedea calceolifera	-	-	-	-	-	-	-	-	-	-	-	-	-	-
D7300	Obelia dichotoma	1	-	-	-	-	-	-	-	-	-	-	1	-	-
G1	NEMERTEA	-	-	-	1	-	-	-	-	-	-	-	-	-	-
HD1	NEMATODA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L01	CHAETOGNATHA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R1940	COPEPODA	72	30	4	7	45	120	1	-	7	3	-	12	11	4
R35180	OSTRACODA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Y2370	Vesicularia spinosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Y6690	Conopeum reticulum	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Y6780	Electra pilosa	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Quantitative Taxa															
D1210	Corymorpha nutans	-	-	-	-	-	-	-	-	-	4	2	2	-	-
D12320	Sagartia troglodytes	1	-	-	-	-	-	-	2	-	-	-	-	-	-
N10	Sipunculidae sp.	5	1	-	-	-	-	-	-	-	-	-	-	-	-
P420	Polynoidae sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P1060	Harmothoe imbricata	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P1160	Malmgrenia andreapolis	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P1190	Harmothoe glabra	2	-	-	2	1	-	1	-	-	-	-	-	-	-
P1210	Malmgrenia marphysae	5	2	-	-	-	-	-	-	-	-	-	-	-	-
P1680	Pholoe sp.	-	2	-	-	-	-	-	-	-	-	-	-	-	-
P1810	Sigalion mathildae	5	3	1	-	-	1	5	11	-	-	-	-	-	-
P1890	Sthenelais limicola	-	1	1	1	-	1	-	-	-	-	-	-	-	1
P2000	Phyllodocidae sp.	2	1	-	-	-	-	-	-	-	-	-	2	-	-
P2000	Phyllodocidae JUV.	-	-	-	-	-	-	-	-	-	1	14	8	-	2
P2020	Eteone sp.	-	-	-	-	-	-	1	3	-	1	-	-	-	-
P2050	Eteone longa	-	-	-	-	-	-	2	1	-	-	-	-	-	-
P2240	Mysta picta	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P2830	Eumida bahusiensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P3110	Phyllodoce groenlandica	-	-	-	-	-	-	-	-	-	-	-	-	1	-
P3110	Phyllodoce maculata	-	1	-	-	-	-	-	-	-	-	-	-	-	-
P3110	Phyllodoce mucosa	-	-	1	-	-	-	-	-	-	-	-	-	-	-
P3110	Phyllodoce rosea	-	2	-	-	-	-	2	6	-	-	-	-	-	-
P4710	Glycera JUV.	-	-	-	-	-	-	-	-	-	1	-	3	-	-
P4810	Glycera tridactyla	6	9	-	-	2	2	5	10	-	-	3	2	-	1
P5410	Podarkeopsis capensis	9	12	1	-	-	1	-	1	-	-	-	-	-	-
P5680	Ophiodromus flexuosus	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P7610	Autolytus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P8340	Nereis longissima	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P8670	Nephtys JUV.	1	1	2	7	4	4	21	27	3	2	1	3	1	6
P8675	Nephtys assimilis	1	1	-	1	-	-	-	-	-	-	-	-	-	-
P8700	Nephtys cirrosa	-	-	9	18	-	-	-	-	5	3	3	5	13	7
P8710	Nephtys hombergii	2	1	-	-	-	-	2	1	-	-	-	-	-	-
P10080	Lumbrineris gracilis	-	-	9	18	-	-	-	-	5	3	3	5	13	7

MCS Code	Taxon Name	58A	58B	59A	59B	60A	60B	64A	64B	84A	84B	87A	87B	88A	88B
P11420	Orbinia latreillii	-	-	-	-	-	-	2	-	-	-	-	-	-	-
P11520	Scoloplos armiger	-	-	-	-	-	-	1	-	-	-	-	-	-	-
P12210	Poecilochaetus serpens	-	-	3	-	3	3	-	-	-	-	-	-	-	-
P13120	Pseudopolydora pulchra	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P13230	Scolelepis bonnieri	3	-	1	-	-	-	-	-	6	4	3	-	1	8
P13330	Spio sp.	9	33	42	45	74	72	41	61	1	-	-	-	1	1
P13430	Spiophanes bombyx	196	212	109	67	180	162	93	112	12	9	2	3	31	6
P13610	Magelona sp.	53	67	13	5	104	140	96	132	-	-	-	-	16	13
P13980	Caulleriella zetlandica	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P14030	Chaetozone setosa	2	6	22	5	25	30	9	10	-	-	-	-	-	-
P14280	Aphelochaeta sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P17430	Scalibregma inflatum	-	1	-	-	-	1	-	-	1	-	-	-	2	2
P13970	Tharyx killariensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P15300	Capitella sp.	2	8	-	-	2	5	-	-	-	-	-	-	-	-
P15620	Notomastus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P16330	Euclymene oerstedii	60	12	-	-	-	-	-	-	-	-	-	-	-	-
P16900	Ophelia borealis	-	-	-	1	-	-	-	-	-	2	-	-	-	-
P18310	Galathowenia sp.	2	-	-	-	-	-	2	1	-	-	-	-	-	-
P18360	Owenia fusiformis	12	9	-	1	2	2	7	6	-	-	-	-	-	-
P18540	Lagis koreni	-	-	-	-	-	-	-	1	-	-	-	-	-	-
P19040	Ampharete sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P20310	Lanice conchilega	3	3	-	-	-	-	-	2	1	1	-	-	1	2
P20810	Proclea graffii	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P24170	OLIGOCHAETA	4	2	-	-	10	8	-	2	-	-	5	10	-	-
Q40	Nymphon brevirostre	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Q620	Anoplodactylus petiolatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Q830	Halacaridae sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S370	MYSIDACEA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S670	Gastrosaccus spinifer	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S2280	Perioculodes longimanus	7	12	12	7	6	8	17	12	3	1	1	-	-	-
S2330	Pontocrates altamarinus	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S2340	Pontocrates arenarius	-	-	8	16	14	11	4	2	3	-	-	-	-	1
S2400	Synchelidium maculatum	3	4	4	13	3	1	5	8	1	3	-	5	1	-
S2810	Amphilochus spencebatei	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S3130	Leucothoe incisa	-	-	-	-	-	-	1	-	-	-	-	-	-	-
S3710	Stenothoe monoculoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S4310	Urothoe poseidonis	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S4360	Phoxocephalidae	-	-	-	-	-	-	-	-	-	-	-	-	-	1
S4640	Lysianassidae sp.	-	-	-	-	-	1	-	-	-	-	-	-	-	-
S4670	Acidostoma obesum	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S6810	Atylus falcatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S7400	Bathyporeia sp.	2	-	3	3	14	3	1	-	-	1	-	-	-	-
S7410	Bathyporeia elegans	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S7480	Bathyporeia tenuipes	-	3	5	-	8	6	-	-	-	-	-	-	-	-
S7540	Haustorius arenarius	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S7680	Gammarus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S7900	Megaluropus agilis	-	1	1	7	3	-	-	-	4	3	2	6	-	1
S9550	Jassa falcata	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S9630	Microjassa cumbrensis	4	1	-	-	-	-	-	1	-	-	-	-	-	-
S10220	Corophium bonnellii	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S10840	Pariambus typicus	-	2	-	-	-	-	-	-	1	1	-	1	-	-
S10960	Phtisica marina	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S19940	Vauntompsonia cristata	1	-	-	-	-	-	-	-	-	-	-	-	-	-

MCS Code	Taxon Name	58A	58B	59A	59B	60A	60B	64A	64B	84A	84B	87A	87B	88A	88B
S19999	Bodotria arenosa	-	-	-	-	-	-	-	-	-	3	-	-	-	-
S20150	Iphinoe trispinosa	-	-	-	1	-	2	4	6	1	-	-	-	-	-
S20720	Pseudocuma longicornis	1	7	18	43	48	26	56	51	56	69	32	71	12	16
S20960	Diastylis bradyi	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S20999	Diastylis rathkei	-	-	-	-	-	-	-	-	-	-	-	3	-	-
S21080	Diastyloides serrata	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S21440	Decapod Larvae	8	10	11	16	40	25	5	-	22	52	5	4	7	2
S23001	Processa edulis crassipes	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S23310	Crangon crangon	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S24399	Diogenes pugilator	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S24440	Paguridae sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S25660	Achaeus cranchii	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S26200	Corystes cassivelaunus	-	-	-	1	-	-	-	-	-	-	1	2	-	2
S26330	Thia scutellata	-	-	-	-	-	-	-	-	-	-	-	1	-	-
S26660	Liocarcinus	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W2200	Skenea serpuloides	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W2820	Rissoa lilacina rufilabrum	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W5080	Chrysallida decussata	-	-	-	-	-	-	-	-	-	-	-	1	-	-
W5940	Turbonilla crenata	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W5990	Turbonilla lactea	-	1	1	1	2	1	1	1	-	-	-	-	-	-
W7770	Polinices pulchellus	-	-	-	-	-	-	-	-	-	-	-	-	-	1
W9690	Cylichna cylindracea	5	3	1	-	-	-	-	1	-	-	-	-	-	-
W9790	Philine aperta	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W12370	NUDIBRANCHIA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W16160	Nucula sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W16750	Modiolus modiolus	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W19050	Mysella bidentata	106	42	1	-	25	16	-	-	-	-	-	-	2	-
W19110	Tellimya ferruginosa	9	14	-	-	7	-	-	-	-	-	-	-	-	-
W19690	Acanthocardia echinata	-	-	-	-	1	-	2	1	-	-	-	-	-	-
W19870	Laevicardium crassum	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W19980	Mactra stultorum	9	18	7	13	-	-	-	-	13	-	21	12	3	4
W20220	Ensis sp.	-	-	-	-	-	-	-	2	-	-	-	-	-	-
W20320	Phaxas pellucidus	7	10	1	4	8	4	10	13	11	-	-	-	1	-
W20570	Fabulina fabula	84	116	42	5	106	68	78	64	2	1	-	1	4	-
W20810	Donax vittatus	-	-	-	-	-	-	1	2	-	-	-	-	-	-
W21190	Pharus legumen	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W21890	Chamelea gallina	6	2	-	-	10	6	13	13	-	-	-	1	-	-
W22390	Corbula gibba	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W23510	Thracia phaseolina	4	2	-	-	1	1	17	22	-	-	-	-	-	-
ZA30	Phoronis sp.	5	2	-	-	1	1	1	1	-	-	-	-	-	-
ZB410	Astropecten irregularis	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ZB2850	Amphiura brachiata	15	3	1	-	-	-	-	-	-	-	-	-	-	-
ZB3150	Ophiura ophiura	4	3	-	-	-	1	1	-	-	-	-	-	-	-
ZB4070	Echinocardium cordatum	1	1	-	-	-	-	-	1	-	-	-	-	1	-
ZB4950	Thyone fusus	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ZC10	ENTEROPNEUSTA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ZD2570	Molgula occulta	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Appendix 3.2 Length Frequency Data for *Fabulina fabula* Baseline Survey June 1998

