Holocene Foraminifera from Tuross Estuary and Coila Lake, South Coast, New South Wales: A Preliminary Study

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Two estuaries on the New South Wales south coast, Tuross Estuary and Coila Lake, were sampled for Foraminifera. Thirty-seven taxa were identified from surface samples but only those requiring extensive taxonomic revision are discussed. The species composition of the total assemblage at each of the sample sites was analysed and the reasons for species distribution explored. A new species, Fissurina breviductus sp. nov., is described.

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KEYWORDS: Coastal; Estuary; Foraminifera; Holocene; New South Wales

INTRODUCTION

Tuross Estuary and Coila Lake are adjacent estuaries situated on the New South Wales south coast (Fig. 1). Despite their close proximity to each other, the two estuaries differ markedly in geomorphological character and depositional history. Tuross Estuary is a convoluted, complex estuary, characterised by numerous sandbars, variable depth and is open to the Pacific Ocean via a narrow channel. Coila Lake, in contrast, is a relatively simple, shallow estuary, periodically closed off from the ocean by a large barrier beach and is therefore more correctly defined as a saline coastal lake. Both are drowned river valleys, filled with sediments of Holocene age (Roy and Peat, 1976).

A study of the modern foraminiferal faunas present in the two estuaries was undertaken in an attempt to define the environmental parameters that control the distribution of the assemblages that inhabit the two estuaries and to note differences in assemblage composition in a marine influenced estuarine environment (Tuross Estuary) in comparison to a recently closed lagoonal environment (Coila Lake). Tuross Estuary and Coila Lake were chosen for this study because of their close proximity to each other and the limited amount of anthropogenic activity in the surrounding area.

PHYSICAL CHARACTERISTICS OF STUDY AREA

Tuross Estuary

Tuross Estuary is the larger and more complex of the two estuaries with a total water area of 12.95 km² (Ozestuaries database, 2002). It is classified as a barrier estuary system (Roy, 1984) and a narrow channel at the north end of a large sand spit is the only link between the estuary and the open ocean. The estuary is considered to be one of the least modified estuaries on the New South Wales coastline (Brierley et al., 1995), due mainly to the limited amount of anthropogenic activity in the area.

The sedimentological environments that dominate the estuary have been comprehensively documented by Roy and Peat (1976) and Brierley et al. (1995). According to these two studies, Tuross Estuary can be divided into four major depositional environments with the differences in each of these environments due to differences in the source of the sediment and the energy of the sedimentation processes present in each environment. Deposition in the estuary is attributed to a variety of mechanisms, including tide, wave and fluvial processes (Brierley et al., 1995; Fig. 1).

Coila Lake

Coila Lake is classified as a saline coastal lake, since it is usually cut off from the ocean by a barrier beach (Roy and Peat, 1976). Total water area of the lake is 6.85 km² (Ozestuaries database, 2002), making it one of the largest coastal lakes on the New South Wales coastline (Roy, 1984). Only one major
tributary, Coila Creek, enters the lake. Freshwater discharge from the creek is low and does not normally possess enough energy to force a channel through the barrier beach located along its southern margin (Roy and Peat, 1976). The lake has however been open to the sea on a number of occasions in recent years. In the period between 1975 and 1999 the barrier beach has been breached four times due to natural events (such as major flooding) and on thirteen occasions by mechanical means in order to lower water levels in the lake (Coila Lake Estuary Management Committee, 2001).

Bathymetrically, Coila Lake is flat bottomed with moderately steep sides. Maximum depth is approximately four metres (Roy and Peat, 1976). Much of the bottom sediment consists of dark coloured sandy muds, deposited by low energy tidal and wind induced currents (Roy and Peat, 1976).

METHODS

Material was described from a total of ten sample sites (see Fig. 1; TL1, TL3, TL4, TL5, TL7 and TL8 in Tuross Estuary and CL1, CL2, CL3, and CL4 in Coila Lake). Each site was examined for foraminifera. The ten sites were chosen because they form a transect across the two estuaries and best exemplify the full gamut of sedimentary environments present in the two estuaries, based upon previous studies of the estuaries by Roy and Peat (1976) and Brierley et al. (1995). Surface sediment was collected at each of the sample sites and was immediately treated with ethanol to preserve any live specimens for later staining. Upon return to the laboratory, each sample was treated with rose Bengal, using the method described by Bell (1996). Samples were then washed through a 1 mm and 63 mm sieve, dried at room temperature and split into 10 gram aliquots for picking.

Water chemistry analysis was undertaken with the use of Hydrolab 4 datasonde. Only the results obtained for conductivity, directly analogous to salinity, obtained at each locality will be discussed herein as the greater portion of this work will form the basis of a later paper (Hoefeleil et al. in prep).
DISTRIBUTION OF MODERN FORAMINIFERAL FAUNAS

Thirty-seven species of foraminifera were identified from surface samples collected in the two estuaries. In terms of species composition, the foraminiferal fauna present in Tuross Estuary and Coila Lake is similar to other estuaries on the New South Wales south coast (Yassini and Jones, 1989; Yassini and Jones, 1995; Cotter, 1996). Results of staining with rose Bengal revealed only minor variation between live and dead assemblages. Because of this, all analysis is based upon total assemblages, rather than only the live assemblage. Of the 37 species identified, thirty-four are benthic species and the remaining three planktonic. All three planktonic species, Globigerina bulloides d’Orbigny, Neogloboquadrina pachyderma (Ehrenberg) and Palliatina obliquiloculata (Parker and Jones), are confined to sample site TL1, suggesting that marine influence over sedimentation and water movement in Tuross Estuary does not extend beyond Tuross Lake (Fig. 1).

