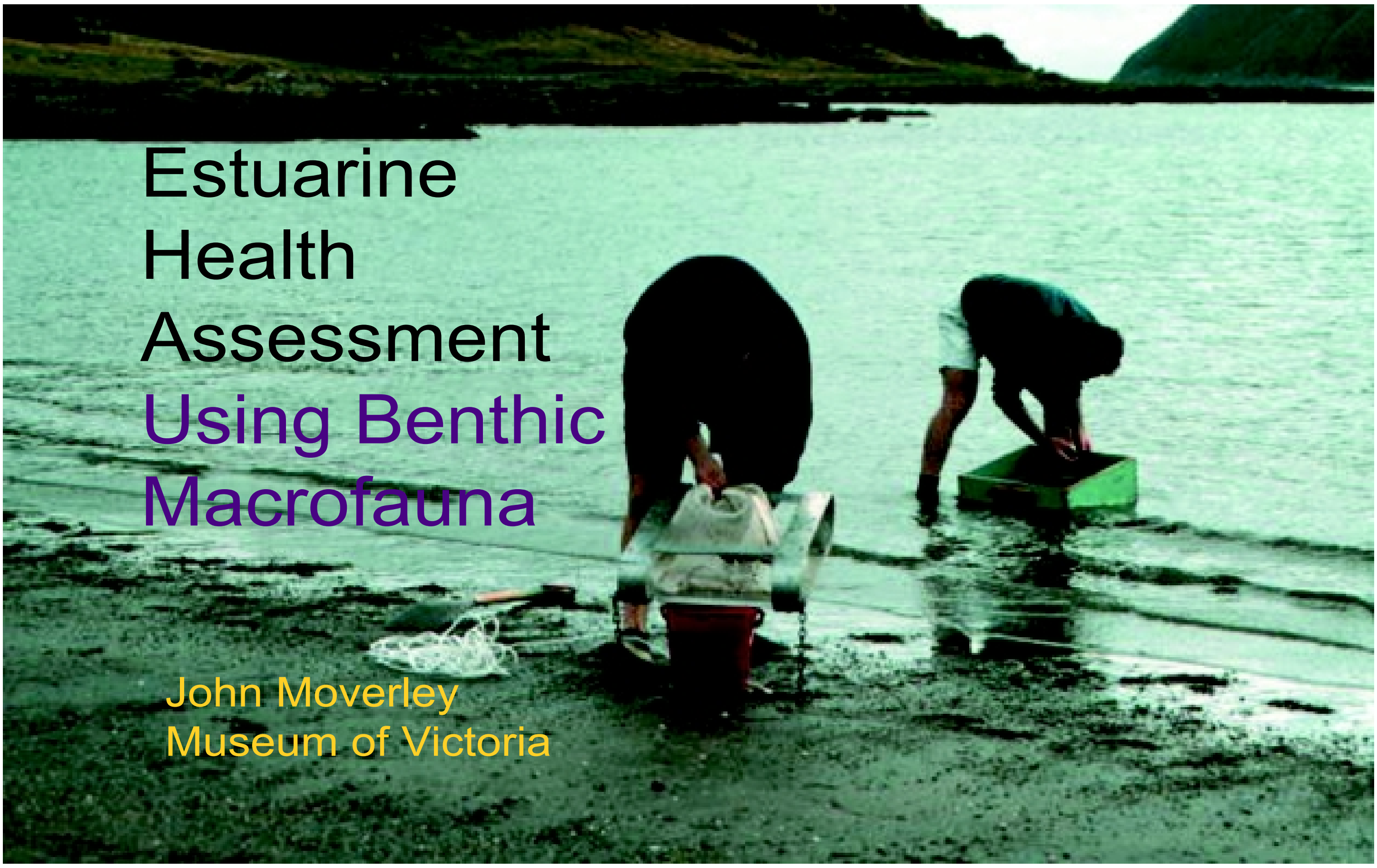

Estuarine Health Assessment Using Benthic Macrofauna

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Introduction

Estuaries are home to a variety of animals and plants the least conspicuous of which is the benthos, the animals living in the sediments of the estuarine floor. The diversity and abundance of the benthos can indicate the overall health of the estuarine ecosystem. This project evaluates whether computer models applicable in river systems for the assessment of environmental health could be applied to Australian estuaries.To achieve this two questions needed to be answered. 1. Can such models be constructed for Australian estuarine habitats? 2. Would these models be useful for assessing estuarine environmental health?

What is an estuary?

