Technical review of existing marine ecological data for Lyttelton Harbour/Whakaraupō

with recommendations for future work

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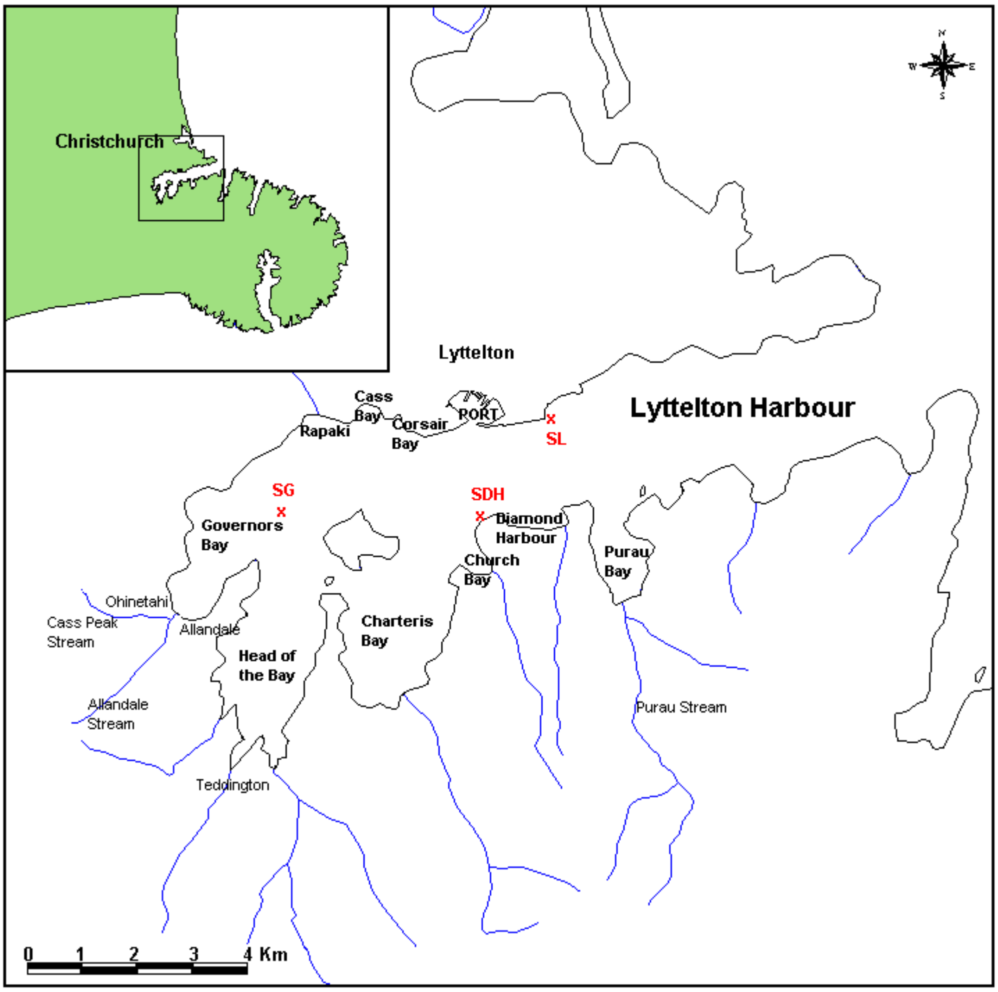
1. The harbour

Lyttelton Harbour, formed by the drowning of the erosion crater of an extinct volcanic complex, is characterised as a muddy bottomed, relatively shallow, rock-walled inlet. The harbour width varies from 1.35 - 5.5 km and at high tide it is approximately 15 km long, covering an area of about 44 km^2 (Spigel, 1993). At low tide a quarter of the harbour area, i.e. 11 km^2, is exposed mud flat with these mud flats occurring at the head of the harbour in Governors Bay, Charteris Bay and Head of the Bay (Figure 1).

Located about midway down the northern side of the harbour is the busy commercial Port of Lyttelton (Figure 1.1). The port facilities include container, oil tanker and roll-on roll-off facilities, coal storage and loading facilities, a dry dock, a cattle wharf, general shipping, fishing boat and cement shipping berths and yacht moorings.



Approximate position of sewage discharges: x SG - Governors Bay
x SL - Lyttelton
x SDH - Diamond Harbour

Figure 1 Lyttelton Harbour/ Whakaraupō: location, bays, streams and sewage discharge

2 Existing information on the presence and abundance of marine biota

The information presented in this report comes from:

1. baseline studies that have been commissioned by Environment Canterbury (Handley *et al,.*2000; Fenwick, 2003).
2. a thesis on the subtidal benthic ecology of Lyttelton Harbour (Knight, 1974).
3. sampling, carried out in 2004 to fulfil a condition of the Lyttelton Port Company coastal permit for dredging and dredge spoil dumping operations in Lyttelton Harbour (Thompson and Barter, 2005).
4. a study to assess the likely ecological and hydrological impacts of a proposed reclamation (Knox, 1983).

2.1 Intertidal

2.1.1 Rocky Shore

In 1982-83, a quantitative assessment of the rocky intertidal biota within the port and along the outer breakwater, was carried out by Knox (1983). Sampling was undertaken at four shore levels at each of nine sites (Figure 2). In this study 109 species were recorded with 35 being algal species and 74 being animal species (Appendix I). Ten species of algae, eight species of gastropod molluscs, one species of bivalve mollusc, two species of crustaceans and two species of polychaete worms were found to dominate the intertidal biota (Appendix I). The between site differences in the presence and abundance of species was attributed to:

- differences in exposure to wave action and swell
- degree of shading
- turbidity
- pollution

In 2000, a baseline study of the rocky intertidal biota at three shore levels at each of seven sites within the port and along the outer breakwater was carried out by Handley *et al.* (2000). Three of these sites were sampled again in 2003 (Fenwick, 2003). Of note is that three of the sites sampled in 2000 were in a comparable locality to three of the sites sampled in 1982-83 (Figure 2). In 2000 a total of 44 species were recorded with 16 being algae species and 28 being animal species (Appendix I). The differences in the number of species recorded between the 2000 and the 1983 studies are attributed to the following:

1. Differences in the shore levels sampled – Knox (1983) sampled four shore levels including the upper part of the algal zone (sublittloral fringe), Handley *et al.* (2000) sampled three shore levels and did not sample the sublittoral fringe. Many of the algae and animal species (for example hydroids, ascidians, sponges) listed by Knox (1983) would have only been found in the sublittoral fringe.
2. Differences in sampling methodology.
3. The algae epifauna i.e. amphipods, isopods and molluscs were identified to species level and recorded by Knox (1983). This epifauna was not investigated by Handley *et al.* (2000).

