Foraminifera of Leschenault Inlet

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Abstract

The foraminiferal fauna of the shallow estuarine Leschenault Inlet lagoon is very unusual. The diversity is extremely high and exceeds that encountered in the most diverse normal marine environments. Virtually all specimens recovered are devoid of protoplasm. The diversity decreases from south to north as environmental conditions change from stable normal marine to more extreme conditions.

Keywords: Leschenault Inlet, south-western Australia, estuary, foraminifera, diversity.

Introduction

The Leschenault Inlet is a shallow estuarine lagoon, separated from the Indian Ocean by the Leschenault Peninsula. The peninsula is a retrograded barrier dune system, which continues to encroach into and prograde over the estuarine environment. Semeniuk studied the physiography, sedimentology and stratigraphy of the Leschenault Inlet in a series of papers (Semeniuk 1983, 1985; Semeniuk & Meagher 1981; Wurm & Semeniuk 2000). About 40 years ago, major human intervention changed the southern part of the inlet considerably. The original outlet to the ocean was filled in, a new outlet dug out more to the north, the Preston River redirected, and an artificial canal dug.

The inlet is an elongate body of water, stretching from south to north over some 13 km, 1.5-2.5 km wide, and with a maximum depth of about 2.5 m. Contact and exchange of water with the Indian Ocean is through "The Cut", a 70 m wide and about 5 m deep channel. The Collie and Preston Rivers discharge fresh water into the southern-most part of the Inlet, while its northern-most part receives fresh water from surface run-off through the Parkfield drain. The tidal regime in the inlet is diurnal and microtidal (0.5 m on average, with a maximum range of 0.9 m), and weather conditions exert a greater influence on water levels. The inlet lies in a temperate climatic zone, with mild wet winters and hot dry summers. The average rainfall for the region is 880 mm per annum, mainly falling between April and August. Mean temperatures lie between 8 °C in winter and 28 °C in summer. Evaporation amounts to some 1980 mm per annum. In summer, winds are land breezes from the east and sea breezes from the west. In winter, winds are mainly mild easterlies, with occasional storms.

The temperature regime of the water body itself and of the sediment surface differs significantly from the land- and air-based regime. The base of the water column experiences temperatures between 10.5 °C and 33 °C. Especially the shallow and intertidal areas covered with fine, dark mud experience substantial heating effects of the sun. The water is highly oxygenated, through a combination of the shallow water column, the stirring effect of the wind and the presence of the seagrass *Halophila ovalis*. The salinity regime changes from stable, marine conditions close to "The Cut" to seasonally fluctuating conditions ranging from almost fresh water to hypersaline in the northern-most part of the inlet. On the western side of the inlet, small scale fresh water seepages result from complex interfingering of estuarine muds with sands from blown out parabolic dunes (Cresswell 2000). The sediment in the shallower peripheral parts of the inlet are sandy muds to muddy sands on the western side, and largely sands on the eastern side. The sediment in the central part of the inlet is mud.

This preliminary study documents the diversity and richness of Foraminifera found in sediments of the inlet. In the absence of any critically documented faunal studies of Foraminifera in the region, the observations cannot be put in a regional context.

Material & Methods

Sediment samples were collected on 9 May, 1999 in the Inlet at the locations shown in Fig 1. The samples are 10 cm diameter core and samples were immediately frozen upon collection. Subsequently, half of the upper 2 cm of each core was thawed (a volume of about 80 mL), washed on a 63 micron sieve and stained with Sudan Black to detect Foraminifera alive at the time of collection (Walker *et al.* 1974). Three samples came from the barrier dunes.

Foraminifera were randomly picked from the residues, mounted on faunal slides and all identified. Abundances are given in Table 1, and summaries of abundances and diversity indices are given in Table 2.

The diversity indices used are Fisher's alpha, Brillouin's H and Simpson-Yule's C. Fisher's alpha is a measure of species richness, Brillouin's H is the equivalent of the Shannon-Weaver Entropy Measure for finite populations, and Simpson's C is a measure of heterogeneity of distribution (Pielou 1977).

Ternary plots of the procentual contribution of taxa with agglutinated, porcellaneous and hyaline calcium carbonate became popular after the work of Murray (1973, 1991). Plots of this nature are shown in Fig 1 to compare and contrast the results obtained from the Foraminifera of Leschenault Inlet with those found in the literature.

Identifications

The taxonomic framework of foraminiferal classification is an increasingly fragile edifice. The scarcity of

Table 1. Abundances of foraminifera from Leschenault Inlet estuary. Sampling sites from Wurm & Semeniuk (2000). Numbers to the numbers of individuals recovered from samples. Numbers may be used as measure of relative abundance.

