Benthic Ecology of Weiti Estuary and Karepiro Bay

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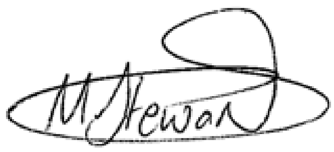

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Benthic Ecology of Weiti Estuary and Karepiro Bay

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1 Executive Summary

In 2007 the Auckland Regional Council identified the potential for changes in the sedimentation regime around Weiti and Okura estuaries, as a result of forest harvesting and roading. Likely effects on the ecology of Okura Estuary were identified by Swales et al. (2007), but not for the Weiti Estuary, or nearby Karepiro Bay, due to a lack of any data on the ecology of these areas. NIWA was contracted to undertake quantitative benthic sampling of intertidal areas of Weiti Estuary and intertidal and subtidal areas of Karepiro Bay. The design was to provide habitat and community information for these areas that would allow gross changes to be detected.

Multivariate analysis of the community structure suggested three major groupings that match with dominant sediment type: upper estuary (muddy sediments dominated by polychaetes; low diversity); middle estuary (silty – sandy sediments with high densities of adult cockles); outer estuary and Karepiro Bay (sandy sediments with mixed communities and variable diversity). Outer estuary and Karepiro Bay sites were generally dominated by long-lived, large species preferring sandy sediment and potentially sensitive to increased sedimentation.

Unlike the intertidal sites, subtidal sites were never dominated by polychaetes and only one site was clearly dominated by bivalves (Site 5 dominated by the invasive *Musculista senhousia*). Instead sites were either dominated by crustaceans or a mix of crustaceans, gastropods and echinoderms. Site 6 was dominated by sand dollars and had low abundance of macrofauna and low number of taxa. The remaining 6 sites could be split into two groups. (1) sites in the channel area of Weiti Estuary or immediately offshore from the channels of Weiti or Okura, displaying average abundance and number of taxa . (2) Sites located in the middle of Karepiro Bay, displaying high variability in community type, but generally including shrimps and hermit crabs.

For most of the taxa occurring in the subtidal area, no information is available on their sensitivity to increased sedimentation. However, Sites 5-7 have some species that are documented as sensitive (the soft sediment urchin and the sand dollar). Again these are species that, for macrofauna, have large adults. Thus their exclusion is likely to not only result in lower diversity but in reduced ecological functioning.

2 Introduction

In 2007 the Auckland Regional Council identified the potential for changes in the sedimentation regime around Weiti and Okura estuaries, as a result of forest harvesting and roading. Likely effects on the ecology of Okura Estuary were identified by Swales et al. (2007), but not for the Weiti Estuary, or nearby Karepiro Bay, due to a lack of any data on the ecology of these areas.

In May 2008, the Auckland Regional Council contracted NIWA to undertake quantitative benthic sampling of intertidal areas of Weiti Estuary and intertidal and subtidal areas of Karepiro Bay. The design was to provide habitat and community information for these areas and allow gross changes in these to be detected. It would also allow the best places to locate sites for more detailed monitoring to be determined (if required in future) and the potential sensitivity of these environments to changes in the sedimentation regime to be assessed.

Sampling methodology was similar to that conducted in the Southern Kaipara, Kawau Bay and Tamaki Inlet, i.e., broad-scale coverage with few replicates at each site and sieved on a coarse mesh. Fifteen intertidal and eight subtidal sites were sampled. Sites were well dispersed over the area, but were also targeted to represent different habitat types, e.g., mud, cockle beds, coarse sand and channel areas.

3 Methods

3.1 Intertidal sampling

Fifteen sites, located between the mid and low tide levels of Weiti Estuary and Karepiro Bay, were sampled for macrofauna and sediment type (Fig. 1). The exact locations of these sites were selected in the field to represent major habitat types found in the area. A broad-scale habitat map was produced at this time based on surface characteristics that were easily visible from the channel.

Three replicate cores (13cm diam., 15cm deep, 5m apart) were taken at each site for macrofauna and sieved on a 1mm mesh. Macrofaunal samples were preserved in 70%IPA, before being sorted. Macrofauna were then identified (predominantly to family level) and counted.

Three replicate cores (2cm diam., 2cm deep) were also taken at each site and the sediment amalgamated. This sediment was processed for particle size analysis by wet sieving through 2mm, 0.5mm, 0.25mm and 0.063mm sieves. Sediment collected on each sieve was dried and percentage weight of each size fraction calculated.