Three main foraminiferal assemblages were identified in the two estuaries. These are the Lower Estuary Assemblage, the Upper Estuary Assemblage and the Coastal Lake Assemblage. Assemblages were differentiated based upon the faunal composition of the assemblage and the relative abundances of the various taxa that make up the assemblage. Besides a few notable exceptions, discussed more extensively below, the distribution of these assemblages is unsurprising, with the composition of the foraminiferal faunas at each locality conforming to what would be expected.

The most diverse fauna is the Lower Estuary Assemblage, found at localities TL1 and CL2. The fauna is dominated by rotaliine forms; taxa such as Rosalina australis (Parr), Ammonia aoteana (Finlay), E. crispum crispum (Linne), E. advenum advenum (Cushman) and Parvallina papillosa (Cushman) having the highest relative abundances. An assemblage of this type is indicative of open estuary conditions where normal marine salinities dominate (Hayward et al., 1999). This assemblage is expected at locality TL1 considering its location (Fig. 1) and the conductivity results obtained for the site, approximately 57 mS/cm. Fully marine conditions return conductivity values around 60 mS/cm. Its presence at CL2 however is surprising as the locality is not currently subject to open estuary conditions, cut off from the open ocean by a barrier beach, and conductivity levels obtained for the site were brackish in nature, around 43 mS/cm. The site has been exposed to fully marine conditions in the past when the barrier beach has been opened by either natural or unnatural causes (Coila Lake estuary management committee, 2001). It is therefore proposed that the assemblage found at this site is a relict fauna associated with a time when the lake was open to the ocean. This assertion is supported by the lack of “live” specimens obtained at the site, determined using rose Bengal stain on the collected samples, suggesting that a living foraminiferal fauna does not currently inhabit the locality and the noticeably abraded nature of the material, suggesting deposition occurred some time ago.

The remaining sample localities in Tuross Estuary, excluding TL4, possess a fauna that is herein designated the Upper Estuary assemblage. This assemblage is characterised by a mixture of agglutinated and calcareous taxa; including Scherochorea barvonensis (Collins), Ammobaculites exigius Cushman and Bronnimann, Quinqueloculina oblonga (Montagu), Elphidium advenum advenum (Cushman), Elphidium excavatum clavatum Cushman and Elphidium ino Cushman and McCulloch. This fauna is indicative of shallow sub-tidal middle estuary conditions, with salinity levels slightly below normal marine conditions (Hayward et al., 1999). This assemblage is found at localities TL3, TL5, TL7 and TL8, sites characterised by either mangroves or reed beds. The conductivity values obtained for these sites were between 53-56 mS/cm; only slightly below normal marine values. The presence of this fauna at locality TL8 indicates that even the extremities of Tuross Estuary are subject to moderately saline conditions (Fig. 1).

The Coastal Lake assemblage dominates at the three remaining sample sites in Coila Lake, CL1, CL3 and CL4 and is also present at locality TL4. This assemblage consists of predominantly agglutinated taxa, in most cases dominated by the species Ammobaculites exigius Cushman and Bronnimann and Scherochorea barvonensis (Collins). In areas where high amounts of aquatic vegetation are present, such as marsh settings, Trochammina inflata (Montagu) is also a major constituent of the fauna. This fauna is indicative of a shallow sub-tidal situation where brackish conditions dominate (Collins, 1974; Hayward et al., 1999). Conductivity levels for these four sites do not exceed 45 mS/cm. The presence of this assemblage in Coila Lake is unsurprising, considering the lake is cut off from the open ocean but its presence at locality TL4 is unexpected. Located is the eastern part of Tuross Estuary, close to the estuary mouth, the foraminiferal fauna at the site should be comparable to the Lower Estuary Assemblage found nearby at TL1. This is not the case, with the fauna made up mainly of two taxa, Ammobaculites exigius Cushman and Bronnimann and Scherochorea barvonensis (Collins), which make up to 91% of the total...
abundance; the remaining 9% is composed of minor agglutinated forms and rare calcareous species. The difference in the faunal assemblage found at locality TL4 to that found in other parts of Tuross Estuary is related to the presence of a large sandbar, which isolates the site from the main part of the estuary. This isolation has created an environment, which, in terms of both water chemistry and sedimentary environment, is more comparable to a slightly brackish lagoonal situation, and a faunal assemblage that reflects these conditions.

**DISCUSSION**

Salinity is the main controlling factor on the distribution of foraminiferal species in Tuross Estuary and Coila Lake. Sites that are subject to, or have been subject to, fully marine conditions, such as TL1 and CL2, possess a fauna that is relatively high in diversity and characterised by numerous calcareous taxa. Hayward et al. (1999) noted that localities of this kind, where normal marine conditions are prevalent and there is little tidal exposure, are generally the most diverse localities in any particular estuary. Conversely, sites in the upper, or northern, part of Coila Lake, where brackish conditions dominate, are characterised by a low diversity fauna that is composed of agglutinated taxa. Those areas in Tuross Estuary where salinity is variable, in the middle and upper parts of the Tuross Estuary, possess a fauna which lies somewhere between the previous two and is a mixture of calcareous and agglutinated taxa.

**SYSTEMATIC DESCRIPTIONS**

Unless otherwise stated, the higher level classification follows Loeblich and Tappan (1987). Although revised classification schemes have been published (e.g. Loeblich and Tappan, 1992; Sen Gupta, 1999), Loeblich and Tappan’s (1987) scheme is considered less controversial and since it is in widespread use, allows comparisons to be made between this study and others. The only departure that has been made from Loeblich and Tappan (1987) is the use of –OIDEA rather than –ACEA as the ending of all superfamily names, following recommendation 29A of the ICZN 4th edition.

