Stewart Island Non-Indigenous Species Port Survey

Baseline Surveys of New Ports and Marinas

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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). The Ministry of Agriculture and Forestry – Biosecurity New Zealand (MAFBNZ) has, therefore, implemented a number of baseline port surveys to elucidate the degree of non-indigenous and indigenous species diversity within New Zealand's ports, marinas and also in regions relatively unaffected by human activities (Campbell *et al.*. 2007).

This document presents the results of a baseline survey of native and non-indigenous species undertaken at Stewart Island, New Zealand between 24 and 30 September 2006. The survey was performed by Golder Associates (NZ) Ltd and the Australian National Centre for Marine Conservation and Resource Sustainability in accordance with survey protocols and design prepared by the Centre for Research on Introduced Marine Pests (CRIMP) and MAFBNZ.

Six non-indigenous species and twenty-nine cryptogenic species were detected at Stewart Island during the survey. The non-indigenous species comprised *Bugula flabellata, Champia affinis, Cryptosula pallasiana, Leucandra compacta, Undaria pinnatifida* and *Watersipora subtorquata*. The seaweeds, *C. affinis* and *U. pinnatifida* have been recorded previously from Stewart Island, but the detection of the bryozoans' *B. flabellata, C. pallasiana*, and *W. subtorquata* all represent new records for Stewart Island and a southward range extension of these species in New Zealand (Gordon 1986, Gordon 1989). The occurrence of *L. compacta* at Stewart Island may be a new record for New Zealand. With the exception of *C. affinis*, all non-indigenous species were collected from wharf pilings, indicating an association with shipping and a biofouling habit. *Bugula flabellata* and *C. pallasiana* were also found on pontoons supporting salmon cages, indicating an association with aquaculture activities. The occurrence of *C. pallasiana* and *U. pinnatifida* on natural substrates and in areas that are remote from regular vector traffic suggests that these species have spread from their initial sites of introduction via natural dispersal.

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

Keywords: Stewart Island, 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 (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). The Ministry of Agriculture and Forestry – Biosecurity New Zealand (MAFBNZ) has therefore implemented a number of baseline port surveys to elucidate non-indigenous and indigenous species diversity within New Zealand’s ports, marinas, and in regions relatively unaffected by human activities (Campbell *et al.*. 2007).

Between 24 and 30 September 2006, Golder Associates (NZ) Ltd (Golder) and the National Centre for Marine Conservation and Resource Sustainability undertook a baseline survey of non-indigenous marine species at Stewart Island, New Zealand. The survey targeted 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 provided by MAFBNZ. The biodiversity of marine taxa at each of the sampling locations was also evaluated.

2. Description of the Port

2.1. GENERAL FEATURES OF STEWART ISLAND

Stewart Island is New Zealand's third largest island, lying between latitudes 46° and 47° South. The island is separated from the South Island by Foveaux Strait, but was incorrectly mapped as a peninsula by Captain Cook in 1770. Stewart Island was later named after Captain William Stewart, a sealer and whaler who charted the island in 1809.

Prevailing weather, oceanic circulation and tidal currents are predominantly from west to east and south to north. The Subtropical Convergence passes through the Snares Island depression, 300 km south of Stewart Island, and northward along the eastern coast of the South Island where it forms the Southland Current (Heath 1985). Similarly, water flowing along the south-west coast of South Island flows eastward through Foveaux Strait, which is also subject to abnormally strong tidal currents (Heath 1985).

Stewart Island and its outlying islands encompass 175 819 ha, and have 756 km of coastline (Figure 1). The island is fully forested and over 85% of the area is protected within the Rakiura National Park. In 2004, a 1075 ha marine reserve in Paterson Inlet was established, extending the protection of Rakiura's largely pristine environment from land to sea. Paterson Inlet is one of the largest sheltered harbours in southern New Zealand, being comparable in size to Port Ross in the Auckland Islands and Port Pegasus on the southern side of Stewart Island.

The catchment area surrounding Paterson Inlet consists of relatively unmodified native forest producing clear water with a low sediment loading. This area provides a largely undeveloped, coastal environment hosting a diverse range of marine organisms unaffected by run-off and pollution from land development, notably including several species of brachiopod. The wide range of tidal current regimes present in Paterson Inlet, combined with a wide variety of hard and soft shore types, increases the potential for habitat and species diversity by providing a diverse mosaic of habit types. The algal flora of Stewart Island and Paterson Inlet represents the most diverse flora of any area in New Zealand (Adams *et al.*. 1974). Regions of Paterson Inlet not contained within the marine reserve were included in the Te Whaka a Te Wera Mataitai reserve established in 2005.

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

Human habitation of Stewart Island dates back to c.1270, but occupation appears only to have occurred intermittently (Sanson 1982). More permanent occupation of Rakiura by Maori had occurred by the time early contact was made with sealers and whalers in Foveaux Strait. Ruapuke Island and the shores of Stewart Island were a focus of interaction and inter-marriage between Europeans and Maori. During the early 1800s, sealing gangs encountering Maori were given a mixed reception, with some encounters being violent but the majority sufficiently amicable to allow for trade and even the integration of deserting or captured seamen into adopted tribes. Over time, marriage between local Maori women and early sealers and whalers created strong family and cultural links to Stewart Island.

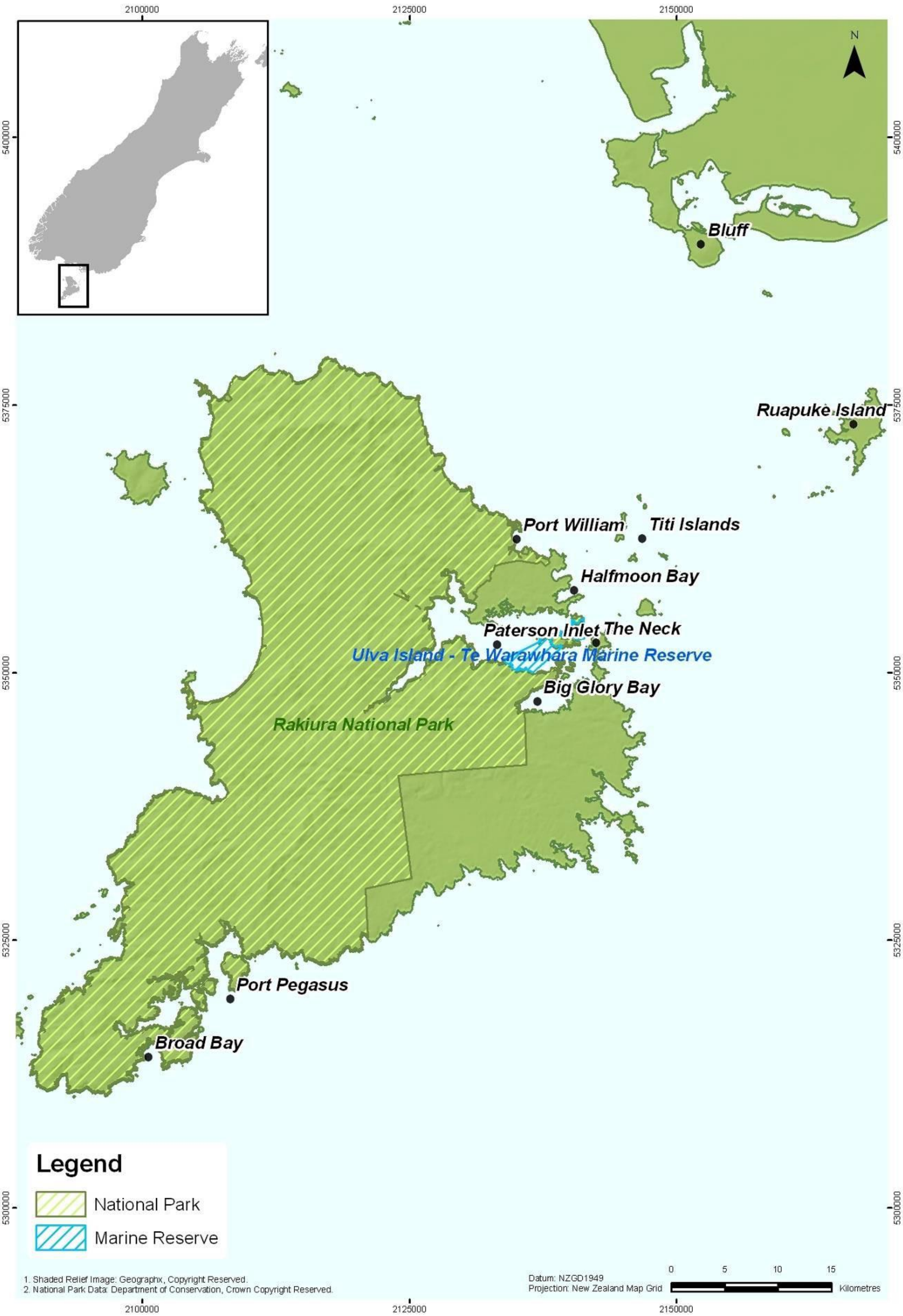

Figure 1: Map of Stewart Island; sampling was concentrated in the area in and near Paterson Inlet.

Maori and European both settled at The Neck until around 1864, when European settlement was no longer permitted there. Land was made available for European settlement at Halfmoon Bay, which remains the focus of settlement on Stewart Island to this day. Maori relocated from their island strong-hold on Ruapuke Island to The Neck after 1873, but the population declined after 1901 and the area was practically deserted by 1920.

Another region of early European settlement occurred about Port Pegasus, near the southern tip of Stewart Island. Sealers and their Maori wives settled at Broad Bay in the 1820s, establishing gardens that provisioned approximately 20 visiting vessels per year. Port Pegasus was settled by Captain William Stewart and associated ship-builders in 1826, resulting in the construction of the schooner *Joseph Weller*, the first vessel to be registered in New Zealand. A brief tin-mining venture brought 200 miners to the area and resulted in the establishment of New Zealand’s most southerly post office in 1889. By 1893, however, the venture had failed and the post office was closed. A brief revival in tin-mining in 1911-1912 also failed (Sanson 1982).

Initial European settlements and contacts were mainly concerned with sealing (1801-1850), and later with shore-whaling (1830-1880). Around 1840, Broad Bay became a trying-out depot (where blubber is rendered to oil) for whalers and Port William was the location of a shore whaling station from 1847 to 1851. During the 1920s the Norwegian Rosshavet whaling enterprise established a repair base at Prices Inlet.

Fishing was always a source of sustenance from the earliest times of human habitation on Stewart Island, but the sale of fish to mainland New Zealand and overseas has only occurred since the early 1860s, when a fishing station was established on the northern coastline of Stewart Island at Port William in 1862 (and later moved to Bunkers Island in Foveaux Strait in 1864). Beginning in 1867, Port William briefly became the centre of a dredge oyster fishery, until a reduction in stock resulted in the closure of the fishery (1877-1879). Bluff vessels continue to dredge oysters from Foveaux Strait, but stocks have been repeatedly depleted by Bonamiosis since the 1960s (Cranfield *et al.*. 1999). Further south, refrigerated fishing stations were established at Port Pegasus in 1897 and nearby Broad Bay in 1908 to supply markets in mainland New Zealand and Australia (Sanson 1982). A small but intermittent fishing community at Port Pegasus persisted through to the 1950s. Today, rock lobster, abalone and blue cod still provide a living for a few Stewart Island fishers, but reductions in fish stocks have seen a large reduction in the fishing fleet since the height of the fishery during the 1960s and 1970s. Tourism, fishing, and the addition of farmed salmon and mussels now provide the greatest source of employment to Stewart Island residents.

Early sealing and whaling vessels collected skins and oil from shore-based stations, as well as provisions sourced from local traders (e.g., at Broad Bay and The Neck). As fishing and mining industries established around Port Pegasus in the late 1800s and early 1900s, transport vessels regularly voyaged between Bluff and Port Pegasus to service the settlement and return with cargoes of refrigerated fish destined for New Zealand and Australian markets. Felling and milling of timber and boat building also supported trade throughout Stewart Island and with mainland New Zealand from 1861 to 1923. Vessels undoubtedly voyaged throughout Paterson Inlet and across Foveaux Strait in the course of servicing the many mills dotted about the inlet and the northern coastline of Stewart Island. Some of these vessels had a wide range of operations. The clipper schooner *Dolly Varden*, for instance, initially serviced Port Pegasus, Fiordland and the Chatham Islands, but later carried fish and passengers between Halfmoon Bay and Bluff, in opposition to the Stewart Island ferry *Theresa Ward* (Sanson 1982). Regular passenger and supply services between Halfmoon Bay and Bluff

Harbour appear to have been established at least by the late 1800s, and continue to this day with twice-daily passenger crossings by a catamaran and a regular freight service. Fishing vessels still cross Foveaux Strait regularly, but mainly for servicing as fish are now processed locally. Vessels regularly transport stock, feed, equipment and staff to mussel and salmon farms established in Big Glory Bay (e.g., Figure 2).

