Benthos and Sediments of Motu Manawa (Pollen Island) Marine Reserve

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ABSTRACT

The Motu Manawa (Pollen Island) Marine Reserve was created in 1995 as a representative example of inner harbour ecosystems. However, little information is available on marine life of the reserve. Benthos and sediments of Pollen Island Marine Reserve were evaluated during May 2002. A survey was conducted on the non-vegetated intertidal and shallow subtidal areas of the reserve using a small hand-hauled dredge to collect samples of sediment and benthos. Results illustrate that the marine reserve has two main benthic associations. To the south of the embankment, the enclosed inlet contains soft muds with relatively few species, including polychaetes and the introduced bivalve *Theora lubrica.* To the north of the embankment, shelly sandy sediments occur along the northeast side of Pollen Island, with higher diversity of marine life. There are extensive beds of small cockles, with associated polychaete worms and large numbers of the small bivalve *Nucula hartvigiana*. Towards and below low tide softer mud occurs with relatively low diversity of marine life. Based on these findings, recommendations were made for monitoring long term changes within the Pollen Island Marine Reserve.

1. Introduction

Marine reserves are a special category of marine protected areas that are designated to promote marine conservation (Halpern & Warner, 2002). Oceans are faced by a series of threats that include habitat destruction, overfishing and pollution (e.g: review by GESAMP, 1990). One way to stop some damage parts to parts of the ocean is to create marine reserves where all extractive and consumptive activities are prohibited.

Once a marine reserve is established, monitoring habitats and ecosystems is desirable to detect the changes happening within the reserve and provide conservation managers with information to base management decisions on. However, designing a long term monitoring program requires a baseline survey which provides simple ecological information about the reserve.

The Motu Manawa (Pollen Island) Marine Reserve which was gazetted in 1995 protects about 500 hectares of the inner reaches of Auckland's Waitemata Harbour around Pollen and Traherne Islands. It includes intertidal mudflats, tidal channels, mangrove forest, saltmarsh, and shellbanks. Auckland's north-western motorway, which was constructed in the 1950s, passes through the reserve. A new motorway interchange by Patiki Road was constructed from 1996 to 1998. The reserve is bounded to the south by the industrial suburb of Rosebank Peninsula and to the east by the residential suburb of Waterview.

Knowledge of marine life and physical characteristics of this reserve is limited, although a few studies have used parts of this reserve for different purposes. This information is required if the ecological condition of the marine reserve is to be determined and monitored. This study describes the distribution of sediments and benthic invertebrates within the marine reserve, excluding the vegetated mud flats. This study also identifies the key species that characterise different communities occurring within the reserve.

2. Brief History of Biological Survey in the Reserve

Chapman and Ronaldson (1958) examined the mangrove and saltmarsh communities at Pollen Island, as part of a larger study of mangrove communities in New Zealand. Beca Carter Hollings & Ferner was commissioned by Transit New Zealand Limited to monitor the intertidal biological resources in and adjacent to the Pollen Island marine reserve before, during and after construction of the motorway on and off ramps near Patiki road. These surveys were carried out in the upper mangrove habitat adjacent to the construction areas during January and February, 1996 (pre-construction survey), September and October 1996, April 1997 (as post-construction), January and May

1998, and January 1999 (operational survey). Five areas were examined including three potential impact areas and two control areas. Saunders (1999) used north and south Pollen Island as study sites to investigate two flounder (*Rhombosolea leporine*, *R.plebeia*) diet and prey selectivity. The National Institute of Water and Atmospheric Research Ltd (NIWA) mapped the distribution and abundance of coastal and estuarine vegetation in the Auckland region and produced a map for Pollen and Traherne Islands for the Auckland Regional Council (ARC) (Morrisey and Hill, NIWA, 1999). Hayward *et al.* (1999) sampled some sites within Pollen Island Marine Reserve and mapped the habitats and important species present in the area.

Despite the above mentioned studies, no systematic study directed at classifying and describing benthic communities of Pollen Island Marine Reserve has been undertaken. The benthic communities are considered some of the key aspects of ecosystem types represented in the marine reserve. Such information would enable the Department to design ongoing monitoring programs, which will contribute to management and administration of the reserve.

3. Material and methods

3.1 DATA COLLECTION

A black and white aerial photograph taken during 2000 (NZ Aerial Mapping Ltd) was used to design this survey. The photograph was orthocorrected and contoured at 0.5m height intervals. The photograph helped to determine seventy-four sampling sites (Fig. 1). A systematic sampling design was used to:

1. To achieve a wide geographic spread over the area to assist with subsequent mapping.
2. To cover as many habitat zones as possible, based on an interpretation of the detailed aerial photograph, and on field observations made during a boat visit at high tide, and on observations made at low tide from the motorway embankment.
3. To attempt to stratify samples along selected contours.
4. To place a high proportion of sample sites on across-shore transect lines to help with possible graphic presentation of data.

NZ Grid System co-ordinates for all predetermined sampling sites were logged into a hand-held GPS (Garmin, GPS 12) and used to navigate to the sites by boat.

Samples were collected using a small rectangular dredge as described by Grace & Whitten (1974). The dredge held approximately 4.5 litres of sediment and under ideal conditions sampled an area of approximately 0.075 square metre to a depth of about six centimetres. The dredge was hand-hauled from a four metre rigid-hulled inflatable boat.

Upon completion of each haul, the boat was positioned over the dredge and its position fixed using a GPS. Occassionally the dredge did not bite cleanly because of a high shell content of the sediments. When this happened in shallow water the dredge was forced into the sediment by standing on it. Depth was measured to the nearest 0.1 metre using a weighted measuring tape, and the time recorded to allow later correction for tidal height. Contours at one metre intervals were derived from depth measured directly at each site and converted to Auckland chart datum using tidal prediction data (Ocean Fun Publishing Ltd 2002).

At the surface, the volume of each sample was estimated as tenths of the dredge filled, to enable conversion to approximate area sampled and thus quantitative estimates of the biota collected. Sediment type was subjectively described from hand specimen.

