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LARGE-SCALE SPATIAL PATTERNS IN THE COMMUNITY STRUCTURE OF BENTHIC HARPACTICOID COPEPODS IN THE BOHAI SEA, CHINA

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ABSTRACT. - To determine the effects of natural and anthropogenic variables on the benthic harpacticoid copepod assemblages of the Bohai Sea, China, samples were collected on two occasions from an extensive grid of 20 stations. Differences among stations between sampling periods, although significant, were a consequence of small changes in abundances of dominant species. This is interpreted as a seasonal effect. Differences between stations were significant, and were used to cluster stations into groups with similar species composition. These station groupings reveal a weak faunal gradient leading from the mouth of the Huanghe (Yellow River) to the Bohai Strait. Analyses relating faunal composition to environmental variables showed that there were significant differences in environmental variables between faunally defined groups of stations. The variables most closely correlated with community structure were those related to natural processes within the Bohai Sea, namely silt/clay content, depth and phaeopigment concentrations at the sediment surface. The Huanghe is the most turbid river in the world, and its inputs into the Bohai Sea are the primary factors affecting variation in community structure of the copepods. A suite of univariate measures are related to distance from the river mouth. Analyses do not suggest strong large-scale pollution gradients within the study area.

KEY WORDS. – Copepods, Biodiversity, Pollution, Bohai Sea, Yellow River.

INTRODUCTION

The Bohai Sea, approximately 77, 000 km^2 in area, is a marginal sea with restricted water-exchange enclosed by the Liaodong and Shandong peninsulas and connected to the Huanghai (Yellow Sea) by the Bohai Strait (Fig. 1). It is shallow, with a maximum depth of 86 m (in the Bohai Strait) and an average depth of 18 m (Geng, 1981). The area is of great commercial importance, providing important spawning and feeding grounds for many species of fish and shellfish and supporting extensive fisheries and mariculture, particularly of prawns, bivalve molluscs, holothurians and nudibranchs. In recent years the Bohai Sea has also been subject to intensive offshore exploration for, and production of, natural gas and petroleum reserves (Fan & Zhang, 1988). The Bohai Sea is considered to be highly polluted, and the state of the environment in the area is of great concern to the Chinese government and agencies, which invest considerable effort in measuring and monitoring environmental variables (Xu & Zheng, 1991). Despite this, little information is available to the wider scientific community.

Although overfishing was recognised as a problem in 1955, when certain areas were closed to fishing, the Bohai Sea has no closed fishing seasons, and overfishing has depleted many species. In the early 1970s industrial and domestic expansion on the shores of, and in the catchments of rivers entering, the Bohai

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began to create pollution and to have deleterious impacts on aquatic life, particularly in the intertidal zone (Fan, 1989). Approximately 137 rivers flow into the Bohai Sea, bringing in some 2.8 × 10^9 t of waste water and 7 × 10^5 t of other pollutants each year. This approximates 50% of China's total maritime discharge of pollutants. According to the Chinese State Environmental Administration the combination of pollution, from excessive amounts of waste water (including industrial effluent) and untreated sewage, and overfishing has severely depleted marine resources in the Bohai Sea. Red tides have become frequent, occurring more than 30 times in the Bohai Sea between 1991 and 1998. Although the blooms are not generally toxic they damage fishery resources by reducing oxygen levels, with losses since 1990 running into millions of dollars.

In order to assess the impacts of energy exploration and increased pollution on mariculture activities a national and international oceanographic and ecosystem study of the Bohai Sea has been launched, which includes annual sampling for benthos, including meiofauna, from a large-scale grid of stations. Large-scale studies are useful precursors to applied monitoring programmes (Schratzberger et al., 2000). Published ecological studies of the biota inhabiting the sediments in the Bohai sea have examined the composition of the macrofauna (Zhang et al., 1990b, c; Sun & Liu, 1991). Meiofauna have evoked considerable interest as potential indicators of anthropogenic perturbation in aquatic ecosystems (see review by Coull & Chandler, 1992) as they have several potential advantages over macrofauna, which have traditionally been the component of the benthos examined in pollution monitoring surveys. These include their small size and high densities, so smaller samples may be collected, shorter generation times and the absence of a planktonic phase in their life-cycles, suggesting a shorter response time and higher sensitivity to anthropogenic disturbance (Heip et al., 1988; Warwick, 1993). Few ecological examinations have dealt with meiofauna in the Bohai Sea, other than preliminary studies of the abundance and biomass in the subaquatic delta of Huanghe (Zhang et al., 1989, 1990a).