Figure 2: Salmon farm in Big Glory Bay, Stewart Island.

A traditional food source of Maori, the Sooty shearwater, titi or muttonbird (*Puffinus griseus*) forms large nesting colonies on small islands on the north-east and south-west of Stewart Island. The islands are owned by individual hapu, who make annual voyages to harvest young birds between April and May (Anderson 1998). Muttonbirding continues to be a seasonal industry to this day with a small number of vessels transporting people, supplies and produce between the Titi Islands, Bluff and Stewart Island.

Passenger and charter vessels associated with tourism now represent the major source of vessel movements about Stewart Island. Along with Department of Conservation (DOC) vessels used to transport staff, equipment and supplies about the island, water taxis regularly transport tourists, hunters and trampers about Paterson Inlet. Charter vessels conduct sight-seeing and fishing tours throughout the island and, in recent years, international cruise ships have visited the island and entered Paterson Inlet.

3. Review of Existing Biological Information

3.1. OVERVIEW

Records of the marine biology of Stewart Island comes mainly from literature describing and reassigning the taxonomic classifications of marine species (e.g., O'Loughlin *et al.*. 2002, 2000, Forest & McLay 2001, O'Loughlin & Alcock 2000, Nelson 1999, Glasby & Read 1998, Nelson & Philips 1996, Adams 1983, Murdoch 1982, Fenwick & Horning 1980, Fenwick 1978, Fincham 1974, Neall 1970, Kensler 1967) and reporting new occurrences or range extensions of species known from elsewhere in New Zealand (e.g., Broom *et al.*. 1999, Adams 1991, MacKenzie 1991, Nelson 1987, Jansen 1973). Other records of marine species in this area have come from investigations of species' biological characteristics such as the attributes of reproduction and growth rates (e.g., Hepburn *et al.*. 2007, Breen & Booth 1989, Annala & Bycroft 1985, McKoy 1985, 1983). There is little published and recent literature that describes benthic or other marine assemblages occurring on or near Stewart Island, with the exception of a recent discovery of patchy biogenic reefs in Big Glory Bay, which were created by serpulid worms and inhabited by a range of fauna (Smith *et al.*. 2005). Based on these and other references, a description of the marine ecology of Stewart Island follows. A species database created as part of this survey also includes a comprehensive list of marine species recorded previously (including records from the New Zealand Oceanographic Institute Memoirs) and during the current port survey at Stewart Island.

3.2. ALGAL RECORDS

In comparison to all other marine taxa recorded at Stewart Island, algal species are well-represented in the published literature with the majority of work concerning both native and non-indigenous seaweeds. Lists from Adams (1983) and Nelson & Philips (1996) provide a basis for describing the flora of New Zealand, including Stewart Island. This information is further updated by several publications, notably Nelson (1999), Nelson & Maggs (1986), Adams (1994, 1991) and Nelson (1987). Parsons (1985) also provides an overview of the number of algal species recorded for the area. Table 1 lists some of the algal species recorded at Stewart Island.

Parsons (1985) reported that 379 species of seaweed had been recorded at Stewart Island prior to 1987, which included 58 species of Chlorophycaea, 87 species of Phaeophyceae and 234 species of Rhodophyceae. This indicates a high diversity of marine flora for the area (e.g., Figure 3). Given that Stewart Island's coastline covers approximately 210 km or less than 7% of the South Island coastline, it has a comparably high number of algal species. Common areas for the collection of marine flora include coastal sites in Pegasus Harbour, Halfmoon Bay and Paterson Inlet and, more specifically, in Whale Passage, Hell's Gate, Blind Passage, Leask's Bay, Chris's Bay, Horseshoe Bay, Cunning Cove, at Wast's Point, Tin Mine Beach, Lonnecker's Nugget, The Neck, and Pearl Island (Nelson & Philips 1996). Several of the species found at Stewart Island are endemic to New Zealand, such as *Gracilaria sordida* (Nelson 1987; which is found in harbours, estuaries and moderately exposed open coasts on rocks, pebbles and shells in the intertidal zone), *Dictyota papenfussi* (Nelson *et al.*. 2004, Adams 1994) and *Apophlaea lyalli* (Saunders & Bailey 1999).

Table 1: Algal species found at Stewart Island (from Nelson & Philips 1996, Adams 1983).

Phylum	Species	Phylum	Species
Bacillariophyta	*Cladophora feredayi*	Rhodophyta	*Chrysymenia (?) polydactyla*
	Cladophora sericea		*Curdiea flabellata*
	Cladophora verticillata		*Dasya collabens*
	Wittrockiella lyallii		*Dasyclonium adiantiformis*
Chlorophyta	*Bryopsis vestita*		*Dasyclonium bipartitum*
Ochrophyta	*Asperococcus bulbosus*		*Dasyptilon pellucidum*
	Cladostephus spongiosus		*Delesseria crassinervia*
	Cutleria multifida		*Delesseria nereifolia*
	Cystophora platylobium		*Delisea plumosa*
	Cystophora scalaris		*Erythroglossum undulatissimum*
	Durvillaea willana		*Euptilota formosissima*
	Halopteris novae-zelandiae		*Gigartina pachymenioides*
	Halopteris paniculata		*Gigartina sp.*
	Herpodiscus durvilleae		*Gloiocladia saccata*
	Herponema maculaeforme		*Griffithsia antarctica*
	Herponema maculaeforme		*Griffithsia crassiuscula*
	Leathesia novae-zelandiae		*Gymnothamnion elegans*
	Macrocystis pyrifera		*Helminthocladia australis*
	Marginariella boryana		*Heterosiphonia concinna*
	Marginariella urvilliana		*Hymenena curdieana*
	Pilayella littoralis		*Hymenocladia sanguinea*
	Ptilopogon botryocladus		*Iridaea lanceolata*
	Punctaria latifolia		*Laungia hookeri*
	Sargassum verruculosum		*Lenormandia chauvinii*
	Scytohamnus australis		*Marionella prolifera*
	Scytothamnus fasciculatus		*Metamorphe colensoi*
	Spatoglossum chapmanii		*Microcladia novae-zelandiae*
	Sphacelaria implicata		*Myriogramme crispata*
	Sphacelaria stewartensis		*Nothogenia pseudosaccata*
	Sphacelaria tribuloides		*Pachymenia lusoria*
	Sphacelaria variabilis		*Phitymophora linearis*
	Sporochnus stylosus		*Polysiphonia abscissoides*
	Sporochnus stylosus		*Polysiphonia brodiei*
	Striaria attenuata		*Polysiphonia muelleriana*
	Undaria pinnatifida		*Polysiphonia sertularioides*
	Xiphophora gladiata novae-zelandiae		*Porphyra subtumens*
Rhodophyta	*Aeodes nitidissima*		*Ptilonia willana*
	Anotrichium crinitum		*Pugetia delicatissima*
	Apoglossum oppositifolium		*Rhodymenia novazelandica*
	Apophlaea lyallii		*Sarcodia flabellata*
	Brongniartella australis		*Schizymenia novae-zelandiae*
	Callophyllis hombroniana		*Stictosiphonia vaga*
	Callophyllis ornata		*Thamnophyllis laingii*
	Champia affinis		*Webervanbossea tasmanensis*
	Chordaria cladosiphon		

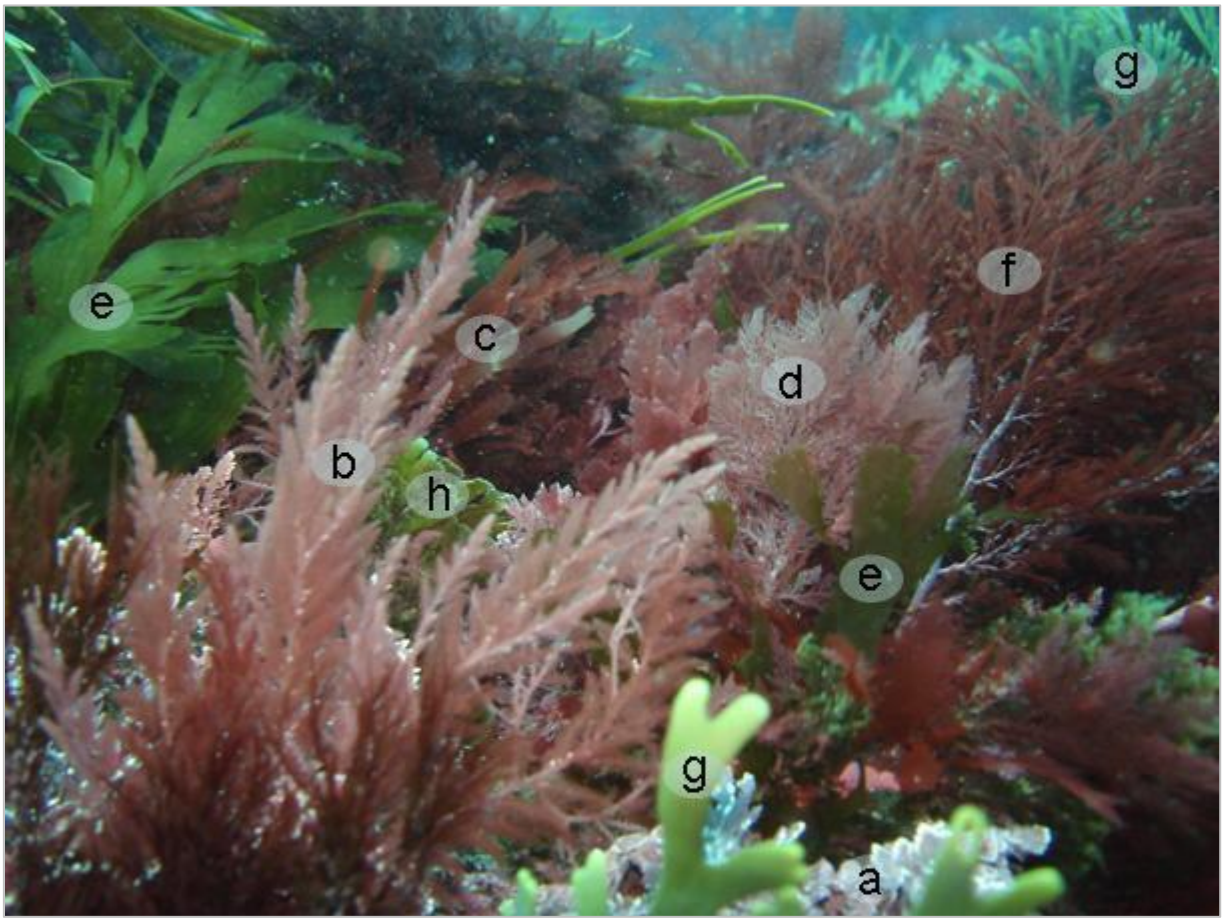

Figure 3: Example of the diverse marine algal flora found at Stewart Island, including (a) *Arthrocardia corymbosa*, (b) *Asparagopsis armata*, (c) *Hymenena palmata*, (d) *Plocamium cirrhosum*, (e) *Spatoglossum chapmanii*, (f) *Streblocladia glomerulata*, (g) *Xiphophora gladiata* and (h) *Zonaria turneriana.*

Much of the literature concerning Stewart Island algae describes non-indigenous and adventive species of seaweed (Nelson 1999, Cranfield *et al.*. 1998, Adams 1991, 1983). Owing to a long and active history of whaling and sealing in this region of New Zealand many species of marine algae have established around the island. In particular, non-indigenous species previously known in the area include *Champia affinis, Cutleria multifida, Griffithsia crassiuscula, Polysiphonia brodiei, P. sertularioides, P. subtilissima, Punctaris latifolia, Sargassum verruculosum, Striaria attenuata* and more recently *Undaria pinnatifida*. Some of these species, such as *P. brodiei* and *P. strictissima* are commonly found attached to wooden structures in busy port areas and are widely ranging throughout New Zealand (Adams 1991). First detected in Wellington in 1987, *U. pinnatifida* is the most serious algal pest species found in New Zealand and there has been significant efforts made to manage the invasive populations of this species.

The phytoplankton fauna of Big Glory Bay has also been investigated in relation to a plankton bloom that occurred in January 1989, which was thought to be associated with Chinook salmon farming in the bay (Chang *et al.*. 1990). The dominant species was *Heterosigma* cf. *akashiwo*, which was the first record of this organism in New Zealand. Other plankton species recorded during this time are listed in Table 2.

Table 2: Phytoplankton found at Big Glory Bay, Stewart Island in 1989 (from Chang *et al.*. 1990).

