INTERIM REPORT ON THE ARTIFICIAL REEF CONSTRUCTED IN THE LONG BAY-OKURA MARINE RESERVE, AUCKLAND

11th August 2003

PERMIT AO1/1 26th APRIL 2001

Preamble:

The aim of the research was to construct two small patterns of artificial reef comprising different sizes of pierced concrete hemispherical shells. These were constructed utilising the American system called "Reefballs". Colonisation of these is now being monitored. It was hoped to extend the study to include work on sedimentation rates and the impact on the benthic population. It is anticipated that this activity will fulfil a range of positive outcomes:

(i) increase conservation awareness from the use of the Reserve as an educational resource and recreational dive site.
(ii) permit future informed decisions to be made on artificial reef construction in New Zealand.
(iii) monitor the problems of run off which are faced by the reserve.

Reef 1 – Zig Zag Reef:

The reef is located at 36^0 40' 52" S, 174^0 45' 14.8" E in 5.5 m at minimum spring low tides. It comprises twelve concrete hemispherical shells made of 60 MPa concrete with microsilca added. There are nine Bay Balls [mass approximately 300 kg, height 0.7 m, base diameter 1.0 m with about 10 piercings] in a N – S line. At the Northern end, there is a Pallet Ball [mass approximately 1200 kg height 0.9 m; base diameter 1.2m with about 15 piercings].]. At the Southern end, there are two further Pallet Balls; one with a 30x30 cm slate plate attached to a vertical surface and the other with a plate attached to close the top hole of the unit; i.e. in a horizontal position. These slates are the same as the ones utilised by current E. O. S. intertidal studies. Placement took approximately 6 weeks because of tide/weather/logistical constraints. All 12 units lie on a N – S line parallel to the beach with an angle of approximately 45^0 between this line and the zigzags and about 1.0 metre between each.

Reef 2 – Octagon Reef.

The reef is located at 36^0 40' 51.1" S, 174^0 45' 19.6" E in 6.2 m at minimum spring low tides. This also comprises twelve units with four of the smaller Bay Ball units planted as the central core. There are four Bay Balls around the perimeter; a Pallet Ball at the Eastern point of the octagon; and one further Pallet Ball on the Southern margin. There are slate plates attached to a vertical surface of both these Pallet Balls. Another Pallet

Ball is placed on the western side. The last Pallet Ball forms a tail to the south since inclement weather prevented it being placed in geometrical perfection. All the spacings are again about 1.0 metre.

Colonisation sequence:

November 2001

Hard surfaces were 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 were vagrant (and opportunistic) benthos, such as the cushion star: *Patiriella regularis*, and 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 and polychaete worms. Two settlements of the rapidly colonising barnacle *Austrominius modestus* were recorded; the first occurring about ten days after the placement of the reefballs. A second, more numerous settlement event of *A. modestus* occurred about four weeks later. Of the annelids, the first was the spiny tubeworm: *Spirobranchus cariniferus* which settled about two-three weeks after reefball placement. After a month, these reached lengths of up to 12 mm.

February 2002

Both artificial reefs are close to being fully colonised. Biodiversity on the two reefs is still somewhat low but new species continue to colonise the reef. Most noticeable was the new settlement of the ascidian (Sea squirt) *Asterocarpa coerulea* around the sides of numerous of the Reef Balls. Larger macro-algae, brown seaweed *Carpophyllum maschalocarpum* (still at early stage approximately 5cm long) is establishing itself around the top of some of the Reef Balls. Also identified on the zigzag reef were two Large Trophon (*Xymene ambiguus*), these are typically sandy shore species and are probably resident in the area. A new fish species, a juvenile Sweep (*Scorpis lineolatus*) was present at the Octagon Reef. Juvenile sweep are often found on shallow reefs, close to shelter (provided by the Reef Balls?).