The estuarine habitat is poorly defined. Different scientific disciplines define estuaries by geographical, topographical, chemical, biological and hydrographical terms. People from different disciplines draw different boundaries and there is even conflict as to whether a body of water is an estuary. For example it is frequently argued that only waters with diluted sea water and regular tidal influences can be estuaries. This would exclude many Australian river mouths because they have closed bars, and thus are not subjected to tidal influences, and/or the evaporation rate exceeds fresh water input so they become hypersaline.

Problems with defining the estuarine habitat were highlighted during the early 1990s in the United Kingdom when, due to there being different regulations for the discharge of effluent into estuarine and coastal waters, courts were required to assess whether discharges were estuarine or not. There is no official definition of an estuary in Australia and this is needed before estuarine health monitoring can be undertaken. For the purposes of this study, we assumed estuaries were the coastal plain regions of streams whether they openly discharged into the sea or formed a coastal saline lake that was intermittently open to the ocean.

What are benthic macrofauna?

Benthic animals are those associated with the bottom of seas, rivers, lakes, etc. Epibenthos lives on the surface and infauna buried within the sediment. Macrofauna is larger and meiofauna smaller. We considered only macrofauna, multicellular animals retained on a 1.0 mm sieve except nematodes and copepods. Nematodes and copepods are the major component of meiofauna and only a small proportion are retained on a 1.0 mm sieve.

Choice of sieve aperture is arbitrary. We used a 1.0 mm sieve because in estuarine sediments there are large amounts of organic detritus which needs to be sorted under a microscope to find the animals. Samples collected with a 0.5 mm sieve take 3–4 times longer to sort and many of the extra animals retained are juveniles that can not be identified to species.Since this work required identification to species it was more appropriate to use a 1.0 mm sieve and sort a larger sample.

There are advantages in using benthic animals for monitoring estuarine health over plankton or fish that live in the water column. Benthos lives essentially in a 2-dimensional dispersal. This makes sample design easier. The distribution of plankton and fish is influenced by tides and diurnal cycles which are additional factors to be considered when sampling these groups. Also, because of their low mobility, benthic animals take some time to recolonise an area after a pulse or intermittent pollution event. Therefore past events can be detected using the benthos which may not be detectable in more mobile plankton or fish.

During our survey 44,477 animals belonging to 275 taxa were collected. The most common group were annelid worms (33% of species, 20% of individuals), crustaceans (32% of species, 43% of individuals) and molluscs (18% of species, 30% of individuals). Unlike the river samples where insects are an important component of the benthos, insects made up only 4% of the species and 2% of the individuals in the estuarine samples.

What is an AusRivAS-type approach to environmental health?

The AusRivAS (Australian River Assessment System) method for assessing environmental health of our rivers was described by Richard Norris in his article 'Bugs and Computers' in the Summer 1999 edition of Rivers for the Future. The method provides a technique that allows managers to compare the environmental health of a river or specific site with reference sites.

Using a database of species and abiotic variables at reference sites, an AusRivAS computer model predicts the probability of collecting each species from a test site based on the site's abiotic variables. This information can then be used to assess the environmental health of the test site by dividing the number of species observed in the sample by the number of species expected to occur, the O/E ratio. Assuming the model is reliable, an O/E ratio of one is anticipated and any divergence indicates an environmental perturbation.

The model is most accurate for the most abundant species so we based predictions on species with a 0.5 or greater probability of being collected.

In the river health project pristine or near pristine reference sites are used. It is not possible to find pristine or near pristine estuarine sites because the catchments of most Australian estuaries have been modified by urban, agricultural, pastoral or forestry activities. Even where the catchment is included in national parks the collection of bait and fish, the upper level preditors, occurs. Therefore, at best, an AusRivAS approach to assessing estuarine health would only be able to compare reference sites from estuaries with low levels of environmental impact or to make temporal comparison to assess how environmental management practices were affecting species richness within estuaries.