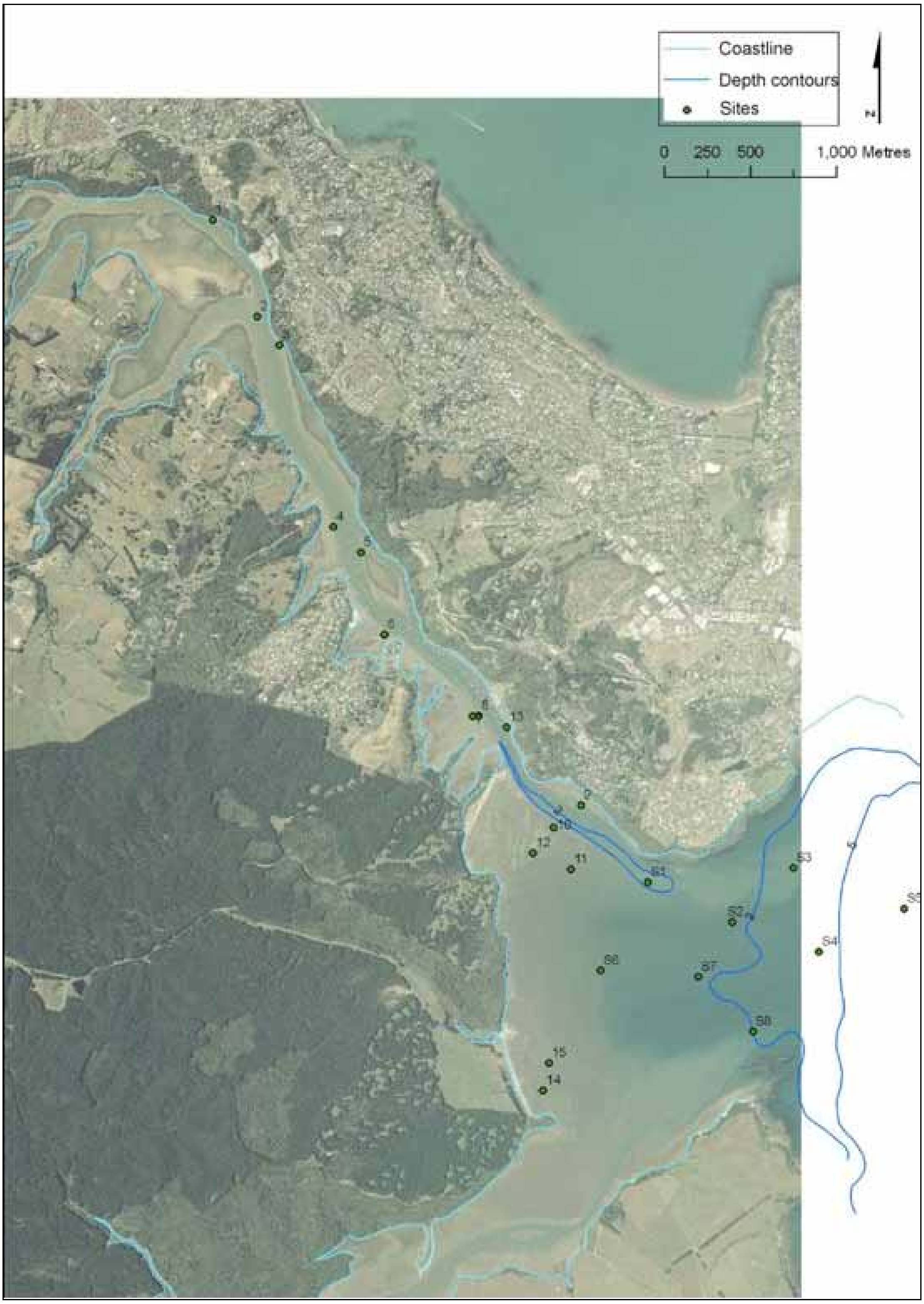
3.2 Subtidal sampling

Eight sites, located between 1 – 6m depth, were sampled for macrofauna and sediment type (Fig. 1). The exact locations of these sites were selected in the field to represent major habitat types found in the area. Macrofauna were sampled by dredge using a 2mm mesh and sediment type was estimated from camera images in the field. The reason for the difference in sampling strategy between the intertidal and subtidal was due to the difficulty in assessing the broad-scale layout of habitats in the subtidal environment. Sampling larger areas is therefore advantageous but necessitates the use of a coarser mesh. Even utilizing this sampling technique strategy it was not possible to sample enough to derive a realistic habitat map.

Three replicate dredge samples (~15m long, ~5cm deep) were taken at each site ~20m apart, and preserved in 70%IPA. Macrofauna were then identified (mainly to family level) and counted.

Figure 1:

Site locations in Weiti Estuary and Karepiro Bay.



4 Intertidal habitats and communities

4.1 Habitat and site descriptions

A habitat map of the intertidal areas of Weiti Estuary and Karepiro Bay is presented in Figure 2. Site 1 in the upper estuary was comprised of thick homogeneous mud (Table 1, Plate 1) densely spotted with large burrows (2 – 3cm diam, average 7.5 per 0.25m^2 quadrat) (Fig. 2). The mud extended up into dense mangroves at the base of a steep hillside. In the estuary above Site 1, the shallow channel (probably exposed at spring tide) was covered with mud and patches of oysters. This habitat extended up to the intertidal area, although the higher intertidal was thick with mangroves and pneumatophores.

Table 1:

Sediment particle size (fraction by percent weight) for intertidal sites.

Site	Shell hash > 2mm	Coarse sand	Medium sand	Fine sand	Mud
Site 1	0.00	0.21	1.89	35.06	62.83
Site 2	30.55	0.00	0.00	36.01	34.14
Site 3	2.56	0.00	2.39	64.05	31.00
Site 4	4.44	2.98	10.18	66.68	15.72
Site 5	2.23	7.14	23.92	50.94	15.77
Site 6	5.59	2.17	6.49	74.83	10.92
Site 7	0.00	0.03	0.16	90.63	9.17
Site 8	0.58	0.06	0.43	92.94	5.99
Site 9	5.31	4.27	8.69	74.45	7.28
Site 10	0.01	0.31	15.75	83.73	0.20
Site 11	0.00	0.18	0.84	97.66	1.31
Site 12	0.00	0.02	0.28	97.49	2.21
Site 13	21.05	3.00	7.28	55.53	13.14
Site 14	0.01	0.31	15.75	83.73	0.20
Site 15	0.14	0.84	0.59	97.49	0.93

Nearby Site 2 was located on a spit that ran out from the mangroves at the entrance to Duck Creek (Plate 2). The area was mud with a few patches of oysters, with the mud overlying (10cm deep) a shell hash layer. A similar density of large burrows was observed to that at Site 1, although here it was interspersed by numerous small worm holes.

Figure 2:

Intertidal habitats of Weiti Estuary and Karepiro Bay. Habitat boundaries are approximate only.

