Macrobenthic community structure in the Fitzroy River Estuary, Queensland

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Introduction

Although it is widely accepted that estuarine ecosystems are highly productive and critical to the maintenance of coastal bird-life and fisheries, very little is known about the invertebrate faunas that inhabit them. Invertebrate organisms play important roles in the diets of many shorebird and fish species, and can profoundly influence the abundance and species composition of these tertiary consumers (Bottom and Jones, 1990; Skagen and Oman, 1996; Stillman *et al.*, 2000). Invertebrates also play an integral role in the recycling of nutrients and conservation of water quality within estuarine systems (Harris, 1999; Peterson and Heck, 1999). Understanding temporal and spatial change in invertebrate community structure, and the factors underpinning them, is therefore essential to the better management of these waterways.

Hutchings (1999) has recently reviewed the knowledge base for macroinvertebrates in Australian estuaries, and has confirmed that most of our taxonomic and ecological understanding stems from only a limited geographical region. Specifically, the review highlights the fact that little quantitative data exist on the biota of estuaries situated outside of the major population centres of south-eastern Australia and particularly the paucity of information on tropical estuaries. In an effort to redress the lack of information on tropical estuarine systems, this study examines the distribution and composition of macrobenthos throughout the saline reach of a large tropical Queensland estuary.

The Fitzroy Catchment is the second largest in Australia and covers nearly 150 000 km^2. Natural flows in the Fitzroy are regulated by a barrage constructed in the early 1970s and located at Rockhampton, 60 km from the river mouth. This barrage prevents any tidal movement of saline water into the upstream freshwater reach of the waterway and allows overflow of freshwater into the downstream estuarine reach during flood events. Freshwater inputs to the system are principally derived from heavy summer rainstorms associated with monsoonal depressions. Cyclonic events within north-eastern Australia occur intermittently, and large inter-annual and seasonal variations in flow are apparent (Faithful and Griffiths, 2000). During severe floods, large volumes of sediment may be transported down river and may have a considerable impact on bottom dwelling organisms. Effects due to shifts in the boundary of the freshwater/saltwater interface are also likely to be significant during such flood events, as estuarine species become subject to less saline conditions. In 1991, spill-water from a major flood broached the barrage at Rockhampton and temporarily transformed the normally fully saline waters of the Fitzroy Estuary into a brackish waterway (O'Neill *et al.*, 1992).

Methods

Field sampling

A survey of spatial differences in benthic community structure within the estuarine zone of the Fitzroy River was conducted from 14–16 November 2001. A total of 16 stations were sampled during the survey (figure 1); thirteen of these stations were located at sites regularly sampled by the EPA for water quality parameters (i.e. Stations 1–13) and the remainder were placed at new locations close to the Fitzroy Delta (Station 14 – Port Alma, Station 15 – Keppel Bay and Station 16 – The Narrows, not shown).

On each sampling date, co-ordinates marking the start and end points of transects running the width of the Fitzroy River at each sampling station were fixed using a differential GPS. Research staff then profiled variations in depth along each transect using an echo-sounder. This profile data was used as the foundation for a stratified sampling scheme designed to limit depth related variations in community composition. The