Findings

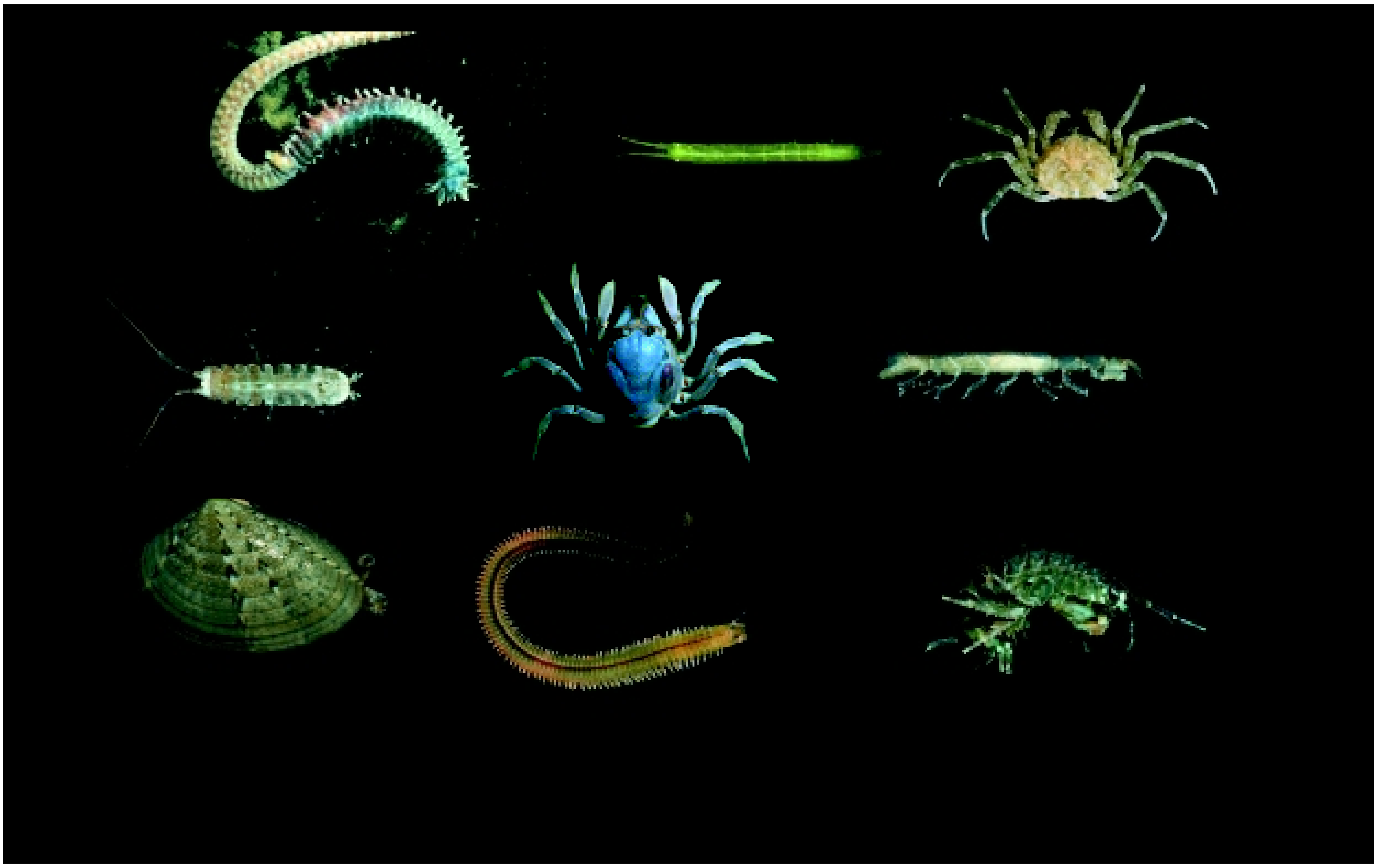
Samples were collected from 89 sites in upper, mid and lower reaches of 30 randomly selected estuaries in Victoria and southern NSW (to Batemans Bay). At each site two methods were used to collect samples. An Ekman Grab was used to target infauna and a dredge for epibenthos. It was intended to use these as separate data sets to investigate which was the most appropriate sampling method. However, neither method collected sufficient numbers of species per site to develop an AusRivAS type model. To overcome this we amalgamated the two data sets. This was possible because AusRivAS type models require only that a standard sampling method be employed and uses presence/absence data rather than abundances of the different taxa.

Almost a fifth of the estuaries visited were 'layered'. These did not have tidal mixing because the mouth was closed and had only limited opportunity for wind mixing because they were narrow, i.e. they did not flow into coastal lakes. Layered estuaries usually had fresh water on the surface and a submerged body of denser brackish water. Probably because of the low availability of oxygen, such estuaries had very sparse macrofauna, with numbers in samples being too low to give an accurate representation of the community. Data from some other sites were excluded from model construction due to incomplete biological or environmental data. The pilot model was based on 58 sites. This compares with several hundred reference sites in most AusRivAS models. Nevertheless, with the exclusion of the layered estuaries we found that our model was relatively accurate in predicting O/E ratios for our test sites.

