Summary of existing Ecological Information and scoping of further Assessments for Port Otago Dredging Project

NIWA Client Report: HAM2007-156
October 2007

NIWA Project: POL08201

Summary of existing Ecological Information and scoping of further Assessments for Port Otago Dredging Project

Mark James
Keith Probert*
Rick Boyd**
Anna John

* University of Otago
** Boyd Fisheries Consultants Ltd

Prepared for

Port Otago Limited

NIWA Client Report: HAM2007-156
October 2007

NIWA Project: POL08201

National Institute of Water & Atmospheric Research Ltd
Gate 10, Silverdale Road, Hamilton
P O Box 11115, Hamilton, New Zealand
Phone +64-7-856 7026, Fax +64-7-856 0151
www.niwa.co.nz

Contents

Reviewed by:

Graham Fenwick

Approved for release by:

David Roper

Formatting checked

A. Bartley

Executive Summary

Port Otago Ltd ("the Port Company") wishes to prepare Port Chalmers for the next generation of larger container ships that will come into New Zealand. To achieve this, the Port Company proposes dredging the approaches to Port Chalmers and berth area by deepening the channel to between 14 and 15 metres (Project Next Generation). This may involve dredging up to 5,000,000 cubic metres of material (mostly fine sand with some mud and smaller amounts of rock and clay). There are a number of potential environmental issues associated with this dredging and the disposal of dredged material, which need to be addressed in the environmental assessment process.

Port Otago Ltd has contracted NIWA, University of Otago, and Boyd Fisheries Consulting Ltd to: 1) produce an annotated bibliography identifying studies that have been carried out in the harbour itself and region offshore which could be potentially a receiving area for dredged material, focusing on sediment characteristics and movement, hydrodynamics and ecology (including birds, mammals and fisheries), and, 2) provide a situation analysis report which covers a brief overview of the present status of knowledge, identifies gaps and scopes the type of work that would be required as part of an Assessment of Environmental Effects.

This report covers the ecological aspects for the situation analysis report and includes:

- State of knowledge of benthic ecology, birds, mammals and fisheries, important habitats and distribution of major species and activity, and some commentary on potential effects.

- Risk table summarizing potential areas/issues that may need to be addressed.

- Ecological studies which need to be carried out.

Benthic habitats of the wider Otago marine environment mainly comprise sheltered rocky shores, intertidal sandbanks, and subtidal soft sediment bottoms within Otago Harbour, and open ocean habitats immediately outside the harbour, notably wave-exposed rocky shores, sandy beaches, and sediment soft bottom habitats of the continental shelf. For limited localities within these environments there have been a number of biological studies and impact assessments. Ecologically significant areas within Otago Harbour have been identified at Aramoana, (salt marshes and inter tidal sand flats) bird breeding area at Taiaroa Head, some high density cockle beds and significant seagrass areas in the outer harbour, and bryozoan and queen scallop beds along the middle and outer coastal shelf. Within Otago Harbour, the most sensitive communities to direct and indirect impacts from dredging would appear to be cockle beds and seagrass communities, and these require further study to map important areas before full assessments can be made. The bryozoan and queen scallop beds are found well off-shore and generally south of the proposed disposal grounds so are unlikely to be impacted by the

proposed dredging and disposal. The dredge material disposal site is yet to be finalised but a preliminary site has been identified. Direct and related impacts of the current disposal sites on benthic biota at Heyward Point, Aramoana and Shelly Beach have recently been conducted but there have been no other significant studies on effects of sediment.

The outer Otago Harbour and the adjacent offshore marine environment support a diverse array of bird life including three nationally endangered species, five nationally vulnerable species and five species in gradual decline. Species of note include Northern Royal albatross, Black-fronted and Caspian terns, Hutton's shearwaters, Yellow-eyed and Erect Crested penguins. Although the nesting activity of these species is unlikely to be directly affected by dredging, there is some potential for dredging operations to interrupt habitats and feeding of some species active within the Harbour (e.g., penguins, shags, and various intertidal shorebirds), and for dredged material disposal to interrupt feeding of some species active offshore (e.g., penguins). However, due to their highly mobile nature and large foraging area, such effects on birds are generally likely to be short-term and restricted in spatial extent.

Four seal and six cetacean species have been reported from the Otago coast. One seal species is considered nationally critical (Southern Elephant seal), two cetaceans are nationally endangered (Hector's dolphin and Southern Right whale), and one seal (New Zealand sea lion) and one cetacean (Bottlenose dolphin) are range restricted. All species spend time in the coastal water off Otago, with occasional forays into the outer Harbour. Several species of seal use areas on the Otago Peninsula as haul-out areas and breeding grounds, but these areas are unlikely to be affected by the proposed dredging. For mammals there are potentially direct effects of dredging through noise and physical disturbance, as well as indirect effects through impacts on food availability. However, due to their highly mobile nature and wide geographical foraging range, such effects are generally avoidable by mammals or likely to be short-term and restricted in spatial extent.

The Otago coast supports a diverse and productive commercial fishery for a wide range of fish and shellfish species involving a number of fishing methods. Knowledge of these widespread and dispersed commercial fisheries is generally good, but on a total population basis. Little commercial fishing takes place within Otago Harbour suggesting that any conflict with dredging activities is likely to be minimal. Disposal of dredged material offshore would potentially impact a very small area relative to the overall area available to commercial fishers. Provided that appropriate consultation takes place with the commercial fishing sector, it is unlikely that there would be difficulty in finding a disposal site that minimises commercial fishery impact.

The main recreational fisheries in Otago are based on many of the same species as the commercial fishery, except for the growing Otago Harbour salmon fishery. Given the dispersed nature of recreational fishing and proximity of most of this fishing to the near shore zone, there is limited potential for direct conflict between recreational fishing interests and disposal of dredged material at open coastal locations. Within Otago Harbour, the potential for conflict between the effects of

dredging activities and recreational fishing is more difficult to assess and requires further consultation and assessment. A limited area of cockle beds will be directly affected by dredging and potential siltation from dredging could affect shellfish beds and other benthic habitats, the extent of which is yet to be modelled and assessed. There is some potential for dredging activity to conflict with the recreational salmon fishery.

In terms of pertinent customary fisheries, the East Otago Taiapure extends from Cornish Point in the north and incorporates the inshore waters of Waitati Inlet, Karitane, Blueskin Bay and Purakaunui Bay as far as Potato Point in the south. Within Otago Harbour, cockles and flounders are harvested from the extensive mud flats around Otakou. Rock lobster, paua and kina are harvested from the rocky shores of Otago Peninsula outside of the harbour. Tangata Whenua will have more definitive information that will be discussed and evaluated during the consultation process.

The potential significance of the effects of dredging and dredge material disposal were evaluated based on three criteria: 1) severity (measure of the degree of harm), 2) duration (time between initial effect and recovery once operations have ceased), and, 3) extent of impact (spatial distribution of impact). Derived evaluations are presented in risk assessment tables within this report. For dredging, significant negative effects were evaluated as being highest (i.e., medium to high severity, short to medium-term, site specific) with regards to the possible removal or heavy disturbance of organisms in or close to the channel (e.g., cockles), and plumes of turbid water smothering organisms (in particular cockles and seagrasses) and/or possibly altering hydraulic regimes and benthic ecosystems within the outer Otago Harbour. For the disposal of dredged material, significant negative effects were evaluated as being highest for direct impacts through smothering of resident biota but in a limited area.

There are gaps in our ecological knowledge of the Otago Harbour and immediate offshore region which require further studies before a full assessment of potential effects from the proposed dredging and disposal of dredged material can be made, and to provide adequate baseline data for assessment and monitoring of impacts as the project proceeds. Studies required that have been identified so far are:

- Confirmation of sediment type and level of contaminants at the site to be dredged, associated shipping channels and the proposed disposal site.

- Survey the benthic ecology of the areas adjacent to the main channel (i.e., outer Harbour, cockle and seagrass beds, Aramoana, and unmodified areas around Goat and Quarantine Islands), to assess their vulnerability to the direct and indirect effects of dredging and identify sensitive habitats to increased turbidity. This will also allow ground-truthing of any previous studies.

- Survey the benthic ecology of the proposed offshore disposal site and immediate vicinity that may be impacted by disposal of dredged material.

- Observational study to assess the behaviour of birds and mammals to existing dredging operations.

- Collate further information and data on fisheries through further reviews of catch data, existing hard and soft literature, and consultation with fishers, Tangata Whenua and other parties.

Suggested study methodology and suggested timeframe are provided within this report.

1. Introduction

Port Otago Ltd ("the Port Company") wishes to prepare Port Chalmers for the next generation of container ships that will come into New Zealand. These ships will have up to 50% more capacity and be considerably larger than existing ships with proposed (approximate) dimensions, as follows: length of 320 m (existing 285 m), width 43 m (cf 32.6 m) and draft 14.5 m (12.5 m). To achieve this, the Port Company proposes dredging the approaches to Port Chalmers and berth area by deepening the channel to between 14 and 15 metres. Depending on the final channel alignment and depth this will involve dredging up to 5,000,000 cubic metres of material.

The dredged material is likely to be mostly fine sand with mud in the port area but geotechnical investigations will be necessary as part of the more detailed environmental assessments to characterise and confirm the sediment composition and to test for potential contaminants. A few locations will contain rock and clay substrate. There are a number of potential environmental issues associated with this dredging, including sediment disturbance, sedimentation, coastal erosion, and effects on hydrodynamics and ecology. All of these need to be addressed in the environmental assessment process.

There are three generic methods of disposing of this dredged material, namely: use in beach nourishment/coastal protection works, reclamation and marine disposal. No decisions on a preferred option have been made at this early stage of the project, but the quantities of material involved mean that marine disposal of at least some of the material is likely and a priority area for assessment.

The first stage of this investigation was to produce an annotated bibliography which identifies studies that have been carried out in the harbour itself and region offshore which could be potentially a receiving area for dredged material. The document focused on sediment characteristics and movement, hydrodynamics and ecology (including birds, mammals and fisheries). The next stage is to provide a report which covers a brief overview of the present status of knowledge, identifies gaps and scopes the type of work that would be required as part of a detailed Assessment of Environmental Effects.

This report covers the ecological aspects and includes:

- State of knowledge of benthic ecology, birds, mammals and fisheries including maps showing important habitats, distribution of major species and activity and some commentary on potential effects.

- Risk table summarizing potential areas/issues that may need to be addressed.

- Ecological studies which need to be carried out.