The unidentified filamentous brown algae still dominates coverage on the reef balls, however the barnacle *A.modestus* are now densely populated particularly on the zigzag reef, with several settlements of barnacles evident (small and large live shells, and older empty shells). *A.modestus* is also dominating percentage coverage on the slate tiles over the spiny tubeworm *Spirobranchus cariniferus* (which was formally dominant). Numbers of *Cominella adspersa* and the starfish *Patiriella regularis* appear down. What appeared to be snapper divots were observed around the surrounding reefs. There appears to be an abnormally high sedimentation rate on the two Artificial Reefs, which

may contribute to the absence of some organisms. Further studies on sedimentation rates will hopefully follow.

May - June 2002

Zigzag Reef:

The zigzag reef is now entirely colonised. The make up of organisms on the reef has markedly changed over the past few months. Both biodiversity and biomass of organisms on and immediately around the reefballs has increased, with the appearance of a host of new organisms and an increase in numbers of some already existing organisms (personal observations). Most noticeable was the number of fish, a few new species of which may now be resident. The zigzag reef has seen 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 (less than 90mm long in schools >50), Trevally (less than 100mm long in schools >50), Blue Maomao, and Sweep (less than 70mm), were observed swimming around the reef, with dozens of juvenile Goatfish (*Upeneichthys lineatus*), (less than 90mm in length), pale in colour swimming along the bottom feeding on small invertebrates in and amongst the reefballs. There were also numerous adult Parore (*Girella tricuspidata*) swimming in amongst the reefballs, some large up to 300-350mm long, some adult Red Pig Fish. The Spotties, Triplefins, and adult Sweep are still present in similar numbers. The triple fins have increased in size. There were many snapper divots 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 level of visibility.

The once dominant filamentous algae has been greatly reduced in percent coverage to a few percent only. It has been replaced with a dense covering of barnacles (*A.modestus*), tube worms (including *Spirobranchus cariniferus*), and rock oysters (*Saccostrea glomerata*). These are already creating second and third layers in places colonising on top of dead and empty shells already attached to the reefballs.

There are now at least three different tubeworms including *Chaetopteros sp*, and *Spirobranchus cariniferus*. The third species (unidentified) has a large surface coverage on the outside of the reefballs (approx 20%). There have been at least two different settlements of *S.glomerata* with an older smaller settlement of oysters up to 40mm long (1-2% coverage) and a more numerous recent settlement of oysters up to 20mm long (approx 10% coverage). The oysters are more prominent on the inside cavity walls and hole walls of the reefballs than the outside.

There is a small number of juvenile green-lipped mussels (*Perna caniculus*), approximately 2 cm long, establishing themselves in the base of the side hole walls. New gastropods to the zigzag reef include the Siphon Whelk (*Penion sulcatus*), the Spotted Whelk (*Cominella maculosa*), and the Oyster Borer (*Lepsiella scobina*) which are all carnivorous and were located on the outside of the reefballs.

Brown macro-algae up to 10cm long (possibly *Halopteris novae-zelandiae*) is establishing itself within the holes of the reefballs with at least two species of sponges also are colonising the outside of reefballs. Dozens of small shrimps are to be seen seeking shelter in small cracks underneath the reefballs.

The population of cushion stars is noticeably down from previous dives, with an increase of a larger starfish, *Coscinasterias calamaria* (up to 200mm) resting in the holes of the reefballs and on inside cavity walls.

The Octagon Reef:
Colonisation on the octagon reef is not yet complete at around 80-90%. The colonisation makeup is very similar to that of the zigzag reef with a few differences, most notably the difference in coverage of barnacles and oysters. Very few oysters and barnacles have colonised the octagon reef in comparison to the zigzag reef. The filamentous algae is still present though in increasingly smaller coverage but the tubeworms have a much greater dominance (*S,cariniferis*, and the unidentified species). There are similar numbers and species of juvenile fish present, with various schools sheltering within the octagon.