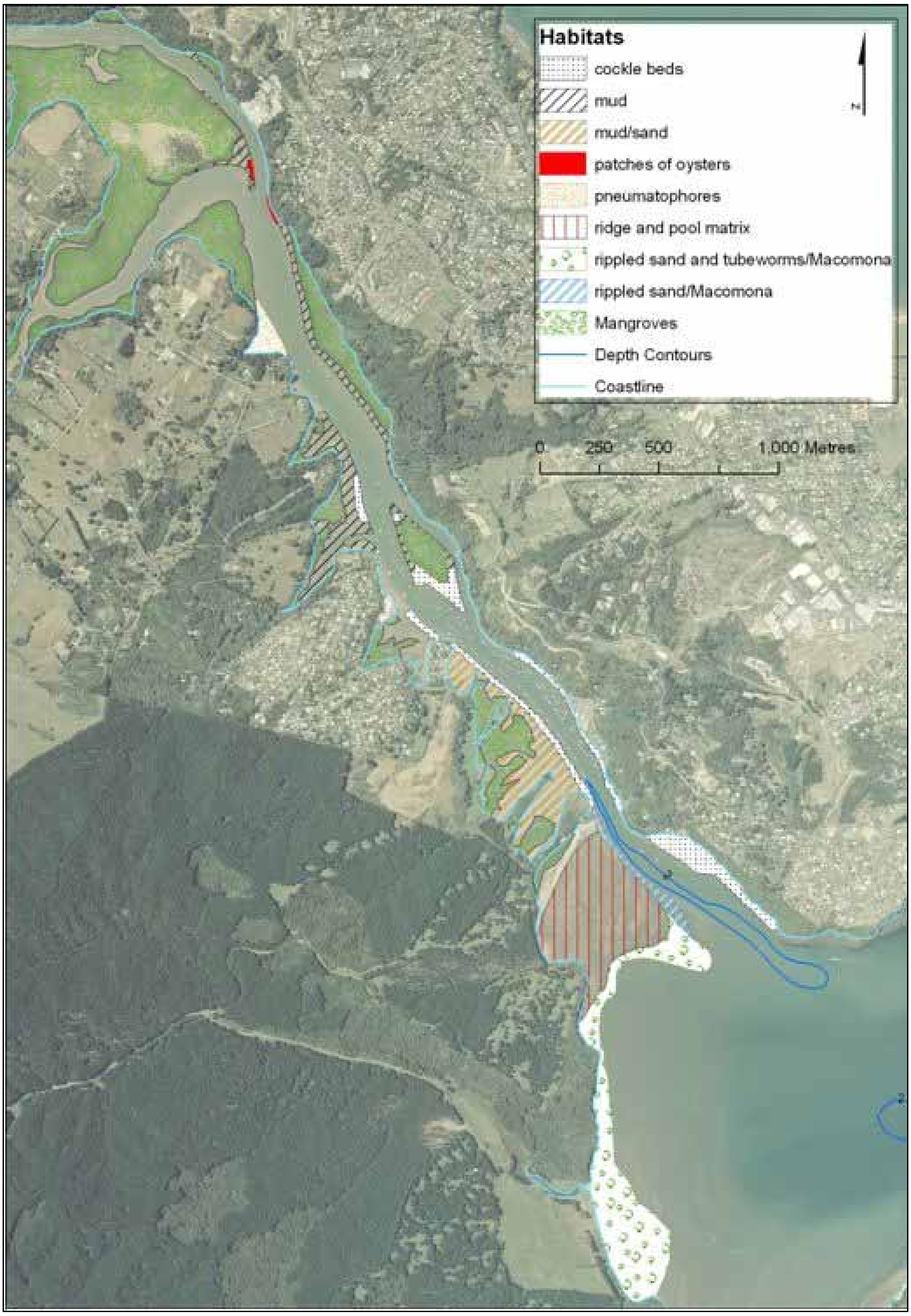


Plate 1:
Thick homogeneous mud densely spotted with large burrows at Site 1.

Plate 2:
Site 2 was located on a spit that ran out from the mangroves at the entrance to Duck Creek.

On the other side of the main channel, homogenous mud also overlay an old shell layer. At site 3 this shell layer was ~ 12cm below the mud surface. Burrows and holes were still the most dominant sign of animal life (Plate 3); although some mounds of polychaete faecal pellets were observed.

Plate 3:
Burrows and holes pockmark the sediment surface at Site 3.

Plate 4:
Site 4, a cockle dominated silt-mud area.

Further down the estuary, near Stillwater, the habitats were still mainly mud, oysters and mangroves. However, patches of cockles (*Austrovenus stutchburyi*) were beginning to occur (Plate 4). At Site 4, a cockle dominated silt-mud area was observed to spread across a third of the flat. Site 5 was located on the upper estuary end of a small island, between extensive mangroves and a mud flat (Plate 5). The site was a 500m^2 patch of cockles in a silt-mud sediment. The other side of the island had a very extensive matrix of shell hash, cockles, polychaetes and mud.

Plate 5:

Site 5, a small patch of cockles surrounded by mud.

From Stillwater down through the marina, on the west side of the estuary, the intertidal generally comprised a flat high area with steeply sloping shelly banks. These banks were predominantly cockle beds (similar to observations by Cummings and Green 2006), increasing in density of adult cockles towards the mouth. However, unlike their observations most of the oyster beds were observed further up the estuary and even small pipis were not observed till nearer the mouth.

At Site 6 (Plate 6), the high flat area was a mix of mangroves and bare mud/sand and the cockles in the bank although dense were small. By Site 8 the high area had become firmer and sandy (Plate 7), a trend continuing towards the mouth of the estuary, with obvious signs of polychaetes and *Macomona liliana* (the wedge shell). The steep banks were still dominated by cockles (Site 8, Plate 7).

Plate 6:

Site 6, Cockles in a silty mud matrix.

Plate 7:

Sites 7 (the high flat area) and 8 (the steeper bank).

On the eastern side of the estuary, the intertidal area was a small muddy sand slope with a muddier channel fringe (Plate 8). Underneath this, an old shell layer lay below the sediment surface. The slope (Site 13) was characterized by cockles and polychaetes, while the fringe showed working by crabs. This heterogeneous cockle, polychaete habitat stretched out into the northeast side of Karepiro Bay (Site 9, Plate 9), although the sediment became sandier and the slope diminished.

Plate 8:

Muddy sand fringe near Site 13.

Plate 9:
Site 9, a heterogeneous cockle and polychaete habitat.

Near the mouth on the western side of Karepiro Bay, was an extensive sandy intertidal area with large transverse ridges (Plate 10). The ridges were comprised of fine sand held together by a polychaete tube mat (*Boccardia syrtis*) (Site 12). In between the mounds, cockles shells and porous sands dominated.

Plate 10:
Large transverse ridges cross the sediment surface at Site 12.

Plate 11:
Strongly rippled sand at Site 10.

On the northeast side of this intertidal area, was a fine sand habitat, strongly rippled (Plate 11) with signs of *Macomona* (Site 10), followed by a sloping shell bank. On the south and east side, the intertidal area sloped very gently (Plate 12). The sand was rippled but worm tubes (Maldanidae) and mounds were common (Site 11). This habitat stretched out towards Dacre Point (Sites 14 and 15, Plate 13), gradually becoming more rippled with obvious signs of adult *Macomona* feeding tracks.

