Golden Bay Non-Indigenous Species Port Survey

Baseline Surveys of New Ports and Marinas

Biosecurity project number ZBS 2005/19

MAF Biosecurity New Zealand Technical Paper No: 2019/04

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ISBN No: 978-1-98-857163-8
ISSN No: 2624-0203

August 2009

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Abstract

New Zealand's geographic isolation presents the opportunity to protect its unique biodiversity and economy. Knowledge of existing non-indigenous and indigenous biodiversity is required to identify new species threats, detect new species introductions, and undertake effective management of marine biosecurity (Hewitt *et al*. 2004). New Zealand has, therefore, implemented a number of baseline port surveys to elucidate the degree of non-indigenous and indigenous species diversity within its ports, marinas and also in regions relatively unaffected by human activities (Campbell *et al*. 2007).

This document reports the results of a baseline survey of native and non-indigenous species undertaken at Golden Bay, New Zealand between 5 and 9 November 2007. The survey was performed by Golder Associates (NZ) Ltd and the Cawthron Institute in accordance with survey protocols and design prepared by the Centre for Research on Introduced Marine Pests and MAF Biosecurity New Zealand.

Nine non-indigenous species and nineteen cryptogenic species were detected during the survey. The non-indigenous species comprised *Barantolla lepte*, *Bugula flabellata*, *Bugula neritina*, *Crassostrea gigas*, *Cryptosula pallasiana*, *Limaria orientalis*, *Tricellaria catalinensis*, *Undaria pinnatifida* and *Watersipora subtorquata*. All non-indigenous species had been recorded previously in New Zealand. *Bugula flabellata, C. gigas, C. pallasiana, U. pinnatifida* and *W. subtorquata* were collected from wharf pilings or pontoons, indicating an association with shipping and a biofouling habit, whereas *B. flabellata* and *U. pinnatifida* were also found on marine farms, indicating an association with aquaculture activities.

The possible origin and potential vectors for the translocation of new species to Golden Bay are discussed in relation to the relative risk of new species introductions and the translocation of non-indigenous species that have established at Golden Bay. Options for the management of vector pathways and non-indigenous species to prevent new species incursions to Golden Bay and the spread of established species are also discussed.

Keywords: Golden Bay, marine biosecurity, non-indigenous species, baseline survey.

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1. Introduction

Non-indigenous species have been identified as one of the major threats to biodiversity (Gurevitch & Padilla 2004, Carlton 1996, Lubchenco *et al*. 1991). The increasing rate of non-indigenous marine species introductions has become a matter of global concern (Carlton 1989, Ruiz *et al*. 1997, Cohen & Carlton 1998, Grosholz 2005). Non-indigenous species can adversely affect natural ecosystems, commerce and human health (Ribera & Boudouresque 1995, Ruiz *et al*. 1997, AFF-Australia 2002). Therefore, management and decision-making in marine biosecurity have to be guided by a precautionary approach both in the identification of biosecurity threats and rapid response to pest incursions before an organism is established and negatively affecting New Zealand's economy, human health, and biodiversity (Gullett 1997, Cooney 2004, Cooney & Dickson 2005, Peel 2005). Effective surveillance is the key to the early detection and effective management of non-indigenous species as eradication is only likely to be feasible at the earliest founding stages of the invasion process.

New Zealand's geographic isolation presents the opportunity to protect its unique biodiversity and economy. Knowledge of existing non-indigenous and indigenous biodiversity is required to identify new species threats, detect new species introductions, and undertake effective management of marine biosecurity (Hewitt *et al*. 2004). New Zealand has, therefore, implemented a number of baseline port surveys to elucidate non-indigenous and indigenous species diversity within its ports, marinas and regions relatively unaffected by human activities (Campbell *et al*. 2007).

Between 5 and 9 November 2007, Golder Associates (NZ) Ltd (Golder) and the Cawthron Institute conducted a baseline survey of Port of Tarakohe (also known as Port Golden Bay) and Golden Bay, South Island. The aim of the survey was to undertake a baseline survey for non-indigenous species for the port and adjacent marine areas using the protocols prepared by the Centre for Research on Introduced Marine Pests (CRIMP) (Hewitt & Martin 1996, 2001) while adhering to the survey design (and CRIMP format reporting template) provided by the Ministry of Agriculture and Forestry – Biosecurity New Zealand (MAFBNZ).

2. Description of the Port

2.1. GENERAL FEATURES OF GOLDEN BAY

Golden Bay is located on the north-western coast of South Island, New Zealand, and covers an area of approximately 850 km^2 with more than 90 km of coastline (Figure 1). Golden Bay's sheltered coastline extends from Separation Point in the south to Farewell Spit at the northern tip. Farewell Spit is New Zealand's longest sandspit system, extending eastward for approximately 40 km into the Tasman Sea, sheltering extensive tidal mudflats to the south up to 6 km seaward at low tide.

The majority of Golden Bay lies within depths of less than 30 m, with typically low-gradient bathymetric contours that follow the coastline. The seabed through this depth range is largely uniform and dominated by fine-textured, silty sediments and patchy distributions of a variable percentage of dead shell material, with no major changes in seabed morphology (Mitchell 1987, Davidson 1999, Gillespie & Forrest 1999, Ritchie 1999). Subtidal soft sediment deposits are mostly limited to estuaries, tidal inlets, river outflows and shallow, near-shore regions (e.g., Farewell Spit), and the fine-grained nature of the bottom sediments reflects the relatively low wave and current activity within the bay (Tuckey *et al*. 2006). Areas of rocky reef habitat featuring macro-algal beds are extremely limited by comparison, and large areas of soft sediment habitat are dominant throughout the bay (Jiang & Gibbs 2005).

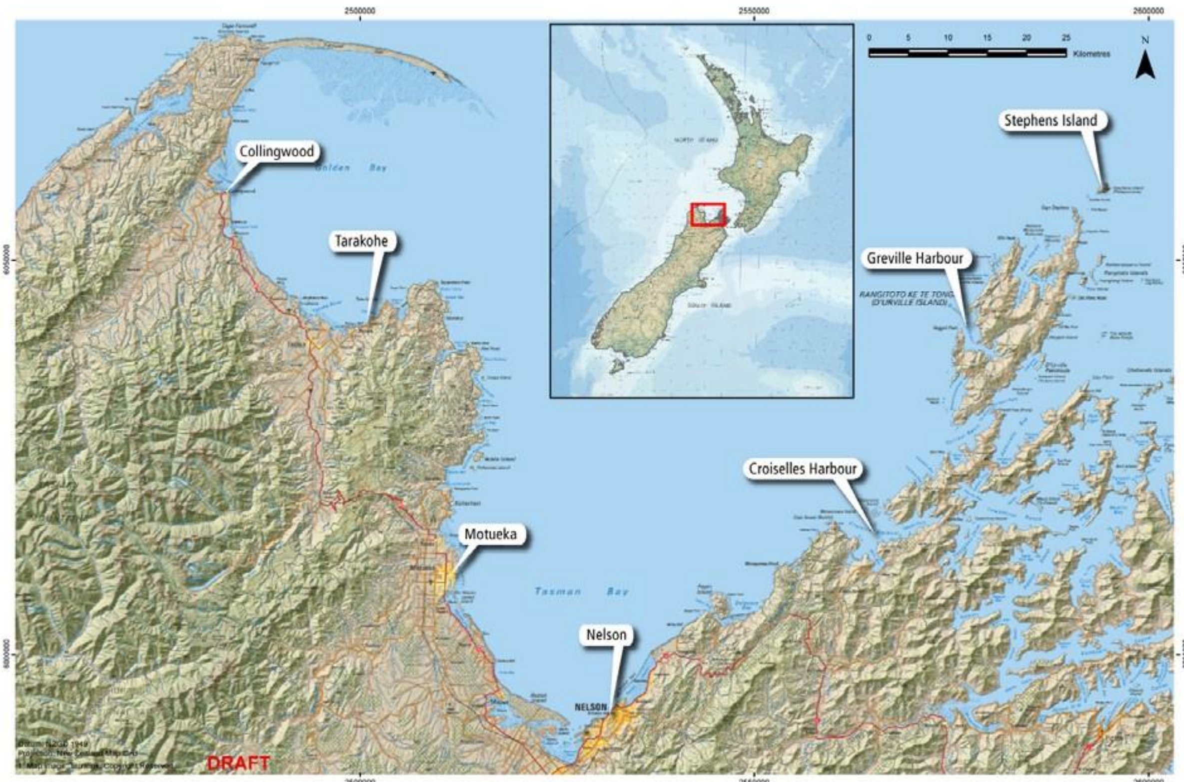

Figure 1: Golden and Tasman Bays in northern South Island, New Zealand.

The physical and chemical characteristics of sediments within Port Tarakohe are consistent with those reported for nearshore locations within Golden Bay, being largely dominated by silt/clay mixed with various amounts of sand and coarse gravel (Bennett *et al*. 2006). Concentrations of sediment trace metals (cadmium, chromium, copper, lead, mercury, zinc) and metalloid arsenic are all reported as well below the Australia-New Zealand Environment

Conservation Council (ANZECC 2000) interim sediment quality guideline (ISQG) levels used to indicate potential biological effects (Bennett *et al*. 2006). Nickel concentrations in the port exceed the ISQG-low guidelines; however, values are consistent with previously reported levels for the region.

The hydrodynamic processes of Golden Bay are dominated by a mix of tidal flows, larger-scale ocean circulation, riverine inputs, wind forcing and wave mixing. The bay's large size and relatively simple geometry mean that each of these elements behaves in a simple fashion; however, the combination of factors is more complicated. Mean circulation in Golden Bay is clockwise within the area bounded by the end of Farewell Spit and Separation Point (Heath 1985). The residual circulation is largely wind-driven and varies with the passage of weather systems through the area on a typical time-scale of a week.

The wave climate consists mostly of locally-generated wind waves with some penetration of ocean swell. The fluctuating tidal flow in Golden Bay is reasonably well understood as a result of modelling work (Heath 1976, Tuckey *et al*. 2006, Plew *et al*. *in press*) backed up by empirical *in situ* measurements. The tidal range is large (mean ~ 2.7 m, maximum ~ 4.2 m) and the margins of the bay relatively broad and shallow (20 m or less), leading to generally strong tidal flows (5-30 cm/s) throughout the bay.

2.2. HISTORICAL INFORMATION – PORT DEVELOPMENT, MAINTENANCE AND SHIPPING MOVEMENTS

Golden Bay was identified in 1642 by the Dutch explorer and navigator Abel Tasman who, after losing four of his men in a battle with the local Maori, named the area Murderers' Bay (McLintock 1966). In 1770, Cook included it as part of Blind Bay but in his second voyage of 1773 correctly located it as the scene of the 1642 massacre and referred to it as Murderers' Bay. In 1827, D'Urville changed this to Massacre Bay, by which name it was known until the early days of European settlement. Following the discovery of coal at Takaka in 1842, it was known for a time as Coal Bay. The final name of Golden Bay was established following the discovery of the Collingwood Goldfields in 1857.

Golden Bay was once extensively used by coastal shipping from wharves at Waitapu (Takaka), Onekaka, Parapara, Collingwood, Pakawau and Puponga. Coal of good quality was plentiful in Golden Bay, and a number of mines operated throughout the area, exporting their coal from small wharves around the coast. Coal mining in the area has now ceased. Golden Bay Cement Works Ltd. was established in 1908 at Tarakohe, due to the availability of lime and clay and its central location (CCANZ 2007). This became the Golden Bay Cement Co. Ltd. in 1919. Cement was transported out of the area via Port Tarakohe (Figure 2), which is located on the south-eastern shore of Golden Bay (40° 49' 21.9"E, 179° 53' 42.7"S). In 1988, the company became known as Golden Bay Cement and the Tarakohe plant was discontinued.

Figure 2: Map of Port Tarakohe showing the main wharf area, pontoon marina, vessels mooring area and boat ramp (modified from Bennett *et al*. 2006).

Table 1 outlines a timeline of industrial and social events that have influenced the development and use of the Port of Tarakohe (Port Golden Bay) over the past hundred years. Today, the port is predominantly used by mussel farmers, scallop fisherman and recreational boaters. The current facilities available at the port include a main berth area of 125 m in length, a 62-berth pontoon marina, vessel mooring area and boat ramp (Bennett *et al*. 2006). The inner seawall on the west side was extended by 70 m in 2008, and there are plans in place to increase the number of marina berths by 150-180 over the next several years.

Table 1: Timeline of industrial and social events influencing the development and use of Port Tarakohe. Information supplied by Allan Kilgour, Tarakohe Harbour Manager.

Date	Event
1906	Private investor begins experimental cement making.
1908	Golden Bay Cement Company founded.
1909	Site of Limestone Bay (Tarakohe).
1911	Cement production starts; original cement plant built.
1917	Union formed at the works.
1919	Cement company build general store in Pohara Valley.
1924	First social hall built at Pohara.
1927	Cement works build larger cement plant.
1929	Original power plant mothballed; Murchison earthquake rocks Golden Bay.
1945	Fire destroys cement works office and laboratory block.
1950	Controlling interest in cement works sold to British firm - cement works expand.
1951	Nationwide waterfront workers strike hits Port of Tarakohe.
1955	First bulk shipment of cement to Wellington aboard cement carrier The Golden Bay; Tarakohe Shipping Company formed.
1956	New Port of Tarakohe office complex built.
1960	Pohara Beach Sailing Club formed.
1964	Ligar Bay enters shipping service.
1968	Inangahua earthquake shuts down cement plant.

1970	Talks begin on creating an all-weather harbour to cope with increased cement production.
1977	Construction of two piers (bund walls) begins; building begins for a new heavy-duty wharf and docking alongside old hardwood wharf
1980	Newer and bigger ship, The Golden Bay, enters service; cement sales drop.
1981	General store burns down.
1983	Redundancies loom at cement works.
1986	Golden Bay Cement Co. and NZ Cement Co. form cooperative arrangement.
1988	Tarakohe cement works closes down.
1994	Tasman District Council buys Tarakohe harbour facilities.
2001	Cement company pulls out of Tarakohe and sells remainder of plant and land.
2005	Tasman District Council opens new marina at Tarakohe.
2008	Westward inner seawall extended by 70 m

Data detailing the shipping movements of vessels using the main wharf of Port Tarakohe over the last three years show that mussel aquaculture vessels and fishing vessels are the primary shipping traffic within the port (Table 2; Figure 3; data provided by A. Kilgour, Tarakohe Harbour Manager). Shipping movements on the main wharf can increase significantly during good mussel and scallop growing years (A. Kilgour, pers. comm.). This data on shipping movements does not include boating activities associated with the 62-berth marina (which is receiving increasing numbers of visiting vessels), nor numbers of recreational vessels utilising the harbour boat ramp (which may be between 5000 to 10 000 vessels per year depending upon the availability of scallops and fishing in Golden Bay (A. Kilgour, pers. comm.)).

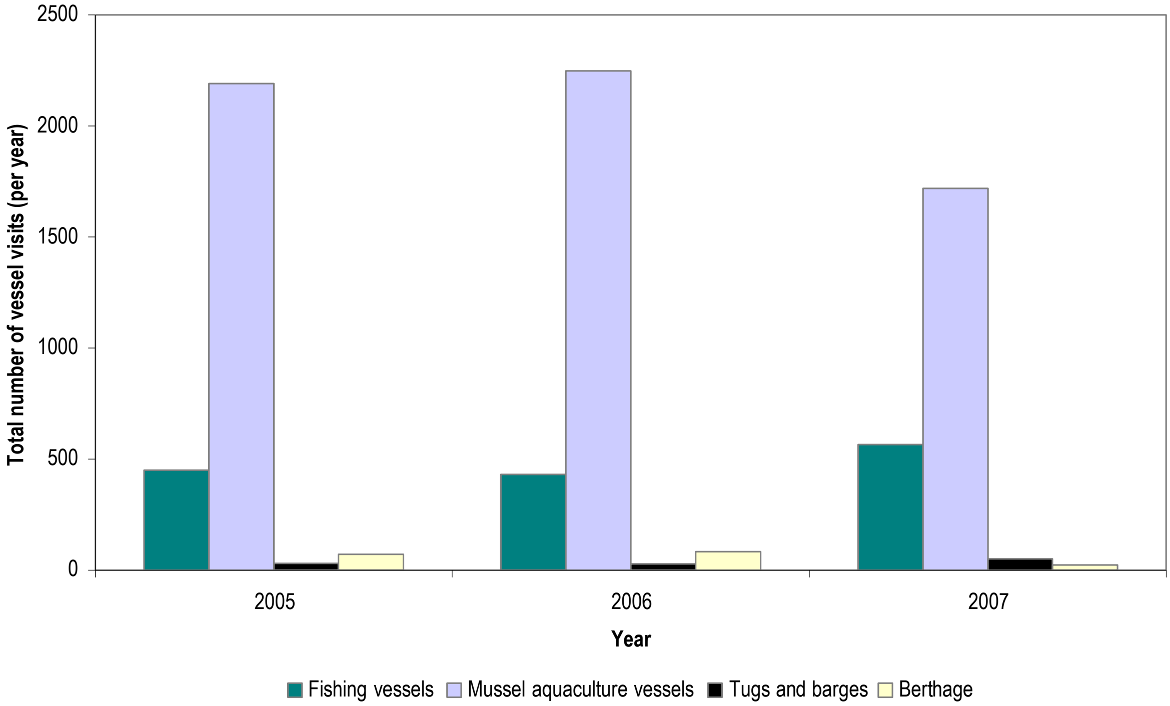

Figure 3: Summary data of shipping movements for a range of vessel types using the main wharf area at Port Tarakohe between 2005 and 2007. Note that this data does not include vessels using the 62-berth pontoon marina or recreational vessels utilising the harbour boat ramp. Data provided by A. Kilgour, Tarakohe Harbour Manager.