2. Environmental status

2.1 Benthic environment

Benthic habitats of the wider marine environment mainly comprise sheltered rocky shores, intertidal sandbanks, and subtidal soft sediment bottoms within Otago Harbour, and open ocean habitats immediately outside the harbour, notably wave-exposed rocky shores, sandy beaches, and soft sediment bottom habitats of the continental shelf.

Otago Harbour is a long shallow inlet aligned SW-NE, about 23 km long, generally about 2 km wide, with a mean surface area at high spring tides of 46 km^2. Peninsulas at Port Chalmers and Portobello and their adjacent islands divide the harbour into upper and lower basins (Figures 1 and 2). Other than the main channel, the harbour is mostly shallow with water depths of less than 2 m, and nearly 30% of its area comprises exposed sediment flats at low spring tides. The only other naturally deep areas (> 30 m) are holes next to the islands. The shipping channel extends along the western shore for much of the harbour's length. Otago Harbour is the only large non-estuarine inlet on the southeast coast of New Zealand and has a number of important sheltered water habitats that are not widely represented elsewhere in this biogeographic region.

Harbour sediments range from silt to coarse shell-sand, with a natural gradation from generally coarser, less muddy sediments in the outer parts to finer grained and muddier sediments towards the more sheltered upper parts. Correspondingly the upper harbour is less well flushed, with salinity decreasing towards the mouth of the Water of Leith, the main riverine inflow. However, this input is relatively small and salinity in the upper harbour rarely falls below about 30 ppt.

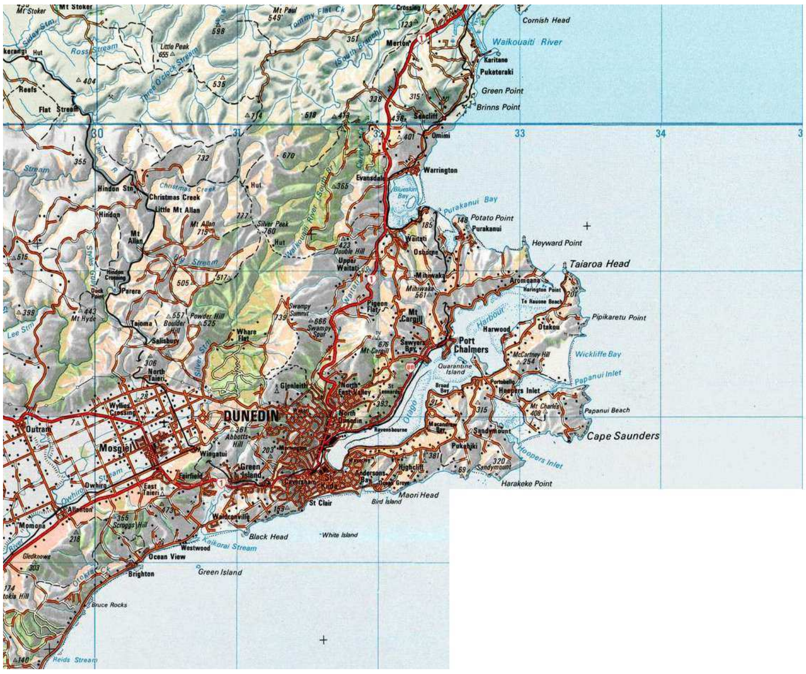


Figure 1. Location map of the Otago Harbour area (from NZMS 260 Series via TopoMap).

Figure 2. The outer harbour (from NZMS 260 Series via TopoMap).

Early studies of the species and communities in the Otago Harbour were undertaken in the 1940s and 1950s. Most of these studies were on particular species, such as the mud snail (*Amphibola crenata)*, or provide species lists for limited localities, particularly around Portobello. A species list was generated for the Port Chalmers area as part of an Otago Harbour Board study in the 1970s and in the late 1970s and early 1980s environmental impact reports were prepared for the proposed aluminium smelter at Aramoana (South Pacific Aluminium 1981). Ecologically significant areas were identified at Aramoana (Figure 3) and benthic community structure, dominant species and habitat types assessed. The assessment provided information on a range of species but the site did not contain “any particularly unusual or unique flora or fauna”. The salt marsh at the site was noted as an important biological resource and is a Department of Conservation designated Ecologically Protected Area.

In the 1970s the Otago Harbour Board commissioned a report on the marine environment around Port Chalmers which provided a benthic species list in the proposed reclamation area (Probert 1975). Further environmental impact assessments were made as part of studies commissioned by Port Otago Ltd in 1990 for further reclamation around Port Chalmers (Probert 1990 a,b,c). It was concluded that there would be little impact on the benthic communities and recolonisation would occur where there were impacts. An environmental assessment for dredging and disposal of material was undertaken in the early 1990s for maintenance dredging of the channel in the outer harbour and dredge material disposal (Paavo and Probert 2005).

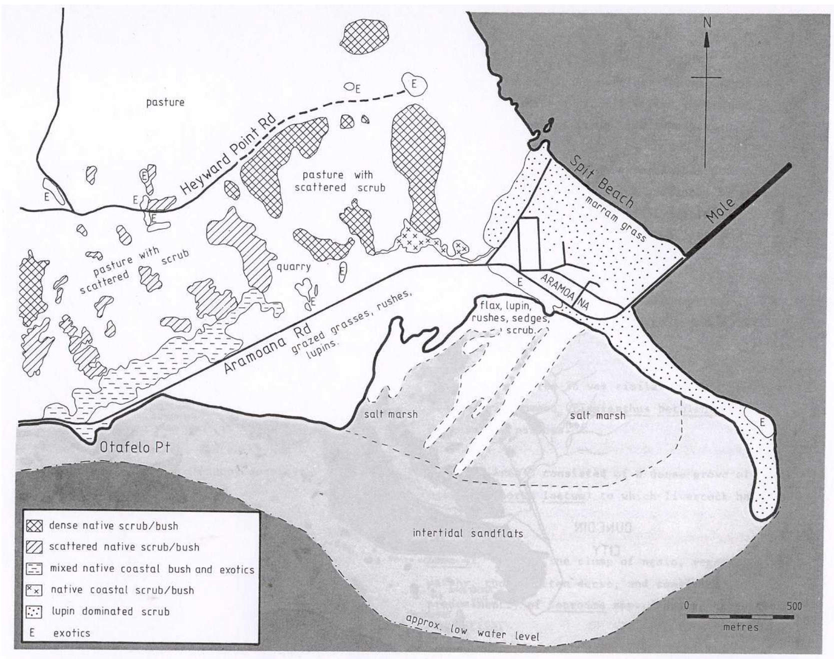


Figure 3. Ecologically significant regions identified at Aramoana (from South Pacific Aluminium Limited 1981: 103).

These studies characterised the benthic biota in the harbour and at three dredge material disposal sites near the entrance to the harbour. These studies concluded that maintenance dredging would maintain the communities in a low diversity early successional state while the disposal would be likely to reduce the abundance and diversity at the disposal sites. It was noted that these effects would be localised to the disposal site.

There have been several studies of soft-bottom benthic assemblages of the harbour. A number of these studies were on the ecology of particular species or groups such as ostracods, crabs, and topshells and in some cases maps of their distribution were produced. The most comprehensive survey, based on sampling 34 stations throughout the harbour between 1965 and 1997, identified nearly 400 macrobenthic species and using various environmental criteria, Rainer (1981) recognised four principal communities in the harbour:

(1) Mud community (see also "*Maoricolpus* association" of Ralph and Yaldwyn (1956) and Grove and Probert (1999)).

(2) Fine sand community (see also "*Austrovenus* association" of Ralph and Yaldwyn (1956) and Grove and Probert (1999)).

(3) Stable shell-sand community.

(4) Unstable sand community. The communities are characterised chiefly by species of polychaete worms, bivalve molluscs and small crustaceans (as is typical for such soft-bottom faunas).

Rainer (1981) assigned most of the samples from the upper harbour to the mud community. The fine sand community was mainly in the middle and outer half of the harbour, the stable shell-sand community in the outer half, and the unstable sand community primarily at the harbour entrance. Broadly, there was a gradation from communities of the upper harbour inhabiting muddy, organic sediments (associated with low current speeds), to those in the outer harbour (in areas of higher tidal velocities) occurring in sand or shell-sand substrata containing little organic matter. Thus the broad pattern of tidal influences in the harbour drives the depositional environments that result in differences in sediment types, which in turn determine the distributions of major benthic assemblages.

The extensive intertidal flats of the harbour (~ 13 km^2 at low spring tide) occur mainly in the middle and outer reaches. A number of recent surveys throughout the harbour

have also attempted to characterise communities based on environmental variables (e.g., Grove 1995, Grove and Probert (1999)) at selected sites. The intertidal flats of the outer harbour consist of fine well-sorted sand. Common animals that have been reported in these areas of the sandbank assemblage include cockle (*Austrovenus stutchburyi*), wedge shell (*Macomona liliana*), lugworm (*Abarenicola affinis*), ghost shrimp (*Callianassa filholi*), and mantis shrimp (*Heterosquilla tricarinata*). The cockle commonly dominates the sandflat macrofauna (densities of 500-1000 individuals per m^2 being common), and as a major filter feeder of the outer harbour, may significantly influence the suspended particulate load (Pawson 2004). Seagrass (*Zostera capricorni*) beds are also a feature of sediment flats of the outer harbour, and likely play an important role in harbour ecology as a source of organic detritus and by providing habitat for many associated organisms. Major benthic communities that have been studied or identified are shown in the figure below (Figure 4). Aerial photos taken by Department of Conservation and the Port Company have been taken recently but these have yet to be analysed. It may be possible that these will provide enough information, with some groundtruthing, to map the seagrass beds in areas close to the channel and areas potentially impacted by the proposed dredging.