Plate 12:

Long flat intertidal area with rippled sand and tube worms at Site 11.

Plate 13:

Rippled sand at Sites 14 and 15 near Dacre Point.

4.2 Communities

Intertidal sites were either dominated by polychaetes (Sites 1, 2, 3, 11 and 12, Table 2), bivalves (Sites 6 and 8) or a combination of polychaetes and bivalves (Sites 4, 5, 7, 10, 14 and 15). A high proportion of crustaceans (amphipods and cumaceans) were found at sites 14 and 15. High densities of adult cockles (sized > 20mm) were observed at Sites 6 and 9, with reasonable numbers (> 200/m2) also occurring at Sites 4, 5, 8 and 13. Reasonable densities of adult *Macomona* (>100/m2 sized >20mm) were found at Sites 7, 10 14 and 15.

Table 2:

Intertidal macrofaunal community characteristics as % numbers within major taxonomic groups, overall abundance and number of taxa found at each site in 3 cores. Full data can be found in Appendix 2.

Sites	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Polychaetes	80	88	92	56	54	18	43	18	24	46	53	85	57	36	52
Bivalves	13	11	5	36	37	60	52	69	54	53	0	4	37	17	15
Other molluscs	0	0	0	1	1	18	0	5	9	0	0	0	3	0	3
Amphipods	4	0	0	0	1	0	0	0	1	1	7	4	1	28	24
Cumaceans	0	0	0	0	0	0	0	0	1	0	0	2	0	14	13
Decapods	4	1	0	1	1	0	0	5	1	0	0	0	2	0	0
Isopods	0	0	0	0	1	0	0	3	1	0	0	0	0	0	0
Echinoderms	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Miscellaneous	0	0	3	6	6	4	5	0	10	0	40	3	0	1	0
Adult cockles	0	0	0	8	9	26	0	12	22	1	0	0	14	2	0
Adult Macomona	0	0	0	0	0	1	4	0	2	4	0	0	0	6	5
Total abundance	54	156	118	181	164	297	21	39	358	148	15	89	171	72	67
Number of taxa	12	14	10	22	19	18	5	8	25	8	6	11	16	13	9

Sites also displayed differences in their most abundant taxa (Table 3). Sites 14 and 15 were the most similar with the three most dominant taxa being the polychaete *Magelona dakini*, the amphipod *Waitangi brevirostris* and the cumacean *Colurostylis lemerum.* Sites 2 and 3 had the two most dominant taxa in common (the polychaetes *Cossura consimilis* and *Heteromastus filiformis*). The other sites differed in the most dominant taxa, although Sites 6 and 8 were numerically dominated by *Austrovenus stutchburyi.*

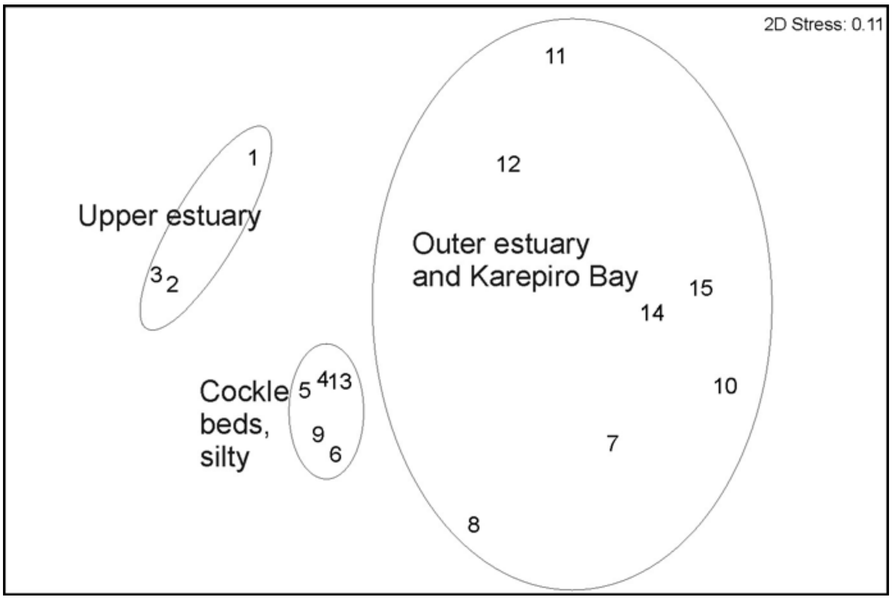
Table 3:

Three most dominant taxa found at each intertidal site.

	Most dominant		
Site 1	Capitella spp.	Boccardia syrtis	Cossura consimilis, Glycera sp.
Site 2	Cossura consimilis	Heteromastus filiformis	Nicon aestuarensis
Site 3	Cossura consimilis	Heteromastus filiformis	Theora lubrica
Site 4	Cirratulidae	Nucula hartvigiana	Austrovenus stutchburyi
Site 5	Prionospio aucklandica	Nucula hartvigiana	Austrovenus stutchburyi
Site 6	Austrovenus stutchburyi	Nucula hartvigiana	Austrominius modestus
Site 7	Macomona liliana	Scoloplos cylindifera	Austrovenus stutchburyi
Site 8	Austrovenus stutchburyi	Lumbrineris sp.	Austrominius modestus, Helice crassa
Site 9	Nucula hartvigiana	Austrovenus stutchburyi	Prionospio aucklandica
Site 10	Paphies sp.	Magelona dakini	Macomona liliana
Site 11	Nemerteans	Aricidea sp.	Colorostylis lemurum, Macroclymenella stewartensis
Site 12	Boccardia syrtis	Macomona liliana	Nemerteans, Waitangi brevirostris
Site 13	Cirratulidae	Prionospio aucklandica	Nucula hartvigiana
Site 14	Magelona dakini	Waitangi brevirostris	Colorostylis lemurum
Site 15	Magelona dakini	Waitangi brevirostris	Colorostylis lemurum

Nonmetric multidimensional analysis of the community structure, based on Bray-Curtis similarities between raw data, suggested three major groupings (Fig. 3). Sites with moderate to high densities of cockles and silty sediment formed a tight cluster. Upper estuary sites with muddy sediments and low diversity formed another, more diffuse, group. The intertidal sites of the outer estuary and Karepiro sites only occurred on the right hand side of the plot.