No attempt has been made to describe those taxa that have been comprehensively monographed in other systematic studies (Albani, 1968a; Albani 1979; Hayward et al., 1997; Hayward et al., 1999). Only new taxa or those requiring substantial revision are described in detail. A full list of species recovered from the two estuaries can be found in Table 1.

Order FORAMINIFERA Eichwald, 1830
Suborder TEXTULARIINA Delage and Herouard, 1896
Superfamily HORMOSINOIDEA Haeckel, 1894
Family HORMOSINIDAE Haeckel, 1894
Subfamily REOPHACINAE Cushman, 1910

**Scherochorella** Loeblich and Tappan, 1984

**Type species:**
Reophax minuta Tappan, 1940

**Scherochorella barwonensis** (Collins), 1974
(Plate 1, Figs. 1-3)
1974 Reophax barwonensis Collins, p. 8; Pl. 1, fig 1.
1980 Reophax barwonensis Aphthorpe, Pl. 29, Fig. 7.
1989 Protoschista findes Yassini and Jones, Figs. 10.10, 10.11.
1992 Reophax barwonensis Bell and Drury, p. 12; Fig. 4.5.
1995 Reophax barwonensis Bell, p. 229; Fig. 2.1.
1995 Protoschista findes Yassini and Jones, p. 69; Figs. 39, 43.
1996 Reophax barwonensis Bell, p. 5; Pl. 1a.

**Description:**

**Remarks:**
The designation of this species has been highly contentious. Much of the confusion associated with this taxon has arisen due to its variable morphology. Specimens found in Tuross Estuary and Coila Lake display variability in the total number of chambers present, the coarseness of the test and the size of the proloculus relative to the subsequent chambers (Plate 1, Figs. 1-2). This variation could be explained by the presence of both microspheric and megalospheric forms (Bell, 2002 pers. comm.), although this possibility was not mentioned by Collins (1974) in his original description of the species.

I have followed Loeblich and Tappan (1984) in assigning this species to the genus Scherochorella based upon its subglobular proloculus, appressed chambers and depressed sutures. This assignment has been previously rejected by Bell and Drury (1992) who state that the specimens illustrated as part of their study (Bell and Drury 1992, Fig 4.5) do not exhibit a flattened test, nor could they be considered tiny; both diagnostic features of the genus Scherochorella (Loeblich and Tappan, 1984). However, as test size cannot be considered a good generic character in foraminifera,
Table 1. Species recovered from Tuross Estuary and Coilla Lake. X indicates the localities at which each species occurs.

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as often it is environmentally controlled, and the flattened nature of the type species could be due to burial distortion (Loeblich and Tappan, 1987). Bell and Drury’s (1992) assertion is herein rejected.

Hayward and Hollis (1994), in their assessment of New Zealand brackish water foraminifera, asserted that S. barwonensis Collins is a junior synonym of Reophax moniliforme Siddall. Bell (1996) indicated this synonymy cannot be justified since barwonensis has a more robust test than moniliforme, and both taxa have differing habitats: R. moniliforme Siddall is associated with inner shelf environments and S. barwonensis Collins is found in shallow-water intertidal environments.

This species has only previously been described from Victoria and Tasmania. This may be
due, in part, to misidentification of the species as *Protoschista findens* Parker, particularly in studies conducted on modern material in New South Wales (Yassini and Jones, 1989; Yassini and Jones, 1995). *Protoschista* is characterised by branching at the proloculus and the formation of two or three uniserial series, a feature that none of the specimens illustrated from New South Wales possess (e.g. Yassini and Jones, 1989 Figs 10.10-10.11; Yassini and Jones, 1995 Figs 39.43). The range of the species can thus be extended to the south coast of New South Wales (Yassini and Jones, 1995; this study).

Specimens of *S. barwonensis* Collins in Tuross Estuary and Coila Lake are generally found in low energy environments, such as localities TL3, TL8 and CL3, where the substrate is composed of predominantly muddy material and where aqueous vegetation, such as reed beds, are absent. The species tolerates a wide range of salinity conditions, from fully marine through to conductivity values below 34 mS/cm.

Superfamily LITUOLOIDEA de Blainville, 1827
Family LITUOLIDAE de Blainville, 1827
Subfamily AMMOMARGINULININAE Podobina, 1978

**Ammobaculites** Cushman, 1910

**Type species:**
*Spiroolina agglutinans* d'Orbigny, 1846

**Ammobaculites barwonensis** Collins, 1974
(Plate 1, Figs. 6-7)

1974 *Ammobaculites? barwonensis* Collins, p. 9; Pl. 1, Figs. 3a-b.
1980 *Ammobaculites barwonensis* Apthorpe, p. 225; Pl. 28, Figs. 4, 5, 10-13.
1989 *Ammobaculites foliaceus* Yassini and Jones, Fig. 10.4.
1992 *Ammobaculites barwonensis* Bell and Drury, p. 13; Figs. 4.7-4.9.

1995 *Ammobaculites barwonensis* Bell, p. 229; Fig. 2.1.
1995 *Ammobaculites foliaceus* Yassini and Jones, p. 71; Figs. 51-53.

**Description:**

**Remarks:**
In his original description of *Ammobaculites barwonensis*, Collins (1974) was doubtful of the generic placement of this species because of the absence of a definite terminal aperture and suggested that “it is possible that minute interspaces between grains on the distal face function as such” (Collins, 1974, p. 9). An amended description by Apthorpe (1980) showed that the aperture is terminal and is generally an ellipse or elongate slit.