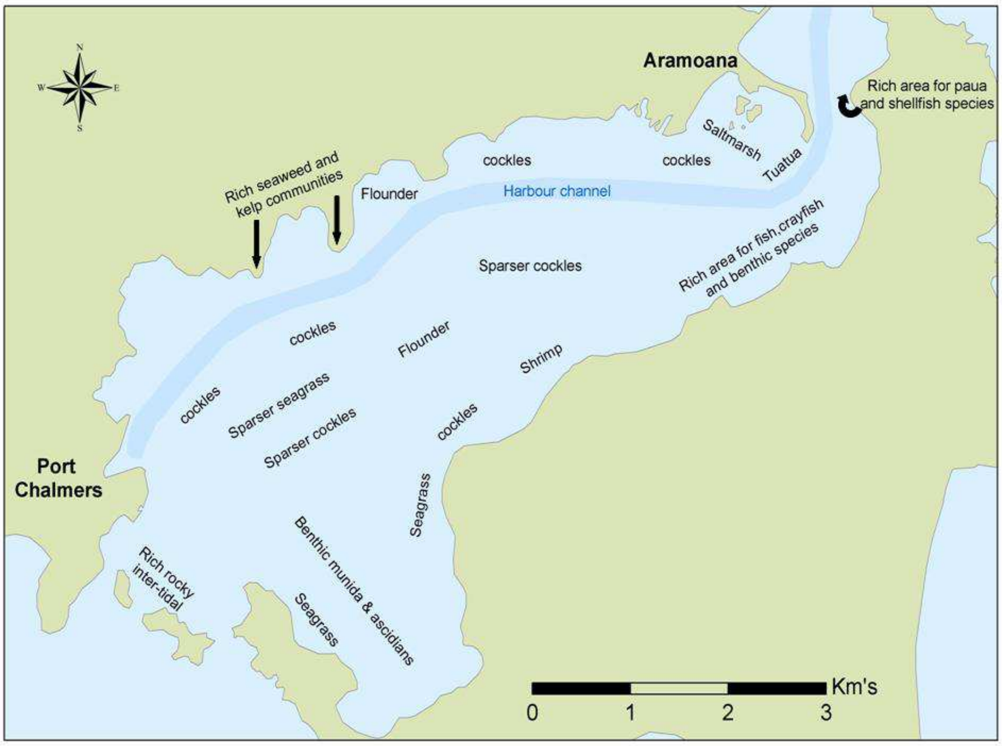


Figure 4. Areas where different benthic communities and habitats have been identified in the outer Otago Harbour (drawn from information and data collected by Otago University – K Probert pers comm).

Some of the benthic animals in the channel where it is to be dredged will be removed or heavily disturbed by the dredging operation. If the channel is dredged down to 14m this would represent 48% of the channel to Port Chalmers being directly impacted. The potential impact on cockle beds at the edge of the channel is difficult to assess until the beds are surveyed and the area of bank where widening is to occur is finalised.

Cockles and other bivalves found in intertidal estuaries are often exposed to high turbidity and sediment loads from storms and catchment runoff. Experiments have demonstrated that rapid accumulations (over 2 cm in one event) can smother benthic communities. The potential for smothering from the dredging operations and rates of recolonisation of invertebrates will need to be assessed once sediment dispersion and settling models have been run. Generally recolonisation is slower for sand communities compared with fine mud communities.

The most sensitive communities to indirect impacts of the proposed dredging are likely to be the seagrass communities, particularly those close to where the channels are to be dredged. More detailed mapping of seagrass beds along with plume modelling will be required to put potential effects on seagrasses into the context of the wider harbour. Generally the impacts of increased turbidity and smothering will be restricted to areas affected by dense plumes. Initial modelling (in progress) suggests that the extent of these plumes will largely be determined by wind direction and state of tide. Dispersion means that the plumes will be diluted away from the dredging activity and will be lower outside the channel zone. Again it must be remembered that these type of communities are subject to episodic high sediment turbidity and settling events that occur in harbours and estuaries.

Portions of the harbour have experienced major physical alteration, especially from changes associated with reclamation, shoreline development and dredging, although these are relatively limited in overall habitat terms. Importantly, most of the harbour's shoreline is now bounded by a rock wall retaining a road or railway that disrupts the natural shore profile. There are few stretches of unmodified rocky shore left in the harbour; the only extensive stretches of natural shore occur in the middle reaches. Based on some studies undertaken by Otago University the zonational pattern on these shores is typical for sheltered southern locations. Often conspicuous at extreme low water are bladder kelp (*Macrocystis pyrifera*) and sea tulip (*Pyura pachydermatina*). Mid-shore species include necklace weed (*Hormosira banksii*), blue mussel (*Mytilus galloprovincialis*), rock oyster (*Tiostrea chilensis*), snakeskin chiton (*Sypharochiton pelliserpentis*), the topshell *Melagraphia aethiops*, and the red alga *Stictosiphonia*

arbuscula. Periwinkles (*Nodilittorina* spp.) and lichens characterise the high-shore. Noteworthy at low water is the brachiopod (lamp shell) *Calloria inconspicua*.

Shores adjacent to the entrance to Otago Harbour comprise wave-exposed sandy beaches (with a seemingly typical but poorly known fauna dominated by amphipod crustaceans and polychaete worms) and rocky shores characterised by bull kelp (*Durvillaea antarctica*) (low shore), barnacles (*Chamaesipho columna* and *Epopella plicata*) (midshore), and winkles (*Nodilittorina* spp.) (high shore). The biotic composition of such shores appears to be typical for the region.

The adjacent continental shelf is relatively narrow, only about 10 km across at its narrowest point off Otago Peninsula, but widening to about 30 km in Blueskin Bay to the north. The Clutha River is the main source of modern sand to the shelf (now ~ 0.4 million tonnes p.a.). River-derived sediment, carried north by longshore drift, forms an inner shelf sand zone to water depths of 20-40 m. Limited surveys in this region have found amphipod crustaceans, spionid polychaetes and trochid gastropods (*Zethalia zelandica* and *Antisolarium egenum*) are typically abundant in this zone (Probert and Wilson 1984; Paavo 2006).

Gravelly sediments of the middle and outer shelf provide habitat for attached epifauna, notably several species of bryozoans (“lace corals”). Surveys and mapping of their distribution have found that large colonies form reef-like thickets at depths of about 70-110 m (Probert et al. 1979; Batson and Probert 2000; Jones 2006). These bryozoans appear to significantly enhance local biodiversity by providing habitat for many associated species (Wood 2005). Also distinctive of the outermost shelf is the queen scallop (*Psychrochlamys delicatula*), the basis of a local fishery. These communities are found well off-shore and generally south of the proposed disposal grounds (Figure 5) so are unlikely to be impacted by the proposed dredging and disposal. (Note that the dredge material disposal site is yet to be finalised and is preliminary at this stage). The queen scallop and bryozoan communities cease at the outer shelf break at water depths of 125-150 m. Beyond, the continental slope is incised by submarine canyons with a diverse benthos, but this habitat is unlikely to be affected by the proposed activities.

Maintenance and development dredging has been in place in Otago Harbour since 1865. Three dredge material disposal sites are currently in use and the Port Company has a Resource Consent to dispose of dredged material from its ongoing maintenance dredging at these sites until December 2011. The Heyward Point site was relocated 600 metres in 1977 following the disposal in 1976 of 3.2 million m^3 from a major dredging programme in the harbour. Although there were no surveys before and after

that disposal, unpublished data from University of Otago (see Raffaelli 1979) indicated that suspended material in the harbour increased by a factor of three during the operation in some parts of the harbour. Experiments being run at the time however, found that grazing molluscs were able to keep the substrate clean of mud.

As part of the most recent consent the Port Company was required to undertake a study of the effects of this disposal on the biota at the disposal sites. The direct impacts on the inner shelf benthos from the disposal of dredged material has been examined, in particular at the Spit Beach (Aramoana) disposal site (Paavo 2006). Macrofauna inside the Spit Beach disposal site was found to have lower species richness and abundance compared to adjacent sediments. Disposal related effects beyond the disposal area boundaries appear, at least in part, to be due to the accumulation mound influencing wave and tidal currents.

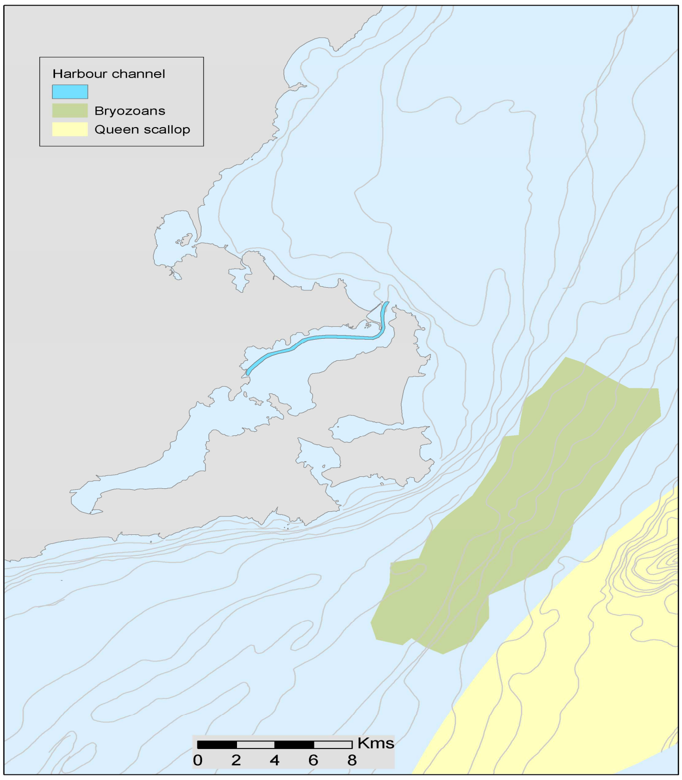


Figure 5. Areas where bryzoans and Queen scallops are found in the Otago Harbour region (redrawn with data from Beentjes and Cole (2002)).

In order to better understand the environmental effects of disposal at the Spit Beach site, the site was protected from dredge material disposal for an extended period followed by experimental disposal of sandy and muddy dredge material. Macrofaunal samples were collected before disposal and at nine sites within 120 days after disposal.

Disposal site samples were depauperate in individuals and taxa compared to an area protected from disposal for greater than 180 days. A drop in abundance and a dissimilar community coincided with muddy sediments, but fine sediments were dispersed within 26 days and macrofaunal assemblages recovered to the pre-existing state. Sandy material, while not altering native sediment textures, had a more prolonged impact due to transplantation of macrofauna (polychaetes, amphipods, molluscs) from the dredged area. These animals survived the transplant and persisted for more than 41 days after disposal thus increasing diversity and abundance of some animals (Paavo 2006).

Further work is required to determine the likely dispersal pathways for finer sediment from the proposed disposal site but based on preliminary modelling it is unlikely that the benthic community in the Blueskin Bay area will be impacted as the site is likely to be located offshore from the gyre that brings material into the Blueskin Bay area.

Recent surveys carried out in Port Otago and Port Chalmers for invasive species did not find the sea-squirt *Styela* but *Undaria* and 25 other new species to New Zealand waters have been recorded from the Otago region (Gust et al. 2006). It is highly unlikely that species like *Undaria* would colonise at the proposed disposal site because of the lack of hard substrate, depth and exposure.

2.2 Birds and mammals

2.2.1 Birds of the Otago harbour and coast

The outer Otago Harbour and the adjacent offshore marine environment support a diverse array of bird life including three nationally endangered species, five nationally vulnerable species and five species in gradual decline (Hitchmough et al. 2005, DOC pers comm). Species of conservation importance are listed below:

Table 1. Bird species of special conservation status found in the Otago region.