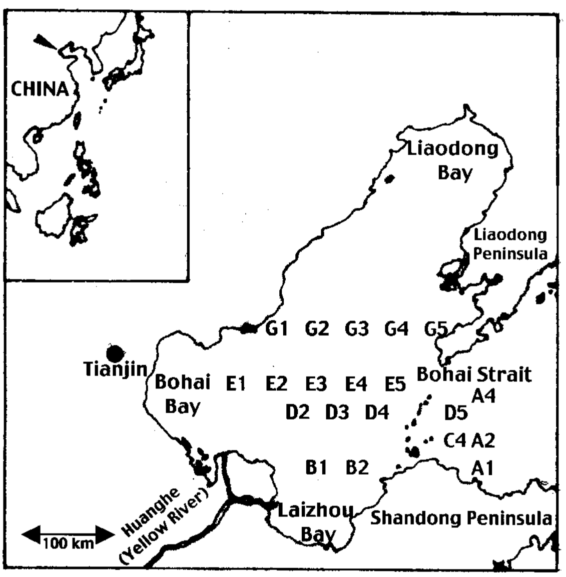

Fig. 1. Map of the Bohai Sea, showing major geographical features and sampling stations.

Harpacticoid copepods are usually the secondmost abundant meiofaunal taxon collected in benthic samples, and are common in all sediment and epibenthic biotopes. Their widespread occurrence, robust bodies, well-elucidated taxonomy and lower spatial heterogeneity (in comparison with nematodes) potentially make harpacticoids a suitable meiofaunal group for pollution monitoring purposes (Heip, 1980; Sandulli & De Nicola-Giudici, 1990; Sandulli & De Nicola, 1991) and they have been shown to be sensitive to a range anthropogenic disturbances (Coull & Chandler, 1992). In some studies copepods have been shown to be more sensitive than nematodes to certain types of disturbance (Heip et al., 1988).

Chen (1986), in a brief review of Chinese marine copepods, stated that 27 (primarily planktonic) species of copepods were known from the Bohai Sea. Shen & Bai (1956) studied the harpacticoid copepods of the region, describing 5 species from fishfarms in the coastal areas of the Bohai Sea. More recently Gee & Mu (2000) and Mu & Gee (2000) described new genera and species from the area. This study explores relationships between harpacticoid copepod community structure and environmental variables in samples from the large-scale sampling programme in the Bohai Sea and has two objectives: 1. To document large-scale patterns in harpacticoid community structure in the Bohai Sea, and 2. To relate the observed patterns to measured environmental variables reflecting natural and anthropogenic influences.

MATERIAL AND METHODS

Field Sampling. - A grid of 20 stations, giving a broad geographic coverage of the Bohai Sea and the Bohai Strait (Fig. 1) was selected. Samples were collected from each station during cruises on board the RV DON FANHONG II in September 1998 and again in April/May 1999. Two replicate samples were collected

Table 1. Suite of environmental variables measured.

Total Hydrocarbons	Total organic content	Sediment water content
Cu	Total Chlorophyll a	Gravel fraction
Pb	Chlorophyll a 0-2 cm in sediment	Sand fraction
Cr	Chlorophyll a 2-5 cm in sediment	Silt fraction
As	Total phaeopigments	Clay fraction
Hg	Phaeopigments 0-2 cm in sediment	Silt/clay fraction
Cd	Phaeopigments 2-5 cm in sediment	Median particle diameter
		Quartile deviation
		Skewness
		Sorting
		Water depth

from each station during the first cruise, and one in the second. Undisturbed sediments were brought on-deck using a modified 0.1 m^2 Gray-O'Hara box-corer. In order to reduce the influence of small-scale spatial variability within box-cores, three subsamples from each box-core were taken using a sawn-off syringe (internal diameter 26 mm) to a depth of 50 mm, taking care to avoid core-compression in the process. These subsamples were pooled and preserved in 5 % formalin pending further analysis. Additional samples for the later determination of environmental variables were also collected from each station and frozen at –20 °C.