Class	Species	Class	Species
Raphidophyceae	*Heterosigma* cf. *akashiwo*	Dinophyceae	*Dinophysis acuta*
Prasinophyceae	*Pyramimonas* sp.		*Polykrikos schwartzii*
Prymnesiophyceae	*Chrysochromulina* sp.		*Ceratium furca*
Cryptophyceae	*Cryptomonas* sp.		*Gonyaulax polygramma*
Chrysophyceae	*Distephanus speculum*		*Scrippsiella* sp.
	Paraphysomonas imperforata		*Protoperidinium* sp.
Euglenophyceae	*Euglena* sp.		*Prorocentrum balticum*
Bacillariophyceae	*Nitzschia pseudoseriata*		*Amphidinium* sp.
	Skeletonema costatum		*Gymnodinium* spp.
	Leptocylindrus danicus		*Gyrodinium* sp.
	Chaetoceros sp.		
	Nitzschia longissima		
	Navicula sp.		
	Eucampia zodiacus		
	Thalassiosira sp.		
	Thalassiothris nitzschioides		

3.3. CRUSTACEANS

The crustacean fauna of Stewart Island has also been relatively well-described including Fincham's (1974) investigation of the peracarid fauna of the area (i.e., cumaceans, amphipods, isopods and tanaidaceans) and species listed in Webber & Wear (1981). Other information has been gathered from literature such as Forest & McLay's (2001) review of New Zealand's hermit crab fauna and studies of rock lobster (Breen & Booth 1989, Annala & Bycroft 1985, McKoy 1985, 1983, Kensler 1967), other New Zealand decapods (Thompson & McLay 2005, McLay & Osborne 1985, Fenwick 1978, Wear 1968) and ostracods (Swanson 1979). Predominant members of the crustacean fauna include hermit crabs from the genera *Paguristes, Propagurus, Bathypaguropsis, Diacanthurus, Porcellanopagurus, Lophopagurus, Pagurus* and *Parapagurus* (Forest & McLay 2001), and of the crab species from the Majidae family, such as *Notomithrax peronii, N. minor, Leptomithrax longimanus* and the southern spider crab *Jacquinotia edwardsii* (Webber & Wear 1981). Another brachyuran, *Heterozius rotundifrons*, which is endemic to New Zealand, has been the subject of reproductive studies conducted from Halfmoon Bay on Stewart Island (Thompson & McLay 2005).

3.4. ECHINODERMS

Another group of organisms that has been relatively well-covered in the available literature is the Echinodermata, with most records being noted from Fenwick & Horning's (1980) list of echinoderms from the Snare Islands and various work on cushion stars and holothurians by O'Loughlin *et al.* (2002), O'Loughlin (2000) and O'Loughlin & Alcock (2000). Notable species include asteroids such as *Allostichaster insignis, Calvasterias suteri, Sclerasterias mollis, Patiriella regularis, Odontaster benhami*, the cosmopolitan ophiuroid genus *Amphiura* spp., holothuroids *Trochodota dunedinensis* and *Oncus brevidentis* (Fenwick & Horning 1980) and the echinoid *Evechinus chloroticus* (Mladenov *et al.*, 1997).

3.5. BIOGENIC REEFS

More recently Smith *et al.* (2005) described an assemblage associated with serpulid reefs of *Galeolaria hystrix* discovered in Big Glory Bay, Paterson Inlet. Approximately 114 reefs were identified within an area of 28 000 km^2 and are reported to support a wide variety of taxa including algae, sponges, other annelids, molluscs, crustaceans, bryozoans, echinoderms, a brachiopod, and ascidians (Table 3). Several fish species, including blue cod (*Parapercis colias*), spotted wrasse (*Notolabrus celidotus*), pigfish (*Congiopodus leucopaecilus*), red cod (*Pseudophycia bachus*), butterfly perch (*Caesioperca lepidoptera*) and triple fins (family Tripterygiidae) were abundant in the vicinity of the reefs and skate (*Raja nasuta*) and shark egg cases were commonly found attached to reefs.

Table 3: Marine taxa found in association with *Galeolaria hystrix* reefs in Big Glory Bay, Stewart Island (from Smith *et al.* 2005).

Taxa	Species	Taxa	Species
Algae	*Lenormandia chauvinii*	Molluscs	*Astera heliotropium*
	Rhodymenia spp.		*Aulacompya ater maoriana*
Porifera			*Barbatia novaezelandiae*
Coelenterata	*Actinia* sp.		*Buccinulum* sp.
	Ceruanthus sp.		*Chlamys* spp.
Annelida	*Eunice* sp.	Molluscs	*Maoricolpus roseus*
	Salmacina sp.		*Octopus maorum*
	Potamoceros sp.	Echinodermata	*Chirodota nigra*
	Serpula sp.		*Evechinus chloroticus*
Crustacea	*Ebalia laevis*		*Ophiomyxa brevirima*
	Notomithrax peronii		*Stichopus mollis*
	Eurynolambrus australis	Ascidiacea	*Astrocarpa* sp.
Bryozoa			*Aplysila suplhurea*
Brachipoda	*Notosaria nigricans*		*Cnemidocarpa bicornuta*

4. Survey Methods

4.1. SURVEY DESIGN AND SAMPLING METHODS

4.1.1. Survey design

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 Stewart Island 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 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. Data records for each site are provided in Appendix A.

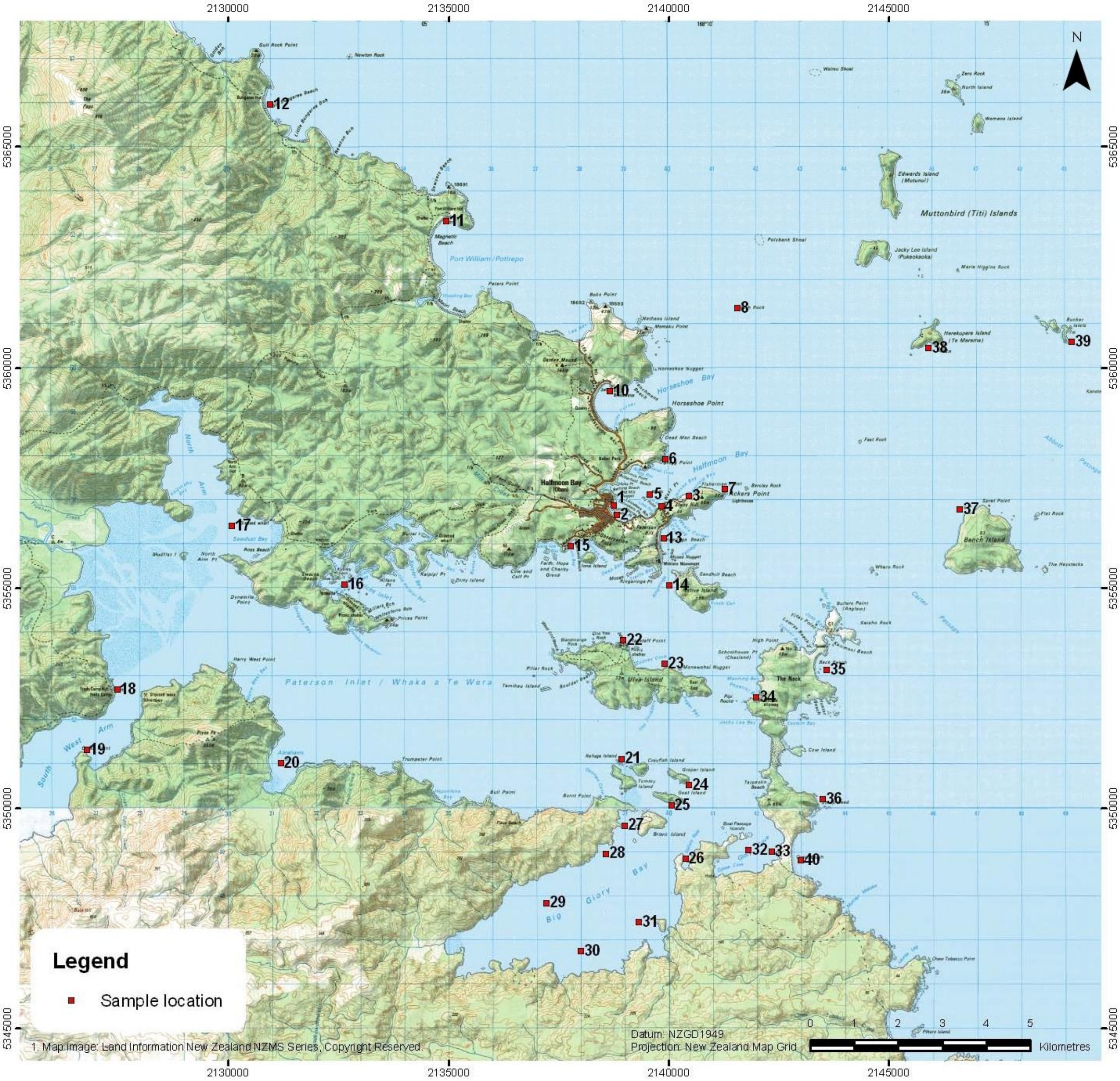

Figure 4: Location of sample sites during the Stewart Island port survey.

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

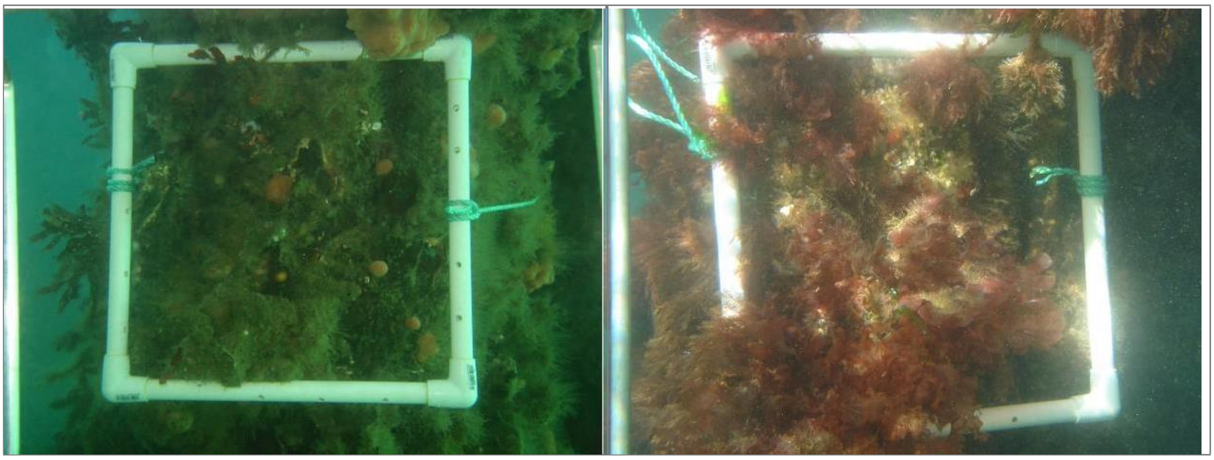

Figure 5*: In situ* photographs of quadrats sampled using the pile scraping method.

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).

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.

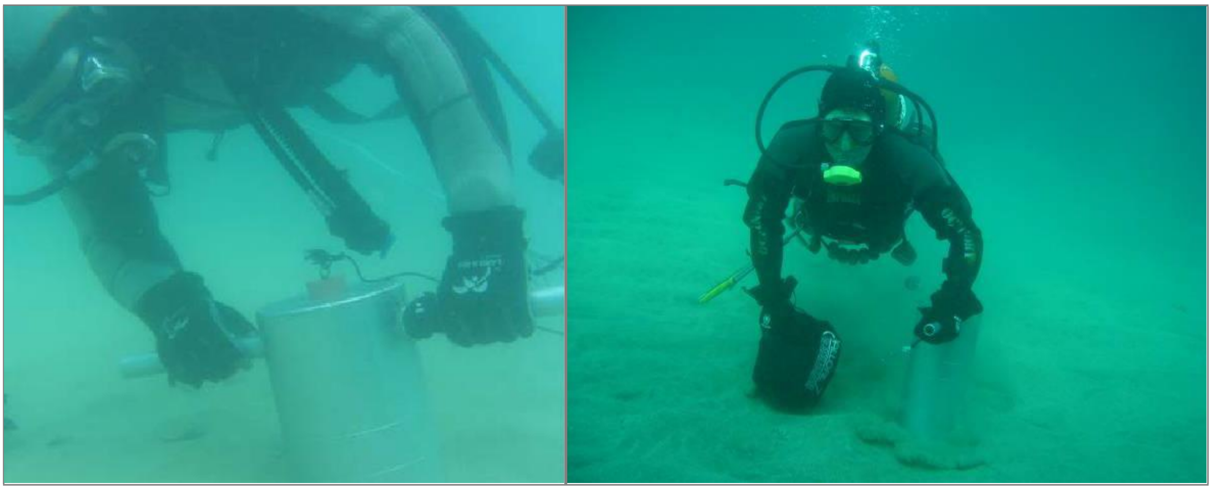

Figure 7: Divers deploying the infaunal core; the contents of each core was emptied into a nylon bag *in situ* (black bag in divers hand; right).

