THE HOLOCENE OSTRACODS OF THE AGULHAS BANK, SOUTH AFRICA: THEIR CLASSIFICATION, DISTRIBUTION AND ECOLOGY

by

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DECLARATION

I hereby declare that all the work presented in this dissertation is my own, except where otherwise stated.

Signed by candidate

Signature Removed

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ABSTRACT

An analysis of the Holocene ostracod fauna of the Agulhas Bank has been carried out on seventy-three surficial sediment samples. Sixty-six species of Ostracoda have been recorded, of which fifty-nine species are accounted for in forty genera and the remaining seven species are of indeterminate classification. The species are described and their distribution and ecology is given. An analysis of the sedimentology, as well as an oceanographic analysis of the bottom water on the Agulhas Bank, has provided environmental parameters for each sediment sample location, enabling relationships to be described between ostracod faunas and environmental conditions. Quantitative factor analysis has been carried out on the twenty-four most abundant species, generating seven factor associations relating ostracod assemblages to a set of environmental parameters. The independent variables analyzed were the temperature, salinity and dissolved-oxygen content of the bottom water, as well as the sand content of the sediment. Contour maps of these variables have been drawn up using SADCO data for the oceanographic variables, and the sediment samples to calculate the sand content. The overall oceanography of the Agulhas Bank has been analyzed by relating the environmental parameters generated at each location to the water masses present on the shelf, and to the oceanic currents affecting them. Finally, the seven factor associations generated have been related directly to the substrate types, the water masses, and the currents present on the Agulhas Bank.

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1. INTRODUCTION

Scope of the Thesis

This thesis examines the micropalaeontology of the Holocene sediments on the Agulhas Bank and the oceanography of the bottom water. The microfossils studied are Holocene shelf ostracods and the oceanographic parameters include temperature, salinity, dissolved-oxygen content and water depth. In addition the texture of the sediments is examined. Micropalaeontological, sedimentological and depth data were obtained from 73 surficial sediment samples, and the oceanographic information from the South African Data Centre for Oceanography (SADCO) at Stellenbosch.

The objective of this study is to relate each ostracod species to a range of environmental and oceanographic conditions. For example, each species is assigned temperature, depth, salinity, and dissolved oxygen averages, as well as a preferred substrate. A database can thus be created identifying the habitat of each species. Similarly, by consideration of the environmental conditions and the abundance of each species at each location, a statistical Q-mode factor analysis of the ostracod counts provides quantitative results for faunal and environmental correlations, and allows transfer functions to be developed for predicting palaeoenvironmental conditions in older sediments on the Agulhas Bank. The results also allow comparisons with similar analyses for the west coast faunas.

Study Motivation

Dr R.V. Dingle, formerly of the South African Museum, conducted a similar study off the west coast of Southern Africa, extending from the Kunene River to Cape Agulhas (Fig. 1.1). The motivation for this project was to extend the database from Cape Agulhas to Port Elizabeth (Fig. 1.2). The geological benefit of this will ultimately be the reconstruction of the palaeoceanography of the two regions. The commercial and industrial application for such research is obvious for oil and diamond exploration, where palaeoenvironmental reconstruction is an aid in the proving and recovery of these resources.

Study Area

The Agulhas Bank is the continental shelf off the southern coast of Africa. The study area extends from Cape Agulhas to Port Elizabeth between latitudes 33° to 37°S and between longitudes 19° to 27°E (Fig. 1.2). The sample sites represent a good coverage of the sediments on the shelf, and range in depth from 30 to 200 m. Figure 1.2 gives the location of the sample sites and their reference numbers as used in the thesis, as well as other locations mentioned in the text. The warm equatorial Agulhas Current, which flows in a general south-westerly direction, is the major ocean current in the region and lies on the eastern margin, and the Benguela Current lies on the western margin.

Previous Research

The first reported marine ostracods from the continental shelves of southern Africa were collected during the 1873-76 HMS *Challenger* expedition. Brady (1880) identified 14 species of podocopid Ostracoda from two samples off the Cape of Good Hope and in False Bay. Brady's *Challenger* collection was re-illustrated and lectotypes established by Puri and Hulings (1976 in Dingle, 1992). Since then, research which is directly applicable to this study on the Agulhas Bank, has been conducted on the west and south coast shelves as well as on the east coast shelf as far north as Kenya.

Müller (1908) reported on fauna from Simonstown Harbour, Klie (1940) on fauna from Swakopmund and Lüderitz, and Benson and Maddocks (1964) described the fauna from Knysna Lagoon. Whatley and Dingle (1989) reported the first known sighted species of the genus *Poseidonamicus*, and Hartmann (1974) recorded faunas from numerous localities between northern Angola and Mozambique.

The most comprehensive study, particularly of the west coast shelf, was conducted by Dingle (1989 to 1994) both at the University of Cape Town and at the South African Museum. His collection of Quaternary ostracods is housed at the South African Museum, and the taxonomy and environmental parameters controlling the distribution of these ostracods are described in the above publications.

Mostafawi (1992) described the modern ostracods from the mid Sunda-Shelf between the Malayan Peninsula and Borneo, while Jellinek (1993) described the recent ostracods from the Kenyan Barrier Reefs. Both these studies describe species which are also found on the Agulhas Bank.

Two important contributions are the unpublished theses by Keeler (1981) on the Agulhas Bank and Boomer (1985) on the continental shelf of south western Africa.

Additional relevant literature includes Benson's study in Antarctica (1964), van den Bold (1966 - Gabon), Neale (1967 - Antarctica), Maddocks (1969), Valicenti (1977 - Patagonia), Hartmann (1986, 1987, 1988 - Antarctica) and Whatley *et al.* (1987, 1988 - Antarctica and south-western Atlantic).

Previous research on the chemical and physical characteristics of Agulhas Bank bottom water is very limited. Most research has been concentrated on surface and central waters, mainly due to economic interest in the fish resources. Schumann *et al.* (1991) give an overview of the research conducted on the continental shelves off southern Africa and Hutchings (1994) gives a specific overview of available information on the Agulhas Bank. These papers show a gap in information about Agulhas Bank bottom water. Current research is, however, being conducted by M. Roberts of the Sea Fisheries Research Institute (SFRI) and by L. Staegemann of the Department of Oceanography at the University of Cape Town (UCT).

Chapman and Largier (1989) conducted research into the origin of Agulhas Bank bottom water. They distinguished between water of Atlantic and Indian Ocean origin below the thermocline on the Agulhas Bank, by careful comparison of high-resolution data sets. A number of authors have described the physical effects of the Agulhas Current on the Agulhas Bank, as well as other characteristics of water circulation. Upwelling is described by Shannon (1966), Bang (1972) and Schumann *et al.*, (1982). Boyd and Shillington (1994) discuss the physical forcing and circulation patterns on the Agulhas Bank, and Swart and Largier (1987) describe the thermal structures on the Bank.

Previous research into the sedimentology of the Agulhas Bank dates back to the *Challenger* expedition. Since then, research has been conducted by the S.A. Navy and the Russian Navy, and recently by the SFRI and UCT. Fuller *et al.* (1965) undertook a comprehensive sedimentological study of the Agulhas Bank which was complemented by Rogers (1971), who documented the Quaternary sediments on the western and central Agulhas Bank. Summerhayes (1972) documented aspects of the mineralogy and geochemistry of Agulhas Bank sediments. A series of maps compiled by Birch *et al.*

(1986) show the texture and composition of surficial sediments along the entire continental margin of South Africa.

Organization of Thesis

Chapter 1 is an introduction to the thesis and includes details of the previous research done on all aspects of this thesis. The methods are outlined in chapter 2. The results of the oceanographic and sedimentological analyses are detailed in Chapter 3. Chapter 4 is the most extensive chapter and contains the taxonomy and descriptions of all the ostracod species found. Chapter 5 describes the detailed methods of the factor analysis and presents the results. Chapter 6 is a discussion of the oceanography of the Agulhas Bank in relation to the ostracod faunal assemblages which occur there. General conclusions are given in Chapter 7. Appendix 1 is a classification list of the species documented and Appendix 2 is the raw data matrix of species counts and the environmental averages at each location. Appendix 3 contains the environmental parameters and correlation coefficients of the fifty most abundant species. Appendices 4-6 are the results of the factor analysis.

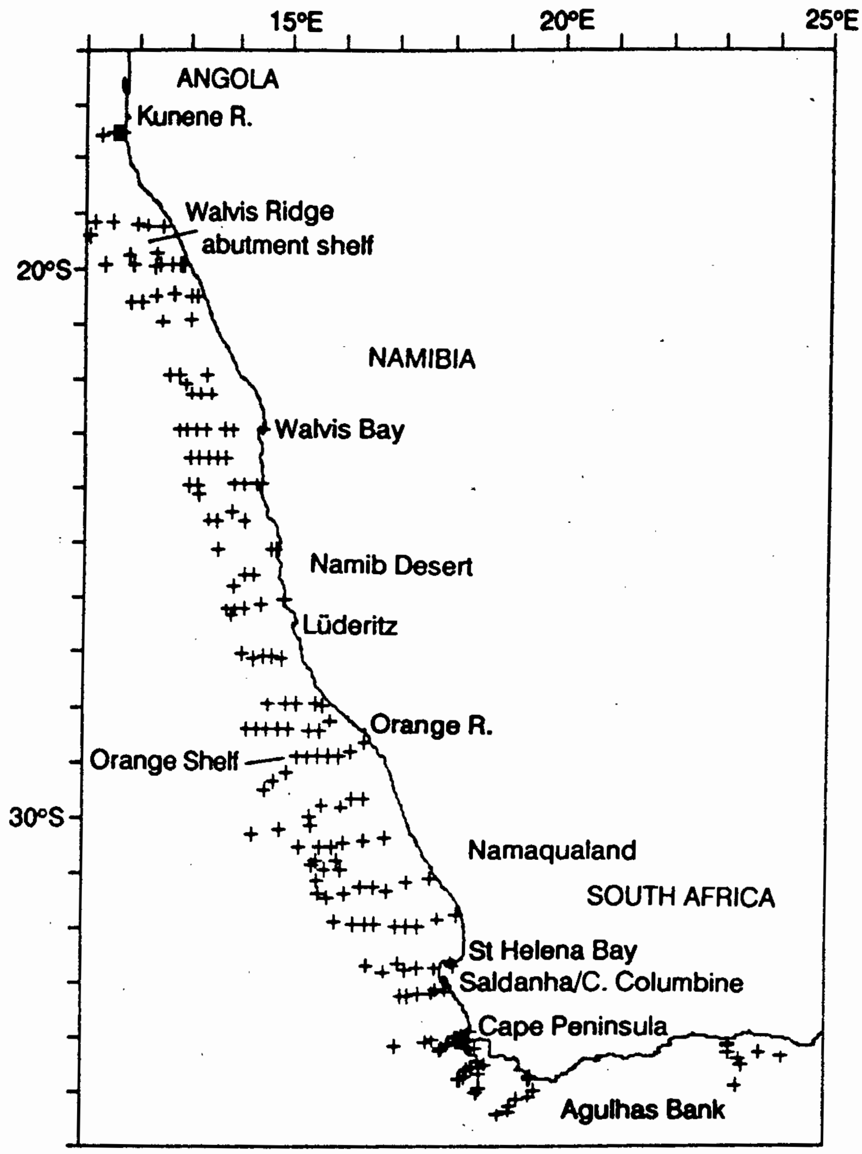


Figure 1.1. The west coast of southern Africa. (From Dingle 1992, showing the distribution of his sample sites).

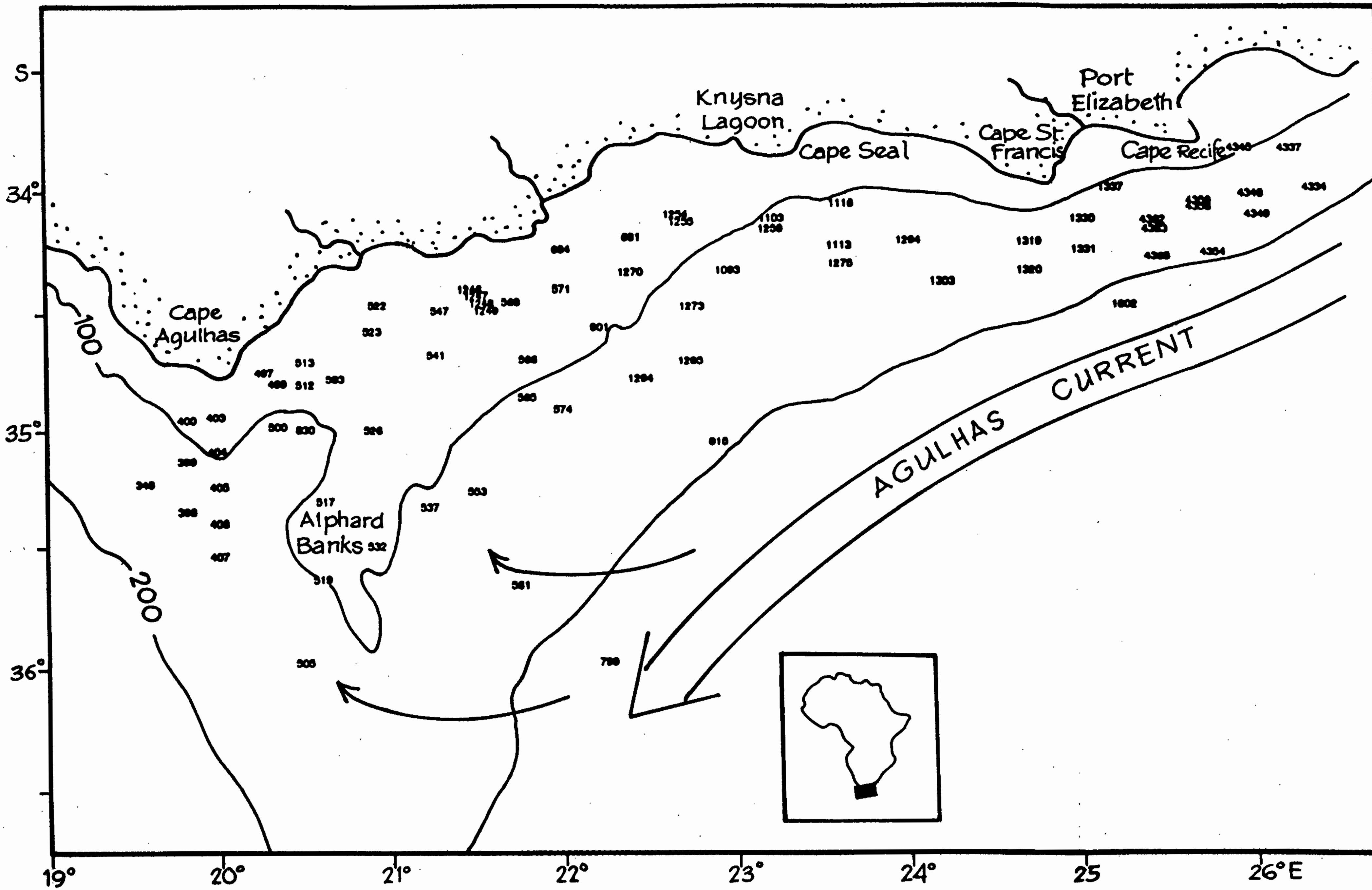


Figure 1.2. The Agulhas Bank off the south coast of South Africa. The distribution of the sample sites is shown.

2. METHODS

Micropalaeontological Analysis

The Joint Geological Survey/ University of Cape Town (UCT) Marine Geoscience Unit collected numerous surface grab samples from the Agulhas Bank during the period 1967-1985. They were taken during research cruises to the area aboard the UCT-owned *Thomas B. Davie* (TBD), using a Van Veen grab which typically penetrates 10cm into the sediment. The samples have been stored in sealed plastic tubs in a sample store, and the ostracods were sourced from this material. The sample numbers used in this thesis are the original TBD numbers.

Seventy-three of the sample sites on the Agulhas Bank were chosen for this study. These represent a good coverage of the study area and all the substrate types. The sediment was dried at a temperature of 50°C, and one hundred grams of the dried material was wet-sieved through a 63-micron sieve. In addition to standard procedures to clean sieves, contamination between samples was avoided by dipping the sieve into malachite green dye after each sieving operation so that any stained ostracods found during picking were then removed.

Once wet-sieved, the sand fraction was dried and weighed in order to calculate the percentage of sand and mud in each sample. The sand fraction was then dry-sieved through 125-micron and 2mm sieves. The 125-micron to 2mm fraction was picked for ostracods using a No.1 artists brush, and the ostracods were stored in glass slides. The ostracods were later sorted, identified and counted. Selected specimens were mounted on stubs and coated with gold. They were then photographed using a JEOL benchtop scanning electron microscope to aid identification and to illustrate the species. At the time of collection, the samples were unfortunately not stained to reveal living tissue, and therefore, it was not possible to calculate living / dead ratios.

The matrix showing the sediment sample numbers, locations and species counts is given in Appendix 2. Distribution maps of each species were plotted using a spreadsheet program.

Analysis of Oceanographic Data

The environmental and oceanographic conditions of the sea floor of the Agulhas Bank have been assessed using data from the SADCO database. These data were supplied to SADCO primarily by the Sea Fisheries Research Institute (SFRI) and by the Oceanography Department at UCT. The database used here contains data from the period 1900-1980, which have been collected during numerous research cruises to the study area.

The aims of analysis for this thesis were:

1. To draw up general contour maps of the various environmental parameters on the Agulhas Bank, and

2. To calculate specific values of each of the parameters for each sediment sample site.

No oceanographic measurements apart from depth and percentage sand were collected from the actual sediment sample sites. This is, however, acceptable for this study, because long-term mean values of the parameters, such as are available from the SADCO database, are preferred because the ostracod faunas represent assemblages that may include specimens up to approximately 5000 years BP.

Bottom-water temperature, salinity and dissolved oxygen values for use in the analyses required careful selection from the SADCO database. A programme written by Mr G. Nelson of the SFRI enabled the selection of areas of a quarter degree square around each sample site. Data falling within these blocks were then selected and used to represent the conditions at the specific sample site. Bad data were excluded by setting reasonable limits for each parameter and values outside these limits were not used. The selection criteria were that, for samples deeper than 50 m, only measurements within the bottom 20 % of the water column could be used, up to a maximum of 50 m off the bottom. Sites shallower than 50 m used all measurements within the bottom 10 % of the water column. This is however, not necessarily an accurate measurement of the bottom boundary layer within which temperature and salinity are known to be fairly constant. There is controversy surrounding the thickness of the bottom boundary layer because of a lack of information about the exact effects of influences such as the strong and highly fluctuating Agulhas Current. Because most of the fluctuations are seasonal and the ostracods present represent a long-term death-assemblage, the criteria described above are deemed to be adequate for the purposes of this thesis. A potential problem, however, is the fact that oxygen measurements were taken within a few tens of metres off the sea floor. Dissolved oxygen values may differ markedly from the bottom water to the interstitial water of the top sediment layers where the majority of the ostracods live. The oxygen values are therefore used as relative measures rather than absolute values, so that a comparison with the distribution of the west coast assemblages could be made, Dingle (1994) also having used such dissolved-oxygen values for his study of west coast ostracods.

Each sample site had a minimum of 5 and a maximum of 70 readings. The readings were averaged and the environmental parameters were added to the matrix of species counts and sample locations (Appendix 2. Raw data matrix).

Factor Analysis

The Factor Analysis was conducted on a PC running a Q-mode Factor Analysis program [Oregon State University's CLIMAP\CABFAC program of Imbrie and Kipp (1971)]. This method of analysis was first used by Imbrie and Kipp (1971) to extrapolate into Quaternary sediments the modern sea-surface temperature and salinity signals of planktonic foraminifera. Since then it has been used for planktonic studies by Hays *et al.* (1989), Dowsett and Poore (1990), Giraudeau and Pujos (1990) and Schrader and Sorknes (1991). For benthic taxa, the technique has been used by Mudie *et al.* (1984) and Cronin and Dowsett (1990). Dingle and Giraudeau (1993) were the first to apply this method to Ostracoda, and studied the relationship between the 36 most abundant species from the west coast continental shelf of South Africa and the various environmental parameters controlling their distribution.

In this study, Factor Analysis was conducted on the 24 most abundant species of Ostracoda on the Agulhas Bank. All 24 species had raw counts of greater than 100 specimens, and together they account for 91.48% of the total specimens available for study. The methods are described in further detail in Chapter 5.

3. OCEANOGRAPHY AND SEDIMENTOLOGY

Introduction

The Agulhas Bank is a roughly triangular extension of the continental shelf off southern Africa. It is the boundary area between two major ocean currents - the Benguela Current to the west and the Agulhas Current to the east. It is approximately 800km in length (18-29°E) and 250km wide at the apex (34.8-36.9°S) totalling approximately 116 000km^2 (Hutchings, 1994). The eastern and southern margins are part of a sheared continental margin, with a well defined shelf break (Shumann and Beekman, 1984). The western margin is rifted and therefore less steep and more irregular (Dingle and Scrutton, 1974). The shelf itself is generally smooth because of erosion by sea-level regressions and transgressions, but important bathymetric irregularities are caused by elongate outcrops of Palaeozoic rock in the west (south of Cape Agulhas), and aeolianites in the east. The Alphard Banks (centered on 21°E) are a major bathymetric feature and are the result of Tertiary plug-like igneous intrusions. Large areas of the Agulhas Bank are regarded as having primary-shelf characteristics - this means that conditions at the open ocean boundary have little effect on circulation and temperature structures on the shelf (Schumann and Beekman, 1984).

The eastern margin is bounded by the temperate, strongly poleward-flowing Agulhas Current, whilst the western margin is occasionally influenced by filaments and rings of Agulhas Current water. The Agulhas Current flows in a general south-westerly direction and follows the bathymetric contours around the tip of the shelf (Hutchings, 1994). The main stream of the Agulhas Current lies beyond the shelf-break (see Figure 1.2), and water originating from it reaches the eastern part of the Bank in a series of complicated mixing processes, rather than by flowing directly onto it (Schumann, Perrins & Hunter, 1982).

The western margin is bounded by the relatively cooler equatorward flowing Benguela Current. The westernmost part of the Agulhas Bank (west of 19.5°E) is considered to be part of the Benguela Ecosystem and has been included in Dingle's (1989-1994) west coast study.

Chapman and Largier (1989) suggest two origins for Agulhas Bank bottom water. Atlantic originating bottom water occurs west of 20.5-21°E, and Indian originating bottom water occurs east of this (See Fig. 6.1). At the boundary there is considerable mixing of the two. (For the purposes of this thesis, the boundary described above (20.5-21°E) is used to seperate the western and eastern Agulhas Bank, respectively.)

Upwelling occurs in certain regions of the Agulhas Bank and the bottom-water characteristics are influenced by these occurrences. The Agulhas Bank can generally be divided oceanographically into a wind-forced inner-shelf, and an oceanically-forced outer-shelf (Boyd and Shillington, 1994). Frictional interaction between the Agulhas Current and bottom topography facilitates shelf-break upwelling along the whole Bank, but it is more noticeable on the eastern margin (Hutchings, 1994). Cold water is upwelled over the shelf-edge onto the shelf, and forms a basal layer into which intrusive plumes of more saline surface water penetrate, resulting in a mixed central layer (Bang, 1972). Wind-driven coastal upwelling also occurs, resulting in areas of relatively cooler water in some of the bays on the eastern Agulhas Bank.

The average temperatures, salinities and dissolved-oxygen content of the bottom water are discussed below, as is the bathymetry and sedimentology of the Agulhas Bank. Appendix 2 gives the calculated temperature, salinity and dissolved-oxygen values for each site, as well as the recorded depth and sand-content values.

Bathymetry

The Agulhas Bank is the largest shelf off South Africa. It drops steeply at the coast to 50m and then deepens gradually to 200m. The shelf break occurs at approximately the 200-m isobath, and the continental slope then drops steeply to more than 5000m (Dingle *et al.*, 1987). The 100m and 200m isobaths, which are shown on all maps in this thesis, are from Dingle *et al.* (1987), based on numerous echosounder traverses.

Temperature

Figure 3.1 is a contour map of the average bottom temperatures calculated using SADCO data. The main features are a warm inshore region (>14°C), a warm to cool inner to mid-shelf region (13-10°C) and a cold outer-shelf zone (<10°C). As previously mentioned, the eastern Agulhas Bank outer-shelf basal water originates from the Agulhas Current and the western Agulhas Bank basal water is of Atlantic Ocean origin. The bottom water is actively intruding and is marked by a weak but clear thermocline between it and the ambient water (Chapman and Largier, 1989).

Between Cape St. Francis and Cape Recife (between 24.5 and 25.5°E), there is a notable pool of colder water. I suggest that this is probably due to semi-continuous upwelling, since Schumann *et al.* (1982) noted that prominent capes and crenulated bays play an important role in upwelling, and that this is especially the case off Cape Recife, Cape St. Francis and Cape Seal. Strong, coast-parallel easterly winds in this area also play an important role in inducing upwelling.

Salinity

Contoured average salinities are shown in Figure 3.2. The overall salinity pattern, as expected, corresponds to the temperature pattern, with highest salinities found on the inner shelf with decreasing values towards the shelf break. Chapman and Largier (1989), in their research on Agulhas Bank bottom water, found consistently lower salinities on the western Agulhas Bank and interpreted this as a signature of Atlantic Ocean origin. As the Benguela Current flows equatorward past the Agulhas Bank it introduces less saline water onto the western regions. The present study also records relatively lower salinities on the outer shelf of the western Agulhas Bank.

Oxygen

Dissolved-oxygen levels in the bottom water of the Agulhas Bank are generally much higher than those of the west coast shelf reported by Dingle and Nelson (1993). The west coast is said to be oxygen deficient, as much of the shelf has an average dissolved-oxygen content of less than 2ml/l (Chapman and Shannon, 1985). The Agulhas Bank is oxygen depleted, as it has an overall average dissolved-oxygen content of less than 5ml/l. Figure 3.3 shows the dissolved-oxygen content in the bottom water on the Agulhas Bank. The eastern Agulhas Bank has consistently higher oxygen levels than the bottom water of the western Agulhas Bank. This also suggests that the westernmost Agulhas Bank is part of the Benguela ecosystem. Localized patches with reduced dissolved-oxygen values occur at various sites and these may be a result of complex circulation patterns as suggested by

Schumann *et al.* (1991), or may be the result of reducing conditions in areas of high organic-matter content.

Sedimentology

Only one aspect of the sedimentology of the Agulhas Bank is considered in this study - the proportions of sand and mud in the surface sediment i.e. the sediment texture. Figure 3.4 shows the texture of the surficial sediment based on the seventy-three sediment samples used in this study. There are several inshore mudbelts (Rogers, 1971), but these are not represented, as no samples were taken from them. It is important to note that all sediment of a grain size greater than 63 microns is considered as sand, and correspondingly, finer material is classified as mud. No distinction has been made between sand and gravel, because the gravel content of the chosen samples was insignificant, and therefore any gravel has been included with the sand. The Agulhas Bank is dominated by very sandy sediment, often containing more than 90% sand. The westernmost part of the Agulhas Bank is the only area with predominantly silty and muddy substrates. Three mudbelts are recorded in this study, as shown in Figure 3.4. The largest mudbelt (situated at 20°E) is referred to as the western Agulhas Bank mudbelt in this thesis, and contains a distinctive ostracod fauna. The texture of the sediment is one of the most widely-differing features between the west coast and the Agulhas Bank: the west coast is largely dominated by mudbelts and this is one of the major reasons for the differing ostracod faunas found in the two regions.

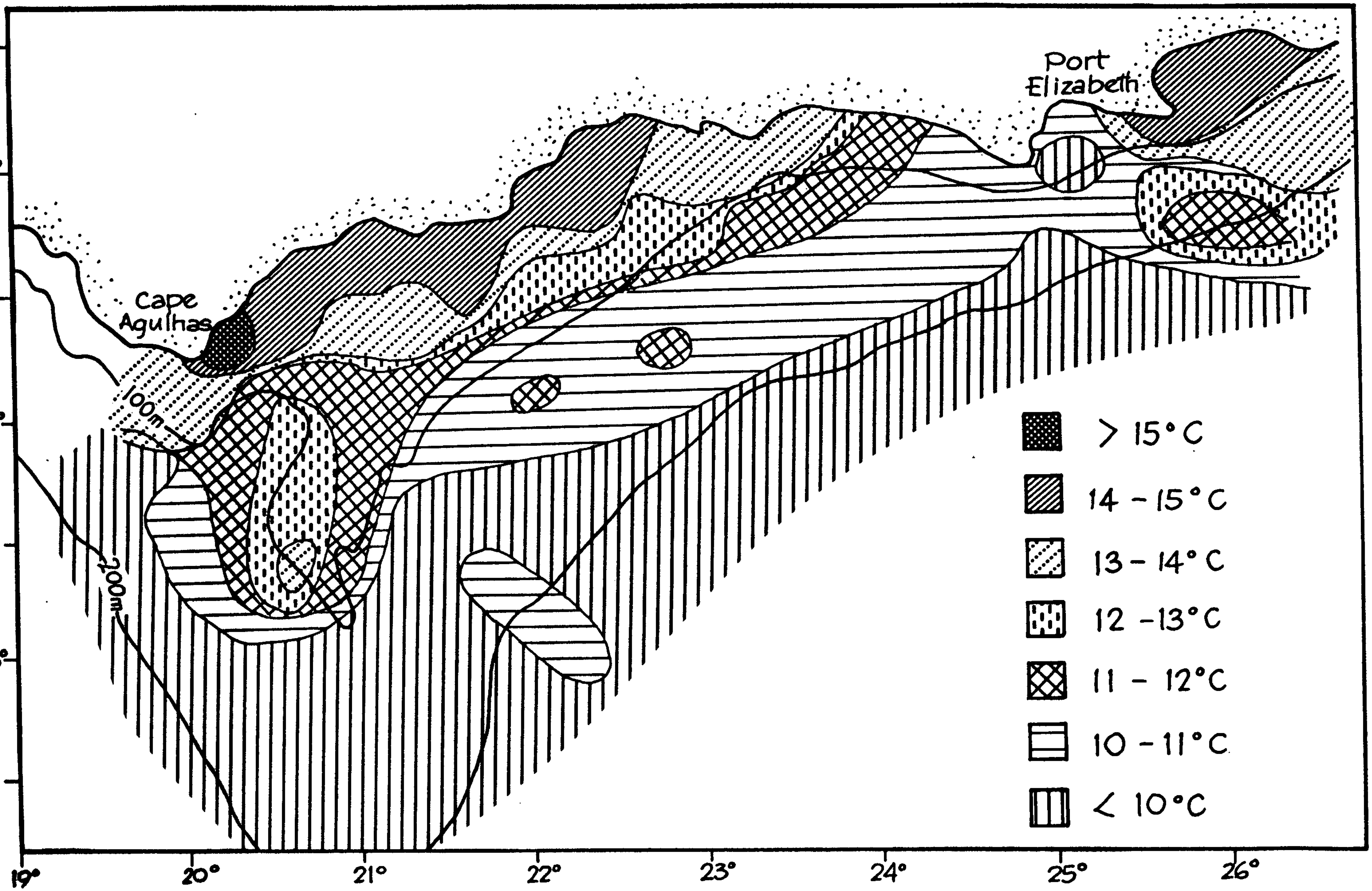


Figure 3.1. Average bottom-water temperatures on the Agulhas Bank.

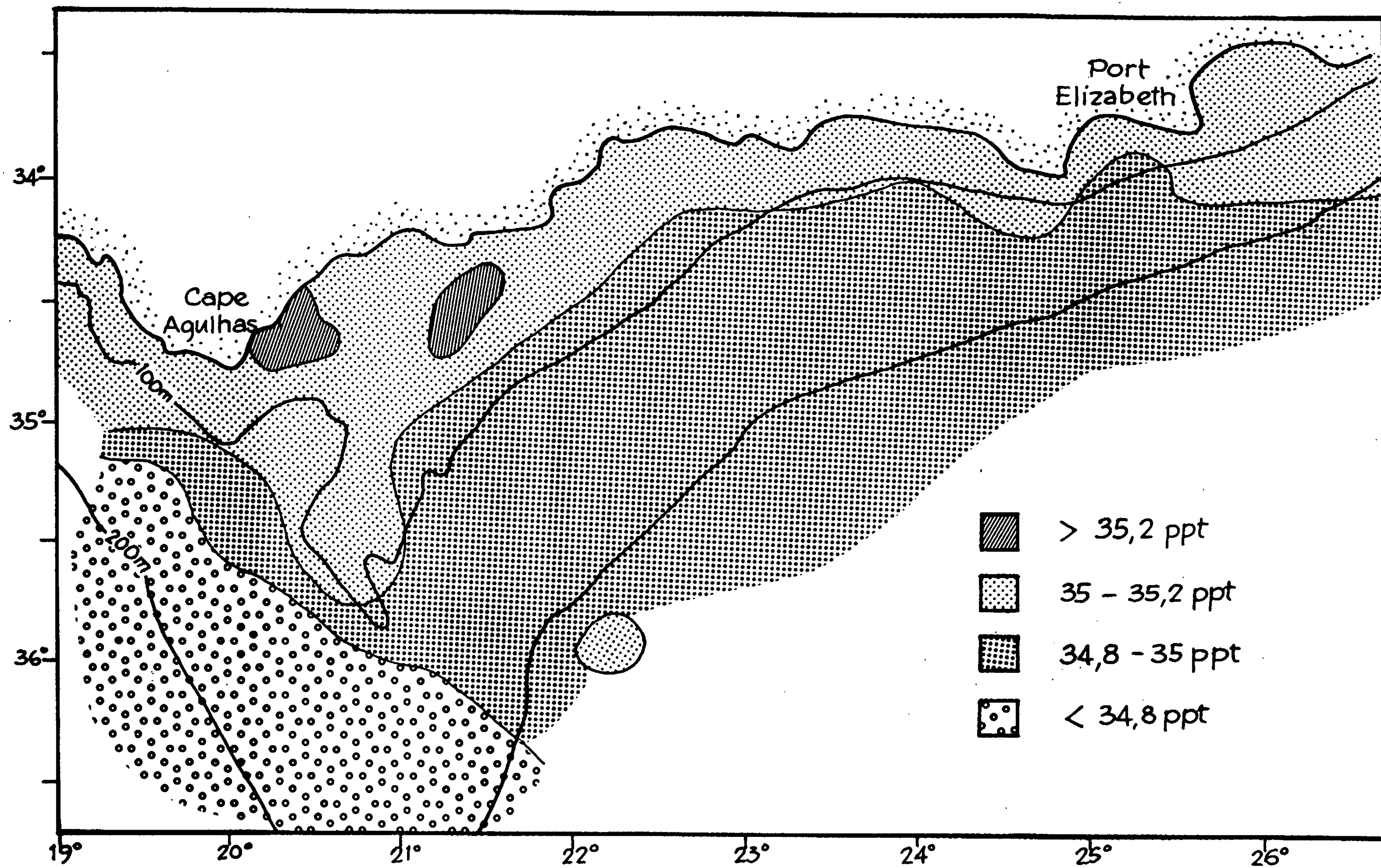


Figure 3.2. Average bottom-water salinities on the Agulhas Bank.

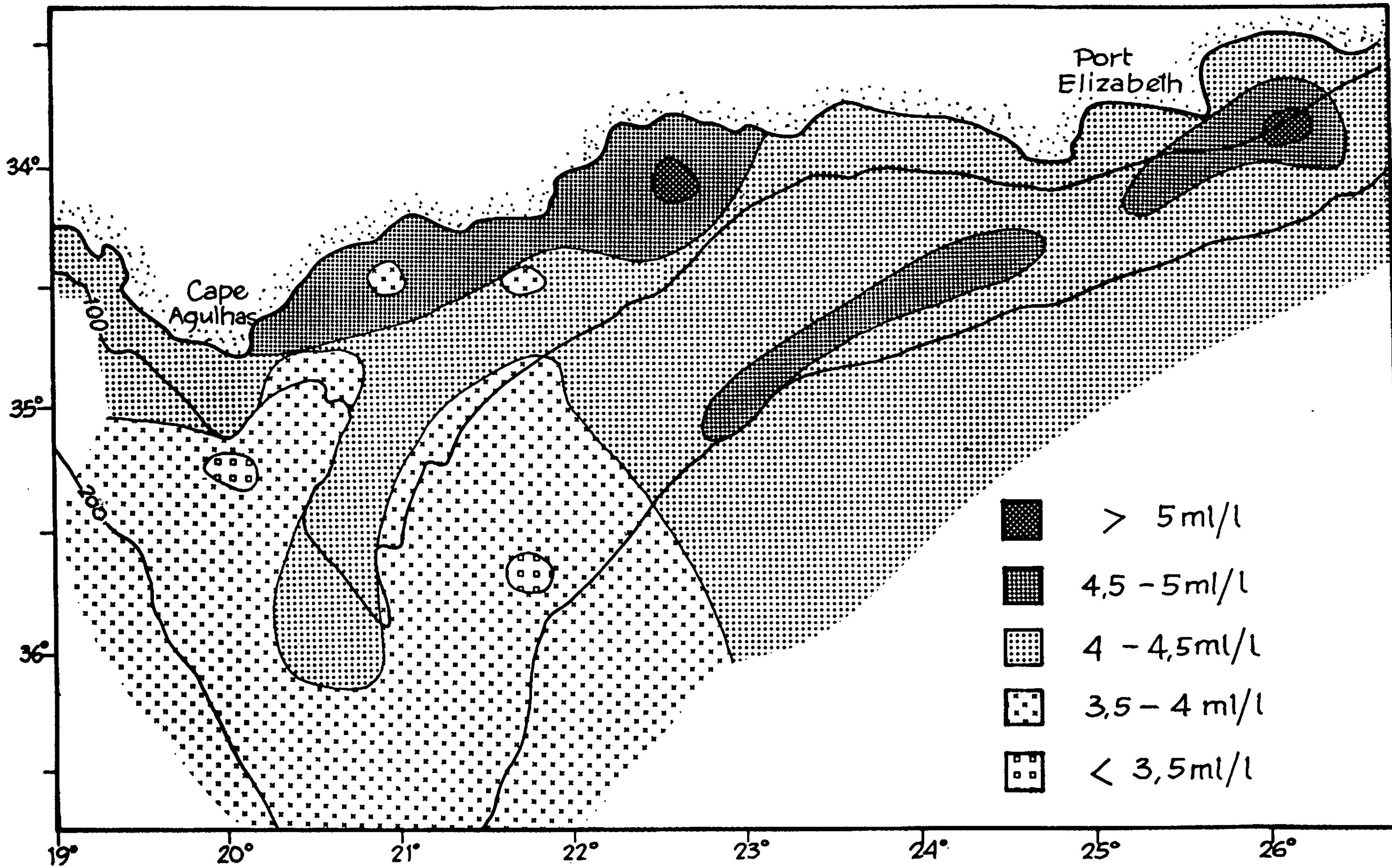


Figure 3.3. Average dissolved-oxygen values on the Agulhas Bank.

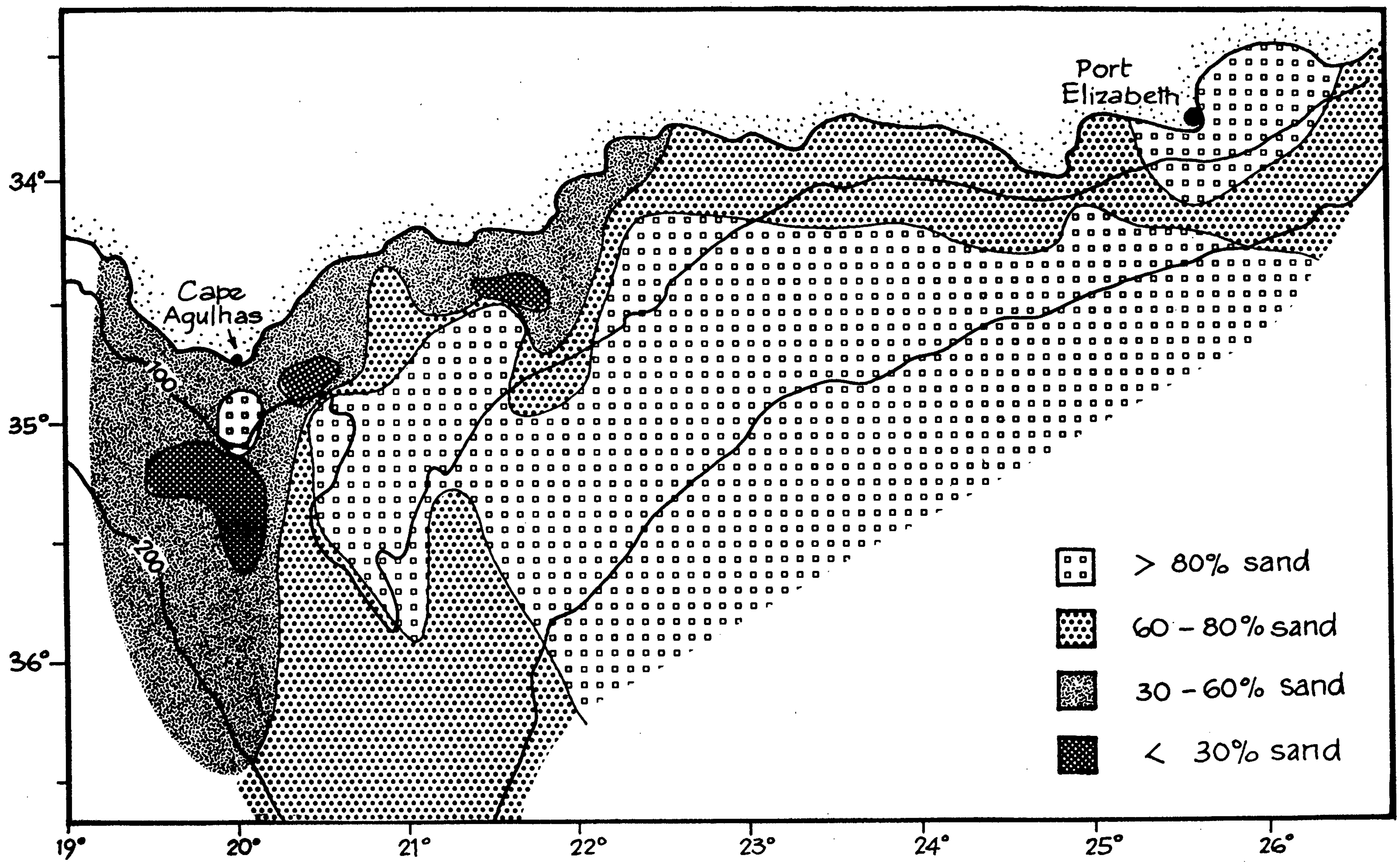


Figure 3.4. Sediment texture on the Agulhas Bank.

4. TAXONOMY OF HOLOCENE OSTRACODS

Introduction

This chapter contains the taxonomic classification and species descriptions of the Holocene Ostracoda of the Agulhas Bank. The 73 sediment samples contained 13424 valves, which are classified into 66 species. Of the 66 species, 59 are accounted for in 40 genera, and there are 7 indeterminate species. Of the 59 classified species, 44 have been previously recorded. The classification is based on Moore (1961), with certain changes necessitated by more recent research. The classification of the 66 species, as well as the abbreviations used for each in the text, is given in Appendix 1. The raw count of the number of ostracod valves of each species at each sample site is given in Appendix 2. Distribution maps for each species are given at the end of the chapter. Appendix 3 gives the average environmental parameters for the fifty most abundant species, and the correlation coefficients resulting from the regression analysis between these species and each environmental parameter. Abbreviations used in this chapter and elsewhere in the text are listed below.

DM / VM	Dorsal / Ventral Margin
AM / PM	Anterior / Posterior Margin
ATE / PTE	Anterior / Posterior / Terminal Element
MS	Muscle Scars
LV / RV	Left / Right Valve
SC / SCT	Sub Central / Tubercle
UDL / LDL	Upper / Lower Depth Limit
ml/l	Millilitres per litre
ppt	Parts per thousand (g. dm^3)
R^2	Correlation coefficient

Systematic Descriptions

Class CRUSTACEA Pennant, 1777

Subclass OSTRACODA Latreille, 1806

Order PODOCOPIDA Müller, 1894

Suborder PLATYCOPINA Sars, 1866

Family **Cytherellidae** Sars, 1866

Genus *Cytherella* Jones, 1849

Cytherella dromedaria Brady, 1880

Fig. 4.1, Pl. 1a-b.

Cytherella dromedaria Brady, 1880: 173, pl.43 (figs 6a-b). Puri & Hulings, 1976: 312, pl.24 (fig 14). Dingle, 1992: 17-20 (figs 6a-d).

Cytherella sp. aff. *C. cuneiformis* Hartmann, 1974. Keeler, 1981: 185-187, pl. 11 (figs 1-3).

Material 1466 valves

Remarks

Specimens from the Agulhas Bank are identical to the material described by Dingle (1992) from the west coast.

Distribution and Ecology

Dingle (1992) recorded this species only at the southernmost regions of the west coast - south of 30°S. On the Agulhas Bank it is the third most abundant species and is widespread over the entire study area (Fig. 4.1). There is, however, a noticeable absence south and west of Cape Agulhas, which is due to the colder temperatures and lower salinities which are present there. The average temperature and salinity preferences for this species are 12.09°C and 35.03ppt respectively. The relatively high correlation coefficients between this species and temperature (0.384), and salinity (0.302), indicate that these parameters are indeed the primary controlling parameters in the distribution of this species, which accounts for its absence south and west of Cape Agulhas. Depths range from 30-200m.

Cytherella namibensis Dingle, 1992

Fig. 4.2, Pl. 1c-e.

?*Cytherella sordida* Müller, 1894. Bold, 1966: 158-159, pl.1 (fig 10).

?*Cytherella* aff. *C. sordida* Müller, 1894. Dingle, 1976: 39, fig 12 (39).

Cytherella spp. Boomer, 1985: 12-13, pl.1 (figs 16-17).

Cytherella namibensis Dingle, 1992: 20-25 (figs 6e-f, 9a-d, 10a).

Material 201 valves

Remarks

As with the west coast populations (Dingle, 1992), specimens from the Agulhas Bank range from strongly punctate (Pl. 1c-d), to relatively smooth. The MS are particularly well preserved in some specimens (Pl.1e), and are the typical feather shaped *Cytherella* MS.

Distribution and Ecology

This species occurs along the entire south-west and southern African continental shelf. It is a deeper-water variety of *Cytherella*, with an Agulhas Bank depth range of 73-161m (Fig. 4.2). The Agulhas Bank population has a more restricted depth range than the west coast population (Dingle, 1992), which ranges from 115-295m. As commented on by Dingle (1992), the shallower sites are dominated by the punctate variety, and therefore on the Agulhas Bank, these are more abundant than the smooth specimens. Average temperatures of 11.19°C and average salinities of 34.96ppt have been recorded at the sites at which this species occurs.

Cytherella sp.

Fig. 4.3, Pl. 1f-g.

Material 185 valves

Remarks

This species of *Cytherella* is distinct from *C. dromedaria* and *C. namibensis* in that it has a very bulbous and inflated PM. The quadrate outline of the posteroventral margin (Pl. 1f), results in an asymmetrical external outline not previously observed in the genus *Cytherella* from Southern and South Western Africa (including Angola). The surface ornamentation ranges from sparsely punctate to smooth.