Length (mm)	23	26	27	28	31	34	36	40	41	42	43	44	45	48	51	54	55	56	57	58	59	60	64	84	87	88
0.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-
0.9	-	-	1	1	1	-	-	-	2	-	-	1	-	1	3	-	-	-	-	-	-	1	-	1	-	-
1	-	1	5	2	-	2	-	-	12	10	1	2	3	4	13	1	2	-	3	14	-	1	4	-	-	-
1.1	1	3	3	3	11	7	-	-	24	17	1	2	6	9	11	11	8	1	12	26	2	1	5	-	-	1
1.2	-	6	5	8	11	9	1	-	40	16	-	3	7	9	8	14	9	10	10	35	1	6	7	-	-	-
1.3	-	4	3	3	13	12	1	-	32	21	-	2	9	13	4	38	13	21	16	37	5	6	4	-	-	-
1.4	2	8	6	5	11	9	2	-	19	9	-	3	11	14	6	29	11	17	13	23	2	10	12	-	-	-
1.5	1	1	9	6	10	9	3	-	22	12	-	2	9	14	4	27	22	27	7	17	9	14	12	-	-	1
1.6	1	4	10	6	11	6	1	1	8	2	-	2	14	7	5	24	15	27	5	12	5	7	6	-	-	1
1.7	-	3	8	4	10	5	2	-	6	3	-	1	8	7	3	20	10	13	3	9	5	17	7	-	1	-
1.8	1	2	5	3	12	4	1	-	4	3	-	1	7	6	2	8	7	11	2	2	2	10	5	-	-	1
1.9	1	2	4	2	7	7	-	-	3	2	-	-	6	-	3	10	5	7	-	2	2	6	5	-	-	-
2	-	1	7	3	9	2	1	-	2	2	-	1	6	3	3	14	1	6	3	1	3	10	9	-	-	-
2.1	-	-	-	2	6	2	-	-	1	2	1	-	3	-	3	7	3	2	-	1	-	6	5	-	-	-
2.2	-	-	4	2	8	4	1	-	-	-	-	1	3	-	3	1	2	5	2	1	-	7	7	-	-	-
2.3	1	-	2	2	5	-	-	-	1	-	-	2	3	3	2	-	2	6	1	1	-	2	5	-	-	-
2.4	1	1	2	1	2	2	1	-	-	-	-	2	2	2	3	-	1	2	-	2	-	4	3	-	-	-
2.5	-	2	-	4	5	2	-	-	1	-	-	3	1	-	5	1	-	2	1	1	-	7	5	-	-	-
2.6	-	-	-	2	2	1	-	-	1	-	-	-	3	-	4	-	1	2	1	1	-	3	3	-	-	-
2.7	-	-	2	3	4	2	-	-	1	-	-	1	3	-	3	-	1	2	-	1	-	6	2	-	-	-
2.8	-	1	1	1	2	1	-	-	1	-	-	-	1	-	4	3	2	2	-	-	-	4	2	-	-	-
2.9	-	1	-	2	1	1	-	-	-	-	-	1	3	1	5	3	-	2	-	-	-	3	4	-	-	-
3	-	2	-	1	2	-	-	-	-	-	-	1	3	1	3	1	1	3	-	1	2	3	7	-	-	-
3.1	-	1	-	3	1	-	-	-	2	-	-	1	1	-	2	-	1	1	-	-	-	1	-	-	-	-
3.2	-	3	-	3	-	1	-	-	-	-	-	-	1	-	5	-	-	-	1	-	-	4	3	-	-	-
3.3	-	-	-	1	2	-	-	-	-	-	-	1	-	-	3	3	-	2	-	1	-	1	2	-	-	-
3.4	-	1	-	2	-	2	-	-	-	-	-	1	1	-	3	3	-	-	-	1	-	4	1	-	-	-
3.5	1	1	-	3	1	1	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	4	2	-	-	-
3.6	-	1	-	1	-	1	-	-	-	2	-	1	-	-	4	1	-	-	-	-	-	-	-	-	-	-
3.7	-	-	-	2	-	1	-	-	-	-	-	1	1	-	3	-	-	16	-	-	-	2	-	-	-	-
3.8	-	-	-	4	1	-	-	-	-	-	-	-	1	-	3	-	-	2	-	-	-	2	-	-	-	-
3.9	-	-	-	1	-	-	-	-	1	-	-	-	-	-	4	-	-	-	-	1	-	1	-	-	-	-
4	-	-	-	1	1	-	-	-	-	-	-	-	-	-	3	1	-	-	-	1	-	4	2	1	-	-
4.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	1	-	-	-	1	-	2	2	-	-	-
4.2	-	-	-	-	1	1	-	-	1	-	-	-	-	-	2	1	-	-	-	1	-	3	-	-	-	-
4.3	-	-	-	-	-	-	-	-	1	-	-	-	-	-	5	1	-	1	-	-	-	-	-	1	-	-
4.4	-	-	-	1	-	-	-	-	1	-	-	-	-	1	3	-	-	-	-	1	-	3	-	-	-	-
4.5	-	-	-	1	-	1	-	-	-	-	-	1	-	-	2	-	-	-	-	-	-	1	-	-	-	-
4.6	-	-	-	-	1	1	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-
4.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-
4.8	-	1	-	1	1	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	1	-	-	-
4.9	-	1	-	1	-	1	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	1	-	-	-	-	1	-	-	1	-	-	1	-	-	-	1	-	-	-	-
5.1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	1	-	-	-	-	-	-
5.2	-	-	-	-	2	-	-	-	-	-	-	-	-	1	2	-	-	-	1	-	1	-	-	-	-	-
5.3	-	-	-	-	1	-	-	-	-	-	-	-	-	-	2	1	-	-	-	1	-	-	-	-	-	-
5.4	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
5.5	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	1	-	1	-	-	-	-
5.6	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
5.7	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-
5.8	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	-	-
5.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	1	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	2	-	1	1	-	-	-	-	-
6.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-

Length (mm)	23	26	27	28	31	34	36	40	41	42	43	44	45	48	51	54	55	56	57	58	59	60	64	84	87	88
6.2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-
6.3	-	1	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
6.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
6.5	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	2	-	-	-	1	-	-	-	-
6.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
6.7	-	-	-	1	-	-	-	-	-	-	-	-	1	-	-	1	-	1	-	-	-	-	-	-	-	-
6.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	1	-	-	-
6.9	-	-	-	-	-	-	1	-	1	-	-	1	-	-	-	-	2	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-
7.1	-	-	1	-	1	-	-	-	1	-	-	-	-	-	-	-	-	2	-	-	-	-	2	-	-	-
7.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	-	-	-	-	-	-	-	-
7.3	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
7.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	-	-	-	-	-	-	-	-	-
7.5	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-
7.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	1	-	-	-
7.7	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	1	-	-	-	-	-	-	-	-	-	-
7.8	-	-	-	1	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
7.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
8.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	1	-	-	-	-	-	-	-	-
8.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
8.3	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	1	-	-	-
8.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-
8.5	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	-	1	1	-	-	-	-	1	-	-	-
8.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	1	-	-	-	-	-
8.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8.8	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-
8.9	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	-	1	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
9.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
9.3	-	1	-	-	-	-	-	-	-	-	-	-	1	1	-	-	1	-	-	-	-	-	-	-	-	-
9.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
9.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
9.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
9.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
9.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-
10.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
10.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
10.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
10.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
10.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-
10.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-
11.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-
11.3	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
11.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11.7	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Length (mm)	23	26	27	28	31	34	36	40	41	42	43	44	45	48	51	54	55	56	57	58	59	60	64	84	87	88
11.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
11.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
12.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
12.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
12.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
13.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-
13.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
13.7	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-
14.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
14.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
14.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-
15.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
15.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-
15.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
15.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
15.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
15.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
15.9	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
16.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-
16.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Length (mm)	23	26	27	28	31	34	36	40	41	42	43	44	45	48	51	54	55	56	57	58	59	60	64	84	87	88
17.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
17.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Total	14	51	78	90	152	102	17	1	190	100	2	39	119	99	178	246	129	205	89	200	47	174	142	3	1	4

Appendix 3.2 Pooled Length Frequencies for *Fabulina fabula* Station 49

Length (mm)	01/06/98	23/11/98	16/04/99	02/09/99	05/05/00
0.5	-	-	-	-	-
0.6	-	-	-	-	1
0.7	-	-	-	3	2
0.8	-	1	-	7	3
0.9	1	4	6	6	1
1	4	15	15	8	1
1.1	9	9	13	11	2
1.2	9	12	6	6	7
1.3	13	3	6	1	3
1.4	14	8	3	2	6
1.5	14	2	5	1	4
1.6	7	-	3	-	2
1.7	7	2	2	1	-
1.8	6	5	1	-	-
1.9	-	6	2	2	-
2	3	16	1	2	-
2.1	-	15	1	3	-
2.2	-	13	1	7	1
2.3	3	12	5	8	-
2.4	2	9	1	9	-
2.5	-	4	4	3	1
2.6	-	3	2	9	-
2.7	-	8	6	3	2
2.8	-	3	1	1	1
2.9	1	2	5	-	2
3	1	2	3	3	3
3.1	-	1	1	-	1
3.2	-	2	5	1	-
3.3	-	4	4	-	1
3.4	-	-	1	-	4
3.5	-	-	6	1	3
3.6	-	-	5	2	-
3.7	-	1	1	1	1
3.8	-	1	-	2	1
3.9	-	1	1	1	-
4	-	-	1	-	-
4.1	-	-	1	-	-
4.2	-	-	-	-	-
4.3	-	-	1	-	-
4.4	1	-	-	-	-
4.5	-	-	1	1	-
4.6	-	-	-	1	-
4.7	-	-	-	2	-
4.8	-	1	1	-	-
4.9	-	-	-	2	-
5	-	-	-	-	-
5.1	1	-	1	-	-
5.2	1	-	-	-	-

Length (mm)	01/06/98	23/11/98	16/04/99	02/09/99	05/05/00
5.3	-	-	1	1	-
5.4	-	-	-	-	-
5.5	-	-	1	-	-
5.6	-	-	-	2	1
5.7	-	-	1	3	-
5.8	1	-	-	1	1
5.9	-	-	-	1	-
6	-	-	-	1	-
6.1	-	-	-	-	-
6.2	-	-	-	-	1
6.3	-	-	-	-	-
6.4	-	-	-	-	-
6.5	-	-	1	1	-
6.6	-	-	-	-	-
6.7	-	-	-	-	-
6.8	-	-	-	-	-
6.9	-	-	-	-	1
7	-	-	-	-	-
7.1	-	-	-	-	-
7.2	-	-	-	-	-
7.3	-	-	-	-	-
7.4	-	-	-	1	-
7.5	-	-	-	-	-
7.6	-	-	-	-	-
7.7	-	-	-	-	-
7.8	1	-	-	-	-
7.9	-	-	-	1	-
8	-	-	-	-	1
8.1	-	-	-	-	-
8.2	-	-	-	-	-
8.3	-	1	-	-	-
8.4	-	-	-	-	-
8.5	-	-	-	-	1
8.6	-	-	-	-	-
8.7	-	-	-	-	-
8.8	-	-	-	-	-
8.9	-	-	-	-	-
9	-	-	-	-	-
9.1	-	-	-	-	-
9.2	-	-	-	-	-
9.3	1	-	-	-	-