Figure 3.
Non-metric multidimensional analysis of the intertidal communities of Weiti Estuary and Karepiro Bay.



5 Subtidal habitats and communities

5.1 Habitat and site descriptions

Site 6 was situated in the very shallow subtidal area near the centre of the bay (Fig.1). The sediment type was rippled sand and the area was dominated by the sand dollar (*Fellaster zelandiae*). As the area offshore of Site 11 was similar and as this is a common shallow subtidal habitat in the Auckland Region (see Southern Kaipara, Whitford), it is likely that this habitat extends throughout the south side of Karepiro Bay in the areas with <1m water depth at low tide. Indeed, a 1999 survey of the area (Morrison et al. 1999) noted its presence at a number of sites.

Sites 1 and 8 were located within the channels running out from Weiti and Okura Rivers respectively. Sediment type at both sites was similar: muddy sand with ripples. Gastropod trails were common on the surface at both sites and at Site 8, polychaete mounds and tubes could be seen.

Further offshore from Weiti the sediment was muddy with many burrows, polychaete mounds and gastropod trails obvious (Sites 2 and 4). Sites 3 and 7 appeared somewhat sandier, although still a muddy sand, with small burrows and gastropod trails obvious at both sites. Extensive areas of gastropods were also observed in the survey done in 1999 by Morrison et al. At the shallower site (Site 7), patches of brown algae were obvious on the sediment surface, and at Site 3 clumps of loose seaweed were seen.

Site 8 was the deepest site sampled (>5m depth). The sediment here appeared covered by fine fluffy mud that could be easily disturbed. Mounds of the invasive Asian date mussel (*Musculista senhousia*) were patchily distributed across the sediment surface. It is interesting to note that the 1999 survey of the area did not find any *Musculista* patches in the area.

5.2 Communities

Unlike the intertidal sites, subtidal sites were never dominated by polychaetes (Table 4) and only one site was clearly dominated by bivalves (Site 5 dominated by the invasive *Musculista*). Instead, sites were either dominated by crustaceans or a mix of crustaceans, gastropods and echinoderms.

Table 4:

Subtidal macrofaunal community characteristics as % numbers within major taxonomic groups, overall macrofaunal abundance and number of taxa found at each site in 3 cores. Full data can be found in Appendix 3.

Sites	1	2	3	4	5	6	7	8
Amphipods	23	4	27	61	1	0	26	13
Decapods	50	58	18	10	2	11	20	40
Bivalves	4	4	24	2	91	1	3	7
Other molluscs	18	26	3	2	1	2	5	19
Echinoderms	1	7	24	7	1	77	29	8
Cumaceans	1	0	0	13	0	0	14	5
Mysids	1	0	1	4	0	10	3	6
Polychaetes	1	0	1	0	2	0	0	0
Isopods	1	0	1	0	0	0	0	0
Tanaids	0	0	0	0	1	0	0	0
Miscellaneous	0	0	0	1	1	0	0	1
Total abundance	169	72	289	182	4320	94	184	141
Number of taxa	20	11	20	15	39	7	20	22

Nonmetric multidimensional analysis of the community structure, based on Bray-Curtis similarities between raw data, did not show any tight clusters (Fig. 4). However, Sites 5 and 6 were clearly separated from the others. Site 5 was the deepest site, dominated by *Musculista* (Table 5), with the highest number of taxa and abundance (even discounting *Musculista*). Many of the taxa found here were either highly mobile, suggesting that they be utilizing the *Musculista* patches as a refuge, or attached epifauna using *Musculista* as a habitat substrate. Site 6 was dominated by the sand dollar (*Fellaster*) (Table 5), and had low numbers of taxa which were in low abundances.

Figure 4:
Non-metric multidimensional analysis of the intertidal communities of Weiti Estuary and Karepiro Bay.

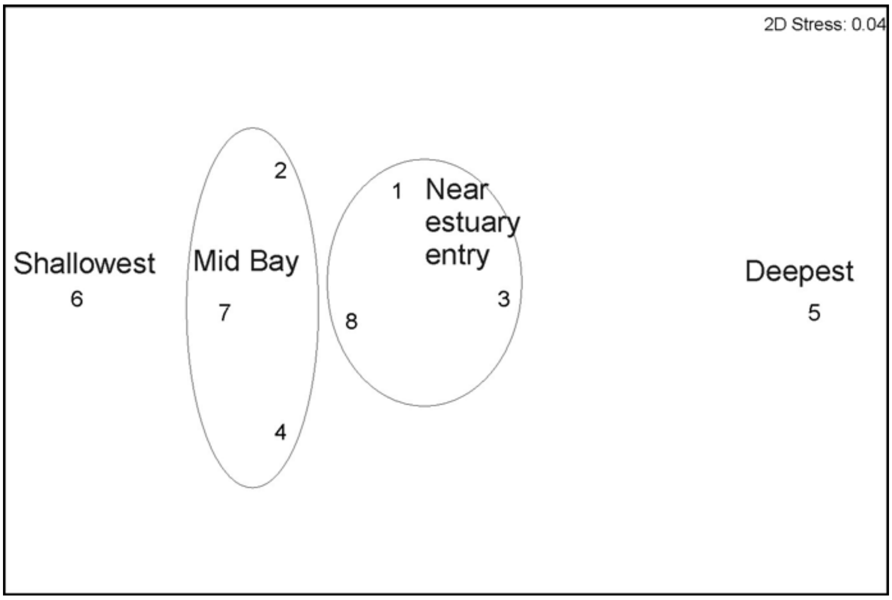


Table 5:

Three most dominant taxa found at each subtidal site.

	Most dominant		
Site 1	Pontophilus australis	*Aora* sp.	Paleomon affinis
Site 2	Pontophilus australis	Amalda novazelandiae	Paguristes setuose
Site 3	Echinocardium australe	*Aora* sp.	Musculista senhousia
Site 4	Torridoharpinia sp.	Methlimedon sp.	Diastylopsis elongata
Site 5	Musculista senhousia	Theora lubrica	Nucula nitidula
Site 6	Fellaster zelandiae	Mysidacea	Pontophilus australis
Site 7	Fellaster zelandiae	Pontophilus australis	Diastylopsis elongata
Site 8	Paguristes setuose	Amalda sp.	Torridoharpinia sp.