As noted by Apthorpe (1980) the morphology of this species is variable, particularly the overall shape and degree of compression of the test. Typical specimens, as illustrated by Collins (1974, Pl. 1 Figs. 3a-b) and Apthorpe (1980, Pl. 28 Figs. 4, 5, 10-13), are moderately compressed and rectangular in outline but a highly compressed, flabelligeriform variant does exist (Apthorpe, 1980, Pl. 28, Fig. 11; Bell and Drury, 1992, Fig. 4.7). There is a morphological continuum between the two forms (Apthorpe, 1980), suggesting that both morphotypes probably belong to *A. barwonensis* Collins. Both variants, as well a number of intermediate forms, were recovered from both surface and core samples collected in Tuross Estuary and Coila Lake, but the majority of specimens tend to be highly compressed and flabelligeriform in shape. It is unknown whether the morphology of the species is affected by environmental conditions.

Like *Reophax barwonensis* Collins, this species has previously only been described from Victoria. Also like *R. barwonensis* Collins, this is probably due to misidentification of specimens as *Ammobaculites foliaceus* (Brady) (Yassini and Jones, 1989; Yassini and Jones, 1995). *Ammobaculites*
*foliaceus* (Brady) differs from *A. barwonensis* Collins by its extremely thin, almost transparent wall, very compressed test and smooth exterior (Brady, 1881; Brady, 1884). The range of *A. barwonensis* Collins can therefore be extended to the south coast of New South Wales (Yassini and Jones, 1989; Yassini and Jones, 1995; This study).

The species is found in both Tuross Estuary and Coila Lake, with highest abundances occurring at shallow intertidal localities, such as CL4 and TL8 (Fig. 1). The species has not been recovered from the eastern, more marine, part of Tuross Estuary, suggesting this species is confined to brackish water conditions.

**Superfamily TROCHAMMINOIDEA** Schwager, 1877

**Family TROCHAMMINIDAE** Schwager, 1877

**Subfamily TROCHAMMININAE** Schwager, 1877

*Portatrochammina* Echols, 1971

**Type species:**

*Portatrochammina eltaninae* Echols, 1971

*Portatrochammina sorosa* (Parr). 1950

(Plate 1, Figs. 8-9)

1950 *Trochammina sorosa* Parr, p. 278; Pl. 5, Figs. 15-17.
1967 *Trochammina sorosa* Hedley et al., p. 23; Pl. 6, Figs. 4a-c, Text Figs. 11-15.
1992 *Trochammina sorosa* Bell and Drury, p. 13; Fig. 4.12.
1996 *Trochammina sorosa* Bell, Pl. 11.
1996 *Trinitis conica* Cotter, Figs. 4.10-4.11.
1999 *Trochammina sorosa* Bell and Neil, p. 221; Fig. 3E.
1999 *Portatrochammina sorosa* Hayward et al., p. 87; Pl. 2, Figs. 4-5.

**Description:**

see Hayward et al. (1999), p. 87.

**Remarks:**

Hayward et al. (1999) placed this species in the genus *Portatrochammina* based on the presence of an umbilical flap, discovered upon re-examination of the toptype material by Hedley et al. (1967). This feature was neither described or illustrated in Parr’s (1950) original description of the species but is present on specimens found in Tuross Estuary and Coila Lake.

*P. sorosa* (Parr) has a restricted distribution and is currently only known from the south-eastern coastline of Australia and New Zealand (Hayward et al., 1999). Specimens of *P. sorosa* (Parr) found in Tuross Estuary and Coila Lake tend to be variable in the number of whorls and are generally more trochospiral than the specimens illustrated by Parr (1950, Pl. 5 Figs. 15-17) from off the east coast of Tasmania. In the modern setting, the distribution of *P. sorosa* (Parr) is widespread in Tuross Estuary but no specimens were recovered from surface samples collected in Coila Lake. This would suggest that *P. sorosa* (Parr) prefers normal marine salinities.

**Suborder MILIOLINA** Delage and Herouard, 1896

**Superfamily CORNUSPIROIDEA** Schultze, 1854

**Family CORNUSPIRIDAE** Schultze, 1854

**Subfamily CORNUSPIRINAE** Schultze, 1854

*Cornuspira* Schultze, 1854

**Type species:**

*Orbis foliaceus* Philippi, 1844

*Cornuspira involvens* (Reuss), 1850

(Plate 2, Fig. 15)

1850 *Orcselulina involvens* Reuss, p. 370; Pl. 46, Figs. 20a-b.
1884 *Cornuspira involvens* Brady, p. 200; Pl. 11, Figs. 1-3.
1967 *Cyclogyra involvens* Hedley et al., p. 24-25; Text Fig. 16.
1999 *Cornuspira involvens* Hayward et al., p. 94; Pl. 3, Fig. 16.

**Description:**

see Hayward et al. (1999).


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Remarks:
This species has a cosmopolitan distribution (Culver and Buzas, 1986; Loeblich and Tappan, 1994) but it has rarely been described from Australia and never from the south-eastern coastline of New South Wales. It is generally found in fully marine conditions, with those specimens found in marsh environments probably carried there by tidal currents (Hayward et al., 1999).

Specimens of C. involvens (Reuss) are extremely rare in the study area and are only found in Tuross Estuary, at TL1 and TL3. Although C. involvens (Reuss) is generally found inhabiting inner shelf environments (Hayward et al., 1999), one of the tests recovered from TL1 during January collection did stain with rose Bengal. This, along with the pristine nature of the test, suggests that live specimens of this species do inhabit the estuary.

Suborder LAGENINA Delage and Herouard, 1896
Superfamily NODOSARIOIDEA Ehrenberg, 1838
Family LAGENIDAE Reuss, 1862

Fissurina Reuss, 1850

Type species:
Fissurina laevigata Reuss, 1850

Fissurina breviductus sp. nov.
(Plate 2, Figs. 5-7)

Diagnosis:
Differs from other species of Fissurina in its small size, short entosolenian tube, perforate flanks with smooth central area and its distinctively depressed simple aperture.

