The Intertidal Zone

Benthic ecology and the effects of grain size

Michelle Wilkinson

Recent NIWA experiments have shown how a combination of habitat type and adult population level can affect settlement by juveniles of some shellfish species. The findings have important implications for the management of New Zealand's intertidal zone – the coastal strip which lies between high tide and low tide.

NEW ZEALAND's intertidal zone is many thousands of kilometres long and varies in width from several kilometres to less than a metre. Until recently it was affected by more than 30 Acts of Parliament (most of which have now been replaced by the Resource Management Act) covering subjects ranging from wildlife, sand drift, swamps, historical sites and marine mammals to fisheries, mining and forests. It may seem that this relatively narrow strip of land and water is over regulated. However, this interface helps to determine the condition of our harbours, estuaries and seas, so there is obviously a need for careful management.

Biological monitoring

Experiments can show that factors such as chemical contaminants, sediment grain-size changes and hydrodynamic changes may alter important ecological interactions in the intertidal zone.

However, in order to understand the subtle effects of gradual changes in physical and environmental factors on ecological communities, biological monitoring of the area is essential.

Monitoring programmes can provide valuable information on long-term trends and the natural variability of communities in terms of both species composition and abundance of individual populations. Biological monitoring allows us to detect changes in the environment that deviate from the common pattern, and helps us to identify possible problem areas worthy of more specific study. Through the interpretation of data from monitoring programmes, we can obtain a greater understanding of the interactions both within species and among species.

Biological monitoring is an important component of environmental assessment and prediction. It provides a link with specific laboratory tests (e.g., toxicity tests) and experiments (such as the one described in the accompanying article) which enables us to make predictions of community or population level responses to pollutants and disturbance.

The benefit of this "community level analysis", compared with tests on particular species, lies in the fact that species differ in their tolerance to pollution and disturbance. Some will decrease in abundance whilst others will benefit from the changes in environmental conditions.

One of NIWA's current research projects aims to improve our understanding of the effects of small changes in the physical environment on intertidal benthic (bottom-living) communities. Through experiments, we can demonstrate how changes in factors such as sediment grain size may influence important ecological interactions. Ultimately, this work will help us both to identify and to predict undesirable effects before they become catastrophic.

What influences intertidal communities?

Several factors are important in determining the structure of intertidal communities.

Biological factors

The main biological factors that act to structure sand flat communities are: species interactions (e.g., competition, predation); recruitment/settlement of juvenile organisms; food resources; and disturbance caused by, for example, burrowing activity.

Physical factors

One of the physical factors most important to the distribution and abundance of organisms is sediment grain size. Its significance rests with its effect on water retention and its suitability for burrowing. For example, fine sand tends to hold water in its interstitial spaces after the tide has retreated. Coarse sand and gravel, on the other hand, allow water to drain away quickly. Therefore, fine sand provides more protection against desiccation than coarse sand, making the latter less hospitable. Fine sand and mud are also more suitable for burrowing than coarser sediments.

Human and environmental factors

Environmental effects on the intertidal zone which are often caused by human activities fall broadly into four categories: sedimentation, nutrient input, contamination and habitat modification. Some impacts may be exaggerations of environmental conditions which occur naturally. One such case is increased sedimentation, the focus of this NIWA study.

Increases in both suspended sediments and sea floor sedimentation can have direct and adverse effects on plants and on suspension-feeding organisms such as bivalve molluscs and some polychaete worms. Suspension-feeding bivalves can have a major influence on energy flows and plankton population dynamics of coastal ecosystems, so any effect on these organisms may potentially affect the whole harbour ecosystem.

Suspended sediments also alter water clarity. Reduction in light penetration reduces photosynthetic activity and, therefore, the productivity of a system.

The areas most prone to sedimentation are sheltered inlets and harbours and these are areas where extra inputs may commonly be expected from human activity.

Sand versus mud

Sand flats occur in areas of the intertidal zone that are exposed to wave activity as the tide comes in. Mud flats are generally restricted to intertidal areas completely protected from open ocean wave activity. However, no sharp boundaries exist between sand and mud flats and their associated communities. With decreasing wave action benthic sediments accumulate more organic matter and finer particles, thus becoming more "muddy". As sand flats blend into mud flats, the fauna and flora also gradually change from organisms typical of open sand beaches to those typical of mud flats.

The best-developed mud flats occur in various partly enclosed bays, lagoons, harbours and estuaries where there is a source of fine-grained sediment particles. These areas are more stable than beaches and sand flats and are more conducive to the development of permanent burrows.

The very fine particle size coupled with the very flat angle of repose of muddy sediments means that the water does not drain away from the substrate. The resulting long retention time for water, together with poor interchange of the interstitial water with the seawater above and a high internal bacteria population, usually results in complete depletion of the oxygen (i.e., anaerobic conditions) in the sediments below the first few centimetres of the surface.

Permanent burrows in the mud .

Worm tubes on a sandflat.

This is one of the most important characteristics of a mud flat which distinguishes it from a sand flat.

To survive while buried in the substrate, organisms must either be adapted to live under anaerobic conditions or must have some way of bringing the overlying surface water with its oxygen supply down to them. The latter is the most common adaptation.

Adult–juvenile interactions are important

For soft-bottom marine environments it has been recognised for some time that interactions between established adults and settling larvae are very important in determining population and community dynamics.

Such interactions can include: ingestion of the larvae by the adults; interference by increased sediment mixing resulting from, for example, the digging of burrows; modification of local flow patterns by either physical structures (such as bivalve shells protruding above the sediment surface) or feeding currents; the provision of refuge from predation; chemical cues.