Faunal Analysis. - Samples were stained with Rose-Bengal for 24 hrs and then washed on a 48 mm sieve to remove formalin and some of the fine sediment fraction. Heavier sediment particles were extracted from the remaining sample using centrifugation in Ludox-TM with a specific gravity adjusted to 1.15 (Heip et al., 1985; Warwick et al., 1998). The remaining light sample fraction was washed into a lined petri-dish and copepods were picked out. All copepods in each sample were identified to putative species using a compound microscope, differential interference contrast and bright-field illumination, and a × 100 oil immersion lens. Where necessary specimens were dissected and mounted in lactophenol.

Analyses of environmental variables. - Table 1 summarises the environmental variables measured. Following extraction of dried sediment with C_6H_6, oil content was determined using fluorescent spectrophotometry. As, Cu, Pb, Cr and Cd concentrations were determined by non-flame atomic absorption spectrophotometry following digestion with $HClO_4$-HNO_3. Hg concentrations were determined using cold atomic spectrofluorometry following digestion with HNO_3-H_2O_2. Organic content was determined by titrating, with $FeSO_4$, the excess $K_2Cr_2O_7$ not reduced after sediments were digested with a $K_2Cr_2O_7$-H_2SO_4 mixture. For the determination of chlorophyll a and phaeopigment concentrations samples were extracted using acetone in the dark and analysed spectrophotometrically. For the determination of granulometry of particles > 63 μm in diameter sediment samples were wet-sieved, and the different fractions dried at 95°C and weighed. Pipette analysis was used to determine the distribution of particles < 63 μm in diameter.

Data analyses. - For the majority of analyses non-parametric multivariate techniques were used. Most of these techniques are discussed by Clarke (1993) and Clarke & Warwick (2001), and are included in PRIMER (Plymouth Routines In Multivariate Ecological Research) version 5.2, a suite of computer programs developed at the Plymouth Marine Laboratory. Copepods varied in abundance between single individuals and hundreds of specimens within samples, so a square root transformation was applied in analyses examining variation in the whole copepod assemblage to reduce the influence of overdominance by numerically abundant species. The significance of Spearman rank correlations (ρ) adjusted for ties (Kendall, 1970) between corresponding elements in similarity/dissimilarity matrices was determined using the non-parametric Mantel test RELATE (Clarke & Warwick, 2001; Somerfield et al., 1995). Relationships between multivariate community structure and environmental variables were examined using BVSTEP (Clarke & Warwick, 1998), a stepwise algorithm which sets out to select subsets of variables from one matrix which maximise the correlation between their intersample distances (defined in terms of some similarity or dissimilarity measure), and another similarity/dissimilarity matrix. In this case the algorithm was used to select the subset of environmental variables from which a normalised Euclidean distance matrix provided the 'best match' with a Bray-Curtis similarity matrix derived from √-transformed nematode abundances. Species contributing to dissimilarities between cruises were investigated using the two-way similarities percentages procedure SIMPER2 (Platell et al., 1998), and between stations using the one-way similarities percentages procedure SIMPER (Clarke, 1993).

Univariate measures calculated included: total abundance (*A*), number of species (*S*), Shannon-Wiener diversity index (*H'*, calculated using natural logarithms), Pielou's evenness measure (*J'*) and Simpson's dominance index (λ).

RESULTS

A total of 115 putative species of copepods were identified. Other meiofaunal taxa ocurring in samples included Nematoda, Polychaeta, Oligochaeta, Pelycypoda, Kinorhyncha, Gastrotricha, Turbellaria, Acari, Ostracoda and Cumacea. Harpacticoids were the second-most abundant group after the nematodes, with mean abundances of 66 individuals.10cm^{-2} in samples from the first cruise, and 51 individuals. 10cm^{-2} from the second.

