State of the Environment Monitoring
Port Taranaki
Monitoring Programme
2006 – 2009

Technical Report 09-18

ISSN: 0114-8184 (Print)
ISSN: 1178-1467 (Online)
Document: 650957

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September 2009

Executive summary

The Port Taranaki water environment programme within the Council's State of the Environment monitoring programmes (SEM) consists of five components: physicochemical analysis of the harbour bed sediments for contaminants, sampling of mussel tissue for evidence of bioaccumulation, a survey of the ecology of the intertidal zone, bacteriological water quality analysis, and a survey to determine the presence of invasive species. This report summarises the results of the Port Taranaki SEM monitoring programmes for the 2006-2009 monitoring period. This is the first comprehensive report for the harbour environs. There is a separate compliance report covering consented stormwater discharges from Port Taranaki's facilities.

Levels of hydrocarbons, lead, arsenic and cadmium in sediments collected from various sites within Port Taranaki did not indicate any significant contamination. Levels of DDT, TBT and zinc were also generally low, although an occasional sample was found to be over guideline (ANZECC[1] and/or ARC ERC's[2]) levels for marine sediments, indicating potential contamination. Copper, while below the ANZECC guideline levels in every sample, was above ARC ERC values in almost every sample.

The results of tissue analysis did not indicate contamination of mussel populations in Port Taranaki (and hence water quality), with most metal concentrations either below ANZFSC[3] guidelines (lead, cadmium) or, where no guideline exists, undetectable (chromium), or found at levels similar to the control sample, other feral samples collected from New Plymouth or from other studies around New Zealand (zinc, nickel, copper). The exception to this was arsenic, which was found to be well over the ANZFSC guidelines for food consumption both in samples collected from Port Taranaki and in the control sample (in other words, there is no specific source of arsenic contamination within the harbour). However, these results were low by comparison with overseas survey findings, and information from Food Standards Australia New Zealand indicates no plausible risk.

The diversity and abundance of intertidal species within the port was found to be much less than on the natural reef outside the port (Kawaroa). This was likely a reflection of the available substrate as opposed to water quality issues within the port, as the control site on the outside of the Lee Breakwater (i.e. with similar substrate) contained a lower number of species and diversity than the two sites inside the confines of the Port.

Bacteriological water quality was found to be generally very good at all sampled sites within the port during fine weather, comparing well with control sites outside of the port. As with most locations around Taranaki, samples collected after significant rainfall often contained high levels of bacteria.

Two surveys to provide a baseline inventory of native, non indigenous and cryptogenic marine species within Port Taranaki have been undertaken by Biosecurity New Zealand and are referenced here. The only species on the New Zealand register of unwanted organisms found in Port Taranaki was the Asian kelp, *Undaria pinnatifida.* It was concluded that most non-indigenous species located in Port Taranaki are likely to have been introduced to New

[1] Australian and New Zealand Environment and Conservation Council
[2] Auckland Regional Council Environmental Response Criteria
[3] Australian New Zealand Food Standards Code (2002)

Zealand accidentally by international shipping or spread from other locations in New Zealand. The predominance of hull fouling species in the introduced biota of the Port (as opposed to ballast water introductions) is consistent with findings from similar port studies overseas.

Given that Port Taranaki is essentially a highly modified industrial working port environment, within an urban catchment, the findings of the various studies reported here show relatively low levels o f measurable effects or of adverse impacts. The main feature is the presence of non-indigenous species, introduced presumably by vessel movements.

This report includes recommendations for future monitoring in Port Taranaki.

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1. Introduction

1.1 State of the Environment monitoring

The Resource Management Act 1991 (the RMA) established requirements for local authorities to undertake environmental monitoring. Section 35 of the RMA requires local authorities to monitor, among other things, the state of the environment for their region or district, to the extent that is appropriate to enable them to effectively carry out their functions under the Act.

To this effect, the Taranaki Regional Council (the Council) has established a State of the Environment Monitoring (SEM) programme for the region. This programme is outlined in the Council's "State of the Environment Monitoring Procedures Document", which was prepared in 1997. The monitoring programme is based on the significant resource management issues that were identified in the Council's Regional Policy Statement for Taranaki (1994).

The SEM programme is made up of a number of individual monitoring activities, many of which are undertaken and managed on an annual basis (from 1 July to 30 June). For these annual monitoring activities, summary reports are produced following the end of each monitoring year (i.e., after 30 June). The purpose of annual SEM reports is to summarise monitoring activity results for the year and provide a brief interpretation of these results.

Annual SEM reports act as 'building blocks' towards the preparation of the regional state of the environment report every five years. The Council's first, or baseline, state of the environment report was prepared in 1996, summarising the region's progress in improving environmental quality in Taranaki over the past two decades. Follow-up reports were published in 2003 and 2009. Annual SEM reports will include comment on trends over time as the data record for each monitoring activity increases with time.

The Council has implemented a Port water quality monitoring programme consisting of five components, namely: sediment quality, bioaccumulation of chemicals, inter-tidal ecology, bacteriological water quality and invasive species. The programme components are described more fully in section 2 of this report. This report summarises the results for the above components, over the period from July 2006 to June 2009. This is the first comprehensive report for the harbour environs. There is a separate compliance report covering consented stormwater discharges from Port Taranaki's facilities.

1.2 Port Taranaki

Port Taranaki (Photographs 1 and 2) is an artificially created harbour (established 1875) which lies between a group of offshore islands to the west, and Kawaroa Reef, a large volcanic breccia reef, to the east. The port is enclosed by two breakwaters, the Main Breakwater and the Lee Breakwater, which were created to provide additional shelter to the port and the ships that visit. A large reclamation has been constructed more recently, to the east of the main port facilities and Ngamotu Beach, for commercial activities. As a result, the breakwaters enclose 94 hectares of sheltered water.

Photograph 1 Port Taranaki with the Main Breakwater in the foreground and Moturoa Wharf behind. The large ship is docked at the Newton-King Tanker Terminal while containers are visible on Blyde Wharf in the background

Access to the main port area is restricted; however, public use of the rest of the area is high, with various recreational activities being undertaken in and around Ngamotu Beach, the boat ramp and in the port waters. This includes boating, fishing, triathlons, yachting, kayaking, and swimming. There are also three café/restaurants and various other businesses along the foreshore between the reclamation and the Lee Breakwater.

Port Taranaki is the only deep-water seaport on New Zealand's western seaboard and is New Zealand's fifth largest seaport, ranking second largest with regard to export volume (freight tonnes handled). Port Taranaki currently has nine main berths capable of handling a wide diversity of cargoes and vessels with an official maximum draught of 12.5 metres (NIWA, 2008).

Ongoing maintenance dredging is carried out at the Port as required. This usually occurs every two years, with removal of approximately 350,000 m^3. The spoil is deposited either off-shore, approximately two kilometres north of the breakwater, or in-shore for beach re-nourishment (clean sand only).

Dredging takes place for two reasons:
(1) To remove littoral sand that accumulates in the entrance chanel and turning basin at approximately 125,000 m^3/yr. These are generally disposed of in an inshore ground to assist the nourishment of the down drift shoreline.
(2) To remove from the berth pockets and inner section of the turning basin, the fine sediments that preferentially settle into the quiet deep waters of the harbour at approximately 25,000 m^3/year. These are disposed of in the offshore ground.

Port Taranaki is surrounded by a large urban/industrial catchment which drains into the harbour. This includes, among other things, residential, tank farms, industrial fabrication, land bulk transport facilities, a power station (no longer operational as of late 2008), cool stores, boat construction, and a roading asphalt plant.

1.2.1 Vessel movements

International vessel movements

As an example of international vessel movements, between 2002 and 2005 inclusive 612 vessels arrived at the Port from overseas ports (NIWA 2008). They arrived from 40 different countries representing most regions of the world. The greatest number of overseas arrivals during this period came from the following areas: Australia (38%), Pacific Islands (20%), Japan (13%), Northwest Pacific (11%), and other (18%). The major vessel types arriving from overseas at the Port of Taranaki were tankers (36%), LPG / LNG carriers (23%), and container ships and Roll on – Roll off vessels (22%).

Domestic vessel movements

The LMIU 'Seasearcher.com' database contained movement records for 1,123 vessel arrivals to the Port of Taranaki from New Zealand ports between 2002 and 2005 inclusive (NIWA, 2008). These arrived from 16 different ports in both the North and South Islands. The greatest number of domestic arrivals during this period came from Lyttelton (24%), Nelson (14%), Dunedin (13%), and Wellington (12%). The dominant vessel types arriving from New Zealand ports were LPG / LNG carriers (21%), container ships and Roll on – Roll off vessels (21%), tankers (18%), general cargo vessels (18%), and bulk / cement carriers (17%).

1.2.2 Description of wharves

Main breakwater

While the primary purpose of Port Taranaki's main breakwater is to protect the harbour from the open sea, it is also a fully operational facility in its own right.

It includes two berths, one of which is multipurpose and is primarily used for coastal bulk traders and offshore support vessel berthage. The second berth has special facilities to cater for the needs of Taranaki's offshore oil and gas operations, including a cutting shed, bulk cement and drilling mud blending equipment.

Port Taranaki-based fishing vessels also make heavy use of the main breakwater, tying up at other smaller berths along its inner side for offloading and provisioning[4].

Moturoa

The two berths at Moturoa Wharf are generally used for dry bulk cargo, with an 18,000 T dry storage facility. There are also bunkering facilities on Moturoa 1 for vessels servicing the offshore oil and gas production operations[5].

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[4] www.porttaranaki.com
[5] www.porttaranaki.com

Newton King Tanker Terminal

The Newton King Tanker Terminal serves the petrochemical industry. It handles a wide range of petrochemical products and bulk liquids including crude oils, liquefied petroleum gas and methanol. These products are piped from onshore and offshore sites throughout the region before being pumped to dedicated load-out facilities[4].

Blyde Wharf

Blyde Wharf is an integrated cargo handling facility based around a terminal operation on the Blyde complex. It caters for Port Taranaki's container trade as well as conventionally handled general and refrigerated cargoes.

A third berth is generally used by vessels servicing offshore oil and gas production operations. Bunkering facilities have been established on Blyde 3 with fresh water and diesel oil bunkers available[6].

Photograph 2 Port Taranaki with the Lee Breakwater in the foreground and main commercial port and wharfs in the middle distance

[6] www.porttaranaki.com

2. Monitoring programme

2.1 Introduction

The Port Taranaki component of the SEM programme comprises the monitoring of several components in order to collect information regarding the environmental health of the Port. Monitoring consisted of: sediment quality, bioaccumulation of chemicals, intertidal ecology, bacteriological water quality and invasive species. These programme components are described below. Table 1 sets out future monitoring.