Dinoflagellate cyst sampling

A gravity or 'javelin' corer was used to collect small sediment cores for dinoflagellate cysts (Figure 8). The corer consisted of a 1.0 m long hollow stainless steel shaft with a detachable 0.5 m long head. The shaft was 150 mm in diameter and a perspex core tube (120 mm diameter) was inserted into the head to retain the sediment sample. Four fins were attached to the end of the shaft to aid in directing the javelin corer vertically through the water so that the device penetrated the sediment from an upright position. The javelin was weighted with lead internally and the head was tapered for penetration of unconsolidated sediments to a depth of 200 to 300 mm. On retrieval, the perspex tube was removed from the spearhead and retained for analysis according to MITS protocols.

In many situations the javelin corer was not effective at collecting samples; for undetermined reasons the sediment samples were not adequately retained within the perspex tube on retrieval. The corer was weighted with additional lead flashing to ensure that the spearhead penetrated the substrate in an upright position, although this still did not always ensure the collection of a suitable sample (see Figure 8, right). Samples were transferred to plastic containers and handled according to MITS protocols. In situations when the javelin corer repeatedly failed to collect a sample, sediment samples were collected as for sediment samples and transferred to plastic containers and handled according to MITS protocols.

Figure 8: Field staff retrieving a sediment sample from the javelin core used for collection of dinoflagellate cyst samples during the Stewart Island survey, September 2006 (left). Additional weight was added for use in stronger currents (right).

Plankton netting

Phytoplankton samples were collected by vertical drops of a hand-deployed plankton net (20 µm mesh, 250 mm diameter aperture) (Figure 9, left). Zooplankton samples were collected by vertical drops of a hand-deployed zooplankton net (100 µm mesh, 700 mm diameter aperture) (Figure 9, 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 9: 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 10) 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.

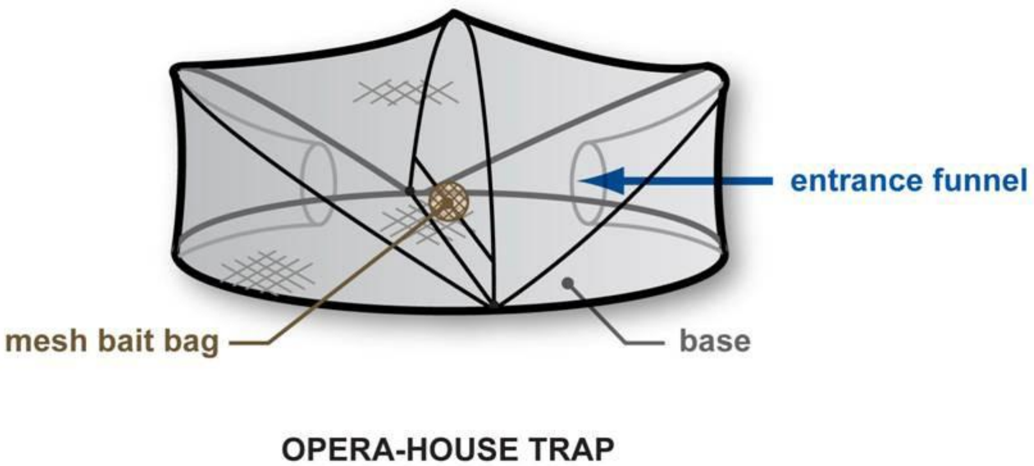

Figure 10: Diagram of an opera house crab trap.

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 11, foreground). 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 11, background). Items that were searched for included crab exuviae, sponges and remnants of unusual or rare species.

Figure 11: Beach seining and beach wrack searches on the nearshore.

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 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).

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 fieldworker's 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 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 4).

Table 4: 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 the MAFBNZ port survey of Stewart Island (Paterson Inlet). 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 Stewart Island Field Office staff.
3. Environment Southland Harbourmaster – preliminary notification of activities.
4. Bluff Maritime Radio –nightly notification of activities.
5. Stewart Island News –placement of a story within the monthly newsletter notifying local residents of the survey.
6. Te Rūnanga o Ngāi Tahu – liaison with Mr. Nigel Scott, Environmental Advisor (Hī Ika/Ngāherehere); notification of the survey and request to collect samples within the bounds of Te Whaka ä Te Wera/ Paterson Inlet Mätaitai Reserve.

Informal discussion with local residents on the survey was also conducted when onsite. Onsite liaison with aquaculture farmers was also conducted during survey of the aquaculture sites within Big Glory Bay

5. Survey Results

5.1. PORT ENVIRONMENT

Environmental data collected during the Stewart Island survey included measurements of water temperature, salinity, dissolved oxygen, substrate type, visibility and maximum depth at each site. This information is summarised in Table 5.

Sea water temperature varied little throughout the region (Figure 12), ranging from 10.4 to 13°C with an overall average of 11.4°C. Water temperatures measured at the sea surface were slightly warmer by approximately 0.2°C than temperatures recorded near the sea floor, and the water column was well mixed during the sampling period.

Salinity was variable throughout the study region (Figure 13) with the lowest salinities recorded at Sites 1-7 in Halfmoon Bay (possibly indicating higher freshwater input into the bay) while the highest salinities were recorded at Fish Rock and Oyster Shoal (Site 8) and West Head jetty (Site 11), which were situated in areas remote for regular human use (and are less likely to have high freshwater input). Salinity was also marginally elevated in the vicinity of Big Glory Bay salmon farms (Sites 30-34). Overall, salinity ranged from 9 to 30.9 psu, with an average of 16.8 psu recorded over the survey area.

Dissolved oxygen (DO) was also variable throughout the study area (Figure 14) with the lowest DO recorded in the offshore and coastal areas that had the highest salinity readings (i.e., Fish Rock, Oyster Shoal and West Head jetty). The highest DO measurements were made in surface waters in the vicinity of Big Glory Bay marine farms and near the Halfmoon Bay jetty. Overall, DO ranged from 8.39 to 20.00 mg/L, with an average of 13.40 mg/L for the study area. 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 encountered during the survey is between 8.5 and 10.2 mg/L. The higher values recorded during the survey therefore raise concerns over the validity of these readings.

The depths of sampling sites varied from 2 m in the vicinity of wharves and jetty structures to 27 m in Big Glory Bay (Table 5). The average water depth at sites visited during the survey was 8 m.

Table 5: Physical data (water temperature, salinity, dissolved oxygen, visibility, maximum depth and substrate type) recorded during the Stewart Island survey, September 2006.

Site No.	Site Name	Temperature (°C)		Salinity (psu)		Dissolved Oxygen (mg/L)		Visibility (% of Depth)	Depth (m)	Substrate Type
		Surface	Bottom	Surface	Bottom	Surface	Bottom			
1	Halfmoon Bay wharf	11.6	11.8	13.8	14.4	20.00	14.17	100	4	mud
2	Halfmoon Bay slipway	11.6	11.8	13.8	14.4	20.00	14.17	100	2	mud
3	Harrold Bay	11.5	11.5	11.4	12.6	12.54	12.33	100	5	sand
4	Leask Bay	11.5	11.3	12.2	12.6	14.17	12.71	100	4	sand
5	Big Rock	11.5	11.3	12.2	12.6	14.17	12.71	100	9	sand
6	Bragg Point	11.7	11.4	12.2	12.2	14.82	12.52	-	8	sand
7	Ackers Point	11.6	11.3	13.3	13.2	13.33	12.52	100	8	sand
8	Fish Rock & Oyster Shoal	11.4	11.4	30.9	30.9	9.45	8.90	-	12	sand
10	Horseshoe Bay jetty	11.7	11.3	10.1	10.9	13.08	12.44	100	2	sand
11	West Head jetty (Port William)	11.7	11.5	30.8	30.8	8.39	9.61	100	2	sand, shell, mud
12	Big Bungaree Beach	11.2	11.3	13.5	13.8	15.64	13.93	100	5	sand
13	Ringaringa Beach	11.6	11.3	13.3	13.2	13.33	12.52	-	5	sand
14	Native Island	11.3	11.2	19.7	20.2	14.52	15.00	-	5	sand
15	Golden Bay wharf	11.2	11.1	20.5	20.4	16.00	16.49	-	3	sand
16	Prices Inlet	13.0	11.6	17.9	18.8	15.50	14.12	100	4	-
17	North Arm	10.4	10.8	13.8	14.4	15.05	13.15	-	5	sand
18	Southwest Arm jetty (Fred's Camp)	12.1	11.2	16.7	19.5	11.30	11.22	-	5	-
19	Ogles Point	12.4	11.8	20.1	22.1	14.30	12.12	100	3	-
20	Abrahams Bay	12.4	11.8	20.1	22.1	14.30	12.12	100	5	-
21	Refuge Island	11.2	11.1	16.8	18.5	13.55	12.70	-	10	-
22	Ulva Island jetty	11.3	11.2	19.7	20.2	14.52	15.00	100	5	sand
23	Sydney Cove, Ulva Island	11.3	11.2	13.8	14.4	14.52	15.00	-	5	sand
24	Groper Island	11.2	11.1	16.8	18.5	13.55	12.70	-	12	-
25	Goat Island	11.2	11.1	16.8	18.5	13.55	12.70	-	10	-
26	Big Glory Bay anchorage 1 (Sailor's Rest)	12.0	11.0	14.2	16.4	12.57	12.90	-	3	sand
27	Big Glory Bay anchorage 2	11.2	11.1	16.8	18.5	13.55	12.70	-	4	sand

Table 5: continued

Site No.	Site Name	Temperature (°C)		Salinity (psu)		Dissolved Oxygen (mg/L)		Visibility (% of Depth)	Depth (m)	Substrate Type
		Surface	Bottom	Surface	Bottom	Surface	Bottom			
28	Big Glory Bay farm 1	11.5	10.9	15.6	19.1	15.83	13.87	-	25	sand
29	Big Glory Bay farm 2	11.2	10.7	13.2	14.8	14.55	13.89	50	20	mud
30	Big Glory Bay farm 3 (Salmon Farm)	11.7	11.2	19.0	20.0	18.76	13.86	37	27	mud
31	Big Glory Bay farm 4 (The Nugget)	11.7	11.2	19.0	20.0	18.76	13.86	37	20	mud
32	Glory Cove anchorage	11.6	11.4	19.1	19.5	14.22	12.97	75	10	-
33	Glory Cove jetty	11.7	11.5	18.9	19.5	15.08	13.81	-	3	-
34	The Neck	10.8	10.8	15.5	16.1	14.53	13.59	100	3	sand
35	Bradshaw Peninsula	11.2	11.3	12.1	12.9	12.68	11.77	-	10	sand
36	Steep Head	11.2	11.3	12.1	12.9	12.68	11.77	-	12	-
37	Bench Island	11.4	11.5	13.1	13.2	13.64	12.30	100	12	-
38	Herekopare Island	11.2	11.2	9.0	10.5	10.27	9.78	-	5	sand
39	Bunker Islets	11.3	11.2	Variable	12.3	10.94	10.66	-	12	-
40	Ocean Beach	11.2	11.3	12.1	12.9	12.68	11.77	-	5	-
	Average	**11.5**	**11.3**	**16.4**	**17.2**	**13.99**	**12.73**	**89**	**8**	
	Minimum	**10.4**	**10.7**	**9.0**	**10.5**	**8.39**	**8.90**	**37**	**2**	
	Maximum	**13.0**	**11.8**	**30.9**	**30.9**	**20.00**	**16.49**	**100**	**27**	

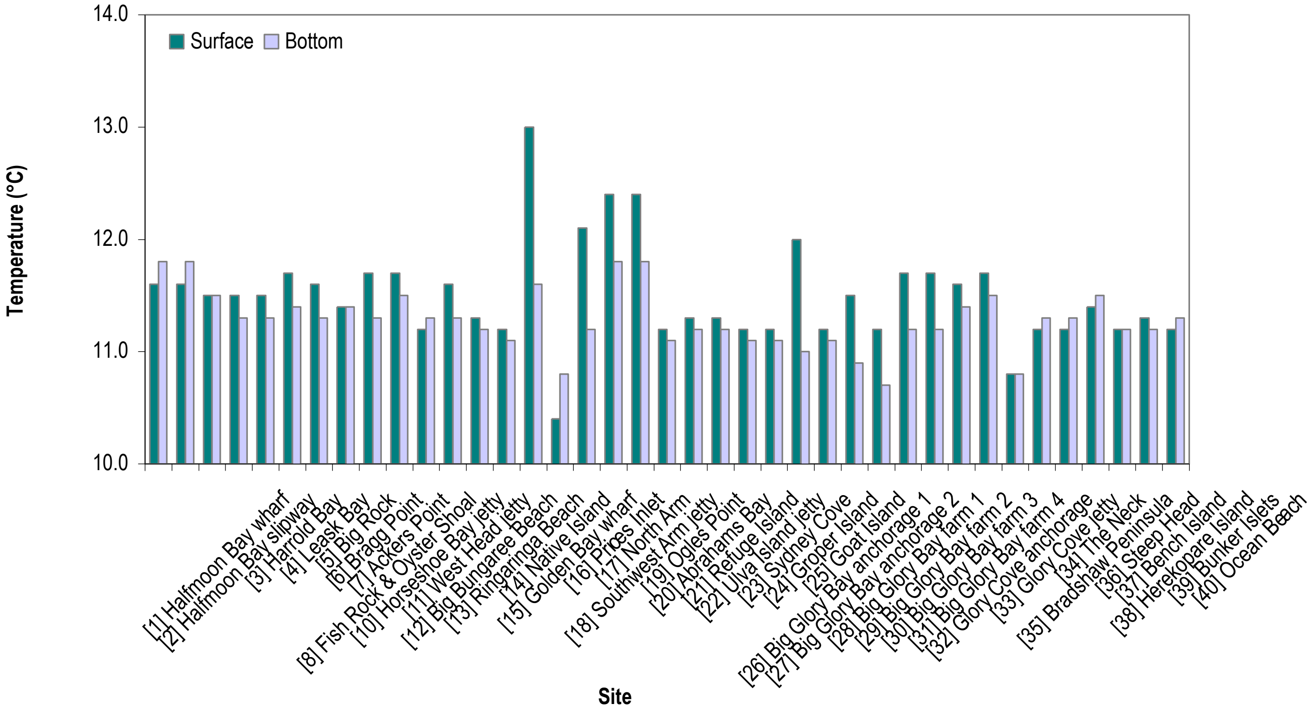

Figure 12: Water temperatures recorded during the Stewart Island survey, September 2006. Dark shading denotes sea surface readings and light shading demotes readings taken near the sea floor.