This study is concerned with patterns of small animals (requiring small samples) over a large area. In order to be assured that conclusions drawn from the dataset are robust two facts need to be confirmed. The first is that the spatial patterns observed are consistent, and not a chance consequence of sampling. The second is that these patterns are consistent through time. The minimal replication within the sampling design is adequate for two-way ANOSIM tests addressing these issues. Two-way crossed ANOSIM reveals that differences between stations were highly significant (R = 0.963, $p < 0.001$). There was also a significant difference in copepod community structure between the two cruises (R = 1.0, $p < 0.001$). Two-way SIMPER2 indicates that the species contributing most to dissimilarities between sampling periods were present on both occasions, and while some species increased in abundance the majority decreased in abundance between them.

Accepting that there were differences in community structure between samples from the two cruises, RELATE tests were used to determine whether spatial patterns were consistent in time. The patterns of changes in harpacticoid community structure between stations from the two cruises are significantly correlated (ρ = 0.357, p = 0.004). Furthermore, there are significant correlations between copepod community structure in the first cruise and inter-station distances (ρ = 0.342, $p < 0.001$) and variation in the measured environmental variables (ρ = 0.262, p = 0.027). Although the harpacticoid community structure from the second cruise is not significantly correlated with station location (ρ = 0.084, p = 0.173) the correlation with the measured environmental variables is significant (ρ = 0.309, p = 0.009), as is the correlation between the environmental variables and inter-station distances (ρ = 0.269, p = 0.004). These results show that the differences between different stations and relationships with the measured environmental variables are not a chance consequence of sampling and are consistent enough to be interpreted. In order to examine the large-scale variation in community structure across stations in more detail a Bray-Curtis similarity matrix was constructed using the weighted-average abundances of copepods from the 2 cruises and a $\sqrt{}$ transformation, thus removing noise resulting from within-station variability. Relationships between this matrix and inter-station distances (ρ = 0.389, $p < 0.001$) and measured environmental variables (ρ = 0.356, p = 0.002) are better than the relationships with the individual biotic matrices, confirming that the removal of within-station variability clarifies the large-scale patterns which are of interest in this study.

A dendrogram derived from this matrix by hierarchical agglomerative clustering (Fig. 2) indicates that Station D2 is an outlier. It was recognised during sampling that this might be the case, owing to the poor penetration of the box-corer into sediment at this site. The pattern of chaining amongst groups of samples suggests that a gradient in community structure exists. In such situations an ordination such as MDS generally gives a clearer representation of intersample similarities than does a dendrogram. Arbitrary divisions at increasing levels of similarity were used to define 5 station groupings from the dendrogram (Fig. 2). Overlaying these groupings on the MDS plot derived from the same similarity matrix (Fig. 3) clarifies the interrelationships between them. There is a gradient in harpacticoid community structure from Group 3, through Groups 4 and 5, to Group 1. Group 2 lies to one side. Overlaying these station groupings on a schematic map (Fig. 4), it can be seen that stations in Group 1 are from the outer Bohai Strait, and Stations in Group 2 are from the southern part of Liaodong Bay. Stations in Group 3 lie in Laizhou Bay and the western part of the central Bohai. Stations in Group 4 occupy the central part of the Bohai, and in Group 5 the eastern parts of the Bohai Sea. The groups, defined according to their similarity in copepod species composition, are clearly geographically separated and lead to the conclusion that there are consistent, if small, differences in copepod community structure between groups of stations related to their position in different parts of the Bohai Sea and along a gradient from the southeastern parts of the Bohai to the outer parts of the Bohai Strait.