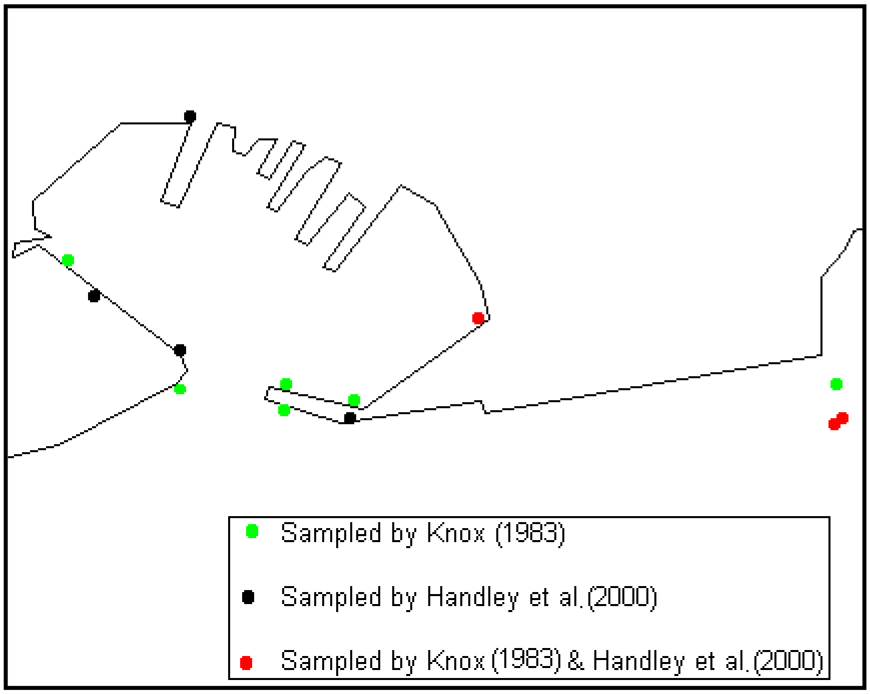


Figure 2: Rocky shore intertidal sampling sites within and outside the Port of Lyttelton

The results from the sampling in 2000 revealed a greater diversity of species outside and seaward of the port than inside the port with this attributed to the greater wave action and current exposure outside than inside the port. Within the port, species diversity was influenced by the proximity of a site to wharf structures because of the shading and shelter effects of the structures. When the intertidal species diversity of the Port of Lyttelton was compared to that of the Port of Timaru it was found to be lower. This was attributed to the more sheltered and turbid conditions in the Port of Lyttelton than in the Port of Timaru.

The comparison of the intertidal biota at three sites between 2000 and 2003 found few obvious differences in the biota between years (Appendix I). However, there was a difference in the prevalence of green algal species, i.e. *Enteromorpha* sp. in 2003 and *Ulva* sp. in 2000. This could have been a seasonal effect because sampling was undertaken at different times of year. In 2003 there was also silt on the low shore rocks at two sites, this silt appeared to have some effect on the biota. The presence of silt was not recorded in 2000.

From the 2003 numerical analyses of the intertidal sampling data it was found that there was high variability in the presence and abundance of the biota at each shore level at each site. This meant that it was not possible to adequately enumerate differences in the biota between shore levels, sites and years. High variability in the presence and abundance of rocky shore biota is universally recognised. Thus it was recommended that in order to identify changes over time, and possibly be able to attribute the changes to port-related activities there should be:

- greater sampling replication at each shore levels; ten replicate samples at each shore level at each site was suggested.
- comparable sampling at more than one control site outside of the port.

Well beyond the port area, qualitative sampling of the intertidal biota has been undertaken at a site in Rapaki and a site in Breeze Bay (Figure 3). This sampling was carried out in 1992, 1995, 2000 and 2004 (Thompson and Barter, 2005). At each site 20-25 m of shoreline was surveyed, the plants and animals present recorded and the density or percentage cover of species categorised as either sparse, occasional common or abundant. In 2004, 33 taxa were recorded from the Rapaki site and 39 from the Breeze Bay site (Appendix I).

The comparison of the 2005 data with those from the previous years revealed that 'in general, the intertidal assemblages of animals and plants at both sites was very similar to previous years' surveys and characteristic of the region. Both sites appeared in a healthy state, with no evidence of excess sedimentation' (Thompson and Barter, 2005).

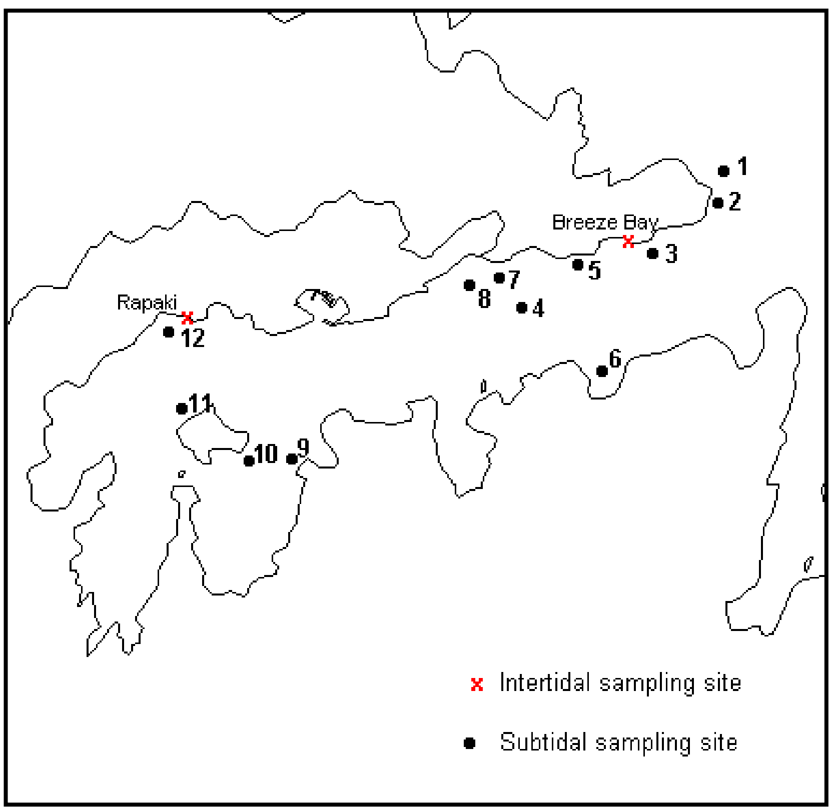


Figure 3: Rocky shore intertidal and soft sediment subtidal sampling sites located well beyond the port but within Lyttelton Harbour/Whakaraupō

(from Thompson and Barter, 2005)

2.1.2 Soft Shore

There are no data on the biota and sediments of the extensive intertidal mudflats (~ 11 km^2) at the head of the harbour in Governors Bay, Charteris Bay and Head of the Bay.