The remaining 6 sites could be split into two groups:

- Sites 1, 8 and 3 were all located either in the channel area of Weiti Estuary (Site 1) or immediately offshore from the channels of Weiti (Site 3) or Okura (Site 8). All three sites displayed average abundance and number of taxa, although the dominant taxa differed (Table 5). Site 3 had a mixed community of *Musculista*, amphipods, decapods and the echinoderm *Echinocardium australe*. Sites 1 and 8 had a mixed community of shrimps, hermit crabs, amphipods and molluscs.
- Sites 2, 4 and 7 were all located in the middle of Karepiro Bay. Site 2 displayed the lowest abundance of all the sites and also had low number of taxa. It was dominated by decapods (*Pontophilus australis* and *Paguristes setuose*) and

gastropods (*Amalda novazelandiae*)(Table 5), with some starfish (*Patriella regularis*). Site 4 and 7 had higher abundances of macrofauna. However, Site 4 had the lowest number of taxa of all the sites and was dominated by amphipods (*Torridoharpinia* and *Methlimedon*) and cumaceans (*Diastylopsis elongata*) with some decapods (*Pontophilus* and *Paguristes*), cumaceans and echinoderms (*Echinocardium*, *Patriella* and some juvenile Ophiuroids). Site 7 displayed an average number of taxa with a mixed community of amphipods, decapods (*Pontophilus* and *Paguristes*), but was dominated by *Fellaster, Pontophilus* and *Diastylopsis.*

6 Sensitivity to changes in sedimentation regime

Catastrophic and thin sub-lethal depositions, together with increased suspended sediment concentrations, can result in long-term changes in species, communities and habitat, frequently resulting in low diversity systems dominated by a low number of species and one or two habitats. At present the sedimentation rates in the subtidal areas of Karepiro Bay are under study by NIWA for ARC and results suggest rates of 2.5 to 5.5 mm per year (increasing from north to south) (Swales et al. 2008). The latter rates are similar to those in the upper Okura estuary. Cummings and Green (2006) considered that deposition events in Weiti under the development scenarios of the time were likely to be minor and infrequent. However, they also point out that effects of resuspended sediments or sediments flushed out to the adjoining coast were not considered. Their assessment was also limited by the lack of extensive information on species and habitats to be found within the Weiti Estuary and Karepiro Bay.

Now that ecological sampling has been conducted in Weiti and Karepiro, we can more specifically consider likely effects on the benthic macrofaunal species inhabiting these areas. The research that is available with which to assess effects on particular species covers both catastrophic and sublethal impacts and is based on field and laboratory experiments and surveys of macrofauna and is summarized in Gibbs and Hewitt (2004). Here Table 4 presents the information for taxa found to be among the five most dominant taxa at any site in the Weiti Estuary and Karepiro Bay area.

For many of the taxa occurring in this area, there is no information available. However from the information that there is we can say that intertidal Sites 9, 10-12 and 14-15 are generally dominated by species that are sensitive to increased suspended sediment or sedimentation. Intertidal Site 7 and subtidal Sites 3 and 5-7 also have some species that are sensitive. Intertidal Sites 4 – 6 are dominated by adult cockles, which have been described variously as intermediate or sensitive depending on the study. In most cases these species are not only sensitive, but are large and slow growing. Their exclusion is likely to not only result in lower diversity but also in reduced ecological functioning. Of particular concern are the potential for decreases in *Macomona*, *Boccardia*, *Echinocardium* and *Austrovenus*, if suspended sediment concentrations or sedimentation rates increase. For these species, a crucial factor, related to the sedimentation rates presently observed in Karepiro Bay, is the maximum depth of deposition per event and the number and timing of events occurring within a year, as opposed to the net long-term measurements made by Swales et al. (2008).

Table 4:

Summary from Gibbs and Hewitt (2004) of likely species sensitivity to changes in sedimentation regime. SS = strong preference for sandy sediment and low suspended sediment concentrations, S = preference for sandy sediment, I = prefers silty sediment and higher suspended sediment concentrations, MM = prefers highly muddy sediment.

Sites	Location	Taxon Information	Taxa	
9	Intertidal	Anenome	Anthopleura aureoradiata	SS
10	Intertidal	Bivalve	Paphies sp	SS
11,12,14,15	Intertidal	Amphipod	Waitangi brevirostris	SS
11,14,15	Intertidal	Crustacean	Colorostylis lemurum	S
3,5	Subtidal	Echinoderm	Echinocardium australe	S
6,7	Subtidal	Echinoderm	Fellaster zelandiae	S
most	Intertidal	Bivalve	Macomona liliana	S
most	Intertidal	Bivalve	Nucula hartvigiana	S
10	Intertidal	Polychaete	Orbinia papillosa	S
7	Intertidal	Polychaete	Scoloplos cylindrifer	S
most	Intertidal	Bivalve	Austrovenus stutchburyi	I, S
1, 12	Intertidal	Polychaete	Boccardia syrtis	I, S
11	Intertidal	Polychaete	Aricidea sp.	I
6	Intertidal	Bivalve	Arthritica bifurca	I
4,5,13	Intertidal	Polychaete	Cirratulid	I
1,2,3	Intertidal	Polychaete	Cossura consimilis	I
1,2	Intertidal	Polychaete	Glycera spp.	I
most	Intertidal	Polychaete	Heteromastus filiformis	I
8	Intertidal	Crustacean	Lumbrinerid	I
11	Intertidal	Polychaete	Macroclymenella stewartensis	I
3,5	Subtidal	Bivalve	Musculista senhousia	I
7,11,12	Intertidal	Nemertean	Nemertean	I
2	Intertidal	Polychaete	Nicon aestuarinensis	I
most	Intertidal	Polychaete	Prionospio aucklandica	I
s5, i1-3	Subtidal/Intertidal	Bivalve	Theora lubrica	I
8	Intertidal	Crustacean	Helice crassa	MM
1	Subtidal	Barnacle	Aaptolasma noleoria	
2	Subtidal	Gastropod	Amalda novazelandiae	
8	Subtidal	Gastropod	Amalda sp.	
1,3	Subtidal	Amphipod	Aora sp.	
6,8	Intertidal	Barnacle	Austrominius modestus	
1	Intertidal	Polychaete	Capitellidae	
2	Subtidal	Gastropod	Cominella adspersa	
4,7	Subtidal	Crustacean	Diastylopsis elongata	