					Sites				
Taxon	**A4**	**B9**	**B11**	**B13**	**C16**	**C17**	**C18**	**D22**	**Total**
Ammobaculites sp	0	0	11	0	1	0	0	0	12
Ammobaculites villosus	0	0	4	0	0	0	0	0	4
Haplophragmoides sp	0	0	35	1	1	0	0	1	38
Iridia?	0	0	0	0	0	0	1	0	1
Lagenammina sp	1	0	0	0	0	0	0	0	1
Leptohalysis catena	0	0	0	1	0	0	0	0	1
Miliammina fusca	0	0	0	0	1	0	0	0	1
Nouria?	0	0	0	0	0	0	0	2	2
Paratrochammina simplissima	0	2	0	0	0	0	0	0	2
Portatrochammina sp	0	0	0	0	0	3	0	0	3
Prolixoplecta pseudofiliformis	0	1	0	0	0	0	0	0	1
Reophax sp.	0	0	3	1	0	0	0	0	4
Repmanina charoides	0	0	0	2	0	0	0	0	2
Textularia earlandi	0	0	2	0	0	1	0	0	3
Textularia lancea	0	0	1	0	0	0	0	0	1
Trochammina challengeri	0	1	63	51	0	4	18	0	137
Trochammina ochracea	2	0	0	0	0	0	0	0	2
Trochammina sp	2	0	0	0	0	0	0	0	2
Valvulina oviedoiana	0	0	2	0	0	0	0	0	2
Cornuspira involvens	2	0	0	0	0	0	0	0	2
Cornuspira planorbis	2	1	1	0	1	1	1	0	7
Dendritina striata	1	0	0	0	0	0	0	0	1
Miliolinella labiosa	0	0	0	0	0	0	0	1	1
Miliolinella subrotundata	8	0	0	0	0	0	0	0	8
Pseudolachlanella slitella	1	4	3	0	0	0	0	0	8
Quinqueloculina bicornis	0	0	0	0	8	2	0	0	10
Quinqueloculina crassicarinata	1	0	0	0	0	0	0	0	1
Quinqueloculina cuvieriana	0	0	0	2	0	0	0	0	2
Quinqueloculina eamesii	0	4	4	0	0	0	0	0	8
Quinqueloculina incisa	2	0	0	2	1	0	0	0	5
Quinqueloculina laevigata	8	0	0	0	0	22	0	0	30
Quinqueloculina patagonica	4	14	0	6	5	4	1	0	34
Quinqueloculina seminula	3	0	0	0	0	0	2	0	5
Quinqueloculina sp 1	0	2	1	2	0	0	5	0	10
Quinqueloculina sp nov	0	3	0	2	0	0	0	0	5
Quinqueloculina tenagos	0	0	0	0	1	0	0	0	1
Quinqueloculina tropicalis	1	0	0	0	0	0	0	0	1
Quinqueloculina tubicola	1	0	0	0	0	0	0	0	1
Quinqueloculina undulata	0	0	0	2	0	0	0	0	2
Sigmamiliolinella australis	4	0	0	0	0	0	0	0	4
Spiroloculina angulosa	0	3	7	2	0	0	10	0	22
Spiroloculina communis	0	0	2	1	0	0	0	0	3
Spiroloculina excisa	0	0	4	0	0	0	0	0	4
Spirophthalmidium sp	2	0	0	0	0	0	0	0	2
Triloculina australis	0	0	0	0	0	0	1	0	1
Triloculina littoralis	5	0	8	0	0	35	0	0	48
Triloculina quadrata	2	0	0	0	0	0	0	0	2
Triloculinella parisa	3	0	0	0	0	0	0	0	3
Wiesnerella auriculata	1	0	0	0	0	0	0	0	1
Conicospirillinoides inaequalis	4	0	0	0	0	0	0	0	4
Mychostomina revertens	4	0	0	0	0	0	0	0	4
Fissurina carinata	1	0	0	0	0	0	0	0	1
Fissurina lucida	2	3	1	3	0	3	1	0	13
Fissurina sp	1	1	0	0	0	0	0	0	2
Lamarckella?	0	0	2	0	0	0	0	0	2
Globigerina sp	1	0	0	0	0	0	0	0	1
Globigerinella calida	0	0	0	1	0	0	0	0	1
Abditodentrix rhomboidalis	5	0	0	0	0	0	0	0	5
Bolivina brittanica	0	0	0	0	0	1	1	0	2

Table 1 (continued). Abundances of foraminifera from Leschenault Inlet estuary. Sampling sites from Wurm & Semeniuk (2000). Numbers to the numbers of individuals recovered from samples. Numbers may be used as measure of relative abundance.

					Sites				
Taxon	**A4**	**B9**	**B11**	**B13**	**C16**	**C17**	**C18**	**D22**	**Total**
Bolivina compacta	2	0	0	0	0	0	0	0	2
Bolivina glutinata	2	1	1	2	0	0	0	0	6
Bolivina pseudoplicata	15	0	0	1	0	0	0	0	16
Bolivina striatula	7	2	7	4	0	9	0	0	29
Bolivina subreticulata	1	0	0	0	0	0	0	0	1
Bolivinella sp	1	0	0	0	0	0	0	0	1
Buliminella elegantissima	0	0	0	0	0	1	0	0	1
Cheilochanus minutus	2	0	0	0	0	0	0	0	2
Elongobula parallela	0	0	1	0	0	0	0	0	1
Globocassidulina bisecta	3	0	0	0	0	0	0	0	3
Loxostomina costatapertusa	0	0	1	0	0	0	0	0	1
Reussella aequa	0	0	0	1	0	0	0	0	1
Sagrina sp	1	2	0	0	0	0	0	0	3
Sigmavirgulina tortuosa	3	0	0	0	0	0	0	0	3
Trifarina sp	2	0	0	0	0	0	0	0	2
Ammonia tepida	32	10	75	99	8	70	76	84	454
Angulodiscorbis quadrangularis	1	0	0	0	0	0	0	0	1
Anomalinoides	5	0	0	0	0	0	0	0	5
Bronnimannia	14	0	0	0	0	0	0	0	14
Cancris carinatus	1	0	0	0	0	0	0	0	1
Challengerella bradyi	2	0	0	0	0	0	1	0	3
Cibicides mahabeti	1	0	0	0	0	1	0	0	2
Cibicides refulgens	3	0	0	0	0	0	0	0	3
Colonimilesia	2	0	0	0	0	0	0	0	2
Cymbaloporetta bradyi	1	1	0	1	0	0	0	0	3
Discorbina sp	6	0	0	0	0	0	0	0	6
Discorbinella sp 1	5	0	0	0	0	0	0	0	5
Discorbinella sp 2	2	0	0	0	0	0	0	0	2
Elphidium aculeatum	1	0	0	0	0	0	0	0	1
Elphidium advenum	7	3	0	0	0	0	0	0	10
Elphidium clavatum	11	0	7	12	2	0	8	17	57
Elphidium crispum	0	0	0	21	0	0	2	0	23
Elphidium excavatum	0	0	1	0	0	0	0	0	1
Elphidium fichtelianum	5	0	0	0	0	0	0	0	5
Elphidium jenseni	12	4	0	0	6	11	2	0	35
Elphidium lene	2	0	0	0	0	0	0	0	2
Elphidium limbatum	12	0	0	0	0	2	0	0	14
Elphidium reticulosum	0	0	0	4	0	0	11	18	33
Elphidium sp 1	10	0	2	0	1	1	0	0	14
Elphidium striatopunctatum	0	0	1	0	0	0	0	0	1
Gavelinopsis sp.	2	3	1	0	0	0	0	0	6
Glabratella sp 1	1	1	3	0	0	0	0	0	5
Glabratella sp 2	1	0	0	0	0	0	0	0	1
Glabratella sp 3	1	0	0	0	0	0	0	0	1
Milesia sp	4	0	0	0	0	0	0	0	4
Neoglabratella sp.	2	0	0	0	0	0	0	0	2
Neorotalia stellata	14	0	4	14	0	0	2	0	34
Nonion pauperatum	1	0	0	0	0	0	0	0	1
Nonion subturgidum	1	0	0	0	0	0	0	0	1
Nonionellina labradorica	0	0	1	0	0	0	0	0	1
Orbitina carinata	0	0	0	1	0	0	0	0	1
Parrellina hispidula	7	0	5	9	0	12	24	9	66
Patellina corrugata	1	0	0	0	0	0	0	0	1
Planorbulina acervalis	1	0	0	0	0	0	0	0	1
Porosononion sp 1	5	1	5	1	0	3	18	2	35
Porosononion sp 2	0	0	8	3	0	0	0	0	11
Pseudoeponides?	0	0	0	1	0	0	0	0	1
Rosalina bulloides	4	1	0	1	0	0	0	0	6
Rosalina pellucida	0	0	0	0	0	1	0	0	1
Svratkina australis	0	0	0	1	0	0	0	0	1