The sample was then sieved using a 1mm mesh. All organisms and shell residue retained on the sieve was bagged and preserved in 5 % formalin. In the laboratory the sample was again washed over a 1mm sieve to remove traces of mud and spread out in a white plastic tray with about 5mm of clean water in the bottom. All organisms alive at the time of sampling were carefully sorted from the residue, identified as far as practical, and counted. Common shellfish (mainly cockles) were measured across their greatest diameter in 5mm classes. Estimates of the volume of residue remaining after sorting were also made as well as distinguishing shell hash, rock and mineral grains and particulate organic matter derived from vegetation

3.2 DATA ANALYSIS

The data consists of counts of species in 74 samples. The data was Log transformed (x+1) and cluster analysis (using Euclidian distance and Ward's method, Ludwig & Reynolds 1988) was performed to produce a dendrogram classification of samples based on species composition (species and their relative densities *i.e.* counts).

The influence of environmental factors on assemblage composition was investigated using Detrended Correspondence Analysis (DCA) (McCune & Mefford 1997). Factors scores for each sample were correlated with values of environmental factors (Ludwig & Reynolds 1988). Factors were then classified as representing a certain environmental gradient that affects species composition if correlation coefficients were significant.

To evaluate whether the classification described by cluster analysis was solely the result of environmental factors, we compared environmental values for samples representing Cluster 1 and 2 (Fig.6) using frequency tests for categorical variables and t-tests for numerical variables (Sokal & Rohlf 1969).

3.3 SPECIES ASSOCIATIONS

To species characterising each faunal association were determined by ranking the taxa in each association using an association score (Hayward & Triggs, 1994) based on a combination of the following criteria:

1. Dominance (Dom): The 10 most abundant taxa of each station in an association were scored with most abundant species given a score of 10, the second most abundant a score of 9, and so on.
2. Fidelity (Fid): Degree to which a taxon is restricted to an association expressed as the proportion of stations within the association in which the taxon occurs less the proportion of stations outside the association in which it occurs.
3. Abundance (Abund): Given as the mean abundance of the taxon within the association.
4. Relative abundance (Rel): Expressed as the mean abundance of the taxon within the association less its mean abundance throughout all the stations.
5. Persistence (Pers): Given as the proportion of the stations within the association in which the taxon occurs.

Association scores were calculated using the formula:

$$4 \times (0.3 \times Dom + 2 \times Fid + 0.11 \times Abund + 0.08 \times Rel + Pers) \quad (1)$$

3.4 MAPPING

Data for each parameter or species was plotted on the stations map and contours fitted by eye. Contour intervals were selected to clearly indicate high and low points in the distribution, and to avoid unnecessary complication.

4.

4.1 PHYSICAL FACTORS

4.1.1 Bathymetry

Most of the study area is intertidal (0.0 to > 2.0 m; Fig: 2(a)). Subtidal areas (< 0.0m) include a deep harbour channel to the northwest of the area, and a shallow channel which passes beneath the motorway bridge to the Oakley Inlet. Subtidal levels are reached northeast of Pollen Island, and a small channel in the upper Oakley Inlet remains water-filled at low tide.

4.1.2 Sediments

The area is dominated by mud with a variable quantity of shelly material (Fig: 2(b)). Shelly sand occurs in a large area east of Pollen Island above mid tidal level. Smaller deposits of shelly sand occur near the Whau Creek and on a raised area north of the motorway embankment.

Coarse gravel, comprised of rock fragments, is present in the tidal current swept channel to the Oakley Inlet beneath the motorway bridge. Gravel also occurred in the sample residue from the entrance to Oakley Creek. Narrow shell banks derived from cockle shells are scattered over upper tidal levels. These were plotted from the aerial photograph and confirmed in the field. The extensive mud of the Oakley Inlet is particularly soft and unconsolidated.

4.1.3 Shell Residue

Quantities of shell in the sample residues (Fig: 2 (c)) are highest around the northern shores of Pollen Island, in the channel leading to Oakley Inlet, and in an area north of the motorway embankment. Low shell residue volumes occur particularly in the soft mud of the Oakley Inlet, and in a low tide area northeast of Pollen Island. The distribution of shell residue closely reflects the sediment description map in Fig 2 (b).

4.1.4 Particulate Organic Matter Residue

Particulate organic matter, in the sample residues occurs in several localised areas (Fig: 2 (d)). In the southern part of the study area, pockets of organic material occur at upper tidal levels and the entrance to Oakley Creek. Another area of high organic matter occurs at the north of the study area, close to the channel leading to the Whau Creek. Moderate quantities of organic matter occur throughout most of Oakley Inlet, whereas the large area of flats northeast of Pollen Island contain very little organic residue.

4.2 BIOLOGICAL OBSERVATIONS

4.2.1 Number of Taxa per Sample

A total of, 63 taxa was recorded during this study. Number of taxa per sample (Fig. 3) shows three main maxima, with the highest number (21) near the shallow zone north of the motorway embankment. Numbers are also high near the Whau Creek, and over a large area east of Pollen Island. Throughout the rest of the area species diversity is low (1-9).

4.2.2 Cockles (*Austrovenus stutchburyi*)

Cockles form dense beds along the bank of the Whau Creek, (maximum 341 at station 2; Fig: 4) and on the shallow area north of the motorway embankment (maximum 217 at station 47). Maximum density of cockles was recorded at station 2 and it was approximately 6000 m^{-2}. An extensive area of cockles, though at lower density, occurs east of Pollen Island. Elsewhere cockles are absent or at very low numbers (< 5). Cockle size ranged from size class 1-5 mm to 35-40 mm. There was no consistent size gradient along transects sampled.

4.2.3 Nut shells (*Nucula hartvigiana*)

Nut shells are abundant in several discreet areas. Along the bank of the lower Whau Creek they reach a maximum of 1650 (density approximately 30,000 m^{-2}) at station 2. Other high density areas include the shallow patch north of the motorway embankment, and a large area east of Pollen Island. This distribution closely parallels that of cockles. At station 19 north of Pollen Island the presence of 258 nut shells in the absence of cockles seems an exception (Fig. 4). In several areas there are large differences in nut shell density over short distances.

