Environmental Engineering in action: enhancing marine biodiversity within the Long Bay-Okura Marine Reserve

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Abstract: A project to determine the suitability of artificial reefs to accentuate biotic rebound of marine organisms within a degraded environment has been undertaken in New Zealand. This involved construction and deployment of 24 concrete "Reef Balls" within Auckland's Long Bay–Okura Marine Reserve. The success of the project was determined by analysing settlement and colonisation rates of sciaphilic organisms on the new reef.

Keywords: Artificial Reef, Reef Balls, Marine Reserve, Environmental Engineering

1. Objectives

1.1 The Long Bay Marine environment

The Long Bay-Okura Marine Reserve was formally established on the 9th of November 1995 and is located on the northeastern boundary of North Shore City (the first marine reserve in NZ in an urban environment). It is a moderate-low energy coastal environment with a complex array of habitats, but predominantly of platform reefs (of siltstone/sandstone flysch) and sand flats. The creation of the reserve resulted from growing public concern about continual degradation of the marine environment (pollution, over-exploitation of resources etc).

North Shore City is one of the fastest growing urban areas in New Zealand. Growth here has outpaced effective planning, leading to a number of environmental problems including sewerage overflows and stormwater runoff in the surrounding marine environment (Buckeridge 1999). Further, it is planned to subdivide the Long Bay rural hinterland to cater for increasing growth in the North Shore region. This will undoubtedly have a negative impact on the local marine environment and Long Bay-Okura Marine Reserve.

While there is plenty of anecdotal evidence to suggest that the marine environment at Long Bay is degrading (Buckeridge 1999), there is sparse scientific research and evidence stating the extent of this degradation (most monitoring occurring post 1990). It is imperative that research be undertaken within the Long Bay reserve, to provide a greater understanding of the environmental conditions and to give us knowledge on how to redress/rebalance the damage caused by human activity over the last few decades.

1.2 Enhancing the marine environment at Long Bay

One system used overseas to speed up the enhancement of the environment is the creation of artificial reefs. Reefs are very productive ecosystems providing bio-diverse environments. They ultimately create their own ecosystems giving structure to the seafloor, providing shelter for fish and other species, and a place for algae and invertebrates to grow and colonise. The amount of available reef (or hard substrate) is a key factor limiting marine biodiversity. By increasing the amount and quality of available habitat, the carrying capacity of the environment is raised and a subsequent increase in the marine biomass and biodiversity can be expected (Polovina 1994).

Marine structures have a recognised potential to attract and concentrate fish and other marine organisms (Bohnsack 1989) and to enhance populations (Pickering *et al* 1996). As a way to increase the numbers of fish and repair damaged reefs, man has created artificial reef systems which may comprise scrap materials and 'materials of opportunity' (concrete blocks, car tyres etc), or specially designed reef systems that mimic natural reefs (Pickering *et al* 1996).

The basis of this project was to create and place an artificial reef in the Long Bay Marine Reserve using an American system called ‘Reefballs’. Using 24 Reefballs, two small patterns of reef (12 a piece) were created and placed approximately 500m offshore in 6m of water (at low tide) at the North end of the marine reserve. This reef was monitored by recording the colonisation and settlement rates of sciaphilic organisms. From this we hoped to make informed decisions on the effectiveness of artificial reef construction in New Zealand, and gain some understanding of the state of the environment in the Long Bay Marine Reserve.

Locating the artificial reef within a “no take” marine reserve allows this project to be studied and monitored without having to account for the negative human impact, particularly avoiding damage caused through fishing methods such as dredging.

2 Methodologies and Constraints

2.1 Legal: Consent constraints

This project is the first in NZ involving the creation and placement of an artificial reef within a marine reserve. There are restrictions on the use of the coastal marine area under the Resource Management Act 1991 (RMA). The placement of an artificial reef in the Long Bay-Okura Marine Reserve affects Section 12(1) and Section 12(2)(a) of the RMA, requiring resource consent from the Auckland Regional Council (ARC) before the project could proceed.