The closest ports-of-call for international vessels in the vicinity of Golden Bay are the ports of Nelson, Picton and Wellington. Information collated from the MAFBNZ Ballast Water Database shows that ballast water discharge in these ports between 2000 and 2007 was greatest from vessels with a known last port-of-call in Australia or New Zealand, the North-

West Pacific and East Asian seas (Table 3). This does not necessarily mean, however, that all ballast water discharged from these vessels originated from the bioregion listed, as ballast water can be approximately a year old when discharged (A. Bell, pers. comm.).

Table 2: Summary data detailing the shipping movements for a range of vessel types using the main wharf area in Port Tarakohe between 2005 and 2007. Note that this data does not include vessels using the 62-berth pontoon marina or recreational vessels utilising the harbour boat ramp. Data provided by A. Kilgour, Harbour Manager, Port Tarakohe.

Vessel type	Month											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
2005												
Fishing vessels	22	22	22	22	22	22	22	150	80	22	22	22
Mussel aquaculture vessels	186	168	186	180	186	180	186	186	180	186	180	186
Tugs and barges	1	4	2	2	2	3	3	3	4	3	2	2
Berthage	1	1	2	6	20	3	7	4	4	18	2	3
Monthly total	210	195	212	210	230	208	218	343	268	229	206	213
2006												
Fishing vessels	22	22	22	22	22	22	22	22	88	122	22	22
Mussel aquaculture vessels	190	160	186	210	180	177	186	180	184	186	209	200
Tugs and barges	2	3	4	3	2	1	2	4	3	1	1	2
Berthage	-	12	26	-	-	5	9	6	10	13		3
Monthly total	214	197	238	235	204	205	219	212	285	322	232	227
2007*												
Fishing vessels	22	22	22	22	22	22	22	22	390			
Mussel aquaculture vessels	188	182	194	212	177	180	192	194	200			
Tugs and barges	3	6	6	8	8	4	6	5	6			
Berthage	3	1	-	3	2	-	-	-	15			
Monthly total	216	211	222	245	209	206	220	221	611			

Table 3: Summary of the volume (MT) of ballast water discharged from international vessels in ports operating closest to Golden Bay between 2000 and 2007. Bioregion denotes the location at which the ballast water was collected based on the classification of Kelleher *et al*. 1995. Values are based on the most up-to-date information from the Ministry of Agriculture and Forestry – Biosecurity New Zealand Ballast Water Database at the time of compilation.

Bioregion of Last Port-of-Call	2000			2001			2002			2003		
	Nelson	Picton	Wellington	Nelson	Picton	Wellington	Nelson	Picton	Wellington	Nelson	Picton	Wellington
Arabian Seas	-	-	-	-	-	-	-	-	-	-	-	-
Australia, New Zealand	10808	-	2309	2838	884	4120	178720	10040	5689	1573	9329	1167
Baltic	-	-	-	-	-	-	-	-	-	-	-	-
Central Indian Ocean	1126	-	-	2706	-	-	-	-	-	-	-	-
East Africa	-	-	-	-	-	-	-	-	-	400	432	401
East Asian Seas	1781	-	3315	17738	752	-	1050	2216	-	-	-	-
Mediterranean	-	-	-	-	19885	0	-	-	-	-	-	-
North East Atlantic	-	-	-	-	-	1037	661	-	-	-	-	-
North East Pacific	-	-	-	-	-	-	508	-	-	-	-	-
North West Atlantic	-	-	-	-	-	-	-	-	-	-	-	-
North West Pacific	68603	-	5543	143796	40761	3112	88571	7392	27378	98111	4546	1251
South Atlantic	-	-	-	-	-	-	-	-	-	-	-	-
South East Pacific	-	-	-	280	-	-	-	-	-	-	-	-
South Pacific	450	-	-	450	-	-	752	-	3045	4796	-	-
Unknown	2925	-	1167	20274	3905	357	35407	-	873	11294	14288	468
West Africa	-	-	-	-	-	-	-	-	-	-	-	-
Wider Caribbean	-	-	-	-	-	-	-	-	-	-	-	-

Table 3 continued.

Bioregion of Last Port-of-Call	2000			2001			2002			2003		
	Nelson	Picton	Wellington	Nelson	Picton	Wellington	Nelson	Picton	Wellington	Nelson	Picton	Wellington
Arabian Seas	-	-	-	-	-	-	-	-	-	-	-	-
Australia, New Zealand	10808	-	2309	2838	884	4120	178720	10040	5689	1573	9329	1167
Baltic	-	-	-	-	-	-	-	-	-	-	-	-
Central Indian Ocean	1126	-	-	2706	-	-	-	-	-	-	-	-
East Africa	-	-	-	-	-	-	-	-	-	400	432	401
East Asian Seas	1781	-	3315	17738	752	-	1050	2216	-	-	-	-
Mediterranean	-	-	-	-	19885	0	-	-	-	-	-	-
North East Atlantic	-	-	-	-	-	1037	661	-	-	-	-	-
North East Pacific	-	-	-	-	-	-	508	-	-	-	-	-
North West Atlantic	-	-	-	-	-	-	-	-	-	-	-	-
North West Pacific	68603	-	5543	143796	40761	3112	88571	7392	27378	98111	4546	1251
South Atlantic	-	-	-	-	-	-	-	-	-	-	-	-
South East Pacific	-	-	-	280	-	-	-	-	-	-	-	-
South Pacific	450	-	-	450	-	-	752	-	3045	4796	-	-
Unknown	2925	-	1167	20274	3905	357	35407	-	873	11294	14288	468
West Africa	-	-	-	-	-	-	-	-	-	-	-	-
Wider Caribbean	-	-	-	-	-	-	-	-	-	-	-	-

3. Review of Existing Biological Information

3.1. OVERVIEW

Several ecological studies have been undertaken within Golden Bay, mainly in the form of baseline assessments of benthic habitats of areas proposed for use in aquaculture farming. A baseline assessment of benthic fauna and epibiota has also been conducted within Port of Tarakohe (Bennett *et al*. 2006).

The dominant habitat in Golden Bay is comprised of relatively shallow subtidal soft substrates with minimal hard substrate available. The common and dominant benthic epifauna assemblage in Golden Bay is typically a mix of deposit-feeding heart urchins (*Echinocardium cordatum*), brittle stars (primarily the rose brittlestar *Amphiura rosea*) and polychaete tubeworms (McKnight 1969, Davidson 1999, Gillespie & Forrest 1999, Ritchie 1999). Larger epifauna can include scallops, mussels and occasional patches of horse mussels (Keeley *et al*. 2003). This common benthic habitat and associated fauna are not considered to be of unusual ecological value in Golden Bay, given their widespread distribution on both a regional and national scale (Gillespie & Forrest 1999). Aside from the area of seabed to the north of Separation Point, which is protected,, regular dredging and trawling by fisheries (mussel farms and scallop fisheries) over a wide area of Golden Bay has resulted in modification of the seabed habitat. This has led to the development of a 'typical' disturbance-tolerant faunal community and an overall reduction in biodiversity (Davidson 1999, Gillespie & Forrest 1999).

3.2. PORT TARAKOHE

Within Port Tarakohe, epibiota is dominated by common hard-substrate invertebrate taxa such as barnacles, oysters, mussels, ascidians and bryozoans (Bennett *et al*. 2006). The red alga *Gelidium* sp. is also conspicuous throughout the port. Benthic infauna is characterised by a patchy distribution of species, which include gastropods, seastars and urchins. Opportunistic polychaete species dominate certain areas of the port, suggestive of moderately compromised environmental conditions that are likely due to factors such as physical disturbance rather than pollution or sediment contamination (Bennett *et al*. 2006).

Bennett *et al.* (2006) conducted a baseline assessment of the benthic infauna and epibiota of Port Tarakohe. Sampling was conducted at four sites within the port (main wharf, boat ramp, pontoon marina and moorings) using benthic cores (130 mm diameter, 100 mm depth) as well as qualitative photographic and fixed-area observations. Infauna sampling showed high variability between sites, with the observed taxonomic groups including sponges, cnidarians, nematodes, molluscs, oligochaetes, polychaetes, crustaceans, bryozoans, echinoids and ascidians (Table 4 includes a detailed list of infaunal taxa recorded in the port).

Table 4: Macroinvertebrate (infauna) species and abundance per core (0.0135 m^2) sampled at four sites in Port Tarakohe, April 2005 (A, B and C represent replicate samples). Reproduced from Bennett *et al*. 2006.

Taxa	Feeding type	Main Wharf			Boat Ramp			Pontoon			Mooring		
		A	B	C	A	B	C	A	B	C	A	B	C
Porifera													
Calcareous sponges	Filter feeder									1			
Cnidaria													
Hydroida (thecate)	Filter feeder									1			
Edwardsia sp.	Filter & deposit feeder								1				
Nematoda		89	8	102		1	1						
Mollusca													
unidentified gastropod		1											
Cominella adspersa	Carnivore & scavenger				1								
Neoguraleus sp.					1								
Turbonilla sp.	Infaunal deposit feeder	1											
Xymene ambiguus		1			1			1	1	2	2		
Arthritica bifurca	Infaunal deposit feeder			10	5	2		3	4		8		2
Bassina yatei													1
Ennucula strangei		1											
Leptomya retiaria retiaria	Infaunal deposit feeder	2	1	1	15	20	6	1					
Macomona liliana	Infaunal suspension feeder			1									
Nucula cf *gallinacea*	Infaunal deposit feeder	14	6	5	18	42	14	9	6	9	13	5	11
Nucula hartvigiana	Infaunal deposit feeder	4	1	2	5	6	2					1	1
Nucula nitidula	Infaunal deposit feeder				2		1		4				
Serratina charlottae	Infaunal suspension feeder	5			15	76	15	15	5	4	11	1	5
Soletellina nitida	Infaunal suspension feeder									1	1		0
Theora lubrica	Infaunal deposit feeder	29	23	9	25	49	46	30	35	28	28	4	19
Oligochaeta	Infaunal deposit feeder	5		3									
Polychaeta													
Heteromastus filiformis	Infaunal deposit feeder	103	31	67	19	42	15	23	16	40	6	15	3
Cossura consimilis	Deposit feeder	148	44	69	26	23	7	4	6	5	5	11	4
Maldanidae	Infaunal deposit feeder				1		1						
Armandia maculata	Infaunal deposit feeder	4				1		1					
Paraonidae	Infaunal deposit feeder	5						2	1				
Dorvilleidae	Facultative carnivore	5								1			
Lumbrineridae	Infaunal carnivore & deposit feeder	1	2	4		3	1				1		

Table 4 continued.

Taxa	Feeding type	Main Wharf			Boat Ramp			Pontoon			Mooring		
		A	B	C	A	B	C	A	B	C	A	B	C
Polychaeta													
Glyceridae Hesionidae	Infaunal carnivore & deposit feeder	2	1	1	1	1	1			1		1	
Aglaophamus macroura	Carnivore and deposit feeder	1	1										
Sigalionidae *Polydora*	Infaunal carnivore Infaunal												1
sp.	carnivore Surface								1				
Prionospio sp.	deposit & filter feeder		4	1	3	10	5			1			
Cirratulidae	Surface deposit feeder	207	125	120	56	25	16	5	20	2	12	6	10
Pectinaria australis	Deposit feeder	1			1								
Crustacea	Infaunal deposit feeder			2				2	1				
Mysidacea													
Cumacea	Filter and deposit feeder	1											
Amphipoda a	Infaunal filter or deposit feeder						1						
Amphipoda b	Epifaunal scavenger	3			12	16	16	1	1	10	21	12	20
Amphipoda c	Epifaunal scavenger	1	1					1	1	1			
Macrophthalmus hirtipes	Epifaunal scavenger	1											
Ostracoda Copepoda	Deposit feeder & scavenger					1		3	1	2	3	2	5
Bryozoa	Omnivorous scavenger				4	5	4	1					
encrusting bryozoan	Epifaunal scavenger	1				4		1	3				
erect bryozoan													
Echinoidea	Filter feeder		1	1									
Echinocardium cordatum	Filter feeder		1										
Ascidiacea													
Asterocarpa cerea	Deposit feeder				1								
Diplosoma listerianum													
	Filter feeder							1					
										1			

Infauna density was highest at the main wharf (250-636 individuals per core) followed by the boat ramp, pontoon marina and mooring sites (152-327, 104-110 and 58-111 individuals per core, respectively). Infauna species richness ranged from 15-26 taxa per core (main wharf, boat ramp and pontoon sites) to 10-12 taxa per core (mooring site). A range of opportunistic polychaete species dominated some sites (in particular *Heteromastus filiformis*, *Prionospio* sp., and *Cossura consimilis*), which are generally characteristic of physically disturbed, organically-enriched sediments. The bivalves *Theora lubrica* and *Nucula* cf. *gallinacean* dominated the boat ramp site.

No epifaunal species of special ecological or conservational value were observed in densities above trigger values identified in the Department of Conservation guidelines (1995). A summary of conspicuous epibiota observed at each site is presented in Table 5. The gastropods *Notoacmea* sp. and *Turbo smaragdus* were abundant at the mooring site, and present in lower numbers at the pontoon and ramp sites. The main wharf was dominated by the presence of barnacles, and the invasive bryozoan *Watersipora subtorquata*. The pilings at the wharf were also encrusted with occasional clumps of mussels, oysters, and sea squirts. The pontoon site contained occasional clumps of bivalves and sea squirts.

Several species of algae were also observed at all sites, and were largely dominated by the red algae *Gelidium* sp. The potentially invasive sea squirt, *Didemnum vexillum*, was not observed at the study sites at the time of the survey. The presence of this species in Port Tarakohe was, however, confirmed in early June 2006 and an eradication attempt was immediately organised (A. Coutts, Cawthron Institute, pers. comm.). *Didemnum vexillum* may still be present at other locations within the port environs (Bennett *et al*. 2006). The current report of *D. vexillum* in Tarakohe is of particular significance as it is in close proximity to the established mussel farms in Wainui Bay, and is also adjacent to the coastal boundaries of the Abel Tasman National Park and Tonga Island Marine Reserve.

3.3. BIOGENIC REEFS

Bryozoan ‘reefs’ have been recorded in an area of seabed offshore from Separation Point (40° 47' S, 173° 00' E; Bradstock & Gordon 1983). Bryozoan beds are known to support assemblages of high species diversity and are considered important areas for juvenile fish (Saxton 1980). This particular area is deemed to be of significant conservational value (Mace 1981). Bryozoans and hydroids were also found in other areas of the bay during dredge transect surveys (Golden Bay Aquaculture 1999), but were considered temporary populations as it was suggested that they would be removed by regular dredging activity in the area.

Bradstock & Gordon (1983) used divers to characterise these bryozoan reefs. The bed covers an area of approximately 75 km^2 at depths between 10-35 m. Two species of encrusting bryozoans (*Celleporaria agglutinans* and *Hippomenella vellicata*) formed the bulk of the structures and provided attachment surfaces for other calcareous frame-building species, including other encrusting bryozoans, serpulid tube worms and the homotrematid foraminifera *Miniiacina miniacea*.

Species of branching bryozoans forming secondary frame components included *Galeopsis grandipora*, *Galeopsis polypora* and *Telopora digitata*. The extensive encrusting bryozoan growths were characterised by elevated faunal diversity, including polychaetes, hydroids, sponges, colonial and solitary ascidians, and bivalve molluscs, gastropods and decapod crustaceans. Numerous commercially important demersal fish species were also observed in the reef area, including snapper *Pagurus auratus*, tarakihi *Cichla macropter*, leatherjacket *Parika scaber*, blue cod *Parapercis colias* and sea perch *Helicolenus papillosus* (Bradstock & Gordon 1983).

3.4. BIVALVES

Bivalve molluscs (scallops *Pecten novaezelandiae*, Greenshell™ mussels *Perna canaliculus*, horse mussels *Atrina zelandica* and oysters), assorted gastropods, hermit crabs and ascidians (sea squirts) have previously been the most conspicuous epifauna over much of Golden Bay (Ritchie 1999). Scallops are consistently present, at times at densities exceeding the Department of Conservation guidelines (1995) for Marlborough Sounds; however, this is likely to be reflective of reseeding efforts of Challenger Scallop Enhancement Company (CSEC).

Handley *et al*. (1999) surveyed the seabed around and in the Ring Road spat catching area near Takaka for scallops, Greenshell™ mussels and juvenile eleven-armed starfish (*Coscinasterias muricata*). The survey goal was to determine whether starfish recruiting to spat-catching equipment and falling to the seabed represented a significant source of mortality to juvenile scallops. Seven sites were surveyed by diver transects, including spat-catching areas, spat-release areas, an unseeded area where no trawling occurs, an area where natural settlement occurs, and a previous spat-release area. Transect lengths ranged from 25-100 m and the area searched ranged from 25-50 m^2.