4.2.4 Small limpet (*Notoacmea helmsi*)

The distribution of small limpets largely parallels that of cockles and nut shells, with three distinct areas of high numbers: along the bank of the Whau Creek, a large area east of Pollen Island, and a smaller area north of the motorway embankment (Fig. 4). Although the distribution pattern is similar, absolute numbers of limpets are much lower than of cockle and nut shells.

4.2.5 Sea anemone (*Anthopleura aureoradiata*)

This anemone shows a very similar pattern of distribution to that of cockles (Fig: 4 (d)). Maximum number (23) was reached at station 2.

4.2.6 Window shell (*Theora lubrica*)

The window shell occurs mainly in soft mud, toward low tide northeast of Pollen Island, in the central part of the Oakley Inlet, and adjacent to the motorway embankment. Maximum number reached is 42 at station 27 (Fig. 5).

4.2.7 Palp worms (Family Spionidae)

Polychaete worms in the family Spionidae are represented by at least three species in this area. Moderate numbers were present in the Oakley Inlet, but also occur on the shallow area north of the motorway embankment and east of Pollen Island. Low numbers were recorded in the north of the study area (Fig. 5).

4.2.8 Mud snail (*Amphibola crenata*)

Small numbers of mud snails occurred around the fringes of mangrove areas, especially in Oakley Inlet (Fig: 5). Most were juveniles.

4.3 FAUNAL ASSOCIATIONS

Two major faunal associations are indicated by Hierarchical cluster analysis (Fig.6). Their distribution in the study area is shown in Fig.7. DCA illustrates overlap between these associations (Fig.8). Cluster one was dominated by a cockle-nutshell community. Cluster two was characterised by a polychaete-*Theora lubrica* community (Table 1). The Pearson correlation coefficients values (*r*) from the DCA of the species abundance data show a similar pattern to the association scores: i.e.cockles, nutshells, *Notoacmea*, *Theora lubrica* and Nereids have *r*-values greater than 0.5 (Table 2). All these species show strong correlations with axis 1.

4.7.1 **Cockle-Nutshell community (Cluster 1)**

Association scores for the characterising species are given in Table 1. This association is the most diverse (49 taxa) and the species characterising this association are more abundant than other species, especially nut shell and cockle numbers in the samples. This occurs along the eastern margin of the Whau River, over a large area east of Pollen Island, and on a bank north of the motorway embankment (Fig.7).

4.7.2 **Polychaete-*Theora lubrica* community** (Cluster 2)

This community is a mixture of all other species and not a distinct association. It is dominated by a variety of polychaetes, (Nereids, Spionids, Capitellids and carnivorous *Glycera* sp.) and *Theora lubrica*. It also included small numbers of juvenile mud snails (*Amphibola crenata*). Species densities were lower in this assemblage compared to those in the cockle-nut shell assemblage. This community tends to occur in lower shore and subtidal areas. Association scores of these species are given in Table 1 .

4.8 INFLUENCE OF ENVIRONMENTAL FACTORS

The results of DCA overlaid with environmental factors recorded are shown in Fig. 9. Pearson correlation coefficient (*r*) values for these factors are given in Table 2. There were no strong relationships between any of these factors and species abundance. However, comparison of Fig. 8 and Fig: 9 (a) indicates that shelly sand occurs where association one was clustered. Frequency analysis for catergorical values of sediment also showed that sediment type varied significantly between clusters (G-test: G_9=79.81, $p< 0.01$). There was a significant difference in the volume of particulate organic matter in the dredge sample (t-test: t_{72},=-2.44, $p < 0.01$) and tidal level (t-test: t_{72}3.26, $p < 0.001$) between clusters. Cluster one occurs at relatively high tidal levels. However, no significant difference was found for volume of shell in the dredge sample (t-test: t_{72},=1.50, $p < 0.14$).

5. Discussion

Pollen Island Marine Reserve is characterised by extensive intertidal flats of soft mud and sandy sediments, covered in many areas by loose shell material. The distribution of sediments and habitats (cockle beds, sand flats, soft mud, oyster beds) recorded in this study is similar to those reported by Hayward *et a*l (1999). Hayward *et a*l (1999) did not report the coarse gravel bed habitat under the motorway embankment. This appears to have been produced by the strong tidal current caused by construction of the motorway.

The distribution of the cockle and nutshell community (*i.e.* Cockle and nutshell) corresponds well with the distribution of the shell banks and shelly sand areas observed during this study. This shelly habitat supports a higher number of taxa. This is similar to the findings in a review of research on benthic communities conducted in Long Island (Zajac, 2001). Species richness is usually higher in sediments that are comprised primarily of shell and gravel. In addition, wave action appears to have pushed shells into narrow banks in several upper-tidal areas of the marine reserve.

Particulate organic matter occurs close to the vegetated areas and near the Whau River, and is probably derived from extensive mangrove and coastal vegetated areas upstream. Mud snails, which are associated with vegetated areas were found around the fringes of the mangrove areas. However, most of the mud snails found during this study are juveniles as sampling was done outside the vegetated areas.

Theora lubrica was introduced to New Zealand in the mid 1970’s (Willan, R; pers.com.) and is widespread in muddy sediments within the marine reserve. The densities of these shells were very low compared to those recorded in other areas in the mid-1970’s, a few years after its introduction.

Species groupings by cluster analysis and DCA identified two faunal associations and key organisms that are associated with these. Association one was dominated by cockles and nut shells which were also the two numerically dominant species among 63 taxa recorded. Some overlap in community composition between the clusters suggested that the benthic fauna in Pollen Island Marine Reserve is not distributed as well defined communities, but rather forms a faunal continuum from one area to another. However, more extensive sampling within communities would be required to confirm this distribution.

6. Recommendations

Based on these findings, we recommend that:

- A monitoring programme with transects running from the centre of the main Cockle/Nucula bed east of Pollen Island, in a northeast direction into the soft muds of the *Theora*/polychaete community should be designed to detect the changes in community structure.
- Sites on both sides of the main communities should be sampled to find out the changes in movement of boundaries.
- Oakley Inlet should be included in the sampling design to detect changes in species abundance and composition due to the increase in the accumulation of soft sediment because of the presence of motorway embankment.
- Monitoring is recommended for every three years as the changes in the community structure is likely to be slow.