Appendix 5.1 Long-Term Species x Station Matrix. Data from Warwick (1974), Hobbs and Smith (1998) and Present Study Scaled to 0.1m^2

Taxon	**February-1974**	**March-1996**								
	Station 126	**CB19**	**CB20**	**CB21**	**CB22**	**CB23**	**CB26**	**CB27**	**CB28**	**CB29**
Sagartia troglodytes	-	-	-	-	-	-	-	-	-	-
Edwardsia callimorpha	-	-	-	-	-	-	-	-	-	-
NEMERTEA	1.8	3	6	1	-	1	1.8	3	6	1
Tubulanus polymorphus	-	-	-	-	-	-	-	-	-	-
Cerebratulus sp.	-	-	-	-	-	-	-	-	-	-
SIPUNCULA	-	-	-	-	-	-	-	-	-	-
Phascolion strombi	-	-	-	-	-	-	-	-	-	-
Aphroditidae sp.	0.1	-	-	-	-	-	0.1	-	-	-
Harmothoe glabra	-	-	-	-	-	-	-	-	-	-
Harmothoe lunulata	-	-	-	-	-	-	-	-	-	-
Pholoe sp.	-	-	-	-	-	-	-	-	-	-
Pholoe inornata	0.1	-	-	-	-	-	0.1	-	-	-
Sigalion mathildae	3.4	-	1	-	-	-	3.4	-	1	-
Sthenelais sp.	-	-	-	-	-	-	-	-	-	-
Sthenelais boa	-	-	-	-	-	-	-	-	-	-
Sthenelais limicola	-	-	-	-	-	-	-	-	-	-
Eteone sp.	-	-	-	-	-	-	-	-	-	-
Etone longa	0.05	-	1	-	-	-	0.05	-	1	-
Hesionura elongata	-	-	-	-	-	-	-	-	-	-
Phyllodoce sp.	0.6	-	-	-	-	-	0.6	-	-	-
Phyllodocedae groenlandica	-	-	-	-	-	-	-	-	-	-
Phyllodocedae rosea	-	-	-	-	-	-	-	-	-	-
Eulalia sp.	0.25	-	-	-	-	-	0.25	-	-	-
Eumida sp.	-	-	-	-	-	-	-	-	-	-
Eumida bahusiensis	-	-	-	-	-	-	-	-	-	-
Paranaitis kosteriensis	-	-	-	-	-	-	-	-	-	-

Taxon	February-1974	March-1996								
	Station 126	CB19	CB20	CB21	CB22	CB23	CB26	CB27	CB28	CB29
Glycera sp.	-	-	-	-	-	-	-	-	-	-
Glycera alba	13.9	-	-	-	-	-	13.9	-	-	-
Glycera tridactyla	-	6	8	2	1	4	-	6	8	2
Goniada maculata	0.05	-	-	-	-	-	0.05	-	-	-
Hesionidae sp.	-	-	-	-	-	-	-	-	-	-
Gyptis helgolandicus	-	-	-	-	-	-	-	-	-	-
Podarkeopsis helgolandica	-	-	-	-	-	-	-	-	-	-
Kefersteinia cirrata	0.1	-	-	-	-	-	0.1	-	-	-
Exogone sp.	-	-	-	-	-	-	-	-	-	-
Exogone naidina	-	-	-	-	-	-	-	-	-	-
Autolytus sp.	-	-	-	-	-	-	-	-	-	-
Nereis longissima	0.3	-	-	-	-	-	0.3	-	-	-
Nephtys sp. (juv.)	-	-	-	1	-	-	-	-	-	1
Nephtys assimilis	-	-	-	1	-	2	-	-	-	1
Nephtys cirrosa	-	-	-	1	2	3	-	-	-	1
Nephtys hombergi	4.9	4	4	-	-	2	4.9	4	4	-
Nephtys kersivalensis	-	-	-	-	-	-	-	-	-	-
Lumbrineris sp.	-	-	-	-	-	-	-	-	-	-
Lumbrineris latreilli	-	-	-	-	-	-	-	-	-	-
Lumbrineris gracilis	-	-	-	-	-	-	-	-	-	-
Dorvilleidae unident	-	-	-	-	-	-	-	-	-	-
Orbinia latreillii	0.3	1	-	-	-	-	0.3	1	-	-
Scoloplos armiger	-	-	-	-	-	-	-	-	-	-
Aricidea catherinae	-	-	-	-	-	-	-	-	-	-
Poecilochaetus serpens	-	-	-	-	-	1	-	-	-	-
Spionidae unident	0.1	-	-	-	-	-	0.1	-	-	-
Aonides paucibranchiata	-	-	-	-	-	-	-	-	-	-
Polydora sp.	-	-	-	-	-	-	-	-	-	-

Taxon	February-1974	March-1996								
	Station 126	CB19	CB20	CB21	CB22	CB23	CB26	CB27	CB28	CB29
Pseudopolydora sp.	-	-	-	-	-	-	-	-	-	-
Pseudopolydora pulchra	-	-	1	-	-	-	-	-	1	-
Scolelepis sp.	-	-	-	-	-	-	-	-	-	-
Scolelepis squamata	-	-	-	-	-	-	-	-	-	-
Nerinides sp.	-	-	-	-	-	-	-	-	-	-
Spio sp.	1.9	5	6	21	-	-	1.9	5	6	21
Spiophanes bombyx	92.3	2	27	11	-	15	92.3	2	27	11
Magelona sp. (juv.)	-	-	-	-	-	-	-	-	-	-
Magelona alleni	-	-	1	-	-	-	-	-	1	-
Magelona filiformis	-	37	18	32	2	31	-	37	18	32
Magelona mirablis	243.6	2	1	7	1	-	243.6	2	1	7
Magelona johnstoni	-	-	-	-	-	-	-	-	-	-
Cirratulidae unident.	-	-	-	-	-	-	-	-	-	-
Caulleriella sp.	-	-	-	-	-	-	-	-	-	-
Caulleriella zetlandica	-	-	-	-	-	-	-	-	-	-
Chaetozone setosa	0.2	12	29	3	-	50	0.2	12	29	3
Chaetozone gibber	-	-	-	-	-	-	-	-	-	-
Aphelochaeta sp.	2.5	-	-	-	-	-	2.5	-	-	-
Diplocirrus glaucus	-	-	-	-	-	-	-	-	-	-
Capitellidae sp.	-	7	1	4	-	-	-	7	1	4
Capitella capitata	-	-	-	-	-	-	-	-	-	-
Mediomastus fragilis	-	-	-	-	-	-	-	-	-	-
Notomastus latericeus	0.1	-	-	-	-	-	0.1	-	-	-
Euclymene sp.	-	-	-	-	-	-	-	-	-	-
Euclymene oerstedii	-	3	-	-	-	-	-	3	-	-
Heteroclymene robusta	-	-	-	-	-	-	-	-	-	-
Ophelina acuminata	0.1	-	-	-	-	-	0.1	-	-	-
Scalibregma inflatum	0.05	-	-	-	-	-	0.05	-	-	-

Taxon	February-1974	March-1996								
	Station 126	CB19	CB20	CB21	CB22	CB23	CB26	CB27	CB28	CB29
Myriochele sp.	-	2	1	-	-	-	-	2	1	-
Myriochele oculata	-	-	-	-	-	-	-	-	-	-
Myriochele heeri	-	-	-	-	-	-	-	-	-	-
Galathowenia sp.	-	-	-	-	-	-	-	-	-	-
Owenia fusiformis	-	-	-	3	1	-	-	-	-	3
Pectinariidae sp.	-	-	-	-	-	-	-	-	-	-
Lagis koreni	0.3	-	-	1	-	-	0.3	-	-	1
Ampharetidae unident	-	-	-	-	-	-	-	-	-	-
Ampharete falcata	-	-	-	-	-	-	-	-	-	-
Ampharete lindstroemi	-	-	-	-	-	-	-	-	-	-
Terebellides stroemi	-	-	-	-	-	-	-	-	-	-
Lanice congeliga	0.1	-	1	-	-	1	0.1	-	1	-
Polycirrus sp.	-	-	-	-	-	-	-	-	-	-
Oligochaeta sp.	-	-	-	-	-	-	-	-	-	-
Tubificoides sp.	-	14	1	1	-	2	-	14	1	1
Tubificoides cf glaiciensis	-	-	-	-	-	-	-	-	-	-
Tubificoides benedii	-	-	-	-	-	-	-	-	-	-
Grania sp.	-	-	-	-	-	-	-	-	-	-
Achelia echinata	-	-	-	-	-	-	-	-	-	-
Anoplodactylus petiolatus	-	-	-	-	-	-	-	-	-	-
Mysidae sp.	-	-	-	-	-	-	-	-	-	-
Gastrosaccus spinifer	-	-	-	-	-	-	-	-	-	-
Paramysis arenosa	-	-	-	-	-	-	-	-	-	-
Schistomysis spiritus	-	-	-	-	-	-	-	-	-	-
Oedicerotidae sp.	-	-	-	-	-	-	-	-	-	-
Perioculodes longimanus	-	11	3	-	-	2	-	11	3	-
Pontocrates sp.	-	1	2	6	5	27	-	1	2	6
Pontocrates altamarinus	-	-	-	-	-	-	-	-	-	-

Taxon	February-1974	March-1996								
	Station 126	CB19	CB20	CB21	CB22	CB23	CB26	CB27	CB28	CB29
Pontocrates arenarius	5.9	-	-	-	-	-	5.9	-	-	-
Synchelidium maculatum	-	-	-	-	-	-	-	-	-	-
Amphilochidae sp.	-	-	-	-	-	-	-	-	-	-
Leucothoe	-	-	-	-	-	1	-	-	-	-
Leucothoe incisa	-	-	-	-	-	-	-	-	-	-
Leucothoe lilljeborgi	0.4	-	-	-	-	-	0.4	-	-	-
Stenothoidae sp.	-	-	-	-	-	-	-	-	-	-
Urothoe poseidonis	-	-	-	-	-	1	-	-	-	-
Lysianassidae sp.	-	-	-	-	-	-	-	-	-	-
Hippomedon denticulatus	-	-	-	-	-	-	-	-	-	-
Argissa hamatipes	-	-	-	-	-	-	-	-	-	-
Atylus falcatus	-	-	-	-	-	-	-	-	-	-
Atylus swammerdami	-	-	-	-	-	-	-	-	-	-
Ampelisca sp.	-	-	-	-	-	-	-	-	-	-
Ampelisca brevicornis	-	-	-	-	-	-	-	-	-	-
Ampelisca spinipes	-	-	-	-	-	-	-	-	-	-
Bathyporeia sp.	-	1	-	-	-	2	-	1	-	-
Bathyporeia elegans	-	-	-	-	-	-	-	-	-	-
Bathyporeia guilliamsoniana	6.4	-	-	-	-	-	6.4	-	-	-
Bathyporeia pelagica	-	-	-	-	-	2	-	-	-	-
Bathyporeia tenuipes	-	3	7	6	-	11	-	3	7	6
Haustorius arenarius	-	-	-	-	-	-	-	-	-	-
Megaluropus agilis	-	-	-	-	-	-	-	-	-	-
Melita sp.	-	-	-	-	-	-	-	-	-	-
Melita obtusata	-	-	-	-	-	-	-	-	-	-
Melita palmata	-	-	-	-	-	-	-	-	-	-
Microprotopus maculatus	-	-	-	-	-	-	-	-	-	-
Photis sp.	-	-	-	-	-	-	-	-	-	-