Coscinasterias muricata were only recorded at one site (a spat-release area) and maximum population densities were 0.4 individuals per m^2 (Handley *et al*. 1999). Not surprisingly, abundances of scallop spat were largest at the spat-release sites, with maximum densities of 3.28 individuals per m^2. Abundances within these sites were spatially variable. Largest abundances of adult (>50 mm) scallops were recorded in the natural settlement and previous spat release areas (up to 0.62 individuals per m^2). Moderate abundances of adults (up to 0.24 individuals per m^2) occurred in the spat-catching site and one of the spat-release sites. Mussel spat were most abundant (up to 0.44 individuals per m^2) in one of the spat-release areas and most were attached to adult mussels. Large numbers of juvenile horse mussels and hermit crabs were found at one of the scallop-release sites and cushion stars were common at the previous spat-release site. Adult horse mussels occurred at the unseeded, untrawled site.

Table 5: Abundance of epibiota observed in the survey of Port Tarakohe in April 2005. r = rare (0-2 individuals), o = occasional (3-5 individuals), c = common (6-10 individuals), a = abundant (>10 individuals) (from Bennett *et al*. 2006).

Taxa	Main Wharf	Pontoon	Boat Ramp	Moorings
	Wharf piles and rock wall	Boulders/rocks/ cobbles/gravel	Boulder beach, fine silt, muddy seabed	Cobble and boulder
Molluscs				
Gastropods				
Notoacmea sp.	r	r	o	a
Turbo smaragdus	-	c	c	a
Maoricolpus roseus	-	-	-	o
Bivalves				
Crassostrea gigas	-	r	-	-
Mytilus galloprovincinalis	c	o	-	-
Perna canaliculus	-	r	o	o
Monia zelandica	a	-	-	c
Chitons				
Acanthochitona zelandica	-	-	o	o
Crustaceans				
Paguridae	-	-	o	-
Palaemon affinis	-	o	-	o
Cirripedia	a	-	-	-
Ascidians				
Cnemidocarpa bicornuata	c	o	-	o
Botrylloides sp.	o	-	-	-
Aplidium sp.		o		
Bryozoans				
Watersipora subtorquata	a	-	-	-
Bugula sp.	o	o	-	-
Echinoids				
Patiriella regularis	-	o	c	r
Evechinus chloroticus	-	-	o	o
Polychaetes				
Galeolaria hystrix	o	c	c	a
Spirorbidae	-	-	-	o
Fish				
Forsterygion sp.	o	c	c	a
Algae				
Colpomenia sinuosa	r	-	-	-
Coralliniaceae	-	-	c	a
Laurencia thyrsifera	r	-	-	-
Ceramium apiculatum	r	-	-	-
Undaria pinnatifida	-	a	-	-
Anotrichium sp. c.f *Sargussum sinclairii*[1]	-	r	-	-
Carpophyllum maschalocarpum	r	-	-	-
Ulva lactuca	r	-	-	-
Polysiphonia sp.	-	a	-	-
Codium fragile	-	o	-	-
Gelidium sp.	a	a	a	a

[1]Note: It is unclear which algal genus *(Anotrichium* or *Sargassum)* is meant to be recorded here; the table is reproduced directly from Bennet *et al*. 2006.

3.5. SOUTHERN SUBTIDAL HABITATS

Grange & Cole (1999) surveyed the seabed within and adjacent to the Ring-Road mussel and scallop spat-catching areas near Takaka using a video camera mounted on a benthic sled. Four tows, each 3-5 km long, ran through the area perpendicular to the shore between the 10 m and 20 m depth contours. The conspicuous species recorded included sponges, gastropods (*Austrofusus glans*, *Maoricolpus roseus* and *Struthiolaria papulosa*), horse mussels, scallops, Greenshell™ mussels, hermit crabs (*Pagurus* sp.), heart urchins (*Echinocardium cordatum*), cushion stars (*Patiriella regularis*) and sea squirts (*Cnemidocarpa bicornuta*). Red algae were present in one tow, although these may have fallen from the spat-catching lines above. Various fish were also recorded, namely carpet sharks (*Cephaloscyllium isabellum*), spiny dogfish (*Squalus acanthias*) and sand-diver fish (*Tewara cranwellae*). Scallops were the dominant conspicuous organisms and were present in all four tows at mean densities per tow of 0.33-1.62 individuals (maximum recorded abundances were approximately 7 individuals per m^2). In general, however, Grange & Cole (1999) described large, conspicuous taxa (other than clumps of mussels) as rare and attributed this to the soft-sediment habitat and the frequency of trawling and dredging in the area.

During a survey carried out at offshore sites ~4 km north-east of Collingwood, a total of 32 species of surface-living invertebrates were recorded by divers (Grange 1998). The species assemblage was described as typical of soft sediment habitats in Tasman and Golden Bays. Notable species encountered were native sabellid tubeworm mounds and the side- gilled slug *Pleurobranchaea*. The slug was common at all sites. Clumps of Greenshell™ mussels were common beneath and inshore of mussel farms in the area, and horse mussels were recorded at all sites.

Subsequent studies surveying locations nearby to that of Grange (1998) have further characterised the infauna and epifauna of the area (Davey *et al*. 2004, Morrisey *et al*. 2005a, b, Brown *et al*. 2002, Grange et al. 2001, Morrisey et al. 2005c, d, Gillespie & MacKenzie 1999). The infauna is dominated numerically by polychaete worms, scaphopod, gastropod and bivalve molluscs, various types of crustaceans, brachiopods (lampshells, namely *Magasella sanguinea* and *Waltonia inconspicua*), rose brittle stars, cushion stars and the heart urchin. Several of these taxa live at the sediment-water interface and feature in both infaunal and epifaunal samples.

The dominant families among the polychaetes were Chaetopteridae, Glyceridae, Lumbrineridae, Nephtyidae, Onuphidae, Orbiniidae, Polynoidae, Serpulidae (living on hard substrata such as bivalve shells), Sigalionidae and Trichobranchidae. The most abundant gastropods were *Amalda mucronata, A. glans* and *S. papulosa,* and for the bivalves *Dosinia lambata, Neilo australis, Nucula nitidula, P. novaezelandiae, Tellina edgari* and *Theora lubrica.*

Dominant crustaceans included amphipods (not identified beyond Order), hermit crabs, the stalk-eyed crab *Macrophthalmus hirtipes*, and an unidentified tanaid. Most of these taxa were dominant members of the fauna sampled both by dredge (Brown et al. 2002, Grange *et al*. 2001, Gillespie & MacKenzie 1999) and by crab (Morrisey et al. 2005d, Davey *et al*. 2004). Exceptions were scallops, which are not likely to be sampled effectively by the grab, lampshells, which were patchily distributed and may therefore have been under- sampled by the grab, and tanaids, which are often temporally patchy in distribution. Benthic algae were more or less absent from the area. None of the taxa collected can be considered vulnerable or under stress, nor are any unwanted or invasive (as far as the level of taxonomic discrimination allows).

3.6. INTERTIDAL HABITATS OF FAREWELL SPIT

Battley *et al*. (2005) conducted an extensive survey of the intertidal benthic fauna of Farewell Spit. A total of 192 sites were sampled along the tidal flats using benthic cores (100 mm diameter) to a maximum depth of 250 mm. The distribution and coverage of the seagrass *Zostera muelleri* was also estimated at each sampling site using 0.25 m^2 quadrates and counting percent cover. A total of 91 taxa were recorded in the area (Table 6). Six taxa dominated the samples numerically that accounted for ~70% of all individuals recorded: cockles *Austrovenus stutchburyii,* spionid polychaetes; pipis *Paphies australis,* amphipods, the modest barnacle *Austrominius modestus* and isopods.

Most taxa were quite widely distributed and there was evidence of an increase in species diversity with increasing *Zostera* cover. There was some evidence that numbers of shorebirds at high tide roosts may be related to the amount of potential prey present in adjacent intertidal areas. Sampling was done at a time when shorebird numbers are at an annual maximum, and thus prey stocks may have been depleted.

Table 6: Taxa or taxonomic groups recorded during a survey of Farewell Spit in March 2003. Taxonomic levels used vary between species groups, with molluscs identified to species or genus level, polychaetes and small crustaceans to family level. (Reproduced from Battley *et al*. 2005.)

Phylum	Class	Order or Family	Species
Cnidaria	Anthozoa	Actinaria	*Anthopleura aureorodiata*
			Edwardsia tricolor
Nemertea			nemertean/proboscis worn
Annelida	Polychaeta	Ampharetidae	
		Amphinomidae	
		Arenicolidae	*Abarenicolo assimilis*
		Capitellidae	*Capitella capitata*
			Heteromastus filiformis
		Cirratulidae	
		Glyceridae	*Hemipodus* sp.
		Lumbrineridae	
		Magelonidae	*Magelona* sp.
		Maldanidae	*Axiothella quadrimuculata*
			Clymenella sp.
			Macroclymene sp.
		Nephtyidae	*Aglaophamus* sp.
			Nephtys sp.
		Nereididae	rag worms
		Opheliidae	*Armandia maculata*
			Ophelia sp.
		Orbiniidae	*Orbinia papillosa*
		Oweniidae	*Owenia fusiformis*
		Paraonidae	
		Pectinariidae	*Pectinaria australis*
		Phyllodocidae	paddle worm
		Sabellidae	peacock worm
		Scalibregmatidae	*Travisia olens*
			unidentified species
		Serpulidae	*Pomatoceros caeruleus*
		Spionidae	*Aonides* sp.
			Laonice sp.
			Polydora / Baccardia sp.
			Prionospio sp.
			Scolecolepides benhami
		Syllidae	
		Terebellidae	
Mollusca	Bivalvia	Galeommatidae	*Divariscintilla maori*
		Lasaeidae	*Arthritica bifurca*
		Lucinidae	*Divaricella huttoniana*
		Mactridae	*Mactra discors*
			Zenatia acinaces
		Mesodesmatidae	*Amphidesma subtriangulatum*
			Paphies australis
		Mytilidae	*Perna canaliculus*
			Xenostrobus pulex
		Nuculidae	*Nucula hartvigiana*
		Psammobiidae	*Soletellina nitida*
		Solemyidae	*Solemya parkinsonii*
		Tellinidae	*Macomona liliana*
		Veneridae	*Austrovenus stutchburyii*
			Tawera spissa
			Venerupis largillerti
	Gastropoda	Amphibolidae	*Amphibola crenata*
		Batillariidae	*Zeacumantus lutulensis*

Table 6 continued.

Phylum	Class	Order or Family	Species
Mollusca	Gastropoda	Batillariidae	*Zeacumantus subcarinatus*
		Buccinidae	*Cominella adspersa*
			Cominella glandiformis
		Eatoniellidae	*Eatoniella* cf *lambata*
		Haminoeidae	*Haminoea zelandiae*
		Littorinidae	*Risellopsis varia*
		Lottiidae	*Notoacmea helmsi*
		Muricidae	*Xymene* sp.
		Olividae	*Amalda* sp.
		Pyramidellidae	*Turbonilla* sp.
		Rissoidae	*Rissoina* sp.
		Trochidae	*Dioloma bicanaliculata*
			Diloma zeylandica
			Micrelenchus tenebrosus
		Turbinidae	*Turbo smaragdus*
	Polyplacophora	Acanthochitonidae	*Acanthochiton zelandicus*
		Chitonidae	*Chiton glaucus*
Arthropods	Maxillopoda	Cirripedia, Balanidae	*Elminius modestus*
	Maxillipoda	Copepoda	
	Ostracada		mussel shrimp
	Malacostraca	Amphipoda	sand hopper
		Caprellidae	skeleton shrimp
		Insecta	
		Isopoda	
		Flabellifera	*Isocladus spicatus*
		Valvifera	*Euidotea*
		Lophogastrida (Mysidacea)	opossum shrimp
		Stomatopoda	*Lyiosquillo spinosa*
		Squillidae	*Squilla armata*
		Decapoda	
		Callianassidae	*Callianassa filholi*
		Crangonidae	*Pontophilus cf australis*
		Grapsidae	*Cyclograpsus lavauxi*
			Helice crassa
		Hymenosomatidae	*Hemigrapsus crenulatus*
		Ocypodidae	*Halicarcinus cookii*
			Halicarcinus whitei
		Pinotheridae	*Macrophthalmus hirtipes*
			Pinotheres novaezeelandiae
	Insecta	Diptera	
		Empipidae	dance fly
		Ephydridae	*Neoscatella* sp.
		Tipulidae	*Hexatomini* sp.
		Trichoptera	
		Chathamiidae	*Philanisus plebeius*
Echinodemata	Echinoidea		*Fellosrer zelandiae*
	Holothuroidea	Apodida	*Trochidoto dendyi*
	Stelleroidea	Asteroidea	*Coscinasterias calamaria*
			Patiriella regularis
		Ophiuroidea	

4. Survey Methods

4.1. SAMPLING DESIGN AND METHODS

The survey design was provided by Ministry of Agriculture and Forestry – Biosecurity New Zealand (MAFBNZ) and developed using the protocols of the Centre for Research on Introduced Marine Pests (CRIMP) (Hewitt & Martin 1996, 2001) with the aim of maximising the detection of non-indigenous species. Site selection concentrated on habitats and sites within the port and adjacent areas that were near the point of inoculation, or were most likely to have been influenced by ballast water discharge, mariculture, and hull fouling transfers (including fishing and recreational vessels).

Sampling methods were selected to ensure comprehensive coverage of habitats and were intended to provide presence/absence information or semi-quantitative indices of abundance only. Typically, non-indigenous species are rare (at least initially), having both limited distribution and abundance. Thus, to detect a rare species, sampling concentrated on maximising coverage within a site with minimal sampling replication. Replicate sampling was only undertaken in situations where small-scale heterogeneity was likely to influence detection of non-indigenous species, such as dinoflagellates.

The survey was conducted from 24 to 30 September 2006. The sampling strategy used for the Golden Bay marine biosecurity survey relied on the detection thresholds determined for non-indigenous species in Australia (see Hewitt & Martin 2001). Hewitt & Martin (2001) cite the previous work of Green & Young (1993), which indicates approximately 13 samples are required in a given location to detect a rare species (i.e., species with a mean Poisson density of 0.1 individuals per sample unit) at a 95% probability. Hence, the sampling strategy used for Stewart Island was based on a suggested minimum sample size of at least seven sites to detect rare species.

Sampling targeted three regions including:

- Potential inoculation sites within the port;
- The adjacent area; and
- Port approaches.

4.1.2. Sampling methods

Visual surveys, pile scraping and coring were undertaken by scuba divers; trapping and plankton sampling were carried out from the research vessel. Photographic records were taken where visibility was adequate. Areas specifically targeted included shipping berths, anchorage areas, the shipping approach channels, and other potential sink areas where non-indigenous species may be deposited due to currents and geographic position. The distribution of sampling sites visited during the survey is illustrated in Figure 4.

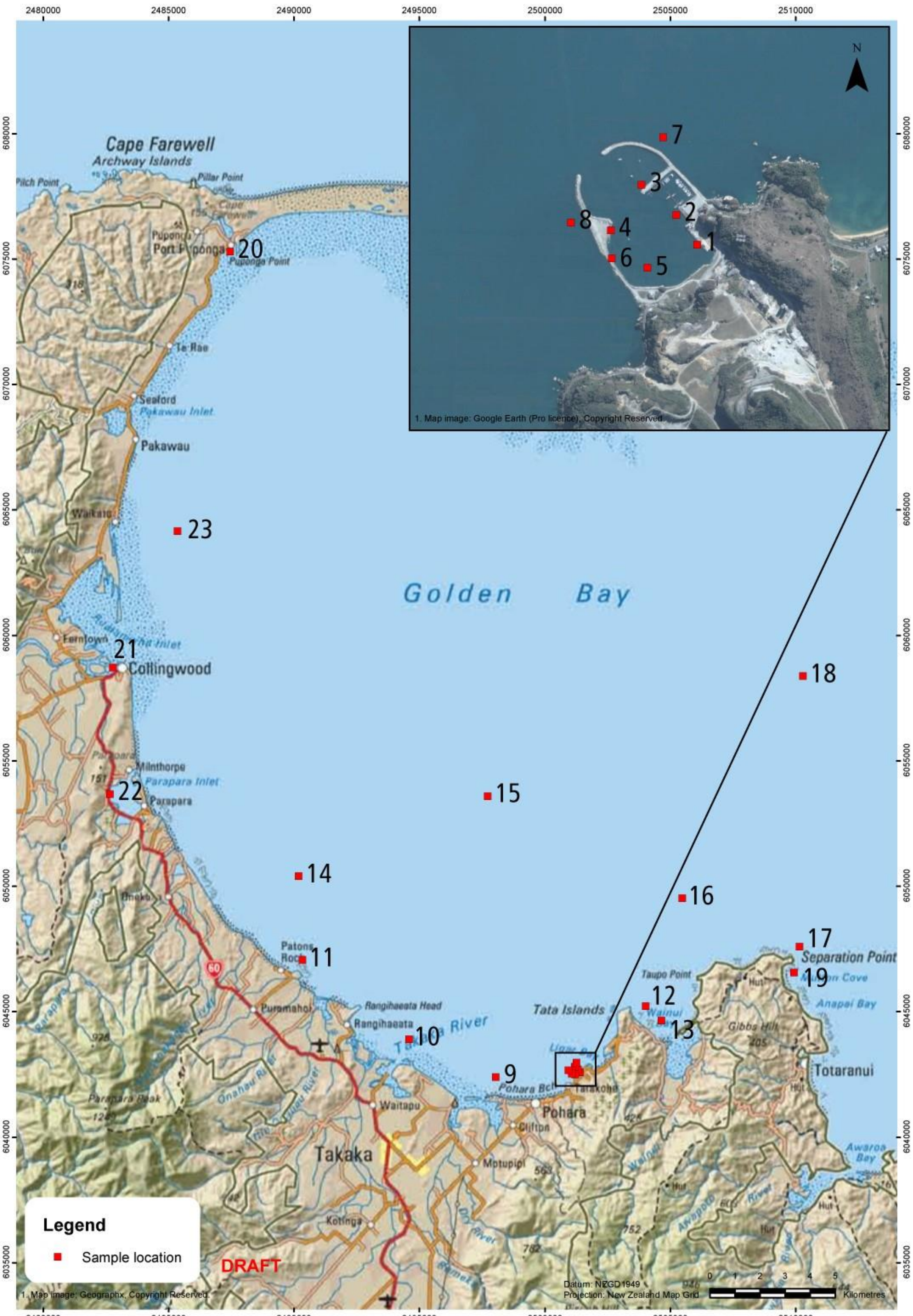

Figure 4: Distribution of sampling locations (numbers indicate site name; listed in Table 8 and Appendix A) during the Golden Bay Port Survey November 2007.