December 2002

Zigzag Reef
Bottom Conditions: The seafloor and Reefballs had a thick blanket of a fine silt/clay deposit. The silt/clay was much more pronounced than on previous dives, but could in part be attributed to the high rainfall experienced in the region over the past few days, and the close proximity to the Vaughn Stream and Okura River. This layer is the greatest experienced so far (personal observation) since January 2000 making visibility extremely low (0.5m-2m). The sediment was gelatinous and over 20 cm deep in the area around the reef.
Whilst the Reefballs still sit relatively flush with the seafloor, scouring around the outside of the Reefballs has continued and the entire artificial reef is now approximately 20cm below the seafloor norm. Even greater scouring has occurred between the Reefballs, in some instances lateral movement is occurring with the Reefballs subsiding and slipping together. The gaps between some of the Reefballs (initially >1m) have been reduced to as little as 20cm.

Colonisation: The reef is close to being fully colonised with biodiversity somewhat lower than in August 2002 (NB: Because of the low visibility and thick layer of sediment blanketing the Reefballs some species may have been missed). Visibility inside the Reefballs was close to zero, hence accurately detailing colonisation on the inside surface was difficult.

Algae/Seaweed: The brown filamentous algae has returned and covers close to 80% of the Reefballs, growing on existing sciaphilic and other organisms. There have been some new settlements of the green seaweed *Codium fragile* and the brown seaweed *Halopteris novae-zelandiae*, they seem to have become relatively well established reaching lengths upwards of 8cm (*C.fragile*) and 6cm (*Halopteris novae-zelandiae?*). The plant numbers are still relatively low (1-2 of each species per RB), with the majority located on the top surface of the Reefballs, and around the side holes. Low numbers of seaweed is probably due to a number of factors, including grazing by invertebrate and fish species.

Echinoderms: Numbers of both the *Patiriella regularis* and *Coscinasterias calamaria* were well down on numbers found in August 2002. There were a few *P.regularis* on the outside of the Reefball and no sighted *C.calamaria*.

Sciaphilic Organisms: With the silt/clay mixture cleared, the Reefballs reveal a large number of dead/empty shell remains. Many of these are already being colonised by spat settlements of other sciaphilic organisms. There seems to be a high turnover rate with regular spat settlements of a number of different organisms, (namely the barnacle *Balanus trigonis*, pacific oyster *Saccostrea glomerata*, and tubeworm species including *Spirobranchus cariniferus*) of which there are a number of different population sizes. There are few living larger older specimens though many dead shell remains of this cohort, (the cause of which is probably a mixture of predation, competition, and smothering from silt and clay deposits), with a large number of living small juvenile species. The number of live oysters on the outside surface of Reefballs has been drastically reduced, in saying this, on previous dives most oysters had colonised the inside surface of Reefballs which was difficult to see with such a low visibility. It appears only the hardy species are surviving to maturity and adulthood, with a lot of casualties of the more sensitive species, and a high turnover of animals. The barnacle (*B.trigonis*) is out competing most of the tubeworm populations. There were a couple of new unidentified calcareous tubeworm species.

Other organisms: The most prominent species on the Reefballs was the spotted whelk (*Cominella maculosa*), there were well over a hundred on many of the Reefballs, grouped together with egg sacks littered around the outer Reefball surface. These ranged in size up to 4cm (Similar results were observed this time last year).

The sea squirt (*Ascidian*) population common during the last dive has been largely reduced to a few individual specimens of a small size (5cm length). The remaining few were heavily covered in algal (filamentous algae) and sediment deposits.

There were no sponges seen on this dive.

There were some large specimens of the siphon whelk (*Penion sulcatus*) up to 9cm, along with a few attached balls of egg capsules.

The mussel (*Perna caniculus*) has a stronghold on the bottom inner surface walls of the Reefball holes where they are growing in small clusters. Some have grown in size to 5cm or more in length.

The Turret shell (*Maoricolpus roseus*, small to 2cm) was present in small numbers in the hole walls.
The sea anemone numbers were well down, most Reefballs had none, a few small populations have survived on a couple of the pallet balls.