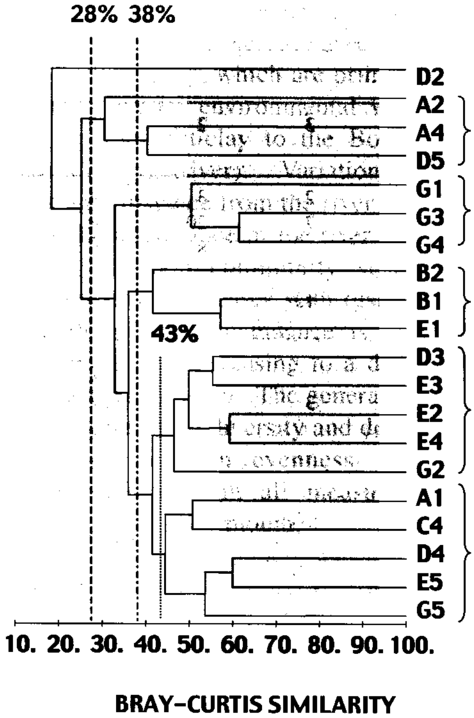

Fig. 2. Dendrogram showing interstation relationships in copepod community structure and arbitrary division into 5 groups at increasing levels of similarity. Dendrogram derived from √-transformed weighted-average abundances at each station by hierarchical agglomerative clustering using group average linkage of Bray-Curtis similarities.

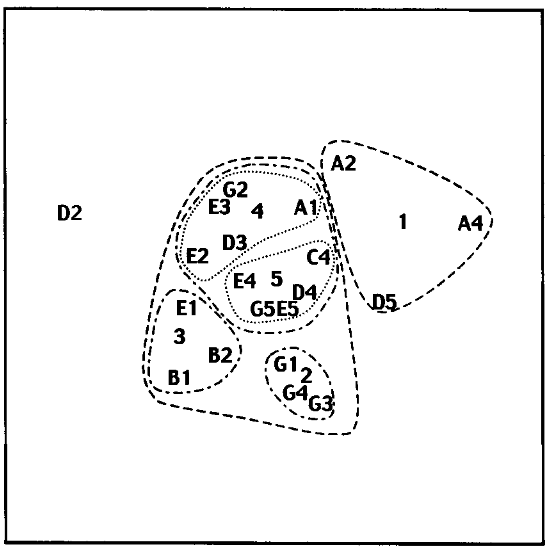

Fig. 3. MDS ordination (Stress = 0.13) derived from Bray-Curtis similarities between stations from √-transformed weighted-average abundances, showing interstation relationships. Superimposed clusters are divisions into 5 groups based on cluster analysis (Fig. 2) at 28 (dashed lines), 38 (dashed and dotted lines) and 43 (dotted lines) % similarity.

ANOSIM confirms the significance of differences in environmental variables between the biotically defined groups of stations ($R = 0.416$, $p < 0.001$). BVSTEP was used to explore relationships between groups of environmental variables and the biotic similarity matrix, and it consistently defined a group of three variables, phaeopigment concentrations in the upper two cm of the sediment, percent silt/clay and depth, as providing the best match ($\rho = 0.59$) with variations in copepod community structure. PCA of this subset of variables (Fig. 5) shows that there is a close match between the majority of the five biotically-defined groups of stations and these variables alone. Taking each variable in turn, BIOENV identified components of the sediment as providing the best matches (Gravel, $\rho_W = 0.353$; Sand, $\rho_W = 0.195$; Silt/clay, $\rho_W = 0.193$), followed by depth (0.168), Pb (0.137), Cu (0.117) and Phaeopigments at 0-2 cm depth (0.102). When entered into the analysis separately, clay was more closely correlated with copepod community structure ($\rho_W = 0.174$) than silt ($\rho_W = 0.09$). Most of these correlations are low, representing weak relationships between copepod community structure and individual environmental variables.

Similarity percentages analysis (SIMPER) was used to determine the contribution from individual species to the Bray-Curtis dissimilarity between groups (Table 2). The majority of the 115 species identified were rare, and did not contribute significantly to inter-group dissimilarities. Three main groups of

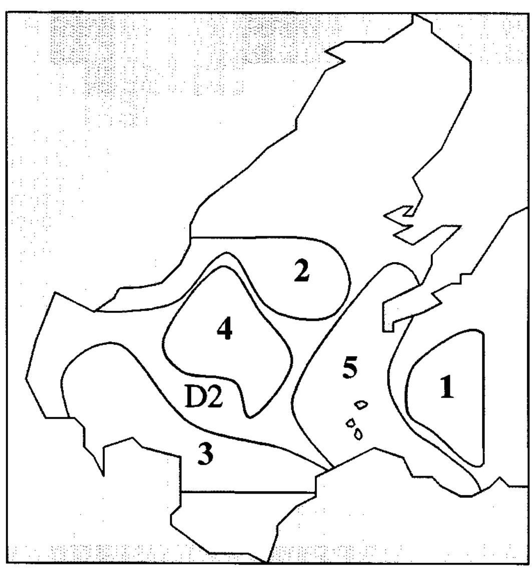

Fig. 4. Schematic map of the Bohai Sea, showing the areas occupied by each of the faunally-defined station groups.