Sites	Location	Taxon Information	Taxa
14,15	Intertidal	Amphipod	Gammaridae
10,14,15	Intertidal	Polychaete	Magelona ?dakini
4,7	Subtidal	Amphipod	Methalimedon sp.
4,6,8	Subtidal	Crustacean	Mysidae
5	Subtidal	Bivalve	Nucula nitidula
most	Subtidal	Crustacean	Paguristes setosus
1	Subtidal	Crustacean	Paleomon affinis
3	Subtidal	Amphipod	Paradexamine pacifica
3	Intertidal	Polychaete	Paraonidae
2	Subtidal	Echinoderm	Patriella regularis
7	Intertidal	Polychaete	Perinereis nuntia
most	Subtidal	Crustacean	Pontophilus australis
5	Subtidal	Polychaete	Serpulidae
4,7,8	Subtidal	Amphipod	Torridoharpinia sp

- Adult *Macomona*, *Echinocardium* and *Austrovenus* have strong influences both on other macrofauna and on nutrient and oxygen fluxes (Thrush et al. 1992, Thrush et al. 1997, Lohrer et al. 2004, Thrush et al. 2006). Although experiments suggest that *Austrovenus* cope with higher suspended sediment loads and sedimentation rates than the other two species, the large number of cockle shells underneath the muddy sediment at Sites 4 and 5 and the small size of the patches relative to nearer the mouth of the estuary suggest that the populations at the these two sites may be remnants, already under pressure from sediment runoff events.

- The habitat at the mouth of Weiti Estuary on the south western side is a complicated matrix of ridges and pools. The ridges are thick with *Boccardia* tube mats, which is likely to be holding sediment and stabilizing the ridges. A small-scale experimental removal of *Boccardia* mat in a similar habitat in Manukau Harbour demonstrated very slow recovery of communities as animals and sediment were swept away before colonization occurred (Thrush et al. 1996). The ridges did not disappear, however, probably due to the small size of the removals (maximum size 1.8 x 1.8 m).

7 Conclusions

This survey reveals communities living in the outer estuary near the mouth that are sensitive to sedimentation events (both depositional events and increased levels of turbidity in the water column) and to contamination by copper, lead and zinc (Anderson et al. 2007). The taxa observed are generally those that would be expected in a healthy estuary, with the exception that no large pipi beds were observed. However, this species, although one of the most sensitive to sedimentation events, is also usually distributed in a highly patchy fashion, is highly mobile and a target for shellfish collection by humans. Thus, their absence may not be indicative of sedimentation stress.

As is typical in many Auckland estuaries, cockle beds are most extensive near the mouth of the estuary and become less extensive (smaller patches surrounded by mud) moving away from the mouth. Approximately 500m up the estuary from the boat ramp at Stillwater they have been replaced by mud flats and patchy oyster reefs, although cockle shells are found beneath the sediment surface. No work on sedimentation rates has been conducted above Stillwater, so we can not determine whether the small patches of cockles are remnants from ongoing sediment deposition or events that occurred post deforestation. However, Swales et al. (2008) observe that, even further towards the mouth of the estuary, the tidal flats in Weiti are accumulating mud, suggesting that sedimentation is ongoing.

Contamination by zinc and copper may also pose a threat in the years to come. While the levels predicted by Williamson et al. (2005) for 2051 in the estuary near the mouth and around Stillwater (subestuaries 3 & 4) are below the amber ERC level, results of the ARCs Benthic Health Model (Anderson et al. 2007) indicate changes to macrofaunal communities can occur below this level.

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10 Appendices

10.1 Appendix 1: Macrofaunal data from intertidal sites

Sites	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
?Bogidellidae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Aglaophamus macroura	0	0	0	0	0	0	0	0	0	0	0	2	0	2	1
Alpheus sp.	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Anthopleura aureoradiata	0	0	0	9	9	10	0	0	33	0	0	0	0	3	0
Aricidea sp.	0	1	0	0	0	0	0	0	1	0	5	0	0	0	0
Armandia maculata	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Arthritica bifurca	0	0	0	4	1	15	0	0	0	0	0	0	2	0	0
Austrominius modestus	0	0	0	0	0	44	0	2	15	0	0	0	0	0	0
Austrovenus stutchburyi	0	0	0	28	22	82	3	26	79	3	0	0	30	2	0
Boccardia syrtis	10	3	0	2	2	5	0	0	2	0	0	70	2	0	0
Capitella sp.	0	4	0	6	0	0	0	0	0	0	0	0	0	0	0
Capitellidae?H	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ceratonereis sp.	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Cirratulidae	0	0	0	32	11	10	0	0	0	0	0	0	40	0	0
Colorostylis lemurum	0	0	0	0	0	0	0	0	0	0	3	2	0	10	9
Cominella glandiformis	0	0	0	0	1	1	0	0	2	0	0	0	2	0	2
Corophiidae	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Cossura consimilis	6	62	61	3	2	0	0	0	0	0	0	0	0	0	0
Cyclapsis argus	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
Diloma subrostrata	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0
Duplicaria sp.	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Exosphaeroma chilensis	0	0	0	0	1	1	0	1	2	0	0	0	0	0	0
Fellaster zelandiae	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Gammaridae	0	0	0	0	0	0	0	0	0	0	0	0	0	7	5
Glycera spp.	6	6	1	4	2	1	0	0	1	0	0	0	3	0	0
Glycinde trifida	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Halicarcinus sp.	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
Helice crassa	0	0	0	0	0	0	0	2	0	0	0	0	3	0	0