Distribution and Ecology

Cytherella sp. is widely distributed over the eastern Agulhas Bank, but is sparse in the region south of Cape Agulhas (Fig. 4.3). This inner to mid-shelf species has a depth range of 30-116m. It does not occur in the mudbelts and has a preference for relatively high oxygen levels, the average being 4.41ml/l.

Suborder PODOCOPINA Sars, 1866

Superfamily BAIRDIACEA Sars, 1888

Family **Bairdiidae** Sars, 1887

Genus *Bairdoppilata* Coryell, Sample & Jennings, 1935.

Bairdoppilata simplex (Brady, 1880)

Fig. 4.4, Pl. 1h & 2a.

Bairdia ovata? Bosquet, 1854. Brady, 1880: 53-54, pl. 7 (figs 3a-d).

Bairdia simplex Brady, 1880: 51 pl.7 (figs 1a-d). Puri & Hulings, 1976: 266, pl. 3 (figs 11-14).

Nesidea labiata Müller, 1908: 99, pl. 14 (figs 1-6).

Bairdia villosa? Brady, 1880. Benson & Maddocks, 1964: 14-15, pl. 1 (figs 3, 6 & 8).

Bairdoppilata (Bairdoppilata?) simplex (Brady, 1880) Maddocks, 1969: 77-78, text-fig. 42.

?Bairdoppilata sp. 44 Hartmann, 1974: 253-254, pl. 23 (figs 168-169).

Bairdoppilata sp. aff. *B. (B.) villosa* (Brady, 1880) Keeler, 1981: 24-26, pl. 1 (figs 1-2).

Bairdia spp. Boomer, 1985: 14-15, pl. 2 (figs 19-20).

Bairdoppilata simplex (Brady, 1880) Dingle, 1993: 7-10 (figs 3c-f, 6a-b).

Material 1806 valves

Remarks

There is a wide morphological range in the specimens found, but because of a lack of consistent differences I adopted a conservative approach and placed the whole population in Brady's species *simplex*. Pl.1h & Pl.2a represent the "average" specimens. There is also a wide variation in size, which appears to represent more than just the state of maturity. Surface ornamentation ranges from punctate and hirsute to smooth. Both the left and right valves appear in general to be less angular than the specimens described by Dingle (1993).

Distribution and Ecology

This abundant species is widespread over the south-west and southern continental shelf of Africa, but is confined to areas south of 22°S (Dingle, 1993). It is particularly abundant on the Agulhas Bank, where it occurs in all areas except for the mudbelts (Fig. 4.4). Its distribution is controlled by substrate, as shown by a significant correlation with sand content (0.225). It has a depth range of 47-200m.

Superfamily CYPRIDACEA Baird, 1845

Family **Paracyprididae** Sars, 1923

Genus *Aglaiella* Dayday, 1910

Aglaiella railbridgensis Benson & Maddocks, 1964

Fig. 4.5, Pl. 2b-d.

Aglaiella railbrigensis Benson & Maddocks, 1964: 16-17, pl. 1 (figs 7, 9-10), text-fig. 7. Hartmann, 1974: 357-358, pl. 138 (figs 952-961). Dingle & Honigstein, 1994: 72 (figs 4d-h).

Material 68 valves

Remarks

The MS of the Agulhas Bank specimens are identical to the specimen from the Quaternary of the west coast (Dingle & Honigstein, 1994). The illustrations in Benson & Maddocks (1964) are not very clear, but appear to be of the same species.

Distribution and Ecology

On the Agulhas Bank this species occurs at one location only (Fig. 4.5). This is the shallowest sample site (30m) and its relative abundance in this sample (30%), leads to the conclusion that this is a shoreline, shallow-water species. This is supported by the fact that Benson and Maddocks (1964) recorded this species in the shallow water environment of the Knysna Lagoon. As with that study, the preference for muddy or silty substrates (57% mud on the Agulhas Bank) is observed.

Genus *Paracypris* Sars, 1866

Paracypris lacrimata Dingle, 1992

Fig. 4.6, Pl. 2e-f.

Paracypris sp. aff. *P. polita* Sars, 1866. Keeler, 1981: 34-35, pl.1 (fig 14).

Paracypris sp. Keeler, 1981: 35-36, pl. 1 (fig 15).

Pontocypris sp. Boomer, 1985: 16-17, pl. (fig 64).

Paracypris lacrimata Dingle, 1992: 25-29, (figs 9e-f, 12c, 12f).

Material 174 valves

Remarks

The reddish brown ?chitinous lining observed by Dingle (1992) in specimens from the west coast was very rarely observed in the Agulhas Bank population. Dingle (1992) attributes this phenomenon to dissolution of the calcareous valves in deeper water. The Agulhas Bank population has a LDL of 121m, whereas the chitinous material from the west coast has an UDL of 150m, and therefore chitinous material is generally absent from the shallow Agulhas Bank environment. The diagnostic branched anterior radial pore canals are clearly seen in well preserved specimens.

Distribution and Ecology

Occurs along the entire continental shelf from 19°S (Dingle, 1992), to the eastern Agulhas Bank at 26°E (Fig. 4.6). Abundances increase towards the east on the Agulhas Bank. A restricted depth range (47-121m) is recorded, and is a similar range to modern west coast populations - 15-133m (Dingle, 1992).

Paracypris sp

Fig. 4.7, Pl. 2g-h.

Material 13 valves

Remarks

Species of *Paracypris* with a long, asymmetrical, pointed PM, whose apex is strongly ventrally directed. AM is also ventrally directed. Several branched anterior radial pore canals.

Distribution and Ecology

The seven sample sites where this species occurs are widely distributed over the Agulhas Bank (Fig. 4.7). A slightly more restricted depth range (65-111m) than that of *P. lacrimata* is recorded. Only sandy substrates are tolerated, the average sand content being 77.9% sand. High average temperatures and salinities are recorded - 12.23°C and 35.06ppt respectively.

Family **Macrocyprididae** Muller, 1912

Genus *Macrocypris* Brady, 1867

Macrocypris sp

Fig. 4.8, Pl. 3a-b.

Material 98 valves

Remarks

This is a large species of ostracod, with some specimens being up to 2mm long. MS are not clearly visible, and therefore a specific classification is not possible.

Distribution and Ecology

Macrocypris sp. has a wide distribution and depth range (58-162m) on the Agulhas Bank (Fig. 4.8), but is not reported elsewhere on the southern African continental margin. Preferences are indicated for temperatures between 11 and 12°C, and for salinities between

35 and 35.2ppt.

Family **Pontocyprididae** Muller, 1894

Genus *Argilloecia* Sars, 1866

Argilloecia sp.

Fig. 4.9, Pl. 3c-e.

Argilloecia sp. 2 Maddocks, 1969: 47-48 (figs 34a, b, e & f).

?Cytherois sp. 3538 Dingle, 1993: 28 (fig 18a).

Material 52 valves

Remarks

Based on Maddocks (1969), the MS pattern shown in Pl.3e is typical of *Argilloecia*, as are the overall internal and external features of the valves. The specimen of *?Cytherois* described by Dingle (1993) from the west coast appears to be conspecific with the Agulhas Bank material, but because no muscle scars were visible, it was provisionally placed in *Cytherois*.

Distribution and Ecology

This species occurs at sites off the Cape Peninsula (Dingle, 1993), and its distribution extends eastwards to sites south of Port Elizabeth (Fig. 4.9). This is predominantly an inner-shelf species with depths ranging from 30-108m. Average temperatures and salinities are very high - 13.15°C and 35.10ppt respectively. Only muddy substrates are tolerated, the average sand content being 51.8% sand.

Genus *Australoecia* McKenzie, 1967

Australoecia fulleri Dingle, 1993

Fig. 4.10, Pl. 3f-h.

Australoecia fulleri Dingle, 1993: 19-22, (figs 12a-c).

Material 130 valves

Remarks

This species is very distinctive due to the difference in size and shape of the left and right valves. The RV is more elongate than the larger, more ovate LV. The brown chitinous lining observed by Dingle (1993) in the west coast specimens is not visible in the Agulhas Bank specimens, similarly with *Paracypris lacrimata*. Flaking and poor preservation of the external surface - a feature commented on by Dingle (1993) - is noted.

Distribution and Ecology

A. fulleri is widely distributed on the mid to outer-shelf, and is far more abundant on the Agulhas Bank than on the west coast (Fig. 4.10). Depths range from 47-200m, but abundances increase with increasing depth, which is probably due to the fact that the coarsest substrates on the Agulhas Bank are found on the mid-outer shelf. The average sand content of the sediment in which this species is found is 90.7% sand.

Genus *Propontocypris* Sylvester-Bradley, 1947

Propontocypris sp

Fig. 4.11, Pl. 4a-b.

Material 22 valves

Remarks

Asymmetrical shape with greatest height at one third length. Distinctive prontocyprid MS (Pl.4b) as described by Maddocks (1969). Punctate surface.

Distribution and Ecology

Species of the genus *Propontocypris* occur on the south and south-western continental shelf of Africa. This species, not previously described, occurs at 3 sites south and east of Cape Agulhas, and at 1 site south of Port Elizabeth (Fig. 4.11). This is an inner-shelf species with a depth range of 65-84m. The distribution of this species is controlled by temperature (R^2=0.803), and salinity (R^2=0.687). Average temperatures and salinities are high - 13.19°C and 35.11ppt respectively.

Superfamily CYTHERACEA Baird, 1845

Family **Buntoniidae** Apostolescu, 1961

Genus *Buntonia* Howe, 1935

In contrast to the west coast, where six species have been recorded (Dingle, 1993), this genus is poorly represented on the Agulhas Bank. This is due to a preference by species in this genus for colder water environments than those generally found on the Agulhas Bank.

Buntonia rogersi Dingle, 1993

Fig. 4.12, Pl. 4c-d.

Buntonia rogersi Dingle, 1993: 129-131, (figs 71e-f, 73a-f, 74a).

Material 13 valves

Remarks

The few badly preserved specimens show the diagnostic small blunt spine on the exterior surface near the central PM, and the characteristic 'fish-hook' shaped anterior MS (Dingle, 1993).

Distribution and Ecology

Found only on the western Agulhas Bank (west of 21°E), this is a deep and cold water species (Fig. 4.12). Depths range from 95m (Dingle, 1993) to 161m and the average temperature is 9.94°C. Relatively lower salinity (34.82ppt) and dissolved-oxygen values (3.84ml/l) are also noted. Greatest abundances exist in the western Agulhas Bank mudbelt - this species occurs in sediment with an average of 34.4% sand.

Family **Bythocytheridae** Sars, 1926

Genus *Bythocythere* Sars, 1866

Bythocythere sp.

Fig. 4.13, Pl. 4e-f.

Bythocythere sp. 3349 Dingle, 1993: 23-25, (figs 12e-f, 15a-b).

Material 8 valves

Remarks

This species is very similar to the species found by Dingle (1993) on the west coast. However, the latter is slightly more elongate and has less distinctive punctae and longitudinal ventro-lateral ribs on its exterior surface. The size and shape of the alae also differ slightly. Given the fact, however, that the number of specimens is small in both data sets, the two species are probably conspecific.

Distribution and Ecology

The six sites at which this species is found, are scattered between 20 and 26°E (Fig. 4.13). They lie on the inner-shelf with a depth range of 47-111m. This species has a preference for bottom water temperatures over 10°C.

Family **Campylocytherididae** Puri, 1960

Subfamily Campylocytheridinae Puri, 1960

Genus *Doratocythere* McKenzie, 1967

Doratocythere exilis (Brady, 1880)

Fig. 4.14, Pl. 4g-h.

Cythere exilis Brady, 1880: 69, pl. 16 (figs 5a-h). Puri & Hulings, 1976: 276, pl. 10 (figs 1-11).

Doratocythere exilis (Brady, 1880) Keeler, 1981: 39-41, pl. 1 (figs 20-22). Dingle 1992: 29-32, (figs 15a-f).

Reymentia exilis (Brady, 1880) Boomer, 1985: 49-50, pl. 2 (fig 21).

Material 717 valves

Remarks

There are two minor differences between the west coast and the Agulhas Bank specimens:

the latter have a slightly larger PTE, and a less pronounced antero-marginal rib. The overall lateral rib pattern is also somewhat less well developed. Nevertheless the populations are considered conspecific and morphological differences are ascribed to the differing ages of the specimens found [west coast specimens are relict (Dingle, 1992)], as well as to environmental factors.

Distribution and Ecology

D. exilis is widespread and abundant over the entire Agulhas Bank (Fig. 4.14). No modern specimens were recorded on the west coast (Dingle, 1992). This species has a large depth range - 47-200m, and has no obvious temperature, salinity or dissolved-oxygen level preference. None of the environmental parameters correlate significantly with the distribution of this species.

Family **Cytherettidae** Triebel, 1952

Subfamily Cytherettinae Howe, 1961

Genus *Garciaella* Dingle & Honigstein, 1994

Garciaella knysnaensis (k) (Benson & Maddocks, 1964)

Fig. 4.15, Pl. 5a-b.

Cytheretta knysnaensis Benson & Maddocks, 1964: 22-23, text-figs 11-12, pl.2 (figs 7-11).

Bensonia knysnaensis (Benson & Maddocks, 1964) Keeler, 1981: 43-45, pl. 2 (figs 2-4).

Bensonia knysnaensis knysnaensis (Benson & Maddocks, 1964) Dingle, 1992: 32-34, (figs 18a-f).

Cytheretta sp. Boomer, 1985: 24-25, pl. 3 (fig 44).

Garciaella knysnaensis knysnaensis (Benson & Maddocks, 1964) Dingle & Honigstein, 1994: 83-85, figs (8e-f).

Material 424 valves

Remarks

Within the population there is a wide variation in the strength of the surface ornamentation. Some specimens have well defined ribs with a distinct reticulation between them, whilst some have broader, less well defined ribs, and lack the reticulation. The random geographical distribution of the two types suggests that this only represents newer specimens and more relict specimens respectively, rather than two different species. This is supported by the fact that both types occur within the same sediment samples.

Distribution and Ecology

The distribution of this species ranges from isolated sites near Lüderitz on the west coast (Dingle, 1992) to a wide distribution on the Agulhas Bank ranging from the Cape Peninsula to Port Elizabeth (Fig. 4.15). This is an inner to mid-shelf species with depths ranging from inshore in Knysna Lagoon (Hartmann, 1974) to 110m. Well oxygenated water, silty substrates, and high temperatures and salinities are indicated by the averages recorded at the relevant locations. These are 4.48ml/l, 74.5% sand, 12.75°C and 35.06ppt respectively.

Family **Cytheridae** Baird, 1850

Subfamily Phacorhabdotinae Gründel, 1969

Genus *Strobilocythere* Jellinek, 1990

Subgenus *Strobilocythere (Keniacythere)* Jellinek, 1993

Strobilocythere (K) malzi Jellinek, 1993

Fig. 4.16, Pl. 5c-d.

Strobilocythere (K) malzi Jellinek, 1993: 131 (figs 242-246).

Material 16 valves

Remarks

Agulhas Bank specimens have a stronger rib structure and more pronounced reticulation than the specimens from the Kenyan barrier-reefs described by Jellinek (1993). These differences are probably accounted for by the differing environments from which the two populations have been reported.

Distribution and Ecology

This species occurs on the inner to mid-shelf of the eastern Agulhas Bank (Fig. 4.16). Preferred bottom conditions are warm, saline water (over 12°C and 35ppt respectively) which is well-oxygenated (over 4.5ml/l). Water depths range from 30 to 104m. This environment has certain similarities to the Kenyan reef environments, where temperatures and salinities are also high, and the water is also well oxygenated. The preferred depth of this species on the Kenyan reefs is 22m (Jellinek, 1993). The distribution of this species is controlled by temperature, salinity and substrate type, and therefore correlations with these variables are high - 0.350, 0.334 and 0.638 respectively. The particularly high correlation with sand content may indicate that this species has been carried south by the Agulhas Current from the vicinity of Kenya, as the sediment in the path of the current is very coarse.

Family **Cytherideidae** Sars, 1925

Subfamily Neocytherideidinae Puri, 1957

Genus *Neocytherideis* Puri, 1952

Neocytherideis boomeri Dingle, 1992

Fig. 4.17, Pl. 5e-f.

Neocytherideis sp. Keeler, 1981: 56-57, pl. 2 (fig 19).

Copytus sp. Boomer, 1985: 58-59, pl. 3 (fig 43).

Neocytherideis boomeri Dingle, 1992: 37-42, (figs 19e-f, 23a-d).

Material 136 valves

Remarks

Agulhas Bank specimens display a fine reticulation on the exterior surface, which has the appearance of a rectangular maze, and which was not reported from the west coast populations by Dingle (1992). In all other respects however, the specimens are identical to *Neocytherideis boomeri.*

Distribution and Ecology

Widely distributed on the Agulhas Bank (Fig. 4.17). As noted by Dingle (1992), this is predominantly an inner-shelf species and depths range from 30-139m. Average bottom water temperature is high at 12.34°C.

Family **Cytheruridae** Muller, 1894

Genus *Cytheropteron* Sars, 1866

Four species of *Cytheropteron* occur on the Agulhas Bank making it one of the more diverse genera. On the west coast, however, the genus is even more diverse - Dingle (1992) recorded fourteen species. Despite this, it is never numerically abundant.

Cytheropteron whatleyi Dingle, 1993

Fig. 4.18, Pl. 5g.

Cytheropteron sp. 1 Boomer, 1985: 53-54, pl. 4 (figs 59-60).

Cytheropteron whatleyi Dingle, 1993: 64-67, (figs 37d-f, 40a-d).

Material 119 valves

Remarks

Agulhas Bank specimens are identical to west coast material, but are less well-preserved.

Distribution and Ecology

C. whatleyi is the only *Cytheropteron* species which occurs only on the western Agulhas Bank (W of 22°E) (Fig. 4.18). It is abundant and widespread on the west coast (Dingle, 1993) which suggests that it is a cold water taxon. This is supported by the fact that the average temperature at the relevant locations on the Agulhas Bank is 10.12°C. Relatively lower average salinities and oxygen levels are also recorded (34.86ppt and 3.68ml/l respectively). Depths range from 91-161m. The distribution is strongly controlled by the coarseness of the substrate - the correlation coefficient for sand is 0.567, and the average percentage sand is 41.9%.

Cytheropteron trinodosum Dingle, 1993

Fig. 4.19, Pl. 5h.

Cytheropteron sp. B Keeler, 1981: 58-59, pl. 3 (figs 1-2).

Cytheropteron spp. Boomer, 1985: 51, pl. 1 (figs 11-12).

Cytheropteron trinodosum Dingle, 1993: 67-71, (figs 40e-f, 42a-e, 43, 44a).

Material 19 valves

Remarks

Specimens from the Agulhas Bank are identical to those from the west coast populations (Dingle, 1993).

Distribution and Ecology

Occurs at four widely-separated sites on the Agulhas Bank (Fig. 4.19). This mid-shelf species has a relatively narrow depth range of 71-108m (37m) on the Agulhas Bank, and a much wider range on the west coast of 90-437m (347m) (Dingle, 1993). This difference in depth range may be artificial - specimens on the west coast may have been carried downslope, or it may be that too few specimens were collected from the Agulhas Bank to determine an accurate depth range. Coarseness of substrate is the primary controlling factor in the distribution of this species. The correlation coefficient with depth is 0.901, and the average sand content is 64.1% sand.

Cytheropteron cuneatum Dingle, 1993

Fig. 4.20, Pl. 6a.

Cytheropteron cuneatum Dingle, 1993: 71-73 (figs 42f, 45a-b).

Material 26 valves

Remarks

Specimens are identical to west coast material (Dingle, 1993). The LV has a more pronounced lace-like reticulation on its surface than on the RV. This feature, although not commented on by Dingle (1993), is shown in his illustrations.

Distribution and Ecology

This species occurs only on the Agulhas Bank from the Cape Peninsula (Dingle, 1993) to Port Elizabeth (Fig. 4.20). It is the most abundant of the *Cytheropteron* species and has a wide depth range at 47-115m. It also shows the widest temperature, oxygen and salinity tolerance of the four species. Average dissolved-oxygen content is low at 3.83ml/l, and muddy substrates are preferred (average sand content is 36% sand).

Cytheropteron sp

Fig. 4.21, Pl. 6b.

Material 9 valves

Remarks

Specimens bear a resemblance to sp. 2882 in Dingle (1993), but are much less strongly punctate. The punctae are concentrated on the alae of the Agulhas Bank specimens, but occur over the entire surface area of the west coast material.

Distribution and Ecology

A similar distribution to *C. cuneatum* is noted, but this species is less abundant and not as widespread (Fig. 4.21). It is not found east of 24°E and depths of occurrence range from 47-117m.

Genus *Kangarina* Coryell & Fields, 1937

Kangarina mucronata (Brady, 1880)

Fig. 4.22, Pl. 6c.

Cytherura mucronata Brady, 1880: 133-134, pl. 32 (figs 9a-d). Puri & Hulings, 1976: 305, pl. 21 (figs 11-12).

Kangarina mucronata (Brady, 1880) Dingle, 1993: 83, (fig 49f, 50a-b).

Material 4 valves

Remarks

Agulhas Bank specimens have slightly more subdued ornamentation than material from the vicinity of Brady's types in False Bay described by Dingle (1993), but are otherwise identical. (False Bay is the first bay to the east of the Cape Peninsula).

Distribution and Ecology

The four sites at which this species occurs are concentrated in the region of 22°E (Fig. 4.22). Brady (1880) also recorded this species in False Bay, and Dingle (1993) records it west of the Cape Peninsula. Depths range from 40m (Dingle, 1993) to 104m.

Genus *Paracytheridea* Müller, 1894

Paracytheridea sp.

Fig. 4.23, Pl. 6d.

Paracytheridea sp. 3339 Dingle, 1993: 94-95, (figs 53e-f).

Material 25 valves

Remarks

This is the same species found by Dingle (1993) as a single valve in False Bay. The Agulhas Bank material is better-preserved and allows the ornamentation of the coarse crested ribs to be illustrated.

Distribution and Ecology

This species is widely distributed on the Agulhas Bank (Fig. 4.23), but does not extend onto the west coast. An inner to mid-shelf species with a depth range of 47-110m. The average temperatures and salinities recorded are high - 12.99°C and 35.09ppt respectively.

Family **Hemicytheridae** Puri, 1953

This family is very diverse and numerically abundant on the south and west coasts of southern Africa. Dingle (1993) recorded 18 species in 10 genera on the west coast continental shelf. The same 10 genera occur on the Agulhas Bank and are represented by 20 species. The primary difference between the two areas is that, on the Agulhas Bank, the genus *Urocythereis* is far more diverse and numerically abundant than on the west coast.

Genus *Ambostracon* Hazel, 1962

Valicenti (1977) distinguishes between two subgenera - *Ambostracon* (Hazel, 1962), and *Patagonacythere* (Hatmann, 1962) - on the strength of the ocular ridge. *A. Ambostracon* has a stronger or more well defined ocular ridge than *Patagonacythere*.

Subgenus *Ambostracon (Ambostracon)* Hazel, 1962

Ambostracon (A) flabellicostata (Brady, 1880)

Fig. 4.24, Pl. 6e-h, 7a-b.

Cythere flabellicostata Brady, 1880: 88-89, pl. 1 (figs 6a-h). Puri & Hulings, 1976: 276-277, pl. 8 (figs 1-4).

Ambostracon sp. B Keeler, 1981: 113-115, pl. 6 (figs 9-10).

Ambostracon sp. D Keeler, 1981: 116-118, pl. 6 (figs 13-14).

Ambostracon sp. 2 Boomer, 1985: 45-46, pl. 4 (figs 62, 65).

Ambostracon (Patagonacythere) sp. A468 Frewin, 1987: 40, pl. 13A.

Ambostracon (A) flabellicostata (Brady, 1880) Dingle, 1992: 43-46, (figs 28a-d, 29a, c, f). Jellinek, 1993: 146, (figs 389-390).

Material 243 valves

Remarks

There appear to be three variants of *flabellicostata* on the Agulhas Bank. The population is dominated by the variety found by Dingle (1992) on the West Coast and upon which Brady (1880) based his type *A*, but two other possible subspecies occur. These show consistent variations from the classic *flabellicostata* morphology. Type A (Pl. 6g-h) has a very pronounced ocular ridge, whilst Type B (Pl. 7a-b) has a very weak ocular ridge, and is also larger with a squarer morphology.

Distribution and Ecology

Ambostracon flabellicostata is abundant and widespread over the entire Agulhas Bank (Fig. 4.24), and occurs as far north as Saldanha Bay (Dingle, 1992). Dingle (1992) noted a restricted and shallow depth range for modern specimens (15-131m), whereas on the Agulhas Bank a depth range of 30-200m is noted. *A. flabellicostata* has a relatively wide temperature, salinity, and dissolved oxygen tolerance. No obvious distribution differences are noted for the three possible subspecies of *A. flabellicosta*.

Ambostracon (A) keeleri Dingle, 1992

Fig. 4.25, Pl. 7c-d.

Ambostracon sp. C Keeler, 1981: 115-116, pl. 6 (figs 11-12).

Ambostracon sp. E Keeler, 1981: 118-119, pl. 6 (figs 15-17).

Ambostracon sp. F Keeler, 1981: 119-120, pl. 6 (figs 18-19).

Ambostracon sp. 1 Boomer, 1985: 45-46, pl. 4 (figs 67-69).

Ambostracon (A) keeleri Dingle, 1992: 46-50, (figs 29a, d, g, 34d-f, 35a-b).

Material 287 valves

Remarks

Agulhas Bank populations are typical species of the genus - although the overall lateral rib pattern is slightly more pronounced than in the bulk of the west coast populations.

Distribution and Ecology

A slightly more abundant species than *A. flabellicostata*, it is also widely distributed over the Agulhas Bank (Fig. 4.25), and extends around the Peninsula as far north as St Helena Bay (Dingle, 1992). A depth range of 15m (Dingle, 1992) to 200m is recorded, which is greater than that noted by Dingle (1992). Sandy substrates are preferred - the recorded average is 85.2% sand. Despite the abundance of this species, the nearshore confinement of its distribution around the Cape Peninsula and further north (Dingle, 1992) suggests that the very cold water temperatures of the west coast cannot be tolerated. The average Agulhas Bank temperature is 11.56°C.

Subgenus *Ambostracon (Patagonacythere)* Hartmann, 1962

Ambostracon (P) sp.

Fig. 4.26, Pl. 7e.

Ambostracon (P) sp. 3556 Dingle, 1993: 98, (figs 54c-e).

Material 113 valves

Remarks

The taxonomic position of this species is uncertain, since the specimens were largely juveniles. They closely resemble the species described by Dingle (1993).

Distribution and Ecology

Widely distributed on the Agulhas Bank, with abundances increasing towards the east (Fig. 4.26). Dingle (1993) recorded a species of *Patagonacythere* in deep water (188-265m) on the mid to outer west coast shelf. Agulhas Bank depths range from 47-116m. These widely differing depth ranges suggest that the west coast and Agulhas Bank populations are not conspecific, as do the high average temperatures and salinities of the Agulhas Bank populations at 12.26°C and 35.04ppt respectively.

Genus *Aurila* Pokorny, 1955

?Aurila sp.

Fig. 4.27, Pl. 7f-h.

Material 62 valves

Remarks

This species is provisionally placed in *Aurila*, however, it may belong in *Austroaurila*. It has an overall resemblance to *Aurila dayii* (Benson & Maddocks, 1964), but has a coarse reticulation and less convex DM in the LV, as well as a different MS pattern. It is possibly a new species.

Distribution and Ecology

This inner-shelf species has a wide longitudinal distribution on the Agulhas Bank (Fig. 4.27), and a depth range of 30-108m. It has a preference for high temperatures, high salinities and high dissolved-oxygen values, the averages being 12.86°C, 35.06ppt and 4.47ml/l respectively.

Genus *Austroaurila* Whatley, Chadwick, Coxhill & Toy, 1987

Austroaurila rugosa Dingle, 1993

Fig.4.28, Pl. 8a-b.

Nereina? sp. B Benson & Maddocks, 1964: 30-31, pl. 5 (figs 13-14), text-fig. 18.

Species 75 Boomer, 1985, text-fig. 5.

Austroaurila rugosa Dingle 1993: 99-103, (figs 55e-f, 56b, 58a-c).

Material 158 valves

Remarks

The same species is recorded by Dingle (1993) from off Namaqualand and the S. Western Cape, but the Agulhas Bank population has a generally coarser ornamentation in which the characteristic postero-dorsal protuberance is more pronounced. This may reflect the better preservation of the Agulhas Bank specimens.

Distribution and Ecology

This species is widespread over the Agulhas Bank, and occurs on the west coast south of 28°S (Dingle, 1993). Abundances generally increase towards the eastern Agulhas Bank (Fig. 4.28) and a wide depth range of 47-200m is recorded. Coarse substrates are preferred, and the average sand content is 86.8% sand.

Genus *Coquimba* Ohmert, 1968

Coquimba cf *C. birchi* Dingle, 1993

Fig. 4.29, **Pl.** 8c-d.

Coquimba birchi Dingle, 1993: 119-122, (fig 67a-e).

Material 14 valves

Remarks

Specimens are more elongate and have more regular reticulate ornamentation than the species described by Dingle (1993) from off the Cape Peninsula. This could be environmentally controlled morphological variation and the populations may be conspecific.

Distribution and Ecology

The three sites at which this mid-shelf species occurs lie between 20 and 21°E (Fig. 4.29) and indicate a narrow depth range of 111-140m. Specimens of a very similar taxon were recovered by Dingle (1993) only between the Cape Peninsula and Cape Agulhas, so that together they occupy a very restricted geographical area, which suggests that the species are very similar if not conspecific. Distribution is controlled primarily by substrate (R^2 for sand content is 0.997), and the average sand content is 59.8% sand. The location of this species on the western Agulhas Bank is due to its preference for low temperature, low salinity and low dissolved-oxygen values. The averages are 10.67°C, 34.9ppt and 3.74ppt respectively.

Genus *Falklandia* Whatley, Chadwick, Coxhill & Toy, 1987

Falklandia sp.

Fig. 4.30, Pl. 8e.

Nereina? sp. A Benson & Maddocks, 1964: 29-30, pl. 5 (figs 1-2, 5, 7), text-fig. 17.
?Falklandia sp. 3546 Dingle, 1993: 107, (figs 59c-d).

Material 9 valves

Remarks

Specimens are identical to the material described by Benson & Maddocks (1964) from Knysna. Both types, however, have a bolder ornamentation of rounded pits and delicate ribs than the two valves found west of the Cape Peninsula by Dingle (1993). However, they have the same overall, subdued appearance.

Distribution and Ecology

There are five widely separated sites on the Agulhas Bank where this species occurs (Fig. 4.30) in addition to one occurrence west of the Cape Peninsula (Dingle, 1993). This inner-shelf species has a depth range from inshore at Knysna Lagoon (Benson and Maddocks, 1964), to 107m.

Genus *Meridionalicythere* Whatley, Chadwick, Coxhill & Toy, 1987

Meridionalicythere petricola (Hartmann, 1974)

Fig. 4.31, Pl. 8f.

Aurila petricola Hartmann, 1974: 285-286, pl. 56 (figs 417-427), pl. 57 (figs 428-432), pl. 149 (fig 8).

Meridionalicythere petricola (Hartmann, 1974) Dingle, 1993: 103-106, (figs 58d-f, 59a).

Material 5 valves

Remarks

Specimens from the Agulhas Bank exhibit the same bolder ornamentation that Dingle (1993) recorded from the inner shelf of the west coast, compared to Hartmann's (1974) original coastal faunas.

Distribution and Ecology

Recovered from two sites on the Agulhas Bank at 20 and 22°E (Fig. 4.31). Hartmann (1974) recorded this species from offshore Lüderitz to Knysna, and found that it occurs on rocky substrates. The two Agulhas Bank sites also have relatively very coarse substrates consisting of more than 90% sand. The UDL is 15m and the LDL is extended to 104m.

Genus *Mutilus* Neviani, 1928

Mutilus bensonmaddocksorum Hartmann, 1974

Fig. 4.32, Pl. 8g.

Mutilus sp. Benson & Maddocks, 1964: 34-35, pl. 6 (figs 7-11), text-fig. 21.

Mutilus bensonmaddocksorum Hartmann, 1974: 280-281, pl. 48 (figs 365-374). Dingle, 1993: 107-108, (figs 59e-f, 61a-b).

Material 29 valves

Remarks

Dingle (1993) recovered only two valves of this species (from Hout Bay), and these are identical to the specimens from the Agulhas Bank. (Hout Bay is a small bay on the Cape Peninsula).

Distribution and Ecology

Mutilus bensonmaddocksorum occurs as far north as Lüderitz (Hartmann, 1974) and is widespread over the Agulhas Bank, with abundances increasing towards the east (Fig. 4.32) because of a preference for the sandier substrates occurring there. The average sand content is 82.2% sand. Studies by Hartmann (1974), Benson and Maddocks (1964) and Dingle (1993), indicate that this is an inshore to inner-shelf species. The present study supports this view, with generally higher abundances at the shallower sites and the indication of a LDL of 127m.

Mutilus malloryi Dingle, 1993

Fig. 4.33, Pl. 8h.

Mutilus malloryi Dingle, 1993: 108-112, (figs 61c-f, 62a, 63e).

Material 24 valves

Remarks

Specimens from the Agulhas Bank are identical to the type material from Hout Bay.

Distribution and Ecology

This species is found concentrated in two regions - between the Cape Peninsula and Mossel Bay, and east of Cape St. Francis (Fig. 4.33). This is an inner-shelf species with a depth range of 30-108m. High temperatures and correspondingly high salinities are preferred, the averages being 12.65°C and 35.07ppt respectively. The relatively high correlation with sand content (R^2=0.243) indicates that substrate is a controlling factor in the distribution of this species - the average sand content is 72.2% sand.

Genus *Quadracythere* Hornibrook, 1952

?Quadracythere sp.

Fig. 4.34, Pl. 9a.

?Quadracythere sp. 3333 Dingle, 1993: 112-113, (figs 62b-c).

Material 134 valves

Remarks

The specimens from the Agulhas Bank are very similar in overall architecture to the west coast material (Dingle, 1993) and are therefore classified as the same species. The lateral surfaces of the Agulhas Bank specimens do, however, lack the robust reticulation of the west coast material.

Distribution and Ecology

Widely distributed over the Agulhas Bank (Fig. 4.34) as far west as the region adjacent to the Cape Peninsula (Dingle, 1993). A wide depth range of 30-200m was recorded. Coarse substrates are preferred, the average sand content of the sediment being 87.9% sand.

Genus *Urocythereis* Ruggieri, 1950

Dingle (1993) remarked that this genus is moderately diverse, but numerically rare, with five species occurring on the west coast and western Agulhas Bank (west of 20°E). Eight species have been found on the Agulhas Bank in this study, four of which Dingle did not record. Keeler (1981) recorded four of the species from the Agulhas Bank, some of which have been reclassified.

Urocythereis arcana Dingle, 1993

Fig. 4.35, Pl. 9b-c.

Urocythereis sp. B Keeler, 1981: 101-103, pl. 5 (figs 11-13).

Urocythereis sp. Boomer, 1985: pl. 4 (fig 56), fig. 7.

Urocythereis arcana Dingle, 1993: 113-117, (figs 62d-f, 65a-b).

Material 378 valves

Remarks
This is the most abundant and widespread species of *Urocythereis*. Morphologically the Agulhas Bank specimens are identical to the west coast material illustrated by Dingle (1993).

Distribution and Ecology
U. arcana is very widely distributed on the south-western (Dingle, 1993) and southern African continental shelf (Fig. 4.35). On the Agulhas Bank, the UDL is 47m and the LDL is 121m. This is a fairly restricted depth range considering its abundance, and this feature cannot be explained by any specific temperature, salinity or dissolved-oxygen level preferences, as wide variations in these parameters are tolerated. It is likely that other factors, not included in this study, are influencing the distribution of this species.

Urocythereis sp. A
Fig. 4.36, Pl. 9d.

Coquimba sp. A Keeler, 1981: 110-112, pl. 6 (fig 5).
?Urocythereis sp. 3570 Dingle, 1993: 117 (fig 65d).

Material 68 valves

Remarks
Keeler (1981) recorded this species on the Agulhas Bank and placed it in the genus *Coquimba.* A single valve was recorded west of Walvis Bay by Dingle (1993). Morphologically all the material is identical, and the classification of *Urocythereis* is adopted based on Dingle's more recent classification of the species.

Distribution and Ecology
Urocythereis sp. A is widely distributed on the eastern Agulhas Bank (Fig. 4.36), but occurs at only one site on the west coast (Dingle, 1993). Depths range from 55-200m (predominantly a mid-shelf species), and coarse substrates are preferred - the average sand

content being 85.8%.

Urocythereis sp. B

Fig. 4.37, Pl. 9e.

Coquimba rugosa Keeler, 1981: 106-108. pl. 5 (figs 18-20), (invalid name - unpublished manuscript).

?Urocythereis sp. 3472 Dingle, 1993: 118 (fig 65e).

Material 154 valves

Remarks

Keeler (1981) recorded this species on the Agulhas Bank and placed it in *Coquimba.* Dingle recorded a single valve south of False Bay and provisionally placed the specimen in *Urocythereis*. All the material is identical.

Distribution and Ecology

Urocythereis sp. B has a very similar distribution to *U.* sp. A (Fig. 4.37). The UDL is 40m and the LDL - also recorded by Keeler (1981) - is 127m. In the present study, no specimens were recovered west of 20°E, and this is due to this species' preference for high temperatures and salinities, the averages being 12.30°C and 35.05ppt respectively.

Urocythereis sp. C

Fig. 4.38, Pl. 9f.

Urocythereis sp. A Keeler, 1981: 100-101, pl. 5 (figs 8-10).

?Urocythereis sp. 3567 Dingle, 1993: 118 (fig 65f).

Material 61 valves

Remarks

The hinge is robust amphidont, and the specimens have very large TEs. The AM areas are wide, and although the MS are not very clear, there is a prominent ovate scar lying in an antero-dorsal position relative to the SC depression. The Agulhas Bank material is identical to the material described by Keeler (1981), and also to the single carapace found by Dingle (1993) near Walvis Bay.

Distribution and Ecology

The distribution is concentrated on the eastern Agulhas Bank, east of 21°E (Fig. 4.38). Keeler (1981) recorded this species in this area, and Dingle (1993) recovered 2 valves off Walvis Bay, which are geographically very isolated from the Agulhas Bank populations. A wide depth range of 47-200m was recorded, as well as a restricted substrate tolerance - specimens are only found in very coarse sediment - the average sand content is 90.7% sand.

Urocythereis sp. C1

Fig. 4.39, Pl. 9g.

Material 206 valves

Remarks

This species is very similar to *Urocythereis* sp. C and may be a subspecies, but there are certain consistent differences between the two. For example, *Urocythereis* sp. C1 has a more quadrate PM outline and more prominent surface ornamentation. In addition the AM and PM outlines, in internal view, have numerous small conical spines on them.

Distribution and Ecology

This species of *Urocythereis* has not been previously recorded, but is abundant and widespread over the entire Agulhas Bank (Fig. 4.39). The UDL is 47m and the LDL is 200m. Wide tolerances of temperature, salinity, oxygen level and substrate type were noted, and there were no significant correlations between any of these parameters and the distribution of this species.

Urocythereis sp. D

Fig. 4.40, Pl. 9h.

Material 21 valves

Remarks

A further species that resembles *Urocythereis* sp. C, but two large cavities in the posteroventral margin of *Urocythereis* sp. D serve to distinguish the two. In addition, lateral surface reticulations are more pronounced in *Urocythereis* sp. D.

Distribution and Ecology

This species, although occurring at only 8 sites, is longitudinally very widespread, and has a narrow depth range of 55-100m (Fig. 4.40). Depth has a relatively strong correlation with the distribution of this species (R^2=0.279), as does salinity of the bottom water (R^2=0.224). Coarse substrates (over 80% sand content) were recorded at all sites.

Urocythereis sp. E

Fig. 4.41, Pl. 10a.

Material 7 valves

Remarks

Resembles sp. A, but has a distinct PM ridge, and the anterior cardinal angle lies in a more posterior position, creating a reflexion in the antero-dorsal outline, particularly when viewed internally.

Distribution and Ecology

Occurs on the eastern Agulhas Bank with a similar distribution to *U. sp. D* (Fig. 4.41), but has a slightly greater depth range at 55-117m. Only substrates containing more than 60% sand are tolerated.

Urocythereis sp. F

Fig. 4.42, Pl. 10b.

Material 19 valves

Remarks

The outline of this species most closely resembles sp. E, but the ornamentation is much less coarse, and the prominent PM ridge is lacking. The two species are obviously closely related, and may be two subspecies of an undescribed taxon.

Distribution and Ecology

The distribution of this species is concentrated between 21 and 23°E (Fig. 4.42). It is an inner-shelf species with a depth range of 47-96m. Average oxygen levels are 4.55ml/l and average temperatures are high at 12.88°C.

Family **Loxoconchidae** Sars, 1925

Genus *Loxoconcha* Sars, 1866

Loxoconcha paiki Whatley & Zhao, 1987

Fig. 4.43, Pl. 10c-d.

Loxoconcha sp. A Paik, 1977: pl. 6 (figs 112-115), pl. 10 (fig 170).

Loxoconcha paiki Whatley & Zhao, 1987: 351, pl. 5 (figs 14-16). Mostafawi, 1992: 151, pl. 5 (fig 105).

Material 65 valves

Remarks

Agulhas Bank specimens are very similar to the material from the Malacca Straits described by Whatley and Zhao (1987), but have less well defined ventero-lateral ribs. Mostafawi's (1992) material from the Sunda Shelf is slightly more rounded, and has even better developed ventero-lateral ribs than either the Agulhas Bank or the Malacca Straits material.

Distribution and Ecology

Occurs on the eastern Agulhas Bank (Fig. 4.43), predominantly on the inner-shelf and depths range from 47-118m. The Sunda Shelf material (Mostafawi, 1992) has a preferred depth of 22m. Warm water and high salinity is preferred by the Agulhas Bank specimens, and the averages are 12.82°C and 35.08ppt respectively.

Loxoconcha sp A

Fig. 4.44, Pl. 10e.

Material 5 valves

Remarks

Specimens are very similar to *Palmoconcha walvisbaiensis* (Hartmann, 1974), but have a slightly broader ventral margin rim in external view. *Palmoconcha walvisbaiensis* also has a convexly curved VM not seen in the Agulhas Bank material.

Distribution and Ecology

Occurs at 5 sites on the eastern Agulhas Bank east of 21°E (Fig. 4.44). This is a mid-shelf species with a depth range of 62-127m.

Loxoconcha sp B

Fig. 4.45, Pl. 10f.

Material 5 valves

Remarks

This species is similar to sp. A above, but is much smaller and rounder, has slightly coarser surface ornamentation and a less prominent eye spot. However, the MS of sp. A and sp. B are very similar, suggesting a close relationship: they may be conspecific.

Distribution and Ecology

Loxoconcha sp. B has a very similar distribution to that of *Loxoconcha* sp. A (Fig. 4.45): the UDL of both types is 62m, whilst *Loxoconcha* sp. A has a shallower LDL at 104m.

Genus *Kuiperiana* Bassiouni, 1962

Kuiperiana angulata Dingle, 1992

Fig. 4.46, Pl. 10g.

Kuiperiana angulata Dingle, 1992: 61-63, (figs 39d-f, 40a, 41a).

Material 4 valves

Remarks

Material from the Agulhas Bank is identical to that from the west coast (Dingle, 1992).

Distribution and Ecology

Dingle (1992) comments that this is the most widely distributed loxochonchid on the south-western shelf of Africa. On the Agulhas Bank it is found to the west of 22°E, and is very rare (Fig. 4.46). It is an outer-shelf species with an UDL of 100m and a LDL of 161m on the Agulhas Bank. The sparcity of this species on the Agulhas Bank is probably due to a preference for much colder and deeper water environments than are generally found there - on the west coast the preferred depth of this species is 300m (Dingle, 1992).

Family **Schizocytheridae** Mandelstam, 1959 (in Benson & Maddocks, 1964)

Genus *Sulcostocythere* Benson & Maddocks, 1964

Sulcostocythere knysnaensis Benson & Maddocks, 1964

Fig. 4.47, Pl. 10h.

Sulcostocythere knysnaensis Benson & Maddocks, 1964: 20-21, fig 9, pl. 3 (fig 1-10).

Material 6 valves

Remarks

Specimens are identical to the material from Knysna Lagoon (Benson & Maddocks, 1964).

Distribution and Ecology

Occurs at two locations on the inner-shelf of the eastern Agulhas Bank (Fig. 4.47), where water depths are 60 and 85m. This is the most common species in the Knysna Lagoon fauna (Benson and Maddocks, 1964) and, therefore, it can be assumed that this a nearshore species and that the environments at the Agulhas Bank locations represent the extreme conditions at which this species can survive.

Family **Trachyleberididae** Sylvester-Bradley, 1948

Genus *Occultocythereis* Howe, 1951

Jellinek (1993) described four species of this genus from the coral reefs off Kenya, but there has been no previous record of this genus in Southern Africa.

Occultocythereis sp.

Fig. 4.48, Pl. 11a.

Occultocythereis sp. A Jellinek, 1993: 141, pl. 11 (figs 237-238).

Material 10 valves

Remarks

The Agulhas Bank material is remarkably similar to the Kenyan material illustrated by Jellinek (1993) considering the specialised environments of the Kenya populations. The only noticeable differences are: the slightly less regular DM outline of the Kenyan specimens and the faint, delicate reticulation on some of the Agulhas Bank specimens.

Distribution and Ecology

Occurs on the mid to outer-shelf of the Agulhas Bank at three locations between 20 and 21°E and at one isolated location at approximately 25°E (Fig. 4.48). This species favours sandy substrates and bottom water having dissolved-oxygen values over 4ml/l - the Kenyan environments in which this species occurs are also generally sandy and well oxygenated.

Genus *Ruggieria* Keij, 1957

Ruggieria cytheropteroides (Brady, 1880)

Fig. 4.49, Pl. 11b-c.

Cythere cytheropteroides Brady, 1880: 78, pl. 15 (figs 5a-d). Puri & Hulings, 1976: 272-273, pl. 9 (figs 5-8).

Bosquetina sp. Keeler, 1981: 41-43, pl. 2 (fig 1).

Ruggieria cytheropteroides (Brady, 1880) Boomer, 1985: 19-21, pl. 1 (figs 1-3). Dingle, 1992: 63-68, (figs 41d-f, 43a-b, 44).

Material 649 valves

Remarks

Agulhas Bank populations are identical to those described by Brady (1880) and to the populations from the west coast described by Dingle (1992).

Distribution and Ecology

Longitudinally this species is very widespread over the entire Agulhas Bank (Fig. 4.49). Dingle (1992) records this species as the third most abundant on the west coast and notes that it is a deep water species. On the Agulhas Bank it is located on the mid to outer-shelf, and has an UDL of 60m and a LDL of 200m, but it is most abundant in depths ranging from 100-200m. This cold water species occurs at sites with an average temperature of 10.61°C, and an average salinity of 34.93ppt. It is the most abundant species in the sparsely populated western Agulhas Bank mudbelt, and has strong correlations between distribution and temperature (R^2=0.265), and distribution and salinity (R^2=0.462). This indicates that it is strongly associated with the Benguela Ecosystem.