Sampling methods used during the survey included:

- Pile scraping.
- Poison stations.
- Qualitative visual surveys.
- Benthic coring (large cores).
- Dinoflagellate cyst sampling (small cores).
- Plankton netting (phyto- and zooplankton).
- Trapping (crab and shrimp traps).
- Beach seining.
- Beach wrack searches.
- Collection of photographs and video footage (where visibility allowed).

Pile scraping

Fouling assemblages on wharf pilings and other hard substrates (i.e., channel markers) were collected by pile scraping. Quantitative samples were removed from 0.1 m^2 (32 cm x 32 cm quadrats; Figure 5) using plastic scrapers. A series of piles were selected along the wharf from which samples were collected. Where depths were greater than 7 m, three samples were collected from four piles at 0.5 m, 3.0 m and 7.0 m below the mean low water (MLW) level. Where depths were less than 7 m, two samples were collected from eight piles at 0.5 m and 3.0 m below MLW. Where depths were much less than 3 m or the hard surface was not large enough to appropriately sample using quadrats (i.e., chain-link channel markers, narrow struts on small wharves), qualitative visual surveys were undertaken as an alternative sampling method.

Prior to scraping, still photographs were taken of each quadrat (where visibility allowed). Scraped samples were collected in a 1 mm mesh collection bag or large plastic bag, returned to the research vessel and rough-sorted prior to preservation according to protocols provided by the Marine Invasives Taxonomic Service (MITS).

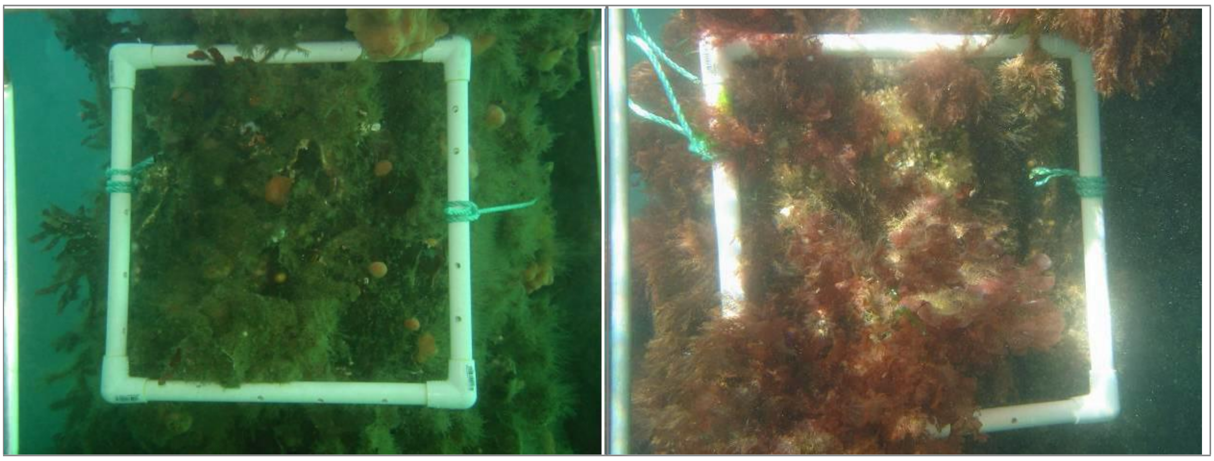

Figure 5: *In situ* photographs of quadrats sampled using the pile scraping method.

Poison stations

An emulsion of seawater, clove oil and a small amount of ethanol was used to sample fish found near breakwaters and around the base of piles and facings. The solution was dispensed by divers from a plastic bottle and the affected organisms were collected using hand nets (Figure 6). Specimens were handled according to MITS protocols.

Figure 6: Diver preparing to deploy clove oil emulsion at a 'poison station'.

Qualitative visual searches

Qualitative visual searches were undertaken by scuba divers for non-indigenous species and other marine organism that appeared to be unusual or rare, or had not been collected by other sampling methods. Divers swam along the length of the wharf, seawall or structure and examined the vertical extend of wharf piles, channel markers or other submerged hard substrates. Visual searches were conducted for at least 30 minutes but were extended relative to the size of the area to be examined. Photographic records were taken where appropriate and when visibility allowed. Samples and specimens were processed according to MITS protocols.

Benthic coring

Benthic infauna were collected by scuba divers using a specifically designed and manufactured aluminium 0.025 m^2 corer devised to sample soft-sediments ranging from fine mud and sand to hard-packed clay and small cobbles. The corer was 180 mm in diameter and 400 mm in length, with marked grooves at 200 mm and 250 mm from the bottom to indicate the appropriate sampling depth (Figure 7). The top of the corer had an aperture (80 mm diameter) that was sealed with a rubber bung after insertion into the substrate, to aide in the retention of the sample when the corer was withdrawn from the sediment.

Samples were transferred underwater to purpose-made, drawstring bags then relayed to the surface. On board the research vessel each sample was sieved through 5 mm graded sieves and stored in sample bags or jars according to MITS protocols.

When sampling sites were located in the vicinity of wharves and boat ramps, three replicate cores were collected within 2 m of the wharf piles or ramp and a further three cores collected at a distance of 50 m from the structure. At sites without berthing or other such structures, three replicate cores were collected in the vicinity of the selected sampling location.

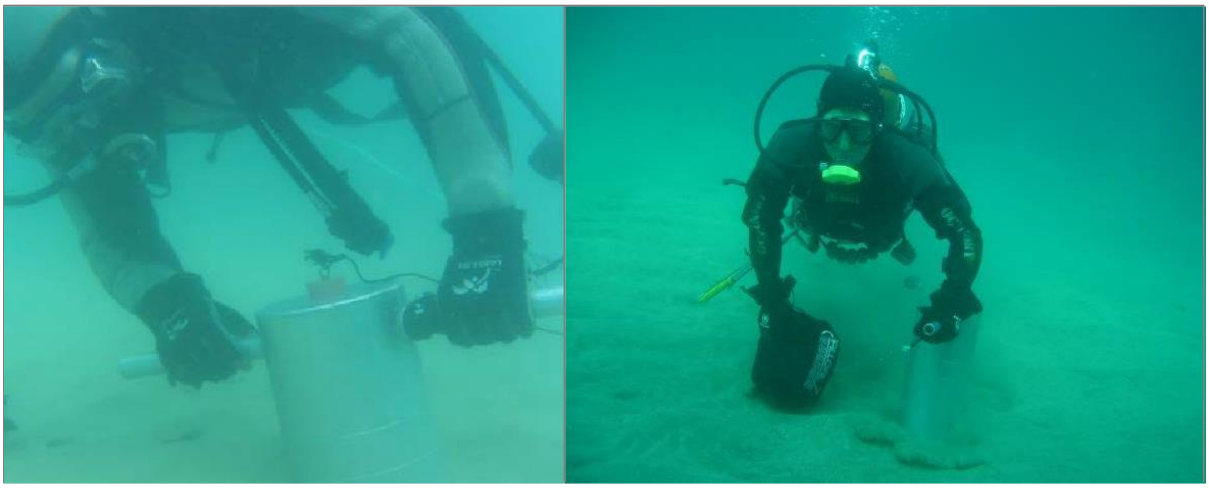

Figure 7: Divers deploying the infaunal core; the contents of each core was emptied into a nylon bag *in situ* (black bag in divers hand; right).

Dinoflagellate cyst sampling

Small diver deployed push tubes were used to collect small sediment cores for dinoflagellate cysts. On retrieval from the sediment the tube was capped with a rubber bung and transported to the laboratory for analysis according to MITS protocols.

Plankton netting

Phytoplankton samples were collected by vertical drops of a hand-deployed plankton net (20 µm mesh, 250 mm diameter aperture) (Figure 8, left). Zooplankton samples were collected by vertical drops of a hand-deployed zooplankton net (100 µm mesh, 700 mm diameter aperture) (Figure 8, right). The nets were weighted with lead to ensure the vertical direction was maintained in strong currents. The nets were released to within 1 m of the seafloor. Three replicate samples were collected using each net (i.e., three samples each for phytoplankton and zooplankton) and retained in plastic sampling jars. Samples were stored as required by MITS protocols.

Figure 8: Field staff retrieving a plankton sample from a small net for phytoplankton (left) and a larger net for zooplankton (right).

Trapping

Mobile epibenthos such as benthic scavengers (crabs and seastars) and fishes were sampled using two types of baited traps. Opera house traps (Figure 9) were used to collect large organisms such as paddle crabs and fish. These oval-shaped collapsible traps were 640 mm x 470 mm and 200 mm in height, with a mesh size of 20 mm. The entrance funnel of the trap was circular with a diameter of 90 mm. Collapsible shrimp (or minnow) traps were used to collect small and juvenile crustaceans and other taxa. These traps were 450 mm x 250 mm and 250 mm in height, with a mesh size of approximately 5 mm.

Traps were attached to leadline and a marker buoy attached to one end. Trap lines were comprised of three opera house traps and two shrimp traps. Traps were baited with frozen pilchards (*Sardinops neopilchardus*) and fresh fish offal (when available from local fishermen), which was contained in mesh bags suspended in the centre of the trap. Trap lines were deployed parallel to the dominant current flow (where possible) and left overnight (~12 hrs) before retrieval.

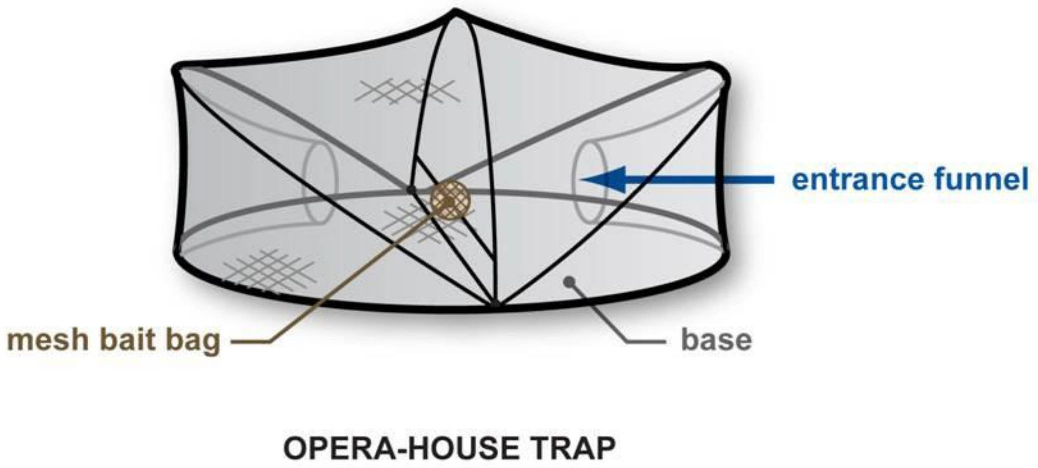

Figure 9: Diagram of an opera house crab trap.

Beach seining

A beach seine was used to sample nearshore fish over sandy and muddy substrates on beaches and in estuaries. A 25 m seine with 15 mm mesh was hauled for approximately 5 m parallel to the shoreline (Figure 10, left). All species of fish and invertebrate collected in the seine nets were recorded and representative samples of each species was retained and stored according to MITS protocols.

Beach wrack

Qualitative searches of beach wrack were made along the shoreline in the region between the low and high tide marks (e.g., Figure 10). Items that were searched for included crab exuviae, sponges and remnants of unusual or rare species.

Sediment texture sampling

Sediment samples (~100 g wet weight) were collected for each site (where soft sediments occurred) for analysis of particle size and organic content. Samples were collected to a depth of 500 mm into the sediment using sealable plastic sample containers of 150 mm x 80 mm and 500 mm in height. Sediments were transferred to double-bagged plastic sampling bags and frozen or keep on ice for transport to the analytical laboratory. Handling errors during shipment resulted in the loss of some sediments. Samples of less than 100g wet weight were analysed by a Mastersizer 2000 laser particle size analyser at the laboratory; those of >100 g were dried for marine textures of gravel (> 2m), sand (< 2mm to > 0.63 mm) and mud (< 0.063 mm) and for total organic carbon content (g/100 g).

Figure 10: Beach seining and beach wrack searches on the nearshore.

Environmental data collection

A submersible data logger (SDL) was used to measure water temperature, salinity (or conductivity), and dissolved oxygen at the water's surface, at mid-depths (< 5m) and/or the seafloor. Water clarity (visibility) was estimated using a secchi disk. Air temperature, wind speed and direction were recorded from local weather reports, and sea state, tidal height and extent of cloud cover were recorded based on fieldworkers' observations. The maximum depth at each site was recorded using the research vessels depth sounder or a scuba divers depth gauge. This information was recorded on boat data sheets at each site.

Sample handling

All samples were labelled and processed according to protocols prescribed by the Marine Invasives Taxonomic Service (MITS) (NIWA 2006) and chain of custody forms were maintained throughout the process of collection, sorting, preservation and taxonomic identification.

4.2. TAXONOMIC IDENTIFICATION

Rough-sorting and preservation of specimens occurred soon (~12 hr) after sampling as prescribed by the Marine Invasives Taxonomic Service (MITS) protocols (NIWA 2006). The samples were then transferred to MITS for taxonomic identification of specimens. MITS is a taxonomic identification service provided to MAFBNZ by the National Institute of Water and Atmospheric Research (NIWA) and draws on taxonomic expertise within NIWA and around the world.

Taxonomic data was cross-referenced with a number of different web-based databases such as the Integrated Taxonomic Information System (ITIS), World Porifera Database, Australian Faunal Directory, Algaebase, and the National Introduced Marine Pest Information System (NIMPIS). Biological and distribution information for the non-indigenous species collected during the Port of Onehunga survey is presented in Appendix B.

Species rarity was expressed relative to the site occupancy of all taxa as the inclusion of higher taxa would skew the data distribution toward higher site occupancy.

Species rarity was defined as follows:

- Rare – species occurring at fewer sites than occupied by 25% of all taxa (i.e., less than the lower quartile).
- Occasional – species occurring at the same number of sites occupied by 25% percent of all taxa, but fewer sites than occupied by 50% of all taxa (i.e., from the lower quartile up to and including the median).
- Common – species occurring at the same number of sites similar or greater than the median, and no greater than was occupied by 75% of all taxa (i.e., from the median up to and including the upper quartile).
- Abundant – species occurring at more sites than occupied by 75% of all taxa (i.e., greater than the upper quartile).

4.3. CRITERIA FOR DETERMINATION OF SPECIES AND BIOSECURITY STATUS

Carlton (1996) commented that the classical view of species' origins meant that native species comprised indigenous or endemic taxa and included prehistoric invasions, whereas exotic species comprised historical invasions including both natural range extensions and human-mediated introductions. Carlton (1996) also observed that the default to this view was to classify species without any obvious record of introduction as native.

For the purpose of determining the status of species collected during this survey, the following criteria were used to determine whether a species is non-indigenous or native. These criteria were amended by Cranfield *et al*. (1998) from Chapman & Carlton (1991) and were largely based on historical information of a species' native range and range extension.

- Has the species appeared locally where it has not been found before?
- Has the species spread subsequently?
- Is the species distribution associated with human mechanisms of dispersal?
- Is the species associated with, or dependent on, other non-indigenous species?
- Is the species prevalent in or restricted to, new or artificial environments?
- Is the species distribution restricted compared to natives?
- Does the species have a disjunctive worldwide distribution?
- Are dispersal mechanisms of the species inadequate to reach New Zealand, and is passive dispersal in ocean currents unlikely to bridge ocean gaps to reach New Zealand?
- Is the species isolated from the genetically and morphologically most similar species elsewhere in the world?

There are, however, species that cannot be assigned to either category owing to a lack of adequate data to reliably determine their native range. Such species have been called 'cryptogenic' to reflect their unknown origin (i.e., *crypt*- Greek, kryptos, secret; -*genic*, New Latin, genic, origin; Carlton 1996). Species are, therefore, assigned to three categories and six sub-categories to better reflect the available information on which species and biosecurity status were determined (Table 7).