2.2 Subtidal

2.2.1 Rocky habitats

There are no data on the biota of the rocky subtidal habitats of Lyttelton Harbour.

2.2.2 Soft sediment

In 1970-71 a study of the benthic ecology of Lyttelton Harbour was carried out by Knight (1974). Sediment and biological samples were collected from 71 sites (most located in the inner and mid regions of the harbour). The grain size and organic matter content of the sediment samples and the presence and abundance of the fauna in the biological samples were measured. One hundred and sixteen animal species were present in the samples. From the analyses of all the data three animal communities were identified, these were:

- the *Hemiplax hirtipes* – *Virgularia gracillima* community associated with muddy sediments.
- the *Zeacolpus vittatus* – *Pectinaria australis* community associated with sandy sediments.
- the *Chione stutchburyi* community present in restricted sandy areas.

In addition there was a continuum of about 12 species between the *Hemiplax hirtipes* – *Virgularia gracillima* and the *Zeacolpus vittatus* – *Pectinaria australis* communities.
There has not been a detailed harbour-wide study of the benthic environment since the study by Knight (1974).

In 2000 a baseline study of the benthic ecology within and beyond the port was carried out by Handley *et al.* (2000). One biological sample was collected from each of 20 sites (Figure 4) and each was analysed for the presence and abundance of the fauna. Twenty-eight taxa were present in the samples with the polychaete worms generally identified to family rather than to species. From the analyses of the data it was determined that:

- the fauna of the well-aerated soft mud sediment was dominated by crabs, mud-encased polychaete worms and bivalve molluscs.
- The fauna at a site beyond the dredge channel indicated that the on-going dredging activity in the port operations area had modified the subtidal habitat such that it suited short-lived opportunistic species.

From the comparison of the results of this study to those of Knight (1974) it was reported that 'the benthic fauna with the Port area comprises species found elsewhere within the harbour, although the faunal diversity and species abundances are lower'.

In 2003, sampling was undertaken at 11 of the sites sampled in 2000 (Figure 4). One sediment sample and three replicate biological samples were collected from each site. Twenty-nine taxa were present in the samples with the polychaete worms generally identified to
family rather than to species. Differences in sampling methods, amount of replication and the sieve size between 2000 and 2003 precluded any valid comparison of the presence and abundance of taxa between these sampling periods. Fenwick (2003)

recommended that in future surveys of the benthic fauna of the port the sampling methods, number of replicates and the sieve size used in the 2003 survey be used. Better control sites were also advised.

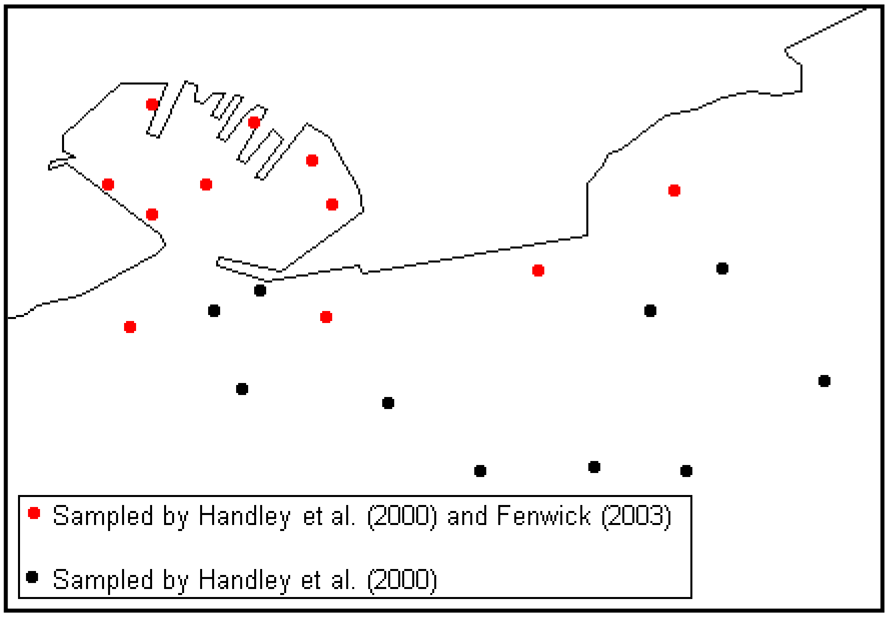


Figure 4: Subtidal sampling sites within and beyond the port.

Beyond the port area, sampling has been undertaken at 12 sites within and just outside the Harbour (Figure 3) (Thompson and Barter, 2005). This sampling was carried out in 1992, 1995, 2000 and 2004. At each site four replicate 13 cm diameter by 10 cm deep core samples were collected for analyses of the biota and four replicate 62 mm diameter core were collected for sediment analyses. Seventy-three taxa were present in the samples with many of the polychaete worms and the isopods identified to family rather than to species (Appendix II). Based on the presence and abundance of the taxa the 12 sites formed five distinct groups (at 50% similarity). These groups consisted of (refer to figure 3):

- sites 3, 5, 8 (dredge spoil disposal sites) and sites 1, 4 and 7 (outer harbour sites)
- inner harbour sites 9 and 12
- inner harbour sites 10 and 11
- site 2
- site 6

The presence and relative abundance of four polychaete worms, a bivalve, nematodes and a shrimp were primarily responsible for the groupings of the sites (Thompson and Barter, 2005). When the 2004 data was compared to the data collected in 1992, 1995 and 2000 it was found that the high level of fluctuations in the presence and abundance of the taxa between surveys made it difficult to resolve any true trends in changes to the biota over time and potential impacts resulting from the dredge spoil disposal. It was concluded that the subtidal habitats in the region appear to be in a continual state of disturbance related to the high degree of sediment mobility in the harbour. With this disturbance largely controlled by natural physical processes in the harbour and possibly, to a lesser extent, by dredging and dumping activities.