Table 2. Foraminiferal abundance, diversity indices, and percentage of wall structure groups at the various sampling sites.

	Sites								
	A4	**B9**	**B11**	**B13**	**C16**	**C17**	**C18**	**D22**	**Total**
No. of specimens	293	68	277	255	36	187	185	134	1435
No. of species	74	23	34	32	12	20	19	8	118
Fisher's Alpha	31.87	12.22	10.18	9.67	6.31	5.67	5.31	1.86	30.47
Brillouin's H	3.48	2.36	2.33	2.06	1.73	1.93	1.89	1.12	3.09
Simpson's C	0.03	0.08	0.15	0.20	0.13	0.20	0.21	0.43	0.12
Agglutinated	1.71%	5.88%	43.68%	21.96%	8.33%	4.28%	10.27%	2.24%	15.26%
Porcellaneous	17.41%	45.59%	10.83%	7.45%	44.44%	34.22%	10.81%	0.75%	16.17%
Hyaline	80.89%	48.53%	45.49%	70.59%	47.22%	61.50%	78.92%	97.01%	68.57%

monographic and revisional studies in general poses serious problems for routine identifications. The absence of critically documented faunal studies for the region does not alleviate the problem for the present study.

Therefore, I have reluctantly taken the more prudent approach of resorting to the use of open nomenclature. This allows the assessment of diversity and the changes in diversity within the Inlet, but it remains unsatisfactory because it does not allow comparisons with faunas elsewhere.

A number of taxa appear to be new to science. These are not included in the overall analysis and the diversities calculated are therefore somewhat lower than the actual diversity in the inlet.

Results

Foraminifera are quite rare in the dune samples, and most of them are altered. Abrasion and etching are common, and some specimens are infilled and iron-stained. Specimens washed into the sediments of the estuary are easily recognisable as allochtonous, but these are quantitatively insignificant.

The foraminiferal species spectrum of the dune sands is very different from that of the estuarine sediments. Apart from the obvious effects of winnowing and sorting, the source of foraminiferal specimens in the dune sands is the Indian Ocean.

Out of a total of 1435 specimens, only 6 were living at the time of collection. The number of species identified amounts to 118 for the estuary as a whole. Table 1 lists all the taxa and their abundance in each sample. Table 2 provides a summary by listing abundance, diversity indices and percentage of the wall structure groups. The dominant species is *Ammonia tepida*, followed by *Paratrochammina challengeri* and *Parrellina hispidula*.

Planktonic taxa are absent from the inlet. The two specimens belonging to the globigerinids have been washed in from the Indian Ocean. With the exception of a single specimen of *Planorbulina acervalis*, encrusting forms are absent as well. Examination of *Halophila ovalis* leaves revealed no epibionts except for a dense cover of diatoms. Foraminifera typically associated with the more marginal environments, such as *Ammotium salsum, Jadammina macrescens, Miliammina fusca* are essentially absent. Some of the samples yielded a number of juveniles, mainly, but not exclusively, of *Ammonia tepida*.

Discussion

The high foraminiferal diversity is unexpected and anomalous. In his compilation, Murray (1991) summarised the diversity observed in modern environments. The most diverse environments listed are Upper and Lower Slope, with a Fisher alpha index between 1 and 22 and a Shannon-Weaver H index between 0.75 and 4.1. Lagoons harbour species numbers yielding Fisher alpha indices between less than 1 to a maximum of 12. Table 2 lists, for the inlet as a whole, a Fisher alpha index of 30.37 and a Brillouin H index of 3.1. Closer inspection reveals that these numbers are due mainly to sample A4. Omitting this sample and recalculating the overall diversity yields a Fisher alpha index of 16.46, which is still very high and certainly exceeds that expected for a marine lagoonal setting.

This high foraminiferal diversity anomaly is difficult to explain. Reworking or the accumulation of foraminiferal tests over hundreds, if not thousands, of years is not an explanation. The geological history of the inlet (see Semeniuk 2000) shows that it has been a very shallow, marginal marine environment for a long time. Even if the high diversity is the result of a mix of species accumulated over this period of time, it remains unclear why so many different species found at least a temporary niche in the inlet. The pristine state of preservation of the vast majority of specimens argues against the possibility of reworking. The top 2 cm of core used represents a time slice which is to be measured in years, certainly not centuries, let alone millennia. Therefore, the diversity measured represents the actual, present diversity.

The purely benthic nature of the fauna is clearly indicative of shallow water. The absence of planktonic taxa implies no significant transport of specimens from the ocean into the inlet.

A puzzling outcome of this study is the virtual absence of specimens alive at the time of collection. The use of the Sudan Black stain is a very effective, consistent and reliable method to identify the presence of protoplasm and is unquestionably superior to the more traditional use of Rose Bengal (see Walker *et al.* 1974). The absence of stained specimens is not due to technical shortcomings. The discrepancy between the very low numbers of live specimens and the moderate to high numbers of tests in the sediments may be the result of reproductive strategies and populations dynamics. If the Foraminifera reproduce episodically, either seasonally or opportunistically, the number of tests in the sediments can thus be generated, while a single collection may easily miss the actual point in time when living organisms are present. However, this is at variance with the implications following on from the high diversity observed. From a traditional ecological perspective, a high diversity would be accompanied by at least a reasonably large standing crop. A monitoring program is the only way of resolving this issue.