Taxon	February-1974	March-1996								
	Station 126	CB19	CB20	CB21	CB22	CB23	CB26	CB27	CB28	CB29
Photis reinhardi	-	-	-	-	-	-	-	-	-	-
Microjassa cumbrensis	-	-	-	-	-	-	-	-	-	-
Aoridae sp.	-	-	-	-	-	-	-	-	-	-
Siphonoecetes kroyeranus	-	-	-	-	-	-	-	-	-	-
Pariambus typicus	0.1	-	-	-	-	1	0.1	-	-	-
Eurydice pulchra	-	-	-	-	-	-	-	-	-	-
Sphaeroma monodi	-	-	-	-	-	-	-	-	-	-
Idotea linearis	-	-	-	-	-	-	-	-	-	-
Tanaidae sp.	-	-	-	-	-	-	-	-	-	-
Bodotria arenosa	-	-	-	-	-	-	-	-	-	-
Bodotria pulchella	-	-	-	-	-	-	-	-	-	-
Iphinoe trispinosa	4.7	1	1	-	-	-	4.7	1	1	-
Eudorella truncatula	-	-	-	-	-	-	-	-	-	-
Pseudocuma sp.	-	-	-	-	-	-	-	-	-	-
Pseudocuma gilsoni	0.2	-	-	-	-	-	0.2	-	-	-
Pseudocuma longicornis	-	-	-	-	-	-	-	-	-	-
Diastylis sp.	0.2	1	-	-	-	-	0.2	1	-	-
Diastylis bradyi	-	-	-	-	-	-	-	-	-	-
Diastylis lucifera	0.1	-	-	-	-	-	0.1	-	-	-
Diastylis rugosa	0.2	-	-	-	-	-	0.2	-	-	-
Processa canaliculata	-	-	-	-	-	-	-	-	-	-
Crangon crangon	-	-	-	-	-	-	-	-	-	-
Diogenes pugilator	-	-	-	-	-	-	-	-	-	-
Paguridae sp.	-	-	-	-	-	-	-	-	-	-
Pagurus pubescens	-	-	-	-	-	-	-	-	-	-
Corystes cassivelaunus	0.05	-	-	-	-	-	0.05	-	-	-
Liocarcinus sp.	-	-	-	-	-	-	-	-	-	-
Liocarcinus holsatus	-	-	-	-	-	-	-	-	-	-

Taxon	**February-1974**	**March-1996**								
	Station 126	**CB19**	**CB20**	**CB21**	**CB22**	**CB23**	**CB26**	**CB27**	**CB28**	**CB29**
Onoba semicostata	-	-	-	-	-	-	-	-	-	-
Hyala vitrea	-	-	-	-	-	-	-	-	-	-
Pyramidellidae	-	-	1	-	-	-	-	-	1	-
Turbonilla sp.(juv.)	-	-	-	-	-	-	-	-	-	-
Turbonilla lactea	-	-	-	-	-	-	-	-	-	-
Turbonilla acuta	-	-	-	-	-	-	-	-	-	-
Polinices pulchellus	-	-	1	-	-	-	-	-	1	-
Euspira catena	0.005	-	-	-	-	-	0.005	-	-	-
Hinia reticulata	-	-	-	-	-	-	-	-	-	-
Mangelia brachystoma	-	-	-	-	-	-	-	-	-	-
Acteon tornatilis	-	-	-	-	-	-	-	-	-	-
Cylichna cylindracea	-	1	2	-	-	-	-	1	2	-
Roxania utriculus	-	-	-	-	-	-	-	-	-	-
Philine aperta	-	-	-	-	-	-	-	-	-	-
Philine scabra	-	-	-	-	-	-	-	-	-	-
Nucula sp.	-	-	-	-	-	-	-	-	-	-
Nucula nitidosa	-	2	2	-	-	1	-	2	2	-
Mytilidae sp.	-	1	-	-	-	-	-	1	-	-
Modiolus modiolus	-	-	-	-	-	-	-	-	-	-
Montacuta substriata	-	-	-	-	-	-	-	-	-	-
Mysella bidentata	0.5	-	3	-	-	1	0.5	-	3	-
Tellimya ferruginosa	0.2	-	-	-	-	1	0.2	-	-	-
Acanthocardia	-	-	-	-	-	-	-	-	-	-
Acanthocardia echinata	-	-	-	-	-	-	-	-	-	-
Mactridae sp.	-	-	-	-	-	-	-	-	-	-
Mactra stultorum	-	-	-	-	-	-	-	-	-	-
Spisula elliptica	0.1	-	-	-	-	-	0.1	-	-	-
Spisula subtruncata	-	-	-	-	-	-	-	-	-	-

Taxon	February-1974	March-1996								
	Station 126	CB19	CB20	CB21	CB22	CB23	CB26	CB27	CB28	CB29
Ensis sp.	-	-	-	-	2	-	-	-	-	-
Ensis siliqua	0.2	-	-	-	-	-	0.2	-	-	-
Ensis ensis	-	-	-	-	-	-	-	-	-	-
Phaxas pellucidus	-	-	-	-	-	-	-	-	-	-
Tellinidae unident	-	-	-	-	-	-	-	-	-	-
Fabulina fabula	8	13	20	3	-	7	8	13	20	3
Donax vittatus	6.7	-	2	6	2	-	6.7	-	2	6
Gari fervensis	-	-	-	-	-	-	-	-	-	-
Abra sp. (juv)	-	5	2	-	-	-	-	5	2	-
Abra alba	0.2	-	4	-	-	-	0.2	-	4	-
Abra prismatica	0.005	-	-	-	-	-	0.005	-	-	-
Pharus legumen	11.7	-	-	1	-	2	11.7	-	-	1
Arctica islandica	-	-	-	-	-	-	-	-	-	-
Dosinia sp. (juv)	-	-	-	-	-	-	-	-	-	-
Venerupis senegalensis	-	-	-	-	-	-	-	-	-	-
Chamelea gallina	1.5	3	3	-	-	-	1.5	3	3	-
Mya truncata	0.1	-	-	-	-	-	0.1	-	-	-
Corbula gibba	0.05	-	-	-	-	-	0.05	-	-	-
Thracia sp.	-	-	-	-	-	-	-	-	-	-
Thracia phaseolina	-	-	-	-	-	-	-	-	-	-
Thracia villosiuscula	-	-	-	-	-	-	-	-	-	-
Cochlodesma praetenue	-	-	-	-	-	-	-	-	-	-
Phoronis sp.	1.8	3	-	-	-	-	1.8	3	-	-
Astropecten irregularis	0.05	-	-	-	-	-	0.05	-	-	-
Asterias rubens	-	-	-	-	-	-	-	-	-	-
Amphiura sp. (juv.)	-	-	-	-	-	-	-	-	-	-
Amphiura brachiata	1.8	-	-	-	-	-	1.8	-	-	-
Amphiura chiajei	-	-	-	-	-	-	-	-	-	-

Taxon	February-1974					March-1996				
	Station 126	CB19	CB20	CB21	CB22	CB23	CB26	CB27	CB28	CB29
Amphiura filiformis	-	-	-	-	-	-	-	-	-	-
Ophiura sp. (juv.)	-	2	3	2	-	-	-	2	3	2
Ophiura ophiura	0.5	1	-	-	-	-	0.5	1	-	-
Echinocyamus pusillus	-	-	-	-	-	-	-	-	-	-
Echinocardium sp. (juv.)	-	-	-	-	-	-	-	-	-	-
Echinocardium cordatum	0.6	-	-	-	-	-	0.6	-	-	-
Holothurioidea sp.	-	-	1	-	-	-	-	-	1	-

Taxon	October 1996					March 1996				
	CB 19	CB20	CB21	CB22	CB23	CB19	CB20	CB21	CB22	CB23
Sagartia troglodytes	-	-	-	-	-	-	-	-	-	-
Edwardsia callimorpha	-	0.3	-	-	-	-	-	-	-	-
NEMERTEA	-	2.3	1.3	14.0	7.7	2.0	3.0	0.3	1.7	4.0
Tubulanus polymorphus	12.3	19.3	5.0	-	2.3	2.0	5.7	3.3	0.7	0.7
Cerebratulus sp.	0.3	0.3	-	-	-	-	-	-	-	-
SIPUNCULA	-	-	-	-	-	-	-	-	-	-
Phascolion strombi	-	-	-	-	-	-	0.3	-	-	-
Aphroditidae sp.	-	-	-	-	-	-	-	-	-	-
Harmothoe glabra	-	-	-	-	-	-	-	-	-	-
Harmothoe lunulata	-	-	-	-	-	-	-	-	-	-
Pholoe sp.	0.3	-	-	-	-	-	-	-	-	-
Pholoe inornata	-	-	-	-	-	-	-	-	-	-
Sigalion mathildae	12.0	13.3	2.3	-	3.3	1.0	3.7	1.7	0.3	0.7
Sthenelais sp.	-	-	-	-	-	-	-	-	-	-
Sthenelais boa	-	-	-	-	-	-	-	-	-	-
Sthenelais limicola	-	-	-	-	0.3	-	-	-	-	-
Eteone sp.	0.3	1.0	0.7	-	4.0	1.5	1.3	1.7	2.7	0.7
Etone longa	0.7	-	0.7	-	0.7	-	-	-	-	-
Hesionura elongata	-	-	-	-	-	-	-	-	-	-
Phyllodoce sp.	-	-	-	-	-	-	-	-	-	-
Phyllodocedae groenlandica	-	-	-	-	-	-	-	-	-	-
Phyllodocedae rosea	-	-	-	-	-	-	-	-	-	-
Eulalia sp.	-	-	-	-	-	-	-	-	-	-
Eumida sp.	0.3	-	-	-	-	-	-	-	-	-
Eumida bahusiensis	0.3	-	-	-	-	-	-	-	-	-
Paranaitis kosteriensis	-	-	-	-	-	-	-	-	-	-