3. Existing information on the contaminant load of sediments and biota

3.1 Sediments

Within the Port of Lyttelton the sediments in the vicinity of the dry dock contain high concentrations of Cu, Hg, Pb, Zn, hydrocarbons, PAH's and organochlorine pesticides (DDT, HCB) (Jones, 1997). While the sediments at three sites sampled in proximity to the oil wharf contain high concentrations of PAH's with almost all measured PAH's exceeding the ISQG-low trigger levels (ANZECC & ARMCANZ, 2000) (Fenwick and Chagué-Goff, 2005). In the sediments collected at two of these sites, four of the PAHs also exceeded ISQG-high trigger levels (Appendix III). There are no other data on sediment contaminant concentrations from other areas within the Port of Lyttelton.

Within Lyttelton Harbour the sediments at two sites (sites 5 and 8, Figure 3) have been analysed for semi-volatile organic compounds, organotins, aliphatic hydrocarbons and trace metals (Thompson and Barter, 2005). The concentrations of organotins, aliphatic hydrocarbons, pesticides and plasticisers (semi-volatile organic compounds) and Cd at both sites were below detection limits. Low concentrations of Cr, Cu, Pb, Hg and Zn were recorded at both sites with concentrations below the ANZECC (2000) ISQG-low values. Detectable concentrations were recorded for seven PAH's at site 8 and for two PAH's at site 5. However, the PAH concentrations were below the ANZECC (2000) ISQG – Low values.

3.2 Biota

Within Lyttelton Harbour blue mussels (*Mytilus edulis galloprovincialis)* from two sites (sites 5 and 8, Figure 3) have been analysed for semi-volatile organic compounds, organotins, aliphatic hydrocarbons and trace metals (Thompson and Barter, 2005). Contaminant concentrations in the mussels were found to be low and within the range deemed safe for human consumption.

4 Recommendations for future marine ecological work

4.1 Rationale

Land use of the surrounds of Lyttelton Harbour has over time, changed from a predominantly rural landscape to a semi-rural one with numerous lifestyle blocks and ever-increasing housing subdivisions within the bays i.e. Purau, Diamond Harbour, Charteris Bay, Church Bay, Governors Bay, Rapaki and Cass Bay (Figure 1). The township of Lyttelton has also increased in size over time. Hand in hand with the increase in the human population of the area has been the increasing burden of sewage disposal. Reticulated sewage systems are in place in Governors Bay, Diamond

Harbour/Church Bay and Lyttelton, with the Lyttelton system servicing the communities of Lyttelton, Corsair Bay, Cass Bay and Rapaki. From the reticulated systems the sewage is discharged into the harbour through outfalls off Diamond Harbour (Pauaohinekotau Head), Governors Bay and Lyttelton (Sticking Point) (Figure 1.1). Sewage contributes nutrients, organic matter and contaminants such as heavy metals to the marine environment. These can accumulate in the soft sediments in the vicinity of the discharge point and can result in impacted sediments and biological communities. Such impacts are anticipated to be localised and decrease with increasing distance away from the discharge point.

With the increase in the number of people living around the harbour comes an increase in the number of buildings, roading and traffic. With this increase comes the increase in the area of impervious surfaces, which, during rainfall, generates stormwater that will end up being discharged directly or indirectly into the harbour. Stormwater can contain nutrients, soluble and insoluble toxic substances (metals, pesticides, petroleum hydrocarbons) litter, pathogens and sediment (Vincent and Thomas, 1997). Stormwater discharge has to been found to cause high concentrations of arsenic, chromium, zinc, lead, copper, nickel and organic matter in sediments in 3-10 m of water in proximity to stormwater outlets in Wellington Harbour (Bolton-Ritchie, 2003).

In Lyttelton Harbour, catchment erosion is a major contributor of sediment (loess and loess colluvium) to the marine environment. It has been estimated that, on average, 44300 t per year is eroded from the harbour catchment and deposited within the marine environment (Curtis as cited in Hart, 2004). The catchment erosion rates are considered to be an order of magnitude greater in the upper harbour between Cass bay and the Head of the Bay, than along the hill slopes adjacent to the central and outer areas of the harbour (Hart, 2004). The current rate of sediment erosion and subsequent sedimentation within the upper harbour is expected to persist as long as the catchment remains in grassland (Hart, 2004). Added to this erosion is sediment runoff during subdivision development. This is an on-going problem as sub-division developments continue to occur in different bays within the harbour. High suspended-sediment loads and sediment deposition are detrimental to marine ecosystems in that they:

- Decrease light levels at the seafloor affecting microphytes and benthic primary producers. This will have effects up the food chain.
- Clog filter-feeding structures of animals. This will affect the growth, condition and long-term the survival of filter feeding species.
- Change sediment properties such as grain size, organic matter content and chlorophyll-a concentration. These will alter the habitat and feeding of benthic species. This will result in a change in species composition.
- Change oxygen concentrations in the sediment. This will affect the survival of the species present.

With the proximity of Lyttelton Harbour to the population of Christchurch this harbour is a popular recreation area for the water-based activities of yachting, jet skiing, water skiing, power boating, SCUBA diving, fishing and wind-surfing. Potential impacts of such activities on the marine environment include:

- spillages of boat fuel.
- disposal of rubbish.

Given that there is a busy commercial Port of Lyttelton on the northern side of this harbour there is considerable potential for the spillage of fuel and cargo both within the port and in the mid to outer reaches of the harbour. In addition, the main channel into the port and parts of the port continue to be dredged. The dredge spoil is dumped near the harbour entrance.

Given all of the activities and potential impacts of these on the marine environment of Lyttelton Harbour there is a need for ecological monitoring of the marine environment of this harbour. To date Ecans marine ecological monitoring focus for this harbour has been within and just outside of the Port of Lyttelton (Handley *et al.*, 2000; Fenwick, 2003). This monitoring was established to identify the effects of the discharge of contaminants and other human-induced disturbances on the benthic environment in this area. However, there is a need for a harbour-wide monitoring programme because of the potential impacts of a wide range of activities on the marine environment of this harbour. There is also a need for specific investigations on the impact of the sewage discharges on the marine environment.

4.2 Monitoring

Monitoring is the routine sampling of the same sites over time. A more precise definition is 'sampling in time with adequate replication to detect variation over a temporal range from short and long term periods, done at more than one location' (Kingsford and Battershill, 1998).

For Environment Canterbury, ecological monitoring in the coastal zone consists of the monitoring of:

- the presence and abundance of the biota (flora and fauna).
- soft sediment quality (grain size and contaminant loads).

This monitoring is used as the environmental indicator of the health of coastal ecosystems with the overall anticipated environmental result being the recognition, protection and enhancement of the life supporting capacity of coastal ecosystems.