The decrease in diversity along the south-north axis of Leschenault Inlet falls within expectations. The aquatic environment becomes more marginal, with the physical parameters becoming more variable and more extreme when moving from the area closest to "The Cut" to the northern-most part of the Inlet.

The limited data also show an increase in diversity along a west-east transect. This increase, observed along transects B and C, is somewhat peculiar: the total number of specimens recovered decreases, while the number of species decreases but not so fast. The Fisher alpha index therefore increases, and heterogeneity increases as well as shown by the Simpson C index (Table 2). These west-east increases coincide with an increase in the relative contri-

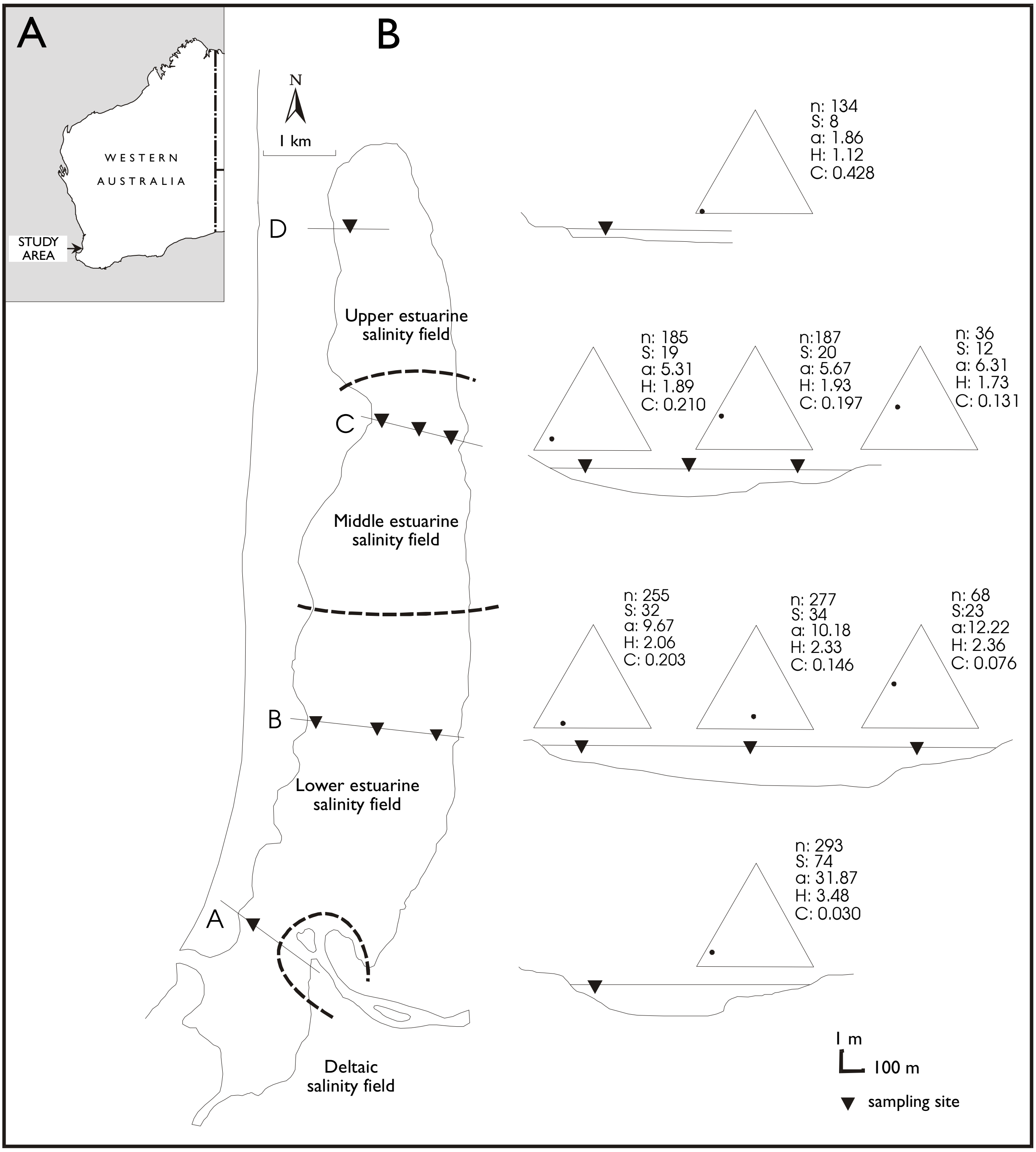

Figure 1. Sampling sites for foraminifera along transects within Leschenault Inlet. Cross sections show bathymetric profile and sampling locations. Ternary plots (after the work of Murray 1973, 1991) and information on abundance and diversity are shown for each sampling site.

bution of the porcellaneous taxa to the overall species spectrum (Fig 1). The raw data show that this increase is due to the reduction in numbers and diversity of the hyaline taxa, rather than an increase in porcellaneous taxa.

The macroscopically recognised habitats on the western margin of the inlet are substantially more diverse than on the eastern side (Wurm & Semeniuk 2000). The complex interfingering of mud-rich inlet sediments with the sands from blowouts of the parabolic dunes, combined with the resulting freshwater seeps, create a diversity of habitats which is reflected in the number of habitats on a scale relevant to the Foraminifera. The boundaries between the various macroscale habitats create micro-environments, possibly changing quite rapidly and episodically, to provide micro-organisms with a richness of niches.

From a foraminiferal point of view, the Leschenault Inlet is certainly an exceptional environment.

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Appendix

List of species of foraminifera identified in sediments from Leschenault Inlet. Species illustrated in plates 1-4. Bar scale for all foraminifera shown in the plates is 100 µm.