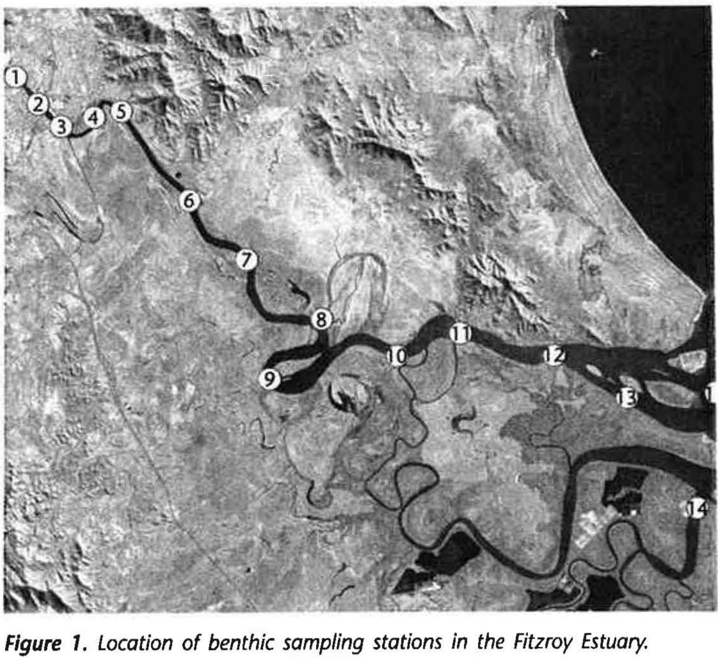

***Figure 1.** Location of benthic sampling stations in the Fitzroy Estuary.*

sampling scheme selected involved the collection of 5 x 0.1 m^2 van Veen grab samples from each transect. Two of the grabs were collected from the intertidal zone on each river bank, two were taken from the 5 m depth zone, and one from the deepest location on the transect. This design makes it possible to examine local ecological gradients occurring within a station, but also permits the assessment of longitudinal variations in community structure over the entire length of the Fitzroy Estuary.

Sediment subsamples (70 ml) were removed from each grab and snap-frozen for metals analysis. The remaining portion of the grab sample was weighed and visually graded into sediment classes before being sieved on a 1 mm mesh screen. All biota retained on the mesh sieve was preserved in 10% formaldehyde solution and later sorted into component species and counted.

While considerable effort was made to ensure that all stations were effectively sampled during the preliminary survey, only 76 of the proposed 80 samples (i.e. 5 grabs from 16 stations) were collected. This shortfall was largely due to localised patches of rock on the river bed which prevented the grab from penetrating the substrate. As a consequence no data are available for two replicate grab samples taken at each of stations 1, 12 and 13.

Statistical analysis

Spatial differences between benthic communities at the 16 benthic sampling stations were examined using Bray-Curtis (B-C) dissimilarity measures (Bray and Curtis, 1957). This dissimilarity measure was chosen because it is not affected by joint absences, it gives more weighting to abundant than rare species and it has consistently performed well in preserving 'ecological distance' in a variety of simulations on different types of data (Field *et al.*, 1992; Faith *et al.*, 1987). Double square root ($N^{1/4}$) transformations were applied to all data before calculating B-C dissimilarity measures. These transformations were made to prevent abundant species from influencing the B-C dissimilarity measures excessively (Clarke and Green, 1988; Clarke, 1993).

Bray-Curtis dissimilarity measures calculated for the stratified sites resulted in a triangular matrix of inter-site relationships. Fifteen grab samples did not contain any benthic organisms and were omitted from the matrix as they could not contribute to the dissimilarity measure. Multidimensional scaling (MDS) was therefore used to map 61 inter-station relationships in two-dimensional space.

The computer package PRIMER (Clarke and Gorley 2001) was employed for the MDS ordinations in this study. The final configurations presented were the best solutions (i.e. exhibited the lowest 'stress' values, or least distortion) from a minimum of 100 random starts.

The statistical significance of regional and depth-related differences in infaunal species abundance and richness was further examined using two-way fixed factor analysis of variance (ANOVA). Homogeneity of variance was examined using Cochran's test and heterogeneity removed from species abundance using a Log10(n+1) transformation.

Results

Depth

Depth profiles in the upper reaches of the Fitzroy River (stations 1–9) are symmetrical in cross-section. Typically depth at these stations increases gradually with increasing distance from the river bank and is greatest in the central portion of the waterway (7–10 m). Further downstream, profiles become distinctly asymmetric and deep channels up to 22 m deep become evident close to the outer banks of large meanders. The width of the river also increases markedly with distance downstream. At 'the barrage' in Rockhampton the river is approximately 200 m wide, at station 9 (which is located about 25 km downstream of Rockhampton) the river is more than 650 m wide and at the river mouth (60 km downstream from Rockhampton) it is almost 9 km in width.