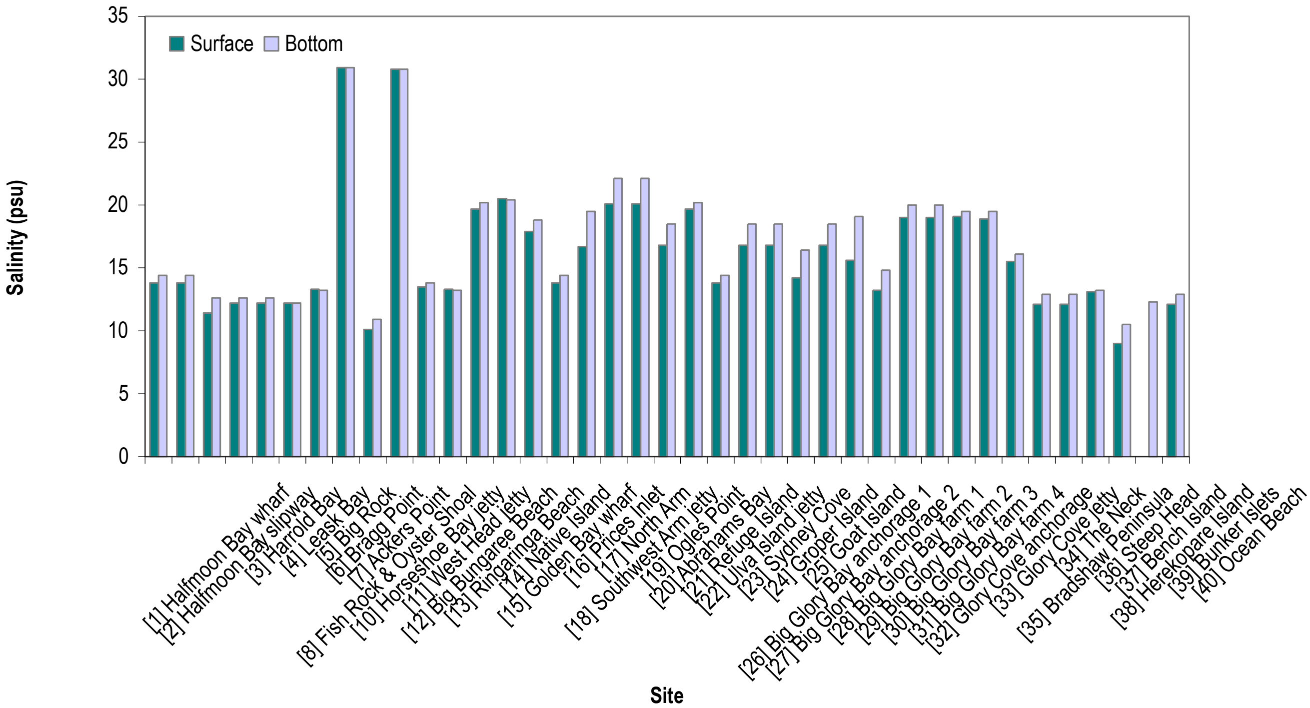

Figure 13: Salinity recorded during the Stewart Island survey, September 2006. Dark shading denotes sea surface readings and light shading demotes readings taken near the sea floor.

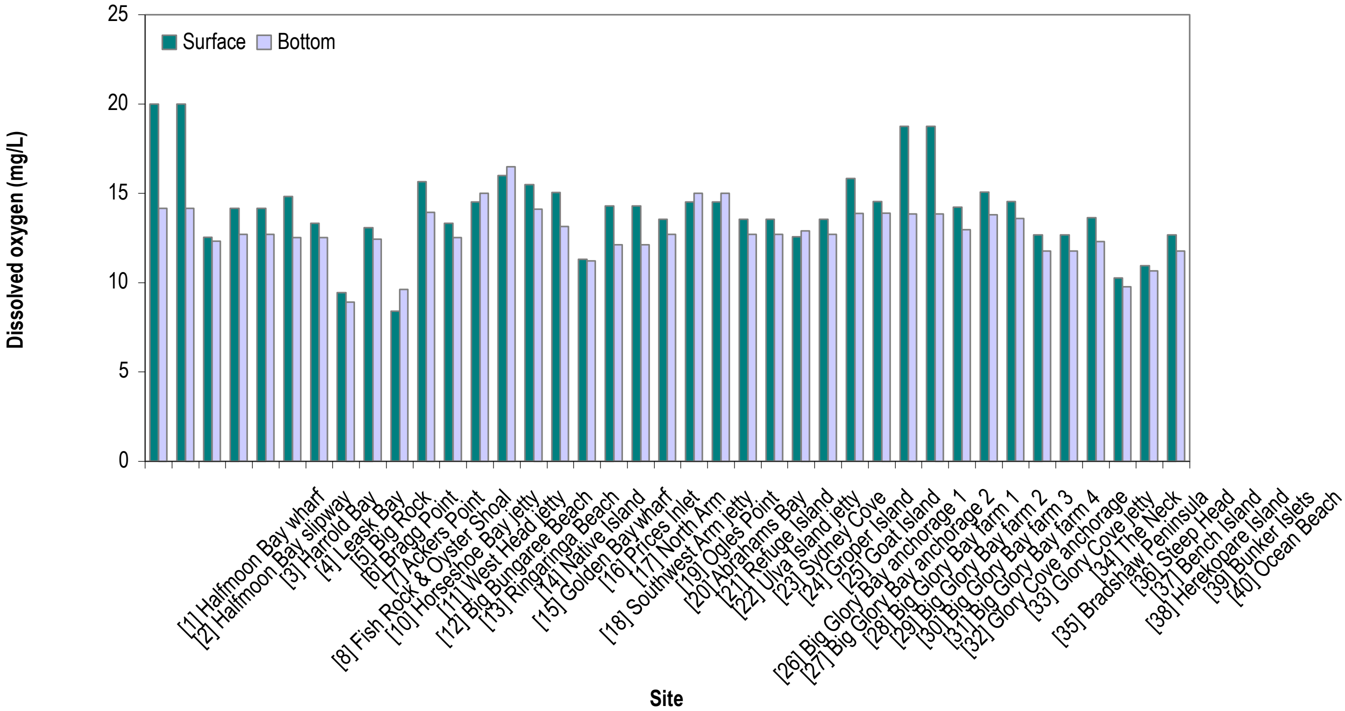

Figure 14: Dissolved oxygen levels recorded during the Stewart Island survey, September 2006. Dark shading denotes sea surface readings and light shading demotes readings taken near the sea floor.

On average the visibility represented 89% of the water depth, indicating high water clarity around Stewart Island. This was also supported by the water clarity as viewed from the surface, with divers and the substrate often visible (e.g., Figure 15).

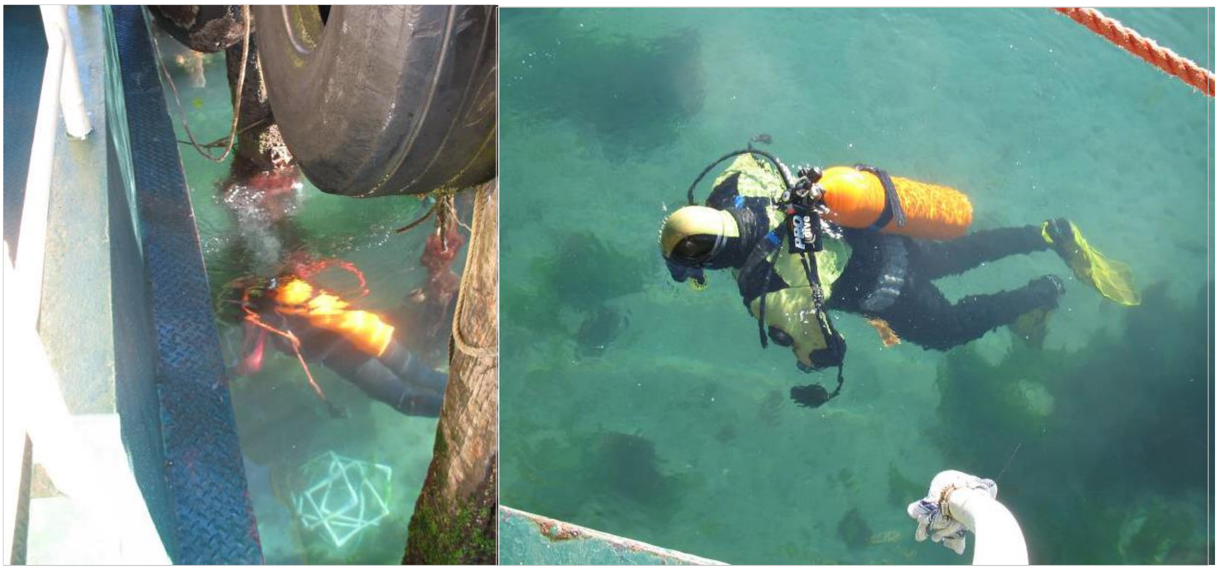

Figure 15: Sample collection by divers during the Stewart Island port survey, with the seafloor visible indicating high water clarity.

Sediment samples collected at each site were assessed for total organic content (g/100g dry weight) (Figure 16) and for the proportions of silt/mud (< 63 µm grain size), sand (63 µm to 2 mm) and gravel (> 2mm) (Figure 15). Substrates at Prices Inlet (Site 16) had the highest organic content while Fish Rock (Site 8) and Achers Point (Site 7) also had relatively elevated levels of organic input. These sites, as with all sites at Stewart Island, had soft substrates that were largely composed of sandy sediment. Abrahams Bay (Site 20) in the inner reaches of Paterson Inlet had a relatively high fraction of coarse gravel while Site 31 in close proximity to the Big Glory Bay fish farm had a relatively high proportion of mud and silt.