4.2.1 <u>Subtidal soft sediment</u>

4.2.1.1 Methodology

4.2.1.1.a *Sampling sites*

There is a need to continue with this monitoring at two sites within and two sites just outside the port area. In addition, there is a need to monitor at sites located down Lyttelton Harbour. The recommended sites are shown on Figure 6. However, one or more of these sites may be dredged, if this is the case the location of the monitoring site/s will be changed.

4.2.1.1.b. *Samples to be collected*

At each site the following biological and sediment samples are to be collected:

- Macrobiota -five random samples
- Sediment- three random surface sediment samples

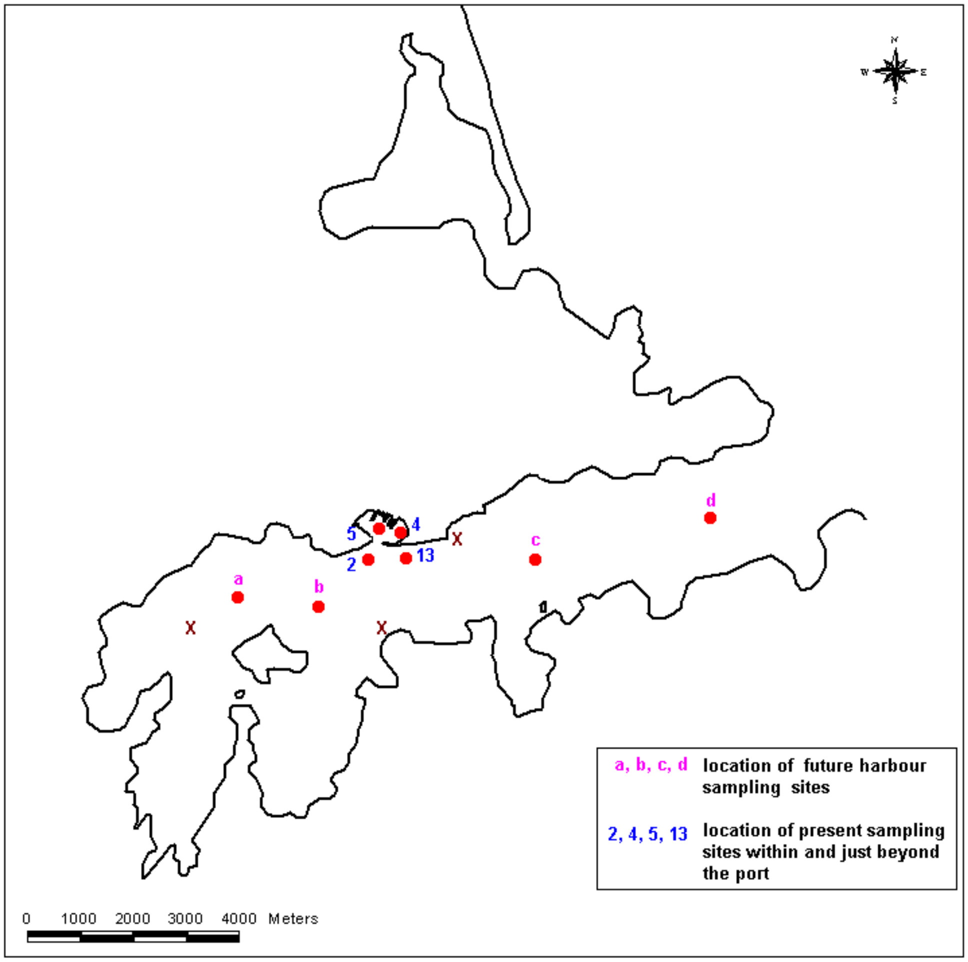


Figure 5: Location of proposed subtidal monitoring sites

4.2.1.1.c. *Sample processing*

Macrobiota

The samples are to be sieved through a 0.5 mm mesh and the material remaining on the sieve is to be preserved and stored in 10 % formalin in seawater. The samples are to be kept in the formalin for at least 24 hours before washing through with freshwater and storing in 70% alcohol. The animals present will be sorted from the debris, identified and counted. This will be done using a binocular microscope. Organisms will be identified, where possible, to species level.

Sediment

The surface sediment is to be analysed for grain size, organic matter content (loss on ignition), Cu, Zn, Pb, TN and TP concentrations.

4.2.1.2. Costs

It is envisaged that this work will be contracted out to an external agency. However, the sediment organic matter content, Cu, Zn, Pb, TN and TP analyses could be carried out by ECan laboratory staff. Lesley Bolton-Ritchie could also assist with the fieldwork and with the identification and counting of the polychaete worms. On this basis it is estimated that this work would cost:

- external contract - $30,000
- laboratory - $3,600
- Hours (Lesley) – 110-130 hrs

4.2.2 <u>Intertidal soft sediment</u>

A baseline study of the biota and sediments of the extensive intertidal mudflats at the head of the harbour is recommended. This data would provide the baseline against which any future monitoring data would be compared.

4.2.2.1 Methodology

4.2.2.1.a *Sampling sites*

It is proposed that sampling will be undertaken at four sites (Figure 5). These sites will be located at mid-low tide. Sampling at this shore level is recommended in the Estuarine Environmental Assessment and Monitoring Protocol (Robertson *et al*., 2002). At each site an area of 50 m by 30 m will be marked out and then divided into 10 m by 10 m plots. GPS readings will be taken at each of the four corners of the 50 m by 30 m area.

4.2.2.1.b *Samples to be collected*

At each site the following biological and sediment samples are to be collected:

<u>Macrobiota</u>

- Fifteen random core samples, one in each 10 m by 10 m plot.
- Four 0.25m^2 quadrat samples to a depth of 15 cm. These samples will be collected from four of the 10 m by 10 m plots.

<u>Sediment</u>

- Ten random surface sediment samples. These samples will be collected from ten of the 10 m by 10 m plots.
- Fifteen 15 cm deep cores with one core collected from each plot.

4.2.2.1.c *Sample processing*

<u>Macrobiota</u>

The quadrat samples are to be sieved through a 2 mm mesh and the material remaining on the sieve is to be preserved and stored in 10 % formalin in seawater. The core samples are to be sieved through a 0.5 mm mesh and the material remaining on the sieve is to be preserved and stored in 10 % formalin in seawater.

The samples are to be kept in the formalin for at least 24 hours before washing through with freshwater and storing in 70% alcohol. The animals present will be sorted from the debris, identified, measured (where required) and counted. This will be done using a binocular microscope. Organisms will be identified, where possible, to species level. Cockle, wedge shell and crab individuals are to be measured.