2.2 Sediment quality

Contaminants within water bodies tend to accumulate on surface sediments over time – thus sediments will reveal any historical pollution. Sediments are also important as an ecological medium for benthic (bottom-dwelling) organisms.

Sediment quality sampling was conducted at seven sites within Port Taranaki prior to the maintenance dredging campaign which commenced in January 2009. The seven harbour sites covered a range of sedimentary regimes and environmental influences within the port, including the mouth of the Hongihongi Stream, Lee Breakwater basin, Blyde wharf, Newton King wharf, Moturoa wharf, main breakwater basin and in the middle of the harbour.

Samples were collected at the bed surface (0-30 mm) and subsurface (30-100 mm). The sediment samples were analysed for hydrocarbons, DDT, tributyl tin (TBT), copper, zinc, lead, arsenic and cadmium.

Sediment sampling is scheduled in five years time and will next be carried out during the 2013-2014 period. As long as no elevated results are obtained it is anticipated sampling will then be carried out at ten-year intervals.

2.3 Bioaccumulation of chemicals

Marine invertebrates, such as mussels and oysters, are good biological indicators for toxic contaminants. They are filter-feeders, accumulating most organic contaminants and metals from the water column. Marine invertebrates are used world wide for pollution monitoring because they are relatively resistant to pollution, transplantable, and because contaminant levels in their tissue generally reflect changes in contaminant levels in their environment (Ministry for the Environment, 1998).

Mussels were collected from three sites within Port Taranaki, and from one control site outside of the harbour. The mussels were tested for hydrocarbons, heavy metals, arsenic, copper and cadmium.

Bioaccumulation testing is scheduled every second year, and will next be carried out during the 2011-2012 period (this has been scheduled during 2011-2012 instead of 2010-2011 to balance annual cost and workload variations against intertidal ecology and bacteriological water quality monitoring).

2.4 Intertidal ecology

The intertidal ecological diversity of a particular area is dictated by environmental factors such as the available habitat, wave climate, and light availability. Comparisons of the abundance and diversity of a site over time can show changes caused by issues with water quality (or other factors).

Intertidal ecological surveys were carried out at three sites within Port Taranaki in February 2007 and December 2008.

Intertidal sampling is scheduled every second year, and will next be carried out during the 2010-2011 period.

2.5 Bacteriological water quality

Bacteriological water quality samples were collected on four occasions (January and May in 2006-2007 and 2008-2009) at five sites within the port, and at one control site outside of the port.

The samples were analysed for enterococci, *E. coli*, faecal coliforms and conductivity.

Bacteriological water quality sampling is scheduled to be undertaken every two years, with the next samples to be collected in 2010-2011.

2.6 Invasive species

Biosecurity New Zealand (BNZ) have carried out two baseline surveys cataloguing the marine species in Port Taranaki, the first in April 2002 (NIWA 2006) and the most recent in March 2005 (NIWA 2008). The results of the surveys are summarised in this report.

Table 1 Programme schedule for future monitoring

Component	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014
Sediment quality					
Bioaccumulation of chemicals					
Intertidal ecology					
Bacteriological water quality					
Invasive species	Biosecurity NZ carry out occasionally – next scheduled for October 2009				

3. Results

3.1 Sediment quality

Sediment was collected from seven sites within the Port on 5 December 2008 (Figure 1 and Table 2). A diver retrieved sediment using a core sampler, with samples then split into the top 0-30mm, and 30mm to the bottom of the corer (around 200mm). The samples were analysed for hydrocarbons (HC), DDT, tributyl tin (TBT), copper (Cu), zinc (Zn), lead (Pb), arsenic (As) and cadmium (Cd). The results are presented in Table 3 below.

Figure 1 Sediment sampling sites

Table 2 Location of sediment collection sites

Site code	Site location	GPS (NZMG)
SOL000155	Mouth of Hongihongi	E 1689821 - N 5676221
SOL000156	Lee Breakwater basin	E 1690585 – N 5676341
SOL000157	Blyde wharf	E 1689729 – N 5676392
SOL000158	Newton King wharf	E 1689496 – N 5676348
SOL000159	Moturoa wharf	E 1689411 – N 5676555
SOL000160	Main Breakwater basin	E 1689397 – N5676605
SOL000161	Middle of harbour	E 1689825 – N 5676744

Both the ANZECC (2000) and the Auckland Regional Council (ARC) ' Environmental Response Criteria' (ERC) have been used to assess the results. The ANZECC guidelines have been adapted from Canadian sediment quality guidelines and consist of low values (ISQG-Low), which are indicative of the contaminant concentrations where the onset of biological effects could possibly occur. These values provide an early warning, enabling management intervention to prevent or minimise adverse environmental effects. The high values (ISQG-High) are contaminant concentrations where significant biological effects are expected.

The ARC ERC values consist of 'amber' and 'red' which provide a conservative, yet practical, early warning of environmental degradation which allows time for investigations into the causes of contamination to be carried out (Kelly 2007b).

Table 3 Results of sediment quality testing 5 December 2008

	HC	DDT+	TBT*	Cu	Zn	Pb	As	Cd
unit	mg/kg	mg/kg	mg Sn/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
ISQG-Low		0.0016	0.005	65	200	50	20	1.5
ISQG-High		0.0460	0.070	270	410	220	70	10
ARC amber				19	124	30		
ARC red		0.0039		34	150	50		
Mouth of Hongihongi	<60	<0.030	<0.008	17	42	3.6	5.0	0.033
	<60	<0.030	<0.008	16	37	4.6	4.7	0.046
Lee Breakwater Basin	<60	<0.030	<0.008	25	60	7.1	9.0	0.057
	<60	<0.030	<0.008	26	70	11	8.7	0.075
Blyde Wharf	<60	<0.030	<0.008	32	64	13	11	0.057
	<60	0.041	<0.008	53	76	9.4	8.6	0.085
Newton King Tanker Terminal	<60	<0.030	0.0490	38	68	11	7.7	0.140
	<60	<0.030	0.0097	41	82	19	12	0.260
Moturoa wharf	130	<0.030	<0.008	46	67	8.6	7.3	0.087
	270	<0.030	0.048	59	82	14	8.0	0.270
Main Breakwater basin	<60	<0.030	0.16	56	93	11	6.7	0.400
	<60	<0.030	0.12	56	180	9.5	7.5	0.470
Middle of harbour	<78	<0.030	<0.008	30	60	10	13	0.054
	<60	<0.030	<0.008	30	46	6.2	7.1	0.039
Range	<60 - 270	<0.030-0.041	<0.008 – 0.12	16 - 59	37 - 180	3.6 – 19	4.7 – 13	0.033–0.470
Mean	<60	<0.030	0.030	38	73	9.9	8.3	0.150

\+ total DDT (DDT + DDD + DDE) * TBT is expressed as equivalent tin (Sn) per kg

Hydrocarbons were generally below the level of detection of 60 mg/kg. However, Moturoa Wharf had a fairly high level of hydrocarbons at 130 and 270 mg/kg in the top and bottom sediments respectively.

Total DDT was below the limits of detection at all but the bottom layer of the Blyde Wharf site, where a 0.041 mg/kg was very close to the ISQG-High level of 0.046 and above the ARC red value of 0.039 mg/kg.

Tributyltin was in most cases below the detection limit of less than 0.008 mg/kg. However, sediment around Newton King Tanker Terminal contained small amounts, as did the bottom sediments of Moturoa wharf. The Main Breakwater basin contained very high values in both the top and bottom sediments, well above the ISQG-High trigger value.

Levels of copper were higher around the wharfs and in the Main Breakwater basin compared with the other sites. Levels ranged between 16 to 59 mg/kg, with most well below the low ISQG of 65. However, with the exception of the Hongihongi Stream, all sites were above the ARC amber or red guidelines.

Zinc levels ranged between 37 – 180 mg/kg and were lowest at the mouth of the Hongihongi Stream and in the middle of the harbour. Levels in the main breakwater basin, especially in the bottom layer, were twice that of any other site, approached the ISQG-Low of 200 mg/kg, and were well over the ARC red guideline of 150 mg/kg.

Lead ranged between 3.6 and 19 mg/kg, with the highest levels at the Newton King Tanker Terminal still well below the ISQG-Low and ARC amber guidelines.

Levels of arsenic ranged from 4.7 mg/kg around the mouth of the Hongihongi Stream to 13 mg/kg in the middle of the harbour. Levels were below the guidelines indicating no ecologically significant arsenic contamination.

Cadmium ranged from 0.033 mg/kg around the mouth of the Hongihongi Steam to 0.470 mg/kg in the Main breakwater basin. Levels of cadmium were highest in the main breakwater basin and also elevated compared with the other sites at both Newton King Tanker Terminal and Moturoa Wharf, especially in the bottom sediments. All results were well below the ISQG-Low of 1.5 mg/kg.

3.2 Bioaccumulation of chemicals

Mussels (*Perna canaliculus*) were collected from three sites within the harbour and one control site outside the harbour on 26 May 2009. The samples were analysed for hydrocarbons, arsenic, cadmium, chromium, copper, lead, nickel and zinc.

The sites are as described in Table 4 and depicted in Figure 2.

Table 4 Location of mussel collection sites. Note: GPS values are approximate only

Site code	Site location	GPS (NZMG)
SEA902066	Along Moturoa wharf	1689286 - 5676482
SEA902064	End of Blyde wharf	1689843 - 5676388
SEA902069	Mid-way down Lee Breakwater	1690603 - 5676442
SEA902038	Northern end of Arakaitai Reef	1694352 - 5677242

The results of testing of the mussel tissue are presented in Table 5 below along with Australia New Zealand Food Standards Code 2002 (ANZFSC) guidelines for concentrations of trace metals in shellfish (for consumption). There are no published guidelines in New Zealand for acceptable concentrations of cadmium, copper, nickel or zinc in shellfish.

Figure 2 Location of mussel sampling sites

Table 5 Results of mussel testing, including the guidelines for concentration of trace metals in shellfish (Australia New Zealand Food Standards Code, 2002)

Parameter mg/kg as rcvd	Site				Guideline mg/kg
	Moturoa Wharf	Blyde Wharf	Lee Breakwater	Arakaitai (control)	
Hydrocarbons	<60	<60	<60	<60	-
Arsenic	1.5	1.7	1.4	1.9	1.0
Cadmium	0.049	0.077	0.042	0.027	2.0
Chromium	<0.10	<0.10	<0.10	<0.10	-
Copper	1.5	1.2	1.2	1.1	-
Lead	0.31	0.065	0.084	0.072	2.0
Nickel	0.15	0.13	0.12	0.36	-
Zinc	11	11	9.7	11	-

Hydrocarbons levels were below the limits of detection in all the mussels tested.

Arsenic was well over the ANZFSC guideline of 1 mg/kg in all samples, with the control sample containing almost double the guideline.