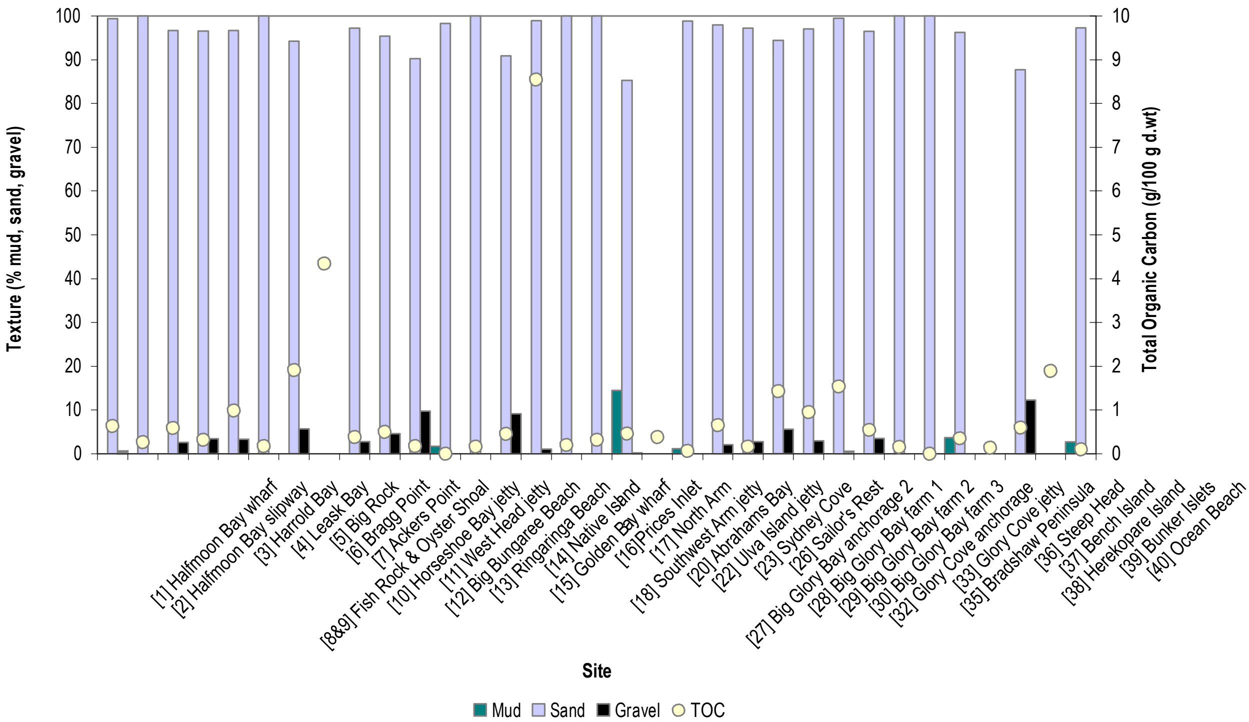

Figure 16: Proportion of mud (<63 µm grain size), sand (63 µm – 2 mm) and gravel (> 2 mm) and total organic carbon from sediment samples collected during the Stewart Island port survey, September 2006. (Note that sediment samples at Sites 8&9, 22, 39 and 39 were not sufficiently to assess grain size proportions).

5.2. NATIVE BIODIVERSITY

A total of 527 taxa (determined to Class level or below) were identified from the Stewart Island survey collection, of which 71.15% (*n* = 375) were determined to be indigenous or endemic to New Zealand (Figure 17, Appendix C). Ninety-eight taxa could not be identified to species level.

Of the native fauna, Mollusca was the most diverse group comprising 17.60% of all native species collected. Other dominant faunal and floral taxonomic groupings included Annelida, Arthropoda and Rhodophyta (14.13% each), and Bryozoa (11.47%). Other taxonomic groups of species collected during the survey included (in order of highest to lowest taxonomic diversity) Ochrophyta (8.00%), Echinodermata (4.35%), Ascidiacea (3.73%), Porifera (2.40%), Actinopterygii (3.73%), Dinophyta (2.13%), Bacillariophyta (1.07%), Cnidaria and Phoronida (0.80% each), Chlorophyta and Brachipoda (0.53% each), Mangnoliphyta (0.27%).

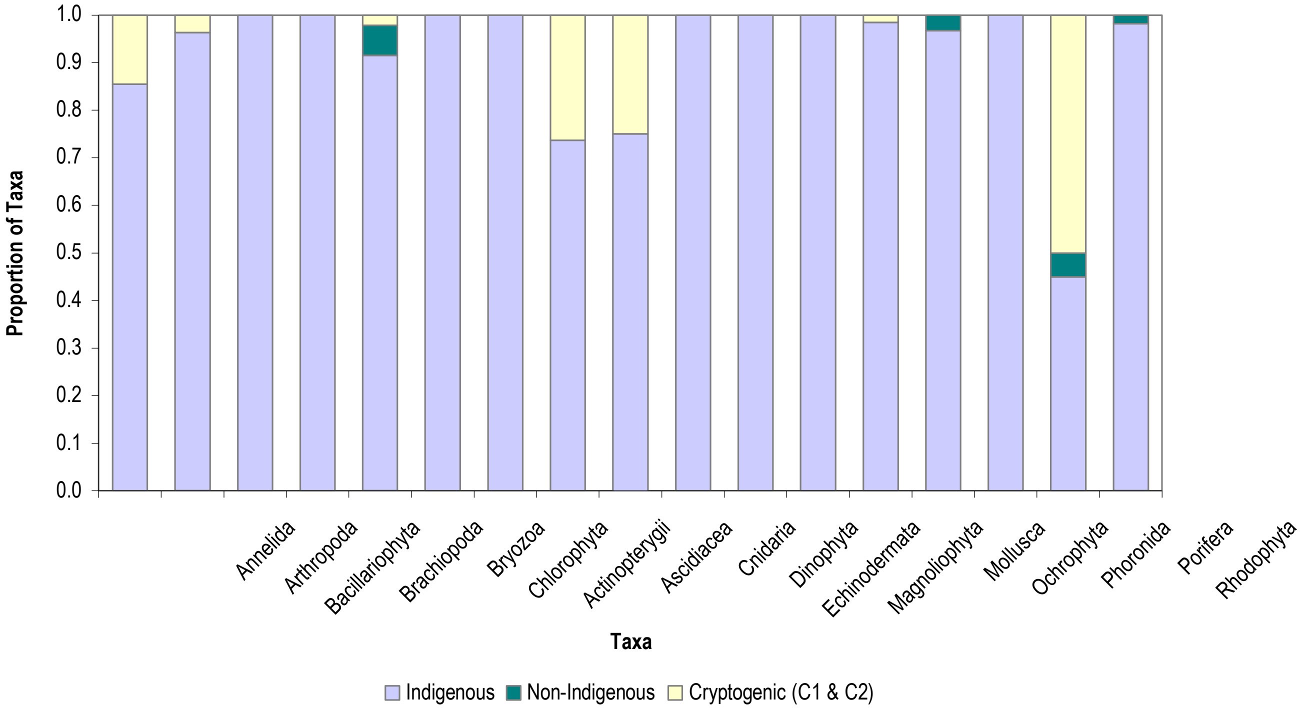

Figure 17: Proportion of species diversity for taxonomic groups detected during the Stewart Island survey, September 2006.

5.3. NON-INDIGENOUS SPECIES IN THE PORT

5.3.1 Overview

Six non-indigenous species and 14 cryptogenic category 1 species were detected during the survey (Table 6), representing 1.13% and 2.7%, respectively, of the 527 taxa collected that were identified to Class level or below. Non-indigenous and cryptogenic species were detected at 47.5% of the sites sampled (n = 40 sites; Figure 18). No non-indigenous or cryptogenic species were considered rare owing to the low incidence of indigenous species (Figure 19). Five non-indigenous or cryptogenic category 1 species occurred occasionally, eight species can be considered common, and the remaining seven non-indigenous or cryptogenic species were considered to be abundant during the Stewart Island port survey.

Table 6: Non-indigenous and cryptogenic marine species detected during the Stewart Island survey, September 2006.

Species Status	Biosecurity Status	Species
Non-Indigenous	Known introduced	*Bugula flabellata*
		Champia affinis
		Cryptosula pallasiana
		Undaria pinnatifida
		Watersipora subtorquata
	Unknown introduced	*Leucandra compacta*
Crypotogenic	Category 1	*Aplidium phortax*
		Asterocarpa cerea
		Botrylloides leachii
		Capitella capitata
		Caprella equilibra
		Corella eumyota
		Crella incrustans
		Diplosoma velatum
		Dipolydora armata
		Heteromastus filiformis
		Jassa slatteryi
		Mytilus galloprovincialis
		Plumularia setacea
		Scruparia ambigua

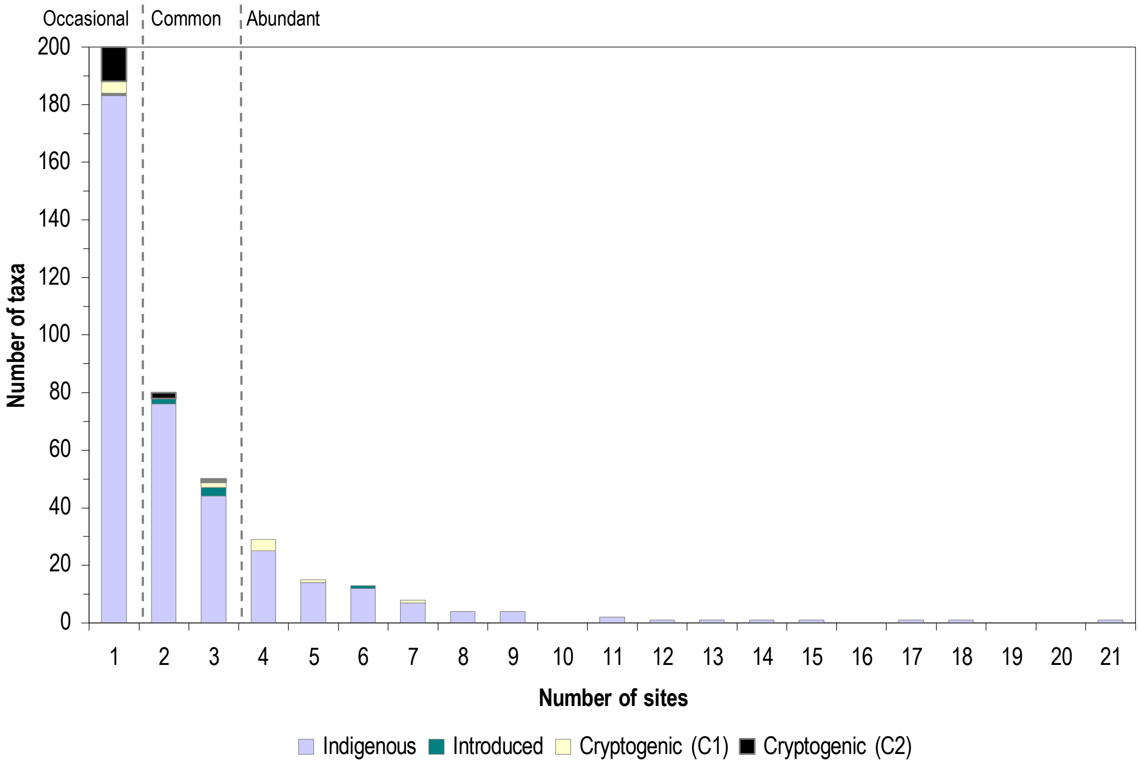

Figure 18: Site occupancy of indigenous, non-indigenous and cryptogenic taxa detected during the Stewart Island survey, September 2006.

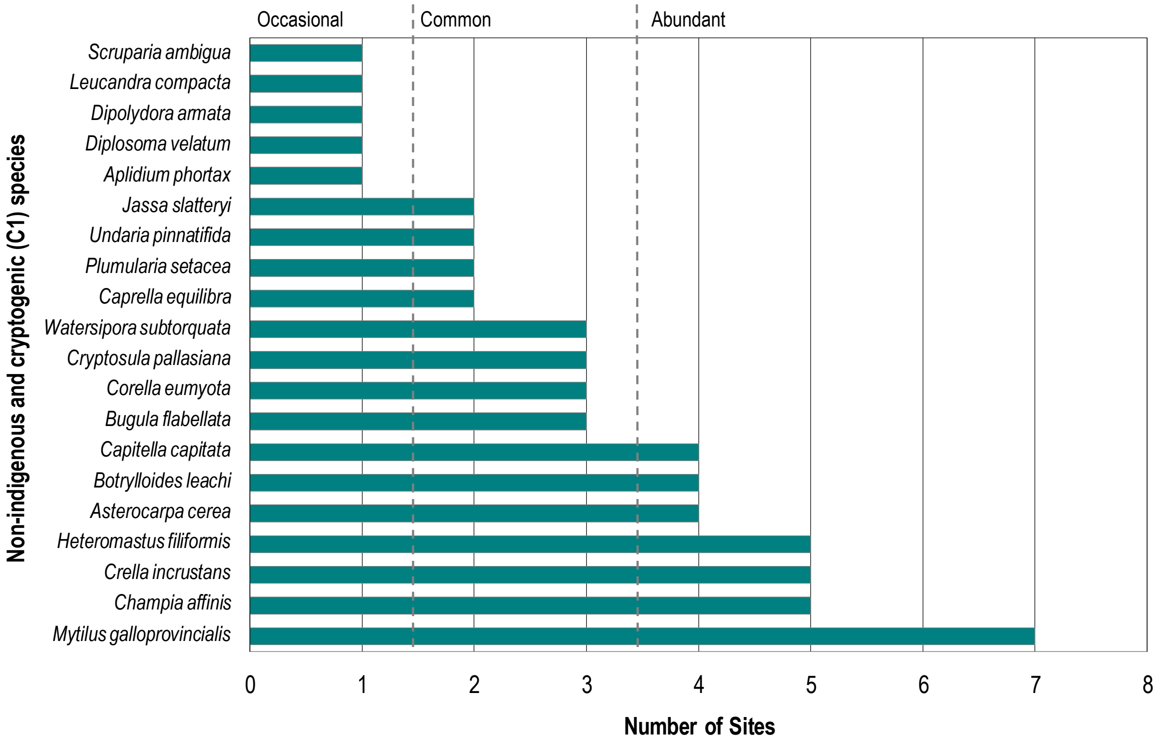

Figure 19: Site occupancy of non-indigenous and cryptogenic (C1) species relative to measures of rarity based on percentage quartiles of total taxa site occupancy.