Table 7: Species and biosecurity status (adapted from Inglis *et al*. 2006a-m).

Species status	Biosecurity status	Explanation
Non-indigenous	Known introduced	Non-indigenous species already established in New Zealand.
	Unknown introduced	Non-indigenous species not previously recorded in New Zealand.
Cryptogenic	Cryptogenic Category 1	Species established in New Zealand, whose identity as native or non-indigenous is ambiguous owing to a cosmopolitan distribution or unknown native distribution. This class also includes newly described species that exhibit invasive behaviours, but for which there are no known records outside of New Zealand.
	Cryptogenic Category 2	New or undescribed species for which there is insufficient taxonomic or biogeographical information to determine whether New Zealand is within their indigenous range.
Indigenous	Native	Species whose indigenous range includes, but is not confined to New Zealand.
	Endemic	Species whose indigenous range is confined to New Zealand.

4.4. PUBLIC AWARENESS PROGRAMME

Prior to undertaking the survey, a programme was designed to inform the general public and stakeholders (notably regulatory agencies) of the nature and goals of MAFBNZs port survey of the Tarakohe and Golden Bay area. The following organisations were contacted as part of this programme:

1. Ministry of Fisheries – notification of sampling under the conditions of a Special Permit.
2. Department of Conservation – discussion with staff at the Nelson–Marlborough Conservancy office staff of the programme; notification provided that there was to be no sampling within the Tonga Island Marine Reserve or disturbance to birdlife at Farewell Spit.
3. Port of Tarakohe harbourmaster – preliminary notification of activities within Tarakohe Harbour.
4. Informal discussions with local residents.

An attempt was also made to publish a notice within the Golden Bay Weekly community newspaper. Unfortunately the late timing in informing the newspaper of this survey resulted in missing the publication deadline.

5. Survey Results

5.1. PORT ENVIRONMENT

Environmental data collected during the Golden Bay port survey included spot measurements of water temperature, salinity, dissolved oxygen, substrate type, visibility and maximum depth at each site. This information is summarised in Table 8.

Water temperatures ranged between 14.2 to 19.6°C. There was no distinct stratification between sea surface temperatures and water temperatures closer to the seafloor, which generally differed by approximately 0.5°C (Figure 11).

Salinity ranged from 21.2 to 37.2 parts per thousand (ppt) with an average of 35 ppt (Figure 12). The lowest reading of 21.2 ppt appears to be an outlier that was recorded from very shallow water near the Parapara Inlet jetty, which is possibly influenced by a relatively higher input of freshwater runoff. There was no distinct stratification between surface and bottom salinity measurements, although salinity was often slightly higher (in the order of 0.1 ppt) closer to the seafloor.

Dissolved oxygen ranged from 10.35 to 12.76 mg/L, with an average of 11.72 mg/L (Figure 13). Dissolved oxygen was slightly higher at Sites 12 to 19, which were located in the vicinity of Separation Point coastline. Relatively low dissolved oxygen was recorded at Sites 5 and 6 in Tarakohe Harbour and Sites 20 and 22 at Farewell Spit and the Parapara Inlet jetty respectively. Using a nomograph of oxygen solubility in seawater (e.g., Gilbert *et al.* 1967), the expected range of dissolved oxygen for the temperatures and salinities recorded during the survey is between 7.2 and 8.9 mg/L. These higher values recorded during the survey thus raise concerns over the validity of the readings from this water quality meter.

Seafloor sediments were analysed for total organic carbon (TOC) content and fractions of mud (<63 µm), sand (63 µm – 2 mm) and gravel (>2 mm) (Figure 14). Sediments with the highest TOC content occurred at Sites 3 and 21, which were located in Tarakohe Harbour and at the Collingwood boat ramp and moorings, respectively. Sites 14 to 16 (which were further offshore in Golden Bay) and Site 18 (located at Separation Point) also had relatively high TOC content, which was likely due to the high abundance of large, erect bryozoans colonising the seafloor in this region (Bradstock & Gordon 1983). These sites also had relatively high proportions of muddy sediments in comparison to other sites within the harbour (Sites 1-7) and in proximity to river mouths and inlets, Patons Rock and elsewhere along the Golden Bay coastline (Sites 13, 9, 11 and 20) where sand was the dominant sediment type.

Table 8: Physical data (water temperature, salinity, dissolved oxygen, visibility, maximum water depth and substrate type) recorded during the Golden Bay Non-Indigenous Species Port Survey, November 2007.

Site No.	Site Name	Temperature (°C)		Salinity (ppt)		Dissolved Oxygen (mg/L)		Visibility (% of Depth)	Total Depth (m)	Substrate Type
		Surface	**Bottom**	**Surface**	**Bottom**	**Surface**	**Bottom**			
1	Tarakohe Harbour 1	17.8	17.4	36.9	37.0	10.66	10.69	35	5.7	boulders, mud
2	Tarakohe Harbour 2	17.8	17.4	36.9	37.0	10.66	10.69	44	4.5	mud
3	Tarakohe Harbour 3	15.8	15.9	36.5	36.7	12.01	11.69	39	5.6	mud
4	Tarakohe Harbour 4	15.8	15.9	36.5	36.7	12.01	11.69	39	5.6	mud
5	Tarakohe Harbour 5	17.8	17.4	36.9	37.0	10.66	10.69	53	3.8	boulders, mud
6	Tarakohe Harbour ramp	17.8	17.7	37.1	37.1	10.85	11.70	100	1.5	large boulders
7	Tarakohe Harbour breakwall east	15.8	15.5	37.2	37.1	11.88	11.82	92	6.4	rockwall
8	Tarakohe Harbour breakwall west	15.9	15.5	37.0	37.1	11.34	11.82	98	6.0	mud
9	Motupipi River	15.6	15.6	37.1	37.1	12.18	11.96	100	4.6	sand
10	Takaka River	16.6	(too shallow)	32.2	(too shallow)	11.09	(too shallow)	100	1.5	sand
11	Patons Rock	17.8	17.4	31.9	32.5	11.82	11.67	100	2.1	rocks, sand
12	Wainui Bay	15.6	15.6	36.4	37.0	12.45	12.21	46	10.6	mud under farm
13	Wainui Inlet	15.7	15.7	37.0	37.1	12.43	11.96	100	3.3	sand
14	Golden Bay 1	16.2	16.1	37.1	37.2	12.61	12.59	53	14.8	-
15	Golden Bay 2	14.2	13.9	37.0	37.2	12.04	11.92	13	25	mud
16	Golden Bay 3	14.9	14.9	37.1	37.1	12.34	12.47	27	26	mud, shell
17	Separation Point 1	15.2	15.2	36.9	37.0	12.59	12.24	26	18	mud, shell
18	Separation Point 2	15.0	15.1	36.9	36.8	12.76	12.55	15	21	mud, shell/sand
19	Separation Point 3	15.4	15.4	36.1	36.6	12.71	12.41	33	15	mud, shell
20	Farewell Spit	15.0	15.0	37.0	37.0	10.35	10.35	100	2	rock, sand
21	Collingwood boatramp	16.5	(too shallow)	37.8	(too shallow)	11.63	(too shallow)	100	<1 m	mud, gravel, pebbles
22	Parapara Inlet jetty	19.6	(too shallow)	21.2	(too shallow)	10.4	(too shallow)	100	<1 m	rocks, pebbles, mud
23	Collingwood mussel farms	15.7	15.0	36.9	36.9	11.72	11.32	56	12.8	mud
	Average	**16.4**	**16.1**	**35.4**	**36.7**	**11.73**	**11.72**	**64**	**10.08**	
	Minimum	**14.2**	**14.9**	**21.2**	**32.5**	**10.35**	**10.35**	**13**	**1.5**	
	Maximum	**19.6**	**17.7**	**37.2**	**37.2**	**12.76**	**12.59**	**100**	**26**	

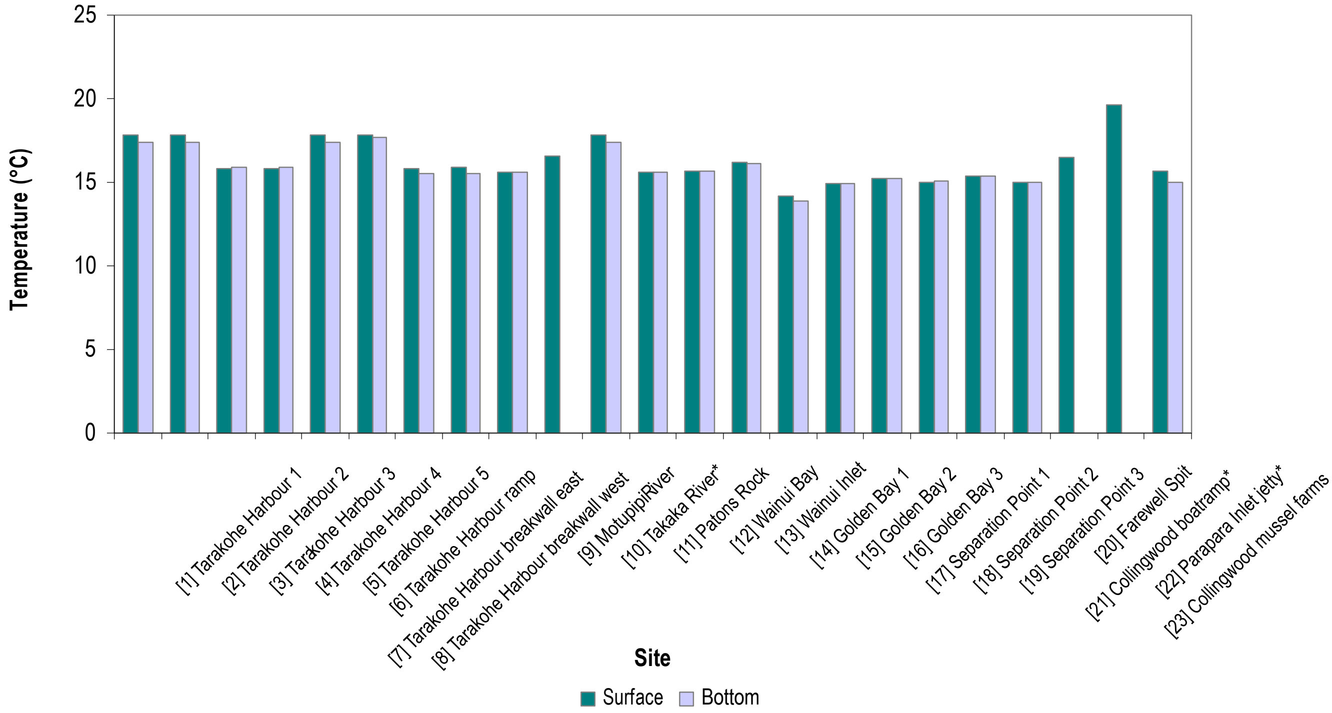

Figure 11: Water temperature recorded during the Golden Bay Port Survey November 2007. Dark shading denotes sea surface readings and light shading denotes readings taken near the sea floor. * indicates sites that were too shallow to take two readings.

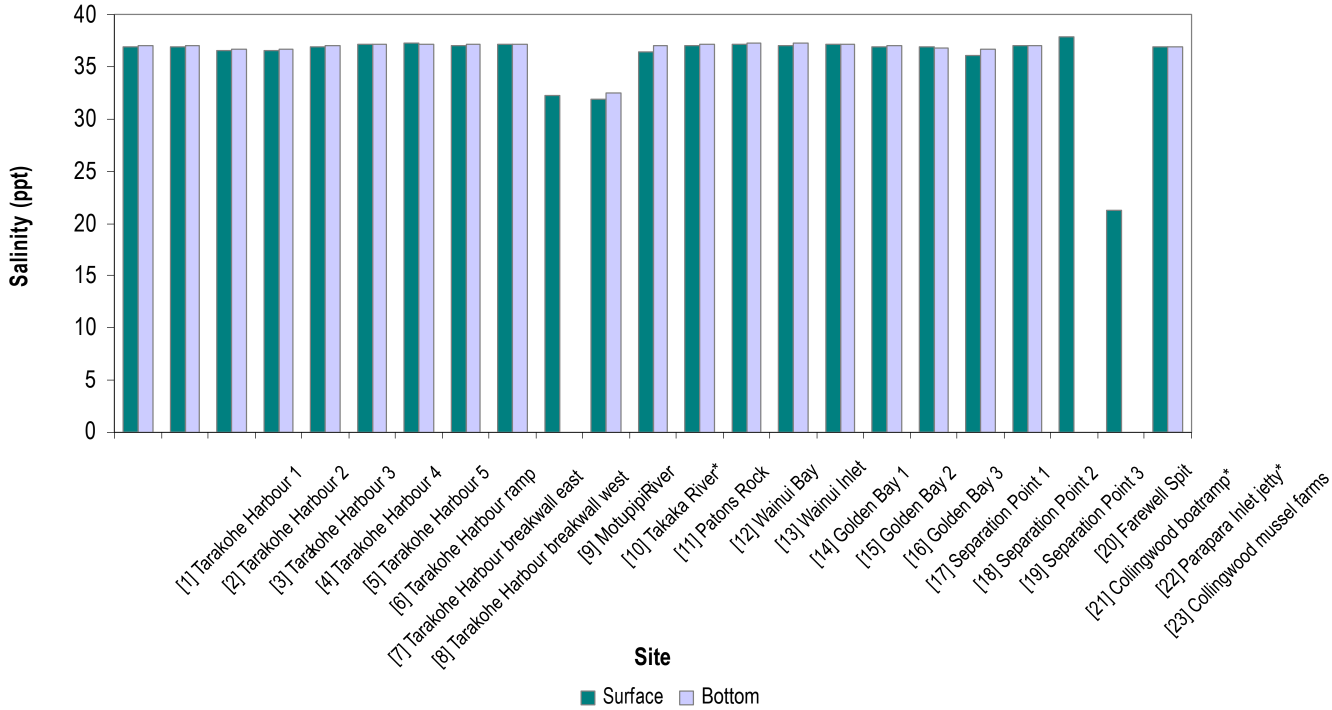

Figure 12: Salinity recorded during the Golden Bay Port Survey November 2007. Dark shading denotes sea surface readings and light shading denotes readings taken near the sea floor. * indicates sites that were too shallow to take two readings.

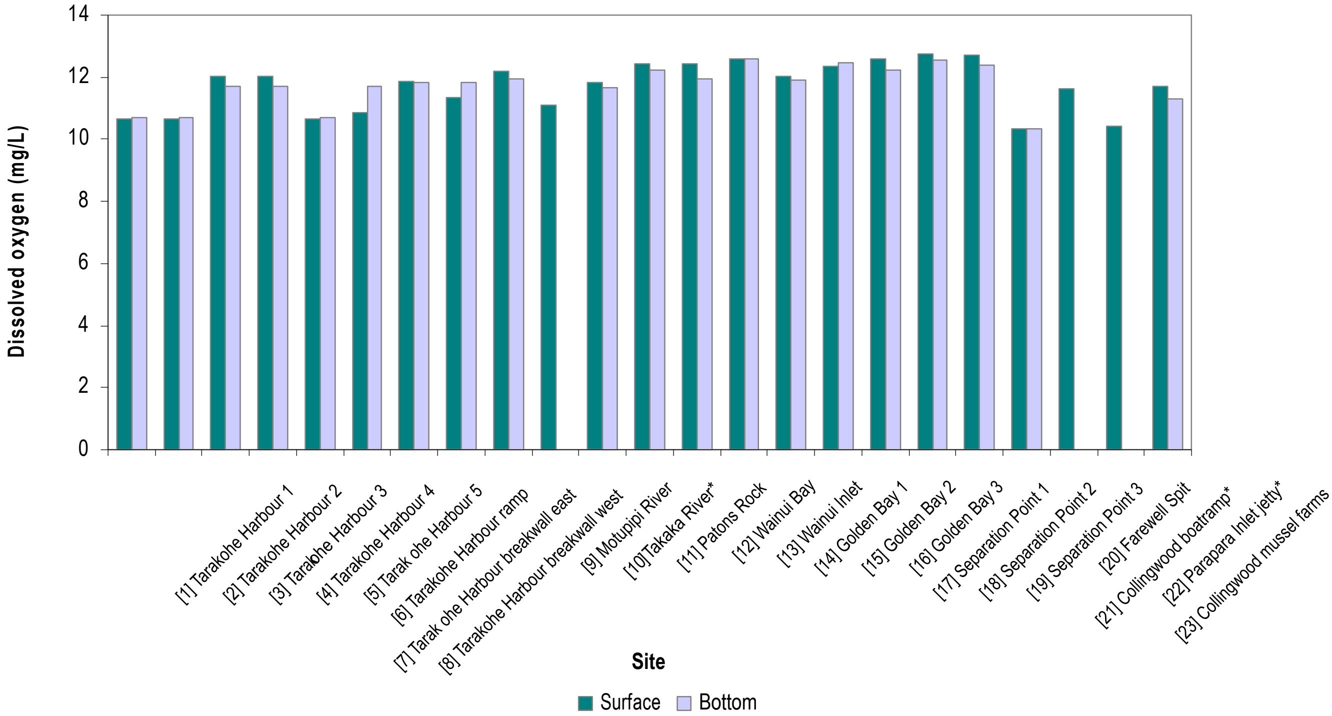

Figure 13: Dissolved oxygen recorded during the Golden Bay Port Survey November 2007. Dark shading denotes sea surface readings and light shading denotes readings taken near the sea floor. * indicates sites that were too shallow to take two readings.