7. Acknowledgements

We thank Karl Mcleod for the participation in field survey and skippering the boat. Chris Wild provided assistance with GIS mapping. We appreciate Jonathan Boow and Justine Saunders in assisting with statistical analysis. Thanks to Sam Ferreira for providing valuable comments on the draft.

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Table 1. Main characterising species of the two benthic faunal associations recognised by cluster analysis. Species are arranged in order of decreasing Association scores (Assoc score) calculated from each species abundance (Abund), fidelity (Fid), persistence(Pers), dominance (Dom) and relative abundance (Rel) within each association.

	Abund	**Fid**	**Pers**	**Dom**	**Rel**	**Assoc Score**
Association One						
Nucula hartvigiana	294.2	0.83	1	10	190.66	209.12
Austrovenus stutchburyi	74	0.61	0.96	9	47.04	63.27
Notoacmea helmsi	18.5	0.86	0.88	8	12.01	28.51
Cominella glandiformis	3.12	0.80	0.85	7	1.99	16.84
Anthopleura aureoradiata	5.2	0.63	0.69	6	3.32	15.59
Zediloma subrostrata	2.3	0.63	0.65	5	1.48	12.55
Zeacumantus lutulentus	1.62	0.44	0.46	4	0.94	9.33
Amaurochiton glaucus	2.15	0.42	0.42	3	1.40	8.38
Micrelenchus huttoni	1.58	0.42	0.42	2	1.02	6.81
Cominella adspersa	0.577	0.346	0.35	0	0.374	3.14
Spionids	0.81	0.03	0.38	1	-0.178	1.74
Glycera sp.	0.35	0.005	0.31	0	-0.041	0.178

Association Two

Nereids	3.23	0.51	0.63	10	1.07	17.83
Theora lubrica	2.98	0.38	0.38	9	1.05	15.45
Ninoe leptognatha	1.46	0.18	0.33	6	0.31	9.37
Spionids	1.08	-0.03	0.35	7	0.097	8.66
Glycera sp.	0.52	0.004	0.31	5	0.06	6.28
Capitellid	0.35	0.13	0.21	4	0.097	6.03
Polynoid	0.23	0.17	0.21	3	0.067	5.08
Amphibola crenata	0.5	0.13	0.21	2	-0.03	3.66

Table 2. Pearson Correlation Coefficient (*r*) with ordination axis for key species in associations and physical factors recorded. (Note that sediment type has categorical variables hence no regression produced).

Key species	**Axix 1**	**Axis 2**
Austrovenus stutchburyi	-0.604	0.114
Nucula hartvigiana	-0.556	0.075
Nereids	0.604	-0.483
Theora lubrica	0.568	0.091
Physical factors		
Depth	-0161	-0.203
Volume of shell residue in dredge samples	-.373	0.418
Volume of particulate organic matter in dredge samples	0.405	-0.023

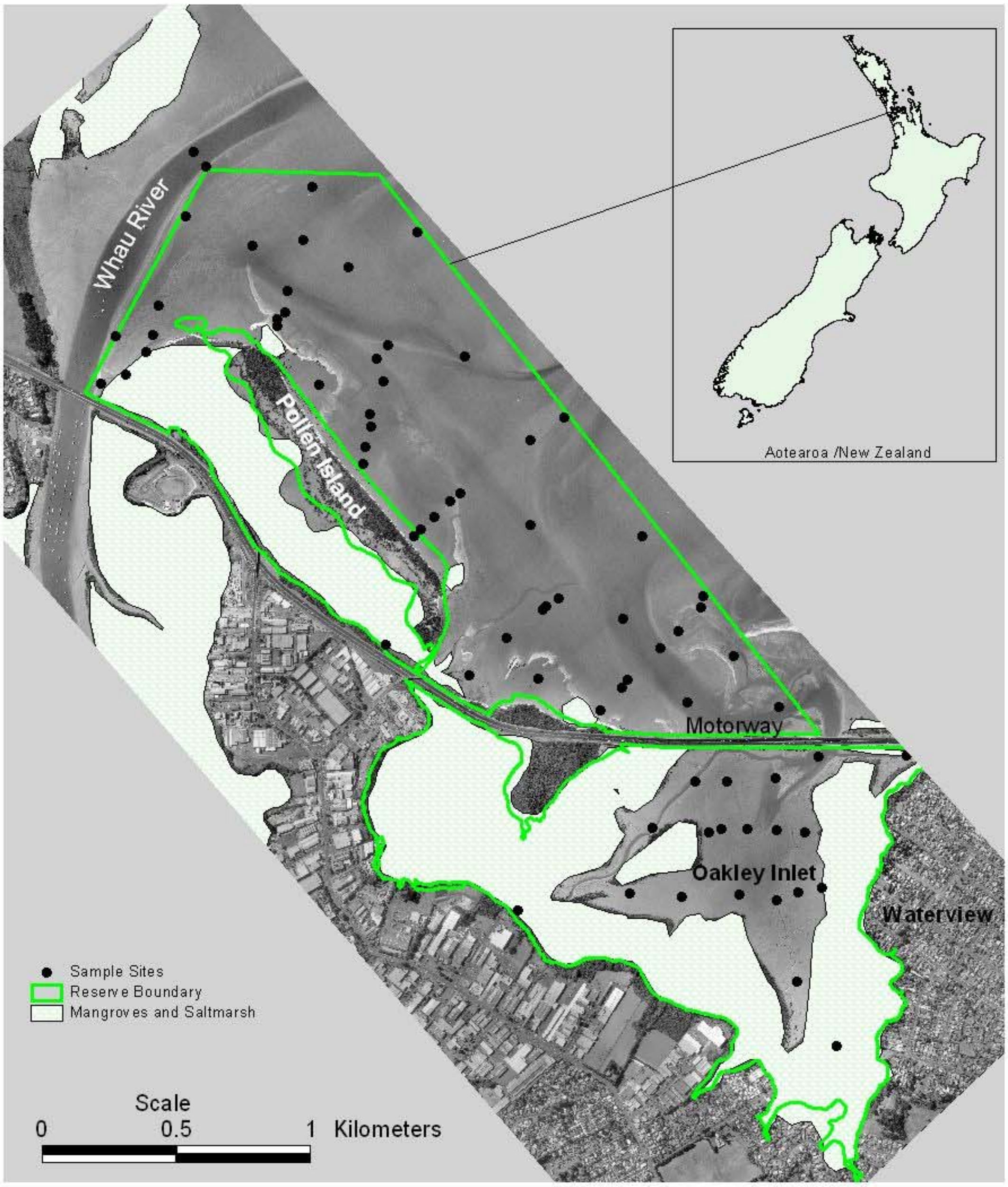


Fig. 1 Map showing boundary of Pollen Island Marine Reserve, names of local places, sites sampled and areas covered by mangroves and salt marsh around the marine reserve.