5.3.1. Detected Non-Indigenous Species

Six non-indigenous species were detected at Stewart Island during the survey; *Bugula flabellata*, *Champia affinis*, *Leucandra compacta*, *Plumularia setacea*, *Undaria pinnatifida* and *Watersipora subtorquata*. The seaweeds, *C. affinis* and *U. pinnatifida* have been recorded previously from Stewart Island, but the detection of the bryozoans *B. flabellata*, *C. pallasiana*, and *W. subtorquata* all represent new records for Stewart Island and a southward range extension of these species in New Zealand (i.e., Gordon 1986, Gordon 1989). The occurrence of *L. compacta* at Stewart Island may to be a new record for New Zealand.

With the exception of *C. affinis*, all non-indigenous species were collected from wharf pilings, indicating an association with shipping and a biofouling habit. *Bugula flabellata* and *C. pallasiana* were also found on pontoons supporting salmon cages, indicating an association with aquaculture activities. The occurrence of *C. pallasiana* and *U. pinnatifida* on natural substrates and in areas that were remote from regular vector traffic suggests that these species spread from their initial sites of introduction by natural dispersal.

5.3.2. Cryptogenic Species

Twenty nine cryptogenic species were recorded from Stewart Island during this survey. Fifteen 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 cryptogenic category 1 species were recorded from Stewart Island during this survey. Most species in this category included species or species complexes with a cosmopolitan distribution and undetermined indigenous range (*Botrylloides leachii, Capitella capitata, Caprella equilibra, Corella eumyota, Dipolydora armata, Heteromastus filiformis, Jassa slatteryi, Mytilus galloprovincialis, Plumaria setacea* and *Scruparia ambigua)*. Other species, such as *Diplosoma velatum* and *Crella incrustans* have been recorded previously from Australia and New Zealand, but have a disjunctive distribution in both countries. Such species could well be cryptic species that are indigenous to New Zealand and Australia. *Aplidium phortax* occurs in Australia, New Zealand and the Solomon Islands and is, therefore, considered cryptogenic on the basis of its uncertain indigenous range.

A number of cryptogenic species were detected as biofouling on wharf pilings or a salmon farm structures, or occurred in the immediate vicinity of wharves and jetties (i.e., *A. phortax*, *B. leachii*, *C. equilibria*, *C. eumyota*, *D. armata*, *J. slatteryi* and *S. ambigua*). This indicated a possible association with shipping and a proclivity for fouling of artificial substrates such as wharf pilings, pontoons and vessel hulls. The cryptogenic species, *C. incrustans*, *H. filiformis* and *P. setacea*, were found at reefs, anchorages and embayments that are infrequently used as anchorages (i.e., Sailor's Rest) or historical sites such as an abandoned whaling base and ship wreck (i.e., Prices Inlet), and a site of early settlement (i.e., Native Island). The current distribution of these species about Stewart Island could, however, be equally attributed to natural dispersal and biofouling, and cannot be linked directly to marine farming or shipping.

The compound ascidian *Diplosoma velutum* was absent from sites in close proximity to shipping and could be a cryptic species indigenous to Stewart Island or Australia but has been introduced directly to remote areas by such mechanisms not otherwise indicated by its presence on permanent moorings, jetties or shipwrecks. Further examination of its distribution about Stewart Island and New Zealand could indicate that this newly described species is more widespread than indicated by the present survey. The blue mussel, *Mytilus galloprovincialis*, was widespread about Stewart Island indicating that it is either indigenous or represents an early introduction that has spread extensively about Stewart Island.

5.4. PUBLIC AWARENESS PROGRAMME

Consultation with Te Rūnanga o Ngāi Tahu resulted in a discussion with Mr. Nigel Scott. A teleconference of the Mätaitai management committee was held to consider the request to sample within the reserve. Approval to conduct the survey was granted by the Te Whaka ä Te Wera/ Paterson Inlet Mätaitai Management Committee. A copy of the interim post-survey report was provided to Mr. Scott of Te Rūnanga o Ngāi Tahu by MAFBNZ at his request. Mr. Scott was particularly interested in the distribution of the unwanted organism *Undaria pinnatifida.*

No other significant public expressions of interest were fielded by survey team members or the Project Manager. Unfortunately the copy deadline for the Stewart Island News was missed owing to late confirmation of the survey date.

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

Assessing the potential impacts of non-indigenous species requires adequate knowledge of the species' ecology and how its presence may affect the structure and composition of native marine assemblages. Information on species with demonstrable impacts elsewhere can inform on the likely impacts when they are introduced to a new location; but without baseline data on the state of indigenous community before the establishment of non-indigenous marine species any assessment of species impacts is necessarily based on anecdotal information.

Only one unwanted organism or pest (see the MAFBNZ register of unwanted organisms at http://www1.maf.govt.nz/uor/searchframe.htm) was detected during the survey; this was *Undaria pinnatifida*. The majority of non-indigenous species detected at Stewart Island are not known to impact greatly on native communities. Owing to the long history of European settlement some of the non-indigenous and cryptogenic species known to occur at Stewart Island have been present for over a century, are widespread and regarded as naturalised components of indigenous marine communities. For instance, the seaweed *Champia affinis* is a locally-dominant species of soft-bottom algal communities in sheltered harbours about Stewart Island, such as Leask Bay and Port William (M. Stuart pers. obs.) where it is confined owing to an inability to withstand open coast conditions (Nelson 1999). Similarly, non-indigenous fouling species detected in the survey, such as *Bugula flabellata*, *Cryptosula pallasiana*, *U. pinnatifida* and *Watersipora subtorquata* are typically found on artificial substrates such as wharves and jetties were they can be dominant members of the fouling communities. Given these apparent substrate preferences, impacts of these species are likely to be localised and largely confined to specific environments such as sheltered harbours and artificial structures.

The variability in environmental tolerances of the annual macroscopic sporophyte and perennial microscopic gametophyte stages of *U. pinnatifida* allow this species to establish and persist in a wide range of habitats. *U. pinnatifida* has a high visual impact because of its preference for growing on artificial substrates that are otherwise 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 (2003), 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 evident 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.

In summary, most of the non-indigenous species detected at Stewart Island 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 species' effects. One important consideration to this assessment concerns the lack of specific research on the effects of these species on biological diversity and community function. The 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. The exception being *U. pinnatifida* as this species has the greatest potential to affect the indigenous marine communities of Stewart Island.

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

7.1. OVERVIEW

Non-indigenous species detected at Stewart Island 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 also. Typically, species that have planktonic life history phases are capable of some degree of natural dispersal via currents and water movement; with 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 prevailing northward direction of the Southland Current combined with the predominant southwest weather patterns preclude the natural dispersal of non-indigenous species southward along the Otago and Southland coast. The strong tidal currents through Foveaux Strait would also present a significant barrier to the natural dispersal of non-indigenous species from the southern coast of mainland New Zealand across the strait to Stewart Island. It is therefore unlikely that natural dispersal is the mechanism of introduction to Stewart Island, but is likely to contribute significantly to localised dispersal of non-indigenous species once founding populations have established.

7.3. BALLAST WATER AND HULL FOULING

Direct introduction of non-indigenous marine species by international shipping would have been most probable with the arrival of early sealing and whaling ships. International shipping at Stewart Island is now rare and international cruise ships and recreational craft only visit Stewart Island on occasion. Few, if any, water ballasted vessels visit Stewart Island, but it is possible that marine species may have been introduced historically through the disposal of dry ballast from early sailing vessels.

Many of the species detected during the survey are biofouling organisms that are well-known to establish on the hulls of vessels and colonise artificial substrates such as wharf pilings. Domestic vessel traffic to Stewart Island is predominantly from Bluff Harbour and, to a lesser extent, Otago Harbour. Monthly inspections of domestic vessels (commercial and recreational craft) in Otago and Southland conducted by the Department of Conservation over a 24-month period from 1999 to 2001 revealed 59 voyages to Stewart Island comprising 42 from Bluff, 13 from Otago Harbour, three from Riverton and a single voyage from

Oamaru (Stuart 2002). Bluff and Otago Harbours are, therefore, the most probable source of species introduced to Stewart Island by hull fouling.

The annual movement of vessels to offshore island to harvest titi (muttonbird) is a potential pathway whereby vessels voyaging directly from Bluff to the Titi Islands and Stewart Island could introduce non-indigenous species.

7.4. MARINE FARMING ACTIVITIES

Marine farming at Stewart Island comprises both land-based cultivation of abalone, which involves discharging water into Horseshoe and Halfmoon Bays, and extensive sea-based cultivation of mussels, oysters and salmon in Big Glory Bay. Possible pathways for the introduction of species to Stewart Island by marine farming activities include:

- Species transfers of seed, juvenile and breeding stock, (e.g., mussel spat, salmon smolt, abalone, and oysters).
- Translocation as hull fouling on vessels associated with the establishment, operation and maintenance of marine farms.
- Translocation as biofouling on marine farming equipment (e.g., buoys, rope, screw anchors, mooring blocks, salmon cages, and nets).

There is no evidence to suggest that land-based marine farming has resulted in the introduction of non-indigenous species to Stewart Island. Land-based farming of abalone at Stewart Island is a relatively recent development that occurred after the arrival of the majority of non-indigenous species detected in this survey. The distribution and invasion history of more recent arrivals, such as *U. pinnatifida*, do not coincide with the development of land-based farming nor directly correspond with land-based activities.

The development of extensive marine farming of mussels and salmon in Big Glory Bay is also a relatively recent development that occurred after the arrival of the majority of non-indigenous species detected in this survey. The discovery of *U. pinnatifida*, however, in Big Glory Bay on barges and mussels farms in 1997 strongly implicates marine farming activities as the likely pathway for this introduction. Furthermore, the occurrence of *B. flabellata* and *C. pallasiana* on the salmon farms in Big Glory Bay at least indicates an association with aquaculture activities.

Genetic analysis of *U. pinnatifida* from Big Glory Bay and a subsequent incursion of *U. pinnatifida* discovered at Halfmoon Bay indicates that these represent two separate introductions from different sources. The haplotype occurring in Big Glory Bay was similar to that collected from Otago Harbour and locations north of Banks Peninsula, whereas the haplotype occurring at Halfmoon Bay is similar to that occurring at Lyttelton Harbour, Taylor's Mistake, Akaroa, Timaru, Oamaru and Moeraki (Uwai *et al.* 2006). The haplotype collected from Bluff differed from all other recent and historical collections made in New Zealand (Uwai *et al.* 2006). These data suggest that *U. pinnatifida* was not introduced to Big Glory Bay by the transfer of mussel spat, equipment or vessels from Marlborough, but more likely as a fouling organism on a vessel or barge associated with the establishment, operation and maintenance of marine farms. Conversely, the location of *U. pinnatifida* in Halfmoon Bay is not associated with marine farming activities. Its introduction to this location is therefore most likely to have occurred through biofouling on a vessel originating from locations north of Banks Peninsula.

7.5. HULL CLEANING

A slipway situated in Halfmoon Bay used for hull cleaning and general vessel maintenance has no containment facility and discharges directly onto the sandy foreshore (Figure 20). Unless manually collected, any fouling organisms removed during cleaning are deposited directly into the marine environment. The slipway is in relatively close proximity to rocky reef (i.e., Scollay's Rocks) potentially providing a greater range of suitable substrate for colonisation by fouling organisms.

Figure 20: Slipway at Halfmoon Bay, Stewart Island.

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

The marine environment and communities about Stewart Island are relatively intact and unmodified by human impacts associated with deforestation, urbanisation, wastewater discharges and coastal development. This may provide a degree of resistance and resilience to the establishment and localised spread of some species as there is considerable evidence that indicates non-indigenous species recruit into disturbed habitats more readily than undisturbed habitats. However, marine habitats about Stewart Island are extremely diverse, with soft mud and sand, rock reef, boulder and estuarine habitat all occurring within Halfmoon Bay and associated embayments. Such diversity of habitat in close proximity to vector pathways enhances the likelihood of species colonisation and survival.

Moorings, anchorages and wharf structures occur throughout the island and provide artificial substrate for colonisation by non-indigenous fouling species. Although the greatest concentration of permanent moorings occurs in Halfmoon Bay, mooring also occurs in Horseshoe Bay and Paterson Inlet (Deep Bay, Golden Bay and Thule). Vessels regularly move between moorings and wharves throughout Stewart Island, which creates opportunity for the translocation and establishment of non-indigenous species.