Description:
Test unilocular, tiny, approximately 0.1 mm in length and 0.05 mm in width. Relatively ovate in outline but gently tapering towards apertural end. Test is laterally compressed. Aperture simple, ovate in shape, with area immediately around aperture slightly depressed. Wall glassy, perforate on flanks with central area smooth. Possesses a short entosolenian tube that is free, straight and central.

Type Material:
Holotype: MU59414; Paratype A: MU59379; Paratype B: MU59415; All type specimens collected from locality TL1 in Tuross Estuary.

Etymology:
Latin for “short tube”; in reference to its short entosolenian tube.

Remarks:
Based upon its ovate outline, smooth surface, ovate terminal aperture and entosolenian tube, this species is assigned to genus Fissurina. It does not however, accord with any of the described species within this genus, nor does it resemble any species previously described from shallow water environments along the south-eastern Australian coastline. This may in part be due to its small size, generally less than 100 µm in length.

This species does resemble a variant of Lagena globosa Montagu, documented by Sidebottom (1912, Pl. 14 Figs. 13-15) from the outer shelf and abyssal plain of the south-west Pacific, Lagena globosa var. emaciate Reuss. Both the specimens illustrated by Sidebottom (1912) and those found as part of this study are ovoid in shape, smooth walled, possess a free, centralised entosolenian tube, and have a single terminal aperture. It is unclear whether the specimens shown by Sidebottom (1912) are depressed around the aperture.

Sidebottom’s (1912) material was collected from depths of below 710 fathoms, whereas the material from the Tuross Estuary is from shallow water. Such extreme bathymetric differentiation make it unlikely that the specimens illustrated by Sidebottom (1912) and the specimens collected from the study area are conspecific. Specimens of F. breviductus sp. nov. from the study area are confined to surface and core samples from locality TL1 and all specimens found in surface samples had taken up the rose Bengal stain, suggesting the tests were in-situ and their natural habitat is a shallow water open estuary environment.

Family POLYMORPHINIDAE d’Orbigny, 1839
Subfamily POLYMORPHININAE d’Orbigny, 1839

Guttulina d’Orbigny, 1839

Type species:
Polymorphina (les Guttulines) communis d’Orbigny, 1826

Guttulina irregularis (d’Orbigny), 1846
(Plate 2, Figs. 10-11)

1846 Globulina irregularis d’Orbigny, p. 226; Pl. 13, Figs. 9-10.
1930 Guttulina irregularis Cushman and Ozawa, p. 25; Pl. 3, Figs. 3,4; Pl. 7, Figs. 1,2.
1937 Guttulina irregularis Parr and Collins, p. 192; Pl. XII, Fig. 2.
1995 Nevellina coronata Yassin and Jones, p. 89; Fig. 244.
1999 Guttulina irregularis Hayward et al., p. 117; Pl. 7, Figs. 10-11.
Description: see Hayward et al. (1999), p. 117.

Remarks: This species can be distinguished from other species of Gutulina by its pyriform test, rounded periphery and non-depressed sutures (Hayward et al., 1999). It has been recorded from a number of localities throughout the west Pacific (Parr and Collins, 1937; Nomura, 1981; Hayward et al., 1999).

In the study area, this taxon was recovered from surface samples as locality TL1. The abraded nature of the tests suggests they have been transported to the site by onshore oceanic currents, since G. irregularis (d’Orbigny) is generally found at inner and mid-shelf depths (Hayward et al., 1999).

Suborder ROTALINA Delage and Herouard, 1896
Superfamily BOLIVINOIDEA Glaessner, 1937
Family BOLIVINIDAE Glaessner, 1937

Bolivina d’Orbigny, 1839

Type species:
Bolivina plicata d’Orbigny, 1839

Bolivina striatula Cushman, 1922
(Plate 2, Fig. 4)

1922 Bolivina striatula Cushman, p. 27; Pl. 3, Fig. 10.
1937 Bolivina striatula Cushman, p. 154; Pl. 18,
Figs. 30, 31.
1950 Bolivina striatula Parr, p. 239.
1979 Brizalina striatula Albani, p. 33; Fig. 56-6.
1980 Bolivina striatula Apthorpe, Pl. 27, Fig. 2.
1989 Brizalina striatula Yassini and Jones, Fig. 13.3.
1995 Brizalina striatula Yassini and Jones, p. 132;
Figs. 526-529, 543-544, 655.
1996 Bolivina striatula Bell, Pl. 5d.
2001 Brizalina striatula Albani et al.

Description: see Hayward et al. (1999), p. 127.

Remarks: The amendments made by Sgarrella (1992) to the genus Bolivina, with Brizalina now a junior synonym of Bolivina, are adopted herein. B. striatula Cushman is easily distinguished from other species of Bolivina by its parallel fine ribs on the lower half of the test. This species is generally found in sheltered, slightly brackish environments (Hayward et al., 1999) and its geographic distribution is extensive (Murray, 1991). This species is extremely rare in Tutu Estuary with only small numbers recovered from localities TL1 and TL3. The species was not recovered from Coila Lake.

Superfamily DISCORBOIDE Ehrenberg, 1838
Family DISCORBIDAE Ehrenberg, 1838

Lamellodiscorbis Bermudez, 1952

Type species:
Discorbina dimidiata Jones and Parker in
Carpenter et al., 1862

Lamellodiscorbis dimidiatus (Jones and Parker),
1862
(Plate 3, Figs. 3-4).