Taxon	October 1996					March 1996				
	CB 19	CB20	CB21	CB22	CB23	CB19	CB20	CB21	CB22	CB23
Glycera sp.	5.3	6.0	3.3	3.7	1.3	5.0	2.3	1.0	2.0	0.3
Glycera alba	1.0	1.3	0.3	1.3	0.3	-	-	-	-	-
Glycera tridactyla	0.3	-	-	-	0.7	-	-	3.0	0.7	0.7
Goniada maculata	-	-	-	-	-	-	-	-	-	-
Hesionidae sp.	-	0.3	-	-	-	-	-	-	-	-
Gyptis helgolandicus	-	-	-	-	-	0.5	-	-	-	-
Podarkeopsis helgolandica	-	-	-	-	-	-	-	-	-	-
Kefersteinia cirrata	-	-	-	-	-	-	-	-	-	-
Exogone sp.	-	-	-	-	-	-	-	-	-	-
Exogone naidina	-	-	-	-	-	-	-	-	-	-
Autolytus sp.	-	-	-	-	-	-	-	-	-	-
Nereis longissima	-	-	-	-	-	-	-	-	-	-
Nephtys sp. (juv.)	2.0	1.0	1.0	5.7	3.7	0.5	0.3	2.0	4.7	1.7
Nephtys assimilis	6.0	2.7	4.0	1.0	7.3	0.5	0.7	1.0	-	3.3
Nephtys cirrosa	-	-	0.3	32.3	-	-	-	0.3	0.7	1.3
Nephtys hombergi	3.0	0.7	-	-	2.3	1.0	0.3	-	-	-
Nephtys kersivalensis	-	-	-	-	-	-	-	0.3	-	-
Lumbrineris sp.	-	-	-	-	-	-	-	-	-	-
Lumbrineris latreilli	-	-	-	-	-	-	-	-	-	-
Lumbrineris gracilis	-	-	-	-	-	-	-	-	-	-
Dorvilleidae unident	-	-	-	-	-	-	-	-	-	-
Orbinia latreillii	-	0.7	-	-	-	-	-	-	-	-
Scoloplos armiger	3.3	1.3	0.3	-	1.3	3.5	1.3	-	-	-
Aricidea catherinae	-	-	-	-	-	-	-	-	-	-
Poecilochaetus serpens	2.0	-	0.3	-	1.3	-	0.3	-	-	-
Spionidae unident	1.0	-	-	-	-	-	-	-	-	-
Aonides paucibranchiata	-	-	-	-	-	-	-	-	-	-

Taxon	October 1996					March 1996				
	CB 19	CB20	CB21	CB22	CB23	CB19	CB20	CB21	CB22	CB23
Polydora sp.	-	-	-	-	-	-	-	-	-	-
Pseudopolydora sp.	0.7	1.0	-	-	0.3	-	-	-	-	-
Pseudopolydora pulchra	1.0	1.0	0.7	-	0.3	-	-	-	-	-
Scolelepis sp.	0.3	-	-	-	-	-	-	-	-	-
Scolelepis squamata	0.3	-	-	-	0.7	-	-	-	-	-
Nerinides sp.	-	-	-	-	-	-	0.7	-	-	-
Spio sp.	28.3	44.7	27.7	1.7	21.7	3.5	3.7	3.3	1.0	0.3
Spiophanes bombyx	0.3	0.7	3.3	1.7	1.0	-	0.7	0.7	0.3	0.3
Magelona sp. (juv.)	-	-	-	-	7.3	-	-	-	-	-
Magelona alleni	2.7	1.7	-	-	0.7	0.5	1.0	-	-	-
Magelona filiformis	23.3	39.0	18.0	1.7	40.0	30.5	37.3	31.7	7.3	26.0
Magelona mirablis	5.3	5.0	9.0	5.0	1.3	4.0	4.7	5.3	0.7	0.7
Magelona johnstoni	-	-	-	-	-	-	-	-	-	-
Cirratulidae unident.	-	-	-	-	-	7.5	19.7	8.3	1.3	18.7
Caulleriella sp.	-	-	-	-	-	-	-	-	-	-
Caulleriella zetlandica	-	-	-	-	-	-	-	-	-	-
Chaetozone setosa	35.7	54.7	8.0	2.3	60.3	50.0	29.3	5.7	2.7	31.0
Chaetozone gibber	-	-	-	-	-	-	-	-	-	-
Aphelochaeta sp.	-	-	-	-	-	-	-	-	-	-
Diplocirrus glaucus	-	-	-	-	-	-	-	-	-	-
Capitellidae sp.	-	-	-	-	0.3	-	-	0.3	-	-
Capitella capitata	6.3	0.7	1.7	-	1.0	1.0	0.7	0.7	0.3	0.7
Mediomastus fragilis	3.7	-	-	-	-	2.5	-	-	-	-
Notomastus latericeus	-	-	-	-	-	-	-	-	-	-
Euclymene sp.	-	-	-	-	-	0.5	-	-	-	-
Euclymene oerstedii	2.7	-	-	-	-	-	-	-	-	-
Heteroclymene robusta	-	-	-	-	-	-	-	-	-	-

Taxon	October 1996					March 1996				
	CB 19	CB20	CB21	CB22	CB23	CB19	CB20	CB21	CB22	CB23
Ophelina acuminata	-	-	-	-	-	-	-	-	-	-
Scalibregma inflatum	-	-	-	-	-	-	-	-	-	-
Myriochele sp.	-	-	-	-	-	-	-	-	-	-
Myriochele oculata	-	-	-	-	-	-	2.3	0.3	-	-
Myriochele heeri	1.0	2.3	-	-	-	2.0	-	-	-	-
Galathowenia sp.	-	-	-	-	-	-	-	-	-	-
Owenia fusiformis	0.7	-	-	-	1.0	-	0.7	-	-	0.7
Pectinariidae sp.	-	0.3	-	-	-	-	-	-	-	-
Lagis koreni	-	0.3	1.3	0.3	5.0	-	-	-	-	-
Ampharetidae unident	4.3	1.0	-	-	0.3	-	-	-	-	-
Ampharete falcata	6.3	1.7	-	-	-	-	-	-	-	-
Ampharete lindstroemi	-	-	-	-	-	-	-	-	-	-
Terebellides stroemi	-	-	-	-	-	-	-	-	-	-
Lanice congeliga	-	-	-	-	0.3	-	-	-	-	-
Polycirrus sp.	-	-	-	-	-	-	-	-	-	0.3
Oligochaeta sp.	-	0.3	-	-	-	-	-	-	-	-
Tubificoides sp.	7.3	2.7	-	-	3.3	14.0	1.0	-	-	1.0
Tubificoides cf glaiciensis	-	-	-	-	-	-	-	-	-	-
Tubificoides benedii	-	-	-	-	-	-	-	-	-	-
Grania sp.	-	-	-	-	-	-	-	-	-	-
Achelia echinata	-	-	-	-	-	-	-	-	0.3	-
Anoplodactylus petiolatus	-	-	-	-	1.3	-	-	-	-	-
Mysidae sp.	-	-	-	0.7	1.7	-	-	-	-	-
Gastrosaccus spinifer	-	-	-	-	0.3	-	-	-	-	-
Paramysis arenosa	-	-	-	-	-	-	-	-	-	-
Schistomysis spiritus	-	-	-	-	-	-	-	-	-	-
Oedicerotidae sp.	0.3	-	-	-	7.3	-	-	2.7	-	-

Taxon	October 1996					March 1996				
	CB 19	CB20	CB21	CB22	CB23	CB19	CB20	CB21	CB22	CB23
Perioculodes longimanus	85.0	86.7	46.3	2.7	5.0	5.0	10.7	3.0	1.3	1.7
Pontocrates sp.	-	-	-	-	5.7	-	-	3.7	3.0	12.0
Pontocrates altamarinus	-	-	-	1.0	-	-	-	0.3	1.3	-
Pontocrates arenarius	-	2.7	15.7	6.7	23.0	-	0.7	5.0	4.3	18.7
Synchelidium maculatum	3.3	-	0.3	1.7	4.0	0.5	0.3	0.7	-	1.3
Amphilochidae sp.	-	-	-	-	-	-	-	-	-	-
Leucothoe	-	-	-	-	-	-	-	-	-	-
Leucothoe incisa	-	-	0.7	-	-	-	-	-	-	-
Leucothoe lilljeborgi	-	-	-	-	-	-	-	-	-	-
Stenothoidae sp.	-	-	-	-	0.7	-	-	-	-	-
Urothoe poseidonis	-	-	-	-	-	-	-	-	-	-
Lysianassidae sp.	0.7	-	-	-	-	-	-	-	-	-
Hippomedon denticulatus	-	-	-	-	-	-	-	-	-	0.3
Argissa hamatipes	-	-	-	-	-	-	-	-	-	-
Atylus falcatus	0.3	-	-	-	0.7	-	-	-	-	-
Atylus swammerdami	0.3	0.3	0.7	-	0.7	-	-	-	-	-
Ampelisca sp.	-	-	-	-	-	-	-	-	-	-
Ampelisca brevicornis	-	-	-	-	-	-	-	-	-	-
Ampelisca spinipes	-	-	-	-	-	-	-	-	-	-
Bathyporeia sp.	2.7	5.7	14.0	15.7	38.3	2.0	3.3	5.3	5.3	8.0
Bathyporeia elegans	-	-	-	5.0	-	0.5	-	4.0	6.0	2.7
Bathyporeia guilliamsoniana	-	-	-	-	-	-	-	-	-	-
Bathyporeia pelagica	-	-	-	-	-	-	-	-	-	-
Bathyporeia tenuipes	4.0	0.7	1.0	-	12.0	2.0	0.3	1.7	1.3	24.7
Haustorius arenarius	-	-	-	-	-	-	-	-	-	-
Megaluropus agilis	-	-	-	-	1.3	-	-	-	-	-
Melita sp.	-	-	-	-	-	-	-	-	-	-

Taxon	**October 1996**					**March 1996**				
	CB 19	**CB20**	**CB21**	**CB22**	**CB23**	**CB19**	**CB20**	**CB21**	**CB22**	**CB23**
Melita obtusata	-	-	-	-	-	-	-	-	-	-
Melita palmata	-	-	-	-	-	-	-	-	-	-
Microprotopus maculatus	2.3	2.7	0.7	-	-	-	-	-	-	-
Photis sp.	-	-	-	-	-	-	-	-	-	-
Photis reinhardi	-	-	-	-	-	-	-	-	-	-
Microjassa cumbrensis	-	-	-	-	-	-	-	-	-	-
Aoridae sp.	-	-	-	-	-	-	-	-	-	-
Siphonoecetes kroyeranus	-	-	-	-	-	-	-	-	-	-
Pariambus typicus	4.7	2.3	-	-	-	0.5	0.3	-	-	-
Eurydice pulchra	-	-	-	-	-	-	-	-	-	-
Sphaeroma monodi	-	-	-	-	-	-	-	-	-	-
Idotea linearis	-	-	-	-	-	-	-	-	-	-
Tanaidae sp.	-	-	-	-	-	-	-	-	-	-
Bodotria arenosa	-	-	-	-	-	-	-	-	-	-
Bodotria pulchella	-	-	-	-	-	-	-	-	-	-
Iphinoe trispinosa	6.0	19.0	12.7	0.3	3.0	-	0.7	4.7	0.7	0.7
Eudorella truncatula	-	-	-	-	-	-	-	-	-	-
Pseudocuma sp.	10.3	23.7	25.3	0.7	9.3	0.5	2.7	7.0	3.3	-
Pseudocuma gilsoni	-	-	-	-	-	-	-	-	-	-
Pseudocuma longicornis	-	-	-	-	-	-	-	-	-	-
Diastylis sp.	-	-	-	-	-	-	-	-	-	-
Diastylis bradyi	0.7	1.0	0.3	0.3	0.3	0.5	-	-	-	-
Diastylis lucifera	-	-	-	-	-	-	-	-	-	-
Diastylis rugosa	-	-	-	-	-	-	-	-	-	-
Processa canaliculata	-	0.3	-	-	-	-	-	-	-	-
Crangon crangon	-	0.3	-	-	-	-	-	-	-	-
Diogenes pugilator	-	-	0.7	-	-	-	-	-	0.7	-