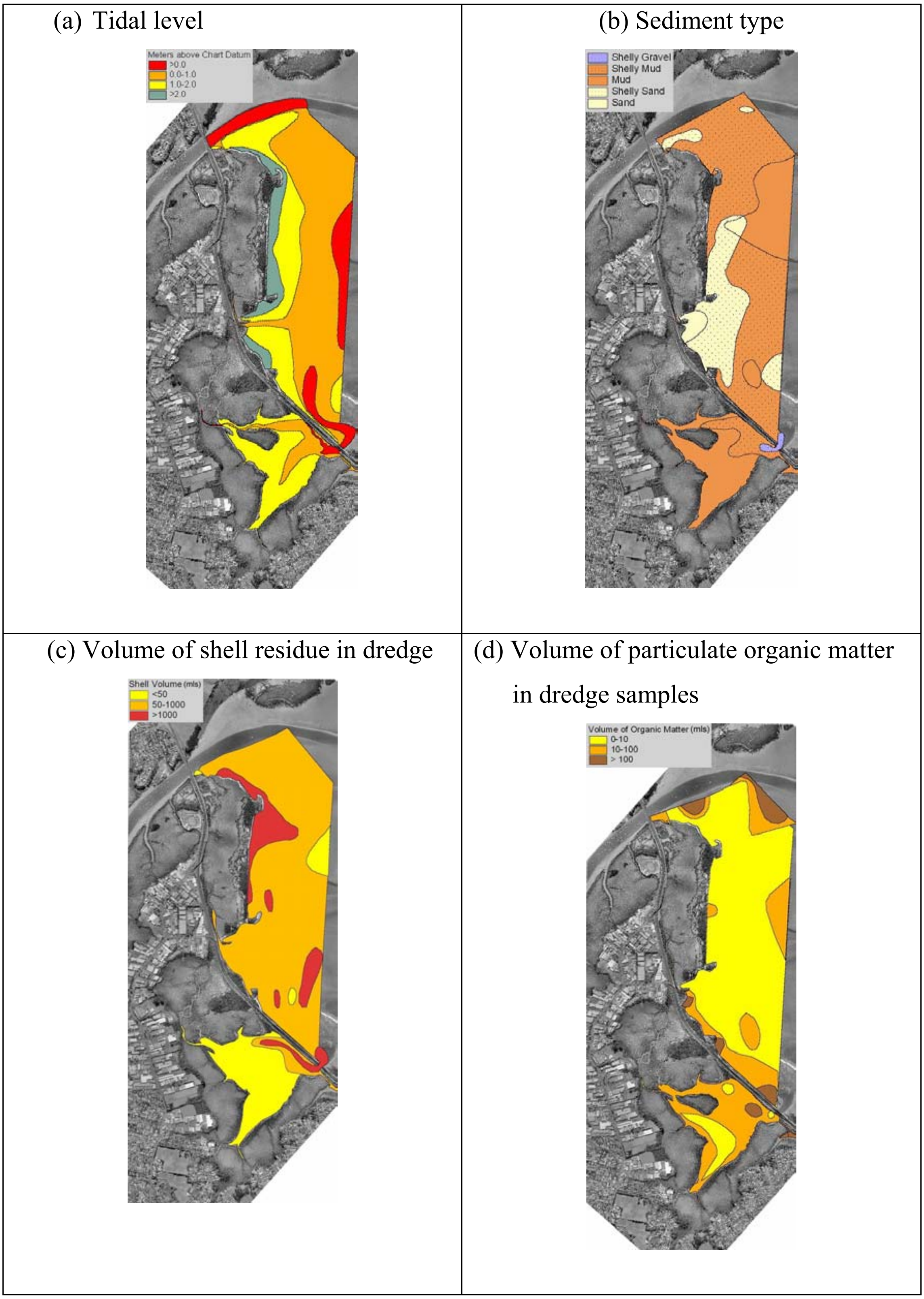


Fig. 2. Contoured maps of physical factors recorded within Pollen Island Marine Reserve.