Cadmium was highest at Blyde Wharf, but as with all the other sites this value was well below the ANZFSC guideline.

Chromium was below the limits of detection in all samples.

Copper was found in similar levels at all the sites, as was zinc.

Levels of nickel were similar in the port samples, with slightly higher levels found in the control.

Compared with the other sites, a much higher concentration of lead was found in the sample collected from Moturoa Wharf. However, all samples were well below the ANZFSC guideline of 2 mg/kg.

3.3 Intertidal ecology

Three sites were established as part of the intertidal ecological component of the monitoring programme (Table 6 and Figure 3). The sites are as follows: Inside the Lee Breakwater (SEA902073) (Photograph 3), Eastern End of the Reclamation (SEA902072) and Outside the Lee Breakwater (SEA902071). The site Outside the Lee Breakwater acts as a control site as it has a similar substrate to the two sites inside the Port, but is outside the confines of the port and thus is not subject to the influences on water quality at work within the Port (however, it should be noted that a stormwater drain enters the sea not far from this site).

Surveys were conducted between 17 and 21 February 2007 and 12 to 14 December 2008, with low tides ranging from 0.1m to 0.4 m.

Table 6 Location of intertidal sites

Site code	Site location	GPS (NZMG)
SEA902073	Inside the Lee Breakwater	1690390 - 5676587
SEA902072	Eastern End of the Reclamation	1690650 - 5676167
SEA902071	Outside the Lee Breakwater	1690908 - 5676313

Figure 3 Intertidal monitoring sites

Photograph 3 Site inside the Lee Breakwater

At each site, a 50 metre transect was laid parallel to the shore, approximately 0.6 metres above chart datum. This transect was used to establish five, 5 metre x 3 metre blocks. Within each block 5 random 0.25 m^2 quadrats were laid giving a total of 25 random quadrats. For each quadrat the percentage cover of algae and encrusting animal species was estimated using a grid. For all other animal species, individuals larger than 3 mm were counted. Under boulder biota was counted where rocks and cobbles were easily overturned. This is a standardised approach to intertidal ecological monitoring within Taranaki.

During the February 2007 survey, the site Inside the Lee Breakwater had the highest species richness, followed by the Eastern End of the Reclamation, then Outside the Lee Breakwater. Diversity was highest at the Eastern End of the Reclamation, followed by Inside the Lee Breakwater and then Outside the Lee Breakwater. During the December 2008 survey, both species richness and diversity were highest at the Eastern End of the Reclamation, followed by Inside the Lee Breakwater and then Outside the Lee Breakwater.

Statistical analysis showed that the site Outside the Lee Breakwater differed significantly from the other two sites in the February 2007 survey, both in terms of species abundance and diversity, due to comparatively lower levels of both these parameters. Although the sites did not differ significantly in terms of species abundance during the December 2008 survey, the two Lee Breakwater sites were significantly different with regards to diversity. This was due to the higher diversity found at the Eastern End of the Reclamation site.

In comparison with intertidal sites on Kawaroa Reef, east of the Port environs, species richness and diversity are significantly lower at the Port sites. However this can be attributed to the habitat at the sampling sites, which is not natural reef, but large boulders. The boulder habitat (substrate and elevation) is not very suitable habitat for algae, with very few species present: *Ralfsia* sp., *Champia* sp., Corraline turf and paint, *Laurencia thryisifera*, *Gelidium* sp., *Hildenbrandtia crouani*, and *Ulva* sp. Similarly, few animal species were adapted to life on the boulders. The tubeworm, *Spirobranchus cariniferus*, and the barnacle, *Chamaesipho columna* were common, as were the limpets *Cellana radians* and *C. ornata*, along with *Siphonaria australis* and *Patelloida corticata*. The gastropods *Melagraphia aethiops* and *Turbo smaragdus* were fairly common. Occasional chitons were also present.

During both surveys, the sites inside Port Taranaki had higher species richness and diversity, however both these parameters were relatively low at all sites. This can be attributed to the modified, predominantly boulder, habitat.

The results of the surveys will be able to be used in conjunction with data collected in the future, as a baseline for comparison. It is intended that a further intertidal ecological survey be conducted at the three sites during the 2010-2011 monitoring period.

Refer to Appendix 1 for a full copy of the results.

3.4 Bacteriological water quality

Bacteriological water quality samples were collected on 16 January and 1 May 2007, and 21 January and 11 May 2009, from five sites within, and one control site outside of the port. The samples were collected during dry weather and again after heavy rain following a dry spell. The sites are described in **Error! Reference source not found.** and shown in Figure 4.

Figure 4 Bacteriological water quality sample sites

Table 7 Location of bacteriological water quality sampling sites

Site code	Site location	GPS (NZMG)
SEA902058	Lee Breakwater jetty	1690792 – 5676309
SEA902059	Reclamation	1690332 – 5676139
SEA902063	Ngamotu Beach west	1689728 – 5676119
SEA902065	Blyde-Newton King wharf	1689399 – 5676331
SEA902066	Moturoa wharf	1689285 – 5676479
SEA902067	Paritutu Rock	1688361 – 5676041

3.4.1 2006-2007

The results of water sampling during the 2006-2007 period are presented below in Table 8.

Table 8 The results of bacteriological water sampling 2006 -2007
Elevated levels (according to MfE/MoH guidelines*) of bacteria are indicated in red font

Site	Enterococci		*E. coli*		Faecal coliforms		Conductivity	
	16-1-07	1-5-07	16-1-07	1-5-07	16-1-07	1-5-07	16-1-07	1-5-07
Lee Breakwater jetty	3	140	2	66	2	66	4640	4660
Reclamation	1	76	1	27	1	29	4640	4710
Ngamotu Beach west	36	180	7	64	8	64	4580	4620
Blyde-Newton King wharf	9	84	9	25	9	27	4630	4680
Moturoa wharf	9	190	9	20	9	20	4620	4670
Paritutu Rock	11	11	15	5	15	5	4620	4700

* 140-280 cfu/100ml = 'Alert' level, >280 cfu/100ml = 'Action' level

The results indicate that levels of bacteria in Port Taranaki during fine weather are generally low. Aside from enterococci at Ngamotu Beach West, all Port results were lower than the control site at Paritutu Rock on 16 January 2007.

However, after rain, some high results were obtained at the Port sites (samples collected 1 May 2007) compared with the control at Paritutu Rock, at which bacteria levels remained low. This is likely a combination of run-off from around the port, and input from various stormwater drains and the Hongihongi Stream, which enters the western corner of Ngamotu Beach.

Ngamotu Beach is a very popular bathing beach, especially for young children (Photograph 4), school groups and sports events/training, as the two breakwaters provide shelter from sea swells and hence a relatively calm and safe swimming area. As such, it is useful to relate the results of sampling to the Microbiological Water Quality Guidelines for Marine and Freshwater Areas (MfE, 2003).

Photograph 4 Children playing on Ngamotu Beach

These guidelines use enterococci as an indicator of water quality, with levels of less than 140 enterococci per 100 ml considered safe for recreational use. Levels of 140 to 280 enterococci per 100 ml put a beach on 'Alert', while two consecutive samples (within 24 hours) containing levels of greater than 280 enterococci per 100 ml activate 'Action', resulting in a public health warning. Enterococci levels on 1 May were equal to or higher than the 140 cfu/100ml guideline at three sites, and although it is unlikely that anyone would be swimming at Ngamotu Beach in May, it demonstrates that sea water quality may be compromised after rain (this is not particular to Port Taranaki as most Taranaki streams, especially those draining agricultural catchments, will contain high levels of bacteria after rain). However, these results all remained below the 'Action' level.

Samples collected from Ngamotu Beach as part of the Council's separate State of Environment beach bathing monitoring programme (20 samples collected from the centre of the beach approximately weekly from November 2006 to March 2007) were all below the 'Alert' level guidelines indicating Ngamotu Beach was suitable for recreational use over the summer period. It should be noted that most of these samples are not collected within three days of significant rainfall (TRC report 08-01).

3.4.2 2008-2009

The results of water sampling during the 2008-2009 period are presented below in Table 8. Due to road closure, a sample was not able to be collected from Paritutu Rock on 11 May 2009. A sample was instead collected from Back Beach, approximately 1 km south.

During fine conditions in January, faecal coliforms and *E. coli* were found in very low levels at all sites, with the maximum of 9 cfu per 100ml found at the control site,

Table 9 Results of bacteriological water quality sampling 2008-2009.
Elevated levels (according to MfE/MoH guidelines*) of bacteria are indicated in red font

Site	Enterococci		*E. coli*		Faecal coliforms		Conductivity	
	21-1-09	11-5-09	21-1-09	11-5-09	21-1-09	11-5-09	21-1-09	11-5-09
Lee Breakwater jetty	1	55	1	7	1	8	4740	4700
Reclamation	< 1	13	< 1	3	< 1	4	4710	4710
Ngamotu Beach West	21	130	2	25	2	28	4650	4660
Blyde-Newton King Wharf	1	600	< 1	20	1	68	4740	4710
Moturoa wharf	39	3600	4	140	4	730	4740	4670
Paritutu Rock	10	39	8	33	9	35	4740	4680

* 140-280 cfu/100ml = 'Alert' level, >280 cfu/100ml = 'Action' level

Paritutu Rock. Levels of enterococci were also generally low, with slightly higher results found at Ngamotu beach west and Moturoa wharf.

Conductivity was high at most sites (Ngamotu Beach West was slightly lower) indicating that the samples were mostly undiluted seawater, as would be expected after a period of fine weather.

When samples were collected after prolonged rain in May (noting that this was well outside the normal bathing season), levels of enterococci were high in the area of port activity – around the Blyde-Newton King and Moturoa wharves. The remainder of the sites contained elevated levels of bacteria compared with the dry weather sample, however only moderate levels of bacteria were found (i.e. all these other results were below even the 'Alert' levels).

As discussed in section 3.4.1 above, Ngamotu Beach is well used over the summer months for recreational purposes. Separate State of Environment sampling indicated that bacteriological water quality was generally good with 18 of 20 samples collected over the 2008-2009 summer falling within guideline 'Alert' levels. One sample exceeded 'Alert' guidelines, while one sample exceeded 'Action' guidelines (a second sample was not collected within 24 hours so it is assumed that this guideline was exceeded). Both samples were found to have lowered conductivities, indicating freshwater intrusion as the source of the bacteria (TRC 09-11).

3.5 Invasive species

In April 2002, NIWA undertook a survey on behalf of Biosecurity New Zealand (BNZ) to provide a baseline inventory of native, non indigenous and cryptogenic marine species within Port Taranaki. The results are discussed in the document 'Port of Taranaki baseline survey for non-indigenous marine species' (NIWA, 2006).