(a) To place artificial reef structures on the seabed and disturb the seabed in accordance with Section 12(1) of the Resource Management Act 1991

(b) To occupy part of the coastal marine area with these structures in accordance with Section 12(2)(a) of the Resource Management Act 1991.

As applicants we were required to “show that the adverse effects on the environment of the activity for which the permit is sought will be satisfactorily avoided, remedied or mitigated, and abide by a set of conditions laid out by the ARC”.

As well as a resource consent from the Auckland Regional Council, which involved consulting local iwi (Ngati Whatua, and Te Hao o Ngati Whatua), it was necessary to gain consent from the Department of Conservation (DOC) who administer the marine reserve. To help with the consent process, extensive local support was provided from local dive clubs, the Marine Education and Recreation Centre, Long Bay College, and from environmental lobby groups such as the Great Park Society and the East Coast Bays Coastal Protection Society. All consent applications were approved by the 24 April 2001.

2.2 Technical: Technical and Environmental Limitations

In order to gain resource consent, the Reefball (RB) design had to demonstrate that the finished RB’s would be non-toxic in the marine environment, and would be structurally stable over the short to medium term (note, after about a decade, it is anticipated that organic encrusting growth would permanently stabilise the structures).

Concrete is both brittle and has low tensile strength. In terrestrial situations, this weakness is overcome by steel reinforcing. However, steel in the oxygen rich marine environment is likely to rust and thus expand destroying the RB’s.

The decision was made to avoid steel reinforcing and other non-ferrous options were considered. It was concluded that mix design alone could result in a RB of sufficient structural integrity to survive over the medium term.

A Reefball (RB) is a semi-spherical concrete structure with a hollow center and a series of circular holes (fig 1). RB's come in a number of sizes ranging up to 1.8m in diameter and 1.2m high. For this project three fiberglass RB moulds were obtained consisting of two different sizes: Bay Ball 2X(600X800mm moulds) and the Pallet Ball 1X(800X1000mm moulds). From these, 24 Reefballs were constructed with between 10-20 holes in each. Concrete is poured into a fiberglass RB mould over a central internal bladder (a large polyform buoy which creates the central hole) and a series of smaller outside bladders (to create outside holes). When the concrete has set it is given a rough surface texture by waterblasting and then cured to full strength. The RB's were aged for at least a month before being deployed. After transport to the beach, central rubber bladders were inserted and inflated. Additional bladders were attached externally. When buoyant the RB's were towed out to the site, at which point the bladders were deflated, and the RB's placed on site with the help of SCUBA divers.

The benefits of using RB's over other reef systems are that they are created from environmentally friendly concrete and contain no harmful toxins and metals. Other factors favouring the use of Reefballs are that they are portable, cost efficient, and stable in the environment.

Fig1: Reef Ball

2.2.1 Concrete mix design:

Compression tests lead to a choice of 19-mm basalt aggregate with a chip and pebble content. This affords a mixed, rough exterior, which is largely "natural rock" after waterblasting, thus reducing the surface pH increasing effect of the cement. Standard Builders Mix with a 1:4 cement: mix ratio and a 0.4: 1 water: cement ratio proved the optimum mix with no additives. Using a microsilica additive increased both the strength of the mix (reducing the need for reinforcing) and significantly reduced the surface pH and porosity, keeping the surface pH as close as possible to the pH level of seawater. All of the units poured used an 8% microsilica (by mass of cement) and a small amount of polycarboxylate superplasticiser (no toxic effects from this additive are known). The superplasticiser is essential to make the strong microsilica concrete workable. The compressive strength of this mix at 28 days was >60 MPa.

The strength of the concrete and weight of the RB in water, combined with the holes (allowing water to flow through), enhanced the RB's stability. The low center of gravity reduces the tendency for the RB's to roll or tumble. The area selected is not a high wave energy region so significant movement is thought unlikely in waves and storms. The smaller external holes also create shelter for the smaller marine organisms from larger predatory fish, and create vortexes, which feed the invertebrates.