Taxon	October 1996					March 1996				
	CB 19	CB20	CB21	CB22	CB23	CB19	CB20	CB21	CB22	CB23
Paguridae sp.	-	-	-	-	-	-	-	-	-	-
Pagurus pubescens	-	-	-	-	-	-	-	-	-	-
Corystes cassivelaunus	-	-	-	-	-	-	-	-	-	-
Liocarcinus sp.	-	-	-	-	-	-	-	-	-	-
Liocarcinus holsatus	-	-	0.3	-	-	-	-	-	-	-
Onoba semicostata	-	-	-	-	-	-	-	-	-	-
Hyala vitrea	-	-	-	-	-	-	-	-	-	-
Pyramidellidae	-	-	-	-	-	-	-	-	-	-
Turbonilla sp.(juv.)	-	-	-	-	-	-	-	-	-	-
Turbonilla lactea	-	-	-	-	-	-	-	-	-	-
Turbonilla acuta	-	-	-	-	2.0	1.5	0.3	-	-	4.3
Polinices pulchellus	-	-	0.3	1.0	0.3	-	-	-	-	-
Euspira catena	-	-	-	-	-	-	-	-	-	-
Hinia reticulata	-	-	-	-	-	-	0.3	-	-	-
Mangelia brachystoma	1.7	1.0	0.7	-	0.3	-	0.3	-	-	0.7
Acteon tornatilis	0.7	-	-	-	-	0.5	-	-	-	-
Cylichna cylindracea	0.3	0.3	-	-	0.7	-	0.3	-	-	-
Roxania utriculus	-	-	-	-	-	-	-	-	-	-
Philine aperta	3.3	-	-	-	-	0.5	-	-	-	-
Philine scabra	-	-	-	-	-	-	0.3	-	-	-
Nucula sp.	-	-	-	-	-	-	-	-	-	-
Nucula nitidosa	14.0	0.3	-	-	0.7	10.0	0.7	-	-	-
Mytilidae sp.	1.7	1.0	3.7	1.0	29.3	1.5	2.7	1.0	-	5.0
Modiolus modiolus	-	-	-	-	-	-	-	-	-	-
Montacuta substriata	-	-	-	-	-	-	-	-	-	-
Mysella bidentata	0.7	0.7	-	-	2.0	-	1.0	-	-	0.7
Tellimya ferruginosa	-	-	0.7	2.3	0.3	-	1.0	6.7	2.3	-

Taxon	October 1996					March 1996				
	CB 19	CB20	CB21	CB22	CB23	CB19	CB20	CB21	CB22	CB23
Acanthocardia	-	-	-	-	-	-	-	-	-	-
Acanthocardia echinata	-	-	-	-	-	0.5	-	-	-	-
Mactridae sp.	-	-	0.3	-	-	-	-	-	-	-
Mactra stultorum	-	-	-	-	-	-	-	-	-	-
Spisula elliptica	-	-	-	-	-	-	-	-	-	-
Spisula subtruncata	-	-	-	-	-	-	-	-	-	-
Ensis sp.	-	0.3	-	-	0.7	1.0	-	-	-	-
Ensis siliqua	-	-	-	-	-	-	-	-	-	-
Ensis ensis	-	-	-	-	0.3	-	-	-	-	-
Phaxas pellucidus	4.0	2.7	-	-	1.7	-	-	-	-	-
Tellinidae unident	-	-	-	-	-	-	0.7	12.0	2.0	-
Fabulina fabula	27.7	16.7	26.7	11.0	10.3	23.5	16.3	5.0	2.0	10.7
Donax vittatus	1.3	2.3	16.3	6.7	-	-	-	1.3	2.0	-
Gari fervensis	-	-	-	-	-	-	-	-	-	-
Abra sp. (juv)	-	-	-	-	-	1.0	1.7	1.3	0.3	2.0
Abra alba	66.0	103.0	14.0	-	27.3	8.5	1.7	-	-	1.3
Abra prismatica	-	-	-	-	1.3	-	-	-	-	-
Pharus legumen	-	-	-	-	-	-	-	0.3	-	-
Arctica islandica	-	-	-	-	-	-	-	-	-	-
Dosinia sp. (juv)	-	-	-	-	0.3	-	-	-	-	-
Venerupis senegalensis	-	-	-	-	-	-	-	-	-	-
Chamelea gallina	7.0	8.0	1.0	-	1.3	8.0	6.7	0.7	0.3	1.3
Mya truncata	-	-	-	-	-	-	-	-	-	-
Corbula gibba	-	-	-	-	-	-	0.3	-	-	0.3
Thracia sp.	-	-	-	-	-	0.5	-	-	-	-
Thracia phaseolina	-	-	-	-	-	-	0.3	-	-	-
Thracia villosiuscula	1.7	0.3	-	-	0.3	6.5	0.3	-	-	0.7

Taxon	October 1996					March 1996				
	CB 19	CB20	CB21	CB22	CB23	CB19	CB20	CB21	CB22	CB23
Cochlodesma praetenue	-	-	-	-	-	-	-	-	-	-
Phoronis sp.	5.3	2.0	0.3	-	1.7	7.0	3.3	0.3	0.3	-
Astropecten irregularis	-	-	-	-	-	-	-	-	-	-
Asterias rubens	-	-	-	-	-	-	-	-	-	-
Amphiura sp. (juv.)	8.0	3.3	-	1.0	5.0	2.5	0.7	0.3	-	0.7
Amphiura brachiata	-	-	-	-	-	-	-	-	-	-
Amphiura chiajei	0.3	-	0.3	-	0.3	-	0.3	-	-	0.3
Amphiura filiformis	-	-	-	-	-	-	-	-	-	-
Ophiura sp. (juv.)	1.7	-	-	-	0.3	-	-	0.3	-	-
Ophiura ophiura	1.7	-	-	-	-	-	-	-	-	0.3
Echinocyamus pusillus	-	-	-	-	-	-	-	-	-	-
Echinocardium sp. (juv.)	-	-	-	-	0.7	-	-	0.3	-	-
Echinocardium cordatum	-	0.3	0.3	4.3	1.3	-	0.3	1.3	0.7	-
Holothurioidea sp.	-	-	-	-	-	-	-	-	-	-

Taxon	November-1998				April-1999				September-1999				May-2000			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Sagartia troglodytes	-	-	-	-	-	-	-	-	2	-	1	-	-	-	-	-
Edwardsia callimorpha	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NEMERTEA	3	-	10	-	2	-	1	-	1	-	-	-	22	26	22	21
Tubulanus polymorphus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cerebratulus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SIPUNCULA	1	-	1	-	1	-	-	-	-	1	19	17	4	12	10	7
Phascolion strombi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aphroditidae sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Harmothoe glabra	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Harmothoe lunulata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pholoe sp.	-	-	-	-	-	-	-	-	-	6	27	25	-	-	-	-
Pholoe inornata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sigalion mathildae	7	2	10	3	5	7	7	6	32	27	28	12	9	5	8	9
Sthenelais sp.	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Sthenelais boa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sthenelais limicola	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eteone sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Etone longa	1	1	-	-	1	1	1	2	4	2	1	-	-	1	2	3
Hesionura elongata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phyllodoce sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phyllodocedae groenlandica	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Phyllodocedae rosea	-	-	-	-	2	-	-	-	1	-	1	1	14	14	8	12
Eulalia sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eumida sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eumida bahusiensis	-	1	-	-	-	-	3	-	1	1	8	1	-	-	-	-
Paranaitis kosteriensis	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-
Glycera sp.	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Taxon	November-1998				April-1999				September-1999				May-2000			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Glycera alba	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Glycera tridactyla	-	-	3	2	2	3	4	1	23	16	19	8	2	6	-	8
Goniada maculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hesionidae sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gyptis helgolandicus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Podarkeopsis helgolandica	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Kefersteinia cirrata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Exogone sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Exogone naidina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Autolytus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nereis longissima	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nephtys sp. (juv.)	-	-	-	-	-	-	-	-	-	1	-	2	16	18	24	17
Nephtys assimilis	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nephtys cirrosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nephtys hombergi	-	-	-	-	1	3	3	1	7	7	6	1	4	-	3	-
Nephtys kersivalensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lumbrineris sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lumbrineris latreilli	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lumbrineris gracilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dorvilleidae unident	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Orbinia latreillii	1	1	3	-	-	-	1	1	1	-	1	-	-	1	1	-
Scoloplos armiger	2	1	12	4	7	7	6	5	9	10	8	6	3	2	8	5
Aricidea catherinae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Poecilochaetus serpens	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Spionidae unident	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aonides paucibranchiata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polydora sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pseudopolydora sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Taxon	November-1998				April-1999				September-1999				May-2000			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Pseudopolydora pulchra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Scolelepis sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Scolelepis squamata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nerinides sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Spio sp.	56	-	39	1	21	6	12	5	43	46	78	44	41	33	34	34
Spiophanes bombyx	26	30	41	13	31	27	34	37	97	193	192	103	117	154	126	133
Magelona sp. (juv.)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Magelona alleni	2	-	-	-	-	-	-	-	1	-	-	2	-	2	-	-
Magelona filiformis	54	6	74	6	82	87	89	74	198	141	157	152	64	182	154	106
Magelona mirablis	-	-	-	-	1	-	-	-	-	-	1	3	-	-	-	-
Magelona johnstoni	12	1	9	4	3	3	7	6	37	28	23	22	-	32	6	5
Cirratulidae unident.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Caulleriella sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Caulleriella zetlandica	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chaetozone setosa	69	2	93	11	69	38	68	87	210	186	425	221	150	160	199	138
Chaetozone gibber	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aphelochaeta sp.	-	-	-	-	-	-	-	-	5	15	17	5	-	-	-	-
Diplocirrus glaucus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Capitellidae sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Capitella capitata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mediomastus fragilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Notomastus latericeus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Euclymene sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Euclymene oerstedii	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-
Heteroclymene robusta	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Ophelina acuminata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Scalibregma inflatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Myriochele sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Taxon	November-1998				April-1999				September-1999				May-2000			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Myriochele oculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Myriochele heeri	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Galathowenia sp.	-	-	1	-	1	1	2	1	2	2	8	-	1	3	2	1
Owenia fusiformis	3	6	4	9	4	1	6	2	15	69	55	67	2	3	5	-
Pectinariidae sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lagis koreni	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ampharetidae unident	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ampharete falcata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ampharete lindstroemi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Terebellides stroemi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lanice congeliga	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Polycirrus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oligochaeta sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tubificoides sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tubificoides cf glaiciensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tubificoides benedii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Grania sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Achelia echinata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anoplodactylus petiolatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mysidae sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gastrosaccus spinifer	2	7	-	2	-	-	-	-	-	-	-	-	-	-	-	-
Paramysis arenosa	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Schistomysis spiritus	2	-	5	1	-	-	-	-	-	-	-	-	-	-	-	-
Oedicerotidae sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Perioculodes longimanus	11	-	8	1	9	6	3	-	35	43	25	31	13	16	25	16
Pontocrates sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pontocrates altamarinus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pontocrates arenarius	5	-	1	-	1	-	1	3	-	-	-	-	1	2	1	1