Thus, the adults may either help or hinder settling juveniles. What happens often depends on the density of the adult population, but differences in habitat may also help determine the outcome of these interactions.

Many sediment-dwelling species (e.g., the cockle *Austrovenus stutchburyi*) can tolerate a variety of physical conditions in intertidal and shallow subtidal habitats. This fact emphasises that variations in biological interactions associated with differences in habitat may represent an important factor in determining the composition of soft-bottom communities.

The supply of larvae provides a framework for all subsequent interactions within these communities. Clearly, larval supply is affected by hydrodynamics (i.e., the movement of water – currents, waves and tides). This may also affect the density and mobility of post larval stages. A variety of species exhibits secondary dispersal and settlement behaviour (i.e., they settle as larvae but move again as juveniles). Some larvae may be transported along beaches and sand flats in sediment disturbed by wave action.

Thus, hydrodynamic processes not only influence sediment grain size, but also may be important in affecting the strength of biological interactions. For example, if the post-settlement mobility of the juveniles of a species is largely passive, then in areas with greater wind-wave exposure the strength of biotic interactions may be expected to be weaker than in calmer areas.

New research: Manukau Harbour

Manukau Harbour, which lies to the south-west of Auckland, is made up largely of intertidal sand flats with mud flats in areas of reduced water movement, such as in inlets and behind bridges, causeways and mangroves.

With increased sedimentation and habitat modification due to building construction, further areas of sand flat may be prone to enhanced siltation.

In a recent study we assessed the interactions amongst bivalves and new recruits by comparing experiments conducted simultaneously at two sites which differed in exposure to wind-generated waves in a harbour environment. The more exposed site was predominantly sandy and the other was muddy.

Adults of two common species were used: the deposit-feeding wedge shell, *Macomona liliana*; and the suspension-feeding cockle, *Austrovenus stutchburyi*.

At both sites plots of substrate were sieved through a 4-mm mesh to remove all existing shellfish, empty shells and shell hash. The plots were then "replanted" with various combinations of a range of densities of adult *M. liliana* and *A. stutchburyi* and also empty articulated shells. The empty shells were used so that we could discriminate between the active effects of live bivalves and the effects of the presence of their shells alone (which are known to influence boundary flow and sediment stability and to provide refuge from predators).

These patches were sampled after 3, 6 and 9 weeks by taking one small core from each plot. To prevent the core holes from influencing local hydrodynamics, they were refilled with sediment which had previously been collected from the vicinity of each site and stored frozen.

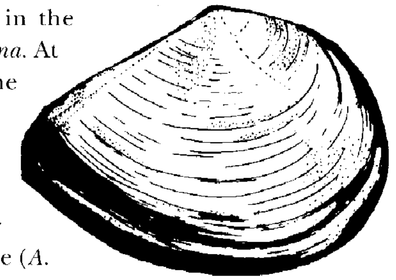
The core samples were "fixed" to preserve any living material, then sieved through a fine screen to extract small bivalves. We found only three species in numbers great enough for statistical analysis: *M. liliana, A. stutchburyi* and the nut shell, *Nucula hartvigiana*.

Juvenile recruitment changes

Our results demonstrated that the strength of the adult–juvenile interactions varied between two adult species with markedly different feeding strategies.

Variations in the density of adults of the deposit-feeding bivalve (*M. liliana*) significantly affected settlement of *M. liliana* and *N. hartvigiana* juveniles. But increasing densities of these adults had opposite effects in sandy and muddy substrates. Settlement of juveniles was inhibited by adult *M. liliana* at the sandy site. Here, the highest density of recruits occurred in the treatments containing no adult *M. liliana*. At the muddy site, however, we found the highest numbers of recruits in the plots containing high densities of adult *M. liliana*.

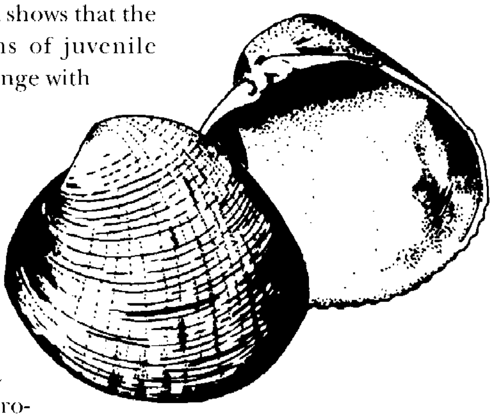
Wedge shell
Macomona liliana
(actual size 40-65 mm)



On the other hand, variations in density of adults of the suspension-feeding bivalve (*A. stutchburyi*) had no significant effect on the numbers of juveniles settling at either site.

This study has helped to illustrate the effects of habitat modification, specifically grain size and hydrodynamic changes, on the bivalve species that live within the sediments. It shows that the success of a species, in terms of juvenile recruitment to an area, may change with the move to finer sediments.

Cockle
Austrovenus stutchburyi
(actual size 50-60 mm)

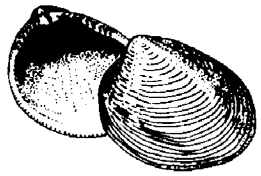


Future research

Further studies are needed to identify the actual mechanisms involved. In particular we are interested in the interaction between post-settlement movement associated with hydrodynamic activity (such as sediment transport) and biological interactions (such as the adult–juvenile interactions described above).

The changes in the direction and strength of ecological interactions from the sandy to muddy sites has implications for highlighting how changes in community composition may result from changes in sedimentation or hydrodynamic regimes associated with the development of coastal and harbour environments. ■

Nut shell
Nucula hartvigiana
(actual size 6-8 mm)



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