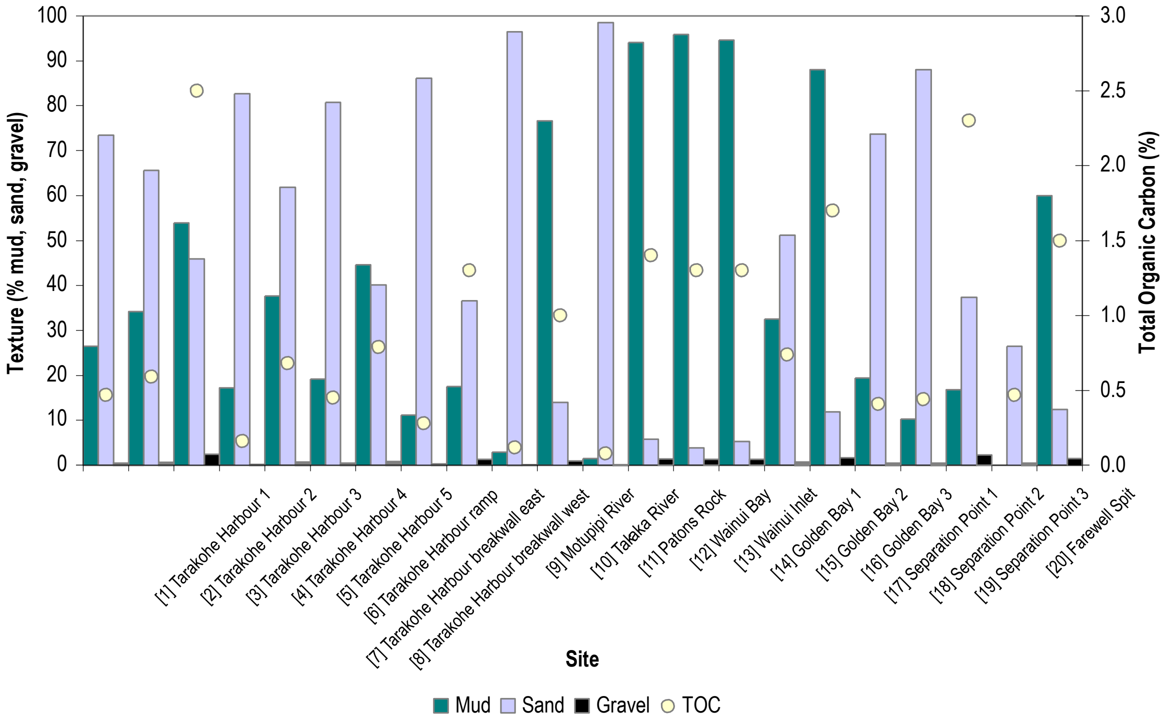

Figure 14: Proportion of mud (<63 µm grain size), sand (63 µm – 2 mm) and gravel (> 2 mm) and total organic carbon from sediment samples collected during the Golden Bay Port Survey November 2007. (Note that sediments at Site 4 were not sampled owing to the close proximity to Site 6 where substrates consistent between these areas).

5.2. NATIVE BIODIVERSITY

A total of 403 taxa (determined to Class level or below) were identified from the Golden Bay survey collection, of which 73% (*n* = 294) were determined to be indigenous or endemic to New Zealand (Appendix C). Of the native fauna, the Mollusca were the most diverse group with 24% of the native species collected during the survey. Other dominant faunal and floral taxonomic groupings included Annelida (14%), Arthropoda (13%) and Bacillariophyta (10%). Other taxonomic groups of species collected during the survey included (in order of highest to lowest taxonomic diversity) Bryozoa (10%), Myzozoa (7%), Rhodophyta (6%), Chordata (5%), Echinodermata (4%) and Ochrophyta (3%). Brachiopoda, Cnidaria and Porifera each contributed < 1% of the native species collected during the survey.

5.3. NON-INDIGENOUS SPECIES IN THE PORT

5.3.1. Overview

Nine non-indigenous species and thirteen cryptogenic species were detected during the survey, representing 2% and 4% (respectively) of the 322 taxa collected (Figure 15). Non-indigenous and cryptogenic species were detected at 70% of the sites sampled (*n* = 23 sites). No non-indigenous or cryptogenic species were considered rare owing to the low incidence of indigenous species (Figure 16). Thirteen non-indigenous or cryptogenic (C1) species occurred occasionally, three species were considered common, and the remaining seven non-indigenous and cryptogenic species were considered to be abundant during the Golden Bay port survey. Site occupancy by non-indigenous and cryptogenic (C1) species relative to rarity is provided in Figure 17.

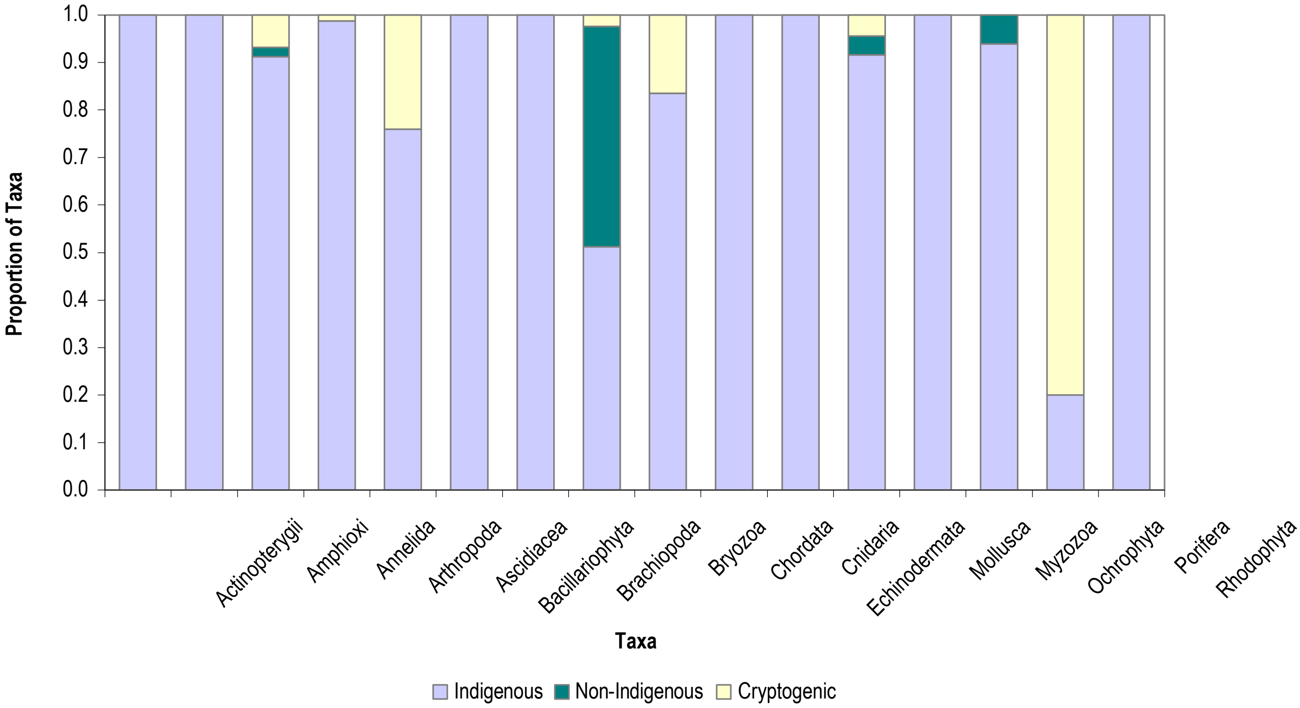

Figure 15: Proportion of species diversity for taxonomic groups detected during the Golden Bay Port Survey November 2007.

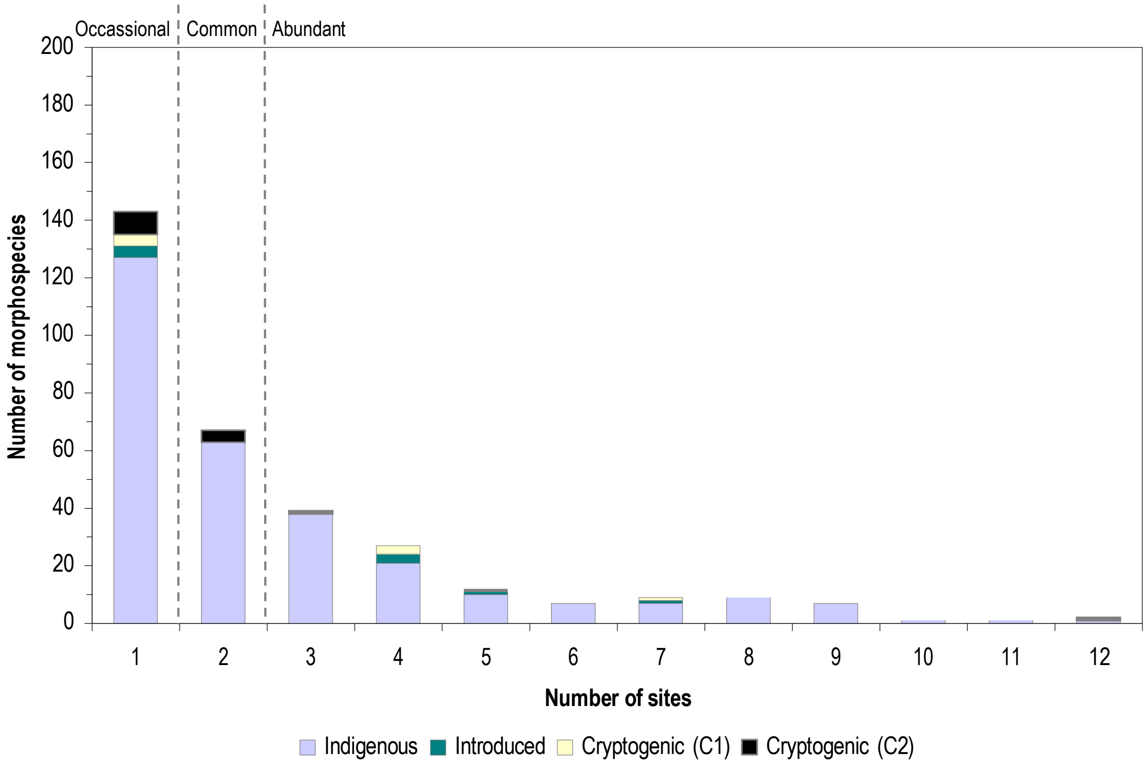

Figure 16: Site occupancy of indigenous, non-indigenous and cryptogenic taxa at Golden Bay.

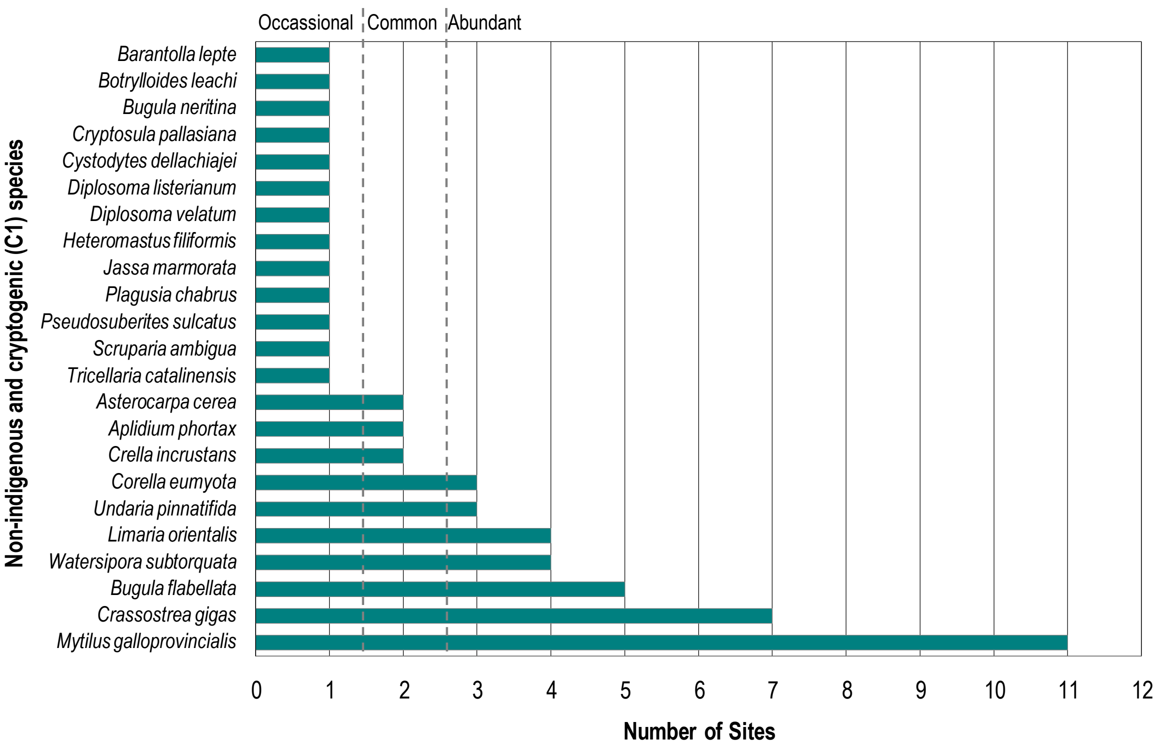

Figure 17: Site occupancy of non-indigenous and cryptogenic (C1) species relative to measures of rarity based on percentage quartiles of total taxa site occupancy.

5.3.2. Detected Non-Indigenous Species

Nine non-indigenous species were detected in Golden Bay during the survey (Table 9). All species have been recorded previously in New Zealand. *Bugula flabellata, C. gigas, C. pallasiana*, *U. pinnatifida* and *W. subtorquata* were collected from wharf pilings or pontoons, indicating an association with shipping and a biofouling habit. *Bugula flabellata* and *U. pinnatifida* were also found on marine farms, indicating an association with aquaculture activities. *Barantolla lepte, B. neritina, C. pallasiana* and *T. catalinensis* were found only within Tarakohe Harbour, whereas *W. subtorquata* was found within the harbour and on the seaward side of the harbour's western breakwater. *Crassostrea gigas* was distributed widely about Golden Bay, but *L. orientalis* occurred only at Separation Point and a single site within Golden Bay (Site 16).

Table 9: Non-indigenous and cryptogenic marine species detected during the Golden Bay Port Survey November 2007.

Species Status	Biosecurity Status	Species
Non-Indigenous	Known introduced	*Barantolla lepte*
		Bugula flabellata
		Bugula neritina
		Crassostrea gigas
		Cryptosula pallasiana
		Limaria orientalis
		Tricellaria catalinensis
		Undaria pinnatifida
		Watersipora subtorquata
Cryptogenic	Category 1	*Aplidium phortax*
		Asterocarpa cerea
		Botrylloides leachii
		Corella eumyota
		Crella incrustans
		Cystodytes dellechiajei
		Diplosoma listerianum
		Diplosoma velatum
		Heteromastus filiformis
		Jassa marmorata
		Mytilus galloprovincialis
		Plagusia chabrus
		Pseudosuberites sulcatus
		Scruparia ambigua

5.3.3. Cryptogenic Species

Nineteen cryptogenic (C1 and C2) species were recorded in Golden Bay during this survey. Five cryptogenic species were new or undescribed species for which there was insufficient taxonomic or biogeographical information to determine whether New Zealand is within their indigenous range (i.e., Cryptogenic Category 2). Fourteen Category 1 cryptogenic species were recorded from Golden Bay during this survey.

Most species in this category included species or species complexes with a cosmopolitan distribution and undetermined indigenous range, i.e., *Botryllus leachii, Corella eumyota, Cystodytes dellachiajei, Diplosoma listerianum, Heteromastus filiformis, Jassa marmorata, Mytilus galloprovincialis, Plagusia chabrus* and *Scruparia ambigua*. Other species, such as *Diplosoma velatum* and *Crella incrustans*, are recorded previously from Australia and New Zealand but have a disjunctive distribution in either country. Such species could well be cryptic species that are indigenous to either or both New Zealand and Australia. *Aplidium phortax* occurs in Australia, New Zealand and the Solomon Islands and is therefore considered cryptogenic on the basis of the uncertainty concerning its indigenous range. Similarly, the cold-water sponge *Pseudosuberites sulcatus* has a widespread circumpolar distribution and is considered cryptogenic on the basis of the uncertainty concerning its indigenous range.

A number of cryptogenic species were detected as biofouling on wharf pilings or mussel farms, or occurred in the immediate vicinity of Port Tarakohe, i.e., *A. phortax, B. leachii, C. eumyota, D. listerianum, J. marmorata, P. chabrus, P. sulcatus* and *S. ambigua*. This indicates a possible association with shipping and a proclivity for fouling of artificial substrates such as wharf pilings, pontoons and vessel hulls. *Crella incrustans, C. dellachiajei* and *D. velatum* were found at exposed reefs that were relatively isolated from areas frequented by vessels such as ports, harbours and anchorages. *Mytilus galloprovincialis* was widely distributed about Golden Bay.

5.4. PUBLIC AWARENESS PROGRAMME

No significant public expressions of interest were fielded by survey team members or the Project Manager.