NIWA undertook a repeat port baseline survey of the Port of Taranaki in March 2005 (NIWA, 2008). This survey provided a second inventory of native, non indigenous and cryptogenic marine species within the port, and compared the biota with the results of the 2002 baseline survey.

To allow a direct comparison between the initial baseline survey and the re-survey of Port Taranaki, the re-survey used the same methodologies, occurred in the same season, and sampled the same sites used in the initial baseline survey. To improve the description of the biota of the port, some additional survey sites were added during the repeat survey (NIWA, 2008).

A wide range of sampling techniques was used to collect marine organisms from habitats within the Port of Taranaki. Fouling assemblages were scraped from hard substrata by divers, benthic assemblages were sampled using a sled and benthic grabs, and a gravity corer was used to sample for dinoflagellate cysts. Mobile predators and scavengers were sampled using baited fish, crab, starfish and shrimp traps (NIWA, 2008).

Sampling effort was distributed to maximise the chances of detecting non-indigenous species. As such, most effort was concentrated on high-risk locations and habitats where non-indigenous species were most likely to be found. Organisms collected during the survey were sent to local and international taxonomic experts for identification (NIWA, 2008).

A total of 267 species or higher taxa were identified in the first survey in April 2002. They consisted of 178 native species, 14 non-indigenous species, 34 cryptogenic species (those whose geographic origins are uncertain) and 41 species indeterminata (taxa for which there is insufficient taxonomic or systematic information available to allow identification to species level) (NIWA, 2008).

During the repeat survey in 2005, 269 species or higher taxa were recorded, including 180 native species, 13 non-indigenous species, 27 cryptogenic species and 49 species indeterminata. Only around half the species were common to both surveys, with around 54% of the native species, 61% of non-indigenous species, and 48% of cryptogenic species recorded during the repeat survey also found in the earlier survey (NIWA, 2008).

The 13 non-indigenous organisms found in the repeat survey of the Port included representatives of 6 major taxonomic groups. The non-indigenous species detected were: (Annelida) *Euchone limnicola*, *Barantolla lepte*; (Bryozoa) *Bugula flabellata*, *Bugula neritina*, *Cryptosula pallasiana*, *Watersipora subtorquata*; (Cnidaria) *Monotheca pulchella*, *Amphisbetia maplestonei*; (Crustacea) *Monocorophium sextonae*; (Mollusca) *Crassostrea gigas*, *Theora lubrica*; (Macroalgae) *Griffithsia crassiuscula*, and *Undaria pinnatifida*. Five of these species - *Euchone limnicola*, *Monotheca pulchella*, *Amphisbetia maplestonei*, *Monocorophium sextonae*, *Undaria pinnatifida* - were not recorded in the earlier baseline survey of the Port. In addition, six non-indigenous species that were present in the first survey - *Bugula stolonifera*, *Tricellaria inopinata*, *Watersipora arcuata*, *Eudendrium capillare*, *Polysiphonia sertularioides* and *Halisarca dujardini* – were not found during the repeat survey (NIWA, 2008).

Eleven species recorded in the repeat survey of Taranaki had not been described from New Zealand waters prior to the baseline surveys. One of these was an indigenous species (the hydroid *Amphisbetia maplestonei*). The remaining ten species do not correspond with existing species descriptions from New Zealand or overseas and may be new to science.

The only species on the New Zealand register of unwanted organisms in the Asian kelp, *Undaria pinnatifida* (Photograph 5). This alga is known from other parts of New Zealand, but the 2005 survey was the first instance of this species being identified in Port Taranaki.

The report (NIWA, 2008) concludes that most non-indigenous species located in Port Taranaki are likely to have been introduced to New Zealand accidentally by international shipping or spread from other locations in New Zealand (including translocation by shipping). Approximately 61 % (8 of 13 species) of non-indigenous species in Port Taranaki are likely to have been introduced in hull fouling assemblages, 8 % (1 species) via ballast water and 31% (four species) could have been introduced by either ballast water or hull fouling vectors. The predominance of hull fouling species in the introduced biota of the Port (as opposed to ballast water introductions) is consistent with findings from similar port baseline studies overseas.

Photograph 5 *Undaria* (brown) growing on a collar of the marina in Port Taranaki

4. Discussion

4.1 Sediment quality

Aquatic sediments are principally derived from weathering processes, with major transportation from terrestrial sources under high runoff from storms and floods (ANZECC, 2000). New Zealand is a geologically young country, relatively rich in minerals, many of which both weather and leach out and ultimately arrive in the sea via run-off from streams and rivers (Nielsen & Nathan, 1975).

Suspended particles gradually settle and accumulate as part of the bottom sediments. Rates of sedimentation vary from 1 mm/year in coastal marine waters, up to 10-20 mm/year in some riverine and estuarine systems. The highest values are found in settling basins removed from high currents and close to point sources, with rates in the range of 3-7mm/year typical (ANZECC, 2000). Sediments often accumulate (magnify) water-borne and water-soluble contaminants over time, and thus can demonstrate historical as well as current water quality and contaminant discharge characteristics.

There are also a number of anthropogenic pathways for entry of contaminants into Port Taranaki, namely direct pipeline discharges, discharges and dumping from ships, riverine inputs and non-point source run-off from land (Rogers, 1995).

The most significant contribution of contaminants is likely to come from stormwater outlets and wash waters. Port Taranaki and surrounding industries hold numerous consents to discharge stormwater, and many other stormwater discharges in this area are permitted activities. In addition, the port drains a large residential catchment from which urban wastes enter the port through the stormwater system and the Hongihongi Stream (Photograph 6).

Photograph 6 The Hongihongi Stream enters the western corner of Ngamotu Beach, with a stormwater drain on the left

Arsenic

Natural sources of arsenic include rocks of volcanic origin, ground water, and hydrothermal vents. Arsenic is used in industries such as timber treatment, alloys, medical, smelting, pulp and paper production, glass manufacturing and the computing and electronic industries. It is also used in herbicides and insecticides and in lead-acid batteries (Kelly, 2007).

Levels of arsenic found in Port Taranaki during this study were well below the ANZECC guidelines, indicating no significant arsenic contamination. Rogers (1995) also found low levels of arsenic in the port, with levels comparable to this study (Table 9). However, he found a level of 3 mg/kg in his control sample (i.e. lower than in the harbour samples) so some enrichment of metal concentrations within the port is evidenced. He proposed that the higher levels that he found at Newton King Tanker Terminal was likely to be related to accidental spills during the loading and unloading of petrochemical products.

Cadmium

Cadmium is a very toxic, non-essential element for humans that can also be toxic to aquatic organisms at very low concentrations. Natural concentrations of cadmium are extremely low in unpolluted seawater. Its primary uses are batteries, plastic stabilisers, pigments, metal plating, and in the manufacture of tyres, and alloys and solders (Kelly, 2007). Continuous ultra-trace amounts are also released from the bodies of metallic vessels, and from anti-fouling paints (Rogers 1995). The application of phosphate fertiliser to soils has increased the concentration of cadmium in New Zealand soils.

Levels of cadmium were highest in the main breakwater basin and also elevated compared with the other sites at both Newton King Tanker Terminal and Moturoa wharf, especially in the bottom sediments. Rogers (1995) found a similar minimum (0.04 mg/kg), however his maximum value of 1.42 mg/kg at Moturoa Wharf was significantly higher than in the present study – approaching the ISQG-low of 1.5 mg/kg. Rogers speculated that the elevated levels near Moturoa Wharf were likely due to accidental losses of superphosphate and/or phosphate rock fertilisers during loading and unloading.

The levels Park (2003) found at various sites in Tauranga Harbour were generally lower than the Port Taranaki samples, as were those tested by Stephenson (2008) in Wellington Harbour (Table 9).

Copper

Natural sources of copper in aquatic environments include weathering of copper minerals and native copper. However anthropogenic sources contribute much greater amounts. Copper is widely used in the electrical, construction, plumbing, and automotive industries, in antifouling paints, in horticultural sprays and as a trace element in some stock foods and supplements (Kelly, 2007). Antifouling paint releases all its copper to the sea, potentially resulting in considerable contamination. Levels of copper are consistently higher in rivers which drain urban and industrial catchments than those which drain natural catchments (Rogers, 1995). Very high levels of copper are found in roadside sediments.

Taranaki soils contain high background levels of copper, Percival and Sutherland (2002) found levels ranging between 2 and 120 mg/kg. These were among the highest natural concentrations found in New Zealand, occurring in a large proportion of the region. This is due to a major soil parent material being the andesitic volcanic ashes.

Levels of copper were higher around the wharves and in the Main Breakwater basin compared with the other sites. The highest results were more than double the lowest, but this needs to be put in the context of all results being much lower than the higher end of copper found in soils in Taranaki (and the fact that Taranaki soils have higher copper levels overall). Although all samples contained levels below the ANZECC guidelines, the ARC ERC values were exceeded in all samples (with the exception of the Hongihongi Stream mouth) with both 'amber' and 'red' values obtained.

Rogers (1995) obtained similar results of between 27 - 74 mg/kg of copper in his sediment samples, and he attributed high levels around the wharfs as a result of accidental fertiliser loss and release of copper from anti-fouling paints.

Levels of copper in sediments from other New Zealand studies varied significantly, with Aggett (1986) obtaining similar results to those currently found in Port Taranaki, while levels in Wellington Harbour were slightly lower (Stephenson, 2008) and both Tauranga (Park, 2003) and Auckland (Kelly 2007b) were significantly lower (Table 9).

DDT

DDT was introduced as an insecticide in 1939. DDT is a chemically stable compound which is very persistent and accumulates in the food chain, hence why traces can still be found despite its removal from sale in New Zealand in the early 1970's.

Total DDT was below the limits of detection in all but the bottom layer of the Blyde Wharf site, where a 0.041 mg/kg was very close to the ISQG-High level of 0.046 and above the ARC red guideline of 0.0039 mg/kg.

Stephenson (2008) also investigated DDT contamination, with all but two of the 17 samples tested in Wellington Harbour containing more than the ISQG-low level and ARC amber levels. Two of these samples exceeded ARC red guidelines (Table 9).

Lead

Prior to its removal in 1996, the major source of lead in New Zealand was from fuel additives. Other sources include industrial processes, paints, pigments, batteries and shot pellets (Kelly 2007b). Most harbour sediments are contaminated with lead, concentrations of which are typically elevated in urban run-off and stormwater (Rogers 1995).

Percival and Sutherland (2002) found background lead concentrations in Taranaki soils ranging between 2 to 30 mg/kg. The highest concentrations of which were among the highest found in New Zealand.

Rogers (1995) found similar concentrations of lead in Port Taranaki to the current survey, with highest levels of lead in both studies found around the wharfs, although it should be noted that at 22 mg/kg, Rogers' control site contained more lead than any other site in either of the surveys. Results obtained by Don (1988) were also similar, with samples from all three surveys conducted in Port Taranaki containing lead well below guideline values.