The second part of our project was to assess if an AusRivAS type model would be of value for monitoring estuarine health. Sensitivity in detecting environmental impacts depends on the number of expected taxa in the O/E ratio. If there are 20 expected taxa, a 25% species loss results in the observed taxa being 15. A loss of five taxa would be seen as significant. However, if there are only four expected taxa, a 25% loss is the disappearance of only one taxon. This may be due to chance. Even a 50% loss of expected taxa is a decrease of only two taxa which would probably not be considered significant. With an expected number of four taxa, a loss of 75% would "set alarm bells ringing". But at this stage the environmental degradation would probably be obvious and not require the collection and sorting of samples.
The numbers of expected taxa for our six test sites ranged from 4 to 13 with the median being 6.6. These are too low for the model to be of practical value. Without any additional work the numbers of expected taxa could probably be increased slightly by using a different sampling design from that in the pilot study. However, to increase the numbers of expected taxa to values similar to those in the river models would require a massive sorting effort.

Another problem to be addressed before an AusRivAS approach could be used in estuarine health monitoring is to understand seasonal patterns in estuarine benthos. In southern Australia estuarine macrobenthos shows strong temporal but not seasonal variability. In tropical and subtropical estuaries there are strong seasonal patterns in numbers and diversity, though numerically abundant taxa change from year to year. When using AusRivAS models to assess river health it is assumed similar seasonal patterns exist from year to year. Consequently, providing they are all collected in the same seasons, the reference samples and test

Some benthic macrofauna - photographer Michael Marmach, Museum of Victoria



samples do not have to be collected in the same years. At least in southern Australia this may not be true for estuaries, so that a new set of reference samples would need to be collected whenever a test was required. This would be prohibitively expensive.

Considering that the AusRivAS approach could not be used in all estuaries and that the sampling effort required to give reliable data would be relatively expensive, it was decided to review other options for looking at estuarine health. Environmental health can be indicated by the macrobenthos community structure; the number of species present, the distribution of individuals among the taxa, the proportion of rare taxa, etc. Such community descriptors can be depicted graphically in *k*-dominance curves, plots of cumulative percent abundance versus species ranked from most to least common. The problems with using *k*-dominance curves for assessing national or regional environmental health is that only a limited number of curves can be compared on each plot.

Our field work generated a large database that could be used to construct *k*-dominance curves for Victorian and southern New South Wales estuarine communities. We investigated multivariate analysis to compare large numbers of curves with each other and test sites. Community indices, many of which described the *k*-dominance curve provided a multivariate ordination analysis of the samples. The ordination plots could be divided into sections containing communities indicative of good, questionable and poor environmental health.

We demonstrated that this ordination method could be used to rate samples from estuaries elsewhere in Australia. Following improved treatment of effluent being discharged from a Tasmanian pulp mill over time there was a clear movement from communities indicative of poor and questionable environmental health to good environmental health. When analysed with the south eastern Australian data, samples from Western Australian and Central Queensland estuaries were also found to fit into the same pattern with samples indicative of stressed communities falling in the same part of the ordination.

Temporal samples collected from the Calliope Estuary at Gladstone, Queensland, showed that frequently sites moved from having an unstressed healthy community to a stressed community, and vice versa. This probably indicates natural high variability in the estuarine environment and is a problem that will plague any attempts to assign estuarine communities into stressed and unstressed states of health. Our work with *k*-dominance curves from these four Australian states suggested that at any one time approximately 15% of Australian estuarine macrobenthic communities indicated they were collected from environmentally stressed sites, 15% had communities indicative of possible environmental stress and approximately 70% of estuarine macrobenthic communities indicated a healthy and unstressed environment. We do not know if these ratios are natural or the result of present day modified estuarine environments.

Our project demonstrated that AusRivAS type models can be developed for Australian estuarine environments but suggested that for the macrobenthic communities more work would be required to increase the numbers of taxa expected to occur in samples. The work demonstrated that an AusRivAS approach does generate a data set that allows regional and national assessment of estuarine health. It is worth investigating if estuarine health could be better assessed using an AusRivAS type model using meiobenthos rather macrobenthos.

Our work has also shown that it is relatively easy to assess estuarine health using *k*-dominance curves with samples collected by different methods at different times and from different regions. Such samples were shown to be good for monitoring an improvement to environmental health. Presumably they could also be used to detect deteriorating environmental conditions. This method appears ideal for assessing how catchment management programs are influencing estuarine communities.

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