Common name	Taxon	Conservation status
Black-fronted tern	*Sterna albostriata*	Nationally endangered
Hutton's shearwater	*Puffinus huttoni*	Nationally endangered
Erect crested penguin	*Eudyptes sclateri*	Nationally endangered
Northern royal albatross	*Diomedia sanfordi*	Nationally vulnerable
Yellow-eyed penguin	*Megadyptes antipodes*	Nationally vulnerable
Stewart Island shag	*Leucocarbo chalconotus*	Nationally vulnerable

Caspian tern	*Sterna caspia*	Nationally vulnerable
Black browed mollymawk	*Thalassarche impavida*	Nationally vulnerable
Black billed gull	*Larus bulleri*	Serious decline
Black fronted tern	*Sterna albostriata*	Serious decline
Grey headed mollymawk	*Thalassarche chrysostoma*	Serious decline
Southern blue penguin	*Eudyptula minor minor*	Gradual decline
Red-billed gull	*Larus novaehollandiae scopulinus*	Gradual decline
Flesh-footed shearwater	*Puffinus carneipes*	Gradual decline
Sooty shearwater	*Puffinus griseus*	Gradual decline
White-fronted tern	*Sterna striata striata*	Gradual decline

These species, and other birds reported from the area, inhabit two major ecosystems within the area of interest to this study – coastal (including the outer Otago Harbour and the offshore area where dredged material may be disposed) and intertidal within Otago Harbour. Sagar et al. (2002) listed 34 species of seabirds previously reported from or are likely to occur frequently in Otago coastal waters. Thirteen of these species breed on the Otago coast (see Figure 6 for important sites) and another six commonly frequent the intertidal zone in the outer harbour. The following is a summary of the species of conservation interest that occur within the dredging and potential disposal zones.

2.2.2 Coastal species

The one mainland breeding colony of Northern Royal Albatrosses is situated on Taiaroa Head, Otago Harbour and thus is of high conservation value. The important foraging areas off the Otago coast of eighteen Royal Albatrosses from the Taiaroa Head colony, during the incubation stage of their breeding season, was monitored using global positioning system (GPS) loggers (Waugh et al. 2005). This study showed that waters within 100 km of the breeding colony were extremely important for the albatrosses (tagged individuals spent 28% of their time, on average within this area). This area is also frequented by albatrosses from Campbell Island, making it an important feeding habitat for this species. A large amount of foraging also occurred in areas much farther off shore. Birds spent multiple days at sea and travelled over large distances when searching for food (2-19 days at sea, travelling on average 2000 km). Consequently, because of the ability of the birds to forage over such a large area potential impacts to the albatrosses due to dredging and dredge material disposal are unlikely to have any discernable effect. The location of the breeding colony, high on the promontory, means that it should not be affected directly by dredging activity.

Sooty Shearwaters breed in colonies on Otago Peninsula. Birds from these colonies forage widely, obtaining their food by diving to depths of over 40 m and have the

ability to cover large areas of ocean rapidly. They feed mainly on small fish, squid, krill and other small crustaceans. Their ability to cover large areas of ocean rapidly and relatively small area of the disposal site means that there is unlikely to be any discernable effect of the dredging and the disposal of dredge material.

Yellow-eyed Penguins and Little Blue Penguins breed in coastal areas outside the harbour (Figure 7). They are predominantly pelagic feeders, foraging for food near the ocean floor (Marchant & Higgins 1990). Off the Otago Peninsula, Moore (1999) and Mattern et al. (2007) found that Yellow-eyed Penguins foraged mostly in waters over the continental shelf at depths between 40-80 m. Individuals were shown to retain foraging patterns throughout the breeding season; some birds were markedly inshore feeders, with centres of activity less than 5 km from the coast. Breeding success was related to foraging time. Failed breeders and non-breeders travelled further and for longer periods of time than breeding individuals. In addition, breeding birds that later failed took longer trips during incubation than successful breeders.

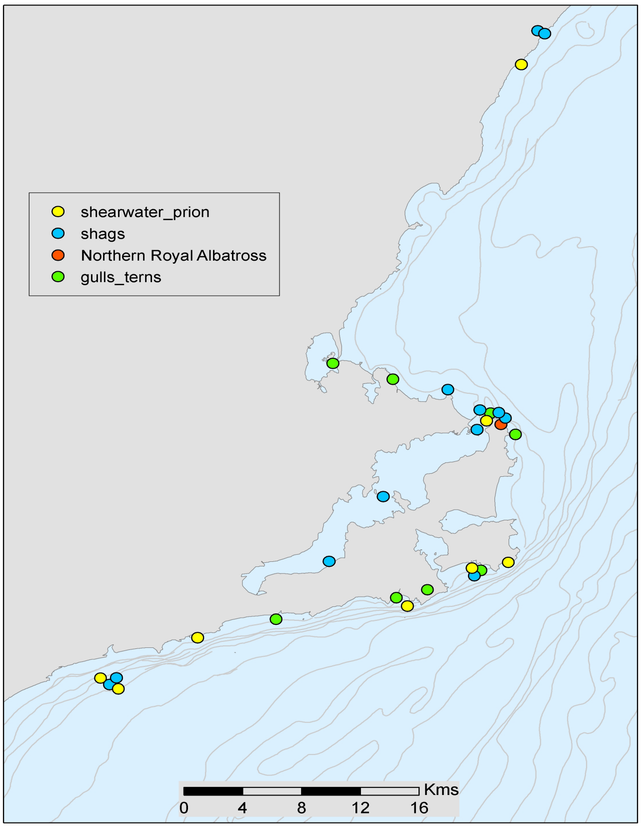


Figure 6. Areas important for marine bird nesting in the Otago region (redrawn with data from Sagar et al. 2002).

Both species of penguin breeding on Otago Peninsula are likely to forage within the proposed offshore dredge material disposal zone. Disruption of benthic communities and associated food sources in this zone may mean that birds will be forced to forage over a larger distance, The potential for disruption will depend on the final location and size of the disposal site. This area is yet to be determined but even if the site was up to 4 km^2 this would only cover a small percentage of the foraging habitat, especially as yellow-eyed penguins tend to forage mostly at depths greater than 40-80m which is well offshore from the proposed disposal area. Potential for impacts would be mitigated if dredging occurred outside the breeding season which is September to April.

Four species of shag inhabit the Otago Harbour and the adjacent coastline. Howlett Point is the only mainland breeding location of the Stewart Island Shag. The Otago population of Stewart Island and Spotted Shags represents about 20% of the species around New Zealand.

The diets of these shags have been analysed allowing the foraging habits of the birds to be deduced from the habits of their prey (Lalas 1983). Black and Little Shags generally forage close to shore in shallow water feeding on small fish. Stewart Island and Spotted Shags feed up to 15 km offshore and mainly on small fish.

Potential effects of dredging in the Otago Harbour include increased sedimentation in the water column, which may reduce visibility and therefore foraging success of these species. Dredging may also interrupt habitats and feeding grounds of fish species that make up the majority of the diet of Otago shag species. However, these effects are likely to be short-term and restricted in spatial extent. Modelling of the settlement of sediments will help identify the potential spatial extent of these effects.

White-fronted Terns breed in colonies on the outer coasts of Otago Peninsula (Sagar et al. 2002), while Caspian Terns and Black-fronted Terns do not breed in the area, thus breeding of these terns should not be affected by the proposed dredging. However, Lalas (1977, 1979) reported that 50-70, and occasionally almost 200 birds, of the Nationally Endangered Black-fronted Tern roosted on the Aramoana tidal flats at the harbour mouth and plantonic larvae, taken from the surface or just below the surface, were an important food source of these birds in the harbour region. The preferred prey of Caspian and White-fronted Terns are fish, crustaceans and squid, which they capture by diving. Consequently, dredging may temporarily interrupt habitats and feeding grounds of the terns and their prey species.

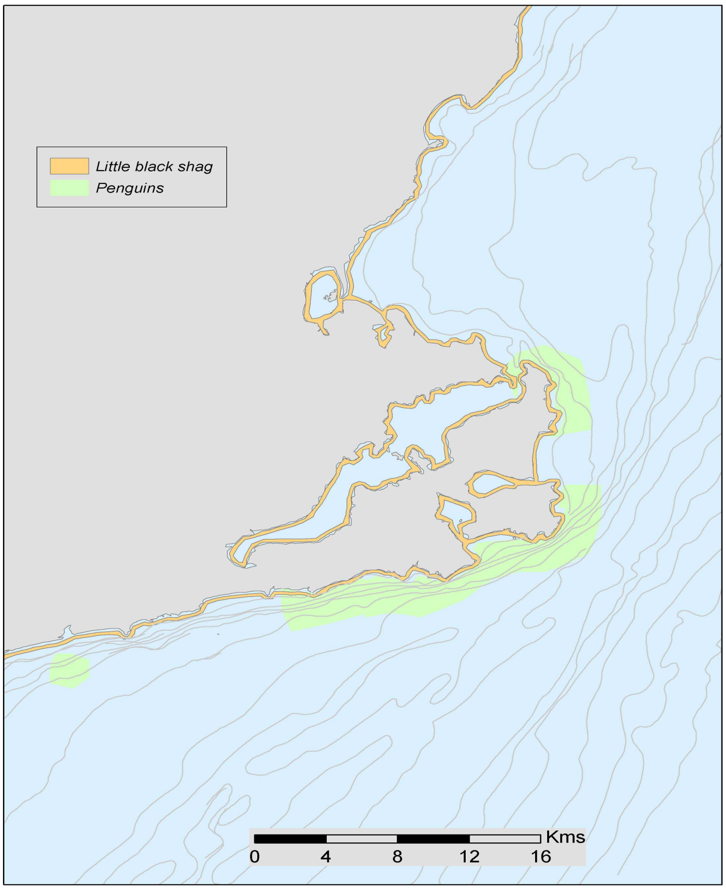


Figure 7. Areas where Little black shag and penguins are found (redrawn with data from Sagar et al. 2002).

Intertidal shorebirds

Large numbers of intertidal shore birds (comprising mainly South Island Oystercatchers, Variable Oystercatcher, Bar-tailed Godwits, Lesser Knots, Banded Dotterels, and Pied Stilts) feed within Otago Harbour and on sand flats at Aramoana. (Sagar et al. 1999; Sagar, *unpublish data*). The largest numbers of wading birds in the Harbour have been recorded in the Aramoana region but most of these species use the area for feeding rather than breeding.