1862 Discorbina dimidiata Jones and Parker in
Carpenter et al., p. 201; Text Fig. 32b.
1945 Discorbina dimidiata Parr, p. 208.
1967 Discorbina dimidiatus Hedley et al., p. 33;
Text-Figs. 28-43.
1974 Discorbis dimidiatus Collins, p. 34.
1989 Lamellodiscors dimidiatus Yassini and Jones,
Figs. 17.9-17.11.
1992 Lamellodiscorbis dimidiatus Yassini and
Reves, p. 176; Pl. 4, Figs. 1-3, 7-8
1995 Trochulina dimidiata Yassini and Jones, p. 158;
Figs. 916-917.
1996 Lamellodiscorbis dimidiatus Bell, Pl. 5b.
1999 Trochulina dimidiatus Hayward et al., p. 139;
Pl. 10, Figs. 9-11.

Description: see Hayward et al. (1999), p. 139.

Remarks: A number of authors (Loeblich and Tappan 1987, Yassini and Jones 1995, Hayward et al. 1999) have assigned this species to the genus Trochulina, suggesting that both Discorbina and Lamellodiscorbis are junior synonyms of Trochulina. However, Hansen and Revets (1992) clearly illustrate the validity of both Discorbina and Lamellodiscorbis and so herein dimidiatus has been assigned to Lamellodiscorbis.

This species is distinguished by its characteristic umbilical side, which has short, thickened umbilical plates bordered by deep clefts along the sutures (Hayward et al., 1999). Collins (1974) noted that specimens are sometimes strongly biconvex with secondary thickening on both faces. The geographic distribution of L. dimidiatus (Jones and Parker) is confined to coastal waters of Australia and the Pacific (Hedley et al., 1967; Yassini and Jones, 1995; Hayward et al., 1999) and it is generally found
in stenohaline environments (Cann et al., 2000) with
greatest abundance occurring in exposed, shallow, high
energy environments.

Specimens from the study area were only
recovered from samples collected at locality TL1. The
broken and abraded nature of the tests, as well as the
lack of any "live" specimens of L. dimidiatus (Parker
and Jones) in the surface samples from locality TL1,
suggests that living examples of this species do not
inhabit the estuary but rather are transported in via
currents.

Superfamily GLABRATELLOIDAE Loeblich and
Tappan, 1964
Family GLABRATELLIDAE Loeblich and Tappan,
1964

Pileolina Bermudez, 1952

Type species:
  Valvulina pileolus d’Orbigny, 1839

Remarks:
Pileolina was recorded as a genus of uncertain
status by Loeblich and Tappan (1988), however I
follow Hayward et al. (1999) in placing the genus in
the family Glabratellidae.

Pileolina australensis (Heron-Allen and
Earland), 1932
(Plate 2, Figs. 18-20)

1932 Discorbis australensis Heron-Allen and
Earland, p. 416.
1995 Glabratella australensis Yassini and Jones, p.
160; Figs. 731-734.

Description:
see Heron-Allen and Earland (1932), p. 416.

Remarks:
With the validity of the genus Pileolina
established by Hayward et al. (1999), the species
australis Heron-Allen and Earland is herein re-
assigned to the genus. The genus Glabratella, where
australis Heron-Allen and Earland was most
recently assigned by Yassini and Jones (1995), is
characterised by the presence of globular chambers
and a rounded periphery (Loeblich and Tappan, 1988;
Hayward et al., 1999) whereas specimens of
australis described by Heron-Allen and Earland
(1932) and illustrated by Yassini and Jones (1995, Figs.
731-734), as well as those found as part of this study,
do not have globular chambers and have an acute
periphery. These features, along with the flat, involute
umbilical site with radiating striae and papillae clearly
place the species in Pileolina.

Pileolina australensis (Heron-Allen and
Earland) is easily distinguished from most other species
of Pileolina by the ornament present on its umbilical
side, which consists of strong tubercules located
centrally and numerous prominent striae around the
outer edge (Plate 2, fig. 20). P. australensis (Heron-
Allen and Earland) does resemble P. zealandica Vella,
which has a similar ornament on the umbilical side,
but can be discriminated by the nature of the chambers
on the spiral side, which in P. australensis (Heron-
Allen and Earland) are much longer than in P.
zealandica Vella (Hayward et al. 1999).

Pileolina australensis (Heron-Allen and
Earland) is endemic to Australia and its distribution is
confined to a variety of marine dominated
environments (Yassini and Jones, 1995). Specimens
found in the study area conform to these ecological
parameters and tests were only found at locality TL1,
where marine conditions dominate.

Superfamily PLANORBULINOIDEA Schwager,
1877
Family CIBICIDIDAE Cushman, 1927
Subfamily CIBICIDINAE Cushman, 1927

Cibicides de Montfort, 1808

Type species:
Cibicides refugens de Montfort, 1808

Plate 3 Facing page: (Unless otherwise specified all scale bars = 100 µm) - 1-2. Cibicides dispers (d’Orbigny),
TL1 July; 3. Lamellodiscorbis dimidiatus (Jones and Parker) TL1 300-320; 4. Lamellodiscorbis dimidiatus
(Jones and Parker), TL1 July; 5-6. Ammonia aoteana (Finlay), TL4 S15-S35; 7-8. Ammonia aoteana (Finlay)
TL4 140-160; 9. Elphidium lene Cushman and McCulloch, TL7 July; 10. Elphidium lene Cushman and
McCulloch, TL7 July (Scale bar for figure 5 = 10µm); 11-12 Elphidium excavatum clavatum Cushman,
crispum (Linne), TL1 180-200; 17-18. Elphidium crispum (Linne) ssp. TL1 300-320; 19-20. Elphidium
advenum macelliforme McCulloch, TL1 515-535.
Cibicides dispers (d’Orbigny), 1839
(Pl. 3, Figs. 1-2)
1839 Truncatulinna dispers d’Orbigny, p. 38; Pl. 5, Figs. 25-27.
1980 Cibicides dispers Boltskoy et al., p. 24; Pl. 8, Figs. 12-16.
1995 Cibicidoides floridanus Yassini and Jones, p. 169, Figs. 889-896.
1999 Cibicides dispers Hayward et al., p. 154; Pl. 14, Figs. 22-24.