Nationally, lead concentrations were found to be greatest in the harbours with a larger population – Mangere and Auckland generally (Aggett, 1986 and Kelly 2007b) and in Wellington harbour (Stephenson, 2008). Park (2003) found moderate levels in Tauranga Harbour (Table 9).

Tributyl tin

The basic way to deter underwater fouling on painted structures is with broad-spectrum biocides in paints; these usually rely on the toxic biocide being available or released from the surface of the paint. One of the most popular biocides was Tributyl tin (TBT), which kills organisms before, or soon after, they settle on a treated surface. However, TBT was found to be severely contaminating many estuaries and bays, causing deformities and the disappearance of some organisms. Consequently, the application of TBT to boats less than 25 m long was banned in the late 1980s, with a complete ban in 2008[7]. TBT is also used in timber treatment.

TBT was in most cases below the detection limit of <0.008 mg/kg. However, it was found in varying amounts around Newton King Tanker Terminal and Moturoa Wharf, with high levels in the Main Breakwater basin – well above ANZECC guideline levels.

In comparison, Stephenson (2008) found much lower levels in Wellington Harbour (Table 9).

Zinc

Zinc is a ubiquitous element in urban areas. Zinc is used in galvanising, the production of alloy materials, in synthetic rubbers such as tyres and in paint manufacture. Very high levels are found in roadside sediments.

Background levels of zinc in Taranaki soils range from 20 to 170 mg/kg (Percival and Sutherland, 2002). These are among the highest natural concentrations found in New Zealand.

Most of the results for zinc were between 37 and 93 mg/kg, with the exception being in the bottom sediments of the Main Breakwater basin at 180 mg/kg (which exceeded the ARC ERC red value). This is interesting when compared to Rogers (1995) results, in which zinc levels ranged between 72 and 500 mg/kg, with the majority of results above 93 mg/kg (mean = 164 mg/kg). Also of note was that Rogers found his highest result around the mouth of the Hongihongi Stream – where this study found the lowest concentration. With a mean result of 73 mg/kg, the results of this present study are more similar to Don (1988), which found an average of 68 mg/kg.

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[7] http://www.niwa.co.nz/news-and-publications/publications/all/wa/14-3/foul

The results of Kelly (2007b) and Stephenson (2008) in Auckland and Wellington Harbours, respectively, were similar to this study, while Park (2003) found much lower levels in Tauranga Harbour (Table 9).

Summary

In summary, levels of hydrocarbons, lead, arsenic and cadmium in sediments collected from various sites within Port Taranaki did not indicate any significant contamination. Levels of DDT, TBT and zinc were also generally low, although an occasional sample was found to be over guideline (ANZECC and/or ARC ERC's) levels, indicating contamination at a level that could potentially affect ecology. Copper, while below the ANZECC guideline levels in every sample, was above ARC ERC values in almost every sample.

4.2 Bioaccumulation of chemicals

Filter-feeding shellfish process large amounts of water from a fixed location, and as such have the tendency to accumulate a wide range of contaminants in their tissues. Tissue contaminant levels can provide an indication of ambient water quality conditions, with the added advantage that the accumulated contaminants are representative of only those forms which are biologically available to other organisms (Milne, 2006).

Arsenic

Arsenic is a non-essential element and known carcinogen. It is toxic to both humans and aquatic organisms. Arsenic can exist in a number of inorganic and organic forms that have different toxicities and abilities to accumulate in aquatic organisms (Kelly, 2007). Sources of arsenic to the aquatic environment are discussed in section 4.1 above.

All samples contained levels of arsenic above the ANZFSC guideline value, with the control sample the highest at nearly double this value. No other New Zealand studies reviewed tested for arsenic concentration, so it is difficult to compare these values to other sites. A study carried out by the United Kingdom Food Standards Agency in 2005 [8] found levels of arsenic in mussel tissue (34 samples) to be between 1.3 and 4.2 mg/kg (average 2.2 mg/kg). That is, the local samples were all in the lower range of results from the United Kingdom.

In following up the local results with Food Standards Australia New Zealand, they noted that the guideline value is not a standard. This level is set at 1 mg/kg for arsenic, and this equates to someone eating one kilogram of mussel flesh per week over a lifetime without appreciable risk (assuming that there is no exposure to arsenic from consumption of other foods).

As the control was higher than the port sites it is not likely that activities at the port are solely the cause of the high concentrations found. It will be worthwhile to locate a control population of mussels further south, away from the influence of streams draining urban catchments.

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[8] http://www.food.gov.uk/multimedia/pdfs/fsis8205.pdf#page=9

Table 10 Comparison of sediment quality at various locations around New Zealand

Component (mg/kg)	Study	This study	Aggett (1986)	Don (1988)	Rogers (1995)	Park (2003)	Kelly (2007b)*	Stephenson (2008)	ISQG-Low ISQG-High	ARC amber ARC red
	Location	**Port Taranaki**	**Mangere**	**Port Taranaki**	**Port Taranaki**	**Tauranga**	**Auckland**	**Wellington**		
Arsenic	Range	4.7 – 13	-	-	3.0 – 12	1.3 – 8.5	-	5.0 – 8.6	20 70	
	Mean	8.3	-	-	8.0	4.0	-	6.7		
Cadmium	Range	0.03 - 0.47	-	-	<0.05 – 1.42	0.01 – 0.20	-	0.03 – 0.09	1.5 10	
	Mean	0.15	-	-	0.29	0.08	-	0.05		
Copper	Range	16 – 59	33 - 69	-	27 – 74	0.1 – 8.3	0.0 – 43	12 – 32	65 270	19 34
	Mean	38	53	-	45	2.8	11	18		
Lead	Range	3.6 – 19	98 - 247	<0.01 - 30	4.8 – 22	1.8 - 5.9	0.0 – 86.1	25 - 67	50 220	30 50
	Mean	9.9	155	14	12	18	22	47		
Zinc	Range	37 – 180	-	40 - 90	72 – 500	6.5 - 82	0.0 - 264	84 - 132	200 410	124 150
	Mean	73	-	68	164	30	92	89		
TBT	Range	<0.008 – 0.12	-	-	-	-	-	<0.003 – 0.009	0.005 0.070	
	Mean	0.03	-	-	-	-	-	0.003		
DDT	Range	<0.03–0.041	-	-	-	-	-	0.0018 – 0.0142	0.0016 0.0460	0.0039
	Mean	<0.030	-	-	-	-	-	0.0047		
Hydrocarbons	Range	<60 – 270	-	-	-	-	-	-		
	Mean	<60	-	-	-	-	-	-		

* results from three different studies in 2002, 2004 and 2005

Note: All of these studies have different methods of collection, different methods of analysis and different levels of detection and this table is intended as a rough comparison and summary only.

Cadmium
Cadmium is a very toxic, non-essential element for humans that can also be toxic to aquatic organisms at very low concentrations. It may exist in a number of forms which influence its toxicity, bioavailability and mobility in the environment. Cadmium is accumulated by many aquatic organisms with bio-concentration factors in the order of 100 – 100,000. There is also some evidence to suggest that cadmium is also accumulated through the food chain (ANZECC 2000). Sources of cadmium are discussed in section 4.1 above, with natural concentrations in unpolluted seawater extremely low.

Levels of cadmium were low, well below the ANZFSC guidelines. The concentrations found in the mussels in Port Taranaki were very similar to long-term monitoring of other mussel populations around New Plymouth, and levels were generally lower than found in other mussel tissue studies around New Zealand (Table 10).

Chromium
Chromium is an essential element to humans, but toxic at higher concentrations, and is thought to be a carcinogen. However, there is little evidence that chromium is accumulated through the food chain (Kelly, 2007). Refer to section 4.1 above for sources of chromium.

Chromium was below the limits of detection in all the samples and levels were similar to those found in feral populations around New Plymouth. Few national studies have included this metal, although Milne (2006) found much higher concentrations in Wellington Harbour (Table 10). These results are not directly comparable though as a different species of mussel was used.

Copper
Copper is an essential element in metabolic processes, with low toxicity for humans. Aquatic organisms have widely varying sensitivities to copper, algae in particular are sensitive hence its use in algaecides and antifoulants (Kelly, 2007). Sources of copper are discussed in section 4.1 above.

Levels of copper were similar at control and Port sites, and within the ranges of other studies (Table 10).

Lead
Lead is a cumulative metabolic poison in humans. It is acutely and chronically toxic to aquatic life at very low concentrations. It is accumulated by molluscs and may be passed up the food chain (Kelly, 2005). Sources of lead are discussed in Section 4.1 above.

Lead concentrations were within the ANZFSC guideline at all three sites. However, levels at Moturoa Wharf were elevated compared with other sites, including biennial samples collected around New Plymouth as part of the New Plymouth Waste Water Treatment Plant monitoring. Nielsen & Nathan (1975) found that *Perna* seemed to have a predilection for accumulating lead, and generally has higher lead levels in the vicinity of large cities

Nickel

In small quantities nickel is essential, but when the uptake is too high it can be a danger to human health. Nickel and certain nickel compounds have been listed by the National Toxicology Program (NTP) as being reasonably anticipated to be carcinogens[9]. Nickel can have high acute and chronic toxicity to aquatic life, with toxicity to aquatic organisms determined by water hardness - the softer the water, the higher the toxicity. Nickel is not known to accumulate in plants or animals and as a result nickel will not bio magnify up the food chain[10]. For a discussion on the sources of nickel to the environment refer to section 4.1 above.

Concentrations of nickel were very similar at the port sites, with the amount found in the control sample almost three times higher. One explanation for this may be that the mussels collected as the control sample were much smaller than the port samples, and metal concentrations can vary with shellfish size (age), with nickel concentrations known to decrease with increased mussel size (Milne, 2006). The results from the port samples were also much less than found in feral populations sampled as part of the NPWWTP monitoring programme (Table 10).

Zinc

Zinc is an essential element for plants and animals and not particularly toxic to humans unless ingested in high concentrations. Many organisms accumulate zinc to relatively high levels, with some organisms being very sensitive to zinc toxicity, while others are tolerant (Kelly, 2007). Sources of zinc to the aquatic environment are discussed in section 4.1 above.

Levels of zinc found at the four sites were similar, and were within the ranges of other published studies around New Zealand including that of other mussel populations of mussels on New Plymouth reefs (Table 10).

Summary

In summary, the results indicate that there does not appear to be contamination of mussel populations in Port Taranaki (and hence of water quality), with most metal concentrations either below ANZFSC guidelines (lead, cadmium) or, where no guideline exists, undetectable (chromium) or found at levels similar to the control sample, other feral samples collected from New Plymouth or from other studies around New Zealand (zinc, nickel, copper).