Subfamily Pterygocytherinae Puri, 1957

Genus *Incongruellina* Ruggieri, 1958

Incongruellina venusta Dingle, 1993

Fig. 4.50, Pl. 11d.

Incongruellina cf. *I. semispinescens* Ruggieri, 1958. Boomer, 1985: 21-23, pl. 2 (figs 24-26).

Incongruellina venusta Dingle, 1993: 47-50, (figs 26e, 28a-f, 29).

Material 27 valves

Remarks

Agulhas Bank populations are identical to those from the west coast described by Dingle (1993).

Distribution and Ecology

I. venusta occurs predominantly on the west coast, where it is widely distributed on the mid to outer-shelf (Dingle, 1993). On the Agulhas Bank it occurs only west of 22°E (Fig. 4.50), on the mid to outer-shelf, where it has a depth range of 73-154m. It is a cold water species with a preference for temperatures below 11°C and correspondingly lower salinities. It is most abundant in the western Agulhas Bank mudbelt, where it is associated with *Ruggieria cytheropterioides*, and therefore also with the Benguela Ecosystem.

Subfamily Thaerocytherinae Hazel, 1967

Genus *Bradleya* Hornibrook, 1952

Subgenus *Bradleya (Quasibradleya)* Benson, 1972

Bradleya (Q) sp.

Fig. 4.51, Pl. 11e-f.

Material 5 valves

Remarks

This species bears a resemblance to the Oligocene-Miocene species *B (Q) paradictyonites* (Benson, 1972: 45-46, pl. 8 (fig 3)) from the North coast of Tasmania. The coarse ornamentation is similar, but the Agulhas Bank species has a weaker ocular ridge. More of the mural struts between principal members are lacking, creating much larger fossae than the species from Tasmania. Dingle (1993) describes species of *Bradleya* and *(B) Quasibradleya*, but neither has the strength nor style of secondary ornamentation seen in the Agulhas Bank material.

Distribution and Ecology

Bradleya (Q) sp. occurs at three locations on the outer-shelf of the Agulhas Bank (Fig. 4.51). Depths range from 115-200m, average temperatures are low (below 10.1^{0}C), and substrates are coarse, containing over 90% sand.

Genus *Poseidonamicus* Benson, 1972

Poseidonamicus cf. panopsus Whatley & Dingle, 1989

Fig. 4.52, Pl. 11g-h.

Bradleya? sp Boomer, 1985: 42-43, pl. 3 (figs 35-36).

Poseidonamicus panopsus Whatley & Dingle, 1989: 442-447 (figs 2, 3, 4a-e, 5c).

Material 35 valves

Remarks

Very similar to *Poseidonamicus panopsus* (Whatley & Dingle, 1989), but differs in having a more prominent dorso-lateral ridge, which is posteriorly flared in the RV. There is also a post-dorsal spine in the LV. The eye spot of the Agulhas Bank specimens is more prominent compared to that of the west coast material.

Distribution and Ecology

Bradleya (Q) sp. and *Poseionamicus cf panopsus* have a very similar distribution on the outer-shelf of the Agulhas Bank (Fig. 4.52). *Poseidonamicus cf. panopsus* occurs in deep water ranging from 110-200m (the average depth is 139m). This environment has cool average temperatures - 10.26°C, and low salinities - 34.93ppt. Temperature is the primary controlling factor in the distribution of this species, as shown by the high value of the correlation coefficient - 0.637. Dingle (1993) documented specimens from the west coast which may be conspecific - and a deep water environment was also indicated.

Subfamily Trachyleberidinae Sylvester-Bradley, 1947

Genus *Chrysocythere* Ruggieri, 1962

Chrysocythere craticula (Brady, 1880)

Fig. 4.53, Pl. 12a.

Cythere craticula Brady, 1880: 89, pl. 21 (figs 7a-d). Puri & Hulings, 1976: 271, pl. 14 (figs 9-12).

Costa craticula (Brady, 1880) Keeler, 1981: 159-162, pl. 9 (figs 10-13).

Cativella sp. Boomer, 1985: 28-29, pl. 2 (figs 22-23).

Chrysocythere sp. A105 Frewin, 1987: 71-72, pls 23c, 24c-d, text-fig. 2.19c.

Chrysocythere craticula (Brady, 1880) Dingle, 1993: 30-33, (figs 18c-f).

Material 441 valves

Remarks

Specimens from the Agulhas Bank show no significant morphological differences to the ?Palaeocene-Eocene material described by Frewin (1987) and the Quaternary material from the west coast described by Dingle (1993). The Holocene specimens from the Agulhas Bank do, however, show a slightly stronger development of secondary ribs.

Distribution and Ecology

Chrysocythere craticula is widely distributed and abundant over the entire Agulhas Bank (Fig. 4.53). Dingle (1993) records this species around the Cape Peninsula and on the west coast shelf south of 28°S. Recorded depths on the Agulhas Bank range from 47-200m, which is a very similar range to that recorded by Dingle (1993). No specific temperature, salinity, dissolved-oxygen content or substrate type, is indicated.

Genus *Henryhowella* Puri, 1957

Henryhowella melobesioides (Brady, 1869)

Fig. 4.54, Pl. 12b.

Cythere melobesioides Brady, 1869: 162, pl. 12 (figs 10-11); 1880: 108, pl. 18 (figs 1e-g). Puri & Hulings, 1976, pl. 25 (figs 1-2).

non *Cythere melobesioides* Brady, 1869. Brady, 1880, pl. 18 (figs 1a-d).

Cythere nodulifera Brady, 1869: 163, pl. 19 (figs 24-25).

Henryhowella sp. Keeler, 1981: 162-163, pl. 9 (fig 14).

Henryhowella sp. Boomer, 1985: pl. 1 (figs 6-8, 18).

non *Henryhowella* sp. Boomer, 1985: 25-27, pl. 3 (figs 38-39).

Henryhowella melobesioides (Brady, 1869) Dingle, Lord & Boomer, 1990: 311-318, (figs 42c-f, 43a-f, 44a-d, 47a). Dingle, 1992: 68-71, (figs 43c-f).

Material 160 valves

Remarks

As on the west coast, there is a slight variation in the external morphology, and in the shape and size of the spines of *Henryhowella* specimens. Following Dingle *et al.* (1990), the Agulhas Bank populations have all been accommodated in Brady's (1880) species *H. melobesioides*, as no geographical boundaries could be identified for the variants. The majority of the specimens are the squatter variety with dense, stubby spines, which Dingle (1992) described as a possible shallow water variety. Water depth may well be the determining factor, because the Agulhas Bank is generally a shallower water environment than most of the west coast study area.

Distribution and Ecology

Although Keeler (1981) did not record this species on the Agulhas Bank, it is widespread on the inner to mid-shelf (Fig. 4.54). Depths range from 47-161m on the Agulhas Bank, and from 140-990m on the west coast (Dingle, 1992). The shallower Agulhas Bank environment may well account for the majority of the specimens having dense stubby spines. No specific environmental conditions are preferred, and there are no significant correlations between the distribution of this species and the environmental parameters.

Genus *Neocaudites* Puri, 1960

Neocaudites cf. *osseus* Dingle, 1993

Fig. 4.55, Pl. 12c-d.

Munseyella sp. Keeler, 1981: 158-159, pl. 9 (figs 8-9).

Occultocythereis sp. 2 Boomer, 1985: 30-31, pl. 2 (fig 32).

Neocaudites osseus Dingle, 1993: 36-39, (figs 22b, 24a-d).

Material 29 valves

Remarks

Dingle (1993) distinguished two similar west coast species with strong lateral ribs - one of which was also punctate (*punctatus*). The Agulhas Bank population is non-punctate, but has a consistently larger, curved ventero-lateral rib than Dingle's non-punctate form (*osseus*). There are two alternatives in accommodating the Agulhas Bank specimens - one is to recognize a new species, and the other is to broaden the definition of *osseus* to include forms with a larger ventero-lateral rib that anteriorly almost joins the ventral margin ridge - unlike *punctatus* where it does join.

Distribution and Ecology

Neocaudites cf. osseus occurs at scattered sites east of 20°E (Fig. 4.55). Dingle (1993) records several locations off the south-western Cape as far north as the Orange River. A restricted depth range of 60-119m is recorded in this study, which compares well with the range noted by Dingle (1993) of 58-120m, possibly suggesting conspecific populations. However, *N. cf osseus* is found on very coarse substrates with sand contents of greater than 90%, which is not a feature of the west coast.

Neocaudites sp.
Fig. 4.56, Pl. 12e-f.

Material 10 valves

Remarks

Similar to *osseus*, but the median ridge is straight, and the continuous AM, ventral and PM bordering ridge is massive. It also bears a strong resemblance to the species placed in the genus *Falsocythere* Ruggieri, 1972 by Jellinek (1993), who records *Falsocythere terryi* (Holden, 1967) off Kenya. This is, however, a more elongate species, with a less well developed median ridge.

Distribution and Ecology

Occurs predominantly south-west of Port Elizabeth, but is also found at one location south-east of Cape Agulhas (Fig. 4.56). The UDL is 52m and the LDL is 119m - a similar range to that of *N. osseus*. Coarse substrates (over 70% sand) are preferred.

Genus *Pseudokeijella* Dingle, 1992

Pseudokeijella lepralioides (Brady, 1880)

Fig. 4.57, Pl. 12g-h.

Cythere lepralioides Brady, 1880: 94, pl. 19 (figs 5a-d). Puri & Hulings, 1976: 280-281, pl. 12 (figs 10-11).

Ruggieria lepralioides (Brady, 1880) Keeler, 1981: 173-175, pl. 10 (figs 1-3).

Leguminocythereis? sp. Boomer, 1985: 47-49, pl. 1 (figs 4-5).

Leguminocythereis sp. 1507 Frewin, 1987: 44-45, pl. 15a-d.

Pseudokeijella lepralioides (Brady, 1880) Dingle, 1992: 72-76, (figs 50a-f).

Material 3608 valves

Remarks

Identical to Brady's (1880) original material from the vicinity of the Cape Peninsula.

Distribution and Ecology

P. lepralioides is the most abundant and widespread species on the Agulhas Bank (Fig. 4.57). It is also the most abundant taxon on the west coast (Dingle, 1992). Depths on the Agulhas Bank range from 47-200m and similarly on the west coast. This species is tolerant of very wide variations in temperature, oxygen level, salinity and substrate type. Its distribution is primarily controlled by substrate type (R^2=0.306); the average sand content of the sediment in which this species occurs is 73.3% sand.

Family **Xestoleberididae** Sars, 1928

Genus *Xestoleberis* Sars, 1866

Xestoleberis africana Brady, 1880

Fig. 4.58, Pl. 13a-b.

Xestoleberis africana Brady, 1880: 126, pl. 30 (figs 4a-c). Puri & Hulings, 1976: 299, pl. 19 (figs 15-16). Dingle, 1992: 77-79, (figs 54a-e, 56a-b).

?Xestoleberis sp. Keeler, 1981: 182-183, pl. 10 (figs 14-15).
Xestoleberis spp. Boomer, 1985: 60-61, pl. 3 (figs 52-53).

Material 247 valves

Remarks
Identical specimens to those recorded by Brady (1880) from False Bay and by Dingle (1992) from the length of the west coast shelf.

Distribution and Ecology
Occurs along the length of the west coast (Dingle, 1992) and abundantly on the Agulhas Bank (Fig. 4.58). The preference for mid-shelf environments indicated by Dingle (1992) is also encountered in the present study, and depths range from 40-140m. Greatest abundances are found where temperatures are below 12°C, and substrates contain more than 80% sand.

Xestoleberis hartmanni Dingle, 1992
Fig. 4.59, Pl. 13c-d.

Xestoleberis hartmanni Dingle, 1992: 79-83, (figs 54f, 55a-d, 56g-h, s, 58).

Material 69 valves

Remarks
This angular species was described by Dingle (1992) from off the Cape Peninsula. Agulhas Bank specimens are identical to his material.

Distribution and Ecology
In the present study *X. hartmanni* is found to occur east of 20°E on the Agulhas Bank, where it has a wide distribution (Fig. 4.59). Dingle (1992) records this species in waters off the south-western Cape. Water depths range from 15m in Hout Bay to 162m on the Agulhas Bank. It is most abundant at locations with an average temperature range of 11-12°C, and only occurs on coarse substrates - the average sand content being 90.8% sand.

Indet sp. 1

Fig. 4.60, Pl. 13e-f.

Coquimba seminudum Keeler, 1981: 108-110, pl. 6 (figs 1-4) (invalid species - unpublished manuscript).

Material 46 valves

Remarks

The Agulhas Bank specimens are identical to *Coquimba "seminudum"* (Keeler, 1981). However, because the anterior, dorsal MS is hook-shaped, this species is more likely to be a trachyleberid, rather than a hemicytherid, and therefore needs a more suitable generic placement than *Coquimba*.

Distribution and Ecology

This predominantly mid-shelf species has a wide distribution on the Agulhas Bank east of 20°E (Fig. 4.60), and is located in water depths ranging from 47 to 127m.

Indet sp. 2

Fig. 4.61, Pl. 13g.

Material 9 valves

Remarks

Species with very coarse surface reticulation, consisting of large, deep, irregularly shaped fossae, and a punctate interior surface.

Distribution and Ecology

An inner-shelf species which, despite its rarity, is widely distributed on the Agulhas Bank (Fig. 4.61). Depths range from 47-119m, and warmer water conditions (over 11°C) are preferred.

Indet sp. 3

Fig. 4.62, Pl. 13h & 14a.

Material 31 valves

Remarks

This ovate species has distinctive surface ornamentation which consists of regular reticulation of fossae, with secondary reticulation superimposed.

Distribution and Ecology

Occurrences are concentrated between 21 and 22°E (Fig. 4.62). This inner-shelf species has a depth range of 47-104m and a preference for very warm water (over 13°C), and high salinities (over 35ppt).

Indet sp. 4

Fig. 4.63, Pl. 14b-c.

Material 144 valves

Remarks

This species has similarities to *Garciaella* sp. (Keeler, 1981: pl. 2 figs 5-9), but lacks the two distinctive lateral ribs, and has less pronounced surface reticulation. External morphology is, however, very similar.

Distribution and Ecology

This species has a wide longitudinal distribution on the Agulhas Bank (Fig. 4.63) and occurs on the mid to outer-shelf, where its average depth is 118.5m. (Depths range from 91-200m). Average temperatures are cool - 10.86°C, and average salinities are relatively low - 34.96ppt.

Indet sp. 5

Fig. 4.64, Pl. 14d.

Material 28 valves

Remarks

Species with a quadrate external morphology and regular reticulation consisting of shallow fossae separated by punctated muri. Specimens are badly preserved.

Distribution and Ecology

Distribution is scattered east of 21°E (Fig. 4.64). This is a mid-shelf species with a restricted depth range of 82-127m. Locations at which this species occurs have average temperatures of 10.69°C. The dissolved-oxygen content of the bottom water is a controlling factor in the distribution of this species (R^2=0.351), which only tolerates relatively well-oxygenated water, with an average oxygen content of 4.33ml/l.

Indet sp. 6

Fig. 4.65, Pl. 14e.

Material 6 valves

Remarks

Large quadrate species with surface ornamentation which strongly resembles that of *Pseudokeijella lepralioides*. Short stubby spines occur on the postero and antero-ventral margins.

Distribution and Ecology

Occurs at two deep water locations on the outer-shelf of the Agulhas Bank (Fig. 4.65). Depths are 162 and 200m, which suggests that the rarity of this species is accounted for by the fact that the majority of the sediment samples were taken from sites too shallow for this species to occur in.

Indet sp. 7

Fig. 4.66, Pl. 14f-h.

Material 43 valves

Remarks

Species with an elongate, rectangular external morphology. Surface ornamentaion is complex, consisting of primary maze-like reticulation, within which the secondary reticulation consists of deep fossae, which occur in groups on the surface. Tertiary reticulation consists of punctae found within the maze-like walls.

Distribution and Ecology

This species is found in two regions on the Agulhas Bank - between 20 and 23°E, and between 25 and 26.5°E (Fig. 4.66). Depths range from 47-117m for this inner to mid-shelf species, which prefers high bottom-water temperatures and relatively saline environments - averages for these parameters being 12.48°C and 35.06ppt, respectively.