Fish Species: Because of the low visibility the number of fish counts were extremely low. Those seen include the Spotty, and the three Triplefin species. Numbers were obviously low due to the visibility. There was evidence of snapper and stingray/eagleray

activity with numerous divots around the Reefball site. Large numbers of the Hermit Crab (*Pagurus* sp. c.f. *P. novaezelandiae*) littered the outer walls of the Reefballs.

Slate Tiles: Colonisation still dominated by the barnacles *B.trigonis* and *A.modestus* , up to 80%. The were no Ascidians found on the slates. The tubeworms (particularly Chaetopteros sp.) made from, 10-15% coverage, with bare rock the remaining few percent. One of the slates (the slate tile covering the top central hole) had a 7cm *Codium fragile* plant growing from it. There was little difference in coverage and in species between the 3 different slates.

The Octagon Reef

Bottom Conditions: A similar >20cm deep gelatinous silt/clay layer on seafloor, and blanketing the Reefballs. Conditions are more silty/muddy than the Zigzag Reef. Colonisation is at best at around 80% with the concrete visible when silt cleared away. Biodiversity is similar to that of the Zigzag Reef with barnacles, tubeworms the dominant species. The oyster populations have disappeared with only a few live specimens observed (plenty of dead shell remains). There are now no mussels within the hole walls (Predation by octopus??). The "resident" octopus was not observed!

February 2003

Zigzag Reef

Bottom Conditions:

- Substrate: fine sand/shell, 1 – 2cm layer of clay/silt also covering Reef.
- Visibility: 4-5m
- Reef Ball positioning: Scouring around reef to 30cm deep extending 2-3m either side of reef, Reef still flush with seafloor.
- Minor lateral Reef Ball movement due to deeper scouring between Reef Balls, with two Bay Balls in Zigzag Reef now only 30cm apart.

Colonisation:
Algae/Seaweed: Filamentous algae much reduced. Good algal growth of brown seaweed *Melanthalia abscissa*. Most plants young up to 3-4cm in length, irregularly dotted over Reef Balls there are a few older specimens up to 15cm in length. Some large specimens of the green seaweed *Codium fragile* are present ranging in size from 4 to 16cm in length, most common on top of Reef Balls. There is a new colonisation of unidentified red seaweed in small numbers to 4cm.

Sessile Invertebrates: Heavy colonisation of *Perna caniculus* (Green lipped mussel) in clumps particularly around piercings and base of Reef Balls ranging in size up to 8cm. *Saccostrea glomerata* (Pacific Oyster) has good coverage on outer and inner surfaces of Reef Balls, generally small in size to 3cm. High majority coverage of the two barnacles (*Austrominius modestus, Balanus trigonis*), have generally displaced much of

the tubeworm populations (*Spirobranchus cariniferus, Chaetopteros sp, Pomatoceros terranovae)* though these tubeworms are still present in small numbers. The encrusting sponge (*Cliona celata*) growth is irregular they are more common around piercings and outer surface of Reef Balls and range in size to 20cm length. A few Golf Ball sponges are present around outside of Reef Balls to 2cm in diameter.
A new ascidian (*Asterocarpa coerula*) is present with populations up to 2-3cm in length, a few older ascidians to 9cm in length and densities relatively low at an average of around 7-8 per Reef Ball.
Good numbers of sea anemones (*Anthopleura aureoradiata*) were seen, most in dense congregated populations, with a few scattered isolated specimens.

Vagrant Benthos: Hermit crabs (*Pagurus novaezelandiae)* common in piercings of Reef Balls and around the outer surfaces. Spotted whelks (*Cominella adspersa*) in small numbers only. Small numbers of *Patiriella regularis* (av of 1-2 per Reef Ball) and *Coscinasteris muricata* (3 seen on Reef) in and amongst the Reef Balls.