6. Potential Impacts of Non-Indigenous Species Found in the Port

Assessing the potential impacts of non-indigenous species requires adequate knowledge of the non-indigenous species' ecology and how its presence may affect the structure and composition of indigenous species assemblages. Information on species impacts elsewhere can inform on the likely impacts when they are introduced to a new location, but assessments of species impacts are often based on anecdotal information due to a general lack of baseline data on the state of indigenous community assemblages before the establishment of non-indigenous marine species.

Fouling species detected in the survey, such as *Botrylloides leachii, Bugula flabellata, Corella eumyota, C. pallasiana, Pseudosuberites sulcatus* and *Watersipora subtorquata* were found on artificial substrates such as wharves and jetties were they can be dominant members of the fouling communities. Impacts of these species are therefore likely to be localised and confined largely to specific environments such as sheltered harbours and artificial structures.

Limaria orientalis and *Theora lubrica* are bivalve molluscs and are dominant members of soft sediment benthic communities of the Waitemata Harbour, where *L. orientalis* is an important dietary component of snapper, *Pagrus auratus* (Hayward 1983, Hayward 1997). *Limaria orientalis* and *T. lubrica* have also been suggested to play important roles in species interactions within the Waitemata Harbour (Lohrer *et al.* 2008). *Theora lubrica* was not detected in the present survey but is reported previously from Golden Bay (refer to Section 3). *Barantolla lepte* is a small capitellid polychaete lugworm native to Australia and found predominantly in estuarine sublittoral mud and weed beds (Inglis *et al*. 2006f). Little is known of the potential impacts of *B. lepte.*

Undaria pinnatifida and *Crassostrea gigas* are the two non-indigenous species detected in the survey that have the greatest potential to effect the marine environment. The ecological impacts of the Pacific oyster *C. gigas* in New Zealand remain largely undocumented, but as with most other non-indigenous oysters, *C. gigas* is a significant ecosystem engineer that has the potential to greatly modify intertidal environments (Ruesink *et al*. 2005). *Crassostrea gigas* forms intertidal banks and has established in most rocky, intertidal inlets and mangrove areas in northern and central New Zealand (Dinamani 1971, Dinamani 1991, Hayward 1983, Hayward 1997).

Anecdotal evidence would suggest that the establishment of Pacific oyster in New Zealand may have led to a reduction in abundance of the native rock oyster, *Saccostrea glomerulata.* Pacific oyster are able to rapidly overgrow and smother native shore oysters in the mid to low intertidal zone, but higher mortality of Pacific oyster in the high intertidal allows the native shore oyster to evade competitive exclusion by Pacific oyster and persist at high intertidal elevations (Frederick *et al.* 2007). Spat collected in 1972 strongly favoured the native rock oyster over Pacific oyster (1000:1), but this trend was reversed by 1979 when the ratio of spat favoured the non-indigenous Pacific oyster at 4 to 1 over the native rock oyster (Dinamani 1991). It is unclear, however, if this observed change in larval recruitment is a result of the higher fecundity and survivorship of Pacific oyster or the ability of settled Pacific oyster to out-compete rock oyster due to its higher growth rate (Ruesink *et al*. 2005).

Undaria pinnatifida has a high visual impact because of its preference for growing on artificial substrates that are typically colonised by smaller, inconspicuous algae. The perennial gametophyte effectively acts as a 'seedbank', producing the visible sporophyte generation in response to the clearance of overlying canopy by storm events, wave action or grazing pressure. Research indicates that *U. pinnatifida* requires the clearance of an intact canopy to become established, and suggests that the persistence of the sporophyte stage or regeneration of indigenous algal assemblages depends on the magnitude and frequency of the disturbance events (Valentine & Johnson 2003).

The potential impacts of *U. pinnatifida* have been discussed in detail by Stuart (2003a), who indicated that the impacts of this species could be profound, particularly where moderate levels of grazing pressure or regular storm events promote its establishment and persistence. The author also indicated that the impacts of *U. pinnatifida* would be particularly pronounced when canopy removal corresponded with the seasonal appearance of *U. pinnatifida* sporophytes over spring and early summer. This could lead to the formation of a dense cover of sporophytes in cleared regions, thereby preventing the recruitment of ephemeral or canopy-forming indigenous species.

Another species previously collected from Golden Bay, but not detected in the present survey is the non-indigenous seasquirt, *Didemnum vexillum*. This species could have significant negative effects on the environment, marine farming and commercial fisheries by smothering the seabed, shellfish and marine farming equipment. Assessment of the potential impact of this species is largely based on recent research emerging from the Georges Bank off New England, north-eastern USA where *D. vexillum* has become widespread, colonizing large areas of shell-gravel bottom on Georges Bank including commercial grounds of the sea scallop *Placopecten magellanicus* (Morris *et al*. 2009). Research suggests that *D. vexillum* (sensu Stefaniak *et al*. 2009) could eventually colonize large expanses of hard substrata habitats in temperate waters and may significantly affect fisheries because it can smother bivalves, reduces the structural complexity (i.e., refuge value) of the seafloor, and kills infaunal organisms that provide food for fishes and other bottom feeders (Bullard *et al*. 2007).

Laboratory experiment to assess interactions between larval and *D. vexillum* found that larval bay scallops (*Argopecten irradians irradians*) avoid settling on *D. vexillum* colonies, possibly deterred by the low pH of the tunicate's surface tissue, suggesting that widespread colonization of substrata by *D. vexillum* could affect scallop recruitment by reducing the area of quality habitats available for settlement (Morris *et al*. 2009). These same authors proposed that the bay scallop can serve as a surrogate in estimating the negative impact *D. vexillum* could have on the recruitment of sea scallops on Georges Bank. This study therefore suggests that *D. vexillum* could have similar impacts on recruitment the Pacific scallop, *Pecten novaezelandiae*.

Detailed analysis of bottom photographs of Georges Bank also suggests that *D. vexillum* is able to out-compete other epifaunal and macrofaunal taxa and that *D. vexillum* has had a significant impact on the species composition of the benthic community with the abundance of two polychaete species, *Nereis zonata* and *Harmothoe extenuata*, increasing significantly in infested areas compared with uninfested areas (Lengyel *et al*. 2009). *Didemnum vexillum* colonies are also fouling coastal shellfish aquaculture gear which increases maintenance costs and may affect shellfish growth rates (Morris *et al*. 2009).

In summary, most of non-indigenous species detected at Golden Bay are not known to greatly affect indigenous communities, but this is mainly a default position based on a lack of research and baseline data upon which to assess impacts. Impacts of most non-indigenous species detected during the survey are likely to be localised and confined largely to specific environments such as sheltered harbours and artificial structures.

7. Origin and Potential Vectors for the Introduction of Non-Indigenous Species Found in the Port

7.1. OVERVIEW

Non-indigenous species detected at Golden Bay could have arrived via five mechanisms:

- Natural range extension of species introduced to other parts of New Zealand;
- Directly to the port by international shipping, either in ballast water or by hull fouling;
- Domestic translocation from fishing, charter and recreational vessels;
- Activities associated with marine farming; and
- Hull cleaning.

7.2. NATURAL RANGE EXTENSION

Natural range extension occurs primarily via dispersal of larvae by currents, although motile adults of some species may disperse under their own locomotion. Typically, species that have planktonic life history phases are capable of some degree of natural dispersal via currents and water movement; the distance of dispersal depending largely on local hydrodynamics and the length of time spent as plankton. Non-indigenous bryozoans, polychaetes and ascidians generally have planktonic life history phases capable of natural dispersal, as evident by their broad distributions throughout New Zealand.

The general circulation of currents in Golden Bay is clockwise and in contrast to the anti-clockwise movement of currents in Tasman Bay. This circulation pattern would gradually transport and plankton larvae from Tasman Bay to Golden Bay and enhance larval settlement by entraining planktonic larvae within Golden Bay. Hence the spread of non-indigenous species from Marlborough and Tasman Bay to Golden Bay could have occurred naturally through the transport of planktonic life-history stages by prevailing circulation patterns. *Theora lubrica* and *Limaria orientalis* are most likely to have been introduced by this means as they are not biofouling species and introduction by ballast water discharge is less likely due to the low volume of water ballasted shipping in the region.

7.3. BALLAST WATER AND HULL FOULING

The likelihood of the direct introduction of non-indigenous marine species to Golden Bay by international shipping is relatively low as there is no regular international commercial shipping to Golden Bay and few, if any, water ballasted vessels visit Golden Bay. It is more likely that non-indigenous species would be introduced by hull fouling of domestic vessels that subsequently translocate non-indigenous species to Golden Bay from elsewhere in New Zealand. Many of the species detected during the survey are biofouling organisms known to establish on the hulls of vessels and colonise artificial substrates such as wharf pilings (i.e., *Bugula* spp., *Undaria pinnatifida, Watersipora subtorquata*; Cranfield *et al*. 1998). A survey of vessel biofouling conducted in 2002 indicated that the most likely translocation pathways for *U. pinnatifida* to Golden Bay are from Wellington and Marlborough (Figure 18; after McClary & Stuart 2006). Similar pathways could be expected for the translocation of other non-indigenous species.

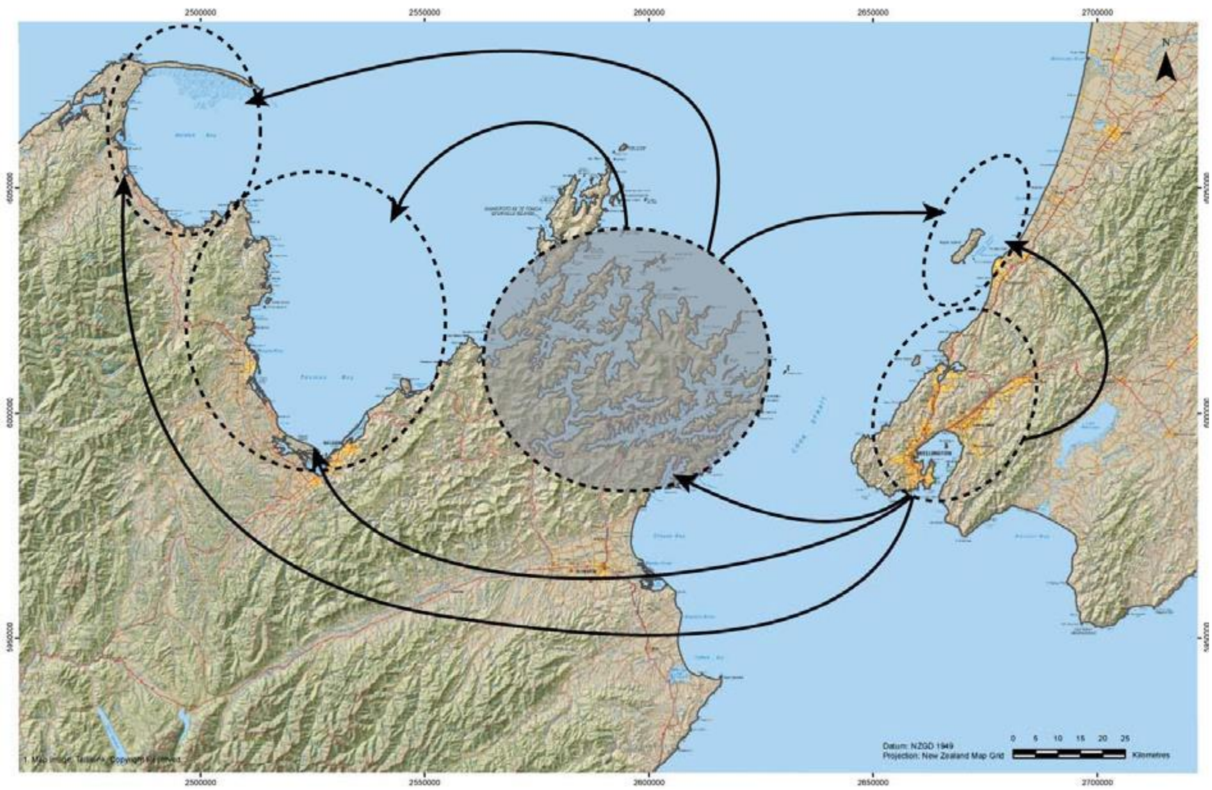

Figure 18: Pathways for the translocation of *Undaria pinnatifida* to Golden Bay by hull fouling. The shaded circle indicates a 'node' characterised by translocation pathways into and out of Marlborough (after McClary & Stuart 2006).

The likelihood of non-indigenous species translocations to Golden Bay from Wellington and Marlborough is relatively high because they contain the greatest concentrations of vessels in the region (McClary & Stuart 2006). However, Nelson Haven and Porirua also contain a significant number of vessels that could also translocate non-indigenous species to Golden Bay. Although not detected in the present survey, the non-indigenous sea squirt *Didemnum vexillum* is known to be present at Tarakohe and is also present in Port Nelson, Marlborough and Wellington (Pannell & Coutts 2007). This suggests that the spread of *D. vexillum* has utilised similar pathways to those previously identified for *U. pinnatifida*.

7.4. MARINE FARMING ACTIVITIES

Marine farms in Golden Bay are situated offshore from Collingwood and at Wainui Bay. Wainui Bay is used year-round for mussel spat catching, whereas some mussel growing occurs near Collingwood (Forrest & Blakemore 2002, Dodgshun *et al*. 2007). Mussel and scallop spat catching elsewhere in Golden Bay occurs at two offshore sites which are used on a seasonal and rotational basis with approximately a third to a quarter of the available area used in any one year (Forrest & Blakemore 2002). Spat-catching gear can be deployed at these sites over the six months between November and April, and all gear and structures are removed for the remainder of the year (Stuart & McClary 2006).

Non-indigenous and cryptogenic species found at the marine farms are presented in Table 9, the majority of which are well-known biofouling species.

Table 10: Non-indigenous and cryptogenic species present in samples from marine farms at Wainui Bay and offshore of Collingwood.

Taxa	Wainui Bay	Collingwood
Non-indigenous species		
Bugula flabellata	Present	Present
Undaria pinnatifida	Present	Present
Cryptogenic species		
Aplidium phortax	Present	Present
Diplosoma listerianum	Absent	Present
Jassa marmorata	Absent	Present
Mytilus galloprovinalis	Present	Absent
Scruparia ambigua	Absent	Present

Possible pathways for the introduction of these species to Golden Bay by marine farming activities include:

- Species transfers of mussel spat and seed stock.
- Translocation as biofouling on vessels associated with the establishment, operation and maintenance of marine farms.
- Translocation as biofouling on marine farming equipment i.e. spat catching gear, buoys, rope, screw anchors, mooring blocks.

Undaria pinnatifida was detected at both marine farm sites in the present survey and has been known to be present at the Collingwood farms since 1998 and Wainui Bay since 2001 (Stuart 2004). *Undaria pinnatifida* was first discovered on vessels at Port Tarakohe in 2002 and had not colonised pontoons, wharf structures or the seabed at this time (Stuart 2003b; McClary & Stuart 2006; M. Stuart pers. obs.). However, it had established on permanent substrates by 2005 (Bennett *et al*. 2006). This suggests that the introduction of *U. pinnatifida* to the marine farms occurred from sources other than Port Tarakohe, either through the translocation of seed mussel, marine farming equipment or as biofouling on marine farming vessels. The subsequent establishment of *U. pinnatifida* to Port Tarakohe could have occurred via biofouling of vessels associated with the Collingwood or Wainui Bay farms, or vessel originating from sources outside of Golden Bay (i.e., Nelson, Marlborough, Porirua, and Wellington). The possible origin and specific vectors for the introduction of the other non- indigenous and cryptogenic species listed in Table 9 cannot be determined due to a lack of detailed information of their invasion histories and their widespread distribution throughout New Zealand and globally.

7.5. HULL CLEANING

There are no cleaning areas within Golden Bay that are designated in the Tasman District Resource Management Plan (TRMP 1996). Cleaning of vessels while they are exposed on tidal flats at swing or pile moorings has the potential to introduce new species. The removal and deposition of hull biofouling onto tidal flats could result in the viable organisms or propagules being introduced to the marine environment.

8. Influences of the Port Environment and Port Practices on Colonisation and Survival of Non-Indigenous Species

Port Tarakohe (Figure 2) is the only anchorage in Golden Bay with suitable subtidal settlement substrate for colonisation by non-indigenous subtidal marine species. The predominance of pile and swing moorings on tidal flats at Ligar Bay and Milnthorpe Quay in Golden Bay (Figure 19) is likely to prevent hull fouling by subtidal species or their establishment in such areas due to repeated emersion of vessels and a lack of suitable subtidal habitat for founding populations in the region. Estuarine conditions at Waitapu Wharf (Takaka) and Collingwood would likely prevent the introduction of stenohaline marine species at these sites (Stuart 2003a).