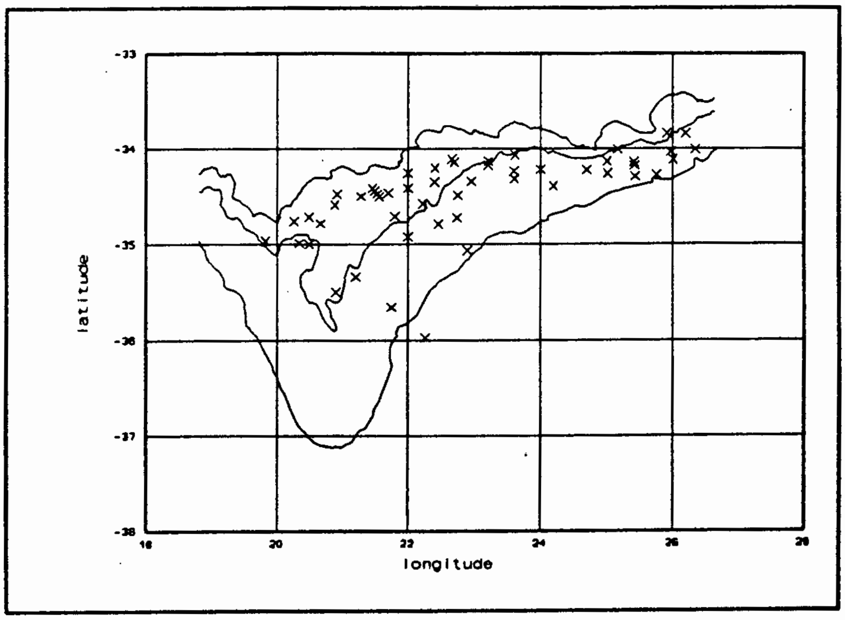


Figure 4.1 Distribution of *Cytherella dromedaria*

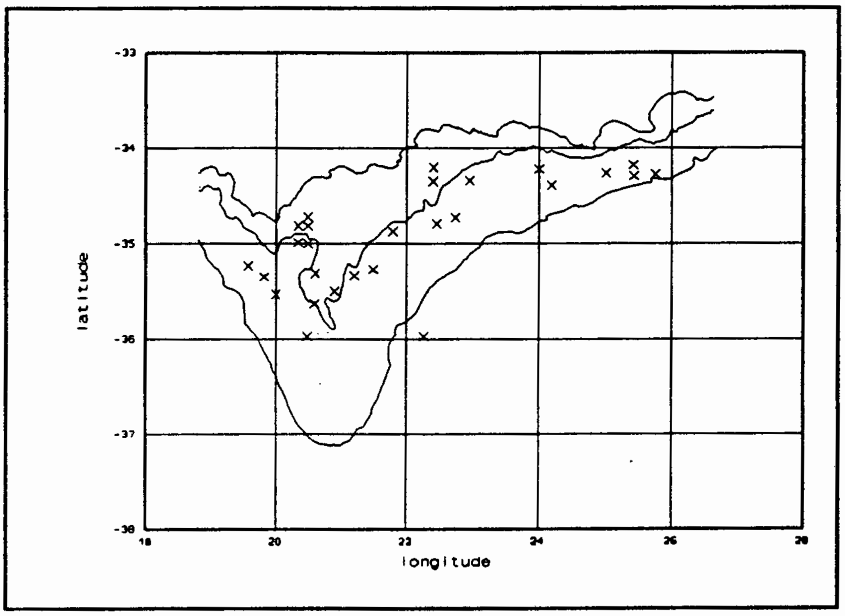


Figure 4.2. Distribution of *Cytherella namibensis*

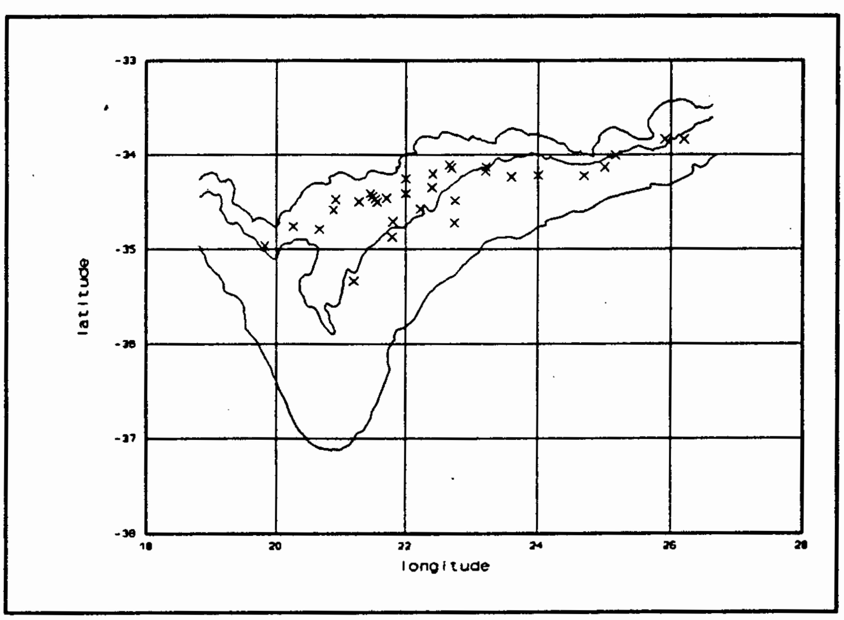


Figure 4.3. Distribution of *Cytherella sp*

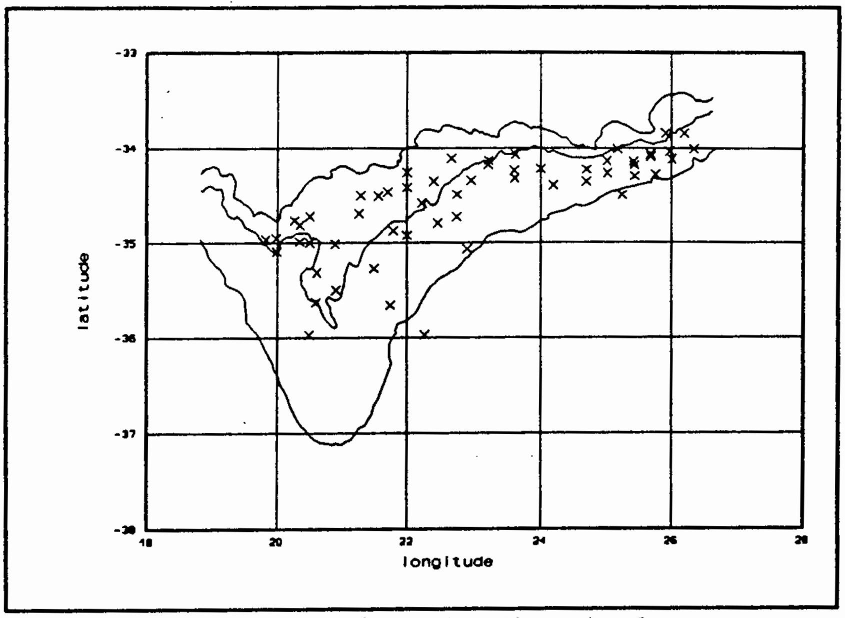


Figure 4.4. Distribution of *Bairdoppilata simplex*

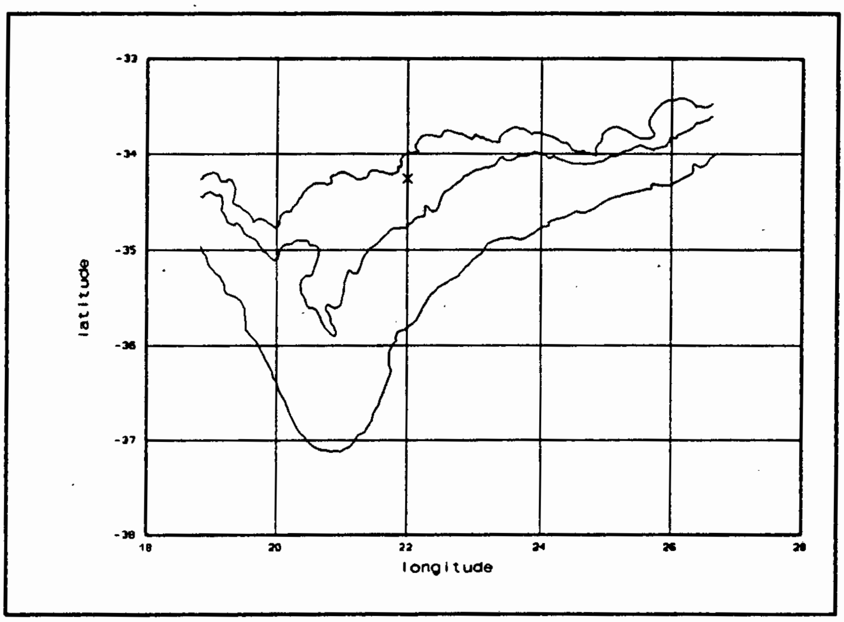


Figure 4.5 Distribution of *Aglaiella railbridgensis*

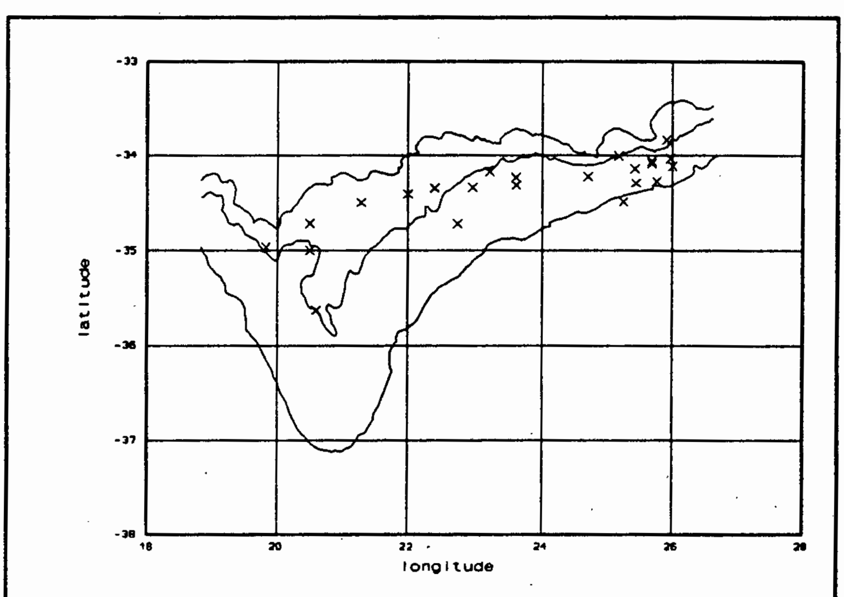


Figure 4.6. Distribution of *Paracypris lacrimata*

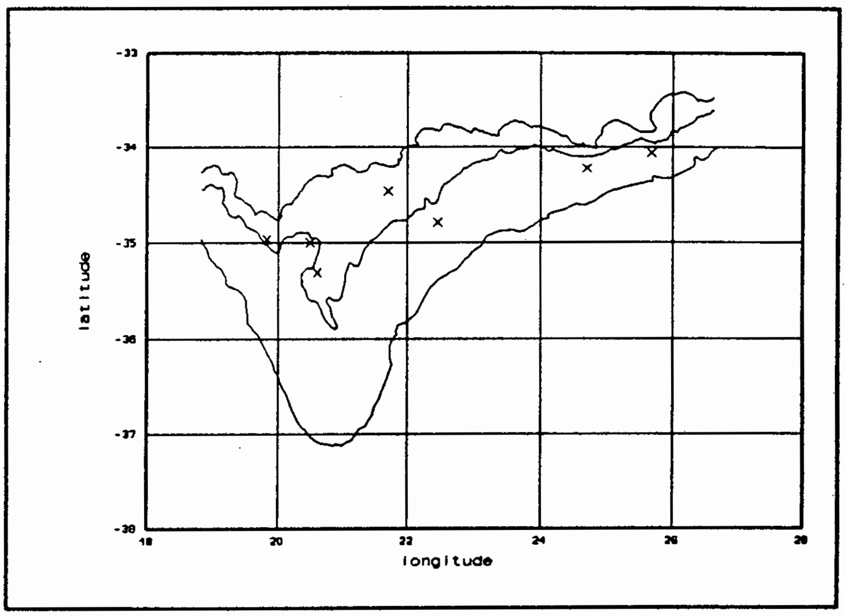


Figure 4.7. Distribution of *Paracypris sp.*

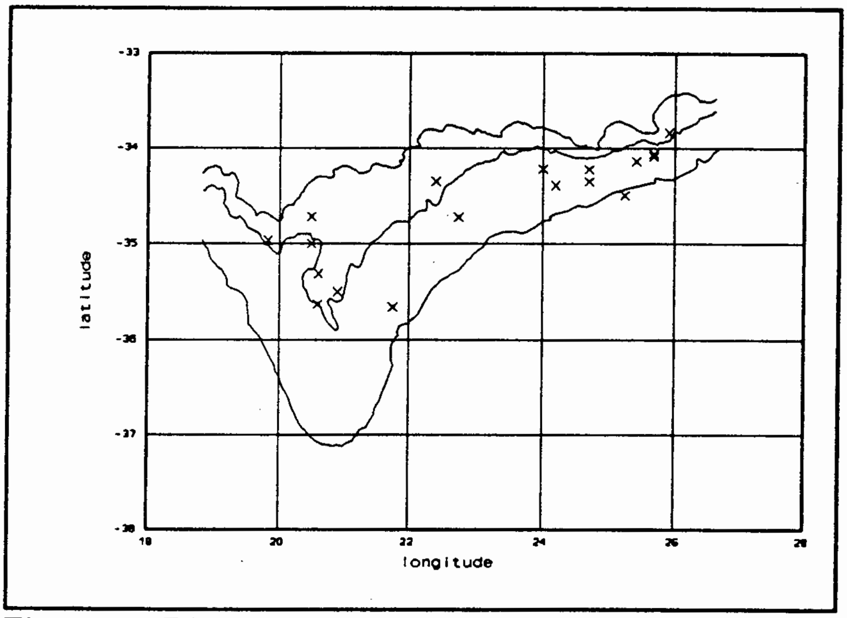


Figure 4.8. Distribution of *Macrocypris sp*

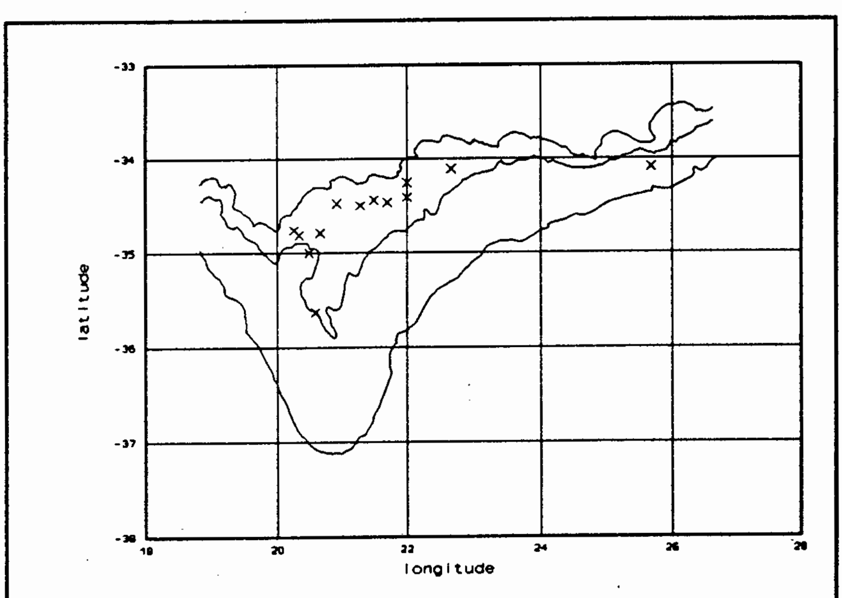


Figure 4.9. Distribution of *Argilloecia sp*

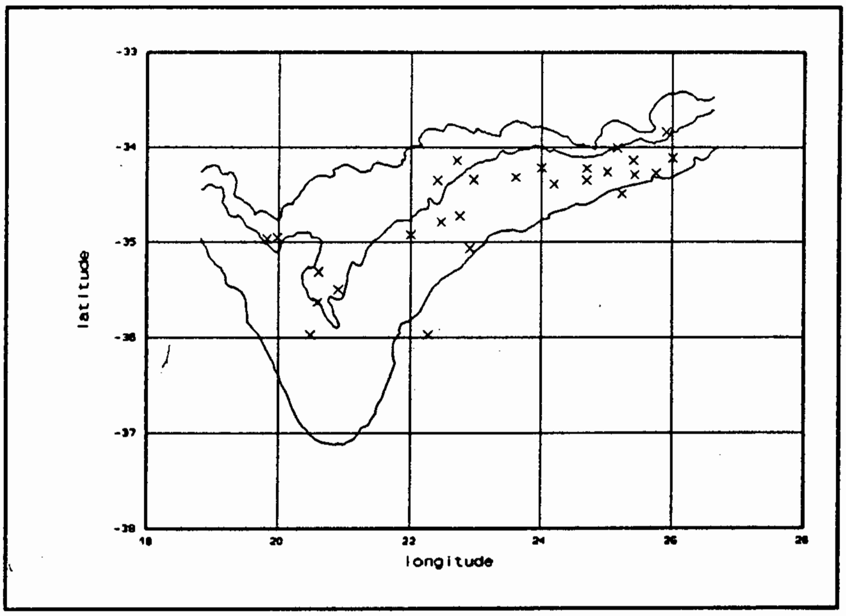


Figure 4.10. Distribution of *Australoecia fulleri*

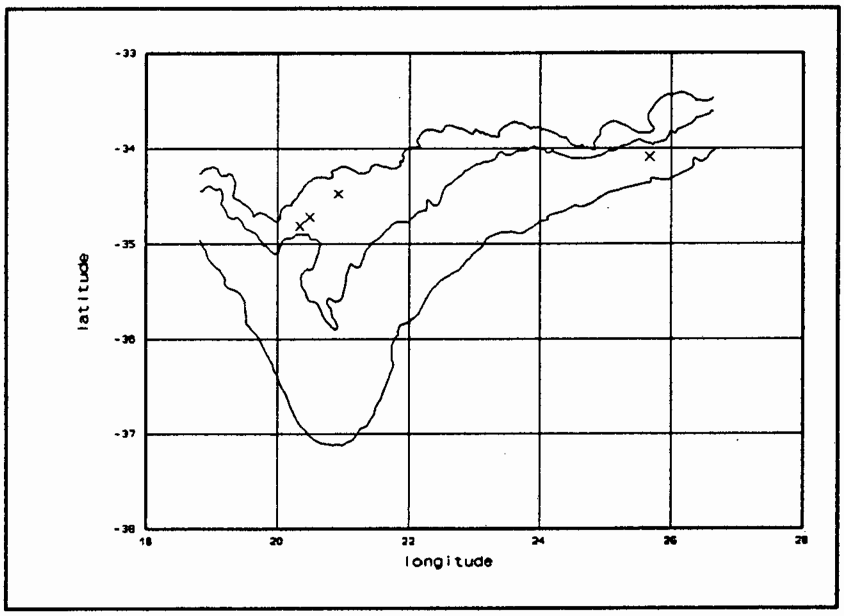


Figure 4.11. Distribution of *Propontocypris sp.*

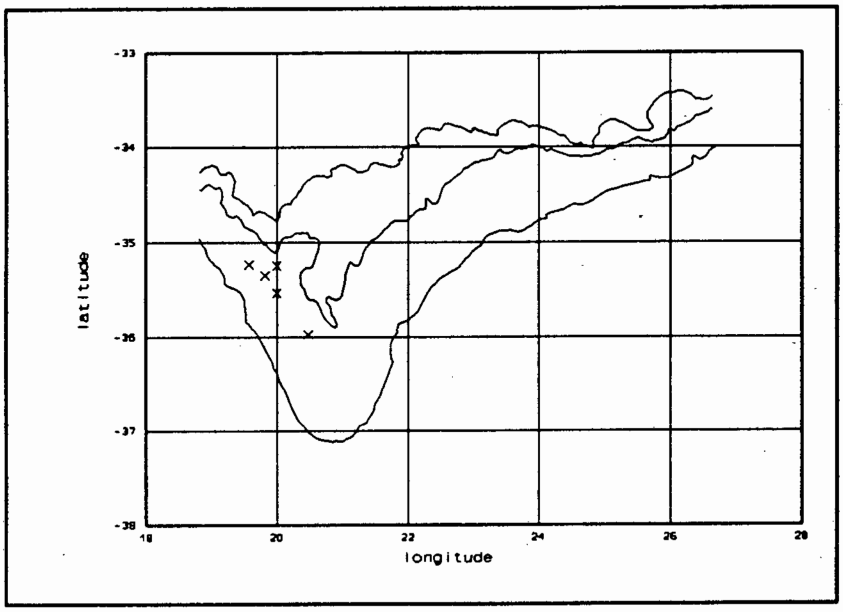


Figure 4.12. Distribution of *Buntonia rogersi*

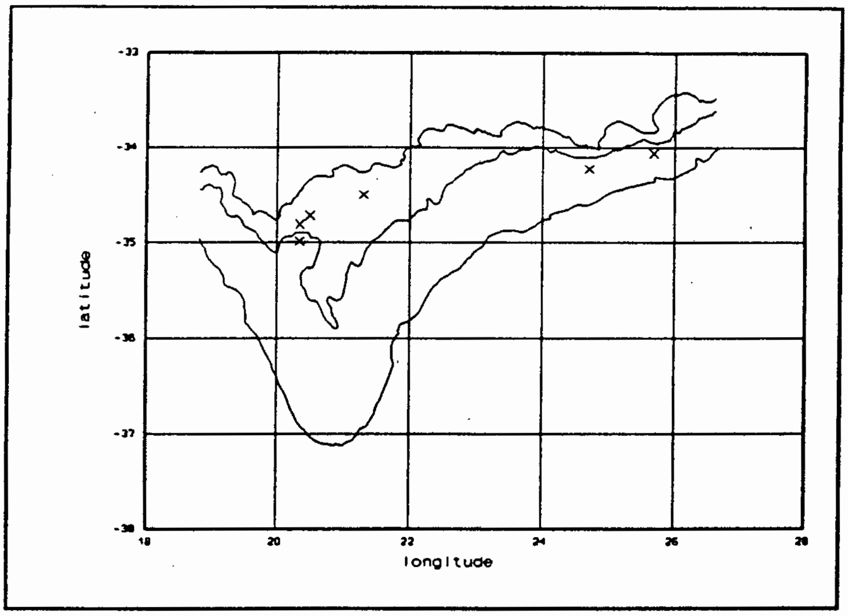


Figure 4.13. Distribution of *Bythocythere sp*

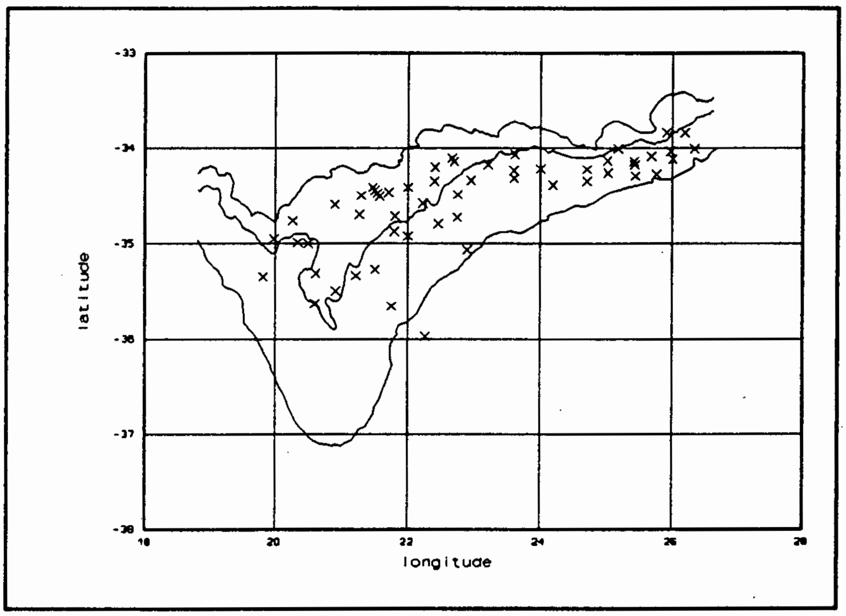


Figure 4.14. Distribution of *Doratocythere exilis*

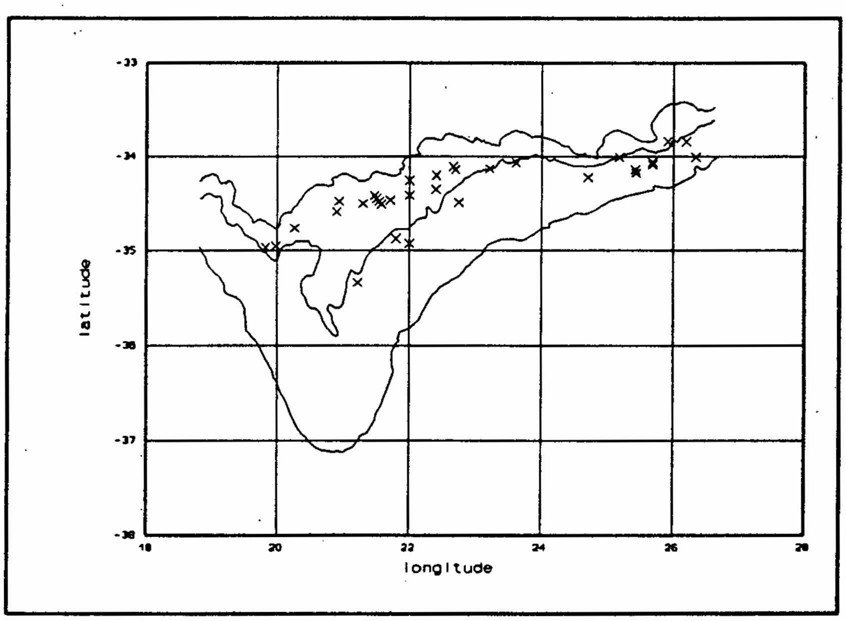


Figure 4.15. Distribution of *Garciaella (k) knysnaensis*

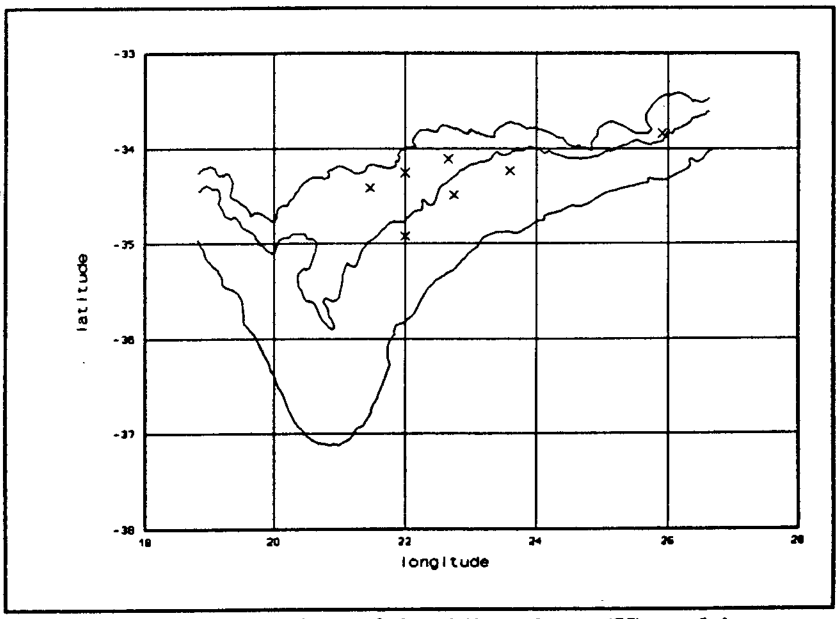


Figure 4.16. Distribution of *Strobilocythere (K) malzi*

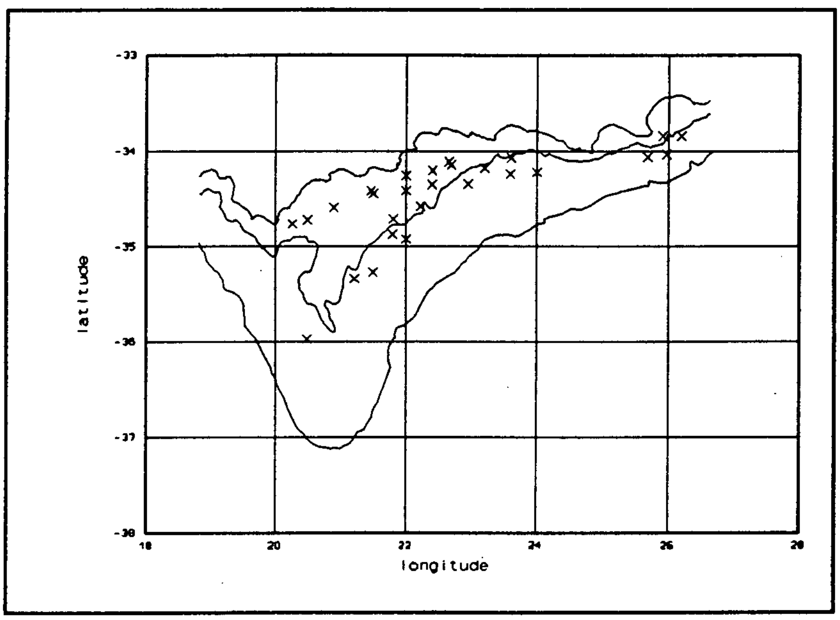


Figure 4.17. Distribution of *Neocytherideis boomeri*

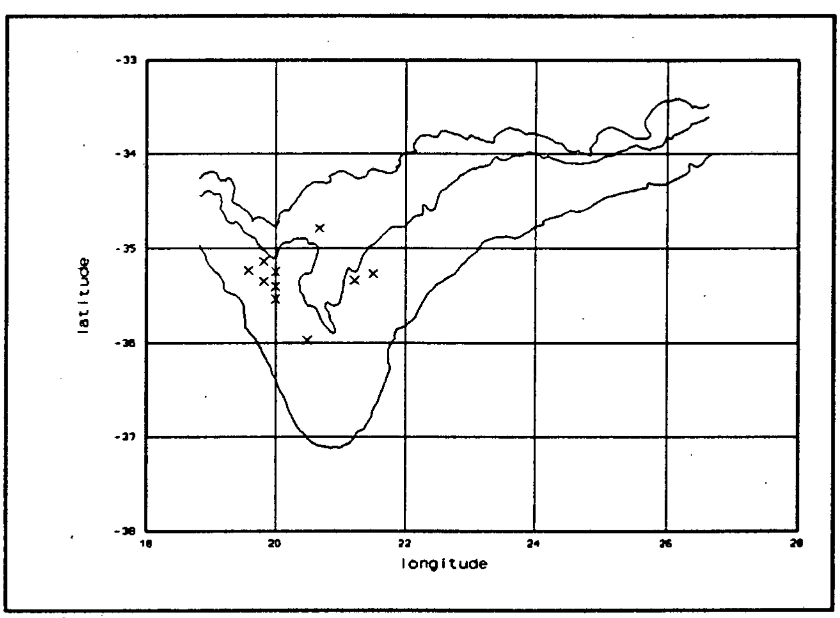


Figure 4.18. Distribution of *Cytheropteron whatleyi*

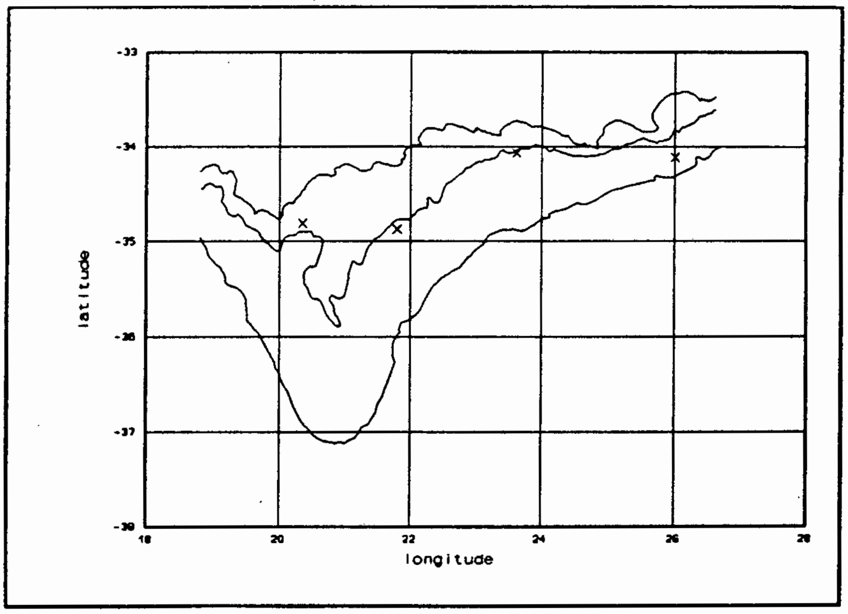


Figure 4.19. Distribution of *Cytheropteron trinodosum*

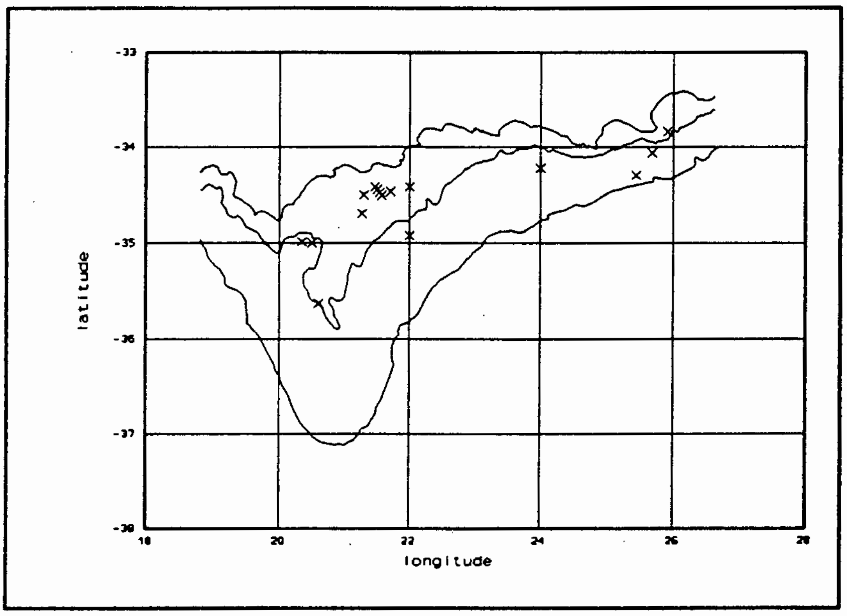


Figure 4.20. Distribution of *Cytheropteron cunneatum*

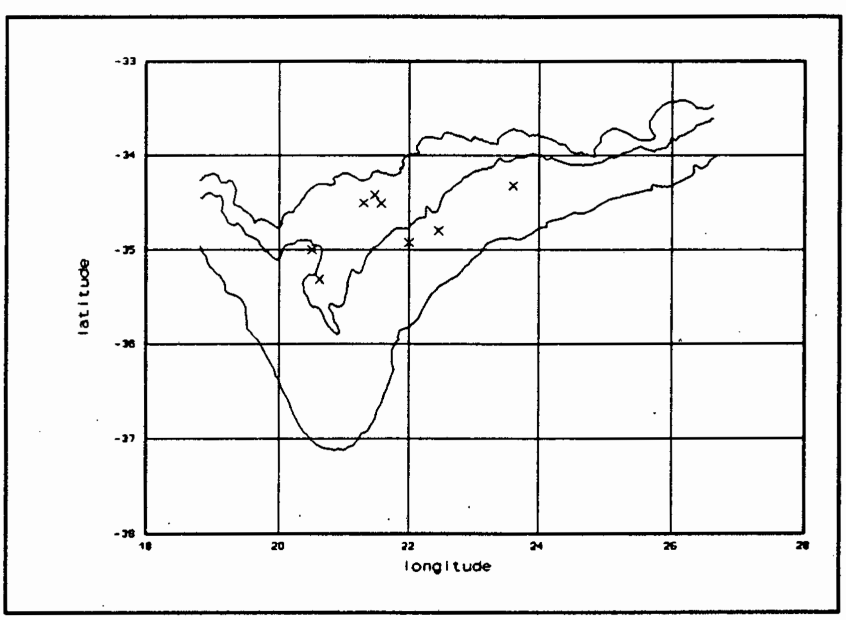


Figure 4.21. Distribution of *Cytheropteron sp.*

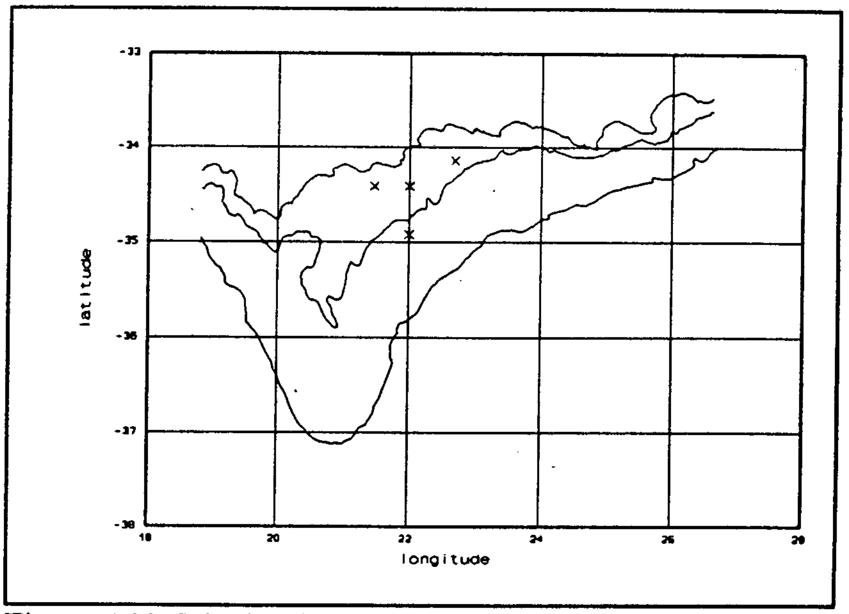


Figure 4.22. Distribution of *Kangarina mucronata*

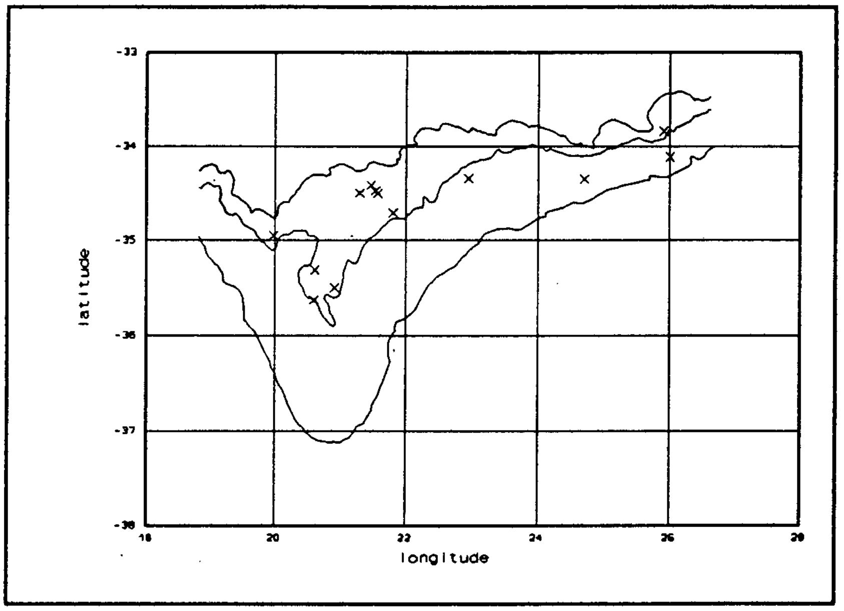


Figure 4.23. Distribution of *Paracytheridea sp*

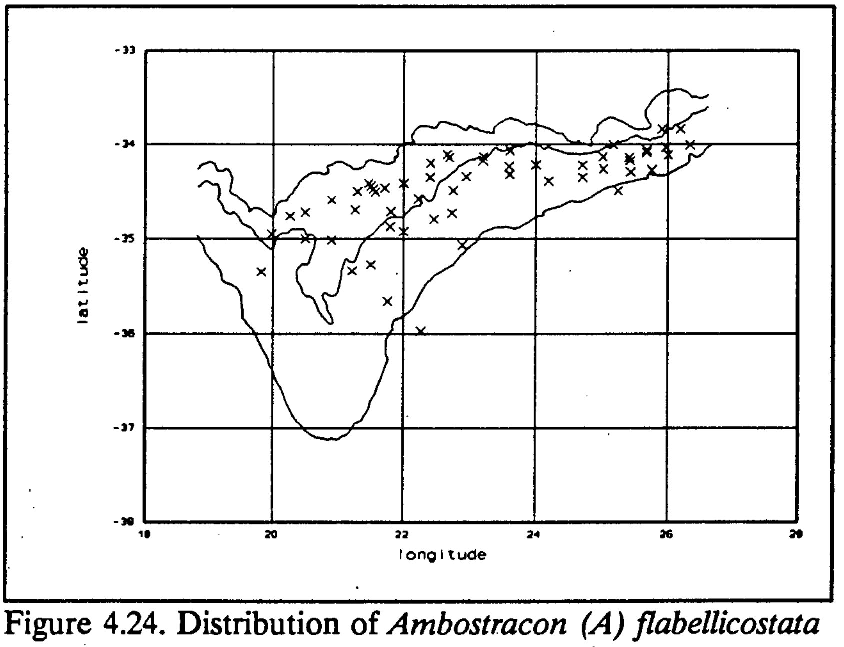


Figure 4.24. Distribution of *Ambostracon (A) flabellicostata*

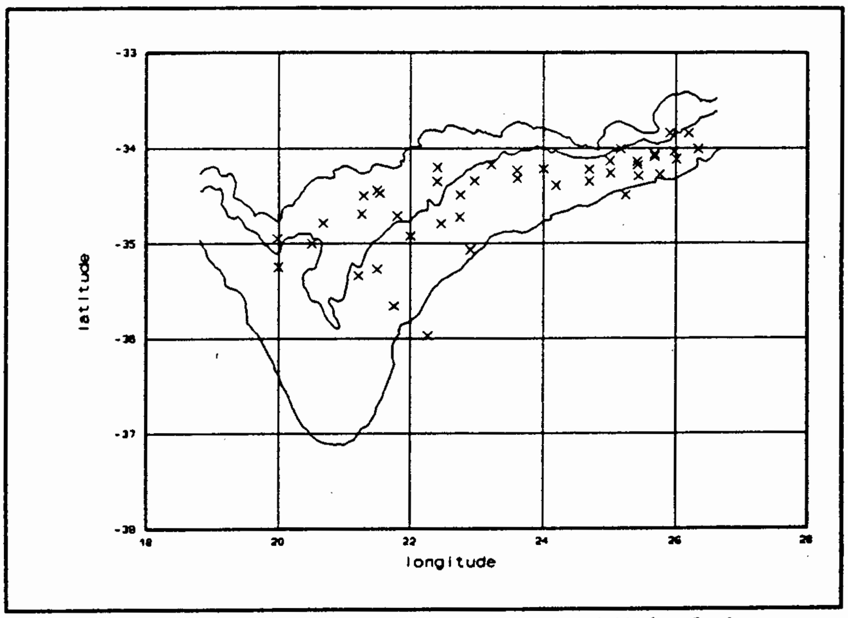


Figure 4.25. Distribution of *Ambostracon (A) keeleri*

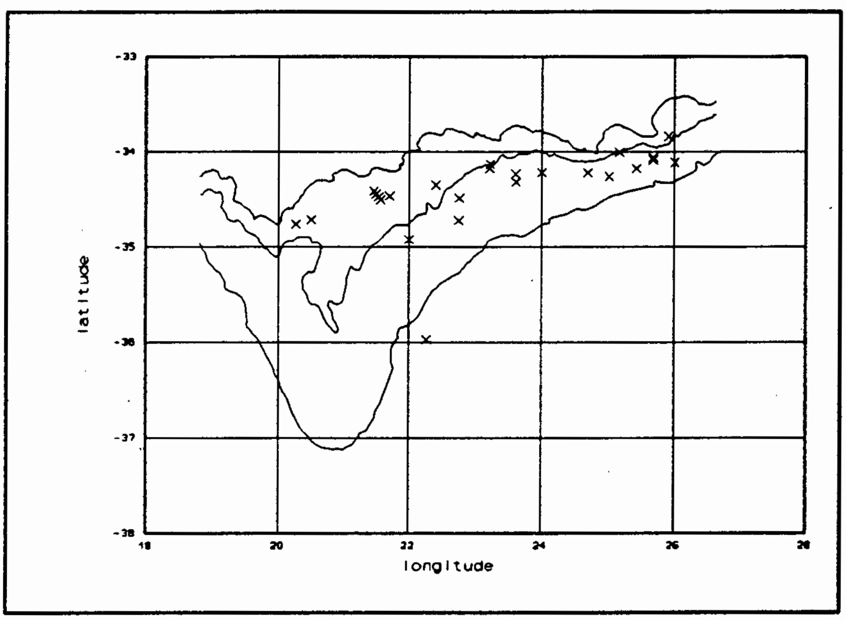


Figure 4.26. Distribution of *Ambostracon (P) sp*

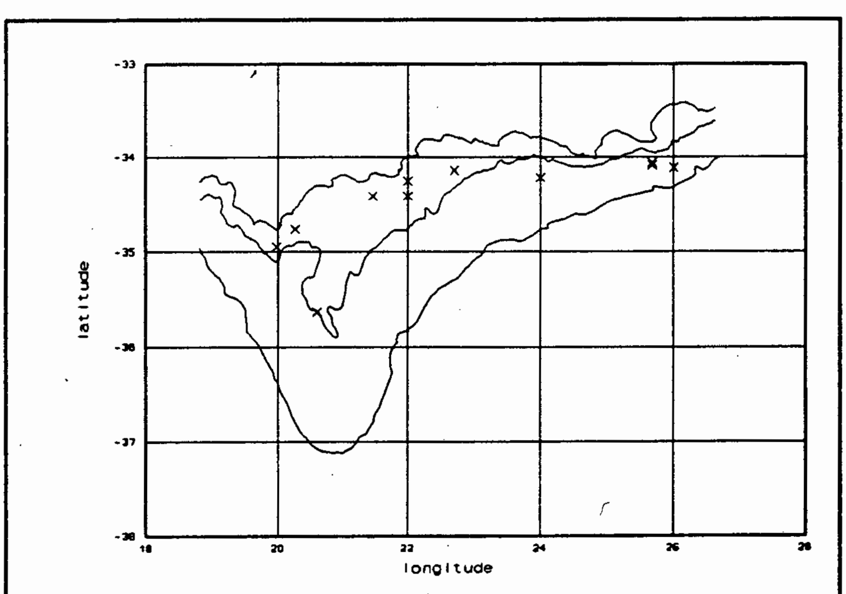


Figure 4.27. Distribution of *Aurilla sp*

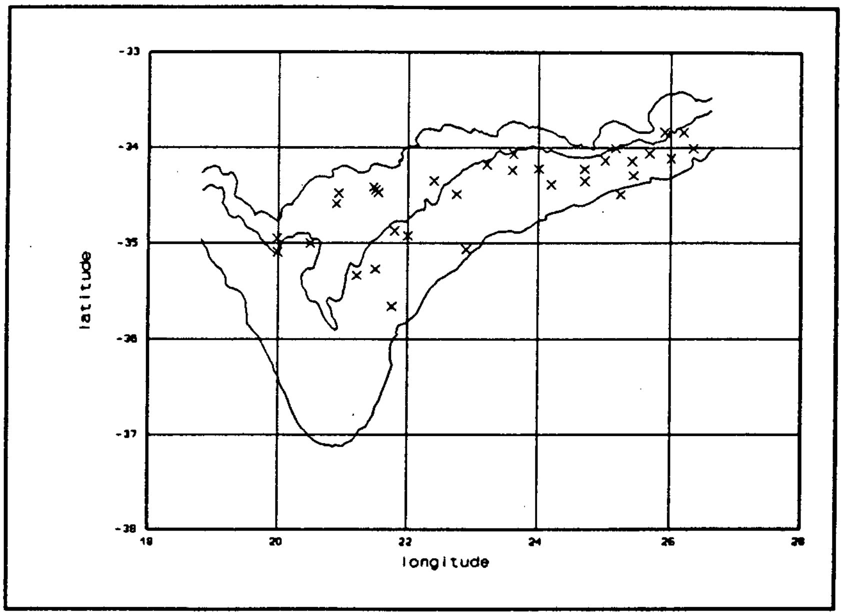


Figure 4.28. Distribution of *Austroaurilla rugosa*

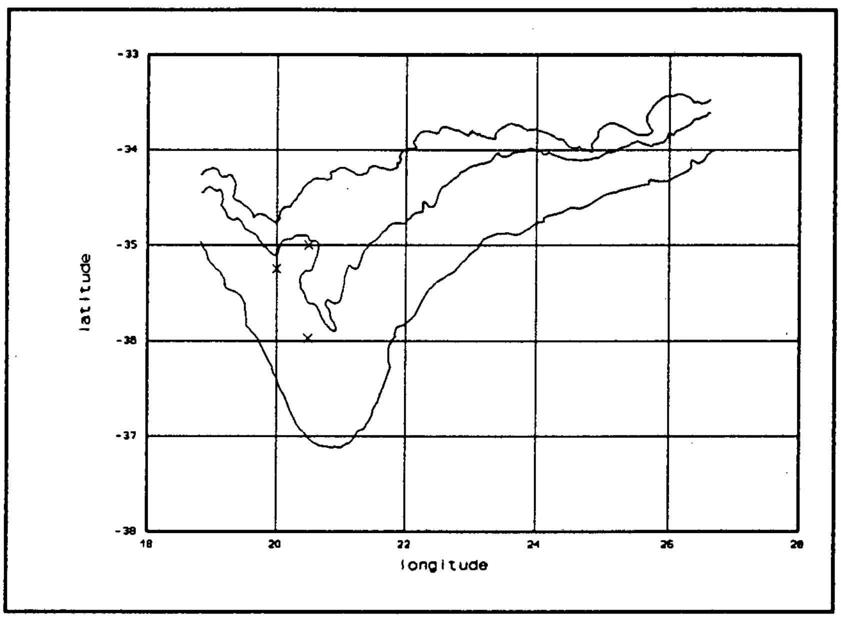


Figure 4.29. Distribution of *Coquimba cf birchi*

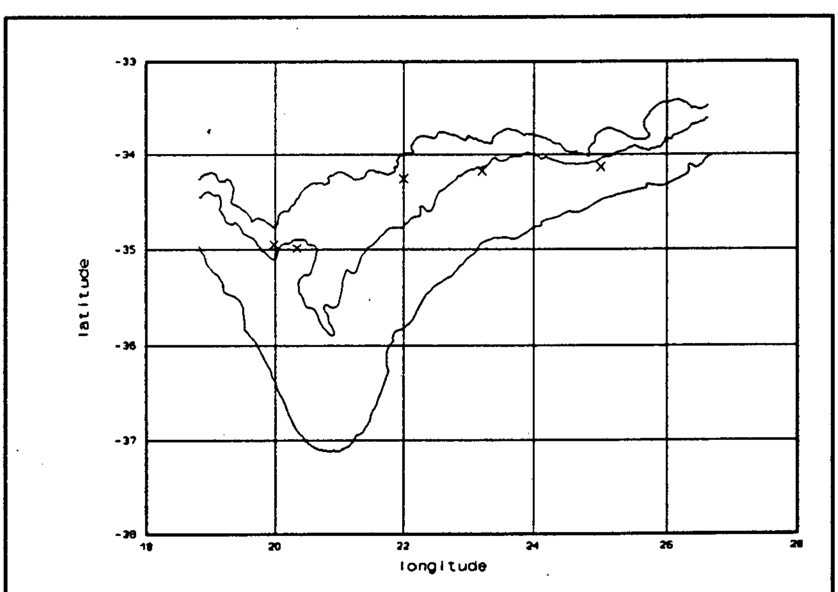


Figure 4.30. Distribution of *Falklandia sp*

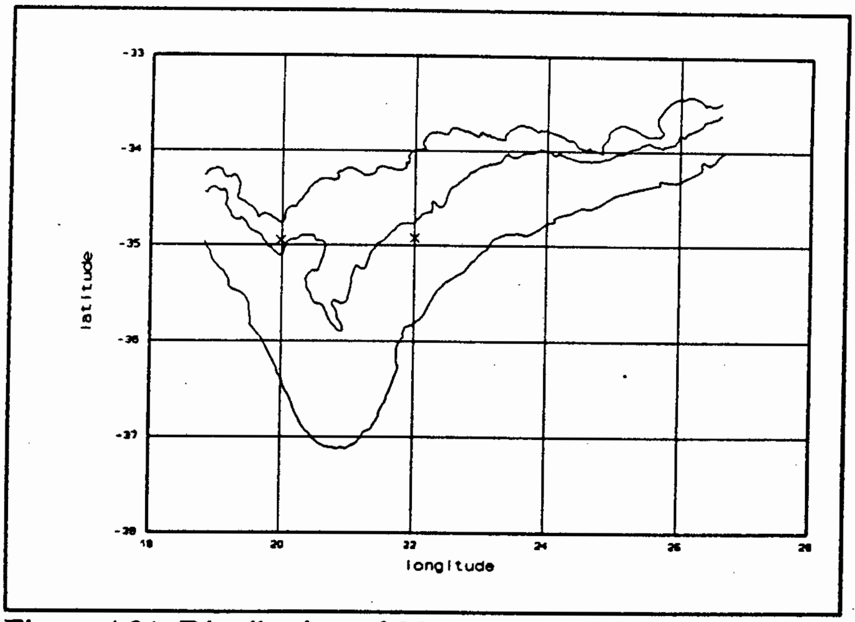


Figure 4.31. Distribution of *Meridionalicythere petricola*

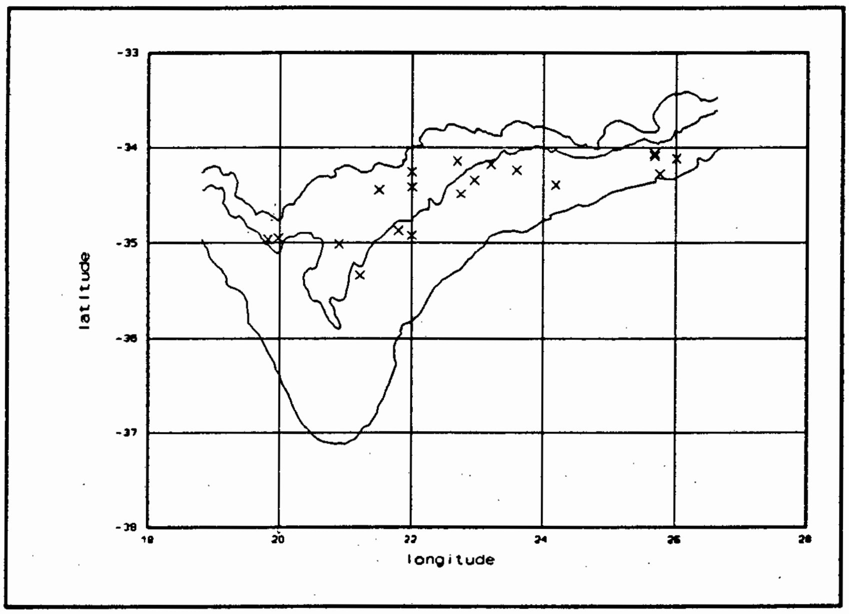


Figure 4.32. Distribution of *Mutilus bensonmaddocksorum*

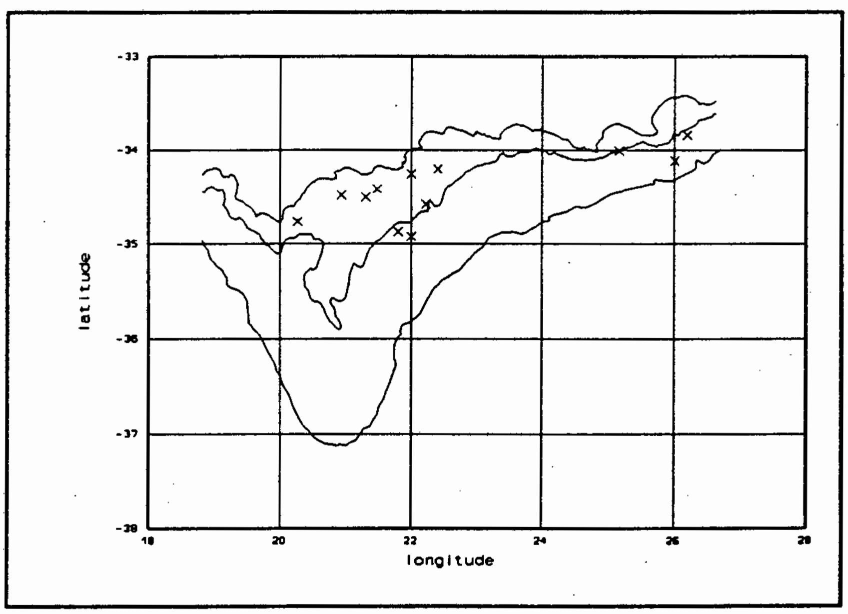


Figure 4.33. Distribution of *Mutilus malloryi*

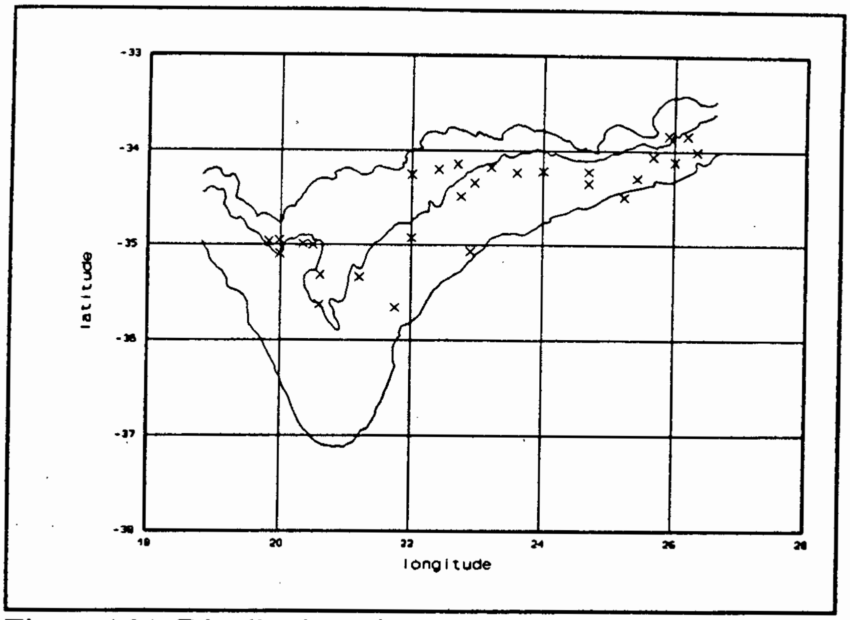


Figure 4.34. Distribution of *Quadracythere sp*

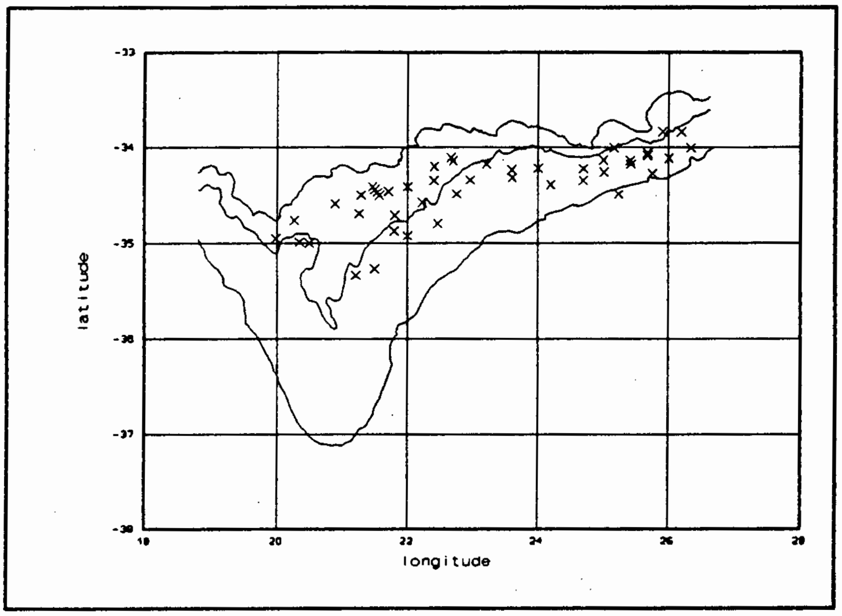


Figure 4.35. Distribution of *Urocythereis arcana*