Species Diversity

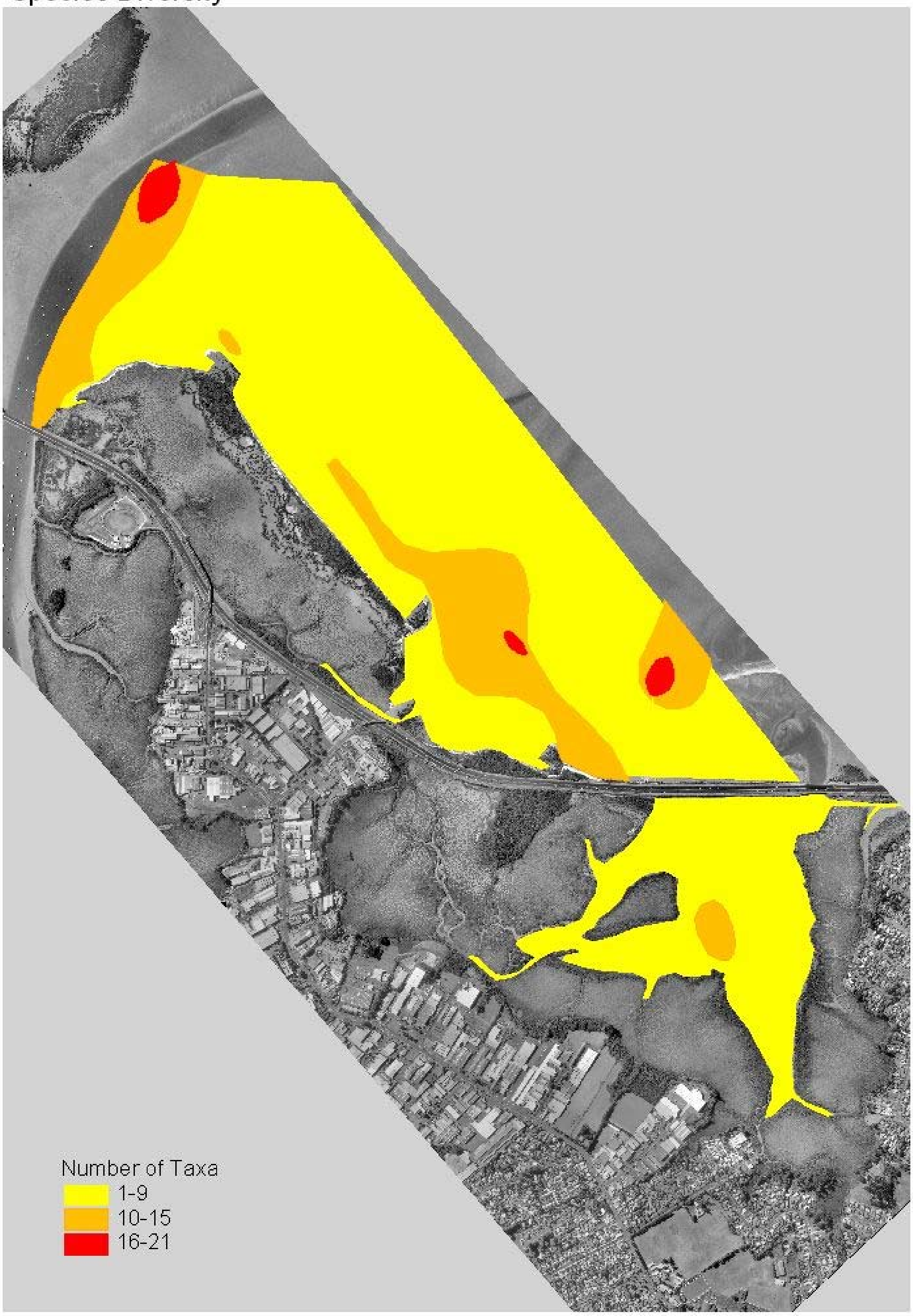
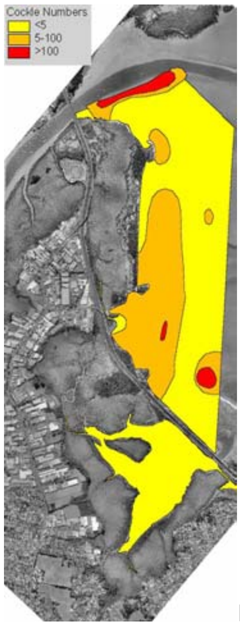
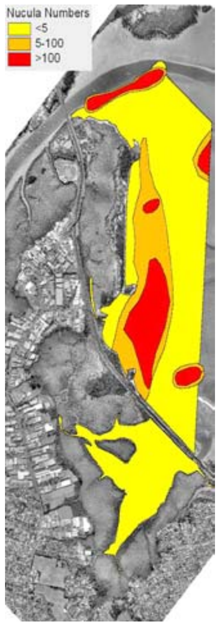


Fig. 3. Contoured map of benthic species diversity (number of taxa per sample) within Pollen Island Marine Reserve.

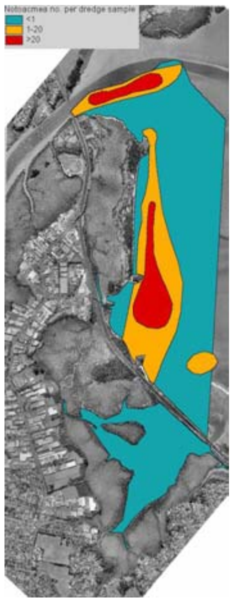
(a)Cockles



(b) Nut shells



(c) Small limpet



(d) Sea anemone

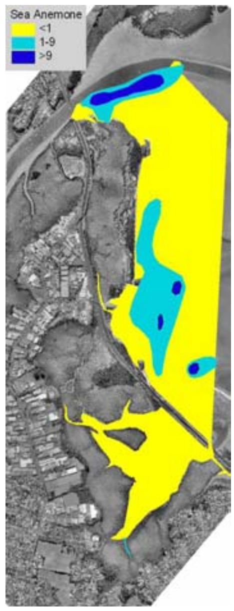
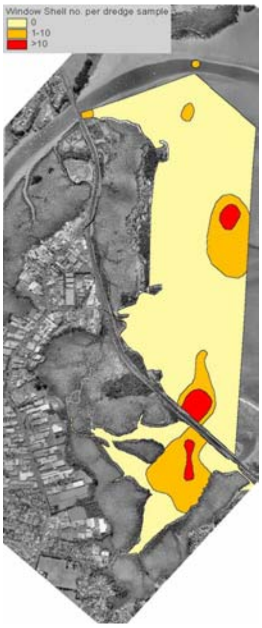
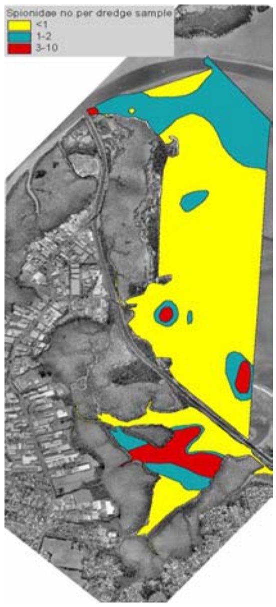


Fig. 4. Contoured maps of number per sample of cockles (*Austrovenus stutchburyi*), nut shells (*Nucula hartvigiana*), small limpet (*Notoacmea helmsi*) and sea anemone (*Anthopleura aureoradiata*) recorded within Pollen Island Marine Reserve.