The majority of these species feed on intertidal invertebrates (including molluscs, polychaete worms and crustaceans). Increases in suspended sediments in the water column and sedimentation due to dredging of the harbour channel has the potential to decrease the abundance and distribution of these benthic communities which in turn will effect foraging of intertidal bird species. However, it must be remembered that

harbours and estuaries are naturally turbid and most of the invertebrates are adapted to episodic high turbidity events.

Marine mammals

Four seal and six cetacean species have been reported from the Otago coast (Sagar et al. 2002). All species spend time in the coastal water off Otago, and several species of seal use areas on the Otago Peninsula as haul-out areas and breeding grounds. The following is a summary of the marine mammal species that occur within the dredging and disposal zone. Mammals with special conservation status are listed below (Hitchmough et al. 2005).

Table 2. Marine mammals of special conservation status known from the Otago region

Common name	Taxon	Conservation status
Southern elephant seal	*Mirounga leonine*	Nationally Critical
Hector's dolphin	*Cephalorhynchus hectori hectori*	Nationally Endangered
Southern Right whale	*Eubalaena australis*	Nationally Endangered
New Zealand sea lion	*Phocarctos hookeri*	Range Restricted
Bottlenose dolphin	*Tursiops truncatus*	Range Restricted

The main seal haul-out and breeding areas are located on the Otago Peninsula's outer coast. The New Zealand Fur Seal (*Arctocephalus forsteri*) is the most common species in the area, where it occupies exposed rocky headlands. In 1998, 27 breeding and 41 non-breeding colonies were identified and, within these, about 5000 non-pups and 1300 pups were counted (Bradshaw et al. 2000). The breeding and haul-out colonies are located on the outer coast, with none occurring within Otago Harbour. The New Zealand sea lion (*Phocarctos hookeri*) inhabits dune areas and sandy beaches, including Papanui Beach, which is used as a main haul-out ground. The total population of sea lions in Otago was estimated to be around 40-100, with observations suggesting that the population was increasing and that their breeding range is expanding to include the Otago Peninsula.

Fur seals forage up to 78 km from Otago rookeries while sea lions are known to spend several days at sea foraging and completing dives as great as 474m (Harcourt et al. 1995; Gales and Mattlin 1997). Consequently, because of the ability of these species to forage over such a large area any potential impacts due to dredging and dredge material disposal would be minimal.

Two other species, the southern elephant seal (*Mirounga leonine*) and leopard seal (*Hydrurga leptonyx*) are also occasionally sighted on the Otago coast. This area represents the most northern extent of their ranges (although stragglers are found further north) and both species are more commonly found off the Subantarctic Islands and over the Antarctic ice shelf (Sagar et al. 2002) and thus are unlikely to be impacted by the proposed dredging and disposal of dredged material.

Off the Otago coast, four dolphin species are found - Hectors dolphin, (*Cephalorhynchus hectori hectori*), Dusky dolphin (*Lagenorynchus obscurus*), Bottlenose dolphin (*Tursiops truncates*) and Common dolphin (*Delphinus delphis*). Dusky and Common dolphins occasionally enter the Otago Harbour, often staying for several days at a time, and travelling as far as the inner basin (Dunedin City Council 2006; Würsig et al. 2007). Hector's dolphins are endemic to New Zealand, and are considered to be at very high risk of extinction in the wild (Ministry of Fisheries 2007a). Hector's dolphins inhabit inshore coastal waters and are generally restricted to local areas, with little movement between areas. Although found throughout the area and along the east coast they are more abundant to the north of the proposed disposal site.

The Humpback whale (*Megaptera novaeangliae*) can be sighted off Otago coast in autumn during their northward migration to breed. The distance from shore and depth of their main migration routes are unknown, however a juvenile Humpback whale was sighted feeding within the Otago Harbour. Sightings of the Southern Right whale (*Eubalaena australiis*) off the Otago coast are also frequently recorded at various locations close to shore. The coastline is part of their migration route, and they probably feed over the entire continental shelf. Direct impact on whales from dredging and disposal activities is highly unlikely as they can avoid areas of activity.

2.3 Fisheries

This summary provides an outline of fishery resources and fishing activities in Otago, concentrating on what is known about the coastal (inshore) waters adjacent to Otago Peninsula that may be within the area of potential impacts from the dredging of the approaches to Port Chalmers and related disposal of dredged material.

2.3.1 Commercial fisheries

There is a substantial knowledge base about commercial fishery resources and commercial fisheries (Ministry of Fisheries, 2007b), although much of the available information is on a population or species level rather than specific to Otago. The

populations of most fish species are very widely distributed along the coast. At least 100 fish species have been found on the continental shelf and upper slope of the east coast of the South Island (Beentjes et al. 2002). Fish are highly mobile and their abundance varies both in space and time which frequently complicates fishery assessment (Peterman 2004). In spite of these difficulties, knowledge of the main commercial fishery resources and fisheries around Otago Peninsula and along the Otago coast is generally very good. Beentjes & Cole (2002) summarised the main commercial fisheries along the Otago coast. A variety of Otago research studies on fish and fisheries conducted through Otago University and Portobello Marine Laboratory provide additional knowledge on local fish species and resources ranging from observations and records of fish species present in Otago waters (Graham 1938, 1940) to more detailed studies of the commercial flatfish fishery (James 1970).

The Otago coast supports a diverse and productive commercial fishery for a wide range of fish and shellfish species involving a number of fishing methods. Fenaughty & Bagley (1981) provide a history and description of the South Island East Coast commercial fishery, including the fishery off Otago.

At present, about 12 commercial fishing vessels operate from Port Chalmers (Ministry of Fisheries, pers. comm.) although the number of vessels operating varies seasonally. A few commercial fishing vessels that fish the Otago inshore fishery operate from Karitane and Moeraki and some larger vessels from other areas may fish for barracouta in late winter/spring off the Otago coast. Many of the smaller local vessels are multi-purpose, shifting between trawling and lining, or set-netting, rock lobster potting or cod potting, seasonally. The number of commercial fishing vessels operating out of Port Chalmers, Karitane and Moeraki has steadily reduced over the past decade due to economic pressures and progressive industry rationalisation (Ministry of Fisheries, pers. comm.).

Flatfishes (sand flounder, lemon sole and New Zealand sole) are the main target species in the coastal Otago commercial trawl fishery. Flatfish catches in Otago coastal waters (Oamaru to Slope Point) varied from about 200 to 650 tonnes per year from 1990 to 2001, with slightly more than half of that catch coming from the coast from Taieri River mouth to Oamaru, which includes Blueskin Bay. Total flatfish landings from all New Zealand fishery waters are over 3,000 tonnes annually (Ministry of Fisheries, 2007b). Bycatch (incidentally caught fishes) of the Otago target trawl fishery for flatfish includes a mix of other fishes; mainly barracouta, blue warehou, elephant fish, giant stargazer, groper, ling, red cod, red gurnard, rig and skates (Beentjes & Cole, 2002).

The seasonal occurrence and distribution of adult, juvenile and planktonic larvae of the flatfish were studied by Roper and Jillett (1981). The larvae of three species were common in the harbour and adjacent inlets during late winter to early summer, resulting in peak abundance of juveniles in these areas over summer. Numbers declined during winter most likely because of emigration and predation. Eight species of flatfish were found offshore, although four of these species were rarely caught. All juvenile fish congregated in finite nursery areas, in inlets or shallow coastal water.

In the Blueskin Bay area, bottom trawling is the predominant commercial fishing method used to catch fin fish, although lining and set-netting are also important for some species (Fishing industry sources, pers. comm..). The smaller Port Chalmers based trawlers mainly target flatfishes. The waters of Blueskin Bay are important for these smaller flatfish trawlers who operate on day trips (Ministry of Fisheries, pers. comm.). Larger trawlers target flatfishes in the shallow waters along the entire Otago coast and also target red cod, barracouta and other species further offshore. Local information indicates that the main commercial red cod and barracouta fisheries take place well to the north and south of Otago Peninsula (Fishing industry sources, pers. comm.).

Lining vessels mainly target ling and groper in deeper waters off the Otago Peninsula. Set-netting targets rig, school shark and elephant fish from shallow inshore waters to the edge of the continental shelf, including the waters of Blueskin Bay. Cod potting is the main method used for blue cod (Beentjes & Cole 2002).

Potting for rock lobster and diving for paua occur adjacent to rocky shores or over rocky reefs. Since 1983, a commercial fishery for cockles has developed in Papanui and Waitati Inlets and these are currently the only commercial cockle fisheries in the Otago Region. Recent cockle landings from Papanui and Waitati Inlets have totalled more than 900 tonnes annually, making this fishery the largest commercial cockle fishery in New Zealand, comprising more than 60% of the New Zealand-wide cockle harvest. A small dredge fishery for queen scallops takes place in waters deeper than 100 m off Otago Peninsula. Diving for kina takes place along rocky shores of Otago Peninsula. Although not presently fished commercially, surf clams are abundant in very shallow waters along the surf-swept sandy beaches of Blueskin Bay and represent a potential future commercial resource.

Inside Taiaroa Head, Otago Harbour is closed to commercial fishing using a box or teichi net, purse seine net, Danish seine net, trawl net, or lampara net, or set nets of a total length in excess of 1000 metres [Fisheries (South-East Area Commercial Fishing) Regulations 1986]. There are additional regulations prohibiting all

commercial set netting in an area of the upper harbour, around Port Chalmers and around Taiaroa Head. Regulations also prohibit all commercial shellfishing in Otago Harbour except for taking rock lobster, oysters and crabs. Although current regulations allow limited commercial fishing activity to take place within Otago Harbour no commercial fishing is known to take place at the present time (Ministry of Fisheries, pers. comm.).

In summary, there are no known unique or special features of the commercial fishery around Otago Peninsula that set it apart from other fisheries on the east coast of the South Island. Fishing effort targets common commercial fish and shellfish species and takes place along the entire coast wherever these species are found. No commercial fishing is known to be currently taking place within Otago Harbour, so that direct conflict between existing commercial fishing and dredging activities is unlikely to occur. Applications are however being made for harvesting of cockles in the harbour. On the open coast of Otago, fishery resources are typical of the east coast of the South Island. The Otago coastal fishery is part of a continuum of commercial fishing activity that takes place along the entire east coast of the South Island. Commercial catches are typical of the east coast of the South Island and consist of common and widely distributed species.