Table 2. Differences (< and >) in average abundances of species contributing to Bray-Curtis dissimilarities between selected pairs of groups of stations identified in the cluster analysis based on √-transformed weighted average abundances. A cut-off at a cumulative % dissimilarity of 50 % was applied.

Station Group: / Species:	1		5		4		3	2		5
Heteropsyllus major	47	>	16	>	0	<	2	3	<	16
Bulbamphiascus spp	3	<	24	>	4	<	7	20	<	24
Haloschizopera sp 1	5	>	0					8	>	0
Danielssenia typica	13	>	2							
Amphiascoides sp 1	7	>	3	>	0	<	13	7	>	3
Stenhelia sp 3	6	>	0							
Heteropsyllus sp 2	8	>	0							
Pseudameira sp 1	5	<	12	>	4			5	<	12
Halectinosoma sp 2	7	>	4	>	1	<	3	1	<	4
Fladenia sp 1	8	>	0							
Stylicletodes sp 2	7	>	0							
Paramphiascella sp 1	3	>	0							
Stenhelia (Stenhelia) sp 1	5	>	1							
Stenhelia (Delavalia) sp 2	3	>	0							
Fladenia sp 2	3	>	0							
Sigmatidium sp 1	4	>	0							
Eurycletodes sp 1	4	>	0							
Microarthridion sp 3	5	>	2							
Amphiascoides sp 2	5	>	1	<	4	>	0			
Zosime sp 1			2	>	0					
Sinamphiascus dominatus			2	<	3			4	>	2
Proameira sp 1			2	>	0					
Halectinosoma sp 5			2	>	1	<	15	3	>	2
Enhydrosoma intermedia			2	>	2	<	6			
Halectinosoma sp 13					5	>	1	0	<	5
Microarthridion sp 1					0	<	3			
Scottolana sp 1					1	<	4	12	>	2
Halectinosoma sp 16					0	<	3			
Stenhelia sp 4					1	<	3			
Pseudameira sp 3								12	>	0

species are apparent. The first group of species predominantly contributes to dissimilarities between Group 1 stations, in the Bohai Strait (where they are present), and the rest of the stations (where they are not). This group includes species such as *Danielssenia typica, Fladenia* spp, *Haloschizopera* sp 1, *Stenhelia* spp, *Paramphiascella* sp 1, *Stylicletodes* sp 1, *Eurycletodes* sp 1 and *Sigmatidium* sp 1. The second group of species contributes to differences between groups of stations within the Bohai, examples being *Zosime* sp 1, *Sinamphiascus dominatus, Halectinosoma* spp, *Enhydrosoma intermedia* and *Scottolana* sp 1. The third group of species are those that contribute to dissimilarities both between Group 1 and the rest, and also within the Bohai Sea. Such species include *Heteropsyllus major, Bulbamphiascus* spp, *Amphiascoides* spp, *Halectinosoma* sp 2 and *Pseudameira* sp 1. It is remarkable how few species are seen to be important in terms of contributing to dissimilarities between stations within the Bohai Sea, suggesting that the differences between stations, although consistent, are very weak.