(a)Window shell



(b) Spionid worms



(c) Mud snail

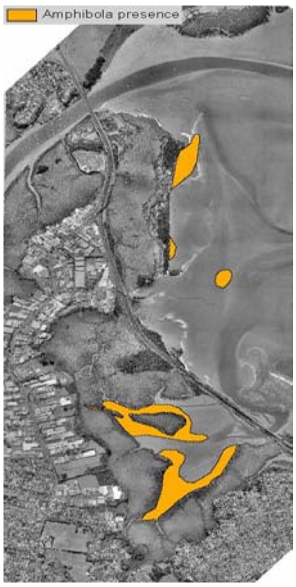


Fig. 5. Contoured maps of number per sample of window shell (*Theora lubrica*), spionid worms and mud snail (*Amphibola crenata*) recorded within Pollen Island Marine Reserve.

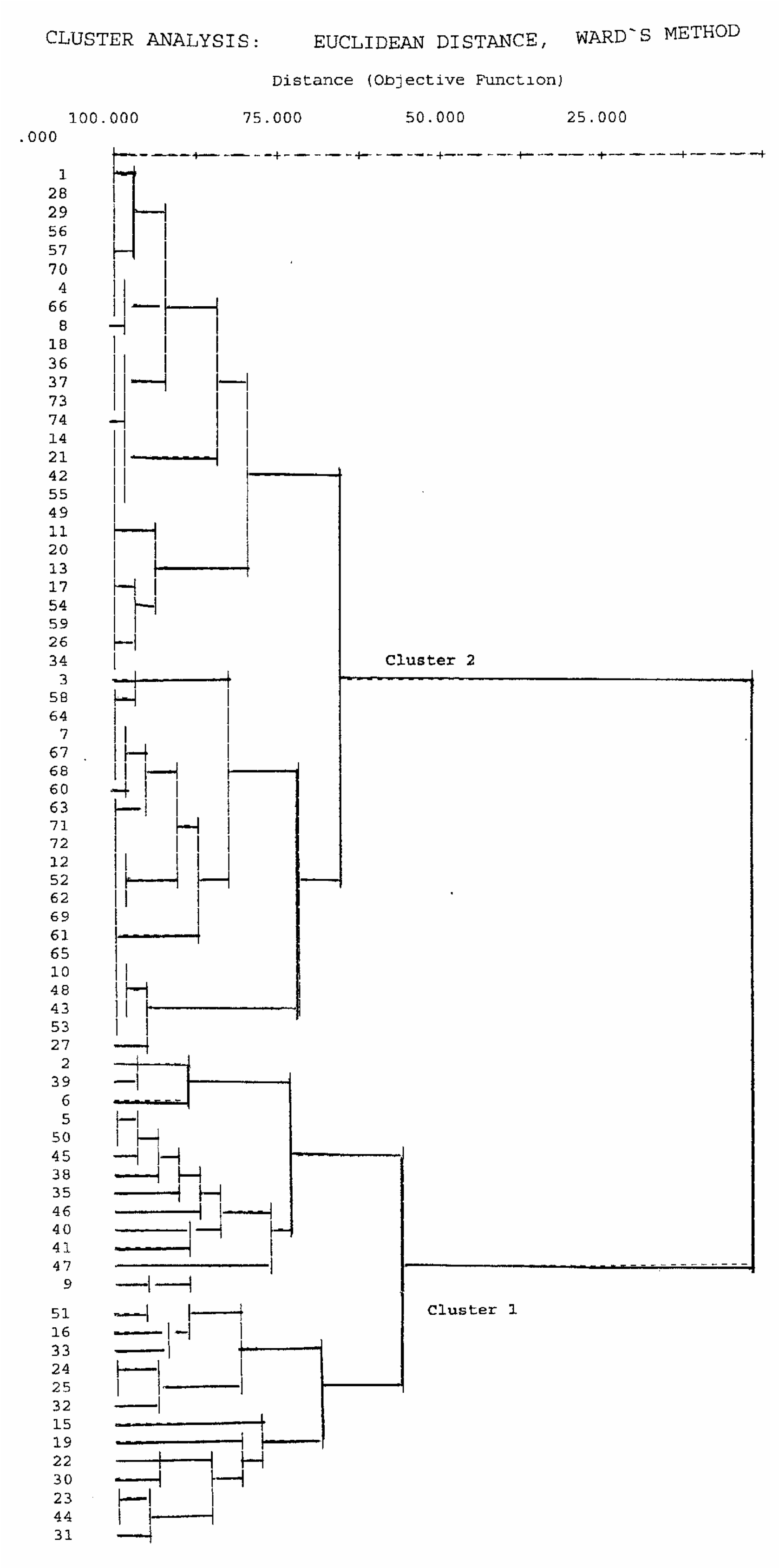


Fig. 6. Dendrogram classification of faunal associations produced by cluster analysis using Euclidean Distance with Ward's method of clustering. Cluster one: Cockle-nutshell association; Cluster two: Polychaete-*Theora lubrica* association.