Description:
see Hayward et al. (1999), p. 154.

Remarks:
There has been a great deal of confusion concerning the taxonomic assignment of planovulval species of Cibicides (Hayward et al., 1999). Because of this, the broad view taken by Hayward et al. (1999) with respect to C. dispers (d’Orbigny) is followed herein. Whilst the material found in the study area does not exactly match the specimens of C. dispers (d’Orbigny) illustrated by Boltskoy et al. (1980, Pl. 8 Figs. 12-16) and Hayward et al. (1999, Pl. 14 Figs. 22-24), mainly due to the lack of perforations on much of the involute side in the Tuross Estuary specimens, they match the original description given by d’Orbigny (1839) and have an overall morphology that is otherwise strikingly similar. Therefore specimens from the study area are referred to C. dispers (d’Orbigny).

Also of note is that the specimens recovered from the study area are clearly conspecific with the material identified by Yassini and Jones (1995) as Cibicidoides floridanus (Cushman), a designation that was later recognised as a junior synonym of C. dispers (d’Orbigny) by Hayward et al. (1999).

Specimens of C. dispers are present in Tuross Estuary and Colia Lake but are confined to localities where marine influences dominate (TL1, CL2). This is not unexpected since the species thrives in fully marine inner- to mid- shelf environments. Some specimens found in surface samples from TL1 did take up the rose Bengal stain, indicating that C. dispers (d’Orbigny) can survive in estuarine conditions and is not necessarily washed in from shelf environments.

Superfamily ROTALIOIDEA Ehrenberg, 1839
Family ROTALIIDAE Ehrenberg, 1839
Subfamily AMMONIINAE Saidova, 1981

Ammonia Brünich, 1772

Type species:
Nautilus beccari Linne, 1758

Ammonia aoteana (Finlay), 1940
(Plate 3, Figs. 5-8)
1940 Strebulus aoteana Finlay, p. 461.
1967 Ammonia aoteana Hedley et al., p. 47; Pl. 11, Figs. 4a-c, Text Figs. 56-60.
1974 Ammonia aoteana Collins, p. 40; Pl. 3, Figs. 30a-c.
1968a Ammonia beccarii Albani, p. 30; Fig. 129
1968b Ammonia beccarii Albani, p. 110; Pl. 9, Figs. 7, 9-10
1979 Ammonia beccarii Albani, p. 40; Fig. 88-1
1980 Ammonia aoteana Apthorpe, p. 225; Pl. 27, Figs. 5-6; Pl. 29, Figs. 1-2.
1994 Ammonia beccarii (Linne) forma aoteana Hayward and Hollis, p. 213; Pl. 4, Figs. 1-3.
1996 Ammonia aoteana Bell, p. 6.
1996 Ammonia beccarii List, p.19; Pl. I Figs. G-H

Description:
see Finlay (1940), p. 461; Hayward and Hollis (1994), p. 213.

Remarks:
The problems surrounding the species, subspecies and formae within the genus Ammonia have been discussed extensively in the literature (see Bell, 1996 for summary). Due to the large deal of morphological overlap within the genus and subjective recognition of key features by workers (Murray, 1979), it appears that genetic studies will be required to sort out the relationships between the numerous morphological variants.

Because of the uncertainty surrounding the genus, two main approaches have traditionally been used in descriptions of Ammonia in estuarine faunas in south-eastern Australia. In New South Wales, specimens falling within the genus Ammonia have been referred to as Ammonia beccarii (Linne) (Albani, 1968a; Albani, 1978; Albani, 1979; Yassini and Jones, 1989; Yassini and Jones, 1995; Cotter, 1996) whereas in Victoria, specimens have been referred to Ammonia aoteana (Finlay) (Collins, 1974; Apthorpe, 1980; Bell, 1996), a species of Ammonia described by Finlay (1940) from the south-west Pacific. The lack of strongly beaded sutures on the umbilical side of specimens from Tuross Estuary and Colia Lake, a feature typical of A. beccarii (Linne) sensu stricto (Hayward and Hollis, 1994, Pl. 4 Figs. 1–3), indicates that the specimens of Ammonia from the study area can be assigned to A. aoteana (Finlay).

The material from the study area displays a wide variation in morphology that is characteristic of the species and widely distributed throughout the two
estuaries. The only discernible trend in morphology is a tendency for specimens recovered from localities where marine conditions dominated, such as TL1, to have an umbilical boss. Specimens from slightly brackish localities such as TL3 and TL8, tend to lack this feature. The correlation between the presence or absence of an umbilical boss with prevailing salinity is also a feature that has been noted in variants of Ammonia beccarii (Linne) (Murray, 1979).

Family ELPHIDIIDAE Galloway, 1933

Remarks:
The family Elphidiidae, and in particular the genus Elphidium, has undergone a great deal of reassessment since it was first described by Galloway (1933), with a number of genera of doubtful validity erected within the family. In an attempt to gain standardisation in identification of the members of this family, particularly in Australia, all Elphidiidae in this study were identified following the concept of the family presented by Hayward et al. (1997), except where otherwise noted.

Subfamily ELPHIDIINAE Galloway, 1933

Elphidium de Montfort, 1808

Synonymy:

Type species.
Nautilus macullus var.? Fichtel and Moll, 1798

Elphidium advenum (Cushman), 1922

1922 Polystomella advena Cushman, p. 56; Pl. 9, Figs. 11-12.
1997 Elphidium advenum Hayward et al., p. 64.

Description:
see Hayward et al. (1997), p. 64.