Agglutinating taxa

Ammobaculites sp Plate 1 Fig 1
Ammobaculites villosus Saidova 1975 Plate 1 Figs 2-3
Haplophragmoides sp Plate 1 Figs 4-5
?*Iridia* sp Plate 1 Fig 6
Lagenammina sp Plate 1 Figs 7-8
Leptohalysis catella (*Reophax catella* Höglund 1947) Plate 1 Figs 9-10
Miliammina fusca (Quinqueloculina fusca Brady 1870*)* Plate 1 Figs 11-12
?Nouria sp Plate 1 Figs 13-14
Paratrochammina challengeri Brönnimann & Whittaker *1988* Plate 1 Figs 15-16
Paratrochammina simplissima (Trochammina pacifica var *simplissima* Cushman & McCulloch 1948*)* Plate 1 Figs 17-18
Portatrochammina sp Plate 1 Figs 19-20
Prolixoplecta pseudofiliformis (Gaudryina pseudofiliformis Cushman 1911*)* Plate 1 Figs 21-22
Reophax sp Plate 1 Fig 23
Repmanina charoides (Trochammina squamata var *charoides* Jones & Parker 1860*)* Plate 1 Fig 24
Textularia earlandi Parker 1952 Plate 1 Figs 25-26
Textularia lancea Lalicker & McCulloch 1940 Plate 1 Figs 27-28
Trochammina ochracea (Rotalina ochracea Williamson 1858*)* Plate 1 Figs 29-30
Trochammina sp Plate 1 Figs 31-32
Valvulina oviedoiana d'Orbigny 1839 Plate 1 Fig 33

Porcellaneous taxa

Cornuspira involvens (Operculina involvens Reuss 1850*)* Plate 1 Figs 34-35
Cornuspira planorbis Schultze 1854 Plate 1 Figs 36-37
Dendritina striata Hofker 1951 Plate 1 Figs 38-39
Miliolinella labiosa (Triloculina labiosa d'Orbigny 1839*)* Plate 1 Fig 40
Miliolinella subrotunda (Vermiculum subrotundum Montagu 1803*)* Plate 1 Fig 41
Pseudolachlanella slitella Langer 1992 Plate 1 Figs 42-43
Quinqueloculina bicornis (Serpula bicornis Walker & Jacob 1798*)* Plate 1 Figs 44-45
Quinqueloculina crassicarinata Collins 1958 Plate 1 Fig 46
Quinqueloculina cuvieriana d'Orbigny 1839 Plate 1 Figs 47-78
Quinqueloculina eamesii (Triloculina eamesii Rasheed 1971*)* Plate 1 Figs 49-50
Quinqueloculina incisa Vella 1957 Plate 1 Figs 51-52
Quinqueloculina laevigata d'Orbigny 1839 Plate 1 Figs 53-54
Quinqueloculina patagonica d'Orbigny 1839 Plate 2 Figs 1-2
Quinqueloculina seminula (Serpula seminulum Linnaeus 1758*)* Plate 2 Figs 3-4
Quinqueloculina sp 1 Plate 2 Figs 5-6
Quinqueloculina sp nov Plate 2 Figs 7-8
Quinqueloculina tenagos Parker 1962 Plate 2 Figs 9-10

Quinqueloculina tropicalis Cushman 1924 Plate 2 Figs 11-12
Quinqueloculina tubicola Zheng 1979 Plate 2 Figs 13-14
Quinqueloculina undulata d'Orbigny 1852 Plate 2 Figs 15-16
Sigmamiliolinella australis Plate 2 Figs 17-18
Spiroloculina angulosa Cushman & Todd 1944 Plate 2 Figs 19-20
Spiroloculina communis Cushman & Todd 1944 Plate 2 Figs 21-22
Spiroloculina excisa (Spiroloculina communis var *excisa* Cushman & Todd 1944*)* Plate 2 Figs 23-24
Spirophthalmidium sp
Triloculina australis Parr 1932
Triloculina littoralis Collins 1958 Plate 2 Figs 25-26
Triloculina quadrata Collins 1958 Plate 2 Figs 27-28
Triloculinella parisa Loeblich & Tappan 1994 Plate 2 Figs 29-30
Wiesnerella auriculata (Planispirina auriculata Egger 1893*)* Plate 2 Fig 31