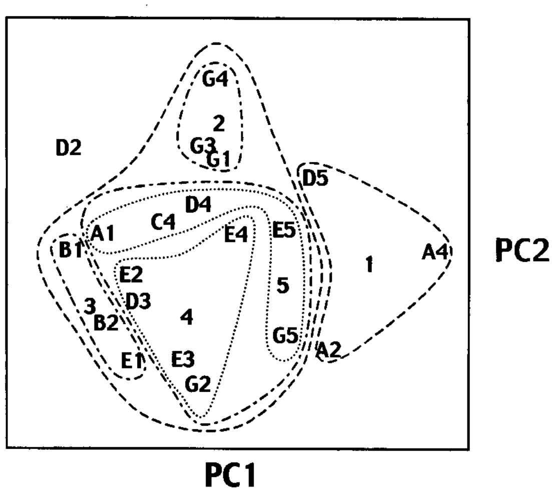

Fig. 5. Ordination by PCA of stations based on the three variables (silt/clay, depth, phaeopigments at 0-2 cm) best explaining variation in copepod community structure (as determined by BVSTEP). Principle components 1 and 2 explain 90 % of the variance. Lines indicate division of stations into groups based on cluster analysis of copepod community structure (Fig. 2) at 28 (dashed lines), 38 (dashed and dotted lines) and 43 (dotted lines) % similarity.

The overall pattern, therefore, appears to be one of small but consistent differences between different parts of the Bohai sea, which are primarily linked to variations in natural environmental variables. The primary input of silt/clay to the Bohai sea is the Huanghe (Yellow River). Variation in univariate measures with distance from the river mouth (Fig. 6) illustrates the importance of the river in determining aspects of copepod community structure. The number of species increases with distance from the river mouth, whereas abundance is high near the mouth of the river, decreasing to a distance of 120 km, and then rising again. The general pattern is one of increasing trends in diversity and dominance, with a decreasing trend in evenness, coupled with increasing variability in all measures at greater distances from the river mouth.

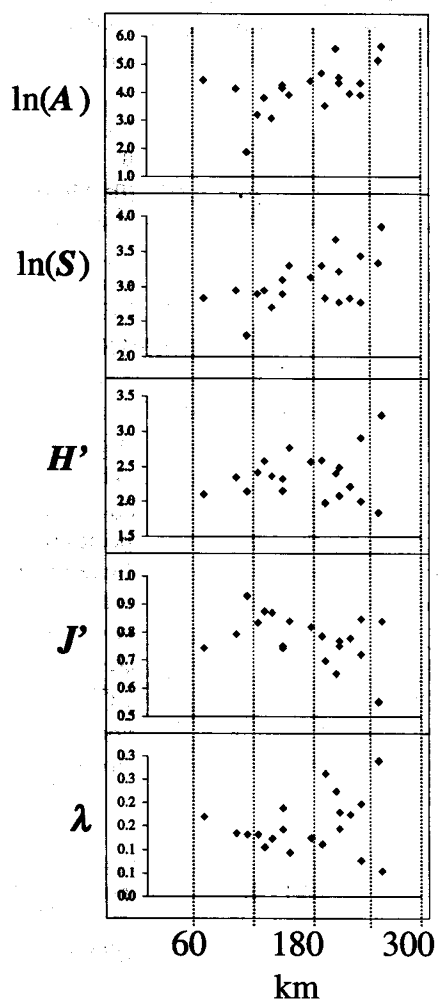

Fig. 6. Variation in univariate measures abundance (*A*), numbers of species (*S*), Shannon-Wiener diversity (*H'*), Pielou's evenness measure (*J'*) and Simpson's dominance index (λ) with distance from the present mouth of the Huanghe (Yellow River).

DISCUSSION

Analyses show that there were small differences in community structure, primarily as a result of decreased abundances of a range of common species, between September and March. The Bohai Sea is a typical northern temperate sea, and seawater temperatures increase during the summer to a maximum in late summer and early autumn. The majority of harpacticoids reach their maximum abundance in warmer months (late spring-early autumn) (Hicks & Coull, 1983), and it seems reasonable to interpret the differences between cruises as resulting from natural seasonal factors.