The exception to this was arsenic, which was found to be well over the NZFSC guidelines for food consumption in samples collected from both Port Taranaki and the control sample.

[9] www.lenntech.com/Periodic-chart-elements/Ni-en.htm#ixzzOIXRuBUQV&C
[10] www.npi.gov.au/database/substance-info/profiles/62.html

Table 11 Comparison of mussel flesh results with other studies around New Zealand

Study		This study	NPWWTP* monitoring	Nielson & Nathan (1975)	Coffey (1996)	Milne (2006)	ANZFSC guidelines 2002
Location		**Port Taranaki**	**New Plymouth**	**Various (199)**	**Waikato**	**Wellington**	
Species		*P. canaliculus*	*P. canaliculus*	*P. canaliculus*	*P. canaliculus*	*M. galloprovincialis*	
Arsenic	Range	1.4 – 1.9	-	-	-	-	1.0
	Mean	1.6	-	-	-	-	
Cadmium	Range	0.027 – 0.077	0.02 – 0.052	0.10 – 1.0	0.056 – 4.2	0.99 – 0.202	2.0
	Mean	0.049	0.037	0.3	0.589	0.137	
Chromium	Range	<0.10	<0.03 – 0.12	-	-	0.329 – 0.596	
	Mean	<0.10	0.055	-	-	0.430	
Copper	Range	1.1 – 1.5	0.46 – 1.42	0.2 – 28	0.50 – 1.10	0.55 – 1.34	
	Mean	1.3	0.809	1.8	0.75	0.795	
Lead	Range	0.065 – 0.31	<0.05 – 0.22	0.1 – 7.8	<0.5	0.215 – 1.476	2.0
	Mean	0.13	0.063	1.8	<0.5	0.493	
Nickel	Range	0.12 – 0.36	0.18 – 0.60	-	-	0.122 – 1.177	
	Mean	0.19	0.38	-	-	0.70	
Zinc	Range	9.7 – 11	5.2 – 10.7	0.5 - 28	8.2 – 26	28.0 – 61.2	
	Mean	11	7.7	21	13	39	
Hydrocarbons	Range	<60	-	-	-	-	
	Mean	<60	-	-	-	-	

* = NPWWTP = New Plymouth Waste Water Treatment Plant

Note: All of these studies have different methods of collection, different methods of analysis and different levels of detection and this table is intended as a rough comparison only.

4.3 Bacteriological water quality

Bacteriological water quality was found to be generally very good at all sampled sites within Port Taranaki during fine weather, comparing well with control sites outside of the port. However samples collected after significant rainfall often contained higher levels of bacteria.

The results were similar to the annual State of Environment beach bathing monitoring programme (at Ngamotu Beach in particular, and around Taranaki in general) where most samples collected during fine weather contain low levels of bacteria. MfE requirements occasionally meant collection of samples after rain (seven of the twenty samples collected over the season were on a fixed day) and these samples were often found to contain high numbers of bacteria, mostly at sites where streams and rivers drained agricultural catchments.

Good tidal flushing and dilution with offshore waters would ensure that bacteriological water quality in Port Taranaki is maintained to a relatively high level.

4.4 Intertidal ecology

The diversity and abundance of intertidal species within the port was found to be much less than on the natural reef beyond the port (Kawaroa). This was likely a reflection of the available substrate as opposed to water quality issues within the port, as the control site on the outside of the Lee Breakwater (i.e. with similar substrate) contained a lower number of species and diversity than the two sites inside the confines of the Port.

4.5 Invasive species

The coastal marine environment may be among the most heavily invaded of ecosystems, as a consequence of the long history of transport of marine species via international shipping. Transport in ballast water, in sea chests and other recesses in the hull structure, and as fouling communities attached to hulls have enabled hundreds of marine species to spread worldwide and establish populations in shipping ports and coastal environments outside of their natural range. Introduced (non-indigenous) plants and animals are now recognised as one of the most serious threats to the natural ecology of biological systems worldwide, with a proportion of these species capable of causing serious harm to native biodiversity, industries and human health (NIWA, 2008).

Interception of unwanted species is best achieved offshore, through control and treatment of ships destined for Port Taranaki from high-risk locations elsewhere in New Zealand or overseas. The Import Health Standard (Biosecurity Act 1993) for ballast water requires large ships to exchange foreign coastal ballast water with oceanic water prior to entering New Zealand. This process of "ballast exchange" doesn't remove all risk, but it does reduce the abundance and diversity of coastal species that may be discharged with ballast (NIWA, 2006).

NIWA, on behalf of BNZ, have now undertaken two surveys to provide an inventory of native, non-indigenous, and cryptogenic marine species within Port Taranaki.

A similar number of species was found during both surveys, along with a similar proportion of native : non-indigenous : cryptogenic : indeterminate species. However not all taxa were common to both surveys, with only around half the species recorded during the repeat survey also found in the earlier survey.

The only species found in Port Taranaki that is on the New Zealand register of unwanted organisms is the Asian kelp, *Undaria pinnatifida*. This species is known from other parts of New Zealand and was most likely transported into Port Taranaki on the hull of a vessel – either commercial or private.

Most non-indigenous species located in Port Taranaki are likely to have been introduced to New Zealand accidentally by international shipping or spread from other locations in New Zealand via ballast water or as hull fouling assemblages (Photograph 7). The predominance of hull fouling species in the introduced biota of the Port (as opposed to ballast water introductions) is consistent with findings from similar port baseline studies overseas (NIWA 2008).

4.6 Overall summary and discussion

Levels of hydrocarbons, lead, arsenic and cadmium in sediments collected from various sites within Port Taranaki did not indicate any significant contamination. Levels of DDT, TBT and zinc were also generally low, although an occasional sample was found to be over guideline (ANZECC and/or ARC ERC's) levels for marine sediments, indicating potential contamination. Copper, while below the ANZECC guideline levels in every sample, was above ARC ERC values in almost every sample.

The results of tissue analysis did not indicate contamination of mussel populations in Port Taranaki (and hence water quality), with most metal concentrations either below ANZFSC guidelines (lead, cadmium) or, where no guideline exists, undetectable (chromium), or found at levels similar to the control sample, other feral samples collected from New Plymouth or from other studies around New Zealand (zinc, nickel, copper). The exception to this was arsenic, which was found to be well over the ANZFSC guidelines for food consumption in both samples collected from Port Taranaki and in the control sample (in other words, there is no specific source of arsenic contamination within the harbour). However, these results were low by comparison with overseas survey findings.

The diversity and abundance of intertidal species within the port was found to be much less than on the natural reef outside the port (Kawaroa). This was likely a reflection of the available substrate as opposed to water quality issues within the port, as the control site on the outside of the Lee Breakwater (i.e. with similar substrate) contained a lower number of species and diversity than the two sites inside the confines of the Port.

Bacteriological water quality was found to be generally very good at all sampled sites within the port during fine weather, comparing well with control sites outside of the port. As with most locations around Taranaki, samples collected after significant rainfall often contained high levels of bacteria.

Two surveys to provide a baseline inventory of native, non indigenous and cryptogenic marine species within Port Taranaki have been undertaken by Biosecurity New Zealand. The only species on the New Zealand register of unwanted organisms found in Port Taranaki was the Asian kelp, *Undaria pinnatifida.* It was considered that most non-indigenous species located in Port Taranaki are likely to have been introduced to New Zealand accidentally by international shipping or spread from other locations in New Zealand. The predominance of hull fouling species in the introduced biota of the Port (as opposed to ballast water introductions) is consistent with findings from similar port studies overseas.

Given that Port Taranaki is essentially a highly modified industrial working port environment, within an urban catchment, the findings of the various studies reported here show relatively low levels of measurable effects or of adverse impacts. The main feature is the presence of non-indigenous species, introduced presumably by vessel movements.

Photograph 7 *Undaria* growing on the hull of a yacht in Port Taranaki

5. Recommendations

Based on the results of the Port water quality monitoring programme over the 2006-2009 monitoring period the following recommendations are made:

1. THAT analysis of sediment quality within the port is undertaken in five years time, and then at ten-yearly intervals, with the next survey completed during the 2013- 2014 monitoring period.

2. THAT analysis of mussel tissue for bioaccumulation of chemicals is undertaken at two-yearly intervals, with the next survey carried out during the 2011-2012 monitoring period.

3. THAT intertidal surveys are conducted biennially, with the next survey carried out in the 2010-2011 monitoring period.

4. THAT bacteriological water quality surveys are carried out within the port biennially, with the next survey carried out during the 2010-2011 monitoring period.

5. THAT data on invasive species, in particular the ongoing NIWA/Biosecurity monitoring, is reviewed and reported as it becomes available.

Glossary of common terms and abbreviations

The following abbreviations and terms are used within this report:

ANZECC	Australian and New Zealand Environment and Conservation Council
ANZFSC	Australian New Zealand Food Standards Code (2002)
ARC	Auckland Regional Council
BNZ	Biosecurity New Zealand
Breccia	A type of rock made of smaller rocks containing sharp, broken clasts
Cryptogenic species	An organism that is difficult to classify as being either native or non-native.
ERC	Environmental Response Criteria (Auckland Regional Council Guidelines)
Hydroid	A carnivorous animals that feed on minute crustaceans. Hydroids are related to jellyfish, sea anemones and corals. Some species live a solitary existence, others live in colonies.
Indeterminata	Undetermined species, one not identifiable with the description for a name already published
Indigenous	species that evolved and still exist within an original ecosystem
ISQG-High	Sediment guideline levels with contaminant concentrations where significant biological effects are expected.
ISQG-Low	Sediment guideline levels which are indicative of the contaminant concentrations where the onset of biological effects could possibly occur.
NIWA	National Institute of Water and Atmosphere
Non-indigenous	plants and animals that are living outside their natural geographic boundaries
RMA	Resource Management Act 1991 and subsequent amendments
Roll on – Roll off	Roll on, roll off ship is specifically designed to carry wheeled and tracked vehicles as all or most of its cargo.

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Appendix 1
Intertidal ecological surveys

Memorandum

To: SEM Monitoring Manager, Richard Fitzpatrick
From: Marine Ecologist, Kate Giles
File: #272687
Date: 15 March 2007

Port Taranaki water quality monitoring programme – intertidal ecological surveys

1. Introduction

Port Taranaki is an artificially created harbour which lies between a group of offshore islands to the west, and Kawaroa Reef, a large volcanic breccia reef, to the east. The port is enclosed by two breakwaters, the Main breakwater and the Lee Breakwater, which were create to provide additional shelter to the port and the ships that visit. As a result, the breakwaters enclose 94 hectares of sheltered water.

Access to the main port area is restricted; however, public use of the rest of the area is high, with various recreational activities being undertaken in and around Ngamotu Beach, the boat ramp and in the port waters. This includes boating, fishing, triathlons, yachting, kayaking, and swimming. There are also three café/restaurants and various other businesses along the foreshore between the reclamation and the Lee Breakwater.