Hyaline taxa

Conicospirillinoides inaequalis (Spirillina inaequalis Brady 1879*)* Plate 2 Figs 32-33
Mychostomina revertens (Spirillina vivipara var *revertens* Rhumbler 1906*)* Plate 2 Figs 34-35
Fissurina carinata (Lagena fasciata var *carinata* Sidebottom 1906*)* Plate 2 Figs 36-37
Fissurina lucida (Entosolenia marginata var *lucida* Williamson 1848*)* Plate 2 Figs 38-39
Fissurina sp Plate 2 Figs 40-41
?Lamarckella sp
Globigerina sp Plate 2 Fig 42
Globigerinella calida (Globigerina calida Parker 1962*)* Plate 2 Fig 43
Abditodentrix rhomboidalis (Textularia rhomboidalis Millett 1899*)* Plate 2 Fig 44
Bolivina brittanica Macfadyen 1942 Plate 2 Figs 45-46
Bolivina compacta (Bolivina robusta var *compacta* Sidebottom 1905*)* Plate 2 Figs 47-48
Bolivina glutinata Egger 1893 Plate 2 Figs 49-50
Bolivina pseudoplicata Heron-Allen & Earland 1930 Plate 2 Figs 51-52
Bolivina striatula Cushman 1922 Plate 2 Figs 53-54
Bolivina subreticulata Parr 1932 Plate 3 Figs 1-2
Bolivinella barcooae (Rugobolivinella barcooae Cann & Hayward 1990*)* Plate 3 Figs 3-4
Buliminella elegantissima (Bulimina elegantissima d'Orbigny 1839*)*
Cheilochanus minutus Loeblich & Tappan 1994 Plate 3 Figs 5-6
Elongobula parallela (Buliminella parallela Cushman & Parker 1931*)* Plate 3 Fig 7
Globocassidulina bisecta Nomura 1983 Plate 3 Figs 8-9
Loxostomina costatapertusa Loeblich & Tappan 1994 Plate 3 Fig 10
Reussella aequa Cushman & McCulloch 1948 Plate 3 Figs 11-12
Sagrina sp Plate 3 Figs 13-14
Sigmavirgulina tortuosa (Bolivina tortuosa Brady 1881*)* Plate 3 Fig 15
Trifarina sp Plate 3 Figs 16-17
Ammonia tepida (Rotalia beccarii var *tepida* Cushman 1926*)* Plate 3 Figs 18-19
Angulodiscorbis quadrangularis Uchio 1953 Plate 3 Fig 20
?Anomalinoides sp Plate 3 Figs 21-22
?Bronnimannia sp Plate 3 Figs 23-24
Cancris carinatus (Pulvinulina oblonga var *carinata* Millett 1904*)* Plate 3 Figs 25-26
Challengerella bradyi Billman, Hottinger & Oesterle 1980 Plate 3 Figs 27-28
Cibicides mabahethi Said 1949 Plate 3 Figs 29-30
Cibicides refulgens Montfort 1808 Plate 3 Figs 31-32
?Colonimilesia sp Plate 3 Figs 33-34
Cymbaloporetta bradyi (Cymbalopora poeyi var *bradyi* Cushman 1915*)* Plate 3 Figs 35-36
Discorbina sp Plate 3 Figs 37-38
Discorbinella sp 1 Plate 3 Figs 39-40
Discorbinella sp 2 Plate 3 Figs 41-42
Discorbinella sp 3 Plate 3 Figs 43-44
Elphidium aculeatum (Polystomella aculeata d'Orbigny 1846*)* Plate 3 Figs 45-46
Elphidium advenum (Polystomella advena Cushman 1922*)* Plate 3 Figs 47-48
Elphidium clavatum (Elphidium incertum var *clavatum* Cushman 1930*)* Plate 3 Figs 49-50
Elphidium crispum (Nautilus crispus Linnaeus 1758*)* Plate 3 Figs 51-52
Elphidium excavatum (Polystomella excavata Terquem 1875*)* Plate 3 Figs 53-54
Elphidium fichtelianum (Polystomella fichtelianum d'Orbigny 1846*)* Plate 4 Figs 1-2
Elphidium jenseni (Polystomella jenseni Cushman 1924*)* Plate 4 Figs 3-4
Elphidium lene (Elphidium incertum var *lene* Cushman & McCulloch 1940*)* Plate 4 Figs 5-6
Elphidium limbatum (Polystomella macellum var *limbatum* Chapman 1907*)* Plate 4 Figs 7-8
Elphidium reticulosum Cushman 1933 Plate 4 Figs 9-10
Elphidium sp 1 Plate 4 Figs 11-12
Elphidium striatopunctatum (Nautilus striatopunctatus Fichtel & Moll 1798*)* Plate 4 Figs 13-14
Gavelinopsis sp Plate 4 Figs 15-16
Glabratella sp 1 Plate 4 Figs 17-18
Glabratella sp 2 Plate 4 Figs 19-20
Glabratella sp 3 Plate 4 Figs 21-22
Milesia sp Plate 4 Figs 23-24
Neoglabratella sp Plate 4 Figs 25-26
?Neorotalia stellata (Calcarina stellata de Férussac 1827*)* Plate 4 Figs 27-28
Nonion pauperatum (Nonionina pauperata Balkwill & Wright 1885*)* Plate 4 Figs 29-30
Nonion subturgidum (Nonionina subturgida Cushman 1924*)* Plate 4 Figs 31-32
Nonionellina labradorica (Nonionina labradorica Dawson 1860*)* Plate 4 Figs 33-34
Orbitina carinata Sellier de Civrieux 1977 Plate 4 Figs 35-36
Parrellina hispidula (Elphidium hispidulum Cushman 1936*)* Plate 4 Figs 37-38
Patellina corrugata Williamson 1858 Plate 4 Figs 39-40
Planorbulina acervalis Brady 1884 Plate 4 Figs 41-42
Porosononion sp 1 Plate 4 Figs 43-44
Porosononion sp 2 Plate 4 Figs 45-46
Pseudoeponides? Plate 4 Figs 47-48
Rosalina bulloides d'Orbigny 1839 Plate 4 Figs 49-50
Rosalina pellucida (Discorbis pellucidus Said 1949*)* Plate 4 Figs 51-52
Svratkina australis (Discorbis tuberculata var *australis* Chapman, Parr & Collins 1934*)* Plate 4 Figs 53-54

Plate 1

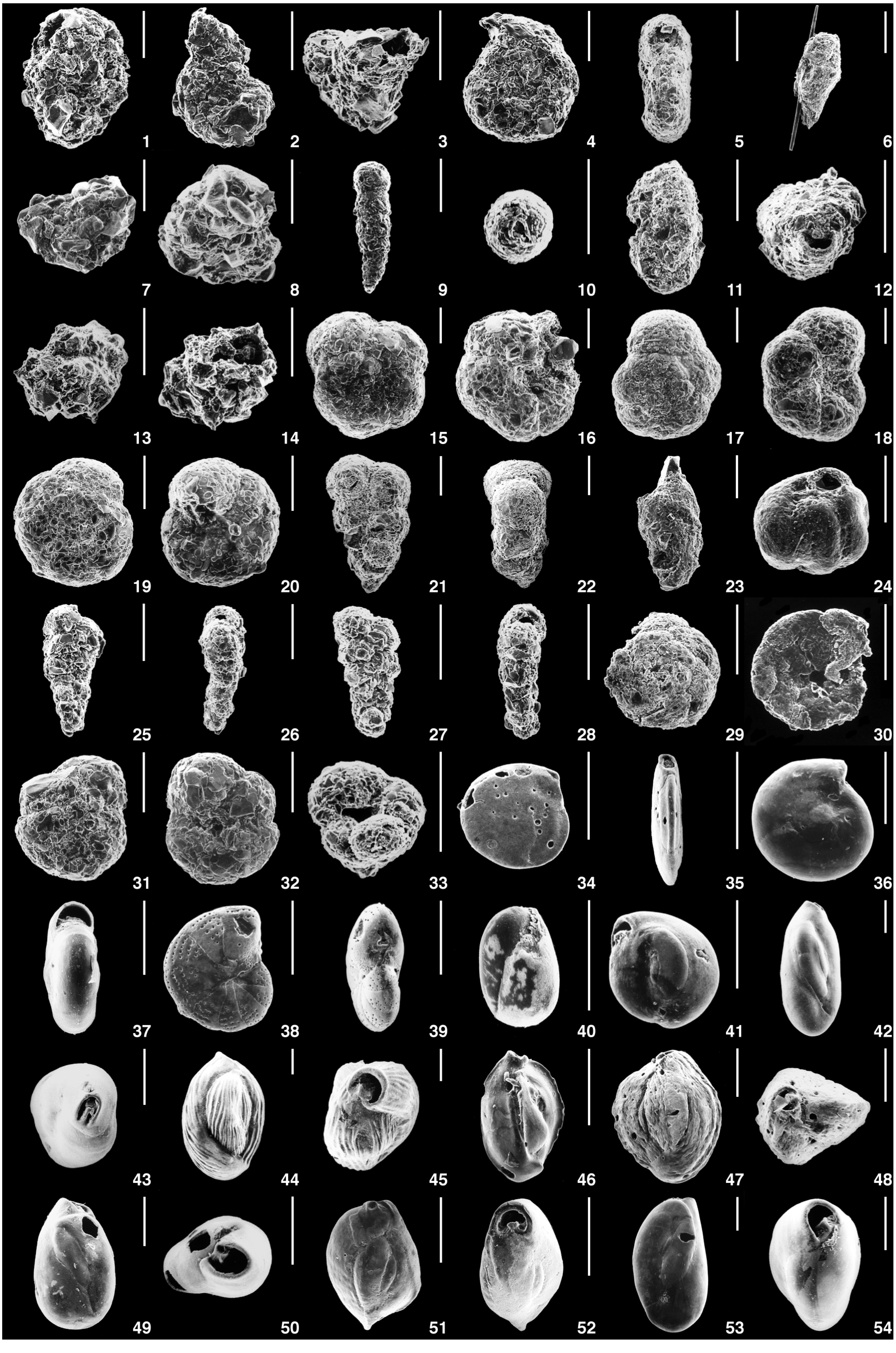
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Plate 2