Within the areas potentially suitable for disposal of dredged material, Blueskin Bay is locally important as an operating area for small commercial trawlers that work out of local ports due to the sheltering effect of Otago Peninsula. However, the relatively expansive and uniform seabed of Blueskin Bay and the dispersed nature of the main trawl fishery resources, such as flatfish, mean that fishing effort does not tend to be concentrated at particular sites but is spread throughout Blueskin Bay. Disposal of dredged material would potentially impact a very small area relative to the overall area available to commercial fishers and the location of the proposed site means it should not impact Blueskin Bay. The main site-specific effects from disposal would be the smothering of benthic organisms on which fishes feed. Recolonisation would occur relatively quickly and any adverse effects would therefore mostly be temporary. Provided that appropriate consultation takes place with the commercial fishing sector, it should be possible to find a disposal site that minimises any commercial fishery impacts. Experience with disposal of dredged material into a similar receiving environment in the Hauraki Gulf by the Ports of Auckland, where the intensity of fishing effort is much higher, lends support to this conclusion.

2.3.2 Recreational fisheries

The main recreational fisheries on the Otago coast are based on many of the same species as the commercial fishery. Regional and national recreational fishing surveys undertaken periodically since the early 1990s provide a good overall knowledge of recreational fishing effort, methods, species and catches (Teirney et al. 1997, Bradford et al. 1998, Boyd & Reilly 2002). As with commercial fishery data, recreational fishery surveys have been mainly aimed at describing the fishery on a broad regional level rather than local fishery details. Most of the data collected for the Otago recreational fishery in the regional and national surveys is for an area of coast extending from the Waitaki River to the Tokomairiro River. Information from recreational fishers provides some additional local details about the recreational fishery.

On the open coast, line fishing for blue cod dominates both recreational fishing effort and harvest, especially north of Otago Peninsula to Moeraki (Fisher & Bradford 1998). Line fishing for red cod and groper takes place in deeper waters along the coast. Set-netting or spearing for flatfish and hand gathering for shellfish is important in all of the shallow harbours. Although fewer fishers are involved, diving for rock lobster and paua is important along the rocky shores, including Otago Peninsula.

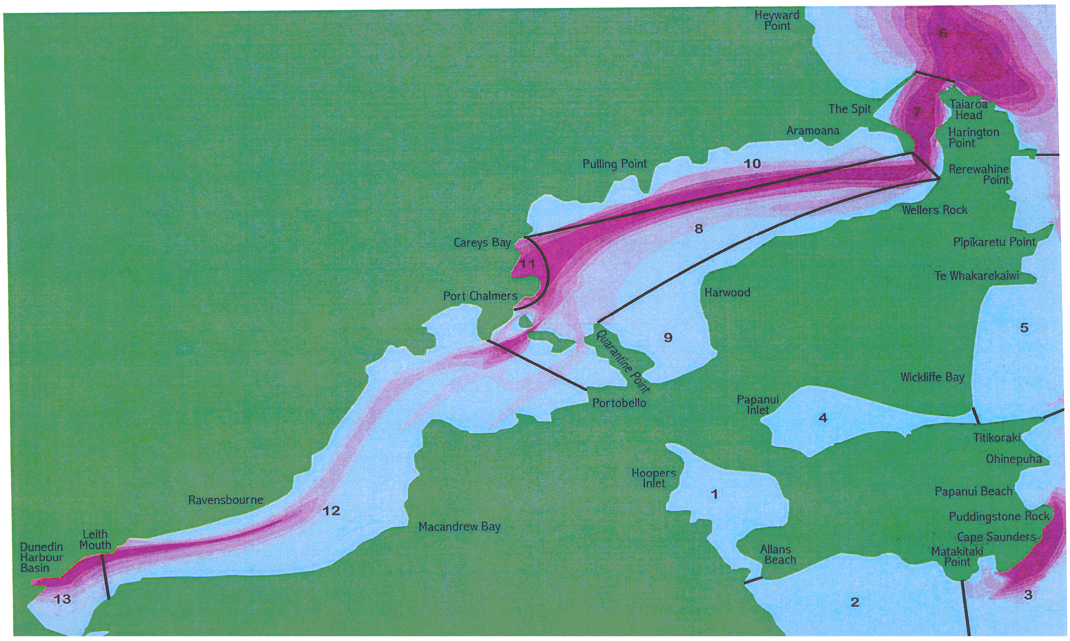
A small number of recreational charter fishing vessels operate seasonally from Moeraki, Karitane and sometimes Port Chalmers, mainly targeting blue cod and groper.

Based on a 12 month diary and interview survey commencing in December 1997, Bell (1999) gives detailed information about recreational fishing within Otago Harbour, Papanui Inlet, Hooper's Inlet and along the open coast from Heyward Point to Allan's Beach, including species targeted and caught, methods used and areas fished. Of more than 6,000 recreational fishing trips reported in the survey, 88% targeted salmon, and 5% targeted blue cod, with the balance targeting a wide range of other species. Fishing with rod and line, either from a boat or from shore, or hand gathering were the most commonly used fishing methods. Although targeting salmon dominated fishing effort, barracouta comprised the greatest catch in numbers harvested (28%), followed by cockles (25%), blue cod (13%) and salmon (7%). The greatest number of recreational fishing trips were made in the upper harbour basin (33% of all trips), followed by trips in the harbour entrance area (15%), and in the open harbour between The Spit and Port Chalmers (12%) (Bell, 1999). Figure 8 shows the location and intensity of recreational fishing effort in Otago Harbour and along the adjacent coast (after Bell, 1999).

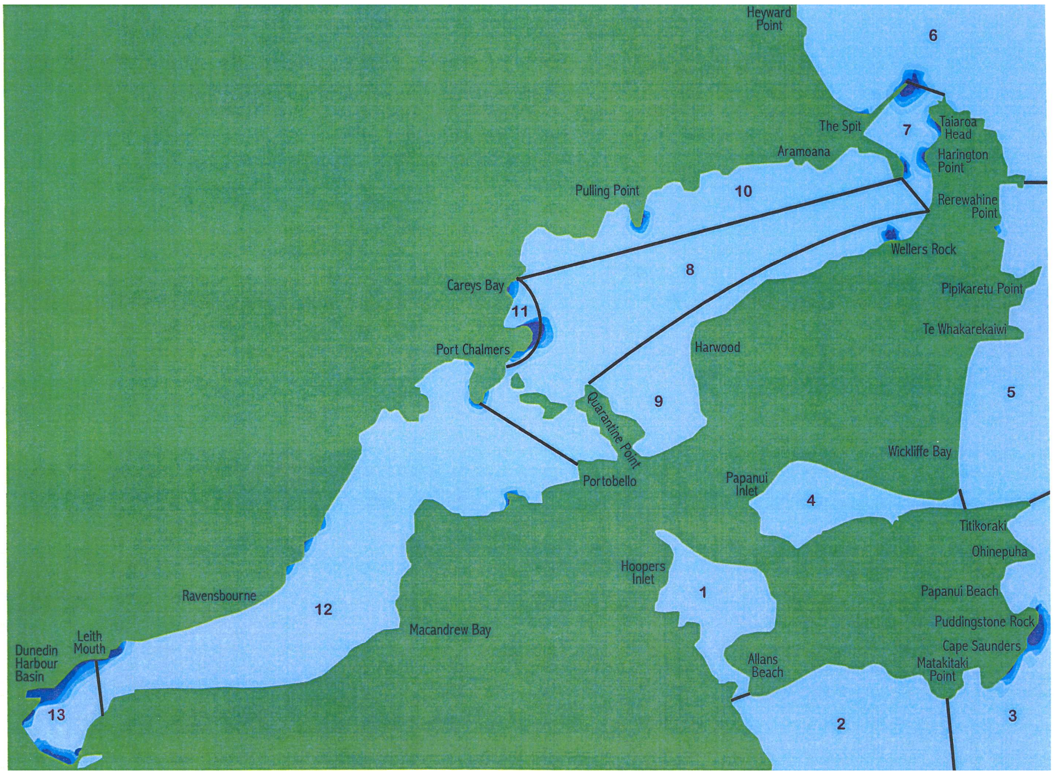
The recreational salmon fishery in Otago Harbour is a unique fishery in New Zealand because the salmon are targeted in marine waters and not at river entrances. The salmon fishery is 'put and take' fishery based on the release of hatchery reared salmon smolts into Otago Harbour which grow at sea and return to Otago Harbour to spawn. Most salmon fishing takes place from December through to March, with boats concentrating effort in the harbour entrance area, and shore fishers from the wharves around the upper harbour basin, at Port Chalmers and at the harbour entrance (see http://www.fishingmag.co.nz/salmon.htm for an article on this fishery).

Within Otago Harbour, recreational set netting is prohibited in three areas. These areas are the main channel in the upper harbour above Kilgour Point, around Port Chalmers and around Taiaroa Head [Fisheries (South-East Area Amateur Fishing) Regulations 1986].

Except for the salmon fishery in Otago Harbour, there are no distinctive or special recreational fisheries unique to the Otago Peninsula or Blueskin Bay. The proximity of Otago Harbour, the coast of the Otago Peninsula and Blueskin Bay to Dunedin means that these areas are more important for recreational fishing than the less populated areas of Otago's coast. Given the dispersed nature of recreational fishing and the proximity of most recreational fishing to the near shore zone, there is limited potential for direct conflict between recreational fishing interests and disposal of dredged material at open coastal locations. Within Otago Harbour, the potential for conflict between the effects of dredging activities and recreational fishing is more difficult to assess. Siltation of harbour shellfish beds from dredging activity is very likely to be a public concern although most harbour resources are well adapted to a silty environment. The main intertidal shellfish beds most accessible to the public are some distance from the shipping channel and occur along the southern shores of the harbour. Provided that siltation of the intertidal zone from dredging activity can be demonstrated to be within biologically acceptable levels this is a manageable issue. There is also some potential for the dredge operation itself to conflict with the recreational salmon fishery although this would be expected to be very localised.