Figure 5: The intertidal area of the inner reaches of Lyttelton Harbour and the proposed sampling sites (depicted by red crosses)

<u>Sediment</u>

Each sediment core is to be extruded onto a white plastic tray, photographed and then inspected for any evidence of stratification. If sediment layers are present the depth of each layer is to be measured.

The surface sediment is to be analysed for grain size (external contract), organic matter content (loss on ignition), Cu, Zn, Pb, TN and TP concentrations.

4.3 Investigation

Investigations are specific sampling programmes aimed at providing answers to a specific question.

Question

What is the impact of the discharged sewage (from the subtidal outfalls) on the benthic environment of Lyttelton Harbour?

4.3.1 Background

There are three wastewater discharges into Lyttelton Harbour (Figure 1) these being the Diamond Harbour outfall, the Governors Bay outfall and the Lyttelton outfall. The volume of input for the wastewater outfalls consists of:

- Lyttelton (Sticking Point) outfall - the maximum permissible discharge volume is 8640 m^3 per day with average dry weather flows expected, at the time the consent was granted, to be 1129 m^3 per day (Royds Consulting, 1992)
- Governors Bay outfall - the maximum permissible discharge volume is 600 m^3 per day with the average dry weather flows expected to be 200 m^3 per day.
- Diamond Harbour outfall (Pauaohinekotou Heads) - to date has been consented to discharge 2000 m^3/day. However, a renewal of the resource consent, for a maximum permissible discharge of 2850 m^3 per day with the average dry weather flows expected to be 875 m^3 per day, is in progress (MWH, 2003).

To date there are no data on the impact of these discharges on the benthic environment of Lyttelton Harbour. The impact of each discharge on the benthic environment, is expected to be localised. However, an investigation of the effect of two of the highest volume wastewater discharges (Lyttelton and Diamond Harbour) on the benthic sediments and macrobiota is recommended.

4.3.2 Objectives of this investigation

This investigation will be to:

- determine if these discharges are having an impact on the benthic environment.
- determine what the impact of these discharges are on the benthic environment.
- determine the extent of the impact of each discharge on the benthic environment.

4.3.3 Methodology

4.3.3.a. *Sampling sites*

Sites should be located close to and at increasing distances away from the discharge point. It is suggested that the closest sites be 20 m away, with sites also at 50, 100 and 200 m away from the discharge point. The sites are to be located directly in front of and at 90 degrees to the left and right of the discharge point.

4.3.3.b *Samples to be collected*

At each site the following biological and sediment samples are to be collected:

- Macrobiota -five random core samples
- Sediment- three random surface sediment samples

4.3.3.c *Sample processing*

Macrobiota

The core samples are to be sieved through a 0.5 mm mesh and the material remaining on the sieve is to be preserved and stored in 10 % formalin in seawater.

The samples are to be kept in the formalin for at least 24 hours before washing through with freshwater and storing in 70% alcohol. The animals present will be sorted from the debris, identified and counted. This will be done using a binocular microscope. Organisms will be identified, where possible, to species level.

<u>Sediment</u>
The surface sediment is to be analysed for grain size (external contract), organic matter content (loss on ignition), Cu, Zn, Pb, TN and TP concentrations.

4.3.4 Costs
This will be an expensive investigation.
The cost being:

- Sample collection
- Processing of biological samples
- Processing of sediment samples
- Data analyses
- Report writing

<u>Sample collection</u>
It is anticipated that the cost of collecting the samples will be ~ $15,000 - $20,000

<u>Sample processing</u>
In total there will be 120 biological samples and 72 sediment samples.
Macrobiota - these samples could be processed by Environment Canterbury staff, with some cost for taxonomic verification of species.
External cost ~ $3,000.
Sediments - Grain size. External cost ~ $5,000
Organic matter content. ECan laboratory cost - $2,520
TN and TP. ECan laboratory cost - $3,024
Cu, Zn, Cr. ECan laboratory cost - $5,184

<u>Data analyses and report writing</u>
This could be completed by Environment Canterbury staff

Staff time required to complete this work
Student – three months
Scientist – six months

OVERALL EXTERNAL COST
$38,728
plus incidentals, e.g. alcohol and formalin.
Plus cost of employing a student

4.4 Scientific rigour

From the review of the existing marine ecological information of Lyttelton Harbour it has become apparent that there are four factors that make it invalid to compare data between studies and over time. These factors are the:

1. differences in sampling methodologies
2. differences in sample processing methodologies
3. differences in the number of replicate samples taken at a site
4. taxonomic resolution.

For all future work that Environment Canterbury undertakes or contracts out the sampling and sample processing methodologies must be consistent between studies and over time, an adequate number of replicate samples must be taken and the taxonomic resolution should be to species level.

5 References

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Appendix I: Intertidal species list

Phylum		Species	Knox	Thompson	Handley	Fenwick
Algae	Chlorophyta	*Bryopsis plumosa*	x			
		Caulerpa sp.	x			
		Codium adherens			x	
		Codium fragile			x	x
		Codium sp.		x		
		Enteromorpha intestinalis	x			
		Enteromorpha sp.		x	x	x
		Monostroma sp.	x			
		Ulva lactuca	x			
		Ulva sp.			x	x
	Rhodophyta	*Apophloea sp.*			x	
		Bostrychia arbuscula			x	x
		Calithamnion gracile	x			
		Cerarmium uncinatum	x			
		Ceramium sp.	x			
		Centroceros clavulatum	x			
		Cheilosporum saggitatum	x			
		Chondria macrocarpa	x			
		Cladulatum sp.	x			
		Coralline turf		x		
		Coralline paint		x		
		Corallina officinalis	x			
		Echinothamnion sp.	x			
		Gelidium caulacantheum	x			
		Gelidium sp.		x	x	
		Griffithsia antartica	x			
		Gracilaria secundata	x			
		Gigartina circumcincta	x			
		Heterosiphonia sp.	x			
		Jania micrarthrodia	x			
		Laurencia sp.		x		
		cf Microcladia sp.		x		
		Pleonosporium sp.		x		
		Plocamium costatum	x			
		cf Polysiphonia?	x	x		
		Porphyra columbina	x	x		
		Porphyra sp.			x	
		Rhodoglossum sp.	x			
	Phaeophyta	*Carpophyllum maschalocarpum*	x	x		
		Cystophora sp.		x	x	
		Durvillea antartica				x
		Ectocarpus confervoides	x			
		Hormosira banksii	x	x		x
		Leathesia difformis	x			
		Macrocystis pyrifera	x	x	x	x
		Petalonia fascia	x			
		Scytosiphon lomentaria	x	x		
		Undaria pinnatifida		x	x	x
		Sargassum sp.			x	
		Splachnidium rugosum	x		x	
		Sargassum sinclairi				x
		Scytothamnus australis	x			
		Scytothamnus sp.			x	
Coelenterata	Hydroida	*Amphisbetia bispinosa*		x		
		Halecium delicatulum	x			
		Plumularia setacea	x			
		Sertularia unguicutata	x			
	Anthozoa	*Actinothoe albocincta*	x			
		Actinia tenebrosa			x	
		Anthopleura aureoradiata	x			
		Epiactis thomsoni		x		
		Isactinia olivacea		x		