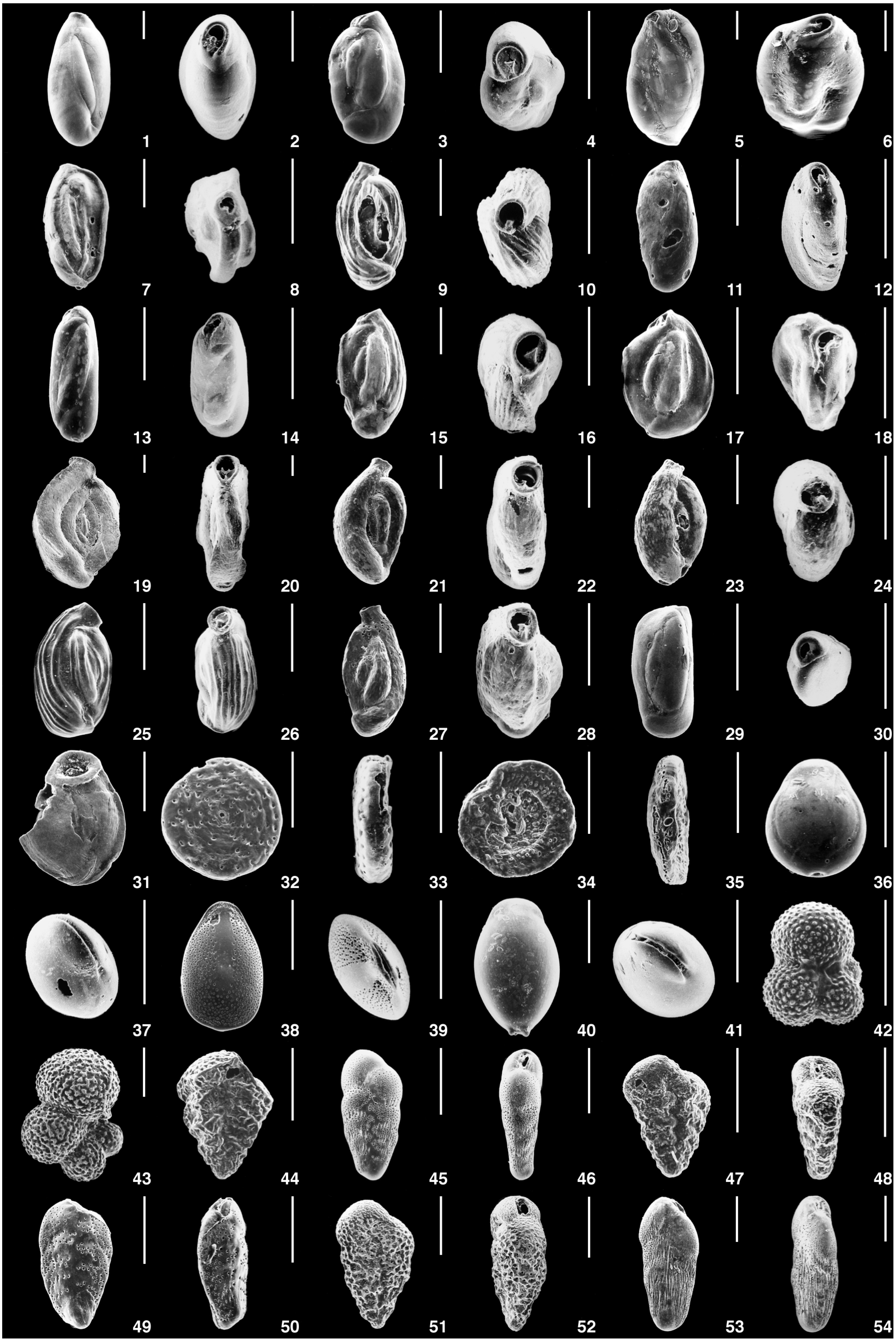
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Plate 3