Sediment

Visual classification of sediment samples provides a quick and relatively inexpensive assessment of gross variations in sediment distribution. A summary of sediment distribution within the Fitzroy River system illustrates that within the immediate vicinity of the barrage (which is principally composed of rock and gravel substrates), there is a higher incidence of fine sediment types in the shallow margins of the estuary and a greater incidence of coarser sediment types in the deeper reaches. This distribution pattern is consistent with tidal and freshwater flows being greatest in the deepest reaches of the river and least near the river banks. This qualitative model does not show any distinct longitudinal trends in sediment structure between the upper and lower reaches of the river. It is, however, likely that such trends may be more readily apparent once quantitative assays of frozen sediment subsamples have been completed.

General species observations

A total of 49 benthic species and 7 449 individuals were identified from the 76 grabs processed. The principal phylogenetic groupings represented included polychaetes (19 species), crustaceans (14 species), molluscs (14 species) echinoderms (1 species) and chordates (1 species). Bivalve molluscs accounted for most of the total abundance (~77%), due largely to the presence of one species (the mussel *Amygdalum* cf *glaberrima*). Polychaetes were much less commonly collected (~17% of total abundance), while crustaceans, chordates and echinoderms were the least abundant taxa (~5%, 0.4% and 0.03% of total abundance respectively). Filter-feeding animals were the best represented trophic group in the Fitzroy River and accounted for nearly 80% of the total species. Other groups were less well represented: deposit feeders (18%), predators (1.5%) and scavengers (0.5%). The filter-feeding organisms (principally mussels) were, however, only dominant in the subtidal zone. In the intertidal they were subordinate to deposit feeding polychaete worms, which accounted for more than 80% of the total abundance.

Macrobenthic community analysis

Species level MDS ordination displays differences in community composition between the 61 grab samples that contained infaunal organisms. While some intergrading of grab samples occurs, particularly towards the centre of the ordination, it is evident that stations from the upper and lower regions of the Fitzroy form discrete clusters; grabs taken from the upper Fitzroy form a loose association of points on the left hand side of the plot while those from the lower reaches of the waterway lay towards the right hand side of the plot. Only one grab sample (14C) fails to conform to this polarised model of community structure in the Fitzroy. Grab 14C is located in the centre of the shipping channel at Port Alma and contains only one individual of the predatory polychaete *Marphysa sp.*1. As small numbers of this species are only found in grabs taken from the upper Fitzroy, grab number 14C is plotted at the extreme left of the MDS ordination, at a point furthest removed from those grabs sampled in the lower Fitzroy. While there is a distinct shift in community structure between the upper and lower reaches of the Fitzroy Estuary, this change does not occur gradually with increasing distance downstream. In practice, station locations in the ordination are widely dispersed and do not appear to conform to any geographical order. In addition, there does not appear to be any obvious pattern of changing community structure with depth. Grabs taken from the intertidal, 5 m depth and >5 m depth zones intergrade and do not form any discrete groupings. Bubble plots of species richness, abundance and diversity superimposed on the MDS ordination provide additional insights into the regional differences in infauna community structure between the upper and lower reaches of the Fitzroy River. From this plot it appears that species richness is generally higher upstream, even though elevated numbers of species are occasionally present in grabs taken downstream (i.e. 8 species at Station 15A in the Fitzroy delta, Station 16B and Station 16C in the Narrows). A formal test of differences in species numbers between the two regions confirms that species richness is significantly higher in the upper reaches of the river (3.9 species/grab in the upper Fitzroy vs. 2.5 species/grab in the lower Fitzroy, ANOVA $p<0.05$).