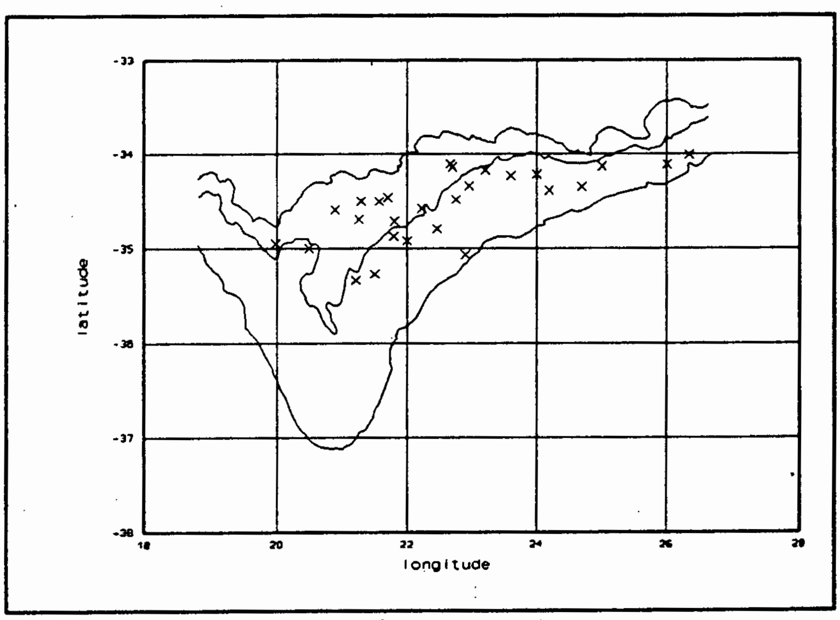


Figure 4.36. Distribution of *Urocythereis sp. A*

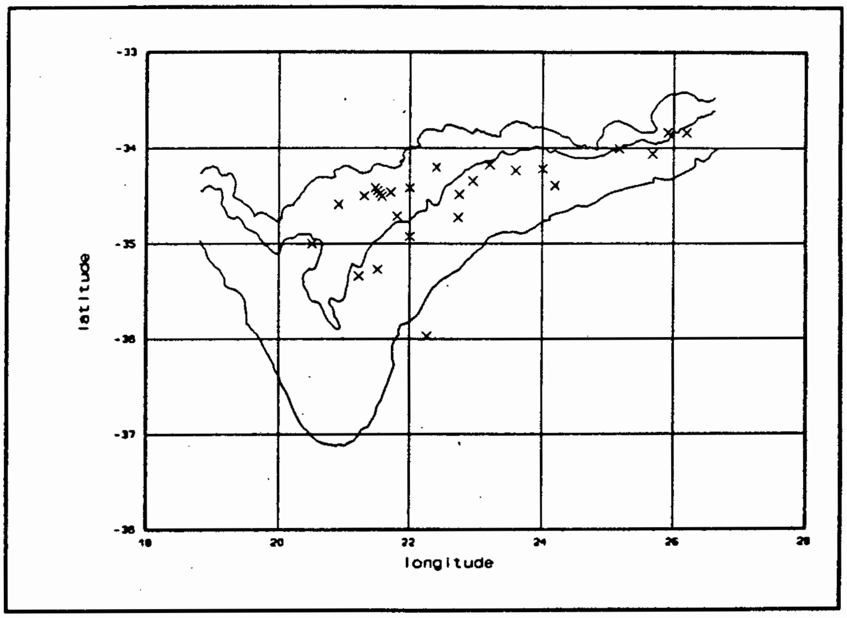


Figure 4.37. Distribution of *Urocythereis sp. B*

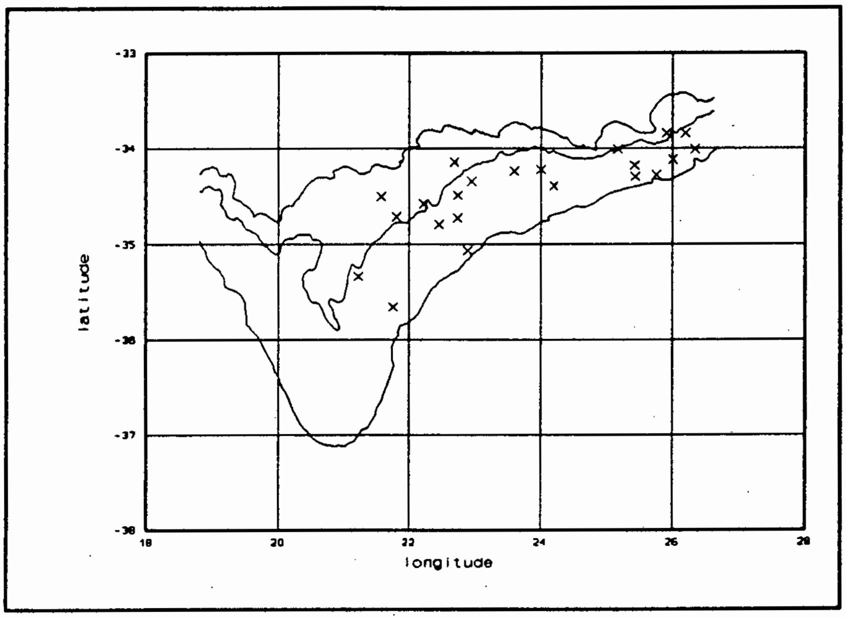


Figure 4.38. Distribution of *Urocythereis sp. C*

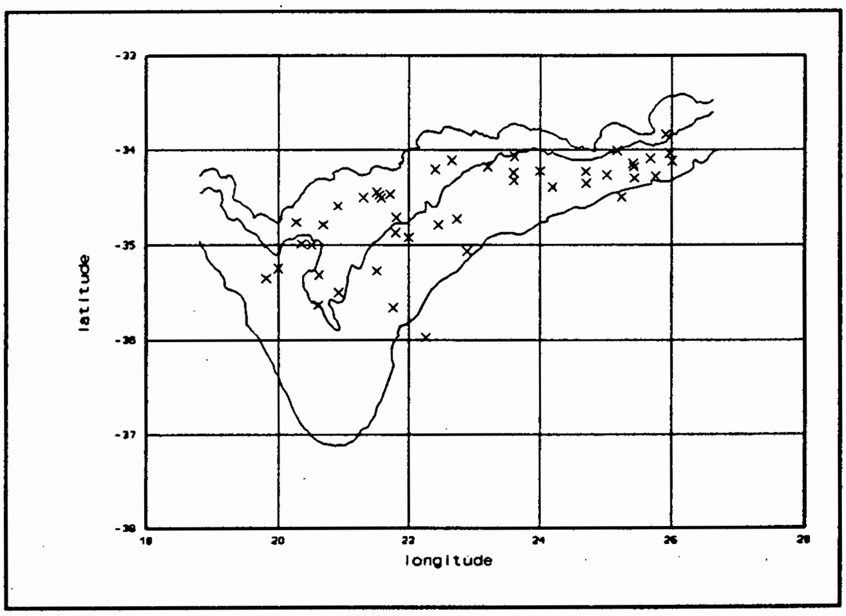


Figure 4.39. Distribution of *Urocythereis sp. C1*

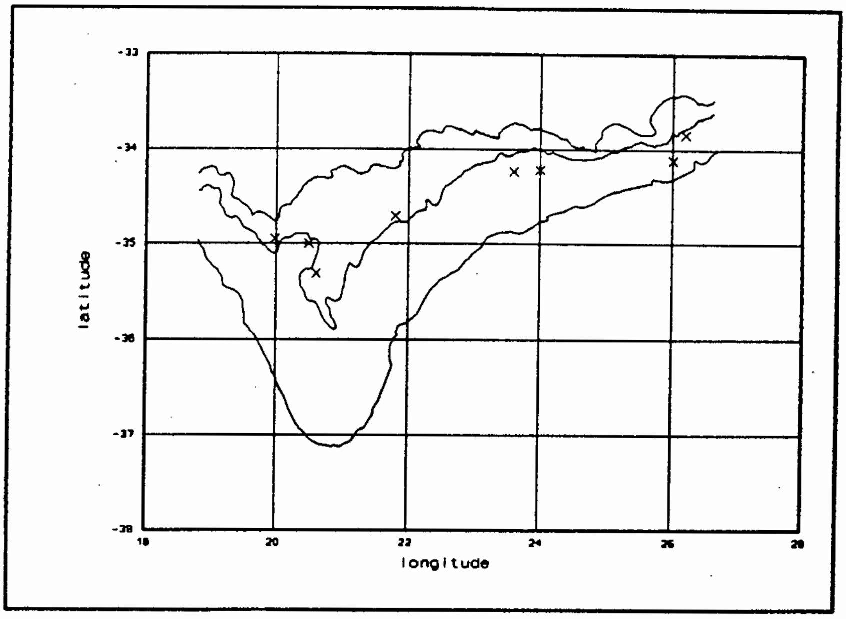


Figure 4.40. Distribution of *Urocythereis sp. D*

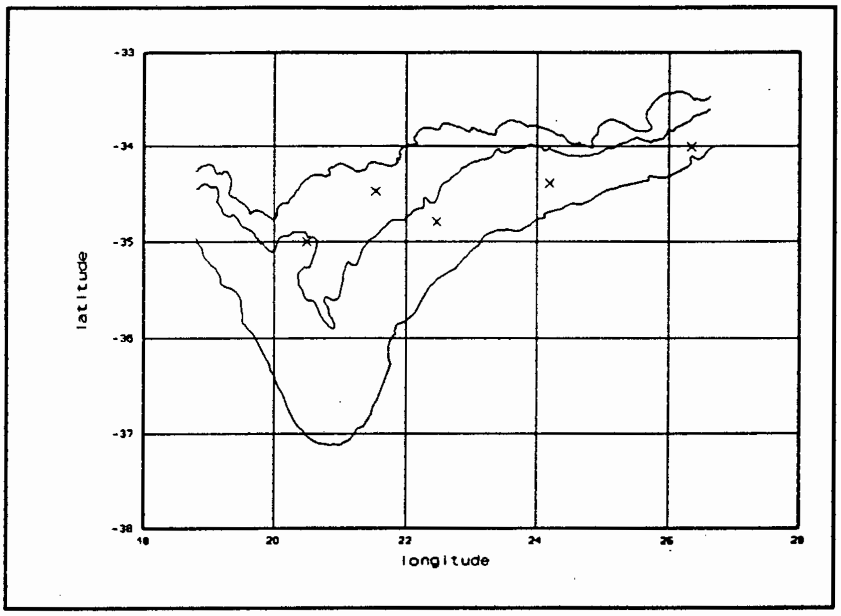


Figure 4.41. Distribution of *Urocythereis sp. E*

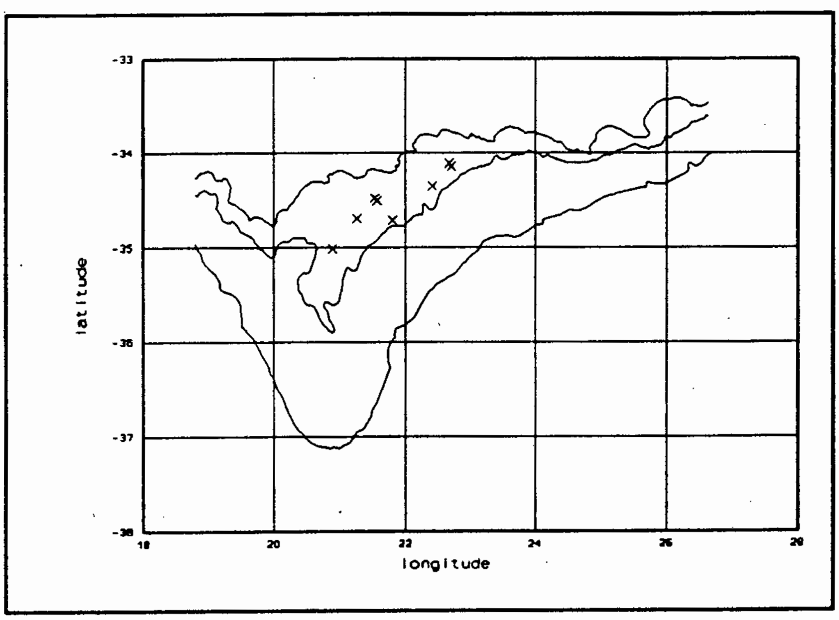


Figure 4.42. Distribution of *Urocythereis sp. F*

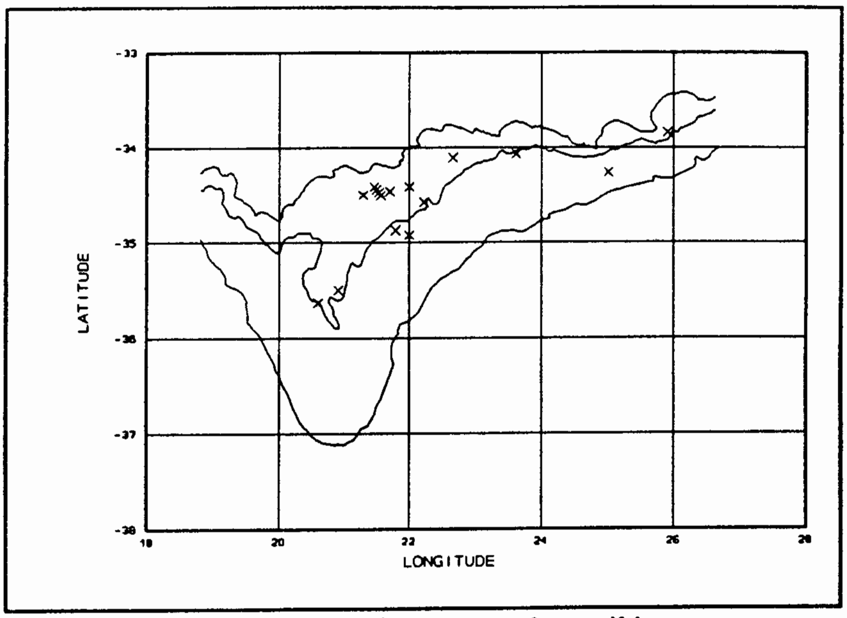


Figure 4.43. Distribution of *Loxoconcha paiki*

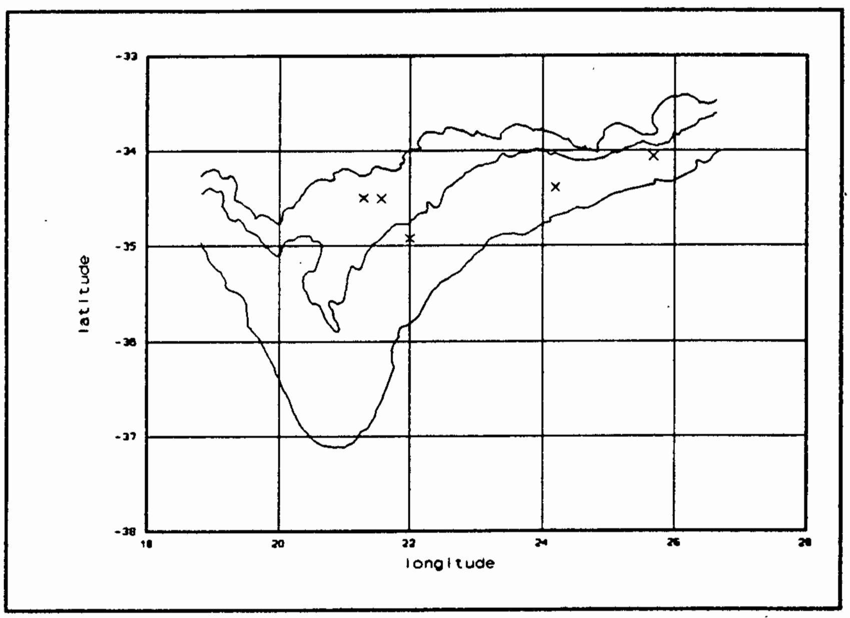


Figure 4.44. Distribution of *Loxoconcha sp. A*

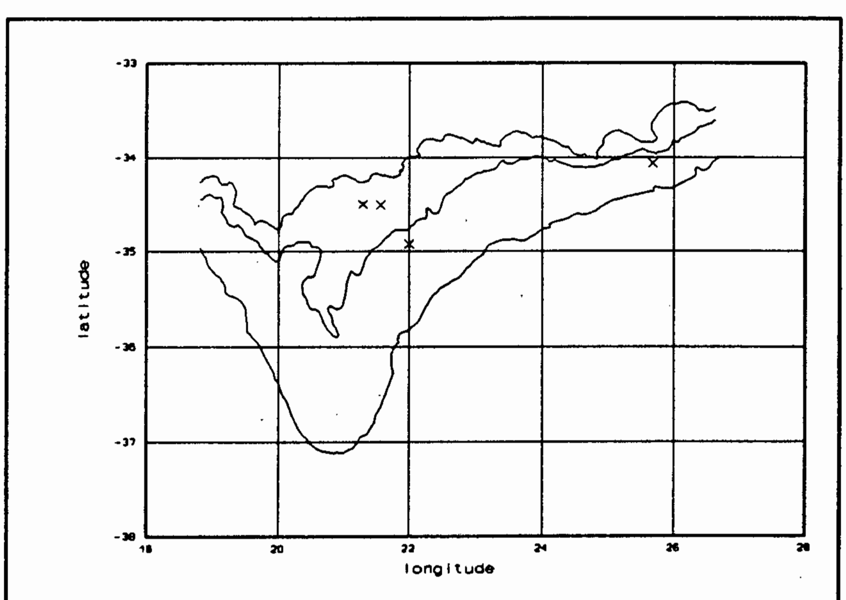


Figure 4.45. Distribution of *Loxoconcha sp. B*

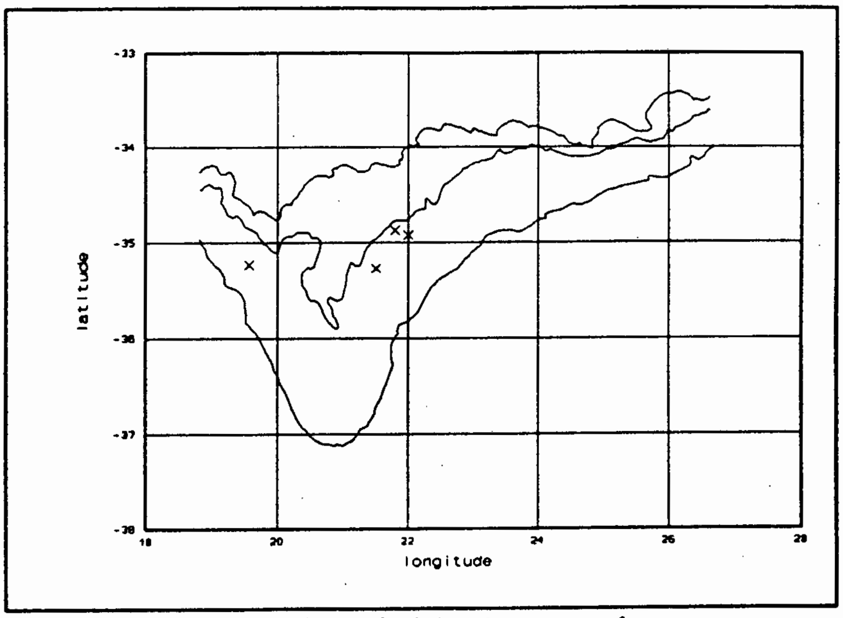


Figure 4.46. Distribution of *Kuiperiana angulata*

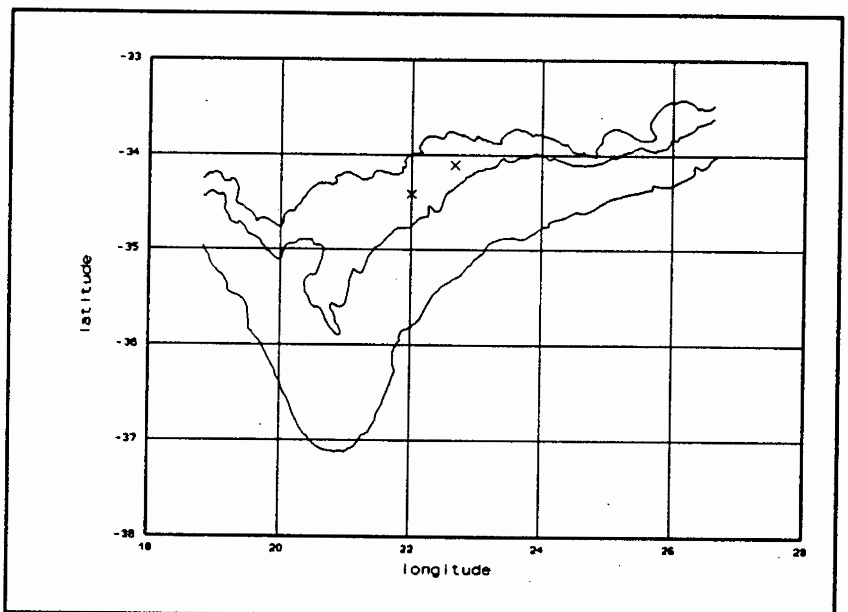


Figure 4.47. Distribution of *Sulcostocythere knysnaensis*

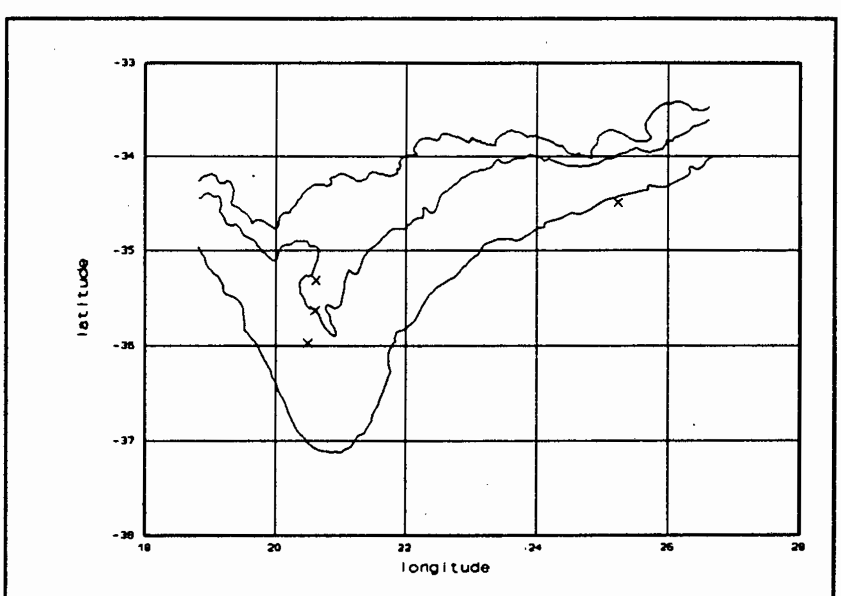


Figure 4.48. Distribution of *Occultocythereis sp.*

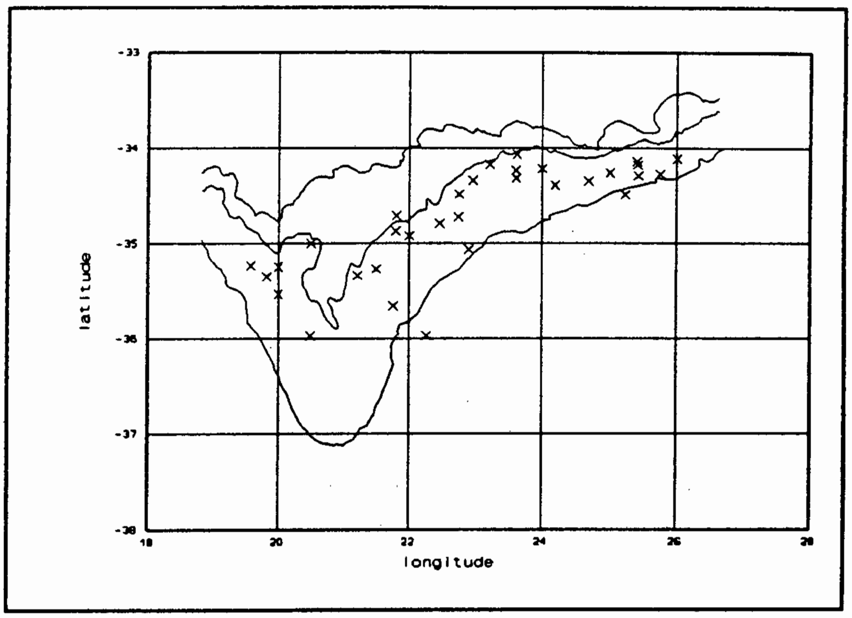


Figure 4.49. Distribution of *Ruggieria cytheropteroides*

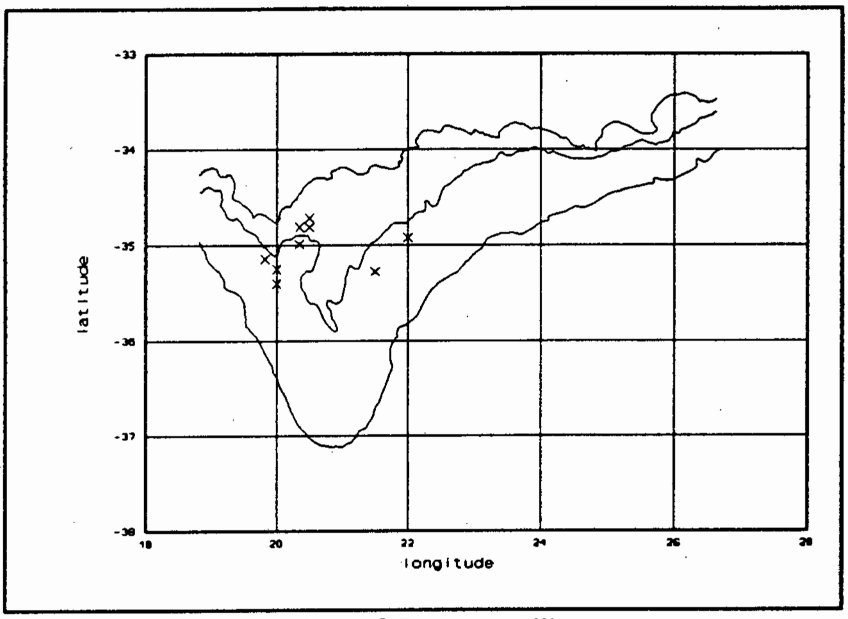


Figure 4.50. Distribution of *Incongruellina venusta*

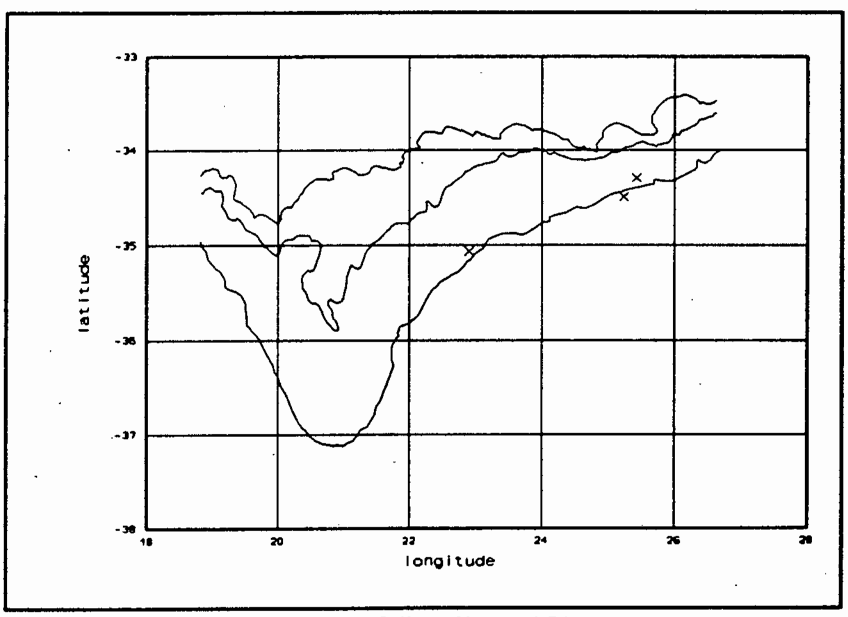


Figure 4.51. Distribution of *Bradleya (Q) sp*

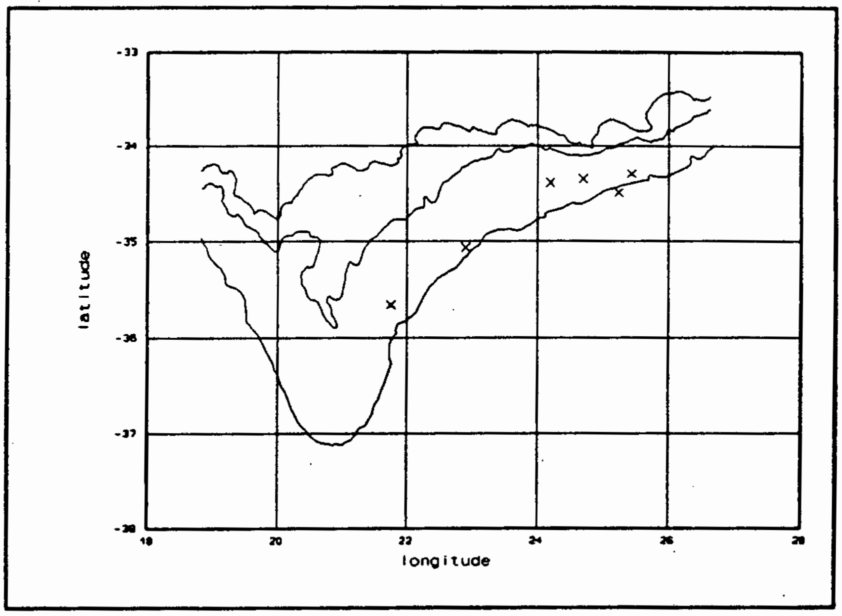


Figure 4.52. Distribution of *Poseidonamicus cf panopsus*

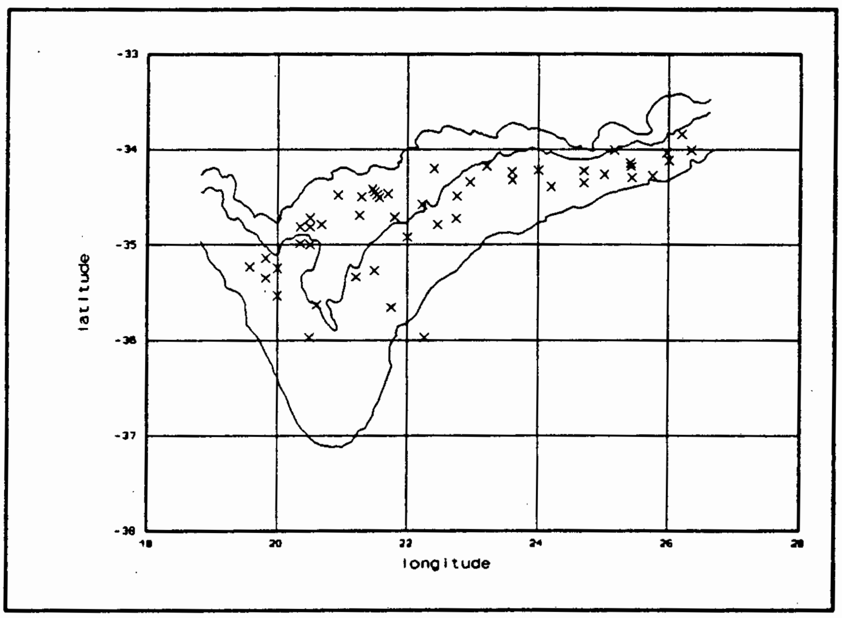


Figure 4.53. Distribution of *Chrysocythere craticula*

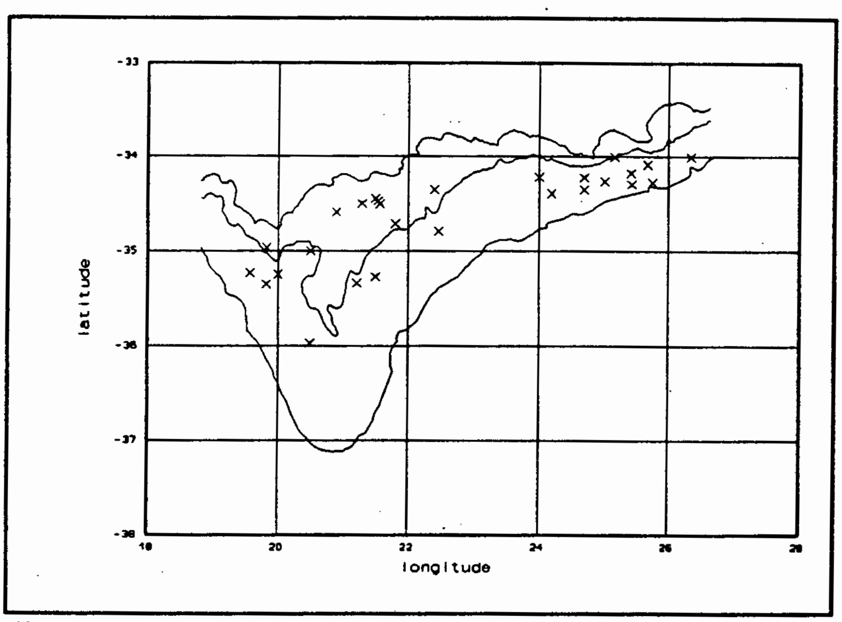


Figure 4.54. Distribution of *Henryhowella melobesioides*

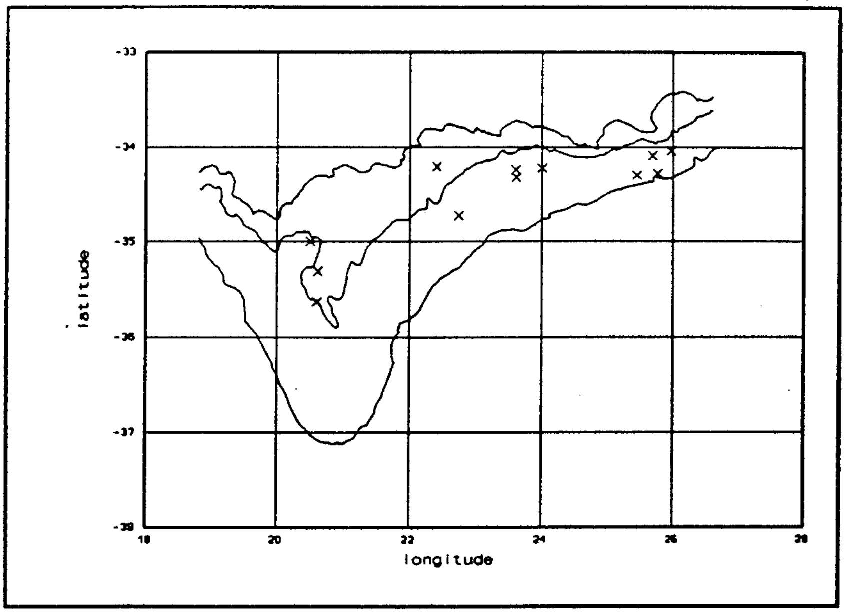


Figure 4.55. Distribution of *Neocaudites cf osseus*

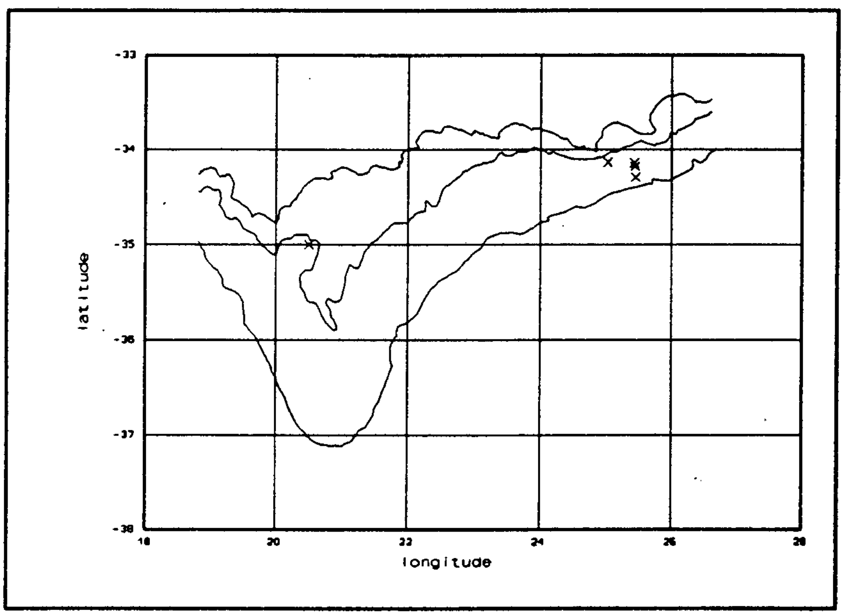


Figure 4.56. Distribution of *Neocaudites sp*

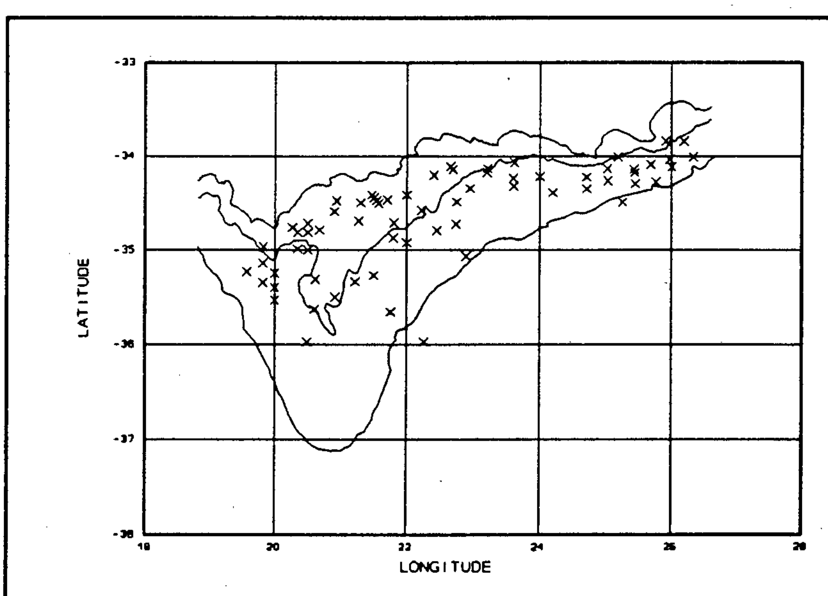


Figure 4.57. Distribution of *Pseudokeijella lepralioides*

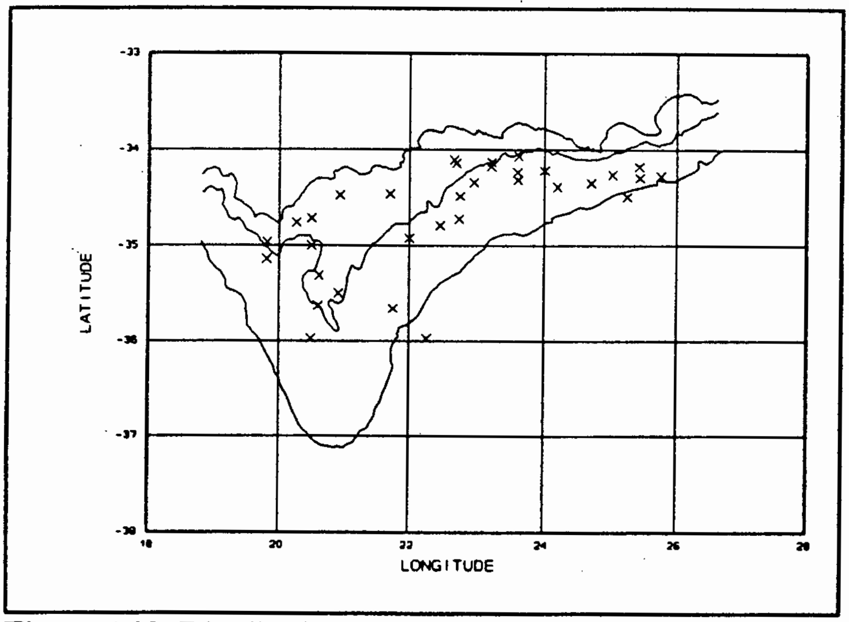


Figure 4.58. Distribution of *Xestoleberis africana*

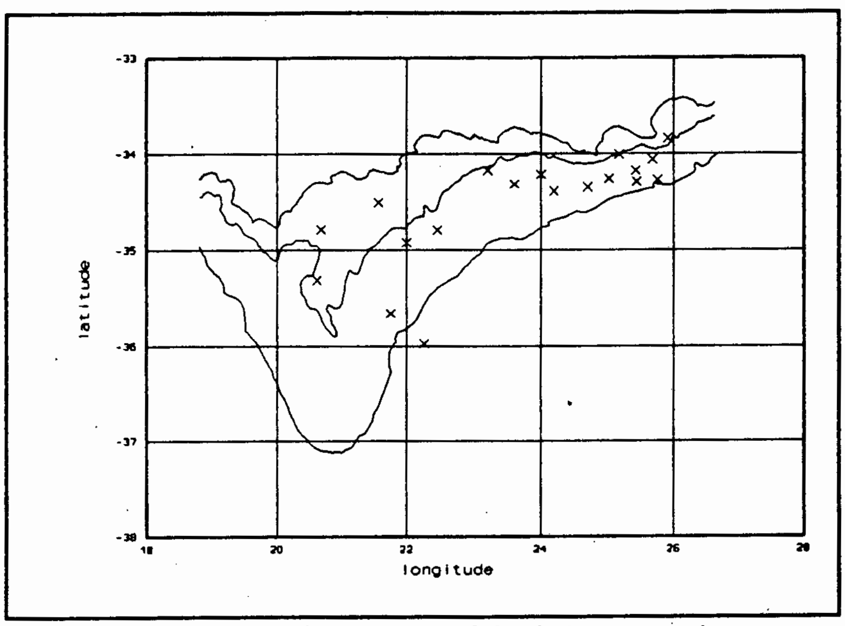


Figure 4.59. Distribution of *Xestoleberis hartmanni*

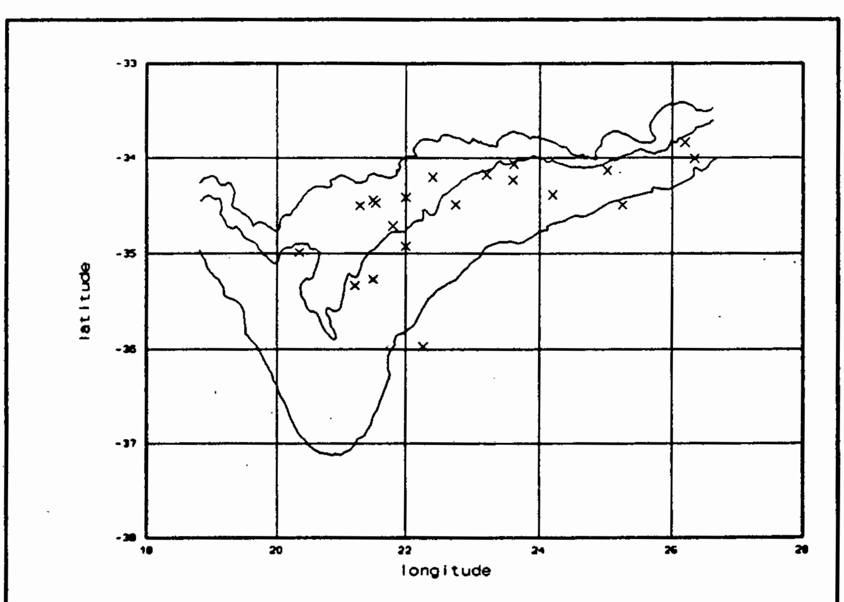


Figure 4.60. Distribution of Indet sp. 1

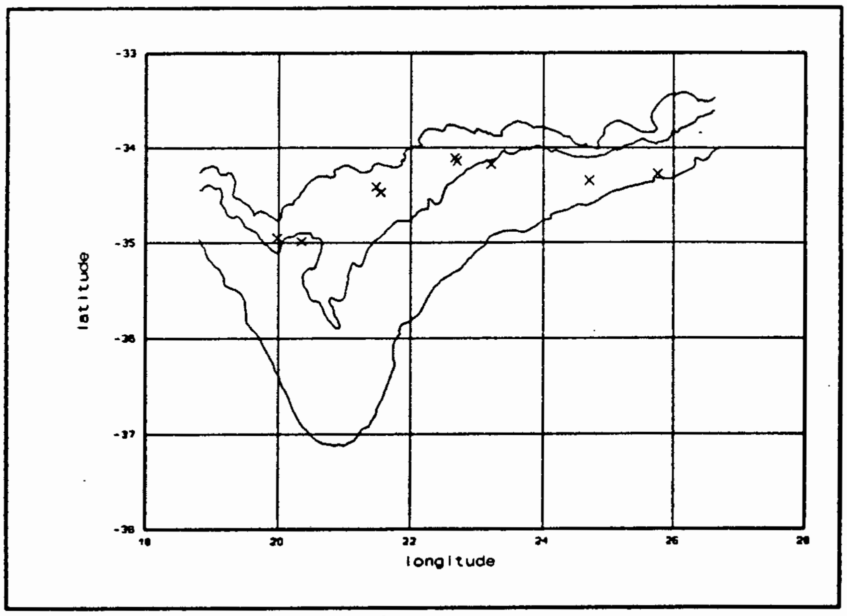


Figure 4.61. Distribution of Indet sp. 2

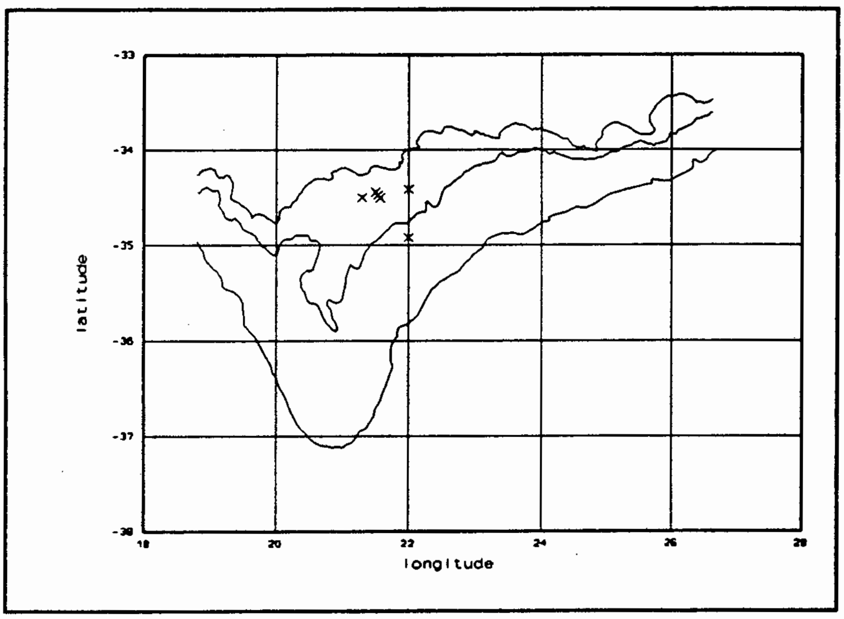


Figure 4.62. Distribution of Indet sp. 3

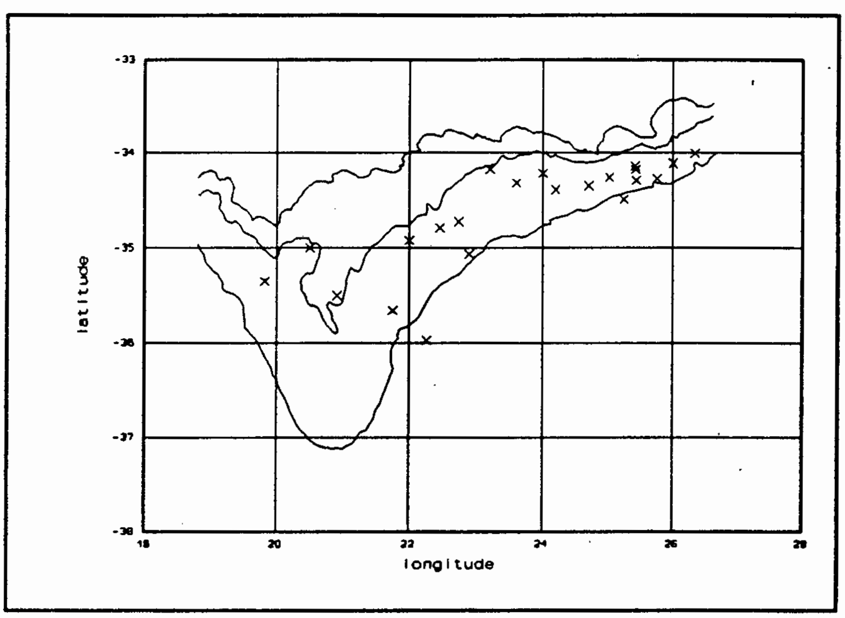


Figure 4.63. Distribution of Indet sp. 4

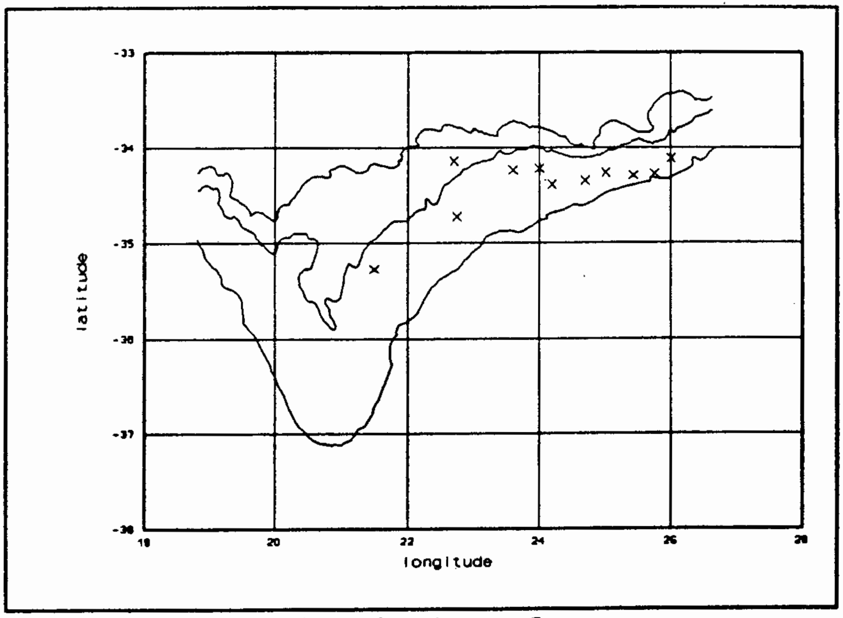


Figure 4.64. Distribution of Indet sp. 5

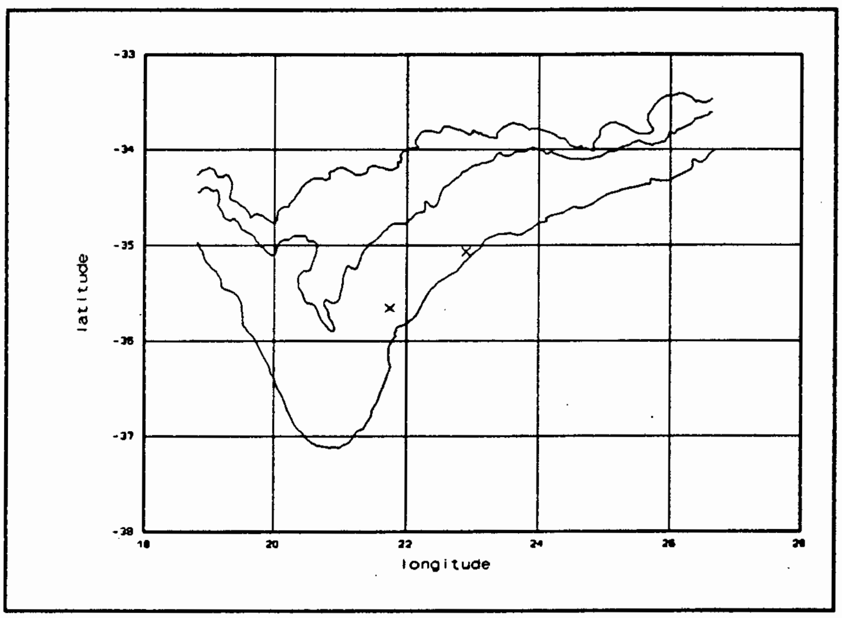


Figure 4.65. Distribution of Indet sp. 6

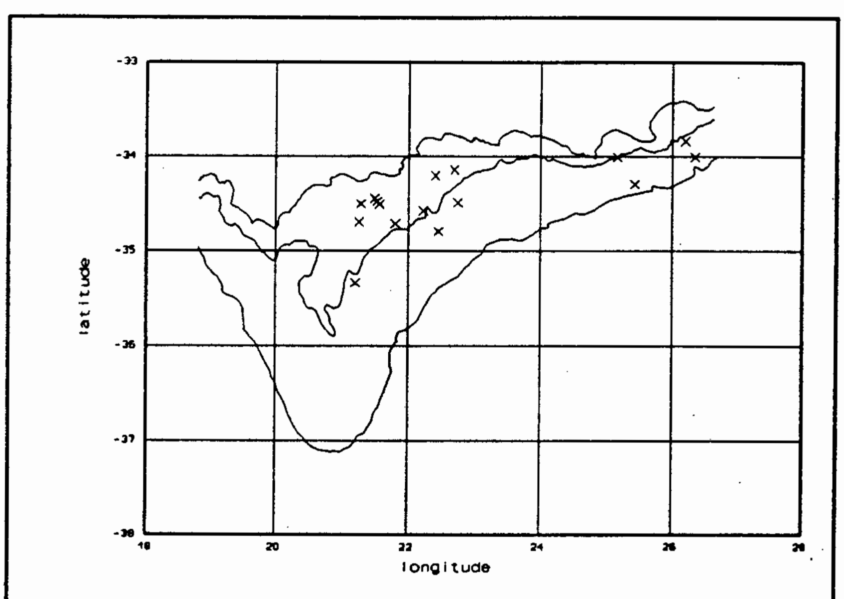


Figure 4.66. Distribution of Indet sp. 7

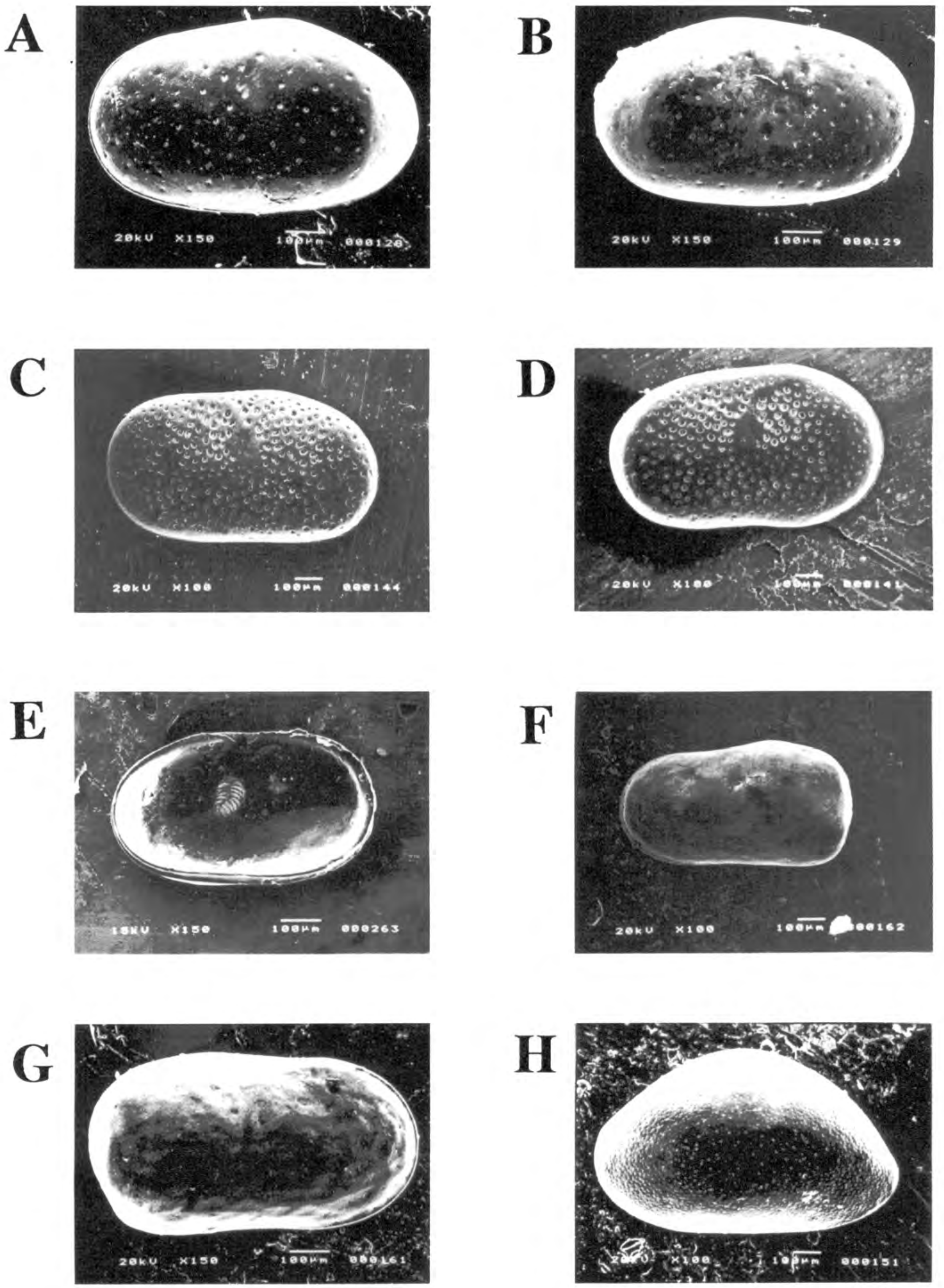


PLATE 1 A-B *Cytherella dromedaria* A-LV, B-RV. C-E *Cytherella namibensis* C-LV, D-RV, E-LV int. F-G *Cytherella sp.* F-LV, G-RV. H *Bairdoppilata simplex* -LV.

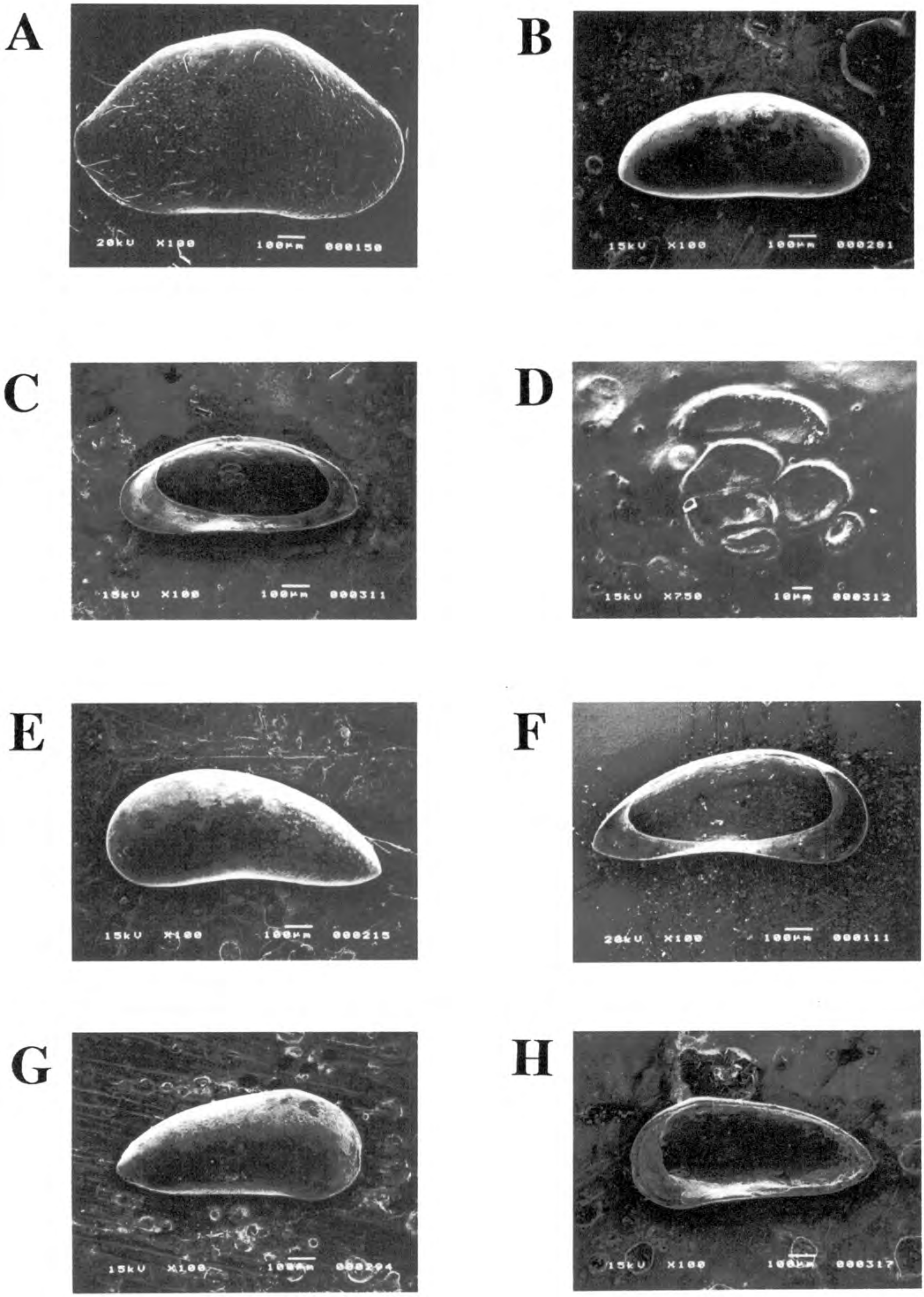


PLATE 2 A *Bairdoppilata simplex* -RV. B-D *Aglaiella railbridgensis* B-LV, C-RV, D-RV MS. E-F *Paracypris lacrimata* E-LV, F-RV int. G-H *Paracypris sp.* G-LV, H-LV int.