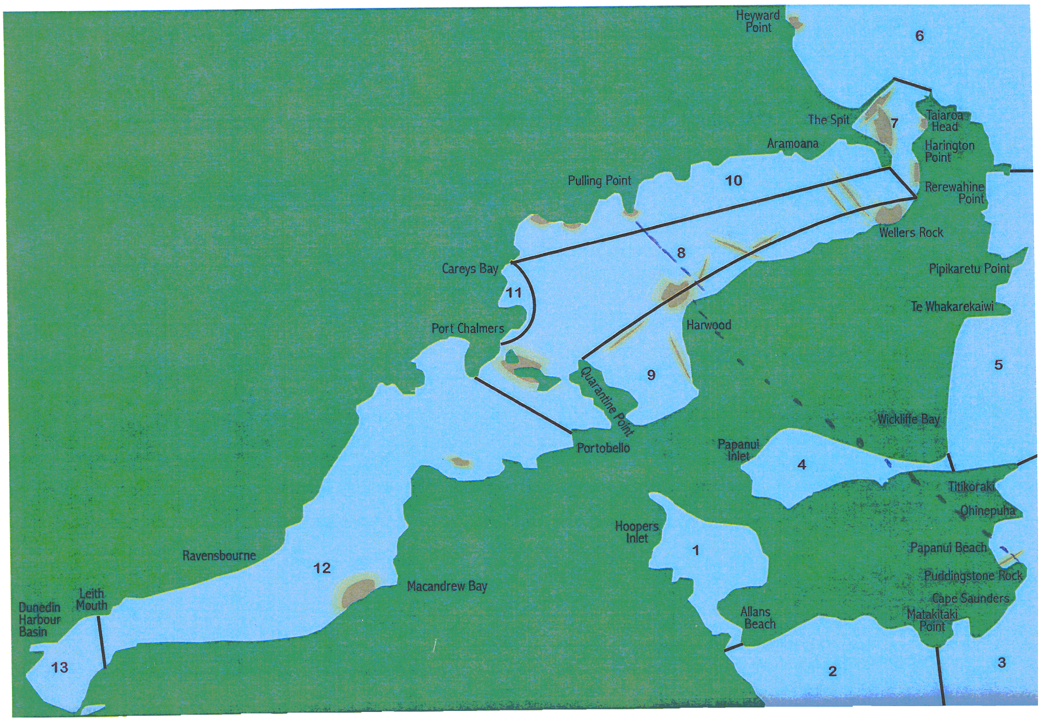


Otago-Map showing location and intensity of “rod/line fishing from a private boat”.

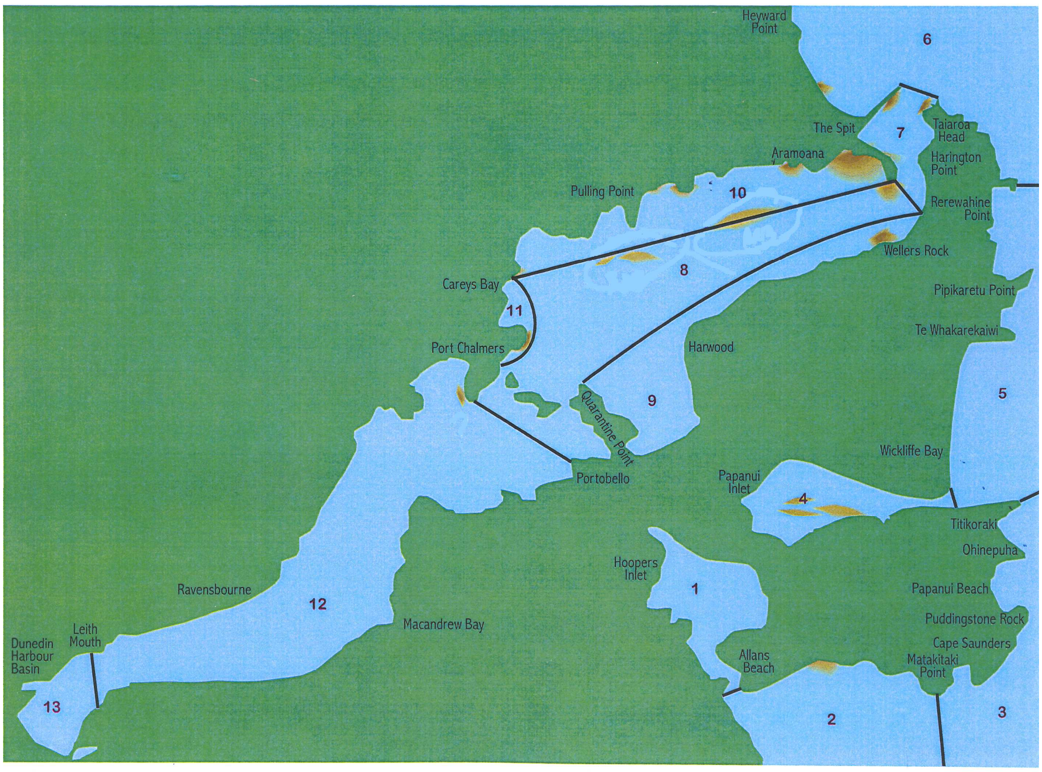


Otago-Map showing location and intensity of “rod/line fishing from the shore”

Figure 8. Maps showing location and intensity of recreational fishing by method (Figures 17-20, Bell 1999).



Otago-Map showing location and intensity of set netting.



Otago-Map showing location and intensity of hand gathering effort.

2.3.3 Customary fisheries

The East Otago Taiapure (a customary fishery area under the Fisheries Act 1996) extends from Cornish Point in the north and incorporates the inshore waters of Waitati Inlet, Karitane, Blueskin Bay and Purakaunui Bay as far as Potato Point in the south. Within Otago Harbour, tuaki (cockles) and patiki (flounders) are harvested from the extensive mud flats around Otakou. Rock lobster, paua and kina are harvested from the rocky shores of Otago Peninsula outside of the harbour. Tangata Whenua will have more definitive information that will be discussed and evaluated during the consultation process.

3. Potential effects of dredging

For this scoping exercise, the potential significance of the effects of dredging was evaluated based on three criteria:

- severity - which is a measure of the degree of harm, without consideration of duration or spatial extent;
- duration - which is the time between the initial effect and recovery once operations have ceased; and
- extent of impact - which is the spatial distribution of the impact**.**

The following rating levels for each of the three criteria have largely been adapted from Emmett (2002) and applied to the assessment of the significance of potential effects of the proposed dredging operation:

1. <u>Severity:</u>

Severity	
LOW	• No threat to critical food supply, species life-cycles. • Minimum impact on species important for structure or function. • No significant changes to species diversity and abundance/biomass. • Minimum impact on habitat complexity/diversity/productivity. • Minor changes to ambient environmental quality.
MEDIUM	• Loss of non-critical food supply/reduction in critical food supply. • Displacement of non-reproductive activity. • Species important for structure or function may be lost or impacted. • Changes to species diversity and abundance/biomass. • Reduction in habitat complexity/diversity/productivity. • Changes to ambient environmental quality.
HIGH	• Major changes to fauna and flora (e.g., through loss of critical food supply, interruption of reproductive life-cycle). • Substantial reduction in abundance/biomass of species important for structure and function. • Significant impact to biodiversity and ecological functioning. • Loss of complex or vital habitat. • Major impacts on ambient environmental quality.

2. Duration:

Duration	
SHORT-TERM	• Short-term impacts last for less than 1 year.
MEDIUM-TERM	• Medium-term impacts last for periods of 1-5 years.
LONG-TERM	• Long-term impacts last for more than 5 years.

3. Extent of Impact:

Extent of Impact	
SITE-SPECIFIC	• Impact or disturbance is restricted to the site at which the activity is occurring.
LOCAL	• Impact or disturbance extends up to 1,000 m beyond the boundary of the site at which the activity is occurring.
REGIONAL	• Impact or disturbance extends further than 1,000 m beyond the immediate boundaries of where the activity is occurring.

Emmett (2002) recommended that, in general, impacts are considered significant if:

- **Severity** ranks high;
- **Duration** is long-term, and **severity** is medium or high; or
- **Extent of Impact** is regional, and **severity** is medium or high.

The following tables apply these criteria to the likely impacts of the proposed dredging and disposal operations.

ACTIVITY	POTENTIAL EFFECT	POTENTIAL CONSEQUENCES	ADDITIONAL INFORMATION	SIGNIFICANCE OF EFFECT		
				SEVERITY	DURATION	EXTENT
Dredging operation	1. Direct impact on biological communities in and alongside the channel (organisms removed with dredged sediments).	Organisms in the dredged channel will be removed or heavily disturbed. This means loss or modification of assemblages and benthic processes within the channel (at least temporarily). In some areas cockles will be removed from the edge of channel during widening.	Recovery is most rapid for disturbed channel muds (weeks to months), as these sediments tend to be occupied by small, fast-growing opportunistic species. Recovery periods are more extended for coarser sediments, particularly those occupied by long-lived organisms such as cockles. Recovery can take years for gravel/shell deposits which have diverse epifaunal life. Most sediments that will be dredged in the Port Otago case are already modified and disturbed through maintenance dredging and are also likely to be predominantly fine sands except in the Port region (this needs to be verified). If the channel was dredged down to 14m this would represent 48% of the channel being directly impacted. Consequences of species loss depends on the species removed; large long-lived organisms often control community structure and ecological functioning, thus their loss can translate to important shifts in productivity and valued ecosystem services. Recovery of benthic animals occurs through larval recruitment. However, bed-load transport of juvenile and adult life-stages can contribute as much or more in highly mobile sediment environments. A highly mobile sand environment that is surrounded by healthy sand-associated communities will recover from dredging more quickly than an isolated, fragmented, low-mobility sediment environment. Cockles do not occur much below MLWS and are unlikely to be present in abundance within most of the channel itself but would be expected to occur along the channel margins. Cockles are a highly valued resource in the region. Removal of cockles during dredging and particularly widening of the channel will occur. The exact area to be impacted is yet to be determined but impacts are likely to be very localised.	High	Medium-term	Site specific (Exact percentage of cockle population on edge of channel affected yet to be estimated but likely to be low cf total population, the channel itself is too deep for cockles).

ACTIVITY	POTENTIAL EFFECT	POTENTIAL CONSEQUENCES	ADDITIONAL INFORMATION	SIGNIFICANCE OF EFFECT		
				SEVERITY	DURATION	EXTENT
	2. Plume of turbid water/smothering of benthic communities	When turbidity is high, suspended sediment can clog gill and filter-feeding structures (particularly in suspension feeding bivalves like cockles, mussels and scallops as well as zooplankton), impairing respiration and food gathering. When the sediment settles in the vicinity of the dredged area, it can smother benthic organisms depending on the amount of sediment settling. Small and recently settled life-stages are especially vulnerable to smothering, as are organisms that must maintain contact with the sediment water interface. In chronically turbid places, benthic communities may shift and become dominated by deposit feeding species. Changes in sedimentation regime and sediment characteristics, including increased settlement of fine material and changes in grain-size, may result in changes in benthic community structure. Generally, muddy sediments have low species richness and are dominated by small surface-associated taxa. Shifts to finer sediments could be accompanied by a shift in benthic food webs from suspension- to deposit-feeding species. Changes in hydraulic regime could also impact on benthic communities further up the harbour (needs to be checked through modelling dispersion).	Fine silt and clay particles have slow fall velocities and are thus transported much further than sand particles. If "clean" sandy sediments are dredged, the turbidity plume will be spatially localised and will not persist for long once the dredging ceases. The dimensions of the plume obviously depend on prevailing water movements. Management of the dredging operation could be an option to mitigate or minimise these effects if identified and necessary. Benthic impacts are generally restricted to areas affected by dense plumes, with the extent and severity of impact most pronounced at low energy locations when water exchange and wave action is limited. Estuaries are naturally turbid relative to coastal waters. Macrofauna and zooplankton living in turbid harbours/estuaries are probably better conditioned to deal with increased sediment concentrations and in the case of macrofauna sediment deposition rates. Understanding potential impacts requires some knowledge of background turbidity conditions and animal sensitivities. Beyond a critical threshold, sediment will have a negative influence on even the hardiest estuarine benthic communities. Rapid accumulations of sediment (>2 cm in a single event) can cause smothering and death, while effects of chronic sedimentation are less well known (likely to slowly cause distribution changes due to feeding/breathing interference). Recovery times are variable, but are likely to take months-to-years (see above). Potential impacts need to be clarified when the amount of sediment potentially deposited has been estimated.	High locally, medium away from dredged area.	Short-term	Site specific/Local (depending on what sediment plume models show).