3.Colonisation Results:

3.1 Bottom Conditions:

The sites selected have bottom sediments classified as grey-brown shelly muddy fine sand. Sediments around the Reefballs contain a larger amount of fine silt than could be expected in this environment (Buckeridge *pers. obs*). The origin of this is probably urban run-off. There are large numbers of empty bivalve shells on/near the surface.

3.2 Settlement into sediment:

After 12 months there was little appreciable settlement into the sediment and no appreciable lateral movement. Approximately 10cm of sediment was scoured out around the Reefballs probably due to currents associated with longshore drift. This occurred since June 2002 during the winter season. During the monitoring period there were storms with nor-east winds gusting up to 100 kmh^{-1} which had little effect on the RB's

3.3 Overall change in biota:

New species have either migrated from other parts of the marine reserve, or have settled from the moving water body (A combination of both is probable). The latter group probably would not have colonised the area if the Reefballs had not been present. Colonisation had begun within a few days of deploying the first Reefball.
The two reef patterns have been submerged for almost a year and are well colonised. Hard surfaces are colonised firstly by planktonic organisms, e.g. pelagic phytoplankton. The first settlement to be observed (after a period of about 6-7 days) was a microfilamentous brown algae (unidentified, but common in the Gulf). The next colonising organisms are vagrant (and opportunistic) benthos, such as the cushion star

Patiriella regularis, the hermit crab *Pagurus* sp. c.f. *P. novaezelandiae* and herbivorous gastropods like the whelk *Cominella adspersa* (egg cases of the latter were recorded on a number of the Reefballs). Concurrent with this, nektonic organisms like the Spotty (*Notolabrus celidotus)* and Triplefins: (*Fosterygium varium* and *Fosterygium* sp.) feed on small invertebrates and graze on the algae. The next wave of colonisation observed was that of sciaphilic invertebrates such as barnacles, oysters, mussels and polychaete worms. Sponges (*Porifera*) have recently become more dominant and growing numbers of Jewel sea anemones (*Cnidarians*) are colonising the Reefballs.

The Reefballs increased the marine biodiversity in the immediate area at Long Bay within a few months. Both biodiversity and biomass of organisms around the artificial reefs increased, with the appearance of a many new marine species not present in the area prior to placement. Diving in May 2002, showed a significant increase in the fish population e.g. the arrival of a number of juvenile fish from the summer spawning season, seeking shelter and food swimming in and around the reef. Schools of small Snapper (*Chrysophrys auratus*, -less than 90mm long), Trevally (*Pseudocaranx dentex*, less than 100mm long), Blue Maomao (*Scorpis violaceus*), and Sweep (less than 70mm), were observed swimming around the reef. Dozens of juvenile Goatfish (*Upeneichthys lineatus*, less than 90mm in length), pale in colour, were observed swimming along the bottom feeding on small invertebrates in and amongst the RB's. There were also numerous adult Parore (*Girella tricuspidata*) swimming in amongst the RB's, some up to 300-350mm long. Also resident were Spotties, Triplefins, and adult Sweep. There were many suspected snapper divets around the reef, and a few larger snapper (up to around 250mm) were seen on the outskirts of the reef, at the edge of our visibility.

4. Discussion:

The construction and deployment of this design of artificial reef using this method was labour intensive, taking up to 30 man hours to create and place one pallet ball or 3-4 bay balls. Towing the Reefballs out to the site and sinking them accounted for most of the time as only 1 Pallet Ball or 3-4 Bay Balls could be deployed at a time. An easier, more efficient way to deploy these would be to use a barge. The units could be formed and dropped off the barge carrying a small crane, permitting a large number of RBs to be placed in a day.

To date the project has been very successful. Local biodiversity increased with encouraging signs of juvenile fish of many species feeding and taking refuge in the shelter. The small amount of scouring is of some concern. If this continues in subsequent years it may threaten to eventually bury the Reefballs. Further monitoring is imperative.

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