Taxon	November-1998				April-1999				September-1999				May-2000			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Synchelidium maculatum	6	-	8	-	1	-	1	2	1	-	1	1	2	2	5	4
Amphilochidae sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Leucothoe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Leucothoe incisa	1	-	-	-	-	-	-	-	2	1	5	3	-	-	-	-
Leucothoe lilljeborgi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stenothoidae sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Urothoe poseidonis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lysianassidae sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hippomedon denticulatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Argissa hamatipes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Atylus falcatus	-	-	-	-	-	1	1	-	-	-	-	-	-	1	-	1
Atylus swammerdami	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ampelisca sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ampelisca brevicornis	-	-	1	-	-	-	-	-	10	12	13	11	-	-	-	-
Ampelisca spinipes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bathyporeia sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bathyporeia elegans	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bathyporeia guilliamsoniana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bathyporeia pelagica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bathyporeia tenuipes	27	23	25	-	14	8	11	9	12	27	33	12	16	13	25	17
Haustorius arenarius	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Megaluropus agilis	-	-	-	-	-	-	-	1	-	1	-	-	1	-	-	-
Melita sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Melita obtusata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Melita palmata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Microprotopus maculatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Photis sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Photis reinhardi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Taxon	November-1998				April-1999				September-1999				May-2000			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Microjassa cumbrensis	-	-	-	-	-	-	1	-	11	3	5	6	-	-	-	-
Aoridae sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Siphonoecetes kroyeranus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pariambus typicus	-	-	-	-	-	-	-	-	2	2	3	-	1	4	3	5
Eurydice pulchra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sphaeroma monodi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Idotea linearis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tanaidae sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bodotria arenosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bodotria pulchella	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Iphinoe trispinosa	6	1	9	2	3	2	3	-	16	14	8	7	-	1	-	1
Eudorella truncatula	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pseudocuma sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pseudocuma gilsoni	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pseudocuma longicornis	-	-	-	-	1	3	3	14	9	4	4	13	31	48	45	35
Diastylis sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diastylis bradyi	-	-	2	1	-	-	-	-	-	-	-	-	-	-	-	-
Diastylis lucifera	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diastylis rugosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Processa canaliculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Crangon crangon	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Diogenes pugilator	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Paguridae sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pagurus pubescens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Corystes cassivelaunus	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1
Liocarcinus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Liocarcinus holsatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Onoba semicostata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Taxon	November-1998				April-1999				September-1999				May-2000			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Hyala vitrea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pyramidellidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbonilla sp.(juv.)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbonilla lactea	-	-	-	1	-	-	-	-	-	-	-	-	1	3	-	-
Turbonilla acuta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polinices pulchellus	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-
Euspira catena	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hinia reticulata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mangelia brachystoma	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Acteon tornatilis	-	-	-	-	-	-	-	-	-	5	2	10	-	-	-	-
Cylichna cylindracea	-	1	1	-	-	-	3	1	2	2	2	3	-	-	-	-
Roxania utriculus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Philine aperta	-	-	-	-	-	-	-	-	-	4	5	5	-	-	-	-
Philine scabra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nucula sp.	1	1	1	-	1	-	-	1	4	-	4	2	4	-	3	-
Nucula nitidosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mytilidae sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Modiolus modiolus	23	1	6	4	100	28	58	32	2	2	-	-	11	7	9	-
Montacuta substriata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mysella bidentata	1	1	5	5	1	1	-	2	12	13	15	-	7	7	2	2
Tellimya ferruginosa	-	-	-	-	-	-	13	-	-	2	-	-	-	-	1	4
Acanthocardia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Acanthocardia echinata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mactridae sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mactra stultorum	-	1	2	-	1	1	-	4	2	5	4	1	4	1	1	2
Spisula elliptica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Spisula subtruncata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ensis sp.	-	1	1	-	-	-	-	1	-	1	2	1	2	-	-	1

Taxon	November-1998				April-1999				September-1999				May-2000			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Ensis siliqua	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ensis ensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phaxas pellucidus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tellinidae unident	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fabulina fabula	29	46	29	44	32	23	27	28	21	32	24	29	18	12	1	2
Donax vittatus	25	38	35	27	9	8	11	7	21	69	24	44	1	6	4	13
Gari fervensis	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Abra sp. (juv)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Abra alba	18	22	23	12	-	-	-	3	23	25	32	24	3	3	6	7
Abra prismatica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pharus legumen	7	1	2	3	7	5	2	5	1	1	1	1	-	-	-	-
Arctica islandica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dosinia sp. (juv)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Venerupis senegalensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chamelea gallina	3	5	8	-	2	3	4	2	-	8	7	4	6	16	9	8
Mya truncata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Corbula gibba	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thracia sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thracia phaseolina	3	15	5	4	6	11	11	8	7	3	8	3	23	34	23	24
Thracia villosiuscula	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cochlodesma praetenue	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phoronis sp.	5	-	-	-	1	1	2	2	-	1	1	1	-	1	3	2
Astropecten irregularis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Asterias rubens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Amphiura sp. (juv.)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Amphiura brachiata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Amphiura chiajei	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Amphiura filiformis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Taxon	**November-1998**				**April-1999**				**September-1999**				**May-2000**			
	A	**B**	**C**	**D**	**A**	**B**	**C**	**D**	**A**	**B**	**C**	**D**	**A**	**B**	**C**	**D**
Ophiura sp. (juv.)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ophiura ophiura	1	1	1	1	-	-	-	-	10	1	3	2	23	26	22	21
Echinocyamus pusillus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Echinocardium sp. (juv.)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Echinocardium cordatum	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Holothurioidea sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Appendix 5.2 SIMPER analysis within and between season (dis)similarities

Within Season Similarity Table November 1998. Average similarity: 54.85

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Fabulina fabula	37.00	11.00	1.81	20.06	20.06
Donax vittatus	31.25	9.11	3.15	16.60	36.66
Spiophanes bombyx	27.50	6.31	3.36	11.51	48.17
Abra alba	18.75	5.02	4.19	9.15	57.32
Chaetozone setosa	43.75	4.13	0.73	7.53	64.86
Magelona filiformis	35.00	3.78	0.93	6.89	71.75
Bathyporeia tenuipes	18.75	3.23	0.90	5.88	77.63
Spio sp.	24.00	1.55	0.45	2.83	80.47
Owenia fusiformis	5.50	1.36	1.52	2.49	82.95
Thracia phaseolina	6.75	1.24	2.48	2.25	85.21
Sigalion mathildae	5.50	0.96	2.71	1.75	86.96
Magelona johnstoni	6.50	0.96	1.38	1.75	88.71
Modiolus modiolus	8.50	0.85	1.61	1.54	90.25

Within Season Similarity Table April 1999. Average similarity: 78.77

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Magelona filiformis	83.00	21.72	8.58	27.57	27.57
Chaetozone setosa	65.50	14.34	4.14	18.21	45.78
Modiolus modiolus	54.50	9.28	3.89	11.78	57.56
Spiophanes bombyx	32.25	8.08	14.36	10.26	67.82
Fabulina fabula	27.50	6.89	20.53	8.75	76.57
Bathyporeia tenuipes	10.50	2.41	15.76	3.06	79.63
Donax vittatus	8.75	2.11	9.56	2.67	82.31
Thracia phaseolina	9.00	2.09	3.09	2.65	84.96
Spio sp.	11.00	1.76	2.93	2.23	87.19
Sigalion mathildae	6.25	1.57	4.74	1.99	89.18
Scoloplos armiger	6.25	1.56	5.92	1.98	91.16

Within Season Similarity Table September 1999. Average similarity: 77.52

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Chaetozone setosa	260.50	19.41	8.14	25.04	25.04
Magelona filiformis	162.00	14.31	9.13	18.46	43.50
Spiophanes bombyx	146.25	10.97	4.00	14.15	57.65
Spio sp.	52.75	4.25	11.40	5.49	63.13
Owenia fusiformis	51.50	3.52	1.52	4.54	67.67
Perioculodes longimanus	33.50	2.82	4.19	3.63	71.30
Donax vittatus	39.50	2.52	2.55	3.25	74.56
Abra alba	26.00	2.30	11.76	2.96	77.52
Magelona johnstoni	27.50	2.27	6.39	2.93	80.45
Fabulina fabula	26.50	2.27	5.99	2.92	83.37
Sigalion mathildae	24.75	1.88	2.51	2.42	85.79
Bathyporeia tenuipes	21.00	1.38	2.99	1.78	87.57
Glycera tridactyla	16.50	1.19	2.71	1.54	89.11
Ampelisca brevicornis	11.50	1.03	12.69	1.33	90.45

Within Season Similarity Table May 2000. Average similarity: 82.52

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Chaetozone setosa	161.75	19.81	15.05	24.01	24.01
Spiophanes bombyx	132.50	16.69	15.26	20.22	44.23
Magelona filiformis	126.50	12.40	3.18	15.03	59.27
Pseudocuma longicornis	39.75	4.69	10.87	5.68	64.95
Spio sp.	35.50	4.57	10.40	5.54	70.49
Thracia phaseolina	26.00	3.16	12.38	3.83	74.31
Ophiura ophiura	23.00	2.95	12.57	3.58	77.89
NEMERTEA	22.75	2.93	13.12	3.55	81.44
Nephtys sp.	18.75	2.27	19.05	2.75	84.19
Bathyporeia tenuipes	17.75	2.01	5.27	2.44	86.63
Perioculodes longimanus	17.50	1.97	12.23	2.38	89.01
Phyllodocedae rosea	12.00	1.42	3.45	1.72	90.73

Between Season Similarity Table November 1998 & April 1999. Average Dissimilarity 47.99