Elphidium advenum advenum (Cushman), 1922
(Plate 3, Figs. 13-14)

Synonymy:
see Hayward et al. (1997), p. 65.

Description:
see Hayward et al. (1997), p. 65.

Remarks:
E. advenum advenum (Cushman) is easily distinguished from other species of E. advenum by its distinctive umbilical boss, which fills the entire umbilical area. The original material illustrated by Cushman (1922, Pl. 9 Figs. 11-12) did not clearly display the presence of an umbilical boss, however it is described in the text as a feature of the species. In a later publication by Cushman (1939), the boss is clearly illustrated. This species has been recorded from a variety of environments, from brackish water intertidal conditions to exposed inner shelf environments (Hayward et al., 1999). E. advenum advenum (Cushman) is found throughout the south-west Pacific (Hayward et al., 1999) as well as the coastline of Australia (Albani and Yassini, 1993).

Specimens of E. a. advenum (Cushman) from the study area differ from the material illustrated by Hayward et al., (1997), in that they have a much weaker keel and are slightly less laterally compressed. Tests of this subspecies were recovered from localities TL1, TL8 and CL2 in both surface and core material. The sites represent a range of environmental conditions, particularly TL8 in comparison to TL1 and CL2, supporting the assertion that this species tolerates a wide range of conditions.

Elphidium advenum macelliforme McCulloch, 1981
(Plate 3, figs. 19-20)

1981 Elphidium macelliforme McCulloch, p. 119;
Pl. 40, Fig. 1
1993 Elphidium macelliforme Albani and Yassini, p. 28; Figs. 65-66
1997 Elphidium advenum macelliforme Hayward et al., p. 68; Pl. 5, Figs. 6-12

Description:
see Hayward et al. (1999), p. 68

Remarks:
This species is distinguished from most other sub-species of E. advenum Cushman by its less inflated chambers and narrower, less incised sutures. It is distinguished from E. advenum limbatum (Chapman) by its distinct umbonal boss. This species is found along the coastline of Australia (Albani and Yassini, 1993) as well as in the eastern part of the Pacific Ocean (McCulloch, 1981). In the study area, this species appears to be only tolerant of marine conditions as specimens were confined to site TL1.

Elphidium crispum (Linne), 1758

Synonymy:
see Hayward et al. (1997), p. 74.
In the study area, *E. c. clavatum* Cushman is distinguished from specimens of *E. lene* Cushman and McCulloch, also found in Tuross Estuary, by its less numerous septal bridges and more numerous papillae. The highest abundance of this species was recorded from locality TL3, indicating it favours middle estuary, intertidal environments. The species is possibly tolerant of a wide range of conditions however, as rare specimens were also recorded from localities TL1 and CL2.

**Elphidium lene** Cushman and McCulloch, 1940  
(Plate 3, Figs. 9-10)

1940 *Elphidium incertum* (Williamson) var. *lene* Cushman and McCulloch, p. 170; Pl.19, Figs. 2, 4.  
1968a *Elphidium poeyanum* Albani, p. 34; Fig. 158.  
1979 *Cribroelphidium poeyanum* Albani, p. 47; Fig. 110-1.  
1989 *Elphidium depressulum* Yassini and Jones, p. 263; Figs. 16.1-16.3.  
1992 *Elphidium poeyanum* Bell and Drury, p. 15; Fig. 4.20.  
1993 *Cribroelphidium poeyanum* Albani and Yassini, p. 17; Figs. 10-15.  
1995 *Cribroelphidium poeyanum* Yassini and Jones, p. 178; Figs. 1074-1075.  
1997 *Elphidium lene* Hayward et al., 1997, p. 84; Pl. 13, Figs. 1-8.

**Elphidium excavatum (Terquem)**, 1875

**Description:**  
see Hayward et al. (1997)

**Remarks:**  
As stated by Hayward et al. (1997), this species is distinguished by its broadly rounded unkeeled periphery, low number of chambers in the final whorl (less than 12) and the presence of papillae of the sides of sutureal pits, the umbilical area and the base of the apertural face. Its distribution is extensive, recorded from a variety of environments worldwide (Miller et al., 1982).

**Elphidium excavatum clavatum** Cushman, 1930  
(Plate 3, Figs. 11-12)

**Synonymy:**  
see Hayward et al. (1997), p. 76

**Description:**  
see Hayward et al. (1997), p. 76

**Remarks:**

*E. excavatum clavatum* Cushman differs from other subspecies of *E. excavatum* (Terquem) because of the intermediate length of its septal bridges, it umbilical collar and the presence of a small umbonal boss (Hayward et al., 1997).

In the study area, *E. lene* Cushman and McCulloch is confined to Tuross Estuary. The highest abundance was recorded at locality TL7, a shallow salt marsh environment but it is also recorded from locality
TL1, where fully marine conditions dominate, suggesting that this species tolerates a wide range of conditions.

**Elphidium macellum** (Fichtell and Moll), 1798
(Plate 4, Figs. 1-2)

**Synonymy:**
See Hayward et al., 1997, p. 84

**Description:**
See Hayward et al., 1997, p. 84

**Remarks:**
This species is distinguished from other species of *Elphidium* by its compressed profile, narrow radial ribs that extend to the peripheral keel and its depressed umbilical area with few irregular papillae (Hayward et al., 1997). Most specimens found in the study area have between 8-10 septal bridges extending across each chamber but rare specimens have less than seven. This species is common of shallow subtidal foraminiferal associations along the eastern Australian coastline. In the study area, specimens are confined to sites were normal marine conditions dominate (TL1, CL2).

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