Hull cleaning practices at the Halfmoon Bay slipway could lead to the establishment of non-indigenous species, particularly if efforts are not taken to prevent biofouling from being released directly to the marine environment in the absence of permanent containment facilities.

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

At least 38 non-indigenous marine species have been detected at ports south of Banks Peninsula that have not yet been recorded at Stewart Island (Table 7). Twelve of these species have been present in New Zealand for at least half a century without spreading to Stewart Island, suggesting that the mechanisms for further range extension of these species are lacking or that there are other factors preventing the establishment of these species in Stewart Island.

More recent arrivals are unlikely not to have established throughout their full range and could be introduced to Stewart Island. Such species include those discovered during other baseline port surveys such as the crabs *Cancer amphioetus* and *Cancer gibbosulus*, the caprellid isopod *Caprella mutica*, the sponge *Leucosolenia* cf. *discoveryi*, and spirobid polychaete *Spirobranchus polytrema*. The discovery of the unwanted clubbed sea squirt, *Styela clava* at Port Otago in February 2009 (L. Hunt pers. comm., March 2009) presents a significant risk of introduction to Stewart Island as this species is established in the Town Basin where vessels that voyage to Stewart Island are permanently berthed. The incursion of another unwanted organism, the Mediterranean fan worm, *Sabella spallanzianii* in Lyttelton harbour also presents a significant translocation risk should management efforts fail to eradicate it from New Zealand.

While hull fouling remains the most likely mechanism of introduction of non-indigenous marine species to Stewart Island, the translocation of marine farming stock and equipment has the potential to introduce species from other regions. New introductions that could occur by these pathways include *Didemnum vexillum*, *S. clava* and *Ciona intestinalis*. The translocation of mussel spat directly between Kaitaia and Stewart Island is not 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 (Rhodes *et al*.. 1994). The translocation of marine farming species, particularly of mussel spat, from other marine farming areas could lead to the establishment of non-indigenous species, although management practices are in place to mitigate this risk including a voluntary ban on the translocation of mussel seed stock from Marlborough to Stewart Island (Dodgshun *et al.* 2007). The on-growth of Kaitaia spat on marine farms before it is later translocated to and seeded onto farms at Stewart Island is a practice that could lead to contamination of seed mussels with non-indigenous species known to foul mussel farms (i.e., *D. vexillum*, *S. clava*, *C. intestinalis*).

Table 7: Non-indigenous marine species found at locations to the south of Banks Peninsula and are not known to be present at Stewart Island.

Species	Location	Time of Introduction or First Discovery (d) in NZ	Reference
Antithamnionella ternifolia	Timaru	Pre-1904	Nelson 1999, Adams 1983
Apocorophium acutum	Timaru, Otago Harbour	Pre 1921	Inglis *et al.* 2006f, i
Barantolla lepte	Timaru	Unknown	Inglis *et al.* 2006f
Barentsia matsushimana	Otago Harbour	Pre-1995	Cranfield *et al.* 1998
Bugula neritina	Timaru, Otago Harbour	1949	Inglis *et al.* 2006f, i
Bugula stolonifera	Timaru and Bluff	1962	Cranfield *et al.* 1998
Buskia nitens	Oamaru	1967	Cranfield *et al.* 1998
Cordylophora caspia	Otago Harbour	Pre-1883	Cranfield *et al.* 1998
Cancer amphioetus	Bluff	Jan 2003d	Inglis *et al.* 2005
Cancer gibbosulus	Timaru	Nov 2001(d)	Inglis *et al.* 2006f
Caprella mutica	Timaru	Feb 2002(d)	Inglis *et al.* 2006f
Chondropsis topsentii	Bluff	Unknown	Inglis *et al.* 2005
Ciona intestinalis	Timaru	Pre-1950	Inglis *et al.* 2006f
Corophium sextonia	Otago Harbour	Pre-1921	Cranfield *et al.* 1998
Crassostrea gigas	Otago Harbour	1961	Inglis *et al.* 2006i
Cuthona perca	Little Papanui, Otago Peninsula	Pre-1960	Cranfield *et al.* 1998
Diplodora giardi	Otago Harbour	unknown	Cranfield *et al.* 1998
Ectopleura larynx	Otago Harbour	Pre-1953	Cranfield *et al.* 1998
Eubranchus agrius	Otago Peninsula	1959	Cranfield *et al.* 1998
Euchone limnicola	Timaru	Unknown	Inglis *et al.* 2006f
Gonothyraea loveni	Otago Harbour	Pre-1898	Cranfield *et al.* 1998
Grantessa intusarticulata	Bluff, Otago Harbour	Unknown	Inglis *et al.* 2005a, 2006i
Halecium delicatulum	Otago Harbour	Pre-1876	Cranfield *et al.* 1998
Halisarca dujardini	Bluff, Otago Harbour	Pre-1973	Inglis *et al.* 2005, 2006i
Jassa marmorata	Otago Harbour	Unknown	Inglis *et al.* 2006i
Leucosolenia cf. *discoveryi*	Bluff, Otago Harbour	Feb 2003(d)	Inglis *et al.* 2005a, 2006i
Monocorophium acherusicum	Timaru, Otago Harbour	Pre-1921	Inglis *et al.* 2006f, i
Phytia myosotis	Aramoana, Otago	Pre-1980	Cranfield *et al.* 1998
Polydora hoplura	Otago Harbour	Unknown	Inglis *et al.* 2006i
Polysiphonia brodiaei	Bluff, Otago Harbour	Pre-1940	Inglis *et al.* 2005, 2006i
Polysiphonia constricta	Otago Harbour	Pre-1983	Nelson 1999, Adams 1983
Polysiphonia subtilissima	Timaru, Otago Harbour	Pre-1974	Inglis *et al.* 2006f, i
Psammoclema cf. *crassum*	Bluff	Unknown	Inglis *et al.* 2005
Spirobranchus polytrema	Otago Harbour	Nov 2001(d)	Inglis *et al.* 2006i
Stylotella agminata	Bluff	Unknown	Inglis *et al.* 2005
Symplectoscyphus indivisus	Bluff	Mar 2003	Inglis *et al.* 2005
Styela clava	Otago Harbour	Pre-2002 [1]	Inglis *et al.* 2006i

Note 1: http://www.biosecurity.govt.nz/publications/biosecurity-magazine/issue-77/styela (accessed 19/03/09)

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, *C. intestinalis*, *U. pinnatifida* and *D. 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 would remain viable after declumping and washing processes (Forrest & Blakemore 2002). Visual 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 of 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*). The code is more likely to prevent the transfer of larger non-indigenous species such as *C. intestinalis* and *S. 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 were developed to avoid or mitigate the presence of toxic algal cysts densities associated within transferred mussel spat (Taylor 2000, NZMIC 2002).

The risk of non-indigenous species and disease transfers with salmon smolt is low or negligible because sea-cage salmon farming undertaken in Big Glory Bay obtains its stock from freshwater hatcheries and stock transfers between the regions do not generally occur as the farms are operated by a different companies (Dodgshun *et al.* 2007). There are three coastal discharge permits for land-based marine facilities at Stewart Island, comprising one abalone hatchery each in Horseshoe and Halfmoon Bays, and an out-growth facility for pearl production in Halfmoon Bay (Forrest & Blakemore 2002). The risk of land-based farms translocating and releasing non-indigenous species, parasites and pathogens is difficult to assess, but overseas examples suggest that land-based farming of abalone can provide pathways for their spread. For example, the introduction of the polychaete worm, *Terebrasabella heterouncinata* to natural populations of intertidal gastropod in California occurred after it was introduced to land-based abalone farms and discharged to the marine environment (Culver & Kuris 2000). More recently, the herpes-like viral disease of abalone, Abalone Virus Ganglioneuritis (AVG), caused high mortalities in Australian abalone farms in 2005 and was detected in natural abalone populations a year later (Hills 2007). Transfer procedures that include the close inspection and cleaning of abalone, combined with quarantine procedures before they are introduced to the general population, would greatly reduce any risk of new introductions by this pathway. It should be emphasised, however, that quarantine procedures should include the use of isolated (re-circulating) seawater systems as well as the physical separation of quarantined stock from the general population.

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

Any fouled vessel has the capacity to translocate non-indigenous species about Stewart Island, but whether this leads to the spread of non-indigenous species depends on a complex array of factors affecting the probability of their introduction and subsequent establishment.

Stewart Island relies heavily on marine transport to service the island and maintain its tourist, fishing and marine farming industries. Vessels regularly move about the island transporting workers and supplies to marine farms in Big Glory Bay. Similarly, Department of Conservation vessels regularly transport workers and supplies about Stewart Island and its offshore islands to maintain tracks and huts, and to undertake wildlife management. Water taxis and charter vessels also regularly transport tourists and hikers about Paterson Inlet and Halfmoon Bay. Fish factories and freezers at Halfmoon Bay and Horseshoe Bay are a focal point of fishing vessel activity where fresh produce is unloaded for processing and preservation before shipping to Bluff.

The high volume of vessel traffic about Stewart Island is, thus, varied in terms of the type and destination of vessels. The likelihood that vessels will spread non-indigenous species about Stewart Island is perhaps reduced by the short duration that many remain berthed at the wharf or jetty before they return to their origin. Vessels associated with the annual titi harvest could also be considered lower risk due to the low frequency of voyages and short duration that many remain at the Titi Islands. Vessels moving permanently between mooring sites present a greater risk of spreading non-indigenous marine species about Stewart Island owing to the longer period they remain at one location and the opportunity for fouling organisms to colonise the mooring (i.e., buoy, line, chain and block).

The localised spread of non-indigenous species could occur about Big Glory Bay in association with the movement of equipment and stock between farms. This would, however, be limited to Big Glory Bay unless sea-based marine farming activities were established elsewhere in Stewart Island.

11. Recommendations

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

The cessation of intensive management of the unwanted algae *U. pinnatifida* at Stewart Island in November 2004 indicated that population control is no longer considered a feasible option for the management of existing populations of this species (Hunt *et al.* 2009). Nevertheless, localised management of fouling populations on wharf structures frequented by vessel traffic could be beneficial in preventing the biofouling of local vessels and thereby slow the spread of *U. pinnatifida* and other non-indigenous biofouling species about Stewart Island.

In the present survey, *U. pinnatifida* was only found on wharf structures at Halfmoon Bay and was not present at wharves and jetties elsewhere about Stewart Island. Periodic management of sporophytes could, therefore, be beneficial in preventing spores from colonising vessels as they are berthed at the wharf. Likewise, management of *U. pinnatifida* on mooring structures (buoy, line, chain and block) could prevent the biofouling of moored vessels. Periodic removal of sporophytes from buoys, ropes and mooring chains would likely 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* management and could be extended to other existing non-indigenous species, either through targeted management or the use of techniques that are applicable to a range of non-indigenous species (e.g., wharf pile wrapping, hull cleaning, and general defouling of moorings). Management of *B. flabellata, C. pallasiana, L. compacta, U. pinnatifida* and *W. subtorquata* would all benefit from this approach.

Continued implementation, review and improvement of industry best practice is an important means of managing existing non-indigenous species within aquaculture. This is best done by identifying and integrating management practices into marine farming activities that keep populations 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

Biofouling of vessels voyaging to Stewart Island from Bluff and Otago Harbour have been identified as presenting the greatest biosecurity risk by virtue of the relatively high volume of traffic to Stewart Island from these ports and the presence of non-indigenous species that have not been recorded at Stewart Island. New introductions to Stewart Island could be best prevented through the management of vessel biofouling at the ports of origin for vessels that are most likely to voyage to Stewart Island (e.g., Bluff, Otago Harbour). 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 and best practice application of antifoulant paints, and the 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 these efforts to identify and respond to specific biosecurity threats (i.e., fouled vessels), and to present a public presence.

Hull cleaning facilities at Stewart Island are currently not of a standard that would be effective for cleaning fouled vessels without releasing biofouling into the marine environment (e.g., McClary & Nelligan 2001). The establishment of hull cleaning facilities at Stewart Island that are capable of containing and capturing biofouling would contribute to the prevention of new introductions to Stewart Island. Thus, improvements need to be made to the hull cleaning facilities at the Halfmoon Bay slipway. The development and application of methods to contain, remove and collect non-indigenous species from vessels whilst they remain in the water would also provide an alternative means of cleaning vessels. The development of portable methods to encapsulate, chemically-treat or clean small to medium-sized vessels would enable an operational system to be stored at Bluff that could be rapidly transported and deployed in response to biosecurity threats at Bluff, Otago Harbour and Stewart Island.

The translocation of aquaculture equipment and stock is a possible mechanism by which new species may be introduced to Stewart Island. 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.

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