Species	Nov. 98 Av.Abund	April 99 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Magelona filiformis	35.00	83.00	8.22	1.31	17.12	17.12
Modiolus modiolus	8.50	54.50	6.87	1.50	14.31	31.43
Chaetozone setosa	43.75	65.50	6.51	1.32	13.57	45.01
Donax vittatus	31.25	8.75	3.45	2.84	7.18	52.19
Spio sp.	24.00	11.00	3.20	1.62	6.67	58.86
Abra alba	18.75	0.75	2.67	3.78	5.56	64.42
Bathyporeia tenuipes	18.75	10.50	2.01	4.21	4.18	68.60
Fabulina fabula	37.00	27.50	1.81	1.11	3.76	72.37
Spiophanes bombyx	27.50	32.25	1.54	1.12	3.20	75.56
Thracia phaseolina	6.75	9.00	0.82	1.96	1.70	77.26
Pseudocuma longicornis	0.00	5.25	0.81	0.96	1.70	78.96
Perioculodes longimanus	5.00	4.50	0.71	1.43	1.48	80.44
Scoloplos armiger	4.75	6.25	0.64	2.68	1.34	81.78
Magelona johnstoni	6.50	4.75	0.60	1.81	1.26	83.03
Owenia fusiformis	5.50	3.25	0.52	1.03	1.08	84.11
Sigalion mathildae	5.50	6.25	0.48	1.59	0.99	85.11
Tellimya ferruginosa	0.00	3.25	0.47	0.55	0.98	86.08
Gastrosaccus spinifer	2.75	0.00	0.46	0.98	0.96	87.05
Synchelidium maculatum	3.50	1.00	0.46	1.40	0.95	88.00
Iphinoe trispinosa	4.50	2.00	0.45	1.48	0.93	88.93
Pharus legumen	3.25	4.75	0.42	1.53	0.88	89.81
NEMERTEA	3.25	0.75	0.41	0.93	0.86	90.66

Between Season Similarity Table November 1998 & September 1999. Average dissimilarity = 62.26

Species	Nov. 98 Av.Abund	Sept. 98 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Chaetozone setosa	43.75	260.50	15.92	2.39	25.58	25.58
Magelona filiformis	35.00	162.00	9.88	2.36	15.87	41.45
Spiophanes bombyx	27.50	146.25	8.68	2.70	13.93	55.38
Owenia fusiformis	5.50	51.50	3.39	1.92	5.45	60.83
Spio sp.	24.00	52.75	2.54	1.41	4.08	64.91
Perioculodes longimanus	5.00	33.50	2.21	2.59	3.54	68.46
Magelona johnstoni	6.50	27.50	1.64	2.11	2.63	71.08
Sigalion mathildae	5.50	24.75	1.46	1.98	2.34	73.42
Donax vittatus	31.25	39.50	1.29	1.24	2.07	75.49
Glycera tridactyla	1.25	16.50	1.14	2.32	1.83	77.32
Phloe sp.	0.00	14.50	1.04	1.18	1.68	79.00
Bathyporeia tenuipes	18.75	21.00	0.92	1.44	1.48	80.48
Fabulina fabula	37.00	26.50	0.90	1.22	1.45	81.93
Ampelisca brevicornis	0.25	11.50	0.84	7.02	1.35	83.28
Aphelochneta sp.	0.00	10.50	0.75	2.11	1.20	84.48
SIPUNCULA	0.50	9.25	0.65	1.00	1.04	85.52
Mysella bidentata	3.00	10.00	0.62	2.23	1.00	86.52
Pseudocuma longicornis	0.00	7.50	0.59	1.65	0.95	87.47
Iphinoe trispinosa	4.50	11.25	0.57	1.36	0.91	88.38
Modiolus modiolus	8.50	1.00	0.55	0.91	0.88	89.26
Abra alba	18.75	26.00	0.54	1.25	0.86	90.12

Between Season Similarity Table April 1999 & Group September 1999. Average dissimilarity = 58.50

Species	April 99 Av.Abund	Sept. 99 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Chaetozone setosa	65.50	260.50	13.48	2.55	23.04	23.04
Spiophanes bombyx	32.25	146.25	7.93	2.83	13.56	36.60
Magelona filiformis	83.00	162.00	5.78	2.73	9.88	46.48
Modiolus modiolus	54.50	1.00	3.80	1.86	6.49	52.97
Owenia fusiformis	3.25	51.50	3.44	2.03	5.88	58.85
Spio sp.	11.00	52.75	2.92	3.39	5.00	63.85
Donax vittatus	8.75	39.50	2.24	1.53	3.83	67.68
Perioculodes longimanus	4.50	33.50	2.12	3.28	3.63	71.30
Abra alba	0.75	26.00	1.80	13.92	3.07	74.38
Magelona johnstoni	4.75	27.50	1.67	2.79	2.85	77.23
Sigalion mathildae	6.25	24.75	1.32	2.22	2.25	79.48
Glycera tridactyla	2.50	16.50	1.00	2.24	1.71	81.19
Phloe sp.	0.00	14.50	1.00	1.19	1.71	82.91
Ampelisca brevicornis	0.00	11.50	0.82	15.95	1.41	84.31
Bathyporeia tenuipes	10.50	21.00	0.73	1.28	1.25	85.57
Aphelochneta sp.	0.00	10.50	0.72	2.14	1.23	86.80
Iphinoe trispinosa	2.00	11.25	0.68	1.98	1.16	87.96
Mysella bidentata	1.00	10.00	0.66	1.88	1.13	89.09
SIPUNCULA	0.25	9.25	0.63	1.02	1.07	90.16

Between Season Similarity Table November 1998 & May 2000 Average dissimilarity = 63.52

Species	Nov. 98 Av.Abund	May 00 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Chaetozone setosa	43.75	161.75	11.77	2.13	18.53	18.53
Spiophanes bombyx	27.50	132.50	10.18	4.27	16.03	34.57
Magelona filiformis	35.00	126.50	8.94	1.71	14.08	48.64
Pseudocuma longicornis	0.00	39.75	3.79	6.36	5.97	54.61
Fabulina fabula	37.00	8.25	2.86	2.11	4.51	59.12
Spio sp.	24.00	35.50	2.46	1.52	3.86	62.98
Donax vittatus	31.25	6.00	2.45	2.92	3.85	66.84
Ophiura ophiura	1.00	23.00	2.12	6.31	3.34	70.18
NEMERTEA	3.25	22.75	1.92	3.03	3.02	73.20
Thracia phaseolina	6.75	26.00	1.81	3.07	2.86	76.06
Nephtys sp.	0.00	18.75	1.80	5.36	2.84	78.89
Abra alba	18.75	4.75	1.32	2.94	2.08	80.98
Perioculodes longimanus	5.00	17.50	1.24	1.73	1.95	82.93
Phyllodocedae rosea	0.00	12.00	1.17	3.47	1.84	84.77
Bathyporeia tenuipes	18.75	17.75	1.01	1.44	1.60	86.37
Magelona johnstoni	6.50	10.75	0.91	1.03	1.43	87.80
Modiolus modiolus	8.50	6.75	0.74	1.38	1.16	88.96
SIPUNCULA	0.50	8.25	0.73	2.65	1.15	90.11

Between Season Similarity Table April 1999 & May 2000. Average dissimilarity = 51.33

Species	April 99 Av.Abund	May 00 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Spiophanes bombyx	32.25	132.50	9.11	8.34	17.74	17.74
Chaetozone setosa	65.50	161.75	8.75	3.24	17.05	34.79
Magelona filiformis	83.00	126.50	4.59	1.66	8.94	43.73
Modiolus modiolus	54.50	6.75	4.27	1.67	8.31	52.05
Pseudocuma longicornis	5.25	39.75	3.10	5.04	6.04	58.08
Spio sp.	11.00	35.50	2.29	2.68	4.45	62.54
Ophiura ophiura	0.00	23.00	2.10	10.57	4.09	66.62
NEMERTEA	0.75	22.75	2.01	9.32	3.91	70.53
Fabulina fabula	27.50	8.25	1.73	2.46	3.38	73.91
Nephtys sp.	0.00	18.75	1.70	7.05	3.32	77.22
Thracia phaseolina	9.00	26.00	1.53	4.20	2.97	80.20
Perioculodes longimanus	4.50	17.50	1.17	2.40	2.28	82.48
Phyllodocedae rosea	0.50	12.00	1.06	3.57	2.07	84.55
Magelona johnstoni	4.75	10.75	0.76	0.84	1.48	86.02
SIPUNCULA	0.25	8.25	0.71	3.02	1.38	87.41
Bathyporeia tenuipes	10.50	17.75	0.68	1.53	1.32	88.73
Chamelea gallina	2.75	9.75	0.61	2.03	1.20	89.93
Donax vittatus	8.75	6.00	0.46	1.83	0.89	90.82

Between Season Similarity Table September 1999 & May 2000. Average dissimilarity = 37.38

Species	Sept. 99 Av.Abund	May 00 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Chaetozone setosa	260.50	161.75	5.34	1.11	14.28	14.28
Magelona filiformis	162.00	126.50	2.93	1.21	7.85	22.13
Owenia fusiformis	51.50	2.50	2.76	2.08	7.38	29.52
Spiophanes bombyx	146.25	132.50	2.57	2.43	6.88	36.40
Donax vittatus	39.50	6.00	1.92	1.62	5.13	41.53
Pseudocuma longicornis	7.50	39.75	1.80	5.22	4.82	46.35
NEMERTEA	0.25	22.75	1.28	9.91	3.41	49.76
Abra alba	26.00	4.75	1.19	7.99	3.19	52.95
Thracia phaseolina	5.25	26.00	1.18	3.97	3.15	56.10
Magelona johnstoni	27.50	10.75	1.15	1.81	3.07	59.17
Ophiura ophiura	4.00	23.00	1.07	4.83	2.87	62.04
Fabulina fabula	26.50	8.25	1.03	2.08	2.77	64.81
Nephtys sp.	0.75	18.75	1.02	5.80	2.72	67.53
Sigalion mathildae	24.75	7.75	0.95	2.06	2.55	70.08
Perioculodes longimanus	33.50	17.50	0.93	1.86	2.50	72.58
Spio sp.	52.75	35.50	0.91	1.26	2.42	75.00
Phloe sp.	14.50	0.00	0.80	1.20	2.13	77.13
Glycera tridactyla	16.50	4.00	0.71	1.82	1.89	79.02
Ampelisca brevicornis	11.50	0.00	0.65	14.31	1.74	80.75
Phyllodocedae rosea	0.75	12.00	0.64	3.82	1.72	82.47
Iphinoe trispinosa	11.25	0.50	0.62	2.37	1.66	84.13
Aphelochneta sp.	10.50	0.00	0.57	2.06	1.53	85.66
SIPUNCULA	9.25	8.25	0.49	2.57	1.32	86.98
Bathyporeia tenuipes	21.00	17.75	0.49	1.62	1.32	88.30
Mysella bidentata	10.00	4.50	0.43	2.43	1.16	89.46
Microjassa cumbrensis	6.25	0.00	0.36	1.81	0.97	90.43

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