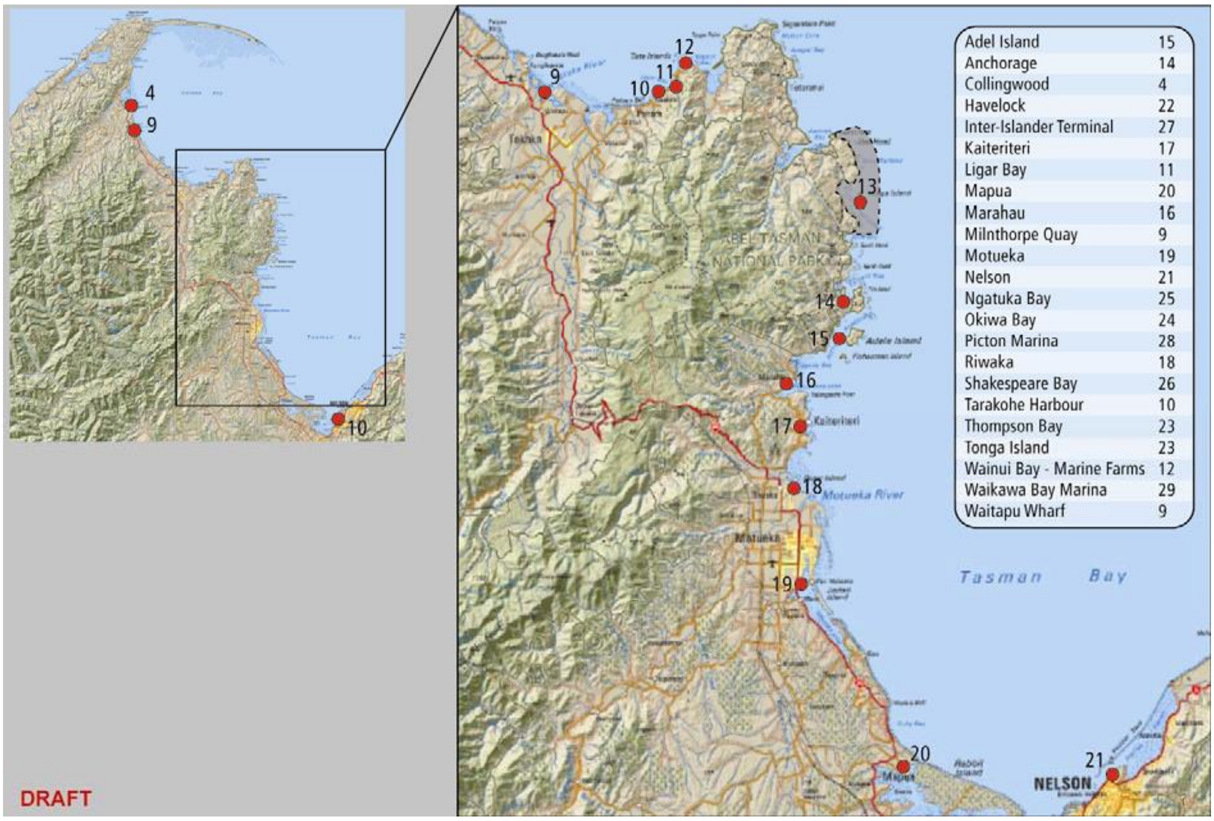

Figure 19: Location of anchorages, moorings and marine farms in Golden and Tasman Bays (after McClary & Stuart 2006).

9. Assessment of the Risk of New Introductions to the Port

Tarakohe and marine farms are the most likely points of introduction of non-indigenous marine species to Golden Bay via fouling of vessels and marine farming equipment. These are the only locations in Golden Bay were vessels and equipment would be permanently immersed in the marine environment and in close proximity to a wide variety of artificial settlement substrates. Several non-indigenous species are known to occur at Wellington, Picton and Nelson which could be introduced to Golden Bay via the pathways listed previously (Table 11, Figure 18).

Table 11: Non-indigenous marine species detected during recent surveys of ports at Nelson, Picton and Wellington, but not detected during present survey of Golden Bay (after Inglis *et al.* 2002 b, c, h). Probable means of introduction; H = Hull fouling, B = Ballast water discharge.

Phylum, Class	Genus and species	Port	Probable means of introduction	Date of introduction or detection (d)
Annelida	*Dipolydora armata*	Picton, Wellington	H	~ 1900
	Dipolydora flava	Picton	H or B	Unknown1
	Polydora hoplura	Nelson, Wellington	H	Unknown
	Spirobranchus polytrema	Wellington		Nov. 2001 d
Bryozoa	*Conopeum seurati*	Nelson	H	Pre-1963
	Cyclicopora longipora	Wellington		Unknown
	Electra angulata	Nelson	H	Unknown
	Celleporaria nodulosa	Nelson	H	Jan. 2002d
	Schizoporella errata	Nelson	H	Pre-1960
	Anguinella palmate	Nelson	H	1960
Cnidaria	*Eudendrium capillare*	Wellington		Nov. 2001 d
	Lafoeina amirantensis	Nelson	H	Jan. 2002d
Crustacea	*Cancer gibbosulus*	Wellington		Nov. 2001 d
Mollusca	*Theora lubrica*	Nelson, Wellington	B	1971
Phycophyta	*Griffithsia crassiuscula*	Picton, Wellington	H	Pre-1954
Porifera	*Halisarca dujardini*	Picton, Wellington	H or B	Pre-1973
Urochordata	*Ciona intestinalis*	Nelson	H	Pre-1950

[1] Date of introduction unknown but known to be present in New Zealand before port survey.

All other species presented in Table 10 could have been introduced by biofouling. The introduction of biofouling species on spat catching gear deployed in Golden Bay is unlikely, provided that:

- The gear had not been previously deployed in areas with non-indigenous species;
- The gear had been decontaminated; or
- There was a six month period between deployments in Golden Bay has killed any fouling species.

Likewise, the transfer of equipment between farms, such as mussel buoys and rope, could introduce non-indigenous species to farms in Golden Bay if it had been previously deployed in areas with non-indigenous species and had not been decontaminated.

Hull fouling of domestic vessels represents the most probable means of new species introductions to Golden Bay. There is no regular international commercial shipping to Golden Bay and few, if any, visits by water-ballasted vessels. Nevertheless, new species could be introduced to Golden Bay by international shipping that can intermittently shelter within Golden Bay. One notable example of an international vector in Golden Bay is the semi-submersible drilling rig, *Ocean Patriot.* The rig, present in New Zealand waters for several years, was moved into sheltered waters within Golden Bay in December 2007 for removal of biofouling prior to it being permitted to enter Australian waters. The South African brown mussel, *Perna perna,* was subsequently discovered to have been present on the oil rig at the time of its defouling. As a result MAFBNZ required that the nearly 50 tonnes of biofouling debris be removed from the seabed and disposed of in a landfill in early March 2008[1].

Although regular international shipping does not routinely enter Golden Bay and the likelihood of non-indigenous species introductions by this pathway is low, the example of the *Ocean Patriot* demonstrates that new species introductions by this pathway pose a hitherto unconsidered risk.

The likelihood that new species will be introduced to Golden Bay through the transfer of mussel (*Perna canaliculus*) spat and seed stock depends largely on farming practices. Spat collected from Kaitaia is on-grown in the Coromandel and Firth of Thames before transfer as seed mussels (ca. 20-50 mm length) to Marlborough, Banks Peninsula and Stewart Island (Forrest & Blakemore 2002; McClary & Stewart 2006). It is unclear, however, if mussels grown in Golden Bay are sourced directly from Kaitaia as spat, are sourced locally, or are transferred to Golden Bay from Marlborough as seed mussel. This transfer of seed mussel from Marlborough could translocate non-indigenous organisms that have previously fouled the seed mussels. The translocation of mussel spat directly between Kaitaia and Golden Bay is not considered likely to lead to the introduction of fouling species associated directly with marine farming, but could lead to the introduction of toxic algal cysts, which can contaminate mussel spat (Mackenzie & Kappa 1993, Rhodes *et al*. 1994).

The New Zealand Mussel Industry Council (NZMIC) has adopted a voluntary code of practice to mitigate the risk of introducing new species through the translocation of seed mussels. The code requires that seed mussels are declumped, thoroughly washed, transferred as single seed, and visually free of blue mussels, *Ciona intestinalis, Undaria pinnatifida* and *Didemnum vexillum* (Dodgshun et al. 2007). While the code does recognise the need for controls, the ability of *U. pinnatifida* gametophytes to survive air drying for up to two days suggests they could remain viable after declumping and washing processes (Forrest & Blakemore 2002). In addition, visual (macroscopic) inspection of seed mussels for *U. pinnatifida* would not detect the microscopic gametophyte stage. The NZMIC code of practice is, therefore, unlikely to be an effective means of preventing the transfer non-indigenous species with microscopic life history stages (i.e., *U. pinnatifida*) or those capable of regenerating from small or microscopic fragments (i.e., *D. vexillum*). It is likely to help prevent the transfer of larger non-indigenous species such as *C. intestinalis* and *Styela clava*. Research has investigated the use of chemical treatments that can be used to decontaminate equipment and mussel spat of *U. pinnatifida* and *D. vexillum* (Forrest & Blakemore 2006, Forrest *et al*. 2007, Denny 2008) and which could prove effective if successfully integrated into marine farming practice. Similarly, treatment methods have been developed to avoid or mitigate the presence of toxic algal cysts densities associated within transferred mussel spat (Taylor 2000, NZMIC 2002).

[1] http://www.biosecurity.govt.nz/pests/perna-perna, http://www.biosecurity.govt.nz/media/20-05-08/dredging (Accessed 25 May 20/09)

In summary, the risk of new species introductions to Golden Bay is presently greatest from hull fouling of domestic vessels and maricultural activities, particularly at Port Tarakohe and marine farms at Wainui Bay and offshore of Collingwood. Voluntary codes of practice adopted by the marine farming industry and the development of effective treatment methods may mitigate the risk of introduction for some species. International shipping presents a relatively low risk of new species introductions provided incidents similar to the *Ocean Patriot* are not repeated. Future coastal development in Golden Bay could also expand existing pathways or establish new pathways for domestic and international vessel traffic and marine farming. For example, a floating coal transfer station in Golden Bay was amongst options considered by the Pike River Coal Company in 2005 to transfer barged coal to international carriers (Anon 2005, Lawless 2008). Self-regulation by the marine farming industry combined with the consideration of biosecurity issues through consenting and permitting processes is likely to provide the most effective means of managing the risk of new species introductions over the long term.

10. Assessment of the Risk of Translocation of Non-Indigenous Species Found in the Port

10.1. OVERVIEW

Translocation of non-indigenous marine species in Golden Bay could occur via the pathways identified in Section 7, provided pathways and environments exist for their introduction and establishment. Marine farms situated in Golden Bay and Port Tarakohe would appear the most likely points of introduction and subsequent dispersal about Golden Bay.

10.2. HULL FOULING

Investigations of vessel traffic to the region would suggest that there are established translocation pathways linking Golden Bay to locations in Tasman Bay, Marlborough and Fiordland (Stuart 2003b, Stuart 2003c, McClary & Stuart 2006). Previous hull inspections of vessels moored at Tarakohe in 2002 found three vessels fouled with *Undaria pinnatifida* (Stuart 2003a). This indicates that vessels at Tarakohe are fouled with non-indigenous species and could be translocating them to other locations by hull fouling.

Stuart (2003a) indicated that the northern fiords are most commonly visited by recreational craft that voyage to Fiordland from central New Zealand via the west coast. This west coast route is preferred over the east coast route because of the extensive delays that can be expected when southwest and northwest winds combine with large southwest or westerly swells and prevent passage through Foveaux Strait and around Puysegur Point into Fiordland (Bell & Foster 1994). Tasman Bay and Golden Bay both provide a staging post for vessels waiting for anticyclonic weather conditions allowing safe passage down the west coast of the South Island (Bell & Foster 1994). Recreational craft waiting at Tarakohe for suitable weather could be colonised by non-indigenous species and subsequently translocate them to Fiordland.

Vessels undoubtedly voyage between Tarakohe and other mooring sites and anchorages throughout Golden Bay and Tasman Bay. Vessels may be fouled by non-indigenous species whilst berthed or moored at Tarakohe and subsequently translocate them locally to new sites. However, the predominant tidal or estuarine conditions at most anchorages and mooring sites around the region is likely to limit the introduction and establishment of most subtidal marine species found at Tarakohe.

In Tasman Bay, the greatest numbers of subtidal moorings with hard subtidal settlement substrates occur at Nelson Haven, Mapua, Kaiteriteri, and the Anchorage. A smaller number occur within tidal channels at Monarcho, pontoon moorings at Motueka, and vessels anchored in the lee of Adel Island (Figure 20). Seabed and tidal flats of sand and mud substrate at Monarcho, Mapua and Motueka would restrict colonisation by biofouling species requiring hard substrate to adjacent artificial substrates such as moorings, wharf structures and pontoons. Likewise, sand seabed below vessels at Kaiterteri, Adel Island and Anchorage is likely to impede the establishment of most biofouling species settling directly under anchored and moored vessels. Granite reef adjacent to anchorages at Kaiteriteri, Adel Island and the Anchorage could, however, be colonised by drifting adults or propagules.

Figure 20: Mooring environment at locations in Tasman Bay showing permanently immersed vessels at Mapua (top left) and Motueka (top right), periodically immersed vessels at pile at Riwaka (bottom left) and swing moorings at Motueka (bottom right).

11. Recommendations

11.1. MANAGEMENT OF EXISTING NON-INDIGENOUS SPECIES IN THE PORT

In the present survey, *Undaria pinnatifida* was only found on floating pontoons in Tarakohe Harbour and was not present at wharves and jetties or the adjacent shoreline. Hence, periodic management of sporophytes could be beneficial in preventing spores from colonising vessels as they are berthed at, or moored adjacent to the colonised pontoons. Likewise, the management of sporophytes on other floating structures, particularly from buoys and ropes is likely to slow the biofouling of moored vessels and prevent the re-colonisation of vessels that have been recently cleaned.

Such activities need not be restricted to *U. pinnatifida* and could be extended for the management of other existing non-indigenous marine species, either through a target-species approach or through the use of management techniques that are applicable to a range of non-indigenous species (i.e., wharf pile wrapping, hull cleaning, defouling of moorings). Management of *Bugula flabellata, Crassostrea gigas, Cryptosula pallasiana, U. pinnatifida* and *Watersipora subtorquata* may also benefit from such a multi-species approach.

Continued implementation, review and improvement of industry best practice is an important means of managing existing non-indigenous species within the aquaculture pathways and vectors. This is best done by identifying and integrating management practices into marine farming activities that keep populations of non-indigenous species at a level that they are less likely to spread to adjacent farms, impact on farming activities or spread to benthic substrates. Such management practices could include the regular turning of mussel buoys to expose biofouling to the elements and management practices that prevent the colonisation of seed mussel with non-indigenous species from adjacent lines.

11.2. PREVENTION OF NEW INTRODUCTIONS

New introductions to Golden Bay could be best prevented through biofouling management of vessel at ports and marinas most likely to voyage to Golden Bay (for example, Picton, Wellington, Nelson). This could be accomplished through raising public awareness of species threats and practical steps that can be taken to reduce the biofouling risk (i.e., regular hull cleaning, best practice application of antifoulant paints, defouling of moorings and berths). It is important, however, to ensure that any public awareness programme is accompanied by monitoring of hull fouling to determine the efficacy of efforts to raise public awareness, to identify and respond to specific biosecurity threats (i.e., fouled vessels), and to present a public presence.

The translocation of aquaculture equipment and stock is a possible mechanism by which new species may be introduced to Golden Bay. While the aquaculture industry has adopted practices to reduce the likelihood of non-indigenous species being spread by aquaculture, these require constant review and improvement in light of new biosecurity threats and changing aquaculture practice.

International shipping and ballast water discharges to Golden Bay are rare and the likelihood of new introductions by these mechanisms is low. However, future coastal development (i.e., ports, marinas, marine farms, hull defouling facilities) could create new pathways for the introduction of new species.

For example, the western breakwater in Port Tarakohe was extended by 70 m in 2008 (Figure 21) and further expansion of the port is currently proposed. This will include provision for an additional 150 to 180 marina berths and associated facilities through extension of the hardstand area by reclamation (Tasman District Council 2009). Provision may also be made for increased landings/transfers of mussel aquaculture product. In this instance, additional vessel, equipment and stock or product traffic would result in a concomitant increase in the risk of incursion by non-indigenous species associated with recreational vessels and aquaculture. Associated biosecurity risks should be considered when permitting discharges and the construction of structures such as these in the coastal environment.

Fiigure 21: Port Tarakohe illustrating a recent extension of the western breakwater (circled) (after Tasman District Council 2009).

Acknowledgements

This project was funded by Ministry of Agriculture and Forestry – Biosecurity New Zealand Contract ZBS2005-19. We gratefully acknowledge personnel from Cawthron Institute for assistance with fieldwork and Mr. Bruce Lines (Diving Services New Zealand Ltd.) for providing logistical support in the field. Personnel and associated taxonomists with the Marine Invasives Taxonomic Service provided identification services, including Dr.'s Wendy Nelson and Roberta D'Archnino (algae), Mr. Mike Page and Ms. Anna Bradley (ascidia), Dr.'s Dennis Gordon (bryozoa), Shane Ahyong (cnidaria, crustacea) and Hoe Chang (dinoflagellates and cysts), Mr. Owen Anderson, Ms. Niki Davey and Ms. Kate Neill (echinoderms), Dr Malcolm Francis (fish), Ms. Jill Burnett (molluscs) and Dr's Geoff Read (polychaetes) and Michelle Kelly (sponges). Ms.' Sandra Hinni, Claire Phipps and Coralie Dignan assisted during preparation of this document and Dr's Justin McDonald (MAFBNZ) and Ian Boothroyd (Golder Associates) provided helpful comments on the final report.

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