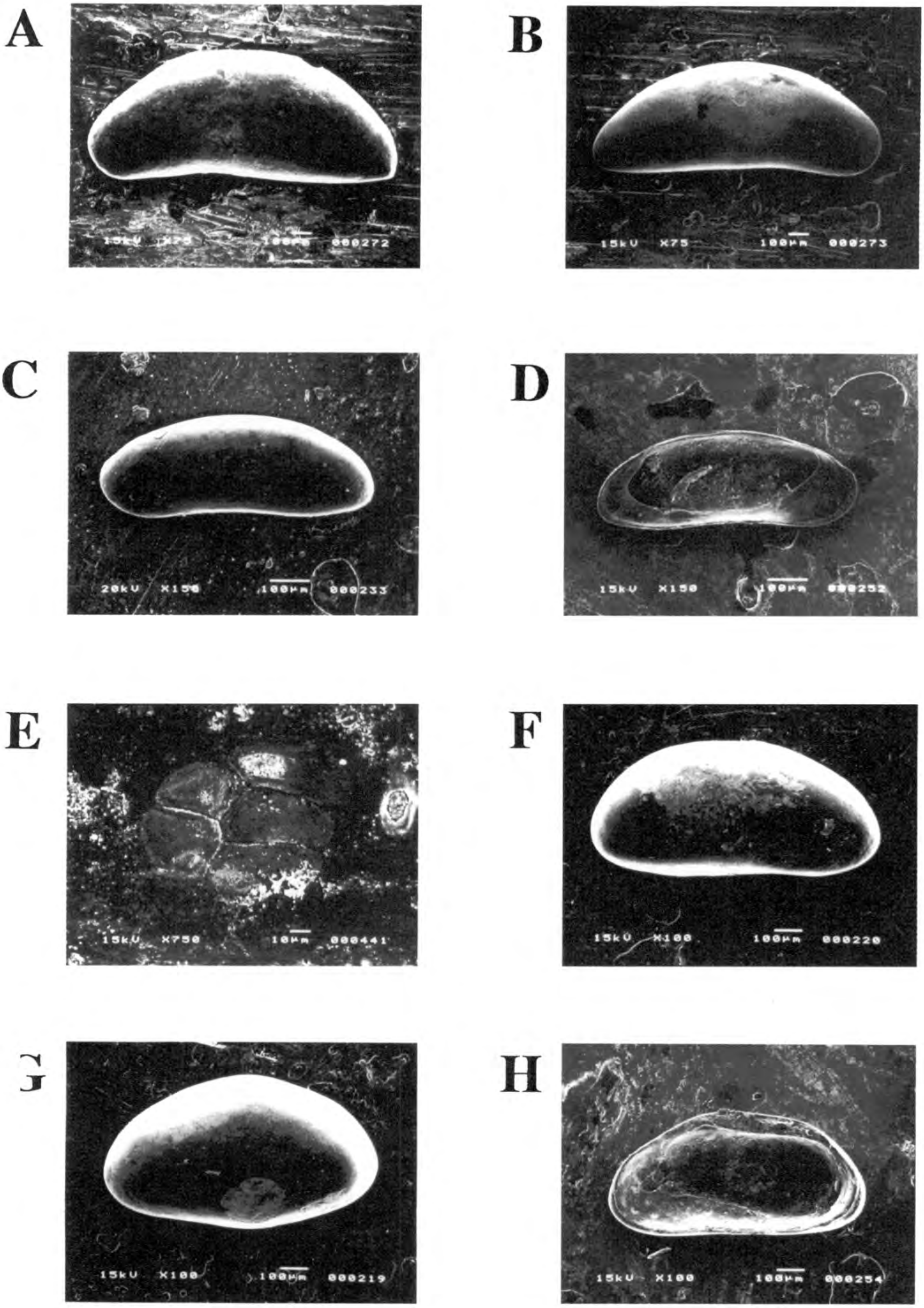
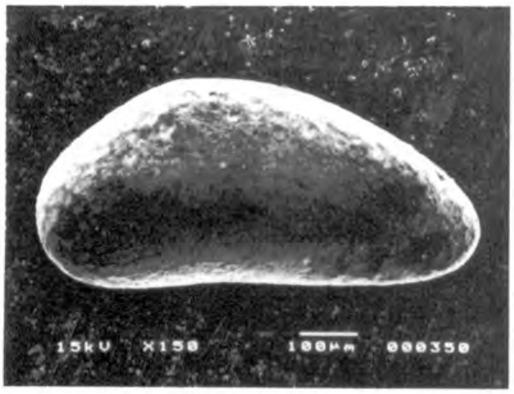


PLATE 3 A-B *Macrocypris sp.* A-LV, B-RV. C-E *Argilloecia sp.* C-LV, D-RV, E-LV int. F-H *Australoecia fulleri* F-LV, G-RV, H-LV int.

A



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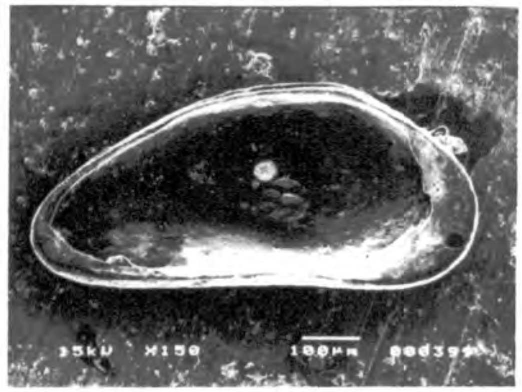

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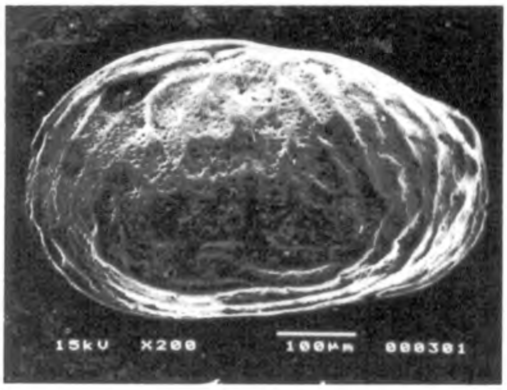

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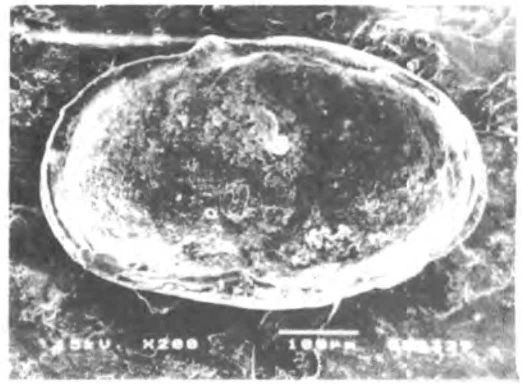

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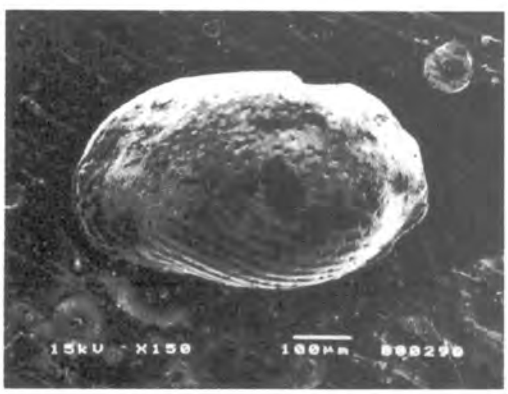

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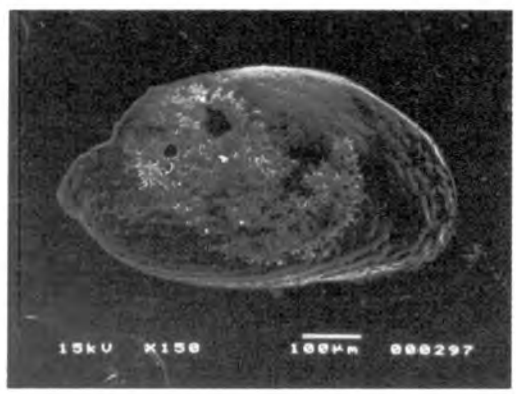

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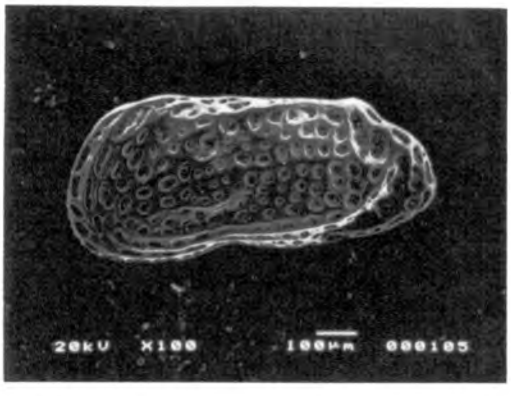

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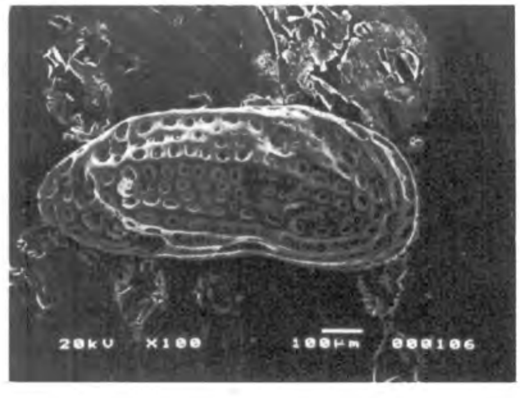

PLATE 4 A-B *Propontocypris sp.* A-LV, B-LV int. C-D *Buntonia rogersi* C-LV, D-RV int. E-F *Bythocythere sp.* E-LV, F-RV. G-H *Doratocythere exilis* G-LV, H-RV.

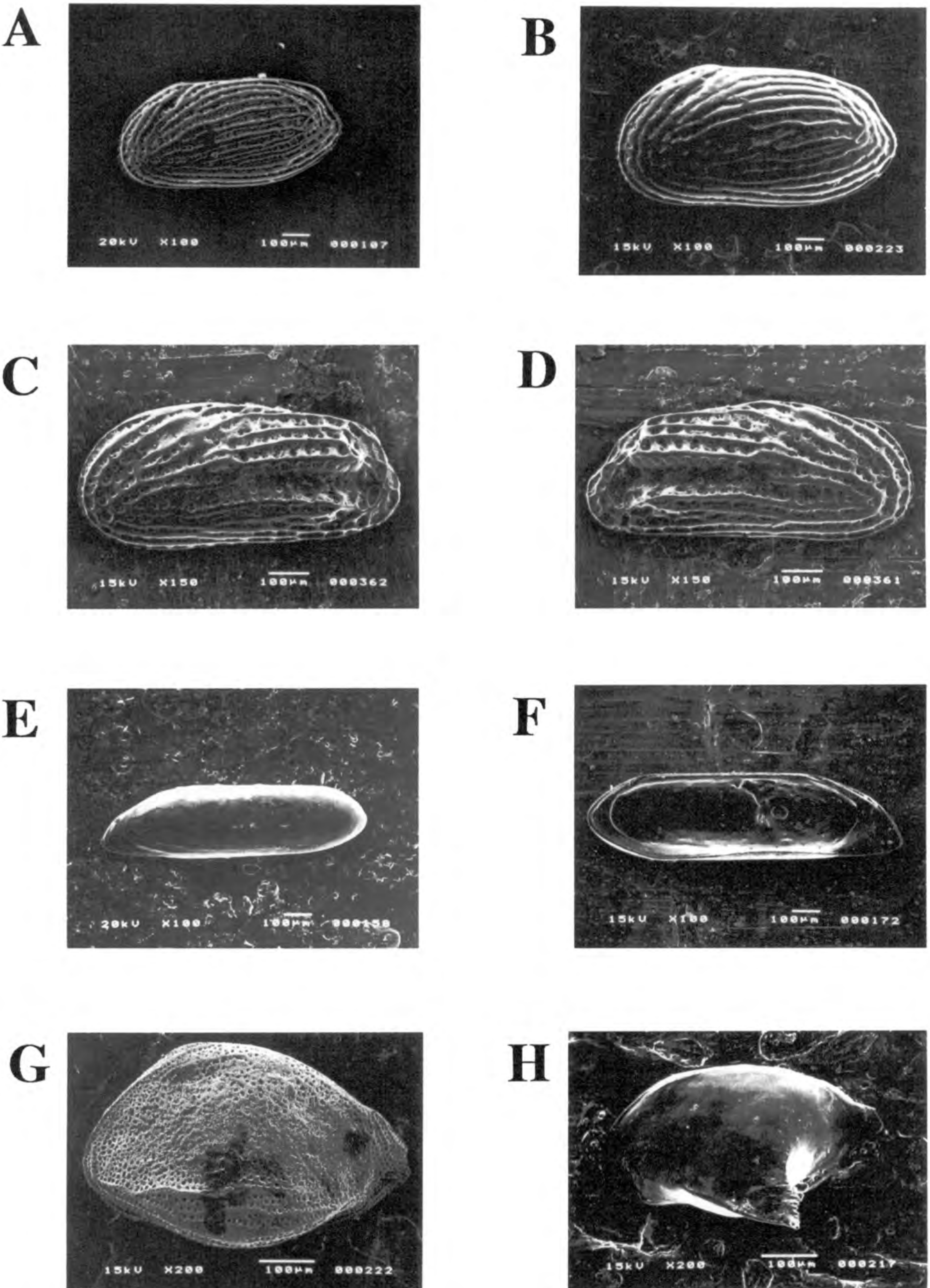

PLATE 5 A-B *Garcaiella knysnaensis knysnaensis* A-LV, B-LV. C-D *Stobilocythere malzi* C-LV, D-RV. E-F *Neocytherideis boomeri* E-LV, F-LV int. G *Cytheropteron whatleyi* -LV. H *Cytheropteron trinodosum* -LV.

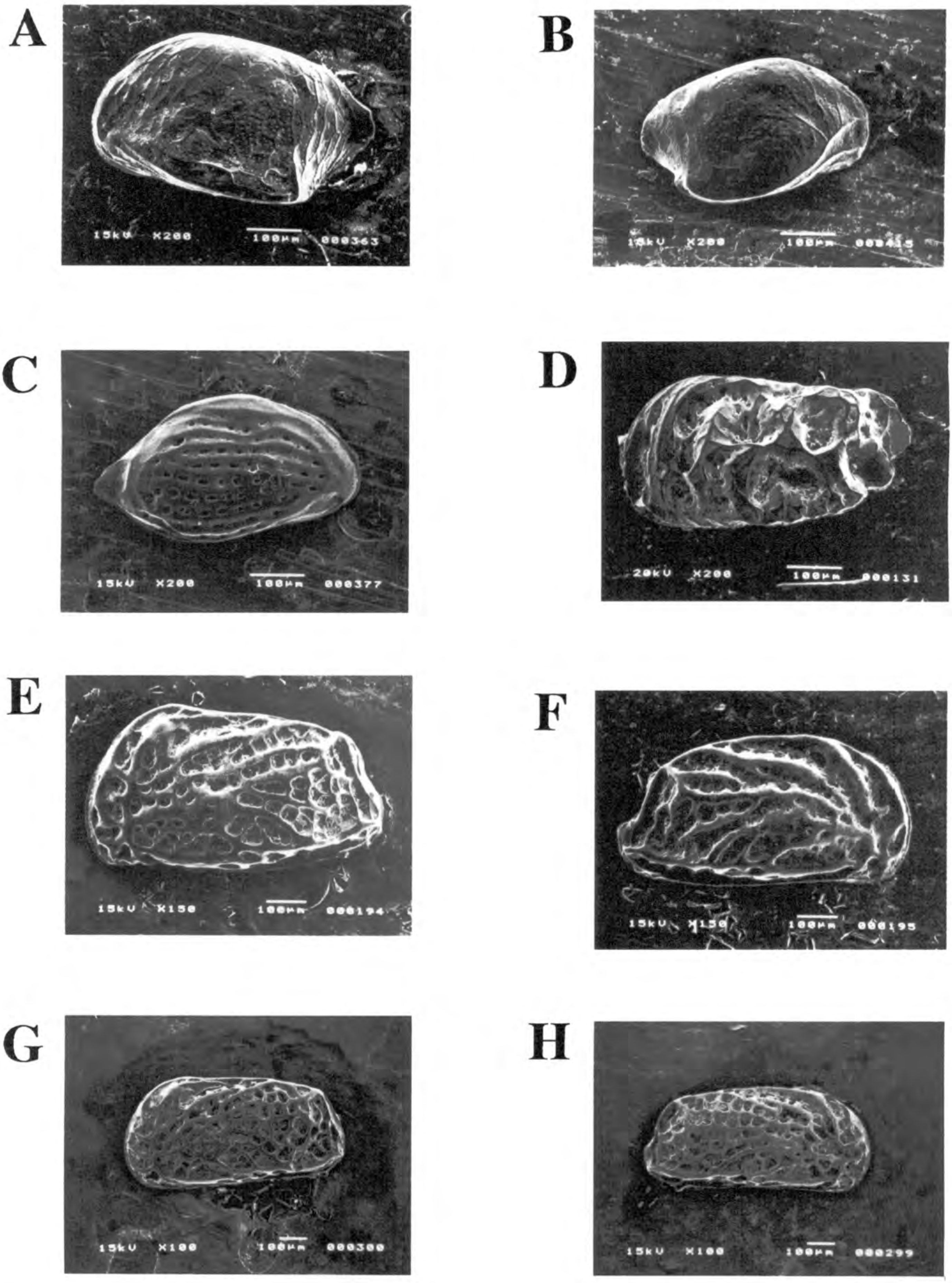

PLATE 6 A *Cytheropteron cunneatum* -LV. B *Cytheropteron sp.* -RV. C *Kangarina mucronata* -RV. D *Paracytheridea sp.* -LV. E-H *Ambostracon flabellicostata* E-LV, F-RV G-H *Ambostracon flabellicostata* Type A G-LV, H-RV.

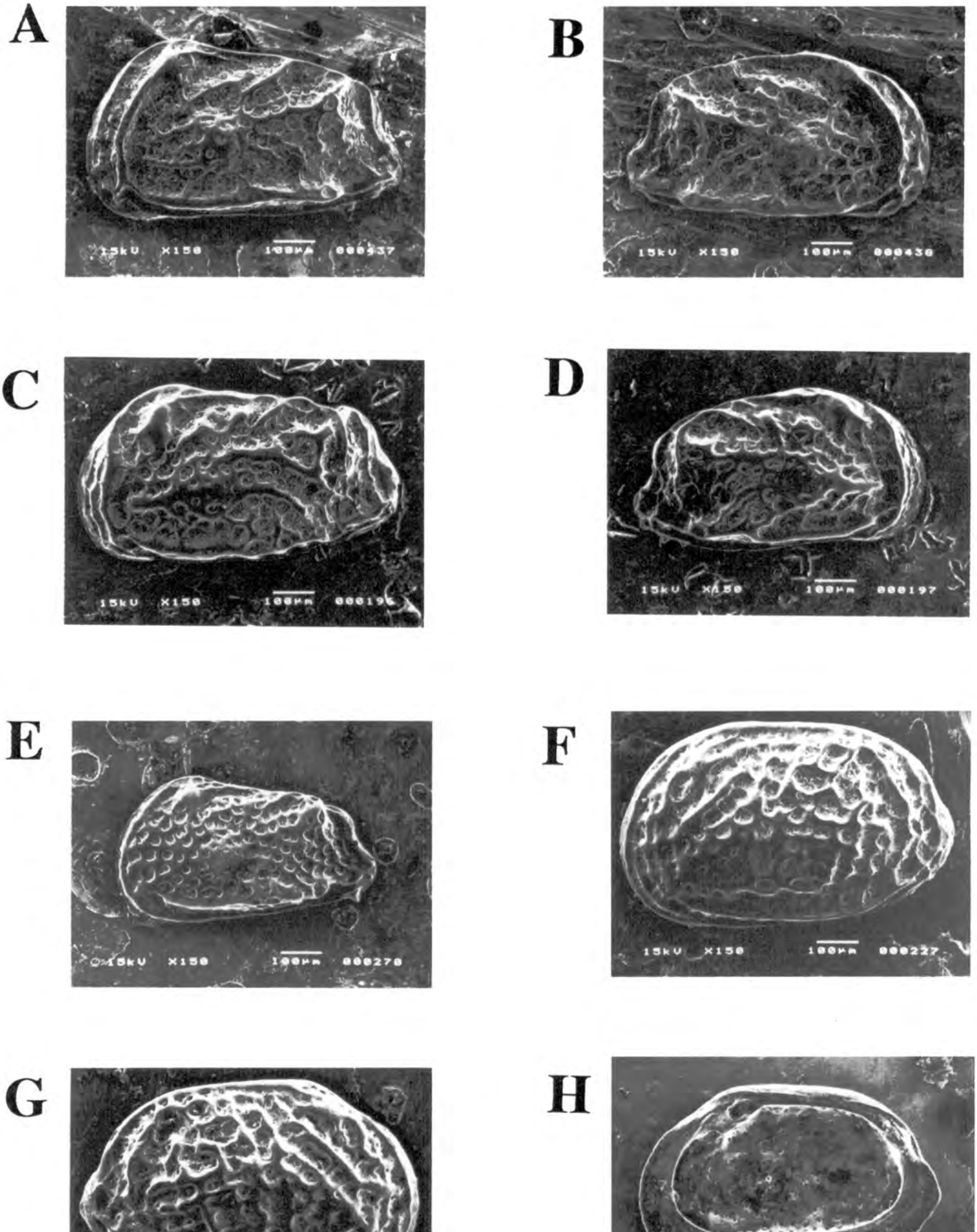

PLATE 7 A-B *Ambostracon flabellicostata* Type B A-LV, B-RV. C-D *Ambostracon keeleri* C-LV, D-RV. E *Ambostracon Patagonacythere sp.* -LV. F-H *Aurilla sp.* F-LV, G-RV, H-RV int.

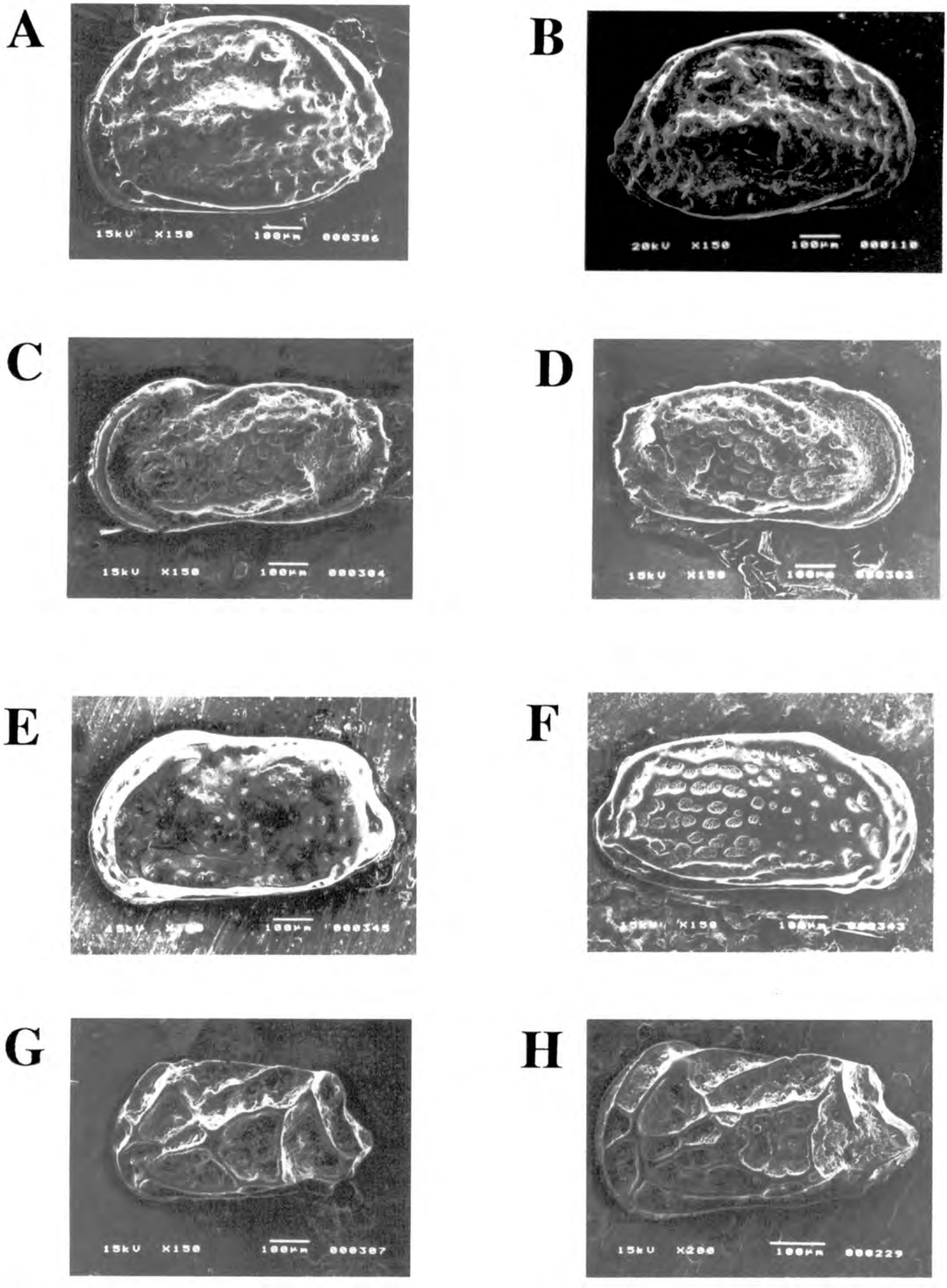

PLATE 8 A-B *Austroaurilla rugosa* A-LV, B-RV. C-D *Coquimba cf birchi* C-LV, D-RV. E *Falklandia sp.* -LV. F *Meridionalicythere petricola* -RV. G *Mutilus bensonmaddocksorum* -LV. H *Mutilus malloryi* -LV.

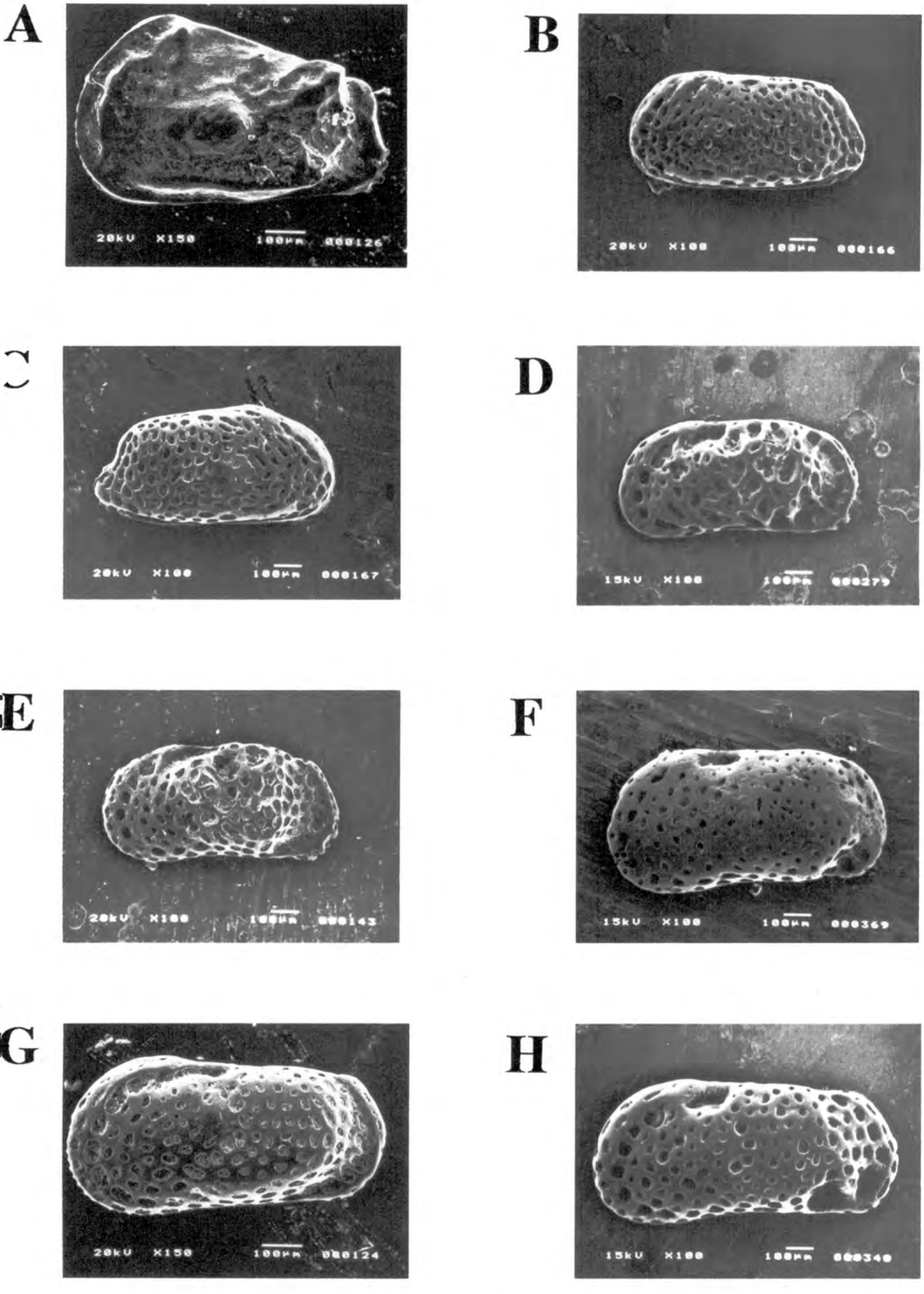

PLATE 9 A *Quadracythere sp.* -LV. B-C *Urocythereis arcana* B-LV, C-RV. D *Urocythereis sp. A* -LV. E *Urocythereis sp. B* -LV. F *Urocythereis sp. C* -LV. G *Urocythereis sp. C1* -LV. H *Urocythereis sp. D* -LV.

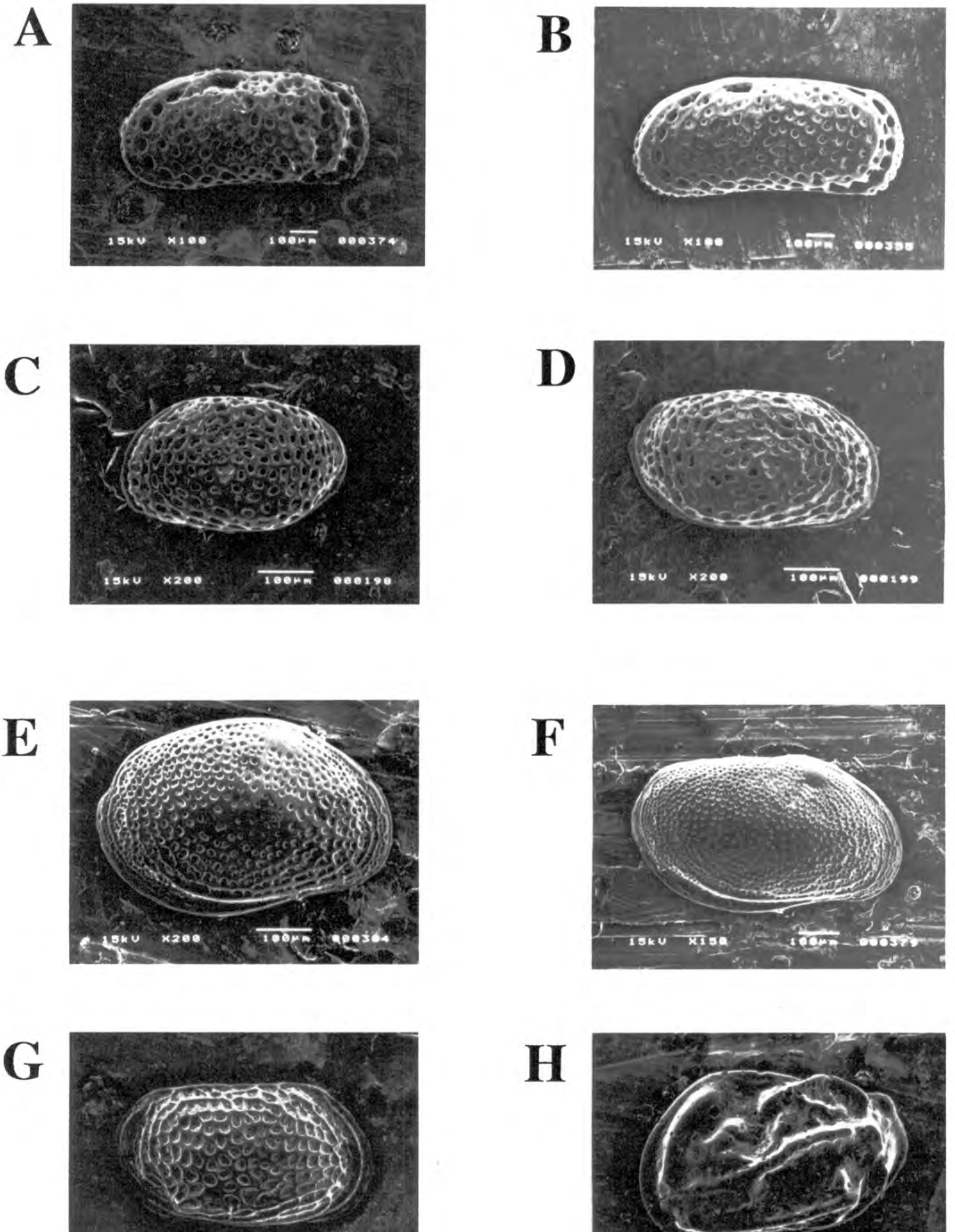

PLATE 10 A *Urocythereis sp. E* -LV. B *Urocythereis sp. F* -LV. C-D *Loxoconcha paiki* C-LV, D-RV. E *Loxoconcha sp. A* -RV. F *Loxoconcha sp. B* -RV. G *Kuiperiana angulata* -RV. H *Sulcostocythere knysnaensis* -LV.

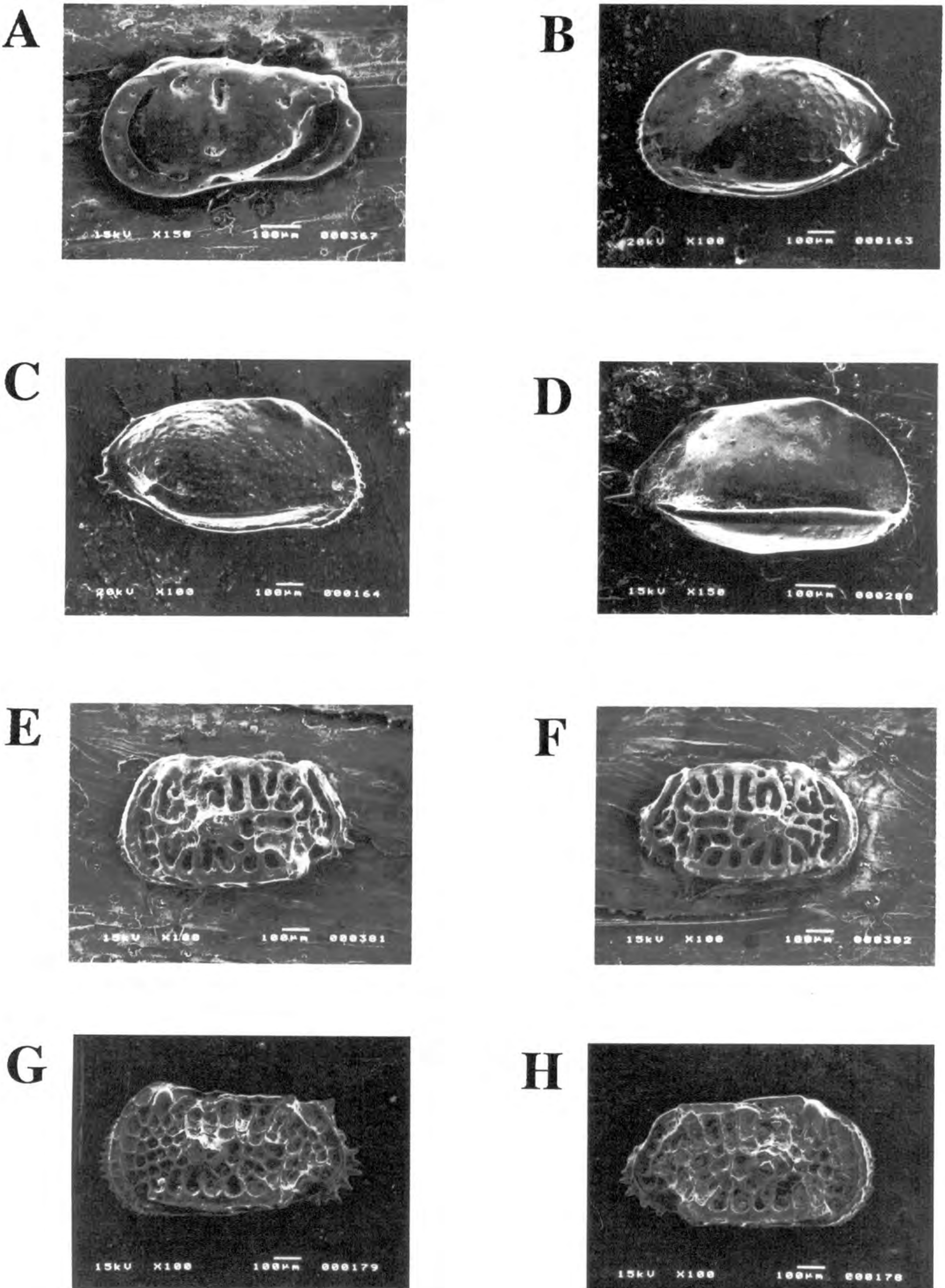

PLATE 11 A *Occultocythereis sp.* -LV. B-C *Ruggieria cytheropteroides* B-LV, C-RV. D *Incongruellina venusta* -RV. E-F *Bradleya sp.* E-LV, F-RV. G-H *Poseidonamicus cf panopsus* G-LV, H-RV.

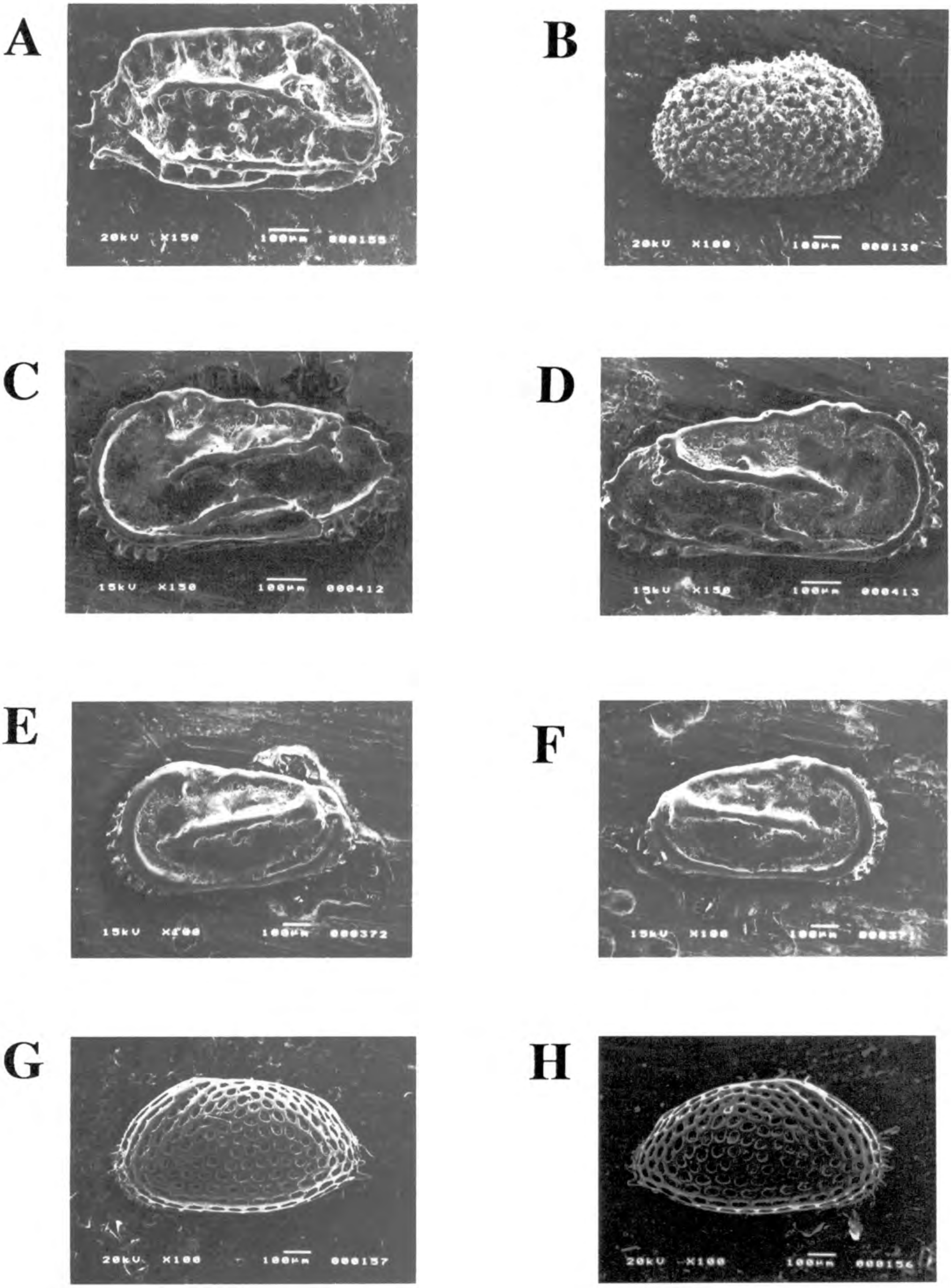

PLATE 12 A *Chrysocythere craticula* -RV. B *Henryhowella melobesioides* -RV. C-D *Neocaudites cf osseus* C-LV, D-RV. E-F *Neocaudites sp.* E-LV, F-RV. G-H *Pseudokeijella lepralioides* G-LV, H-RV.

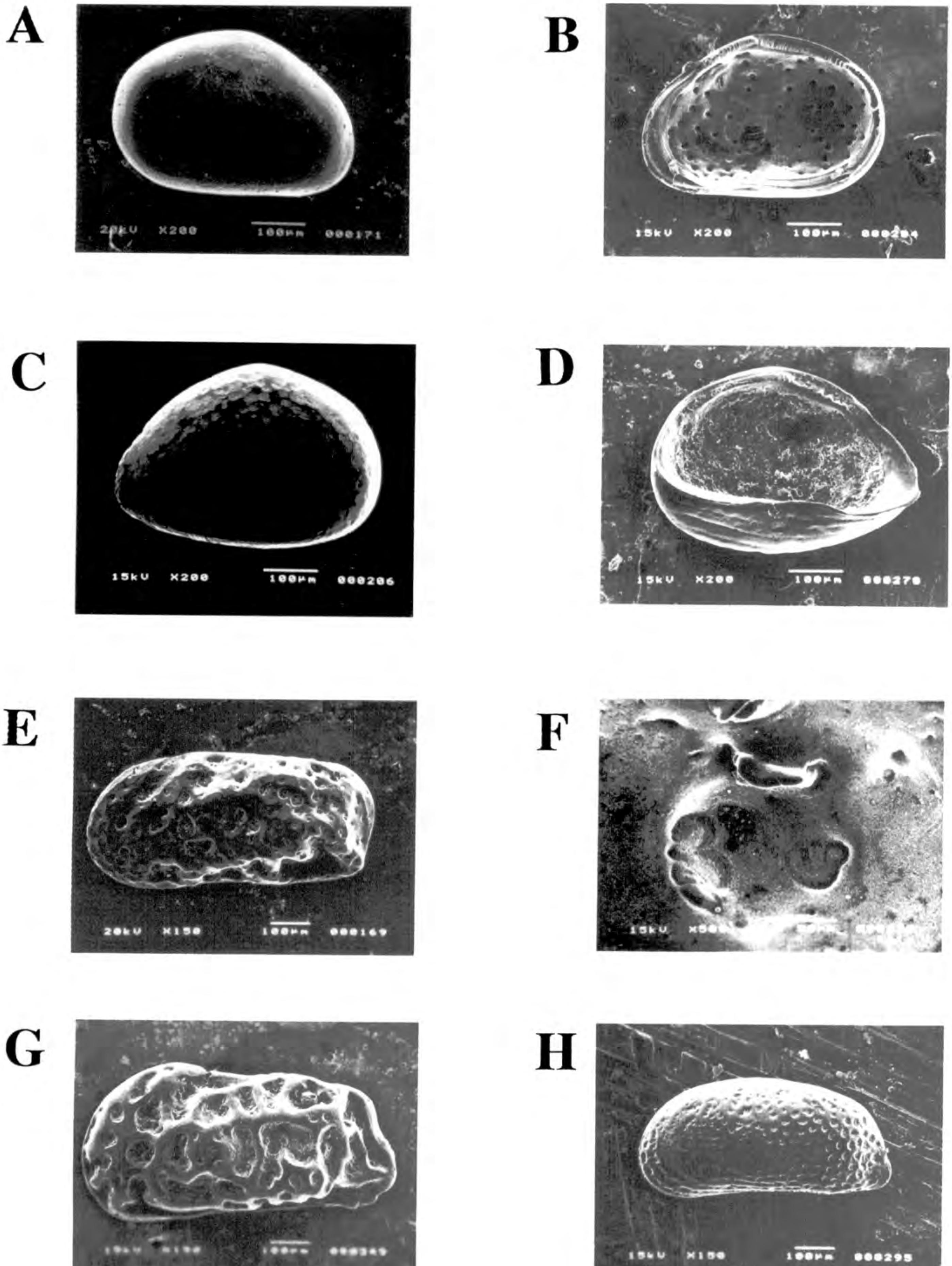

PLATE 13 A-B *Xestoleberis africana* A-RV, B-RV int. C-D *Xestoleberis hartmanni* C-LV, D-LV int. E-F Indet sp. 1 E-LV, F-LV MS. G Indet sp. 2 -LV. H Indet sp. 3 -LV.

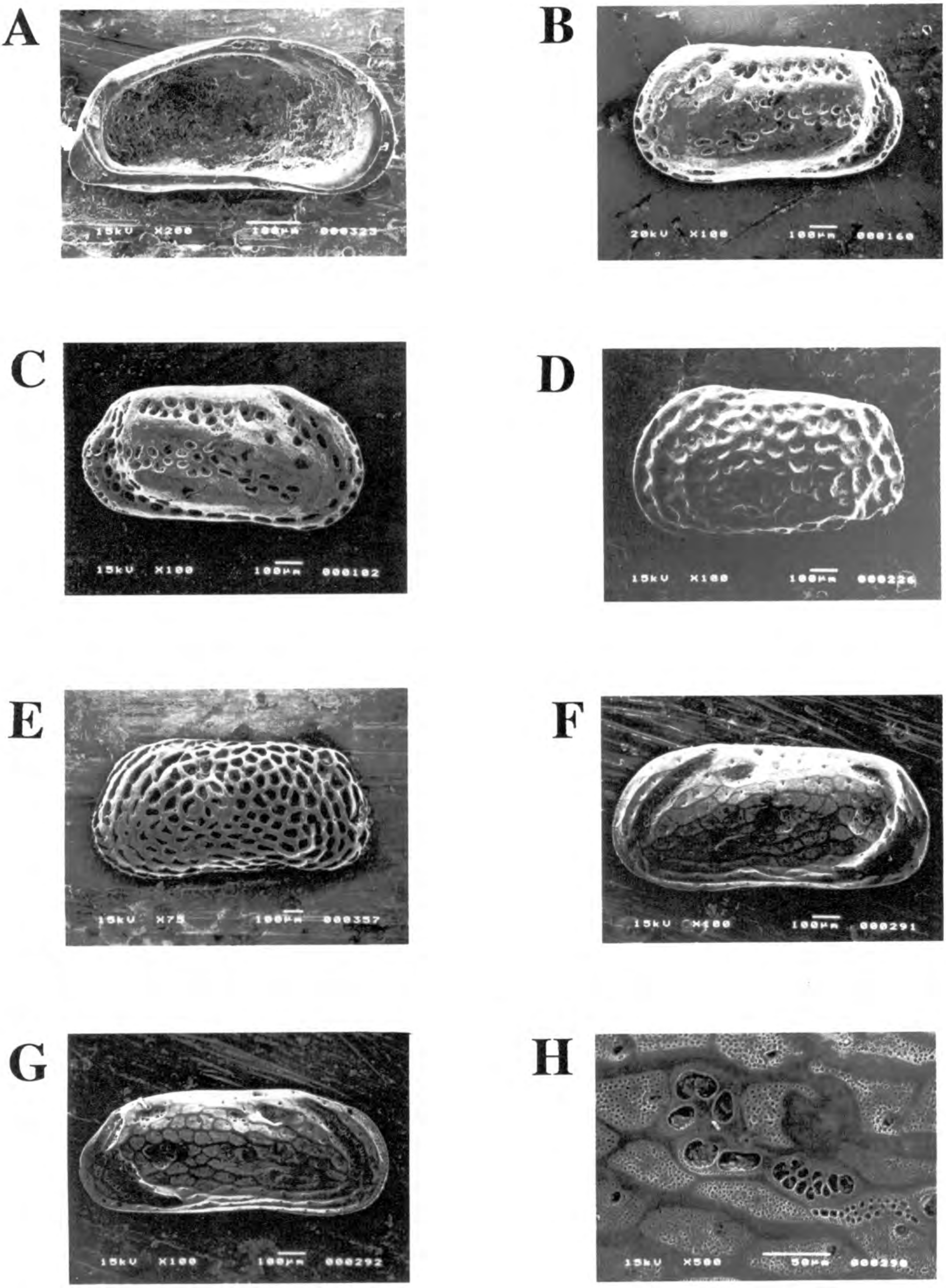

PLATE 14 A Indet sp. 3 -LV int. B-C Indet sp. 4 B-LV, C-RV. D Indet sp. 5 -LV. E Indet sp. 6 -LV. F-H Indet sp. 7 F-LV, G-RV, H-surface ornamentation.