Whilst meiobenthic communities are sensitive to anthropogenic inputs to the marine environment (Coull & Chandler, 1992) it has long been recognised that the structure of the sediment is a major factor influencing meiobenthic community structure, and changes in sediment structure within an area may be expected to change that community structure (Warwick & Buchanan, 1970; Heip et al., 1985; Coull, 1988; Somerfield et al., 1995). The modern Huanghe (Yellow River) estuary is situated in Laizhou Bay, and the Huanghe is second in the world only to the Ganges/Brahmaputra River in terms of sediment load. Approximately 1.1×10^9 tons of sediment, mostly medium to coarse silt (Shanming, 1986), are carried to the delta each year, representing approximately 10-15 % of the world total (Zhang et al., 1990). However, 80 to 90 % of the material is deposited within 20 to 30 km of the river mouth (Bornhold et al., 1986; Keller et al., 1990) and less than 5-10 % escapes from Laizhou Bay and enters the Central Bohai and or North Huanghai (Yellow Sea) (Zhang et al., 1990). Sand concentrations increase towards the central part of the Bohai Sea, where strong currents passing through the Bohai Strait winnow out finer material, leaving a residual coarser-grained sediment that is continually reworked by the strong tidal currents (Keller et al., 1990). These patterns of sediment transport are entirely consistent with the observed variations in copepod community structure in this study, with a more highly dominated and less diverse community in siltier sediments near the river mouth, and a more diverse community further away. All of the species encountered in this study belong to genera and families commonly found in muddy sediments. Harpacticoid groups commonly found in sublittoral sands with a low silt content, such as Leptastacidae, Paramesochridae, interstitial Ameiridae and the *Arenosetella* branch of the Ectinosomatidae, were absent from the entire study area.

The long axis of the Bohai Sea is approximately 400 km in length, and lines up with north winds that prevail during the winter months. These winds induce waves that are a major factor in reworking the bottom sediments in the southern part of the Bohai Sea (Keller et al., 1990). Laizhou Bay is relatively shallow (<18 m), as is much of the southern Bohai, and sediment resuspension induced by wind storms can significantly change the suspended sediment distribution, especially in winter. The upper intervals of the bottom sediments throughout are annually reworked, resulting in a degree of uniformity in time. The bottom topography is therefore relatively featureless, and what variance there is in the mass physical properties seems to reflect slight differences in sediment textures as controlled by currents (Keller et al., 1990). This may explain the fact that variations in copepod community structure throughout the study area are not marked, and that differences between groups of stations from different parts of the Bohai, although significant, are small.

Although sediments derived from the Huanghe are the primary factor influencing variation in copepod community structure, other variables, namely depth and phaeopigment concentrations at 0-2 cm depth within it, are also potentially important determinands of copepod distributions. Depth is a common correlate of community structure, most likely because it determines other factors, such as the amount and quality of phytoplankton-derived carbon reaching the benthos, which are not commonly measured in benthic investigations but which directly affect the communities being investigated. The species separating stations in Group 1 from the rest belong to a range of genera and families, including *Danielssenia* and *Fladenia* (Paranannopidae), *Haloschizopera, Stenhelia, Paramphiascella* (Diosaccidae), *Stylicletodes* (Cletodidae), *Eurycletodes* (Argestidae) and *Sigmatidium* (Ectinosomatidae), which are typically found in somewhat deeper water than many of the others. The correlation with phaeopigments in the surface layers of the sediment also suggests that the supply and nature of food are important factors influencing copepod distributions. Phaeopigments are breakdown products of chlorophyll, and although both chlorophyll and phaeopigments were measured, at both 0-2 and 2-5 cm depth in the sediment, it is only the surface phaeopigments that appear to be of importance in determining copepod community structure in the Bohai.

Marine copepods are known to be sensitive to sediment metal concentrations (Somerfield et al., 1994), oil and a range of other pollutants (Coull & Chandler, 1992; Moore & Somerfield, 1997), but none of the analyses carried out within this study suggest that there is any evidence of anthropogenic disturbance affecting large-scale patterns in the benthic copepod community structure in the Bohai Sea. That being said, the samples for this particular study were collected from an extensive grid of stations appropriate to the study of large-scale processes within the area. The findings of the present study are comparable with large-scale studies in the temperate North Sea (Huys et al., 1992) and UK waters (Schratzberger et al., 2000), which concluded that sediment characteristics are important determinants of meiobenthic community structure. The latter study also found a significant relationship between harpacticoid community structure and trace metals, although no such relationship was found in the Bohai Sea. More focussed studies from NW Europe (Heip et al., 1988; Gee et al., 1992) demonstrated clear effects of pollution on meiofaunal communities. In order to determine the effects of anthopogenic disturbance resulting from oil exploration, pollution, aquaculture, and so on, survey designs appropriate in scale for the effects being studied should be employed.

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