Phylum		Species	Knox	Thompson	Handley	Fenwick
Porifera		*Alcyonium aurantiacum*	x			
		Cliona celata	x			
		Haliclona petrosioides	x			
		Hymeniacidon perlevis	x			
		Perophora amnectaus	x			
		Polymastia granulosa	x			
		Orange enrusting sp.		x		
Platyhelminthes		Unidentified sp.		x		
Nematoda		Unidentified sp.	x			
Bryozoa		Unidentified sp.			x	
		Bowerbankia sp.	x			
		Bugula sp.	x			
		Buska sp.	x			
		Caberea transversa	x			
		Elzerina sp.	x			
		Eurystomella sp.	x			
		Watersipora sp.	x			
Annelida	Polychaeta	*Lepidasthenia comma*	x			
		Odontosyllis polycera	x			
		Perinereis nuntia	x			
		Perinereis novaehollandiae			x	
		Pomatoceros caeruleus			x	x
		Pomatoceros carinferus	x			
		Pomatoceros sp.		x		
		Typosyllis amillaris	x			
		Spirobis sp.	x			x
		Phyllodocidae		x		
Mollusca	Amphineura	*Acanthochiton aereus*	x			
		Acanthochiton zelandicus	x			
		Amaurochiton glaucus	x	x		x
		Chiton pelliserpentis	x	x	x	x
		Sypharochiton sinclairii	x			
	Gastropoda	*Benhamina obliquata*				x
		Buccinulum lineum	x		x	
		Buccinulum heteromorphum	x			
		Buccinulum multilineum	x			
		Cellana ornata	x	x	x	
		Cellana radians	x	x	x	x
		Cellana denticulata			x	x
		Cantharidus purpuratus	x			
		Cantharidus sp.				x
		Diloma zelandica	x			
		Haustrum haustorium		x	x	
		Lepsiella scobina			x	
		Littorina unifasciata	x			
		Melagraphia aethiops		x	x	x
		Micrelenchus tenebrosus	x			
		Nodolittorina cincta	x	x	x	x
		Nodolittorina antipodum		x	x	x
		Notoacmea parviconoidea	x			
		Notoacmea sp.		x		
		Onchidella nigricans	x	x	x	
		Patelloida corticata corallina	x			
		Risselopsis varia	x	x		
		Siphonaria australis	x		x	x
		Siphonaria zelandica				x
		Trochus viridis	x			
		Turbo smaragdus		x		
	Bivalvia	*Aulaucomya maoriana*	x	x	x	
		Aulaucomya ater			x	
		Modiolus sp.			x	
		Mytilus edulis galloprovincialis		x	x	

Phylum		**Species**	**Knox**	**Thompson**	**Handley**	**Fenwick**
		Mytilus edulis aoteanus	x			
		Ostrea heffordi	x	x		
		Perna canaliculus	x	x		
		Tiostrea chilensis			x	
		Xenostrobus noezelandicus	x			
		Xenostrobus pulex		x		
Arthropoda	Amphipoda	*Hyale* sp.	x			
		Stegocephalidae sp.	x			
		Gammarid sp.	x			
		Podoceridae sp.	x			
	Isopoda	*Euidotea stricta*	x			
		Dymanella huttoni	x			
		Isocladus armatus	x			
	Decapoda	*Cyclograpsus lavauxi*			x	x
		Halicarcinus cookii	x			
		Petrolisthes elongatus	x	x	x	x
		Petrolisthes novaezealandiae	x			
	Cirripedia	*Chamaesipho columna*	x	x	x	x
		Elminius modestus	x	x		
		Epopella plicata	x			
Echinodermata	Asteroidea	*Patiriella regularis*	x		x	x
		Stichaster australis	x			
Chordata	Ascidiacea	*Aplidium sp.*		x		
		Asterocarpa cera	x			
		Botryllus schlosseri	x			
		Cnemidocarpa bicornuata	x			
		Diplosoma listerianum		x		
		Pyura cancellata	x			
		Pyura pachydermatina	x		x	
		Pyura sp.		x		

Appendix II: Subtidal species list

PHYLUM		SPECIES	Knight	Knox	Thompson	Handley	Fenwick
Porifera		*Anotrichium crinitum*			x		
		Polysiphonia decipiens			x		
Coelenterata		*Anthopleura aureoradiata*	x				
		Edwardsia sp.			x		
		Edwardsia tricolour	x				
		Hydroida sp.			x		
		Obelia sp.					
		Sertularia sp.			x		
		Thecate hydroid				x	
		Virgularia gracillima	x		x		
Platyhelminthes		Unidentified sp.			x		
Nemertea		Unidentified sp	x		x	x	
Nematoda		Unidentified sp			x		
Bryozoa		*Amathia distans*				x	
		Bugula neritina				x	
		Cellopora sp.	x				
		Retepora sp.	x				
		Unidentified sp.					x
Brachiopoda		*Terebratella inconspicua*	x				
Sipunculoidea		*Dendrostomum huttoni*	x				
		Goldfingia cantabriensis	x				
Annelida	Polychaeta	*Aglaophamus macroura*	x		x		
		Aglaophamus verrilli	x				
		Aglaophamus sp.				x	x
		Amphictes sp.	x				
		Armandia maculata		x	x		
		Branchiomma cingulata	x				
		Capitella capitata		x			
		Clymene insecta	x				
		Cossura consimilis			x		x
		Euphione squamosa	x				
		Euphione sp.	x				
		Glycera lamellipodia	x				
		Glycera sp.				x	
		Goniada sp.			x		
		Harmothoe preclara	x	x			
		Harmothoe spinosa	x				
		Heteromastus filiformis			x		
		Leanira laevis	x				
		Lepidonotus polychromus	x	x			
		Lumbrinereis sp.	x				
		Nereis falcaria	x				
		Nicolea chilensis	x				
		Nicon aestuariensis	x		x	x	
		Onuphis aucklandensis			x	x	
		Orbinia papillosa			x		
		Owenia fusiformis	x		x		
		Paraonis sp.		x			
		Pectinaria australis	x		x	x	
		Pectinaria antipoda		x			
		Perinereis nuntia	x				
		Phyllodoce sp.		x			
		Platynereis australis	x				
		Polydora sp.			x		
		Prionospio pinnata	x	x			
		Prionospio sp.					
		Sabella sp.			x		
		Sphaerosyllis hirsula			x		
		Sternaspis scutata	x		x	x	x
		Terebella haplochaeta	x				
		Terebellides stroemi	x		x		
		Tharyx sp.	x	x			
		Travisia olens	x		x		