5. FACTOR ANALYSIS

Data Analysis

A multivariate statistical analysis was used to establish quantitative links between ostracod assemblages and environmental parameters, and to develop transfer functions for use in palaeoenvironmental reconstruction. Q-mode factor analysis was carried out on the 24 Most Abundant Species (MAS) of Ostracoda, which accounted for 91.48% of the total specimens available for study. Table 1 shows the mean, maximum, minimum and standard deviation of the relative abundances of the MAS in the sediment samples. The environmental variables considered were: water depth, sand content of the substrate, and the dissolved-oxygen content, temperature, and salinity of the bottom water. Table 2 shows the mean, maximum, minimum and standard deviation of the environmental variables.

The varimax solution involved one rotation of the matrix, resulting in two matrices, the one giving the species composition of the factors (varimax factor score matrix - appendix 4), and the other, the composition of each sample in terms of the resultant factors (varimax factor components matrix - appendix 5). Curvilinear regression analysis was then run on the varimax factor and environmental matrices using Oregon State University's CLIMAP-REGRESS program of Imbrie and Kipp (1971), in order to calculate transfer functions for each variable. A variance cutoff value of 0.005 was used.

Results

Seven factors were chosen for the analysis and together they accounted for 94.77% of the total variance; 86.3% of the sample sites had a communality of greater than 0.9.

The factor score matrix is given in Appendix 4. Each factor is characterised by a high loading with one species (after which it is named) and lower correlations with minor species. Table 3 showed the species content of each factor association and the corresponding factor scores. Only species with a correlation of greater than 0.1 are reflected in the factor assemblages.

The varimax factor components matrix (Appendix 5) indicates which factor is dominant at each sample site. The distribution of the various factors on the Agulhas Bank is shown in Figure 5.1, which was constructed by plotting factor scores greater than 0.6.

The matrix of correlation coefficients (Table 4) between all dependent and independent variables is used to assess which independent variable is the major controlling factor in each factor association. Using the most significant correlations, averages of the most strongly influencing parameters have been calculated for various factor assemblages and these are given in Table 5.

A curvilinear regression analysis was run using the seven factors and the independent environmental variables to develop transfer functions for each sea-floor parameter. The results are given in Table 6, which shows the multiple correlation coefficient (MCC) and the standard errors of estimate (SEE) for each independent variable. Full transfer equations are given in Appendix 6.

Factor Associations

Factor 1

This association is completely dominated by *Cytherella dromedaria*. It occurs as a semi-continuous zone from west of Cape Agulhas to east of Port Elizabeth on the mid-shelf of the Agulhas Bank. This factor is particularly dominant on the eastern Agulhas Bank (east of 24°E). The main controlling parameters are the sand content of the sediment (positive correlation) and the dissolved-oxygen values of the bottom water (positive correlation). The mean values for these parameters are 91.7% and 4.39ml/l respectively. The predominance of this association on the eastern Agulhas Bank is thus explained by the coarseness of the sediment and the slightly higher dissolved-oxygen values encountered in the area. Whatley (1991) suggests that high percentages of platycopids are generally associated with decreased levels of dissolved oxygen. This theory, however, does not hold true for the west coast as shown by Dingle (1995), nor for the south coast as shown by this study.

Factor 2

This association is dominated by *Chrysocythere craticula*, with minor contributions by *Urocythereis sp. C1, Ambostracon keeleri,* and *Quadracythere sp.* It occurs on the inner to mid-shelf of the central Agulhas Bank (between 21.5 and 23.5°E). The strongest correlation is with depth (negative correlation) with the average depth being 83.5m, indicating this association's preference for a mid-shelf environment.

Factor 3

This association is dominated by *Ambostracon keeleri,* with minor contributions by *Pseudokeijella lepralioides, Garcaiella knysnaensis, Chrysocythere craticula* and *Ambostracon (P) sp.* It occurs on the western Agulhas Bank between 19.5 and 20.5°E. It is strongly correlated with three environmental parameters - sand content (negative correlation), dissolved-oxygen content (negative correlation) and temperature (positive correlation). Mean values for these parameters are 20.2%, 3.79ml/l and 10.54°C respectively. All the species featuring in this assemblage are common on the west coast. The preference for muddy substrates and low oxygen values indicates a preference for west coast type environments. The distribution of this factor is obviously related to the Benguela Ecosystem and to the west coast faunal assemblages. This factor association therefore appears to be related to the fact that this region has bottom water of Atlantic Ocean origin, and this is discussed fully in the next chapter.

Factor 4

This association is dominated by two species - *Doratocythere exilis* and *Quadracythere sp,* with minor contributions by *Xestoleberis africana* and *Ambostracon (A) flabellicostata.* It occurs on the inner-shelf between 20.5 and 22°E. Three environmental parameters show strong correlations - depth (negative correlation), temperature (positive correlation) and salinity (positive correlation). Averages for these parameters are 47m, 14.17°C and 35.16ppt respectively. These values indicate that this factor is associated with the warmer, more saline, inner-shelf region. It does not occur on the inner-shelf of the far eastern Agulhas Bank (east of 23°E) presumably because upwelling there introduces water to the region which is cooler than preferred.

Factor 5

This association is dominated by *Paracypris lacrimata* with a significant contribution by *Pseudokeijella lepralioides* and minor contributions by *Doratocythere exilis, Quadracythere sp* and *Urocythereis sp. B.* It occurs in two areas - on the western Agulhas Bank between 20 and 21°E, and on the eastern Agulhas Bank between 23 and 24°E. The most significant correlation this factor shows is with sand content (negative correlation). A minor correlation exists with oxygen content (negative correlation). Averages for these parameters are 51.2% and 4.2ml/l respectively. This factor is therefore associated with areas containing silty substrates and with bottom water containing average oxygen contents. The location of this association in two remote regions on the Agulhas Bank cannot be explained by the parameters studied, and one can conclude that there are further more important environmental parameters controlling this association's distribution.

Factor 6

This association is dominated by *Urocythereis sp. C*, with minor contributions by *Urocythereis sp. B, Chrysocythere craticula, Quadracythere sp* and *Ambostracon (P) sp.* It occurs on the inner-shelf of the western Agulhas Bank between 20 and 21.5°E. The most significant correlation is with salinity (positive correlation) and the average value is 35.17ppt. Less significant correlations exist with temperature (positive correlation) and depth (negative correlation) and the average values are 13.66°C and 61m respectively. These values show that this factor is associated with the warm, saline ambient water on the inner-shelf of the Agulhas Bank, which is little influenced by the two boundary currents.

Factor 7

This association is dominated by *Pseudokeijella lepralioides* with a significant contribution by *Paracypris lacrimata* and minor contributions by *Ambostracon (A) keeleri, Ambostracon (P) sp, Doratocythere exilis, Urocythereis sp. B* and *Quadracythere sp.* It occurs on the mid-shelf of the western Agulhas Bank, west of 21°E. The most significantly influencing parameter is sand content (negative correlation) followed by dissolved-oxygen content (negative correlation). Average values for these parameters are 30.65% and 3.5ml/l respectively. A preference for muddy substrates and low oxygen values is the reason why this factor only occurs on the western Agulhas Bank. This factor, like factor 3, shows a preference for west coast type environments and the species found in this assemblage all commonly occur on the west coast except for *Urocythereis sp. B.*

Independent Variables

Amongst the independent variables, the highest correlation, as expected, is between temperature and salinity (0.895). High correlations also exist between depth and salinity (-0.714), depth and temperature (-0.701), depth and oxygen (-0.474), oxygen and sand (0.325), oxygen and temperature (0.406) and salinity and oxygen (0.309).

Temperature, salinity and dissolved-oxygen content are all depth dependent variables, having strong negative correlations with depth. On the inner-shelf, the bottom water is relatively warm, saline and oxygen rich, and it becomes cooler, less saline and oxygen poorer towards the shelf edge, hence the negative correlations of these variables with depth. This is a characteristic feature of a primary shelf - one which is little influenced by conditions and currents at the open ocean boundary.

The positive correlation between dissolved-oxygen content and sand content, indicates that the oxygen content of the bottom water decreases with decreasing grain size. This is related to the fact that in muddy zones there tends to be a higher content of organic matter, the bacterial decomposition of which uses up the oxygen in reduction reactions. The inshore region generally has finer substrates because of the numerous rivers draining onto the Agulhas Bank which contribute fine, muddy material to the inner-shelf and inshore sediments. The sediment on the outer-shelf is composed primarily of relict coarse sand, which is continuously exposed to the winnowing action of the fast-moving Agulhas Current, which prevents deposition of the finer sediment on the outermost regions of the shelf. The positive correlation between sand content and oxygen levels is indicated by the fact that the eastern Agulhas Bank outer-shelf region has much higher oxygen levels than the outer shelf of the western Agulhas Bank.

The high correlations between temperature, salinity and oxygen are related to the gradient of these variables on the shelf, and to their mutual correlation with depth. Correlations between these variables on the west coast, however, indicate a widely differing environment. As expected, there is also a high correlation between temperature and salinity on the west coast (0.896) (Dingle, 1994). Oxygen has a negative correlation with temperature (-0.743), and with salinity (-0.813) on the west coast (Dingle, 1994), and the correlations are stronger than those on the Agulhas Bank. The oxygen content of the water decreases as the temperature and salinity increase on the west coast. This region is characterised by oxygen-depleted water (<2ml/l), which is further depleted by the high biogenic activity which is a result of the nutrient rich upwelling in the region. The west coast has a complicated shelf circulation system, and shows sharp contrasts between water masses, resulting in high correlations between the oceanographic parameters in this region. The Agulhas Bank, in contrast, has relatively well mixed ambient water, and therefore the correlations between the parameters are weaker.

Transfer Functions

The multiple regression analysis is summarized in Table 6 and full transfer equations are given in Appendix 6. The multiple correlation coefficients are all above 0.650, with sand content having the highest correlation coefficient (0.860). The standard error of the estimates shows that the transfer equations will predict depth to ±25m, sand content to ±15.4%, oxygen content to ±0.35ml/l, temperature to ±1.29°C and salinity to ±0.09ppt. In comparison, the transfer equations for the west coast assemblages (Dingle and Giraudeau, 1993) can predict dissolved oxygen to ±0.8ml/l, temperatures to ±1.4°C, and salinities to ±0.13ppt. The most successful factors for predicting palaeoenvironmental conditions are FA's 4 and 6 for depth, FA's 3, 4 and 7 for sand content, FA's 3, 4 and 6 for dissolved-ogygen content, FA 4 for temperature and FA's 4, 3 and 5 for salinity.

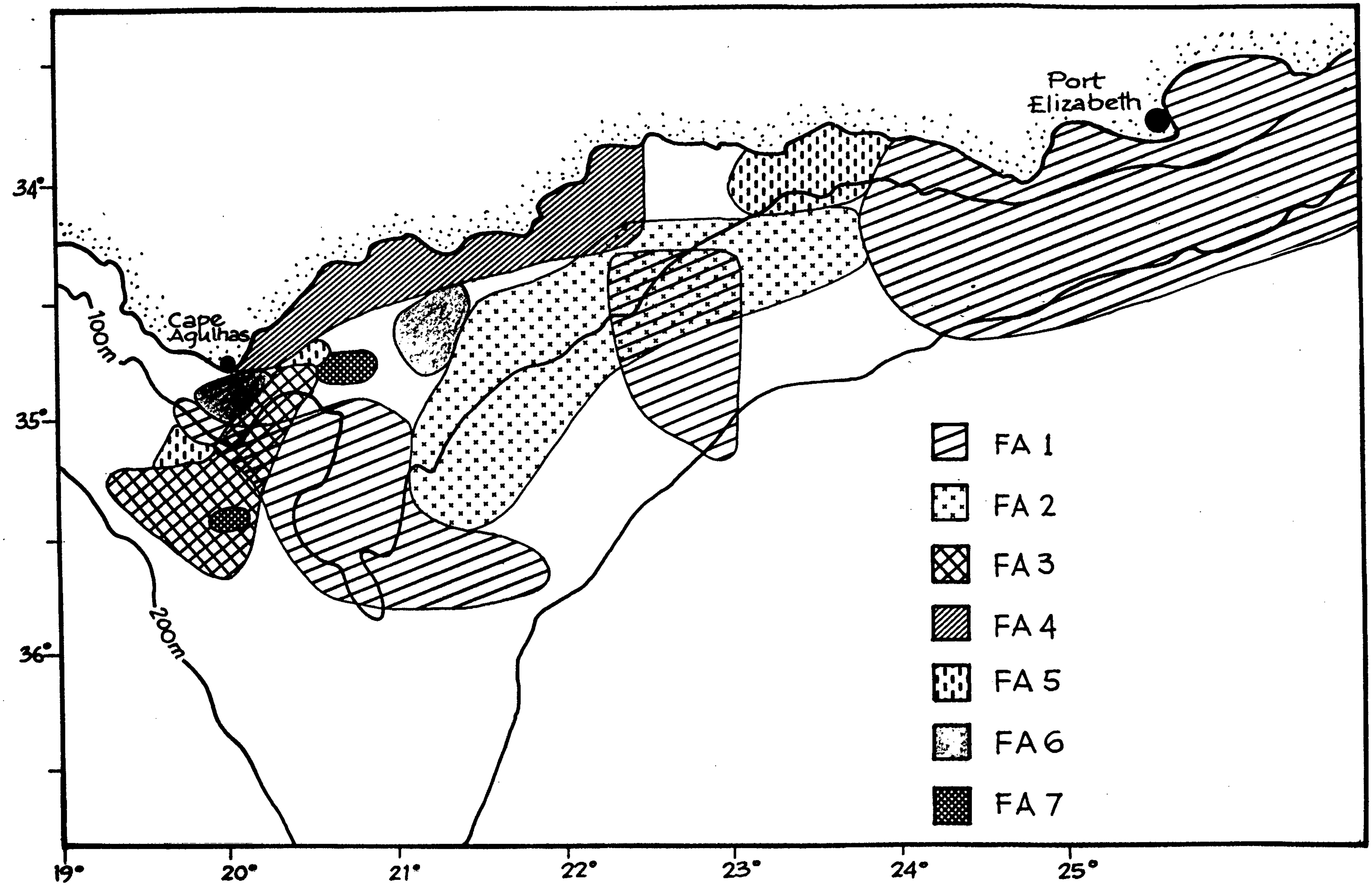

Figure 5.1. The distribution of the various Factor Associations on the Agulhas Bank.

SPECIES	Mean Abun	Max	Min	Std Dev
Pseudokeijella lepralioides	25.00	91.34	0	24.521
Bairdoppilata simplex	15.00	62.69	0	17.669
Cytherella dromedaria	9.58	55.00	0	13.928
Doratocythere exilis	5.43	31.43	0	6.618
Ruggieria cytheropteroides	4.18	46.10	0	9.177
Chrysocythere craticula	3.06	18.42	0	3.819
Garciaella knysnaensis	2.68	34.70	0	6.726
Urocythereis arcana	3.09	25.00	0	4.439
Ambostracon keeleri	2.49	27.27	0	4.185
Xestoleberis africana	1.85	10.69	0	2.813
Ambostracon flabellicostata	2.18	16.67	0	2.744
Urocythereis sp. C1	1.57	10.31	0	2.252
Cytherella namibensis	1.35	16.22	0	3.135
Cytherella sp.	1.36	11.17	0	2.434
Paracypris lacrimata	1.22	11.56	0	2.503
Henryhowella melobesioides	1.03	29.87	0	3.660
Austroaurila rugosa	1.59	34.62	0	4.717
Urocythereis sp. B	1.11	13.40	0	2.492
Indet sp. 4	1.16	14.89	0	2.575
Neocytherideis boomeri	0.91	8.81	0	1.755
Quadracythere sp.	1.33	31.82	0	4.066
Australoecia fulleri	0.97	11.86	0	2.022
Cytheropteron whatleyi	1.44	34.71	0	5.564
Ambostracon (P) sp.	0.83	6.98	0	1.486

Table 1. Statistics of the 24 MAS. Values are in percentages of the total number of valves. N=73.

VARIABLE	Mean	Max	Min	Std Dev
Depth (m)	94	200	30	32.73
Sand (%)	74.6	100	7.2	28.43
Oxy (ml/l)	4.27	5.11	3.28	0.43
Temp (°C)	11.85	15	8.72	1.67
Salin (ppt)	35.01	35.25	34.7	0.012

Table 2. Statistics of the environmental parameters. N=73.

Factor	% Var	Species	Factor Score
1	40.08	*Cytherella dromedaria*	0.993
2	20.45	*Chrysocythere craticula*	0.939
		Urocythereis sp. C1	0.225
		Ambostracon keeleri	0.202
		Quadracythere sp.	0.125
3	9.81	*Ambostracon keeleri*	0.901
		Pseudokeijella lepralioides	0.283
		Garciaella (k) knysnaensis	0.189
		Chrysocythere craticula	0.170
		Ambostracon (P) sp.	0.138
4	7.01	*Doratocythere exilis*	0.683
		Quadracythere sp.	0.665
		Xestoleberis africana	0.236
		Ambostracon flabellicostata	0.102
5	6.68	*Paracypris lacrimata*	0.851
		Pseudokeijella lepralioides	0.440
		Doratocythere exilis	0.135
		Quadracythere sp.	0.134
		Urocythereis sp. B	0.102
6	5.77	*Urocythereis* sp. C1	0.918
		Urocythereis sp. B	0.219
		Chrysocythere craticula	0.200
		Quadracythere sp.	0.176
		Ambostracon (P) sp.	0.153
7	4.97	*Pseudokeijella lepralioides*	0.841
		Paracypris lacrimata	0.385
		Ambostracon keeleri	0.226
		Ambostracon (P) sp.	0.168
		Doratocythere exilis	0.132
		Urocythereis sp. B	0.129
		Quadracythere sp.	0.118

Table 3. Species composition of the seven factors based on 73 samples. (See Appendices 4 and 5 for complete factor matrices).

	Depth	Sand	Oxy	Temp	Salin	FA 1	FA 2	FA 3	FA 4	FA 5	FA 6	FA 7
Depth	1	-0.081	-0.474	-0.701	-0.714	0.103	-0.198	0.402	-0.594	0.051	-0.163	0.02
Sand	-0.081	1	0.325	-0.056	-0.015	0.574	0.109	-0.692	-0.143	-0.347	0.089	-0.361
Oxy	-0.474	0.325	1	0.406	0.309	0.199	0.103	-0.521	0.41	-0.191	0.106	-0.221
Temp	-0.701	-0.056	0.406	1	0.895	-0.15	0.102	-0.212	0.545	0.014	0.185	-0.029
Salin	-0.714	-0.015	0.309	0.895	1	-0.057	0.078	-0.226	0.463	-0.054	0.243	-0.037
FA 1	0.103	0.575	0.199	-0.15	-0.057	1	-0.425	-0.497	-0.338	-0.391	-0.146	-0.347
FA 2	-0.198	0.109	0.103	0.102	0.078	-0.425	1	-0.046	0.078	-0.158	0.154	-0.042
FA 3	0.402	-0.692	-0.521	-0.212	-0.226	-0.497	-0.046	1	-0.248	0.155	-0.111	0.218
FA 4	-0.594	-0.143	0.41	0.545	0.463	-0.338	0.078	-0.248	1	0.046	-0.005	-0.031
FA 5	0.051	-0.347	-0.191	0.014	-0.054	-0.391	-0.158	0.155	0.046	1	-0.091	0.363
FA 6	-0.163	0.089	0.106	0.185	0.243	-0.146	0.154	-0.111	-0.005	-0.091	1	0.037
FA 7	0.02	-0.361	-0.221	-0.029	-0.037	-0.347	-0.042	0.218	-0.031	0.363	0.037	1

Table 4. Correlation matrix for factors and independant variables (r^2).

FA	STAT	TEMP	SALIN	OXY	%SAND	DEPTH
1	Mean			4.39	91.7	
	Max			5.11	100	
	Min			3.64	65.4	
	Std Dev			0.29	8.94	
	N			30	30	
2	Mean					84
	Max					104
	Min					60
	Std Dev					16.03
	N					10
3	Mean	10.54		3.79	20.2	
	Max	11.57		3.97	36.9	
	Min	9.68		3.46	9	
	Std Dev	0.72		0.19	9.36	
	N	6		6	6	
4	Mean	14.17	35.16			47
	Max	14.89	35.22			65
	Min	13.41	35.06			30
	Std Dev	0.6	0.07			14.29
	N	3	3			3
5	Mean			4.2	51.2	
	Max			4.57	83.7	
	Min			4.36	7.2	
	Std Dev			0.41	28.69	
	N			4	4	
6	Mean	13.66	35.17			61
	Max	13.69	35.21			66
	Min	13.62	35.12			55
	Std Dev	0.04	0.05			5.5
	N	2	2			2
7	Mean			3.5	30.65	
	Max			3.68	47.5	
	Min			3.31	13.8	
	Std Dev			0.09	16.85	
	N			2	2	

Table 5. Environmental statistics of each FA. (Only those variables which show a significant correlation are given).

VARIABLE	MCC	SEE
Depth	0.730	25.131
Sand	0.865	15.360
Oxygen	0.772	00.346
Temp	0.699	01.287
Salin	0.778	00.086

Table 6. Summary of multiple regression analysis. (See Appendix 5 for full transfer equations).

MCC - multiple correlation coefficient
SEE - standard error of estimate

6. DISCUSSION

An evaluation of the ostracod population on the Agulhas Bank, and an analysis of the environmental parameters that control their distribution, has provided further evidence for the boundary between the western and eastern Agulhas Bank suggested by Chapman and Largier (1989). There is a significant difference in oceanographic conditions and faunal associations on either side of the boundary, which lies between 20.5 and 21°E.

The eastern Agulhas Bank is relatively broad, and the depth increases along a shallow gradient towards the shelf break. In contrast, the western Agulhas Bank has a steeper depth gradient, and is aereally much smaller. Currents and circulation patterns on the western Agulhas Bank are complex, consisting of several complexly interacting water masses, whereas the eastern Agulhas Bank is characterised by an ambient mass of slow-moving water. It is the inshore regions of the eastern Agulhas Bank that are considered by Schumann and Beekman (1984) to have primary shelf characteristics and thus have little direct influence from the Agulhas Current. This is indicated by the fact that the eastern Agulhas Bank is dominated by fewer factor associations which occupy greater areas, whilst the western Agulhas Bank is characterised by many more factor associations in a much smaller area. Oceanographic conditions on the western Agulhas Bank therefore appear to be more complex than those on the east.

The theory of different origins for the bottom water on the western and eastern Agulhas Banks, suggested by Chapman and Largier (1989), is supported with evidence from the different faunal associations occurring in the two areas. The fauna on the western Agulhas Bank is very similar to that on the west coast, in that many of the same species and similar faunal associations occur in both areas, and therefore similar oceanographic conditions are indicated. It follows then, that water of similar origin is found in both areas. This supports Chapman and Largier's (1989) theory that the western Agulhas Bank bottom water is predominantly of Atlantic Ocean origin, as is the water on the west-coast shelf. The eastern Agulhas Bank bottom water is predominantly of Indian Ocean origin (Chapman and Largier, 1989), and this is indicated in its distinctive fauna and faunal associations. Figure 6.1 shows the two active basal currents on the Agulhas Bank as depicted by Chapman and Largier (1989). Water of Atlantic Ocean origin flows in a south-easterly direction onto the western Agulhas Bank, following the contours. The presence of the Alphard Banks forces the current into a circular motion resulting in the more complex circulation pattern on the western Agulhas Bank, and in turn influencing the faunal associations. On the eastern Agulhas Bank, the active current is the Agulhas Current which flows in a south-westerly direction, predominantly at the shelf break, with a corresponding but weaker flow on the shelf edge.

Figure 6.2 depicts the major faunal associations on the Agulhas Bank, and relates them to the main water masses, currents and substrate types which control their distribution.

The Agulhas Bank is dominated by *Cytherella dromedaria* (FA 1), particularly the mid-outer shelf, because of this associations preference for very sandy substrates, which is a general characteristic of the Agulhas Bank. *Cytherella dromedaria* is strongly associated with the Agulhas Current as FA 1 particularly dominates on the eastern Agulhas Bank, and occurs along the path of the current. This is due to the sorting action of the fast-moving current, which ensures the coarseness of substrate which this species prefers.

On the eastern Agulhas Bank, the mid-shelf region is dominated by *Chrysocythere craticula* (FA 2). This factor association is associated with the stable, slow-moving, ambient water mass of Indian Ocean origin. It is dominated by the species *Chrysocythere craticula* and *Urocythereis sp. C1*, which are not common or absent, respectively, from the west coast.

The inner-shelf is dominated by *Doratocythere exilis* and *Quadracythere sp.* (FA 4), because of their preference for shallow, warm and saline environments. This factor association is associated with the shallow inshore environment in which the basal water layer is heated by solar radiation and therefore has a high seasonal fluctuation. These species tolerate wide ranges in average bottom-water temperature - these are 6.28°C for *Doratocythere exilis* and 5.02°C for *Quadracythere sp.*, indicating their tolerance for broad temperature variations. Two other species, which are not included in the factor analysis, are important components in this zone. *Aglaiella railbridgensis* occurs abundantly at one site, at 30m water depth, but nowhere else on the shelf. *Sulcostocythere knysnaensis* occurs only in this zone on the shelf, but dominates in inshore regions such as Knysna Lagoon (Benson and Maddocks, 1964).

The most widespread factor association on the western Agulhas Bank is FA 3. This factor association is considered to be associated with the basal flow of Atlantic originating water which flows onto the western Agulhas Bank into the region where FA 3 occurs. The connection between this water mass and FA 3 is also indicated by the average environmental parameters of FA 3, which are considered to be similar to west-coast environmental conditions, where the bottom water is also of Atlantic Ocean origin. These include relatively cool water, muddy substrates and low dissolved-oxygen values. The averages for FA 3 on the Agulhas Bank are 10.54°C, 20.2% sand and 3.79ml/l respectively. FA 3 is strongly correlated to the western Agulhas Bank mudbelt, as its distribution corresponds to the location of the mudbelt.

Three factor associations dominate the western Agulhas Bank - FA 3, FA 6 and FA 7, with minor contributions by FA 5 and FA 1. FA 7 and FA 3 occur only on the western Agulhas Bank, and both associations have low average dissolved-oxygen values - 3.5ml/l and 3.79ml/l respectively. As low oxygen environments are characteristic features of the west coast, this is further evidence to support the theory that the western Agulhas Bank is part of the Benguela Ecosystem. This is further suggested by the association of FA 3 and FA 7 with muddy environments with low average sand contents of 20.2% sand and 30.65% sand respectively, as the Benguela Ecosystem is dominated by very muddy areas. Common west coast species such as *Cytheropteron whatleyi* and *Buntonia rogersi*, occur only in the western Agulhas Bank mudbelt, further suggesting the continuation of the Benguela Ecosystem into this region. *Ruggieria cytheropteroides*, a common west coast species is also far more abundant here because of its preference for colder water and lower salinity environments - averages for this species being 10.61°C and 34.93ppt respectively.

Thread analysis (Imbrie and Kipp, 1971) is that part of the factor analysis program which interprets palaeoenvironments using the factor associations and their preferred environmental conditions which have been generated using modern faunas and environments. In this study, FA 3 and FA 4 are the best indicators of environment, and therefore the most useful in the thread analysis. This is because they consist of intolerant species which only occur in very specific environments. FA 3 indicates a west-coast type environment of muddy substrates and low dissolved-oxygen values, whilst FA 4 indicates very shallow and warm-water environments. FA 7 is dominated by *Pseudokeijella lepralioides*, the most abundant species on the Agulhas Bank. It is significant in identifying muddy, oxygen-poor environments only on the Agulhas Bank, because the Agulhas Bank is dominated by very sandy, relatively well-oxygenated environments, and not because muddy, oxygen-poor environments are the preferred habitat of *Pseudokeijella lepralioides*. Species in this assemblage are all tolerant of wide variations in environmental conditions, and are therefore contained in this factor association. It is for this reason that FA 7 hardly features in the regression equations - these species are very tolerant and therefore not really indicative of any specific environment.

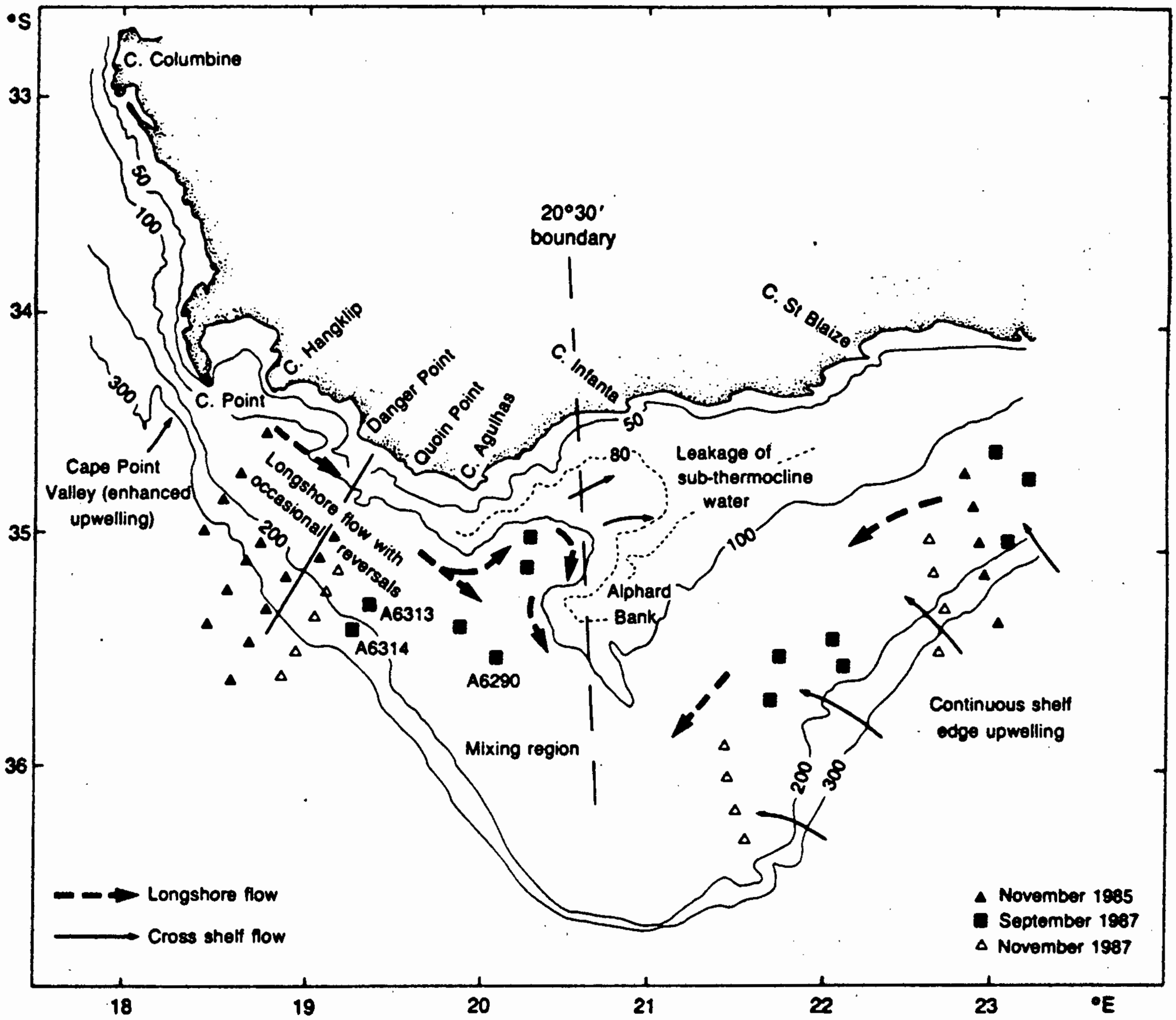

Figure 6.1. The Agulhas Bank, showing the boundary between the western and eastern Agulhas Bank, and the postulated movements of bottom water. (From Chapman & Largier, 1989).

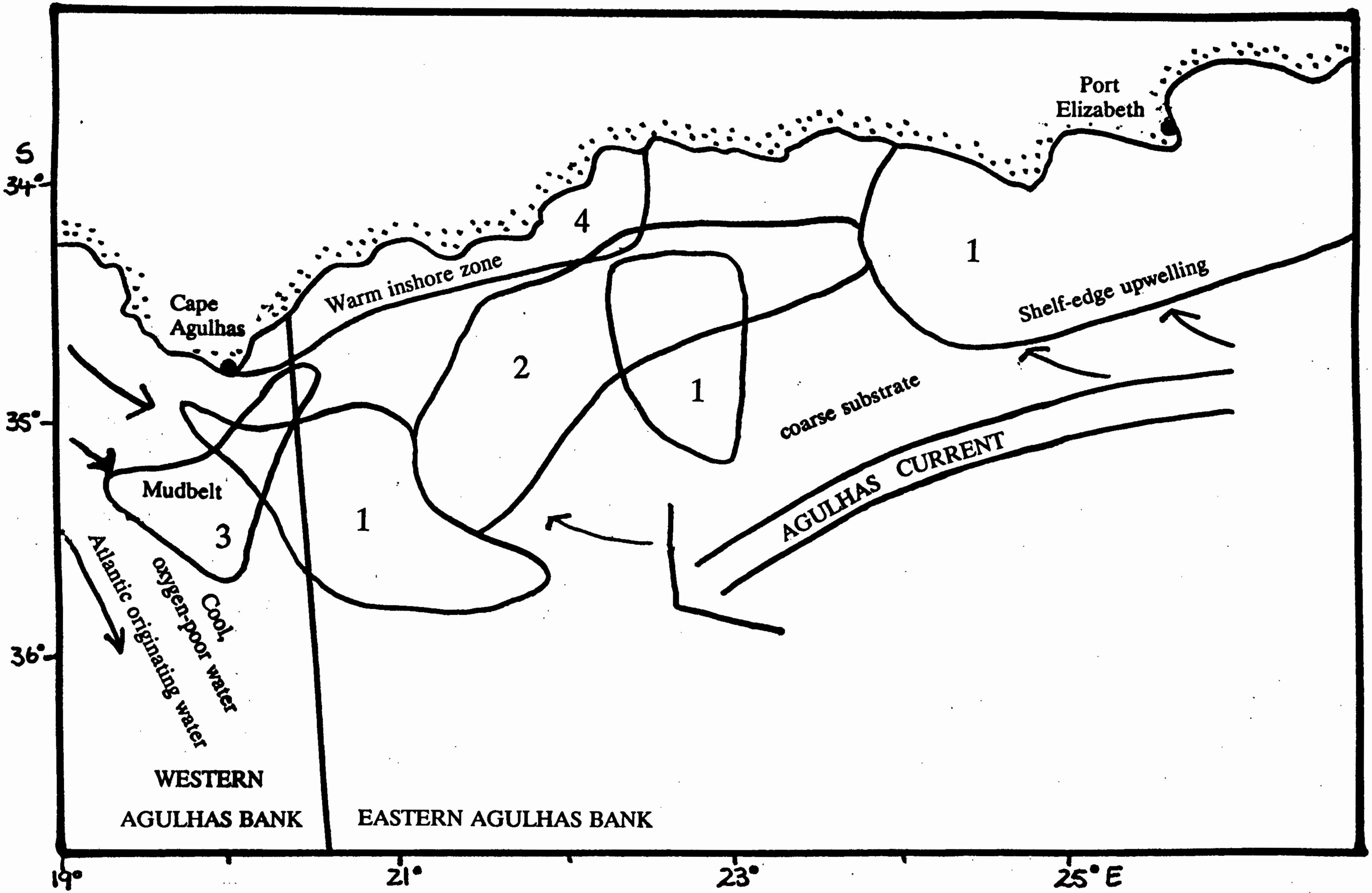

Figure 6.2. The water masses on the Agulhas Bank are shown relative to the major substrate types, the oceanic currents and the predominant factor associations. FA 1 is associated with very coarse sediment and with the Agulhas Current. FA 2 also occurs on a very coarse substrate, and is linked to the ambient water mass located on the primary shelf area. FA 3 is associated with the Benguela Ecosystem, and the western Agulhas Bank mudbelt. The water mass is cool with a low dissolved oxygen content, and is derived from the Atlantic Ocean via the Benguela Current. FA 4 is associated with the warm, saline inshore water mass.

7. CONCLUSIONS

The palaeontological and oceanographic analysis of the Agulhas Bank has resulted in a database of the ostracod species occurring there, their distribution and the environmental parameters which affect them. This has allowed for comparison between the Agulhas Bank and the west coast using Dingle's (1989-1994) study of the west coast. The different environmental parameters and water masses have been compared and contrasted based on ostracod faunal associations. Although the west coast and the Agulhas Bank environments are very different, more than half the Agulhas Bank species occur on the west coast. Ostracods are a very diverse class, and the reason for the similarity in populations is geographical proximity. As a result, the factor associations that have been generated for the west coast and the Agulhas Bank have enough common species for the different areas to be compared. This allows for palaeoenvironmental reconstruction of specific environments within a larger context such as southern Africa as a whole. Dingle and Giraudeau (1993) generated ten factor associations for the west coast and, together with the seven from this study, a total of seventeen factor associations are available for the greater south and south west coast continental shelf area, which can be used for future palaeoenvironmental studies.

Future work should include the formal description of the twenty-two undescribed or new species from the Agulhas Bank. Using the seventeen factor associations and the Thread analysis of Imbrie and Kipp (1971), palaeoenvironmental research could be furthered on the west and south coasts of Africa. The database of Holocene shelf ostracods and their environmental parameters could be extended to include the east coast continental shelf north of Port Elizabeth.

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Appendix 1

Classification of Holocene ostracods

PODOCOPIDA

PLATYCOPINA

CYTHERELLIDAE

Cytherella

Cytherella dromedaria (CD)
Cytherella namibensis (CN)
Cytherella sp (Clsp)

PODOCOPINA

BAIRDIACEA

BAIRDIIDAE

Bairdoppilata

Bairdoppilata simplex (BS)

CYPRIDACEA

PARACYPRIDIDAE

Aglaiella

Aglaiella railbridgensis (AgR)

Paracypris

Paracypris lacrimata (PaL)
Paracypris sp (Pasp)

MACROCYPRIDIDAE

Macrocypris

Macrocypris sp (Msp)

PONTOCYPRIDIDAE

Argilloecia

Argilloecia sp (Agsp)

Australoecia

Australoecia fulleri (AF)

Propontocypris

Propontocypris sp (Prsp)

CYTHERACEA

BUNTONIIDAE

Buntonia

Buntonia rogersi (BR)

BYTHOCYTHERIDAE

Bythocythere

Bythocythere sp (Bsp)

CAMPYLOCYTHERIDIDAE

CAMPYLOCYTHERIDINAE

Doratocythere

Doratocythere exilis (DE)

CYTHERETTIDAE

CYTHERETTINAE

Garciaella

Garciaella (k) knysnaensis (GK)

CYTHERIDAE

PHACORHABDOTINAE

Strobilocythere (Keniacythere)

Strobilocythere (K) malzi (SM)

CYTHERIDEIDAE

NEOCYTHERIDEIDINAE

Neocytherideis

Neocytherideis boomeri (NB)

CYTHERURIDAE

Cytheropteron

Cytheropteron whatleyi (CW)
Cytheropteron trinodosum (CT)
Cytheropteron cunneatum (CyC)
Cytheropteron sp (Cysp)

Kangarina

Kangarina mucronata (KM)

Paracytheridea
Paracytheridea sp (Pdsp)

HEMICYTHERIDAE
Ambostracon (Ambostracon)
Ambos. (A) flabellicostata (Amf)
Ambostracon (A) keeleri (AK)

Ambostracon (Patagonacythere)
Ambostracon (P) sp (Apsp)

Aurila
Aurila sp (Ausp)

Austroaurila
Austroaurila rugosa (AR)

Coquimba
Coquimba cf birchi (CB)

Falklandia
Falklandia sp (Fsp)

Meridionalicythere
Meridionalicythere petricola (MP)
Mutilus
Mutilus malloryi (MM)
Mutilus bensonmaddocksorum (MB)

Quadracythere
Quadracythere sp (Qsp)

Urocythereis
Urocythereis arcana (UA)
Urocythereis sp a (Uspa)
Urocythereis sp b (Uspb)
Urocythereis sp c (Uspc)
Urocythereis sp c1 (Uspc1)
Urocythereis sp d (Uspd)
Urocythereis sp e (Uspe)
Urocythereis sp f (Uspf)

LOXOCONCHIDAE
Loxoconcha
Loxoconcha paiki (LP)

Loxoconcha sp A (Lspa)
Loxoconcha sp B (Lspb)

Kuiperiana
Kuiperiana angulata (KA)

SCHIZOCYTHERIDAE
Sulcostocythere
Sulcostocythere knysnaensis (SK)

TRACHYLEBERIDIDAE
Occultocythereis
Occultocythereis sp (Osp)

Ruggieria
Ruggieria cytheropteroides (RC)

PTERYGOCYTHERINAE
Incongruellina
Incongruellina venusta (IV)

THAEROCYTHERINAE
Bradleya (Quasibradleya)
Bradleya (Q) sp (Bqsp)

Poseidonamicus
Poseidonamicus cf panopsus (PP)

TRACHYLEBERIDINAE
Chrysocythere
Chrysocythere craticula (CC)

Henryhowella
Henryhowella melobesioides (HM)

Neocaudites
Neocaudites cf osseus (NO)
Neocaudites sp (Nesp)

Pseudokeijella
Pseudokeijella lepralioides (PL)

XESTOLEBERIDIDAE
Xestoleberis
Xestoleberis africana (XA)

xestoleberis hartmanni (XH)

INDETERMINATE SPECIES

Indet sp. 1 (Isp 1)
Indet sp. 2 (Isp 2)
Indet sp. 3 (Isp 3)
Indet sp. 4 (Isp 4)
Indet sp. 5 (Isp 5)
Indet sp. 6 (Isp 6)
Indet sp. 7 (Isp 7)