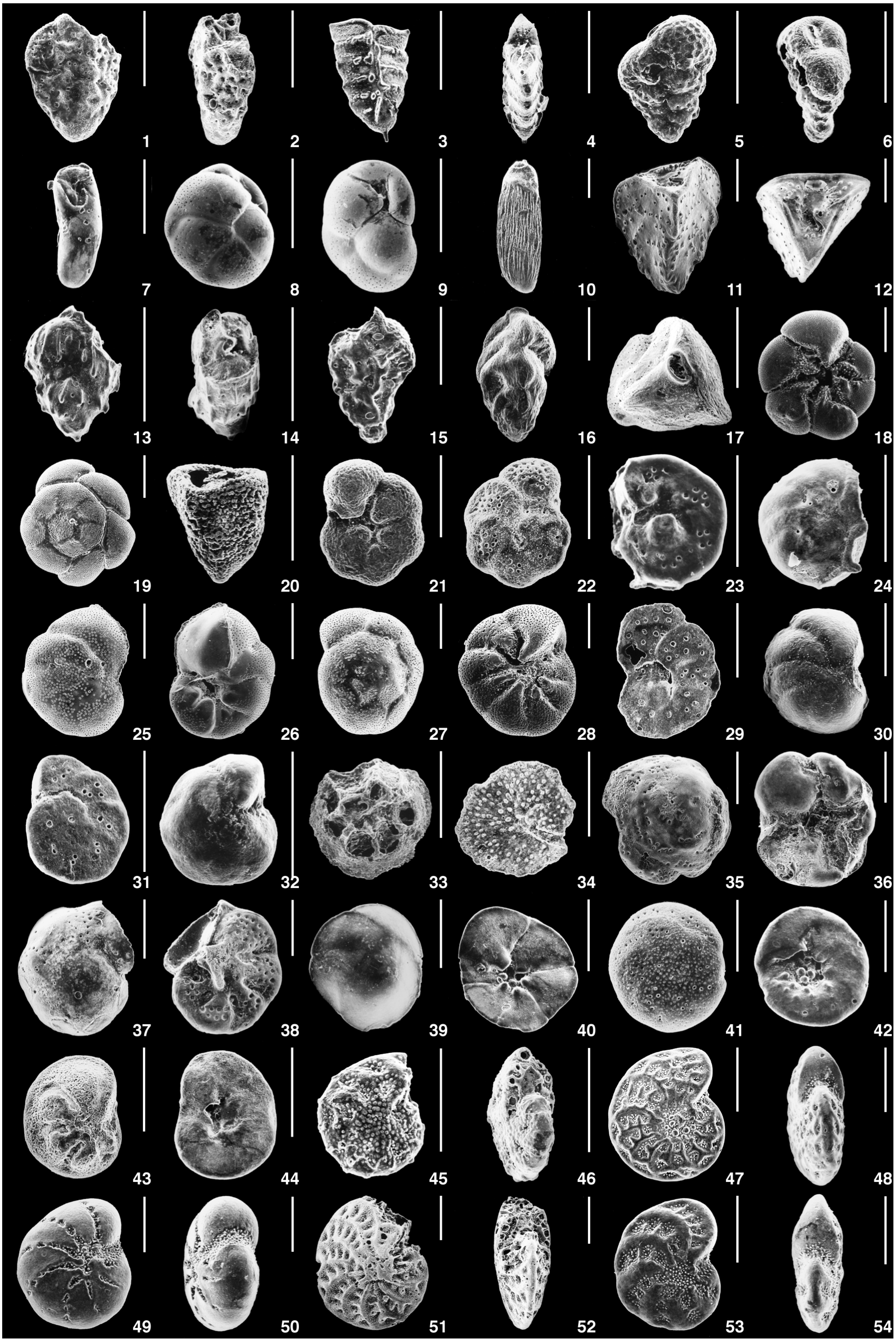
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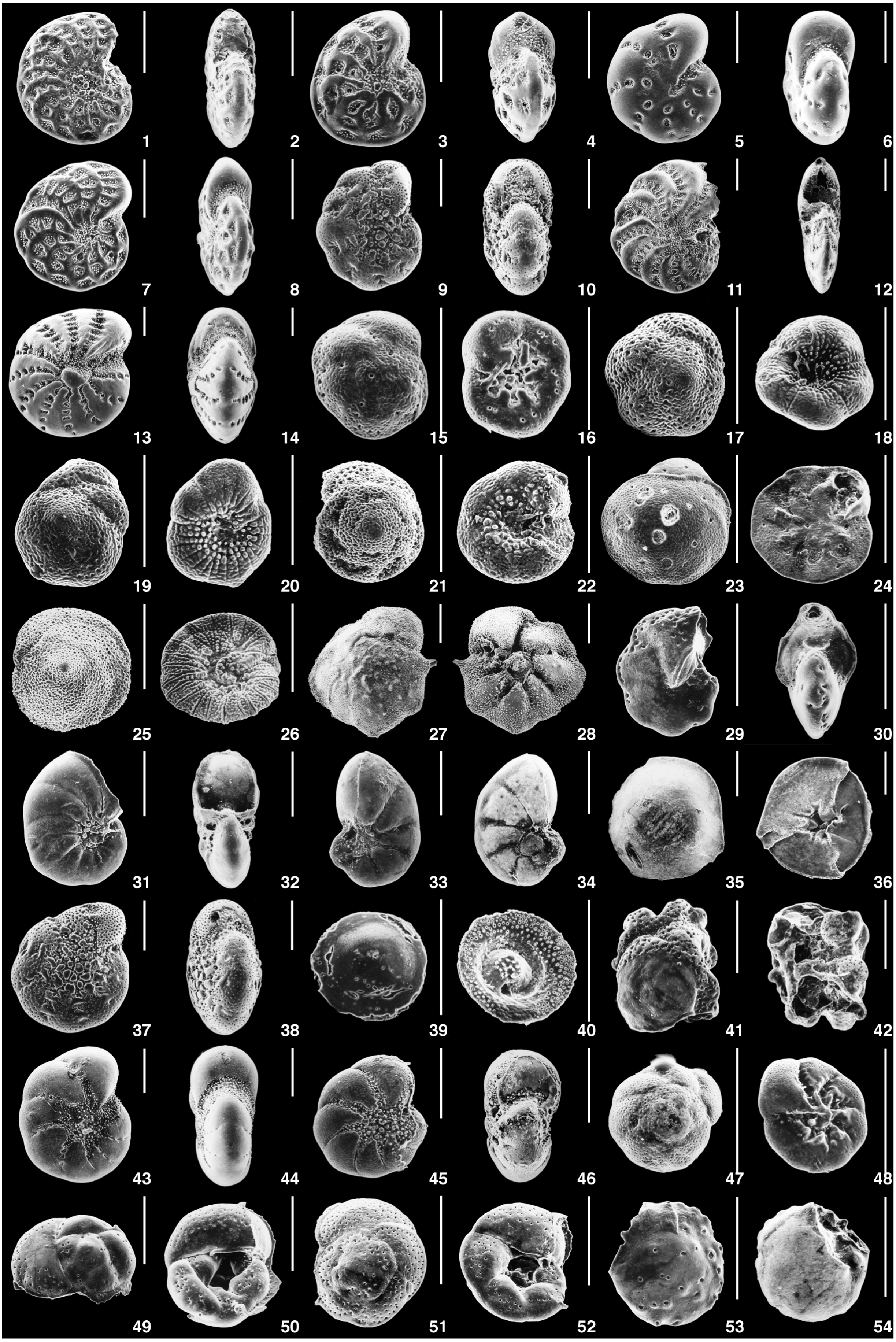
Plate 4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