A monitoring programme has been set up in order to collect baseline information on various aspects of the environment within the port. The programme has six components to be monitored: sediment quality, bioaccumulation of chemicals, intertidal surveys, water quality monitoring, invasive species, water quality and shipping movements. This report discusses the results of intertidal monitoring undertaken during the 2006-2007 monitoring period.

Three new sites were established as part of the intertidal ecological component of the monitoring programme. The sites are as follows: Inside the Lee Breakwater ((SEA902073), Eastern End of the Reclamation (SEA902072) and Outside the Lee Breakwater (SEA902071) (refer to Figure 1). The site Outside the Lee Breakwater acts as a comparison with the other two sites as it has a similar substrate to the two sites inside the Port, but is outside the confines of the port.

The survey was conducted between 17 and 21 February 2007, with low tides ranging from 0.1m to 0.4 m.

Figure 1 Intertidal monitoring sites

2. Methods

2.1 Field Work

The survey was conducted at three sites. The sites were Outside the Lee Breakwater (SEA 902071), Eastern end of the Reclamation (SEA 902072), and Inside the Lee Breakwater (SEA 902073).

At each site, a 50 metre transect was laid parallel to the shore, approximately 0.6 metres above chart datum. This transect was used to establish five, 5 metre x 3 metre blocks. Within each block 5 random 0.25 m^2 quadrats were laid giving a total of 25 random quadrats. For each quadrat the percentage cover of algae and encrusting animal species was estimated using a grid. For all other animal species, individuals larger than 3 mm were counted. Under boulder biota was counted where rocks and cobbles were easily overturned.

Photograph 1 Intertidal site, Eastern end of the Reclamation

2.2 Data Analysis

For each site the mean and standard deviation was calculated for the number of algae, animal species and the total number of species per quadrat. Shannon-Weiner diversity indices were calculated for each quadrat and a mean Shannon-Weiner index for each site. The Shannon-Weiner diversity index (H^1) can give additional information to that provided by the number of species per quadrat data, as this index also incorporates the relative abundance of individual species in addition to the number of species present.

Graphical summaries of the total number of species per quadrat and Shannon-Weiner indices at each site were made using box and whisker plots. Assumptions of normality were tested using the Lilliefors test. One-way analysis of variance (ANOVA) tests were carried out on total number of species per quadrat data and Shannon-Weiner indices for total species. A Tukey multiple comparison test was used to determine where differences occurred when a significantly different result was obtained using the ANOVA.

A graphical comparison of the mean number of total species per quadrat found in summer surveys undertaken in previous years and the present survey is also included.

3. Results

Summary statistics for the number of algae, animal and total species per quadrat and Shannon Weiner indices are presented in Table 1.

Table 1 Summary statistics

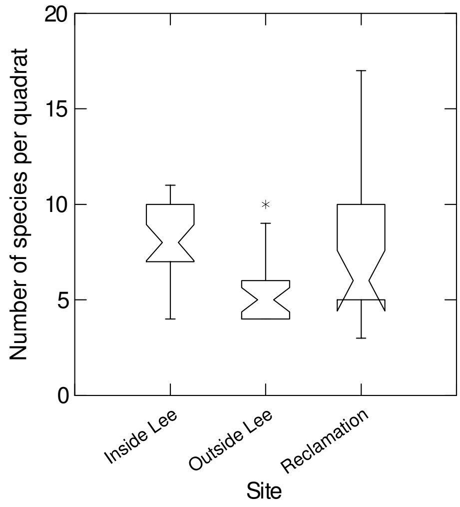
Site	No. of quadrats	Parameter	No. of species per quadrat			Shannon-Weiner indices per quadrat		
			Algae	Animals	Total Species	Algae	Animals	Total Species
Outside Lee Breakwater	25	Mean Std dev	1.48 1.15	4.32 1.43	5.80 1.77	0.104 0.130	0.453 0.143	0.528 0.137
Eastern Reclamation	25	Mean Std dev	1.68 1.57	6.16 2.76	7.84 3.74	0.173 0.199	0.622 0.156	0.702 0.183
Inside Lee Breakwater	25	Mean Std dev	1.12 1.20	6.96 1.36	8.08 1.95	0.102 0.175	0.622 0.129	0.657 0.143

The site inside the Lee Breakwater had the highest species abundance, followed closely by the Eastern End of the Reclamation, with Outside the Lee Breakwater somewhat lower. The site at the Eastern End of the Reclamation had the highest diversity, followed by Inside the Lee Breakwater and then Outside the Lee Breakwater.

3.1 Number of Species per Quadrat Data

Graphical summaries of the total (algae and animals) number of species per quadrat at each site are shown as box and whisker plots in Figure 2. The notched area of the box represents the median plus and minus the 95% confidence interval. This form of graphical representation allows a quick comparison to be made between sites. Generally, if the notched areas of the boxes for the different sites do not overlap you would expect to obtain a significantly different result when an ANOVA test was carried out.

Figure 2 Box and whisker plot for total number of species per quadrat



A Lilliefors test indicated that there was a significant deviation from a normal distribution at a 95% confidence level for the number of species per quadrat at all three sites.

The ANOVA test revealed a statistically significant difference between the sites (F = 5.592, P = 0.000) at a 95% confidence level. This can be seen in Figure 1 above, where the notched areas of the box and whisker plots do not overlap between sites.

A Tukey multiple comparison test was used to indicate which sites had significantly different means. Table 2 shows which combinations of sites were significantly different at a 95% confidence level.

Table 2 Results of Tukey multiple comparison test of number of species per quadrat

Site	Inside Lee	Outside Lee
Outside Lee	SIG	
Reclamation	NS	SIG

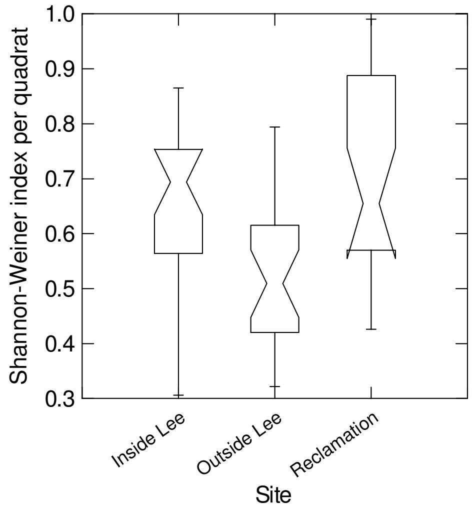
Key: SIG = significant difference at 95% confidence level
NS = no significant difference

From the table above it can be seen that the site outside the Lee Breakwater differed significantly in terms of species abundance from both the Inside Lee Breakwater site and the Eastern Reclamation site.

3.2 Shannon-Weiner Diversity Index Data

Graphical summaries of the Shannon-Weiner index data at each site are shown as box and whisker plots in Figure 3.

Figure 3 Box and whisker plots of Shannon-Weiner diversity indices



A Lilliefors test indicated that all three sites did not significantly deviate from a normal distribution at a 95% confidence level using the Shannon-Weiner diversity data.

The ANOVA test revealed a statistically significant difference between the sites (F = 8.323, P = 0.001) at a 95% confidence level. A Tukey multiple comparison test was used to indicate which sites had significantly different means. Table 3 shows which combinations of sites were significantly different at a 95% confidence level.

Table 3 Results of Tukey multiple comparison test of Shannon-Weiner diversity indices

Site	Inside Lee	Outside Lee
Outside Lee	SIG	
Reclamation	NS	SIG

Key: SIG = significant difference at 95% confidence level
NS = no significant difference

As with the abundance data, Table 3 shows that the site outside the Lee Breakwater differed significantly in terms of species diversity from both the Inside Lee Breakwater site and the Eastern Reclamation site.

3.3 Sand Coverage

In addition to the number of algae and animals in each quadrat, the percentage coverage of sand is also recorded for each quadrat. The mean percent sand coverage per quadrat at each site is presented in Table 4 below.

Table 4 Mean percent sand coverage per quadrat at each site

Site	Mean coverage per quadrat (%)
Inside Lee	0.0
Outside Lee	0.0
Reclamation	0.0

Previous studies on intertidal reefs in Taranaki have demonstrated that at 30% coverage, sand begins to negatively influence the number and diversity of species. Table 4 shows that there was no sand present at any of the sites. It is unlikely that sand would accumulate at any of the three sites as the substrate is almost exclusively boulders.

Photograph 2 Site Inside Lee Breakwater

4. Discussion

An intertidal ecological survey was carried out at three sites in and around Port Taranaki between 17 and 21 February 2007.

The site inside the Lee Breakwater had the highest species richness, followed by the Eastern end of the Reclamation then Outside the Lee Breakwater. Diversity was highest at the Eastern end of the Reclamation, followed by Inside the Lee Breakwater and then Outside the Lee Breakwater.

Statistical analysis showed that the site Outside the Lee Breakwater differed significantly from the other two sites, both in terms of species abundance and diversity.

In comparison with other intertidal sites on Kawaroa Reef, just outside the Port, species richness and diversity is significantly lower at the Port sites. However this can be attributed to the habitat at the sampling sites, which is not natural reef, but large boulders. The boulder habitat (substrate and elevation) is not very suitable habitat for algae, with very few species present: *Ralfsia* sp., *Champia* sp., Corraline turf and paint, *Laurencia thryisifera*, *Gelidium* sp., *Hildenbrandtia crouani*, and *Ulva* sp. Similarly, few animal species were adapted to life on the boulders, the tubeworm, *Spirobranchus* *cariniferus*, and the barnacle, *Chamaesipho columna* were common, as were the limpets *Cellana radians* and *C. ornata*, along with *Siphonaria australis* and *Patelloida corticata*. The gastropods *Melagraphia aethiops* and *Turbo smaragdus* were fairly common. Occasional chitons were also present.

5. Conclusions

This is the first marine ecological intertidal survey conducted as part of the 2006-2007 Port Taranaki water quality monitoring programme.

The sites inside the Port had higher species richness and diversity, however both these parameters were relatively low at all sites. This can be attributed to the modified, predominantly boulder, habitat.

The species of algae and animals found were similar at all three sites.

The results of this survey will be able to be used in conjunction with data collected in the future, as a baseline for comparison. It is intended that a further intertidal ecological survey be conducted at the three sites during the 2008-2009 monitoring period.

Kate Giles
Marine Ecologist

Memorandum

To: SEM Monitoring Manager,
From: Marine Ecologist, Kate Giles
File: #549342
Date: 5 January 2009

Port Taranaki SEM monitoring programme – intertidal ecological surveys

1. Introduction

Port Taranaki is an artificially created harbour which lies between a group of offshore islands to the west, and Kawaroa Reef, a large volcanic breccia reef, to the east. The port is enclosed by two breakwaters, the Main breakwater and the Lee Breakwater, which were created to provide additional shelter to the port and the ships that visit. As a result, the breakwaters enclose 94 hectares of sheltered water.