The bubble plot of species abundance exhibit a similar decline in values from the upper to the lower reaches of the Fitzroy. A formal statistical test confirms the significance of this decrease in total species abundance between the upper and lower reaches (167.2 individuals/grab in the upper Fitzroy *vs.* 8.4 individuals/grab in the lower Fitzroy, ANOVA $p<0.05$). It is apparent that much of this regional difference is due to extremely high abundances at a relatively small number of grabs. On closer examination it is evident that most of the difference in abundance between the upper and lower reaches of the Fitzroy is due to elevated numbers of the filter-feeding mussel *Amygdalum* cf *glaberrima* (Stations 1, 3, 4, 5, 6 and 8). This mussel forms dense subtidal mats on the sediment surface and was most prevalent in a grab taken next to the CMG Abattoir outfall (Station 5C, 2095 individuals/0.1 m^2). The mussel was not, however, encountered in any grab samples collected downstream of station 8.

Shannon-Weiner (S-W) diversity indices are commonly used in benthic ecology to assess the relative richness and evenness of species abundance data. Stations with high S-W diversity generally have a higher number of species however the index may also increase as the proportion of individuals per species becomes more constant. In the plot of S-W diversity from the Fitzroy River no patterns are readily distinguishable. On closer examination it appears that the exceptionally low value of S-W diversity in the upper Fitzroy is the result of a combination of low species richness and dominance by one species (*Amygdalum* cf *glaberrima*) at small number of subtidal sites (i.e. 1B, 1C, 3C, 4C, 5C and 6C).

Two-way ANOVAs on location and depth differences

Tests for the effects of depth and sampling location on species abundance reveal that station, depth and the interaction term (station*depth) are all significant. Post-hoc SNK multiple comparison tests confirm that stations principally located in the upper reaches of the Fitzroy have significantly higher Log abundances than stations primarily located downstream (1.35–2.42 *vs.* 0.23–1.00 individuals/0.1 m^2). SNK tests further confirm that Log abundances are significantly higher in the deepest strata of the river (1.5 species/0.1 m^2 at >5 m depth). The same test also indicates that abundances do not differ significantly between the relatively less populated intertidal zone and the 5m depth strata.

Tests for the effects of depth and sampling location on species richness show that there is a significant difference ($p>0.05$) in the number of species between stations but no significant difference in species numbers with depth. Rank orders of station means suggest that species richness is generally higher in the upper part of the river (stations 1–6) and lower in the downstream reaches (stations 10–12).

Water quality

Observed differences in benthic community structure between stations, were further examined in relation to water quality. The Queensland Environmental Protection Agency (EPA) has collected water quality data at stations 1–13 in the Fitzroy since 1990. Using an automated probe, key parameters measured *in situ* have included temperature, salinity, dissolved oxygen and turbidity. In recent years, daily, depth-stratified measurements at each station have generally been collected once each month. As many invertebrate species have relatively short-life spans (months rather than years), only water quality data from 11 sampling dates in a one-year period prior to the benthic survey have been included here (15 Nov 2000, 12 Dec 2000, 17 Jan 2001, 20 Feb 2001, 10 Apr 2001, 22 May 2001, 13 Jun 2001, 3 Jul 2001, 7 Aug 2001, 11 Sep 2001, 20 Nov 2001).

Data for mean station temperature, salinity, dissolved oxygen content and turbidity were recorded. Three of these parameters were found to change significantly (ANOVA, $p<0.001$) along the length of the Fitzroy; water salinity and turbidity generally increased with increasing distance downstream, while the concentration of oxygen generally declined. Temperature did not differ significantly between stations when formally tested (ANOVA, $p=0.6609$), however a plot of this variable strongly suggests a trend of decreasing temperature with increasing distance downstream.