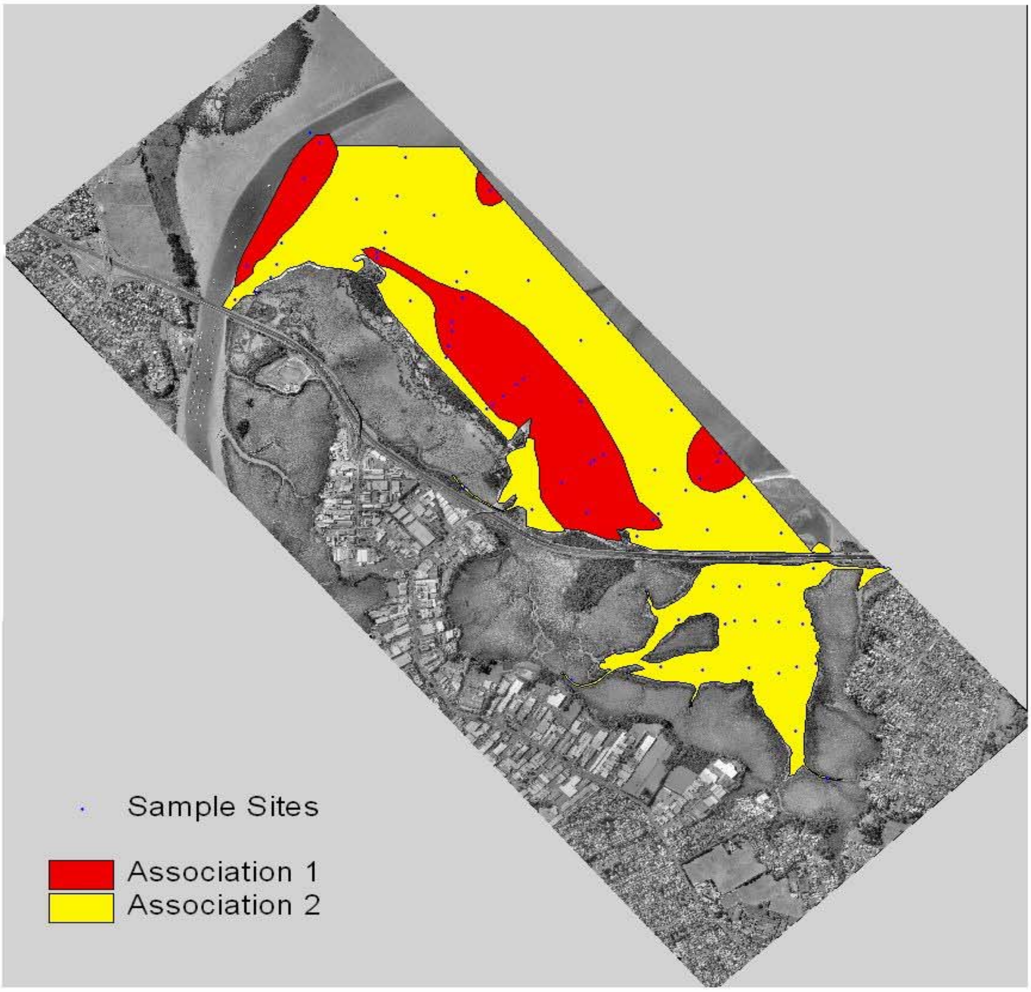


Fig. 7. Contoured map showing the faunal associations around Pollen Island Marine Reserve. Cluster 1-cockle-nutshell association; cluster 2- Polychaete-*Theora lubrica* association.

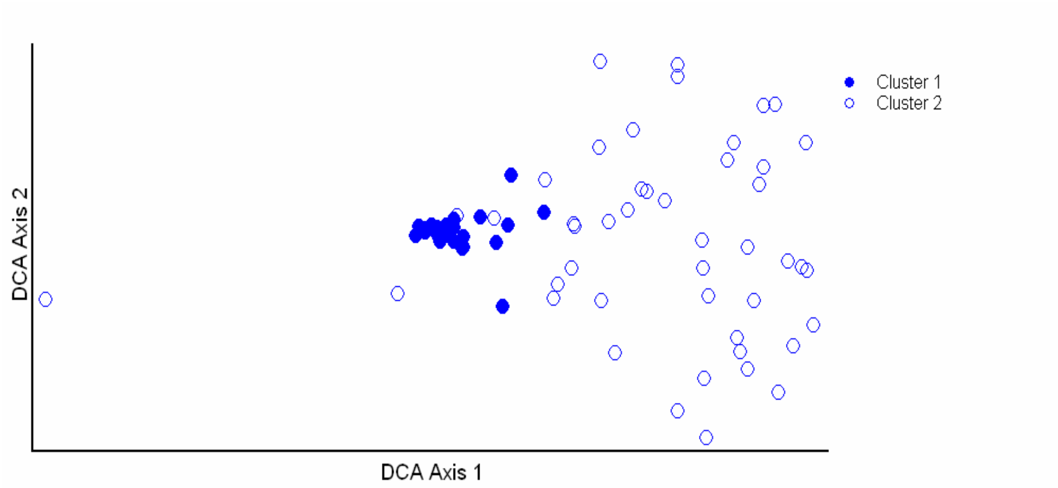
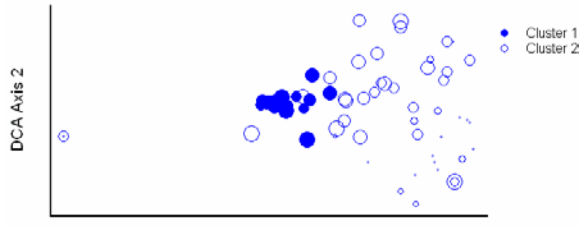


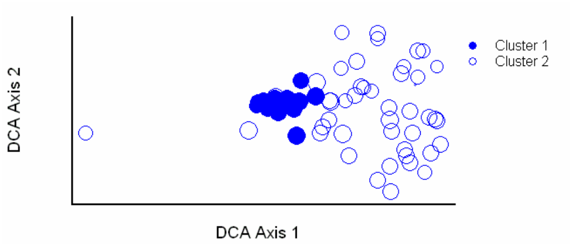
Fig. 8. Two dimensional configuration of samples produced by Detrended Correspondence Analysis with the two associations produced by hierarchical classification superimposed.

(a) Sediment type

(c) Volume of shell in dredge samples



(b) Depth



(d) Volume of particulate organic matter in dredge samples

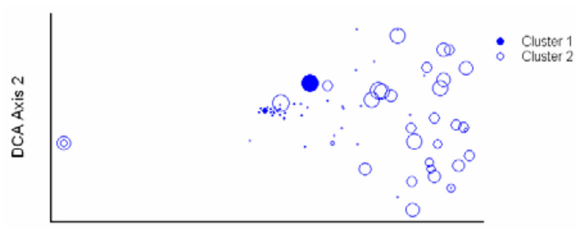


Fig. 9. Two dimensional plots of DCA overlaid with environmental variables recorded. Size of circles reflect the quantity of the variables measured in figures c-d.