Access to the main port area is restricted; however, public use of the rest of the area is high, with various recreational activities being undertaken in and around Ngamotu Beach, the boat ramp and in the port waters. This includes boating, fishing, triathlons, yachting, kayaking, and swimming. There are also three café/restaurants and various other businesses along the foreshore between the reclamation and the Lee Breakwater.

A monitoring programme has been set up in order to collect baseline information on various aspects of the environment within the port. The programme has six components to be monitored: sediment quality, bioaccumulation of chemicals, intertidal surveys, water quality monitoring, invasive species, water quality and shipping movements. This report discusses the results of intertidal monitoring undertaken during the 2008-2009 monitoring period.

Three new sites were established as part of the intertidal ecological component of the monitoring programme. The sites are as follows: Inside the Lee Breakwater (SEA902073), Eastern End of the Reclamation (SEA902072) and Outside the Lee Breakwater (SEA902071) (refer to Figure 1). The site Outside the Lee Breakwater acts as a comparison with the other two sites as it has a similar substrate to the two sites inside the Port, but is outside the confines of the port.

The survey was conducted between 12 and 14 December 2008, with low tides ranging from 0.2m to 0.4 m.

Figure 1 Intertidal monitoring sites

2. Methods

2.1 Field Work

The survey was conducted at three sites. The sites were Outside the Lee Breakwater (SEA 902071), Eastern end of the Reclamation (SEA 902072), and Inside the Lee Breakwater (SEA 902073).

At each site, a 50 metre transect was laid parallel to the shore (this was laid along the 'pink line' ie. where the corraline paint began, in order that the three sites were at approximately the same elevation). This transect was used to establish five, 5 metre x 3 metre blocks. Within each block 5 random 0.25 m^2 quadrats were laid giving a total of 25 random quadrats. For each quadrat the percentage cover of algae and encrusting animal species was estimated using a grid. For all other animal species, individuals larger than 3 mm were counted. Under boulder biota was counted where rocks and cobbles were easily overturned.

2.2 Data Analysis

For each site the mean and standard deviation was calculated for the number of algae, animal species and the total number of species per quadrat. Shannon-Weiner diversity indices were calculated for each quadrat and a mean Shannon-Weiner index for each site. The Shannon-Weiner diversity index (H^1) can give additional information to that provided by the number of species per quadrat data, as this index also incorporates the relative abundance of individual species in addition to the number of species present.

Graphical summaries of the total number of species per quadrat and Shannon-Weiner indices at each site were made using box and whisker plots. Assumptions of normality were tested using the Lilliefors test. One-way analysis of variance (ANOVA) tests were carried out on total number of species per quadrat data and Shannon-Weiner indices for total species. A Tukey multiple comparison test was used to determine where differences occurred when a significantly different result was obtained using the ANOVA.

A graphical comparison of the mean number of total species per quadrat found in summer surveys undertaken in previous years and the present survey is also included.

3. Results

Summary statistics for the number of algae, animal and total species per quadrat and Shannon Weiner indices are presented in Table 1.

Table 1 Summary statistics

Site	No. of quadrats	Parameter	No. of species per quadrat			Shannon-Weiner indices per quadrat		
			Algae	Animals	Total Species	Algae	Animals	Total Species
Outside Lee Breakwater	25	Mean	1.76	3.72	5.48	0.15	0.41	0.49
		Std dev	1.36	1.21	2.10	0.14	0.15	0.16
Eastern Reclamation	25	Mean	1.72	4.88	6.60	0.16	0.59	0.71
		Std dev	1.21	1.09	1.80	0.20	0.10	0.11
Inside Lee Breakwater	25	Mean	1.48	4.48	5.96	0.16	0.46	0.56
		Std dev	0.96	1.36	1.81	0.15	0.17	0.17

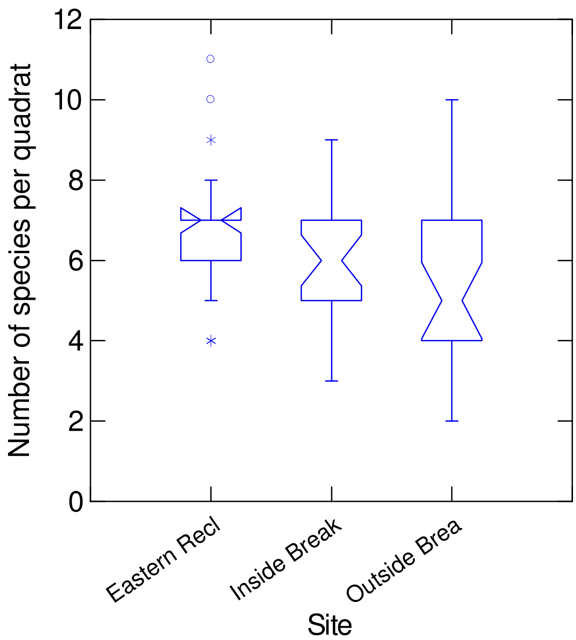
The Eastern Reclamation site had the highest species abundance, followed by Inside the Lee Breakwater and then Outside the Lee Breakwater. A similar pattern was observed with regards to diversity, however the Eastern Reclamation site (Photograph 1) had a much higher diversity than the other two sites.

Photograph 1 Eastern Reclamation site

3.1 Number of Species per Quadrat Data

Graphical summaries of the total (algae and animals) number of species per quadrat at each site are shown as box and whisker plots in Figure 2. The notched area of the box represents the median plus and minus the 95% confidence interval. This form of graphical representation allows a quick comparison to be made between sites. Generally, if the notched areas of the boxes for the different sites do not overlap you would expect to obtain a significantly different result when an ANOVA test was carried out.

Figure 2 Box and whisker plot for total number of species per quadrat



A Lilliefors test indicated that there was a significant deviation from a normal distribution at a 95% confidence level for the number of species per quadrat at both Inside and Outside the Lee Breakwater sites.

The ANOVA test did not reveal a statistically significant difference between the sites (F = 2.159, P = 0.123) at a 95% confidence level. This can be seen in Figure 1 above, where the notched areas of the box and whisker plots do not overlap between sites.

A Tukey multiple comparison test was used to indicate which sites had significantly different means. Table 2 shows that none of the sites were significantly different at a 95% confidence level.

Table 2 Results of Tukey multiple comparison test of number of species per quadrat

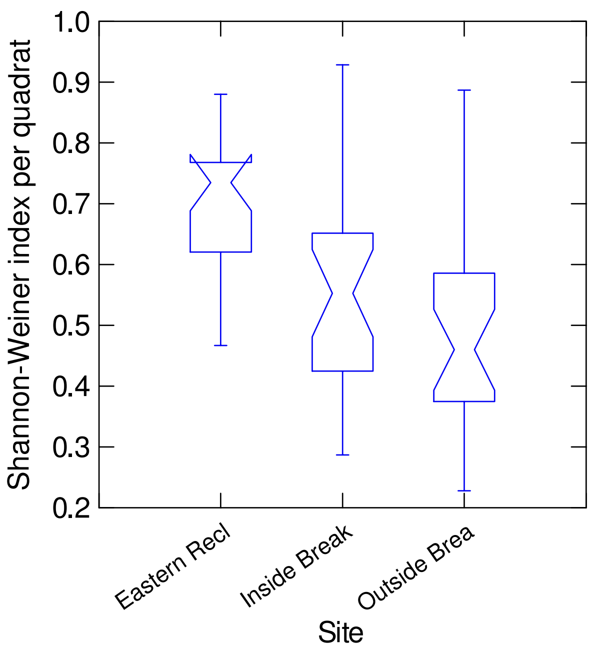
Site	Inside Lee	Outside Lee
Outside Lee	N/S	
Reclamation	N/S	N/S

Key: SIG = significant difference at 95% confidence level
NS = no significant difference

3.2 Shannon-Weiner Diversity Index Data

Graphical summaries of the Shannon-Weiner index data at each site are shown as box and whisker plots in Figure 3.

Figure 3 Box and whisker plots of Shannon-Weiner diversity indices



A Lilliefors test indicated that none of the three sites significantly deviated from a normal distribution at a 95% confidence level using the Shannon-Weiner diversity data.

The ANOVA test revealed a statistically significant difference between the sites ($F = 14.926$, $P = 0.000$) at a 95% confidence level. A Tukey multiple comparison test was used to indicate which sites had significantly different means. Table 3 shows which combinations of sites were significantly different at a 95% confidence level.

Table 3 Results of Tukey multiple comparison test of Shannon-Weiner diversity indices

Site	Inside Lee	Outside Lee
Outside Lee	N/S	
Reclamation	SIG	SIG

Key: SIG = significant difference at 95% confidence level
NS = no significant difference

Table 3 shows that the Eastern Reclamation site differed significantly in terms of species diversity from both the Outside and Inside Lee Breakwater sites.

4. Discussion

An intertidal ecological survey was carried out at three sites in and around Port Taranaki between 12 and 14 December 2008.

The Eastern Reclamation site had the highest species richness and diversity, followed by the Inside Lee Breakwater site, then Outside the Lee Breakwater.

Statistical analysis showed that although the sites did not differ significantly in terms of species abundance, the two Lee Breakwater sites were significantly different with regards to diversity. This was due to the higher diversity found a the Eastern Reclamation site.

In comparison with other intertidal sites on Kawaroa Reef, just outside the Port, species richness and diversity is significantly lower at the Port sites. However this can be attributed to the habitat at the sampling sites, which is not natural reef, but large boulders. The boulder habitat (substrate and elevation) is not very suitable habitat for algae, with very few species present: *Ralfsia* sp., *Champia* sp., Corraline turf and paint, *Laurencia thryisifera*, and *Gelidium* sp. Similarly, few animal species were adapted to life on the boulders, the tubeworm, *Spirobranchus cariniferus*, and the barnacle, *Chamaesipho columna* were common, as were the limpets *Cellana radians* and *C. ornata*, along with *Siphonaria australis* and *Patelloida corticata*. The gastropods *Melagraphia aethiops* and *Turbo smaragdus* were fairly common. Occasional chitons were also present.

5. Conclusions

This is the second marine ecological intertidal survey conducted as part of the Port Taranaki SEM monitoring programme.

The sites inside the Port had higher species richness and diversity, however both these parameters were relatively low at all sites. This can be attributed to the modified, predominantly boulder, habitat.

The species of algae and animals found were similar at all three sites.

The results of this survey will be able to be used in conjunction with data collected in the future, as a baseline for comparison. It is intended that a further intertidal ecological survey be conducted at the three sites during the 2010-2011 monitoring period.

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