Discussion

Subtidal macrofaunal communities in the Fitzroy Estuary were dominated by the filter-feeding mussel *Amygdalum* cf *glaberrima*. This small mollusc species (<1.5 cm length), which forms dense beds on the sediment surface, was solely restricted to upper reaches of the estuary. Several physical, chemical and biological factors might explain this discontinuity, although the relative importance of such factors in the distribution of *Amygdalum* cf *glaberrima* is difficult to assess. Unfavourable salinity regimes, dissolved oxygen contents and temperature are simply a few water chemistry parameters that might preclude the distribution of *Amygdalum* cf *glaberrima* from the lower Fitzroy. The speed of the bottom current and its effect on the particle size of the sediments (both suspended and deposited) are also likely to be major factors in determining the geographical limits of this species in the Fitzroy. It is, however, the availability of suspended particulate food matter in the upper Fitzroy that potentially has the greatest influence on density and distribution of this suspension feeding bivalve. Many filter-feeding bivalves flourish in organically enriched environments (Taylor, 1997), and it is probably quite significant that the highest recorded biomass of this species (118 g wet wt per 0.1 m^2) was obtained from a grab sample taken adjacent to the CMG Abattoir outfall on the eastern outskirts of Rockhampton. According to the National Pollutant Inventory Database approximately 120 tonnes of total nitrogen was discharged into the water column at this location during the 2000/2001 financial year (Environment Australia, 2002). This nitrogen emission is more than an order of magnitude greater than that discharged from a nearby municipal sewerage works over the same period and clearly represents a significant point source for organic enrichment within the Fitzroy Estuary. It is suggested that stable nitrogen isotope tracers could provide a mechanism for a more exact explanation for the elevated abundances of *Amygdalum* cf *glaberrima* in the upper Fitzroy Estuary.

Amygdalum cf *glaberrima* was only rarely encountered in the intertidal sediments of the Fitzroy and it appears as if this species is poorly adapted for life between the tide-marks. Visual assessments of sediments from the intertidal reveal that bedforms comprising the river banks are principally composed of silt and clay fractions. As fine particulate matter only settles in calm water, it is apparent that the nearshore waters of the Fitzroy, and the intertidal zone in particular, are infrequently subject to strong tidal currents. Under such conditions organic debris readily settles and the organic content of the intertidal sediments is likely to be markedly elevated. While there is potentially for an increased bioavailability of food for infaunal organisms inhabiting the intertidal zone of the Fitzroy, this does not in practice result in elevated species abundances and biomasses in the intertidal. Deposit feeding polychaete worms (*Scoloplos simplex* and *Platynereis* sp.) dominate the intertidal sediments of the Fitzroy Estuary, but never attain densities as high as that of the subtidal mussel *Amygdalum* cf *glaberrima*. The trophic implications of this finding are *prima facie* that bottom-feeding fish (i.e. mussel-eating species including catfish) probably benefit most from primary productivity within the estuary, while wading-birds (particularly those species dependant on invertebrates) probably do rather poorly. It should, however, be stressed that this survey has only considered large macrobenthic organisms (>1 mm diam.). Standing stock and productivity of smaller meiofaunal organisms (<0.1 mm diam.) could well exceed that of the intertidal macrofauna and therefore promote quite different trophic outcomes.

While the identities of several benthic organisms collected in the Fitzroy Estuary appear to conform morphologically with native species, not all specimens are readily identifiable. Most infaunal organisms collected in the Fitzroy occurred at very low abundances (90% of species, <1 individual per 0.1 m^2) and because no historical sampling of benthos has been conducted, it is conceivable that some of the organisms encountered during the survey are either endemic to the water body or quite possibly exotic introductions. This latter option is presently receiving considerable international research interest, as the magnitude of impacts caused by introductions on native species become more apparent. Exotic species alter natural interactions in the invaded ecosystem and when present in high numbers, can compete with and even displace native organisms (Carlton and Geller, 1993). In view of the relatively low abundances of most species collected in the Fitzroy, it is unlikely that any exotics present are having a significant ecological impact. Nevertheless, it is clearly important from a precautionary perspective that the identities of all organisms encountered within the Fitzroy are resolved quickly.

Further reading

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