Appendix 2. Raw data Matrix

(See Appendix 1 for abbreviations of ostracod taxa)

sample	lat	long	dep	%sand	oxy	temp	salin
348	35.234	19.573	161	27.7	3.82	9.68	34.79
398	35.350	19.817	159	38.9	3.88	10.06	34.82
399	35.138	19.817	140	7.2	3.51	9.98	34.83
400	34.963	19.823	71	65.5	4.22	13.60	35.12
403	34.950	19.983	55	98.5	4.35	13.62	35.12
404	35.092	19.992	87	97.0	4.33	13.80	35.16
405	35.250	20.000	140	13.6	3.48	10.42	34.96
406	35.400	20.000	154	13.8	3.68	10.09	34.85
407	35.533	20.000	156	17.0	3.95	10.06	34.82
497	34.760	20.267	58	35.4	4.99	15.00	35.25
499	34.810	20.350	84	16.9	3.97	11.57	35.02
500	34.988	20.343	107	32.2	3.76	11.14	34.95
505	35.973	20.492	139	74.6	4.09	9.49	34.70
512	34.815	20.500	90	9.1	3.83	11.47	35.03
513	34.717	20.500	73	46.0	4.57	14.63	35.21
517	35.313	20.617	90	98.6	4.80	12.18	35.12
519	35.633	20.603	108	84.9	4.29	13.32	35.02
522	34.475	20.935	65	73.4	3.71	14.20	35.19
523	34.588	20.900	75	77.9	4.53	13.69	35.19
526	35.012	20.900	76	100.0	4.24	11.97	35.01
532	35.500	20.913	95	99.0	3.83	11.92	35.09
537	35.337	21.220	110	87.7	3.57	9.85	34.90
541	34.692	21.265	68	99.8	4.30	13.69	35.21
547	34.500	21.293	58	40.1	4.79	13.16	35.21
553	35.272	21.500	120	90.6	3.55	9.83	34.94
561	35.660	21.753	162	96.0	3.28	10.77	34.96
565	34.873	21.793	100	88.0	3.93	10.43	34.89
566	34.712	21.802	86	69.6	4.08	10.93	34.96
568	34.462	21.703	65	9.6	3.68	14.10	35.15
571	34.413	22.000	68	48.7	4.05	12.85	35.10
574	34.922	22.000	104	94.7	4.13	11.03	34.98
583	34.787	20.682	91	47.5	3.31	11.76	35.03
681	34.200	22.405	60	91.9	4.99	14.57	35.12
684	34.253	22.000	30	43.6	4.87	13.41	35.06
799	35.973	22.262	112	94.4	3.74	10.78	35.03
801	34.577	22.223	92	97.1	4.03	10.94	34.98

sample	lat	long	dep	%sand	oxy	temp	salin
815	35.067	22.900	200	98.5	4.69	9.81	34.84
830	35.000	20.500	111	91.3	3.64	12.11	35.04
1093	34.345	22.960	86	95.3	4.45	12.44	34.96
1103	34.130	23.217	64	67.7	4.36	13.34	35.03
1113	34.237	23.603	90	96.9	4.39	11.13	34.96
1116	34.067	23.617	71	83.7	4.36	11.30	35.00
1246	34.413	21.465	47	64.0	4.52	14.89	35.22
1247	34.442	21.500	55	25.8	4.70	14.73	35.22
1248	34.473	21.537	62	64.5	4.53	14.79	35.17
1249	34.503	21.568	66	93.0	4.35	14.79	35.17
1254	34.108	22.663	58	77.8	5.10	12.40	35.00
1255	34.142	22.695	70	91.7	4.92	11.68	34.90
1259	34.173	23.208	91	93.4	4.32	11.43	34.97
1270	34.347	22.400	82	95.6	4.87	12.78	34.96
1273	34.488	22.750	103	95.2	4.41	10.79	34.90
1275	34.317	23.607	108	94.2	4.44	10.91	34.95
1284	34.793	22.455	117	96.7	4.22	10.82	34.96
1285	34.722	22.738	116	99.0	4.39	11.03	34.98
1294	34.220	24.002	106	95.6	4.38	10.40	34.94
1303	34.392	24.195	127	94.2	4.59	10.71	34.99
1319	34.225	24.697	77	86.3	4.42	10.47	35.01
1320	34.350	24.697	110	94.9	4.53	10.35	34.91
1330	34.137	25.008	52	98.6	4.44	10.57	34.95
1331	34.263	25.015	118	94.2	4.21	9.57	34.90
1337	34.005	25.167	66	71.9	4.38	8.72	34.90
1802	34.492	25.242	121	96.2	4.47	9.81	34.94
4334	34.006	26.342	109	81.9	4.90	13.68	35.09
4337	33.840	26.195	58	98.1	5.11	13.86	35.09
4345	33.842	25.908	47	95.5	4.69	14.83	35.18
4348	34.033	25.973	80	89.3	4.18	12.30	35.04
4349	34.117	26.003	108	67.9	4.19	11.61	34.99
4354	34.275	25.753	119	98.2	4.14	11.17	34.94
4358	34.087	25.675	90	78.6	4.11	12.37	35.02
4359	34.062	25.675	60	97.6	4.53	12.32	35.01
4362	34.142	25.408	95	78.4	4.56	10.79	34.93
4363	34.177	25.420	105	82.3	4.56	10.08	34.89
4365	34.292	25.433	115	93.0	4.32	10.08	34.91

sample	PL	BS	CD	DE	RC	CC	GK	UA	AK	XA	AmF
348	81	0	0	0	65	11	0	0	0	0	0
398	92	0	0	1	130	26	0	0	0	0	2
399	38	0	0	0	0	1	0	0	0	4	0
400	36	32	138	0	0	0	6	0	0	5	0
403	0	13	0	1	0	0	6	23	5	0	1
404	0	11	0	0	0	0	0	0	0	0	0
405	92	0	0	0	4	22	0	0	1	0	0
406	44	0	0	0	0	0	0	0	0	0	0
407	44	0	0	0	20	11	0	0	0	0	0
497	11	1	73	1	0	0	63	5	0	1	2
499	205	1	0	0	0	12	0	0	0	0	0
500	188	8	8	2	0	8	0	13	0	0	0
505	1	11	0	0	77	18	0	0	0	2	0
512	239	0	0	0	0	56	0	0	0	0	0
513	114	3	40	0	0	2	0	0	0	10	1
517	1	121	0	3	0	0	0	0	0	1	0
519	4	67	0	9	0	7	0	0	0	6	0
522	83	0	132	0	0	1	7	0	0	3	0
523	115	0	45	8	0	0	3	6	0	0	1
526	0	2	0	0	0	0	0	0	0	0	1
532	4	56	11	3	0	0	0	0	0	3	0
537	55	0	4	66	52	25	1	12	8	0	3
541	1	2	0	1	0	1	0	4	1	0	1
547	53	13	3	9	0	7	10	18	1	0	14
553	29	5	0	14	80	20	0	14	11	0	6
561	2	33	7	2	2	1	0	0	4	4	1
565	74	1	0	2	1	0	3	7	0	0	1
566	45	0	2	36	1	5	0	10	1	0	2
568	11	5	11	11	0	10	1	2	0	3	2
571	69	3	27	11	0	0	3	11	0	0	6
574	36	4	17	29	9	12	4	11	5	1	9
583	253	0	7	0	0	9	0	0	1	0	0
681	41	0	100	20	0	1	2	10	2	0	3
684	0	6	71	0	0	0	21	0	0	0	0
799	9	97	14	1	5	17	0	0	5	10	5
801	21	1	6	22	0	6	0	3	0	0	3

sample	Uspc1	CN	Clsp	PaL	HM	AR	Uspb	Isp4	NB	Qsp	AF
348	0	1	0	0	1	0	0	0	0	0	0
398	1	7	0	0	6	0	0	1	0	0	0
399	0	0	0	0	0	0	0	0	0	0	0
400	0	0	10	5	1	0	0	0	0	7	4
403	0	0	0	0	0	45	0	0	0	7	1
404	0	0	0	0	0	4	0	0	0	7	0
405	1	0	0	0	2	0	0	0	0	0	0
406	0	0	0	0	0	0	0	0	0	0	0
407	0	1	0	0	0	0	0	0	0	0	0
497	4	0	1	0	0	0	0	0	5	0	0
499	0	1	0	0	0	0	0	0	0	0	0
500	9	7	0	0	0	0	0	0	0	1	0
505	0	31	0	0	69	0	0	0	5	0	1
512	0	3	0	0	0	0	0	0	0	0	0
513	0	8	0	26	0	0	0	0	4	0	0
517	3	14	0	0	0	0	0	0	0	23	4
519	2	30	0	4	0	0	0	0	0	10	4
522	0	0	6	0	0	2	0	0	0	0	0
523	15	0	3	0	15	2	2	0	2	0	0
526	0	0	0	0	0	0	0	0	0	0	0
532	6	3	0	0	0	0	0	1	0	0	5
537	0	1	5	0	3	1	9	0	4	1	0
541	0	0	0	0	0	0	0	0	0	0	0
547	14	0	1	2	5	0	10	0	0	0	0
553	6	15	0	0	1	3	6	0	10	0	0
561	8	0	0	0	0	2	0	14	0	1	0
565	1	1	1	0	0	1	0	0	3	0	0
566	2	0	4	0	2	0	3	0	2	0	0
568	10	0	2	0	0	0	13	0	0	0	0
571	0	0	7	1	0	0	5	0	1	0	0
574	5	0	0	0	0	1	2	3	3	2	1
583	2	0	1	0	0	0	0	0	0	0	0
681	5	22	16	0	0	0	1	0	1	1	0
684	0	0	6	0	0	0	0	0	20	2	0
799	6	3	0	0	0	0	1	14	0	0	12
801	0	0	1	0	0	0	0	0	2	0	0

sample	CW	Apsp	Msp	XH	AgR	Uspa	LP	Ausp	Uspc	Agsp	Isp1
348	7	0	0	0	0	0	0	0	0	0	0
398	13	0	0	0	0	0	0	0	0	0	0
399	12	0	0	0	0	0	0	0	0	0	0
400	0	0	14	0	0	0	0	0	0	0	0
403	0	0	0	0	0	2	0	10	0	0	0
404	0	0	0	0	0	0	0	0	0	0	0
405	25	0	0	0	0	0	0	0	0	0	0
406	12	0	0	0	0	0	0	0	0	0	0
407	42	0	0	0	0	0	0	0	0	0	0
497	0	7	0	0	0	0	0	11	0	8	0
499	0	0	0	0	0	0	0	0	0	1	0
500	0	0	0	0	0	0	0	0	0	0	1
505	3	0	0	0	0	0	0	0	0	0	0
512	0	0	0	0	0	0	0	0	0	0	0
513	0	1	6	0	0	0	0	0	0	0	0
517	0	0	2	5	0	0	0	0	0	0	0
519	0	0	15	0	0	0	3	12	0	3	0
522	0	0	0	0	0	0	0	0	0	3	0
523	0	0	0	0	0	2	0	0	0	0	0
526	0	0	0	0	0	0	0	0	0	0	0
532	0	0	1	0	0	0	5	0	0	0	0
537	1	0	0	0	0	1	0	0	4	0	9
541	0	0	0	0	0	1	0	0	0	0	0
547	0	0	0	0	0	6	14	0	0	2	1
553	3	0	0	0	0	5	0	0	0	0	1
561	0	0	2	4	0	0	0	0	1	0	0
565	0	0	0	0	0	1	1	0	0	0	0
566	0	0	0	0	0	11	0	0	3	0	7
568	0	3	0	0	0	1	2	0	0	8	0
571	0	0	0	0	0	0	4	1	0	2	1
574	0	4	0	3	0	1	4	0	0	0	1
583	1	0	0	1	0	0	0	0	0	2	0
681	0	0	0	0	0	0	0	0	0	0	1
684	0	0	0	0	68	0	0	14	0	5	0
799	0	2	0	6	0	0	0	0	0	0	1
801	0	0	0	0	0	1	1	0	1	0	0

sample	Isp7	PP	Isp3	MB	NO	Isp5	IV	CyC	Pdsp	MM	Prsp
348	0	0	0	0	0	0	0	0	0	0	0
398	0	0	0	0	0	0	0	0	0	0	0
399	0	0	0	0	0	0	1	0	0	0	0
400	0	0	0	1	0	0	0	0	0	0	0
403	0	0	0	1	0	0	0	0	1	0	0
404	0	0	0	0	0	0	0	0	0	0	0
405	0	0	0	0	0	0	5	0	0	0	0
406	0	0	0	0	0	0	1	0	0	0	0
407	0	0	0	0	0	0	0	0	0	0	0
497	2	0	0	0	0	0	0	0	0	7	0
499	0	0	0	0	0	0	1	0	0	0	11
500	0	0	0	0	0	0	2	2	0	0	0
505	0	0	0	0	0	0	0	0	0	0	0
512	0	0	0	0	0	0	6	0	0	0	0
513	0	0	0	0	0	0	5	0	0	0	4
517	0	0	0	0	2	0	0	0	4	0	0
519	0	0	0	0	4	0	0	1	2	0	0
522	0	0	0	0	0	0	0	0	0	1	2
523	0	0	0	0	0	0	0	0	0	0	0
526	0	0	0	1	0	0	0	0	0	0	0
532	0	0	0	0	0	0	0	0	2	0	0
537	2	0	0	1	0	0	0	0	0	0	0
541	2	0	0	0	0	0	0	1	0	0	0
547	5	0	2	0	0	0	0	2	6	1	0
553	0	0	0	0	0	6	4	0	0	0	0
561	0	2	0	0	0	0	0	0	0	0	0
565	0	0	0	2	0	0	0	0	0	1	0
566	4	0	0	0	0	0	0	0	1	0	0
568	0	0	0	0	0	0	0	1	0	0	0
571	0	0	4	3	0	0	0	1	0	0	0
574	0	0	2	1	0	0	2	1	0	2	0
583	0	0	0	0	0	0	0	0	0	0	0
681	1	0	0	0	1	0	0	0	0	1	0
684	0	0	0	1	0	0	0	0	0	6	0
799	0	0	0	0	0	0	0	0	0	0	0
801	1	0	0	0	0	0	0	0	0	1	0

sample	Uspd	Uspf	CT	SM	CB	BR	Pasp	Osp	Cysp	Fsp	Nesp
348	0	0	0	0	0	3	0	0	0	0	0
398	0	0	0	0	0	3	0	0	0	0	0
399	0	0	0	0	0	0	0	0	0	0	0
400	0	0	0	0	0	0	1	0	0	0	0
403	6	0	0	0	0	0	0	0	0	4	0
404	0	0	0	0	0	0	0	0	0	0	0
405	0	0	0	0	1	1	0	0	0	0	0
406	0	0	0	0	0	0	0	0	0	0	0
407	0	0	0	0	0	3	0	0	0	0	0
497	0	0	0	0	0	0	0	0	0	0	0
499	0	0	15	0	0	0	0	0	0	0	0
500	0	0	0	0	0	0	0	0	0	1	0
505	0	0	0	0	6	3	0	4	0	0	0
512	0	0	0	0	0	0	0	0	0	0	0
513	0	0	0	0	0	0	0	0	0	0	0
517	4	0	0	0	0	0	2	3	1	0	0
519	0	0	0	0	0	0	0	2	0	0	0
522	0	0	0	0	0	0	0	0	0	0	0
523	0	0	0	0	0	0	0	0	0	0	0
526	0	2	0	0	0	0	0	0	0	0	0
532	0	0	0	0	0	0	0	0	0	0	0
537	0	0	0	0	0	0	0	0	0	0	0
541	0	1	0	0	0	0	0	0	0	0	0
547	0	0	0	0	0	0	0	0	1	0	0
553	0	0	0	0	0	0	0	0	0	0	0
561	0	0	0	0	0	0	0	0	0	0	0
565	0	0	1	0	0	0	0	0	0	0	0
566	3	5	0	0	0	0	0	0	0	0	0
568	0	0	0	0	0	0	1	0	0	0	0
571	0	0	0	0	0	0	0	0	0	0	0
574	0	0	0	2	0	0	0	0	1	0	0
583	0	0	0	0	0	0	0	0	0	0	0
681	0	0	0	0	0	0	0	0	0	0	0
684	0	0	0	5	0	0	0	0	0	2	0
799	0	0	0	0	0	0	0	0	0	0	0
801	0	0	0	0	0	0	0	0	0	0	0

sample	Isp2	Bsp	Uspe	SK	Isp6	Lspb	Lspa	MP	Bqsp	KA	KM
348	0	0	0	0	0	0	0	0	0	1	0
398	0	0	0	0	0	0	0	0	0	0	0
399	0	0	0	0	0	0	0	0	0	0	0
400	0	0	0	0	0	0	0	0	0	0	0
403	1	0	0	0	0	0	0	3	0	0	0
404	0	0	0	0	0	0	0	0	0	0	0
405	0	0	0	0	0	0	0	0	0	0	0
406	0	0	0	0	0	0	0	0	0	0	0
407	0	0	0	0	0	0	0	0	0	0	0
497	0	0	0	0	0	0	0	0	0	0	0
499	0	1	0	0	0	0	0	0	0	0	0
500	1	2	0	0	0	0	0	0	0	0	0
505	0	0	0	0	0	0	0	0	0	0	0
512	0	0	0	0	0	0	0	0	0	0	0
513	0	1	0	0	0	0	0	0	0	0	0
517	0	0	0	0	0	0	0	0	0	0	0
519	0	0	0	0	0	0	0	0	0	0	0
522	0	0	0	0	0	0	0	0	0	0	0
523	0	0	0	0	0	0	0	0	0	0	0
526	0	0	0	0	0	0	0	0	0	0	0
532	0	0	0	0	0	0	0	0	0	0	0
537	0	0	0	0	0	0	0	0	0	0	0
541	0	0	0	0	0	0	0	0	0	0	0
547	0	2	0	0	0	1	1	0	0	0	0
553	0	0	0	0	0	0	0	0	0	1	0
561	0	0	0	0	4	0	0	0	0	0	0
565	0	0	0	0	0	0	0	0	0	1	0
566	0	0	0	0	0	0	0	0	0	0	0
568	0	0	0	0	0	0	0	0	0	0	0
571	0	0	0	2	0	0	0	0	0	0	1
574	0	0	0	0	0	1	1	2	0	1	1
583	0	0	0	0	0	0	0	0	0	0	0
681	0	0	0	0	0	0	0	0	0	0	0
684	0	0	0	0	0	0	0	0	0	0	0
799	0	0	0	0	0	0	0	0	0	0	0
801	0	0	0	0	0	0	0	0	0	0	0

sample	PL	BS	CD	DE	RC	CC	GK	UA	AK	XA	AmF
815	21	57	13	26	8	0	0	0	2	0	3
830	30	61	1	20	2	16	0	3	1	19	1
1093	36	28	15	27	13	9	0	4	5	4	9
1103	58	1	63	0	0	0	42	0	0	17	1
1113	47	10	6	19	21	8	0	6	7	2	10
1116	204	1	2	6	1	0	41	0	0	15	3
1246	3	0	125	6	0	4	64	10	0	0	6
1247	8	0	87	11	0	11	22	2	1	0	1
1248	46	0	52	14	0	8	6	10	9	0	2
1249	45	1	59	19	0	7	5	6	0	0	5
1254	17	1	58	3	0	0	76	5	0	2	7
1255	59	0	67	10	0	0	7	6	0	7	7
1259	40	20	18	42	1	24	0	25	7	2	14
1270	0	60	12	26	0	0	1	1	3	0	1
1273	29	7	6	39	9	6	1	41	2	9	6
1275	29	30	11	20	7	10	0	12	4	10	8
1284	50	41	17	17	18	7	0	6	6	17	5
1285	3	56	5	1	2	3	0	0	4	5	2
1294	34	22	13	15	13	8	0	7	7	12	6
1303	4	63	7	3	3	2	0	10	21	4	5
1319	45	73	8	2	0	1	1	2	5	0	4
1320	4	41	0	2	5	2	0	9	15	16	4
1330	1	4	1	2	0	0	0	1	9	0	4
1331	7	65	2	4	4	1	0	3	23	17	5
1337	48	25	37	24	0	1	2	4	15	0	2
1802	4	87	0	0	17	0	0	3	1	4	2
4334	149	13	8	16	0	8	1	11	3	0	8
4337	35	25	9	13	0	1	2	9	3	0	6
4345	7	76	8	12	0	0	2	8	4	0	1
4348	146	29	3	18	0	1	0	0	10	0	6
4349	88	21	1	9	3	1	0	2	5	0	5
4354	10	38	2	4	25	3	0	4	18	16	2
4358	72	31	0	1	0	0	3	8	17	0	7
4359	0	123	0	0	0	0	16	3	11	0	2
4362	55	95	19	22	1	2	1	4	8	0	5
4363	76	52	5	8	27	7	1	4	9	5	12
4365	7	53	10	4	23	1	0	0	7	11	2
	3608	1806	1466	717	649	441	424	378	287	247	243

sample	Uspcl	CN	Clsp	PaL	HM	AR	Uspb	Isp4	NB	Qsp	AF
815	10	0	0	0	0	20	0	17	0	5	6
830	20	1	0	3	3	3	1	3	0	13	0
1093	0	1	0	16	0	0	3	0	2	1	1
1103	0	0	1	0	0	0	0	0	0	0	0
1113	3	0	1	2	0	2	2	0	2	8	0
1116	2	0	0	0	0	2	0	0	15	0	0
1246	0	0	5	0	0	3	10	0	4	0	0
1247	1	0	8	0	1	4	26	0	2	0	0
1248	3	0	6	0	1	3	12	0	0	0	0
1249	4	0	11	0	2	0	16	0	0	0	0
1254	1	0	23	0	0	0	0	0	10	0	0
1255	0	0	6	0	0	0	0	0	2	2	2
1259	4	0	1	1	0	2	6	2	3	2	0
1270	0	7	10	15	1	1	0	0	8	0	3
1273	0	0	2	0	0	1	11	0	0	9	0
1275	4	0	0	3	0	0	0	6	0	0	1
1284	2	1	0	0	1	0	0	6	0	0	11
1285	3	3	1	1	0	0	1	6	0	0	2
1294	6	1	5	0	5	5	1	8	1	7	1
1303	3	1	0	0	4	4	2	7	0	0	12
1319	2	0	1	13	4	9	0	0	0	4	3
1320	9	0	0	0	11	7	0	10	0	2	21
1330	0	0	2	0	0	3	0	0	0	0	0
1331	2	2	0	0	1	0	0	8	0	0	2
1337	2	0	22	6	1	1	1	0	0	0	1
1802	1	0	0	10	0	6	0	14	0	1	5
4334	0	0	0	0	1	2	0	1	0	6	0
4337	0	0	12	0	0	2	8	0	1	4	0
4345	4	0	4	10	0	4	1	0	8	1	2
4348	1	0	0	11	0	0	0	0	1	0	0
4349	1	0	0	3	0	2	0	1	0	2	2
4354	7	10	0	3	4	0	0	7	0	0	5
4358	3	0	0	12	11	0	0	0	0	0	0
4359	0	0	0	4	0	5	1	0	15	3	0
4362	2	0	0	12	0	5	0	1	0	0	4
4363	2	3	0	0	2	0	0	4	0	0	0
4365	4	23	0	11	2	1	0	10	0	2	14
	206	201	185	174	160	158	154	144	136	134	130

sample	CW	Apsp	Msp	XH	AgR	Uspa	LP	Ausp	Uspc	Agsp	Isp1
815	0	0	0	0	0	1	0	0	1	0	0
830	0	0	10	0	0	2	0	0	0	2	0
1093	0	0	0	0	0	1	0	0	1	0	0
1103	0	1	0	0	0	0	0	0	0	0	0
1113	0	4	0	0	0	1	0	0	2	0	2
1116	0	0	0	0	0	0	5	0	0	0	1
1246	0	3	0	0	0	0	5	1	0	0	0
1247	0	5	0	0	0	0	4	0	0	6	3
1248	0	3	0	0	0	0	4	0	0	0	2
1249	0	3	0	1	0	2	3	0	3	0	0
1254	0	0	0	0	0	1	1	0	0	7	0
1255	0	0	0	0	0	1	0	2	1	0	0
1259	0	1	0	1	0	3	0	0	0	0	2
1270	0	5	3	0	0	0	0	0	0	0	0
1273	0	7	0	0	0	9	0	0	12	0	6
1275	0	5	0	5	0	0	0	0	0	0	0
1284	0	0	0	7	0	4	0	0	4	0	0
1285	0	2	2	0	0	0	0	0	6	0	0
1294	0	9	1	7	0	1	0	1	3	0	0
1303	0	0	3	4	0	3	0	0	1	0	3
1319	0	4	5	0	0	0	0	0	0	0	0
1320	0	0	4	6	0	2	0	0	0	0	0
1330	0	0	0	0	0	2	0	0	0	0	1
1331	0	5	0	1	0	0	5	0	0	0	0
1337	0	1	0	1	0	0	0	0	1	0	0
1802	0	0	10	0	0	0	0	0	0	0	1
4334	0	0	0	0	0	2	0	0	5	0	1
4337	0	0	0	0	0	0	0	0	3	0	1
4345	0	9	4	2	0	0	4	0	2	0	0
4348	0	0	0	0	0	0	0	0	0	0	0
4349	0	12	0	0	0	1	0	2	1	0	0
4354	0	0	0	7	0	0	0	0	4	0	0
4358	0	4	3	0	0	0	0	2	0	3	0
4359	0	2	10	1	0	0	0	6	0	0	0
4362	0	0	3	0	0	0	0	0	0	0	0
4363	0	11	0	3	0	0	0	0	1	0	0
4365	0	0	0	4	0	0	0	0	1	0	0
	119	113	98	69	68	68	65	62	61	52	46

sample	Isp7	PP	Isp3	MB	NO	Isp5	IV	CyC	Pdsp	MM	Prsp
815	0	10	0	0	0	0	0	0	0	0	0
830	0	0	0	0	5	0	0	1	0	0	0
1093	0	0	0	2	0	0	0	0	1	0	0
1103	0	0	0	0	0	0	0	0	0	0	0
1113	0	0	0	1	2	2	0	0	0	0	0
1116	0	0	0	0	0	0	0	0	0	0	0
1246	0	0	0	0	0	0	0	2	1	1	0
1247	8	0	3	3	0	0	0	2	0	0	0
1248	1	0	4	0	0	0	0	3	3	0	0
1249	2	0	16	0	0	0	0	3	1	0	0
1254	0	0	0	0	0	0	0	0	0	0	0
1255	2	0	0	2	0	1	0	0	0	0	0
1259	0	0	0	2	0	0	0	0	0	0	0
1270	0	0	0	0	0	0	0	0	0	0	0
1273	6	0	0	1	0	0	0	0	0	0	0
1275	0	0	0	0	2	0	0	0	0	0	0
1284	1	0	0	0	0	0	0	0	0	0	0
1285	0	0	0	0	1	2	0	0	0	0	0
1294	0	0	0	0	1	1	0	2	0	0	0
1303	0	3	0	3	0	2	0	0	0	0	0
1319	0	0	0	0	0	0	0	0	0	0	0
1320	0	1	0	0	0	4	0	0	1	0	0
1330	0	0	0	0	0	0	0	0	0	0	0
1331	0	0	0	0	0	2	0	0	0	0	0
1337	1	0	0	0	0	0	0	0	0	1	0
1802	0	12	0	0	0	0	0	0	0	0	0
4334	1	0	0	0	0	0	0	0	0	0	0
4337	3	0	0	0	0	0	0	0	0	1	0
4345	0	0	0	0	0	0	0	1	1	0	0
4348	0	0	0	0	2	0	0	0	0	0	0
4349	0	0	0	1	0	3	0	0	1	1	0
4354	0	0	0	1	2	4	0	0	0	0	0
4358	0	0	0	1	2	0	0	0	0	0	5
4359	0	0	0	1	0	0	0	2	0	0	0
4362	0	0	0	0	0	0	0	0	0	0	0
4363	0	0	0	0	0	0	0	0	0	0	0
4365	1	7	0	0	5	1	0	1	0	0	0
	43	35	31	29	29	28	27	26	25	24	22

sample	Uspd	Uspf	CT	SM	CB	BR	Pasp	Osp	Cysp	Fsp	Nesp
815	0	0	0	0	0	0	0	0	0	0	0
830	1	0	0	0	7	0	3	0	2	0	1
1093	0	0	0	0	0	0	0	0	0	0	0
1103	0	0	0	0	0	0	0	0	0	0	0
1113	1	0	0	1	0	0	0	0	0	0	0
1116	0	0	2	0	0	0	0	0	0	0	0
1246	0	0	0	4	0	0	0	0	1	0	0
1247	0	0	0	0	0	0	0	0	0	0	0
1248	0	3	0	0	0	0	0	0	0	0	0
1249	0	4	0	0	0	0	0	0	1	0	0
1254	0	1	0	1	0	0	0	0	0	0	0
1255	0	2	0	0	0	0	0	0	0	0	0
1259	0	0	0	0	0	0	0	0	0	1	0
1270	0	1	0	0	0	0	0	0	0	0	0
1273	0	0	0	1	0	0	0	0	0	0	0
1275	0	0	0	0	0	0	0	0	1	0	0
1284	0	0	0	0	0	0	1	0	1	0	0
1285	0	0	0	0	0	0	0	0	0	0	0
1294	2	0	0	0	0	0	0	0	0	0	0
1303	0	0	0	0	0	0	0	0	0	0	0
1319	0	0	0	0	0	0	3	0	0	0	0
1320	0	0	0	0	0	0	0	0	0	0	0
1330	0	0	0	0	0	0	0	0	0	1	2
1331	0	0	0	0	0	0	0	0	0	0	0
1337	0	0	0	0	0	0	0	0	0	0	0
1802	0	0	0	0	0	0	0	1	0	0	0
4334	0	0	0	0	0	0	0	0	0	0	0
4337	1	0	0	0	0	0	0	0	0	0	0
4345	0	0	0	2	0	0	0	0	0	0	0
4348	0	0	0	0	0	0	0	0	0	0	0
4349	3	0	1	0	0	0	0	0	0	0	0
4354	0	0	0	0	0	0	0	0	0	0	0
4358	0	0	0	0	0	0	0	0	0	0	0
4359	0	0	0	0	0	0	2	0	0	0	0
4362	0	0	0	0	0	0	0	0	0	0	4
4363	0	0	0	0	0	0	0	0	0	0	1
4365	0	0	0	0	0	0	0	0	0	0	1
	21	19	19	16	14	13	13	10	9	9	9

sample	Isp2	Bsp	Uspe	SK	Isp6	Lspb	Lspa	MP	Bqsp	KA	KM
815	0	0	0	0	2	0	0	0	1	0	0
830	0	0	1	0	0	0	0	0	0	0	0
1093	0	0	0	0	0	0	0	0	0	0	0
1103	0	0	0	0	0	0	0	0	0	0	0
1113	0	0	0	0	0	0	0	0	0	0	0
1116	0	0	0	0	0	0	0	0	0	0	0
1246	1	0	0	0	0	0	0	0	0	0	1
1247	0	0	0	0	0	0	0	0	0	0	0
1248	1	0	1	0	0	0	0	0	0	0	0
1249	0	0	0	0	0	1	1	0	0	0	0
1254	1	0	0	4	0	0	0	0	0	0	0
1255	1	0	0	0	0	0	0	0	0	0	1
1259	1	0	0	0	0	0	0	0	0	0	0
1270	0	0	0	0	0	0	0	0	0	0	0
1273	0	0	0	0	0	0	0	0	0	0	0
1275	0	0	0	0	0	0	0	0	0	0	0
1284	0	0	2	0	0	0	0	0	0	0	0
1285	0	0	0	0	0	0	0	0	0	0	0
1294	0	0	0	0	0	0	0	0	0	0	0
1303	0	0	2	0	0	0	1	0	0	0	0
1319	0	1	0	0	0	0	0	0	0	0	0
1320	1	0	0	0	0	0	0	0	0	0	0
1330	0	0	0	0	0	0	0	0	0	0	0
1331	0	0	0	0	0	0	0	0	0	0	0
1337	0	0	0	0	0	0	0	0	0	0	0
1802	0	0	0	0	0	0	0	0	1	0	0
4334	0	0	1	0	0	0	0	0	0	0	0
4337	0	0	0	0	0	0	0	0	0	0	0
4345	0	0	0	0	0	0	0	0	0	0	0
4348	0	0	0	0	0	0	0	0	0	0	0
4349	0	0	0	0	0	0	0	0	0	0	0
4354	1	0	0	0	0	0	0	0	0	0	0
4358	0	0	0	0	0	0	0	0	0	0	0
4359	0	1	0	0	0	2	1	0	0	0	0
4362	0	0	0	0	0	0	0	0	0	0	0
4363	0	0	0	0	0	0	0	0	0	0	0
4365	0	0	0	0	0	0	0	0	3	0	0
	9	8	7	6	6	5	5	5	5	4	4

APPENDIX 3

The averages, ranges and correlation coefficients of each of the 50 MAS with respect to each environmental variable.

Species	Stat	Depth	% Sand	Oxygen	Temp	Salin
PL	Ave	96.7	73.3	4.24	11.75	35.00
	Range	153	92.6	1.83	6.28	0.55
	CC	0.004	0.306	0.124	0.005	0.010
BS	Ave	91.9	82.5	4.33	11.82	35.01
	Range	170	90.4	1.83	6.28	0.55
	CC	0.061	0.225	0.001	0.020	0.001
CD	Ave	87.7	78.9	4.34	12.08	35.03
	Range	170	89.4	1.83	6.28	0.41
	CC	0.271	0.114	0.060	0.384	0.302
DE	Ave	92.1	82.4	4.34	11.88	35.02
	Range	153	90.2	1.83	6.28	0.43
	CC	0.000	0.021	0.060	0.015	0.039
RC	Ave	117.7	82.3	4.15	10.61	34.93
	Range	129	85.4	1.41	2.95	0.34
	CC	0.178	0.188	0.097	0.265	0.462
CC	Ave	99.9	71.9	4.18	11.62	35.00
	Range	115	92.6	1.83	6.17	0.52
	CC	0.053	0.154	0.188	0.024	0.022
GK	Ave	72.0	74.5	4.48	12.75	35.06
	Range	80	88.9	1.54	6.28	0.36
	CC	0.175	0.083	0.105	0.070	0.058
UA	Ave	85.7	81.5	4.39	12.00	35.02
	Range	80	90.2	1.56	6.28	0.36
	CC	0.007	0.031	0.005	0.011	0.027
AK	Ave	96.5	85.2	4.31	11.56	35.00
	Range	153	86.2	1.83	6.11	0.38
	CC	0.013	0.073	0.000	0.058	0.041
XA	Ave	99.6	82.2	4.27	11.59	34.99
	Range	104	91.8	1.82	5.51	0.55
	CC	0.086	0.003	0.064	0.078	0.064

Species	Stat	Depth	% Sand	Oxygen	Temp	Salin
AmF	Ave	90.4	82.5	4.36	11.91	35.02
	Range	153	90.4	1.83	6.28	0.43
	CC	0.022	0.045	0.003	0.009	0.004
Uspc1	Ave	98.2	78.5	4.26	11.64	35.01
	Range	153	89.4	1.82	6.28	0.43
	CC	0.012	0.004	0.075	0.029	0.057
CN	Ave	109.9	75.3	4.16	11.19	34.96
	Range	101	89.9	1.44	5.14	0.51
	CC	0.006	0.050	0.082	0.068	0.000
Clsp	Ave	73.1	74.6	4.41	12.54	35.05
	Range	86	89.4	1.80	6.28	0.36
	CC	0.124	0.023	0.156	0.000	0.011
PaL	Ave	88.7	82.8	4.37	11.91	35.02
	Range	74	58.9	1.23	6.11	0.31
	CC	0.028	0.000	0.170	0.050	0.009
HM	Ave	102.0	74.9	4.25	11.42	34.99
	Range	106	84.6	1.42	6.07	0.52
	CC	0.048	0.001	0.002	0.033	0.145
AR	Ave	92.2	86.8	4.34	11.79	35.01
	Range	153	72.8	1.83	6.17	0.38
	CC	0.009	0.063	0.004	0.026	0.029
Uspb	Ave	82.7	79.9	4.33	12.30	35.05
	Range	80	89.4	1.56	6.17	0.32
	CC	0.151	0.554	0.000	0.235	0.224
Isp4	Ave	118.5	89.7	4.25	10.86	34.96
	Range	109	60.1	1.62	4.11	0.27
	CC	0.333	0.201	0.087	0.180	0.044
NB	Ave	78.4	79.5	4.44	12.34	35.03
	Range	109	72.3	1.56	5.51	0.55
	CC	0.091	0.001	0.021	0.000	0.004

Species	Stat	Depth	% Sand	Oxygen	Temp	Salin
Qsp	Ave	94.5	87.9	4.39	11.93	35.01
	Range	170	66.4	1.83	5.02	0.34
	CC	0.001	0.040	0.000	0.071	0.177
AF	Ave	102.3	90.7	4.38	11.26	34.97
	Range	153	33.5	0.70	6.11	0.48
	CC	0.079	0.075	0.011	0.038	0.001
CW	Ave	137.0	41.9	3.68	10.12	34.86
	Range	70	83.4	0.78	2.27	0.33
	CC	0.261	0.567	0.020	0.003	0.023
Apsp	Ave	82.9	77.6	4.39	12.26	35.04
	Range	71	89.4	1.31	6.28	0.36
	CC	0.080	0.000	0.009	0.009	0.025
Msp	Ave	96.7	88.5	4.34	11.91	35.02
	Range	115	53	1.59	5.02	0.30
	CC	0.002	0.037	0.009	0.063	0.004
XH	Ave	100.7	90.8	4.26	11.19	34.99
	Range	115	51.1	1.52	6.11	0.29
	CC	0.479	0.214	0.026	0.058	0.053
AgR	Ave	30.0	43.6	4.9	13.41	35.06
	Range	0	0	0	0	0
	CC					
Uspa	Ave	93.9	85.8	4.31	11.70	35.00
	Range	148	90.2	1.55	4.98	0.37
	CC	0.082	0.000	0.002	0.000	0.021
LP	Ave	75.9	72.5	4.32	12.82	35.08
	Range	71	89.4	1.42	5.32	0.33
	CC	0.000	0.028	0.000	0.002	0.092
Ausp	Ave	72.7	73.3	4.47	12.86	35.06
	Range	78	63.1	0.94	4.6	0.35
	CC	0.091	0.004	0.088	0.223	0.088

Species	Stat	Depth	% Sand	Oxygen	Temp	Salin
Uspc	Ave	102.6	90.7	4.37	11.37	34.97
	Range	153	31.1	1.83	6.11	0.34
	CC	0.000	0.058	0.000	0.005	0.004
Agsp	Ave	72.4	51.8	4.25	13.15	35.10
	Range	81	81.7	1.79	3.43	0.25
	CC	0.114	0.118	0.013	0.287	0.100
Isp1	Ave	88.2	78.9	4.34	11.85	35.02
	Range	75	72.8	1.56	4.98	0.32
	CC	0.000	0.012	0.039	0.105	0.159
Isp7	Ave	79.6	78.4	4.51	12.48	35.06
	Range	62	74.0	1.54	6.28	0.35
	CC	0.047	0.005	0.009	0.032	0.116
PP	Ave	139.2	95.5	4.31	10.26	34.93
	Range	90	5.5	1.41	0.96	0.15
	CC	0.077	0.23	0.049	0.637	0.111
Isp3	Ave	68.8	61.1	4.43	13.56	34.14
	Range	49	68.9	0.74	3.76	0.24
	CC	0.016	0.273	0.056	0.202	0.021
MB	Ave	84.9	82.2	4.32	11.95	35.00
	Range	97	74.2	1.35	4.88	0.33
	CC	0.006	0.029	0.003	0.000	0.001
NO	Ave	99.4	92.6	4.34	11.80	35.00
	Range	59	20.4	1.35	4.49	0.21
	CC	0.281	0.060	0.271	0.025	0.066
Isp5	Ave	109.0	92.4	4.33	10.69	34.94
	Range	57	31.1	1.37	2.11	0.01
	CC	0.195	0.007	0.351	0.005	0.047
CyC	Ave	112.4	36.0	3.83	11.13	34.97
	Range	81	87.5	1.09	4.83	0.38
	CC	0.128	0.047	0.042	0.000	0.006

Species	Stat	Depth	% Sand	Oxygen	Temp	Salin
Pdsp	Ave	78.3	81.9	4.42	12.99	35.09
	Range	63	58.9	0.97	4.54	0.31
	CC	0.000	0.119	0.056	0.005	0.123
MM	Ave	70.5	72.2	4.47	12.65	35.07
	Range	78	62.7	1.40	6.28	0.36
	CC	0.060	0.243	0.102	0.042	0.027
Prsp	Ave	78.0	53.7	4.09	13.19	35.11
	Range	25	61.7	0.86	3.06	0.19
	CC	0.585	0.51	0.001	0.803	0.687
Udsp	Ave	88.0	89.6	4.37	11.98	35.03
	Range	56	30.7	1.47	3.46	0.18
	CC	0.279	0.000	0.001	0.145	0.224
Uspf	Ave	71.0	86.5	4.55	12.88	35.05
	Range	28	35.5	1.02	3.86	0.31
	CC	0.054	0.18	0.199	0.058	0.001
CT	Ave	90.8	64.1	4.11	11.23	34.98
	Range	37	71.1	0.43	1.18	0.13
	CC	0.070	0.901	0.268	0.128	0.216
SM	Ave	68.4	81.1	4.59	12.64	35.04
	Range	74	53.3	0.97	4.10	0.32
	CC	0.468	0.638	0.020	0.350	0.334
CB	Ave	130.0	59.8	3.74	10.67	34.9
	Range	29	77.7	0.61	2.62	0.34
	CC	0.418	0.997	0.348	0.096	0.022
BR	Ave	151.0	34.4	3.84	9.94	34.82
	Range	22	61.0	0.61	0.93	0.26
	CC	0.280	0.026	0.288	0.099	0.155
Pasp	Ave	84.4	77.9	4.22	12.23	35.06
	Range	57	89.0	1.16	3.63	0.19
	CC	0.011	0.002	0.002	0.099	0.002

Appendix 4

Varimax Factor Score Matrix

Spec	FA 1	FA 2	FA 3	FA 4	FA 5	FA 6	FA 7
PL	0.014	0.013	0.283	0.027	0.44	0.053	0.841
BS	0.004	0.004	0.042	0.056	0.044	0.019	0.015
CD	0.993	-0.039	0.006	0.032	-0.078	0.047	0.02
DE	-0.026	-0.017	0.02	0.683	0.135	-0.02	-0.132
RC	0.004	0.021	-0.007	0.052	0.044	0	0.002
CC	0.047	0.939	-0.17	-0.089	0.021	-0.2	0.024
GN	0.003	0.007	0.189	-0.012	-0.024	0.006	-0.074
UA	0.007	0.012	0.018	-0.013	0.007	-0.005	-0.009
AK	-0.005	0.202	0.901	0.003	-0.096	-0.02	-0.226
XA	-0.02	-0.035	0.002	0.236	0.076	0.075	-0.098
AmF	-0.008	-0.002	-0.011	0.102	0.035	0.041	-0.002
Uc	-0.048	0.225	-0.087	0.087	-0.06	0.918	0.028
CN	0.014	0.011	-0.004	0.003	-0.008	0.005	0.003
Clsp	0.009	0.022	0.007	0.001	-0.007	0.01	0.005
PaL	0.08	0.023	-0.072	-0.04	0.851	-0.026	-0.385
HM	0.006	0.016	-0.005	0.009	-0.003	0.012	0.004
AR	0.006	0.024	0.003	0.009	0.025	0.024	-0.013
Ub	0.032	0.062	0.067	0.019	0.102	0.219	-0.129
Isp4	0.004	0.001	0.009	0.004	0.006	0.005	-0.008
NB	0.005	-0.002	0.037	0.001	0.012	0.002	0
Qsp	0.001	0.125	-0.055	0.665	-0.134	-0.176	0.118
AF	0.008	0	-0.003	-0.002	0.026	-0.008	0.005
CW	0.013	0.004	-0.005	0	0.014	-0.008	0.012
Apsp	0.018	-0.021	0.138	0.013	0.056	0.153	-0.168

Appendix 5

Varimax Factor Components Matrix

Site	comm	FA1	FA2	FA3	FA4	FA5	FA6	FA7
348	0.914	0.006	0.156	0.899	0.016	0.159	0.027	0.236
398	0.929	0.008	0.209	0.938	0.009	0.057	0.034	-0.012
399	0.954	0.065	0.062	0.305	-0.005	0.888	0.015	0.252
400	0.981	0.865	-0.003	0.020	0.468	0.108	-0.006	0.020
403	0.936	0.447	0.215	-0.080	0.096	-0.087	0.816	0.032
404	0.997	0.993	-0.039	0.006	0.032	-0.078	0.047	0.020
405	0.964	0.004	0.193	0.954	0.017	0.089	0.024	0.091
406	0.986	0.014	0.013	0.284	0.029	0.441	0.053	0.841
407	0.971	0.001	0.191	0.960	0.012	0.070	0.003	0.085
497	0.751	0.061	0.183	-0.002	0.649	0.237	0.474	-0.108
499	0.990	0.051	0.111	0.701	0.030	0.330	0.039	0.611
500	0.946	0.294	0.255	0.437	0.092	0.265	0.538	0.485
505	0.247	0.170	0.026	0.374	0.017	0.041	0.147	-0.232
512	0.943	0.001	0.191	0.941	0.015	0.085	0.003	0.120
513	0.948	0.232	0.041	0.274	0.172	0.838	0.023	0.292
517	0.998	0.995	-0.013	0.003	0.031	-0.068	0.047	0.014
519	0.995	0.987	0.112	0.074	0.018	-0.004	0.022	-0.033
522	0.900	0.000	0.051	0.170	0.788	0.425	-0.049	0.255
523	0.464	0.033	0.378	0.163	0.221	0.283	0.354	0.198
526	0.995	0.992	-0.037	0.005	0.033	-0.078	0.048	0.020
532	0.993	0.994	0.019	0.003	0.042	-0.015	0.058	-0.011
537	0.987	0.036	0.976	0.179	-0.011	0.003	-0.037	0.007
541	0.925	0.392	0.422	0.091	0.071	-0.091	0.756	0.006
547	0.912	0.436	0.488	0.213	0.103	0.053	0.651	0.037
553	0.965	0.171	0.676	0.569	0.011	-0.035	0.380	-0.092
561	0.968	0.975	0.041	0.033	0.040	0.053	0.081	-0.060
565	0.990	0.086	0.347	0.112	0.148	0.266	0.625	0.605
566	0.989	0.036	0.986	-0.025	0.017	0.039	0.055	0.095
568	0.822	0.310	0.708	0.401	0.086	0.142	0.079	-0.172
571	0.970	0.157	0.720	-0.064	0.369	0.102	0.379	0.363

Site	comm	FA1	FA2	FA3	FA4	FA5	FA6	FA7
574	0.984	0.148	0.948	0.186	0.001	0.049	0.163	0.000
583	0.988	0.013	0.090	0.566	0.074	0.389	0.052	0.707
681	0.962	0.016	0.777	-0.084	0.566	0.046	0.116	0.125
684	0.990	0.506	0.030	-0.014	0.853	-0.009	-0.065	-0.029
799	0.995	0.980	0.014	0.160	0.038	0.006	0.051	-0.061
801	0.982	0.080	0.980	0.085	-0.023	0.023	-0.077	0.047
815	0.972	0.916	0.360	-0.042	0.011	-0.027	-0.004	0.031
830	0.967	0.883	0.308	0.173	0.005	0.193	0.082	-0.138
1093	0.981	0.719	0.670	0.106	-0.004	0.061	-0.015	0.013
1103	0.967	0.107	0.016	0.026	0.286	0.923	0.001	-0.144
1113	0.992	0.440	0.850	0.216	0.016	0.104	0.112	0.066
1116	0.968	0.099	0.235	0.143	0.027	0.845	0.014	0.409
1246	0.889	-0.034	0.459	0.088	0.718	0.045	0.376	-0.100
1247	0.984	0.009	0.697	0.400	0.565	-0.004	-0.076	-0.112
1248	0.991	0.009	0.840	0.255	0.351	0.059	0.291	0.095
1249	0.978	0.069	0.872	0.155	0.420	0.048	0.040	0.095
1254	0.768	0.036	0.258	-0.065	0.830	0.022	0.032	0.072
1255	0.972	0.037	0.668	-0.072	0.482	0.495	0.150	0.138
1259	0.981	0.357	0.850	0.235	0.020	-0.008	0.271	-0.026
1270	0.997	0.918	0.357	-0.069	0.109	-0.078	-0.047	0.041
1273	0.959	0.131	0.814	-0.078	0.032	0.105	0.510	-0.002
1275	0.989	0.760	0.560	0.130	0.019	0.167	0.218	-0.074
1284	0.990	0.873	0.366	0.080	0.021	0.274	0.089	-0.068
1285	0.998	0.995	-0.002	0.050	0.047	0.001	0.049	-0.028
1294	0.976	0.716	0.541	0.165	0.122	0.295	0.164	-0.122
1303	0.997	0.975	0.054	0.022	0.048	-0.022	0.199	-0.019
1319	0.997	0.990	0.001	0.036	0.053	-0.046	0.083	0.056
1320	0.970	0.893	0.073	0.044	0.035	0.240	0.276	-0.173
1330	0.931	0.790	0.437	-0.096	0.285	-0.108	0.069	0.092
1331	0.994	0.979	0.040	-0.005	0.023	0.145	0.077	-0.077

Site	comm	FA1	FA2	FA3	FA4	FA5	FA6	FA7
1337	0.950	0.619	0.612	-0.070	0.393	-0.043	-0.075	0.159
1802	0.997	0.994	-0.028	0.005	0.034	-0.038	0.081	0.004
4334	0.977	0.461	0.654	0.277	0.039	0.162	0.285	0.389
4337	0.962	0.779	0.466	-0.049	0.290	-0.070	0.152	0.155
4345	0.999	0.977	0.142	-0.027	0.071	-0.074	0.112	0.032
4348	0.978	0.803	0.438	0.056	-0.001	0.126	-0.034	0.348
4349	0.982	0.863	0.346	0.079	0.016	0.097	0.073	0.311
4354	0.988	0.922	0.109	0.060	0.023	0.270	0.152	-0.161
4358	0.925	0.887	0.045	0.088	0.065	0.037	0.326	0.131
4359	0.996	0.991	-0.033	0.003	0.039	-0.078	0.070	0.019
4362	0.993	0.974	0.190	-0.001	0.031	-0.044	0.044	0.063
4363	0.996	0.967	0.151	0.142	0.035	0.057	0.101	0.061
4365	0.997	0.986	0.044	0.018	0.032	0.114	0.048	-0.072
Variance		40.083	20.445	9.813	7.010	6.683	5.766	4.965
Cum Variance		40.083	60.528	70.341	77.351	84.034	89.800	94.765

Appendix 6

Regression Equations

DEPTH	MCC	0.73
	SEE	25.131
	FA 4	-584.9488
	FA 6	58.2145
	INTERCEPT	121.7301
SAND	MCC	0.865
	SEE	15.36
	FA 3	-55.85618
	FA 4	-49.07865
	FA 7	-91.92579
	INTERCEPT	96.27396
OXYGEN	MCC	0.772
	SEE	0.346
	FA 3	-2.79763
	FA 4	0.17148
	FA 6	-3.42849
	FA 5	-6.62036
	FA 2	-2.9545
	FA 1	-2.5945
	FA 7	1.6937
	INTERCEPT	6.87607
TEMP	MCC	0.699
	SEE	1.287
	FA 4	9.71164
SALIN	MCC	0.778
	SEE	0.086
	FA 4	1.14186
	FA 3	-1.17539
	FA 5	-0.18778
	FA 7	-0.10479
	INTERCEPT	34.96395