Fish: A lot of fish were seen including adult sweep 20-25cm; adult Parore 35cm; Goatfish adult and juvenile 15-30cm; shoals of 20 to 50 juveniles 5-7cm long probably Koheru. Numerous triplefins including both common and variable and also, possibly, estuarine. These ranged from 3cm juveniles to 12cm adults. Small black [spawning males?] about 4cm long were present at both reefs with half a dozen individuals on each Reefball. Numerous Spotties ranging from 10 –25cm and Snapper [30cm?] lurking at the edge of visibility. Large divots are abundant away from the reefs, some 60cm across and 30 cm deep.

Octagon Reef

Bottom Conditions:

- Substrate: fine sand/shell, 1 – 2 cm layer of clay/silt. Reefballs heavily covered in silty sludge.
- Visibility: 1-2m, a lot of suspended material.
- Reef Ball positioning: Scouring to 30cm deep extending 2-3m either side of reef, Reef still flush with seafloor.
- Minor lateral Reef Ball movement.

Colonisation General: Colonisation and marine life on the Octagon Reef is much lower in comparison to the Zigzag Reef. The silt sludge layer on the Octagon will have smothered a lot of the previous existing life and prevented a lot of new growth.

Algal growth: Filamentous algae much reduced. There is some new growth of the brown seaweed *Melanthalia abscissa*. Most plants small up to 3-4cm in length, irregularly dotted over Reef Balls, much fewer plants in comparison to the zigzag reef. A couple of older specimens on the reef present, up to 10cm in length.
A few specimens of the green seaweed *Codium fragile*, ranging in size up to 10cm in length, most common on top of Reef Balls, with a new colonisation of unidentified red seaweed in small numbers to 4cm.

Sessile Invertebrates: A few isolated mussels present around the Reef Ball piercings, up to 6cm in length. Numbers much less than on zigzag reef. Lots of dead Pacific Oyster shell under silt layer with only a few live specimens. Colonisation on outer surface of Reef Ball dominated by barnacles (*A.modestus, B.trigonis*) and tube worms (*S.cariniferous, P.terranovoe*). Numerous Golf Ball sponges on outer surface of Reef Balls with some colonisation of encrusting sponge (*Clione celata*), with 2-3cm diameter.
Vagrant Benthos: Small numbers of *Patiriella regularis* and *Coscinaster muricata* on and around Reef Balls
Fish: Fewer fish species seen, perhaps because of low visibility. Spotties, small schools of Koheru (3-4cm in length) and a few triplefin fish (same varieties but in lower numbers to Zigzag reef) were sighted.

Overall change in biota:

New organisms are present in the area. These have either migrated from other parts of the marine reserve, or have settled from the moving water body. (A combination of both is likely). The latter group probably would not have colonised the area if the reefballs had not been present. It is very encouraging to observe such large numbers of juveniles present at times. It is also impressive how resilient the reef biota proved after an enormous silt dump in Spring 2002.

Comparison of surfaces:
No significant differences in the colonisation of the smooth areas of concrete surface, rough aggregate surfaces nor the slate plates have been noted.

Bottom Conditions:

Sediment: 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. The origin of this is probably urban run-off. Increasing rates of development locally will undoubtedly increase this. There are large numbers of empty bivalve shells on/near the surface.
Two trial sedimentation collectors (made from a PVC pipe 100mm in diameter and 700mm long, staked to the seafloor) have been tested around the octagon reef in attempt to study the rates of sedimentation. Results of these trials were inconclusive since there was not possible to establish a regular monitoring programme.

Settlement: Although there is a significant depression some 30 cm deep scoured around both reefs, the individual Reefballs still show no appreciable settlement into the sediment. The holes in the base of the units were left open and no additional thickening measures taken in manufacture. There have been many storms over the period with onshore winds gusting up to 100 kmh^{-1} however the site selected appears to be well protected, with the artificial reef remaining stable.

Concrete pH Tests

Tests of the surface pH of the well-weathered units stored at Gibbons Crib Walls show that the surface pH lies in the range 8 – 9. Technical difficulties with the AUT Datasonde have prevented any meaningful results being taken from the reefballs in the water as yet. The lack of difference in colonisation between the available surfaces tends to indicate that the pH range of the concrete substrate is satisfactory.

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