PHYLUM		SPECIES	Knight	Knox	Thompson	Handley	Fenwick
		Ampharetidae			x	x	
		Aphroditidae			x		
		Capitellidae					x
		Cirratulidae			x		x
		Dorvilleidae			x		
		Flabelligeridae			x		
		Glyceridae			x	x	x
		Goniadidae					x
		Hesionidae			x		
		Lumbrineridae			x	x	x
		Maldanidae			x	x	x
		Opheliidae					x
		Paraonidae			x		
		Phyllodocidae			x		
		Sabellidae			x		x
		Sigalionidae			x	x	x
		Spionidae				x	x
		Trichobranchidae				x	x
		Mud encased worms				x	
	Oligochaeta	Unidentified spp.			x		
Mollusca	Amphineura	*Acanthochiton zelandicus zelandicus*	x				
		Cyptoconchus porosus	x				
		Leptochiton inquinatus	x		x		
	Cephalopoda	*Octopus maorum*	x				
		Sepioloidea pacifica	x				
	Gastropoda	*Alcithoe arabica*	x				
		Amphibola crenata	x				
		Austrofusus glans	x		x		
		Austromitra rubiginosa	x				
		Buccinulum sp.			x		
		Chemnitzia zelandica zelandica	x				
		Cominella glandiformis	x				
		Maoricolpus roseus roseus	x	x			
		Maurea punctulata punctulata	x				
		Micrelenchus huttoni	x				
		Micrelenchus tenebrosus				x	x
		Notoacmea daedala	x				
		Penion mandarinus	x				
		Risselopsis varia carinata	x				
		Sigapatella novaezelandiae	x				
		Turbonilla sp.			x		
		Trochus tiaratus	x				
		Xymene plebejus	x				x
		Xymene pumilis				x	
		Zeacolpus vittatus	x				
		Zeatrophon ambiguus	x				
		Zegelerus tenuis	x			x	
		Zemitrella stephanophora	x				
	Pelecypoda	*Amphidesma subtriangulatum*	x				
		Arthritica bifurca			x		
		Atrina zelandica	x				
		Chione stutchburyi	x				
		Chlamys gemmulata radiata	x				
		Gari lineolata	x				
		Kellia cycladiformis					x
		Leptomya retiaria retiaria			x		
		Macomona liliana			x		
		Maorimactra ordinaria	x				
		Myadora striata	x				
		Mysella sp.				x	
		Mytilus edulis aoteanus	x				
		Nucula cf gallinacea			x		
		Nucula hartvigiana	x				

PHYLUM		SPECIES	Knight	Knox	Thompson	Handley	Fenwick
		Ostrea heffordi	x				
		Panopea zelandica	x				
		Paphies australe	x	x			
		Perna canaliculus	x				
		Protothaca crassicosta			x		
		Ruditapes largillierti	x			x	
		Ryenella impacta	x				
		Soletellina siliqua				x	
		Spisula aequilateralis	x				
		Tawera spissa	x				
		Tellinota edgari			x		
		Theora lubrica			x	x	x
		Zenatia acinaces	x				
Arthropoda	Amphipoda	*Ampelisca chiltoni*	x				
		Corophium acherusicum	x				
		Haplocheira barbimana	x				
		Lembos sp.					x
		Paradexamine laevis	x				
		Paradexamine pacifica	x				
		Parhalimedon sp.	x				
		Phoxocephalid sp.		x			
		Proharpinia stephenseni	x				
		Torridoharpinia hurleyi				x	x
		Oedicerotidae					x
		Unidentified sp.			x		
	Caprellidae	Unidentified sp.			x		
		Caprella sp.	x				
	Cirripedia	*Balanus decorus*	x				
	Copepoda	Unidentified sp.			x		
	Cumacea	Unidentified sp.			x		
		Diastylidae					x
		Nebalia sp.			x		
		Bodotriidae					x
	Decapoda	*Cancer novaezelandiae*	x				
		Elamena quoyi	x				
		Halicarcinus whitei	x				
		Macrophthalmus hirtipes	x	x	x	x	x
		Natantia unid.			x		
		Nectocarcinus antarcticus	x				x
		Notomithrax minor	x				
		Ovalipes bipustulentus	x				
		Pinnotheres novaezelandiae				x	
		Petrolisthes elongatus	x				
		Pontophilus australis	x				x
		Pontophilus sp.				x	
		Unidentified sp.			x	x	
	Isopoda	*Amphiroides falcifer*	x				
		Anthuridea sp.			x		
		Cirolana sp. *aff. C.quadripustulata*				x	
		Conodophilus lineatus	x				
		Isocladus armatus	x				
		Flabellifera			x		
		Gnathiidea			x		
		Valvifera			x		
	Mysidacea	Unidentified sp.			x		
		Mysis sp.	x				
	Ostracoda	Unidentified sp.			x		
	Tanaidacea	Tanaid sp.			x		
	Pycnogonida	Unidentified sp.			x		
	Arachnida	*Achelia dohrni*	x				
		Achelia variabilis	x				

PHYLUM		SPECIES	Knight	Knox	Thompson	Handley	Fenwick
Echinodermata	Asteroidea	*Allostichaster insignis*	x				
		Coscinasterias calamaria	x				
		Crossaster japonicus	x				
		Pateriella regularis	x			x	
	Holothuroidea	*Heterothyone alba*	x			x	x
		Paracaudina coriacia	x				
		Pentadactyla longidentis				x	
	Ophiuroidea	*Amphibolis squamata*	x				
		Ophiomyxa brevirima	x				
		Unidentified sp.			x		
Chordata	Ascidiacea	*Ascidia aspersa*	x				
		Ciona intestinalis	x				
		Pyura pachydermatina	x				
		Pyura pulla	x				
		Pyura suteri	x				
	Priapulida	Unidentified sp			x		
		Halicryptus sp.	x				
	Vertebrata	Tripterygiidae			x		