Sites	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Heteromastus filiformis	0	34	37	20	20	5	0	1	26	0	0	0	12	0	0
Lumbrineridae	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0
Macomona liliana	0	0	0	2	1	2	8	0	3	4	0	3	0	6	5
Macroclymenella stewartensis	0	0	0	1	0	0	0	0	2	0	3	0	0	0	0
Macrophthalmus hirtipes	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Cyclomactra ovata	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Magelona dakini	0	0	0	1	0	0	0	1	2	65	1	2	3	21	31
Mysidacea	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Nemertean	0	0	1	1	1	3	1	0	2	0	6	3	0	0	0
Nicon aestuariensis	1	19	1	1	4	1	0	0	0	0	0	0	2	0	0
Notocmea helmsi	0	0	0	0	0	8	0	0	7	0	0	0	2	0	0
Nucula hartvigiana	2	0	0	29	37	78	0	0	111	0	0	0	32	0	0
Oligochaete	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0
Orbinia papillosa	0	0	0	0	0	0	0	0	0	3	1	1	3	3	3
Paphies sp.	0	0	0	0	0	0	0	0	0	72	0	0	0	4	0
Paradoneis lyra	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Paraonidae	0	2	3	0	1	0	0	0	0	0	0	0	0	0	0
Pectinaria australis	0	0	1	4	0	0	0	0	0	0	0	0	0	0	0
Perinereis vallata	1	1	0	1	0	0	1	0	0	0	0	0	0	0	0
Pinnotheres sp.	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
Polynoid	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Prionospio aucklandica	2	4	4	27	46	26	0	0	50	0	0	1	33	0	0
Scoloplos cylindrifer	0	0	0	0	0	4	8	0	0	0	0	0	0	0	0
Soletellina sp.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Sypharochiton pelliserpentis	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
Theora lubrica	5	17	6	3	0	0	0	0	0	0	0	1	0	0	0
Torridoharpinia sp.	0	0	0	0	1	0	0	0	4	0	1	1	0	0	0
Turbonilla sp.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Upogebia sp.	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Waitangi brevirostris	0	0	0	0	0	0	0	0	0	1	2	3	0	12	11
Xymene plebius	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Zeacumantus lutulentus	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0

10.2 Appendix 2: Macrofauna data from subtidal sites

Sites	1	2	3	4	5	6	7	8
Mauricolpus roseus	1	0	0	0	0	0	0	0
?Hippomedon sp.	0	0	0	0	1	0	0	0
Torridoharpinia sp	0	2	3	77	8	0	23	16
Aaptolasma noleoria	20	0	0	0	0	0	0	0
Aglaophamus sp.	0	0	0	0	5	0	0	0
Amalda novazelandiae	1	16	7	1	0	0	0	0
Amalda sp.	0	0	0	0	23	1	7	22
Aora sp.	37	0	65	0	35	0	1	0
Arthritica bifurca	0	0	0	0	6	0	0	0
Barnacle	0	0	0	0	1	0	0	0
Colurostylis lemurum	0	0	0	0	1	0	0	1
Cominella adspersa	7	3	1	0	9	0	1	1
Cominella glandiformis	2	0	0	0	0	1	0	0
Cominella sp.	0	0	0	0	4	0	0	0
Coscinasterias muricata	1	0	0	0	0	0	0	0
Cyclapsis argus	0	0	0	0	0	0	0	1
Cyclapsis sp.	0	0	0	0	0	0	1	0
Cyclapsis triplicata	0	0	0	0	0	0	0	1
Diastylopsis elongata	1	0	0	23	0	0	24	3
Dosinia sp.	0	0	0	0	9	0	1	0
Duplicaria sp.	0	1	1	0	0	0	0	0
Duplicaria tristis	0	0	0	0	0	0	2	2
Echinocardium australe	0	0	68	6	52	0	0	7
Fellaster zelandiae	0	0	0	0	1	72	48	4
Halicarcinus varius	0	0	0	1	13	0	0	0
Halicarcinus whitei	2	0	2	0	0	0	0	0
Isocladus sp.	0	0	1	0	0	0	0	0
Isocladus spiculatus	1	0	0	0	0	0	0	0
Liljeborgia sp.	0	0	0	0	0	0	2	0
Macrophthalmus hirtipes	0	0	0	0	5	0	0	0
Cyclomactra ovata	0	0	0	0	1	0	0	0
Methalimedon sp.	1	0	0	30	0	0	12	3
Musculista senhousia	0	0	64	0	3572	0	0	3
Mysidae	1	0	4	8	1	9	6	8
Neanthes sp.	0	0	0	0	10	0	0	0
Nemertean	0	0	0	0	30	0	0	0
Notomitrax minor	0	0	0	0	2	0	0	0
Nucula hartvigiana	0	0	0	0	0	1	0	0
Nucula nitidula	0	2	5	4	154	0	2	5
Oedicerotidae sp	0	1	0	5	0	0	10	0

Sites	1	2	3	4	5	6	7	8
Ophiuroid juvenile	0	0	0	3	0	0	3	0
Paguristes setosus	18	15	40	7	14	1	10	37
Paleomon affinis	24	2	5	0	42	0	0	0
Paphies sp.	6	0	0	0	0	0	0	0
Paradexamine pacifica	2	0	12	0	0	0	0	0
Patriella regularis	1	5	2	3	3	0	2	1
Pectinaria australis	0	0	0	0	3	0	0	0
Pinnotheres sp.	0	0	0	0	3	0	0	0
Platyhelminthe	0	0	0	1	10	0	0	0
Pleuromeris zealandica	0	0	0	0	9	0	0	0
Pontophilus australis	41	23	2	11	14	9	26	14
Pyromaia tubereulata	0	2	4	0	8	0	1	5
Euchone sp.	0	0	0	0	1	0	0	0
Siglionidae	1	0	0	0	0	0	0	0
Serpulidae	0	0	0	0	59	0	0	0
Tanaid (Apsendes)	0	0	0	0	19	0	0	0
Struthiolaria papulosa	0	0	0	0	0	0	2	0
Struthiolaria vermis vermis	0	0	0	0	1	0	0	0
Theora lubrica	0	0	0	0	188	0	0	0
Unidentified anemone	0	0	0	0	0	0	0	2
Unidentified cumacean	0	0	0	0	0	0	0	1
Unidentified hermit crab	0	0	0	0	1	0	0	0
Unidentified isopod #1	0	0	1	0	0	0	0	0
Unidentified Nereid	1	0	0	0	0	0	0	0
Phyllodocidae	0	0	1	0	0	0	0	0
Xymene plebius	0	0	0	0	0	0	0	1
Xymene sp.	0	0	0	2	0	0	0	0
Zeacumantus sp.	0	0	1	0	1	0	0	3