ACTIVITY	POTENTIAL EFFECT	POTENTIAL CONSEQUENCES	ADDITIONAL INFORMATION	SIGNIFICANCE OF EFFECT		
				SEVERITY	DURATION	EXTENT
	3. Turbid plume effects on birds, mammals and fish	Mammals and most fishes are highly mobile and with the exception of very small fish, juveniles and larvae, fishes are generally able to actively avoid highly turbid dredge plumes. Many benthic species have a larval planktonic phase and it is possible that changes in the composition and abundance of zooplankton associated with a long period of higher turbidity could drive changes in the abundance of benthic species. This will depend on the period and timing of dredging. Bird feeding could be disrupted if suspended sediments become deposited in the intertidal and impact on benthic species that form their main prey. Similarly localised feeding by fishes on benthic organisms could be affected by the smothering of benthic species in the intertidal and subtidal zones.	Because of the ability of albatrosses and shearwaters to forage over such a large area any potential impacts due to dredging and dredge material disposal are likely to be minimal. Penguins are unlikely to be affected directly by the dredging operations or at the proposed offshore site as they forage at depths of 40-80m. They could however be affected if their food supply was impacted over a large area. Management of the dredging operation could be an option to mitigate or minimise these effects if identified and necessary. Increased sedimentation in the water column that reduces visibility and foraging success and indirect effects on fish and invertebrates that make up their diet could impact on shag and tern populations and intertidal shorebirds that are visual feeders. While dolphins and whale are occasionally sighted in the harbour most of their foraging grounds are along the coast and in the case of Hectors dolphins are commonest further north. Fish are mobile and able to move to other areas to feed in order to avoid temporary or localised impacts.	Low	Short-term	Local – but note they are very mobile (exact extent of plume yet to be determined).
	4. Reduced water clarity and increased sedimentation effects on plant communities	Increased suspended sediment and sedimentation due to dredging may result in reduced production and in extreme cases loss of seagrass. Microphtyobenthos (i.e., benthic microalgae like diatoms) are important benthic primary producers in unvegetated habitats. Production by microphytobenthos would also be affected by reduced light levels, and this could impact benthic fauna indirectly via the food web. These effects depend on the extent of plumes and amount settling.	High turbidity is equivalent to low water clarity. Light penetrates much deeper in clear waters than in turbid waters. The amount of sunlight penetrating to the seabed is a factor that controls the growth of seagrasses and other submerged aquatic vegetation, including macroalgae. A number of overseas studies have noted that changes in sediment loads may be the most significant factor controlling seagrass density and distribution. Erosion from catchments and storm-associated waves can elevate turbidity at scales well beyond localized dredge plumes. Thus, in estuarine and harbour environments such as Port Otago, changes in suspended matter need to be assessed against the	Low/Medium (Low if flushing characteristics are sufficient to disperse particulate matter).	Short-medium term	Site-specific/Local (exact extent of plume yet to be determined, likely to be low-medium for total community).

ACTIVITY	POTENTIAL EFFECT	POTENTIAL CONSEQUENCES	ADDITIONAL INFORMATION	SIGNIFICANCE OF EFFECT		
				SEVERITY	DURATION	EXTENT
			high background levels of suspended sediment that occur episodically. The potential impacts need to be assessed once modelling of the plumes and settlement is completed.			
	5. Release of contaminants from dredged benthic sediments	Increase of contaminants into water column that may impact biota and accumulate in biological systems. Contaminants released from benthic sediments during dredging could potentially bioaccumulate. This means that contamination becomes more concentrated in species at the top of the food chain (large fishes, birds, marine mammals) and could ultimately affect human health and the value of commercial fish catches if there were persistent high levels of contaminants.	Previous testing would suggest that levels of contaminants in the sediments in the Otago Harbour and Port Chalmers are unlikely to be above levels known to be toxic to marine organisms and ANZECC guidelines. Dredged material is likely to contain little or no faecal bacteria. These levels need to be verified for sediments that are to be dredged from the outer harbour and Port Chalmers during this project.	Low/Medium [*Low if testing reveals low levels]*	Short-term	Site specific (but will depend on extent of plume and type of contaminants present – yet to be determined).
	6. Release of nutrients from dredged benthic sediments	Nutrients are necessary for the growth of primary producers (e.g., phytoplankton), but excess nutrients can cause algal blooms. Zooplankton and filter-feeding benthos might benefit from excess food resources associated with increased phytoplankton, but could be negatively affected by hypoxia or toxicity associated with some phytoplankton blooms.	Effects of dredging on water column nutrient concentrations could drive changes in the composition and abundance of planktonic communities. Some blooms are harmful, and effects of harmful algal blooms are well documented in the literature. Zooplankton consists of planktonic animals including the larval life stages of benthic fauna such as worms, bivalves, echinoderms, crustaceans, ascidians, etc. Alterations of the nutrient regime could result in changes in the abundance of benthic species due to effects on larval stages. Effects will depend on the duration and magnitude of nutrient enrichment relative to background. Compared to the direct effects of dredging on benthic communities (i.e., elimination of adult communities), these effects are likely to be minor/undetectable.	Low	Medium-term	Local (will depend on extent of plume and nutrients present).
	7. Release of organically enriched / anoxic sediments	The exposure of anoxic sediment can result in local depletion of oxygen and localised water column hypoxia/anoxia.	In shallow areas and in areas with sufficient water movements, this is not likely to be a major concern. The disruption of muddy benthic habitats could cause more oxygen issues than the dredging of sandy	Low	Short- term	Site specific (will depend on extent of plume and level of

ACTIVITY	POTENTIAL EFFECT	POTENTIAL CONSEQUENCES	ADDITIONAL INFORMATION	SIGNIFICANCE OF EFFECT		
				SEVERITY	DURATION	EXTENT
			habitats, as muds are more organically enriched and have shallower redox depths.			anoxic sediments – yet to be determined but likely to be low).
	8. Noise from machinery, blasting.	Ongoing noise and disturbance from machinery may affect fish movements or migrations in and out of the harbour, especially if the harbour channel acts as a migration path. The main effects on birds during the dredging phase would be excess noise, lights and the appearance of large machinery. Many mammals rely on sound for navigation/feeding and have sensitive hearing apparatus. These organisms are large enough to swim away from bothersome background dredging noises, but sudden high-decibel blasts could harm them if they are in close proximity. Fish also have relatively sensitive hearing organs and may be similarly impacted. Depending on the charges blasting can impact on fish with swim bladders.	Dolphins enter the harbour and may be disrupted temporarily by the dredging process if present close to operations. Direct impact on whales from dredging activities within the harbour is unlikely, although increased avoidance of inner coastal areas close to centres of human and vessel activity is possible. Blasting is unlikely to impact invertebrates except ones in immediate vicinity. There are management options to avoid issues around blasting and birds and mammals if these were to arise.	Low (if carried out during non-breeding period)	Short-term	Site specific (fish and mammals generally very mobile and could avoid).
Disposal of dredge material	1. Direct impact on biological communities at the disposal site (impact of sediment release/ /smothering).	Effects on benthic communities, due to the disposal of dredged material at a disposal site, are inevitable. Sudden 20-30 cm thick deposits will likely kill all underlying benthos, with the possible exception of some large bivalves adapted for burrowing in mobile sediments.	Consequences of species loss depends on the species removed; large long-lived organisms often control community structure and ecological functioning, thus their loss can translate to important shifts in productivity and valued ecosystem services. Recovery will be fastest when dredged sediments and dredge material sediments are well matched (i.e., similar grain size and similar biotic composition).	High	Medium-term	Site-specific (relatively small area compared with extent of similar habitat – exact area yet to be

ACTIVITY	POTENTIAL EFFECT	POTENTIAL CONSEQUENCES	ADDITIONAL INFORMATION	SIGNIFICANCE OF EFFECT		
				SEVERITY	DURATION	EXTENT
		Some offshore locations have biogenic habitats (bryozoan thickets, horse mussel beds, sponge gardens, soft-corals) that are ecologically important as settlement habitat for commercially valued finfish and shellfish species. These communities will not be affected as the proposed dredging site is well inshore and to the north of areas where they occur (75-110m depth).	Constraints mapping will be used to ensure the disposal site matches this criteria and minimises such effects. Once dredged material disposal ceases, recovery could still take up to a year, and longer for large animals and biogenic habitats that take many years to mature. Careful selection of a disposal site will minimise impacts on significant biogenic habitat. Systematic disposal (starting at one end of the disposal area and progressing toward the other) rather than haphazard/random dumping would probably help to limit impacts. Repeated disposal in an area would be worse than one-off disposals, especially for communities dominated by large long-lived "climax" species. Data from video or benthic samples should inform the selection of dredged material disposal locations in order to avoid sensitive, structurally diverse areas. Surveys should be carried out at the proposed site to confirm there are no sensitive or rare species or communities present.			determined).
		Birds and mammals could be affected through direct impacts of disposal operations and increased turbidity reducing their foraging grounds. The feeding of demersal fish species such as flatfishes could be affected by smothering of the benthic communities on which they feed.	New Zealand fur seal and sea lion haul-out zones and rookeries will not directly be affected by dredging or disposal; however the disruption of the benthic communities could reduce the food supply of these species. Dredge disposal may potentially displace dolphins temporarily from some foraging habitat. Potential impacts include boat strike (due to an increase in vessel traffic), avoidance of the area because of noise production and the presence of vessels, or alterations in population and migration patterns because of changes in bathymetry and bottom type. Demersal fishes and benthic habitats are widespread along the Otago coast. Disposal is likely to affect only a small proportion of the available benthic habitat	Low	Short-term	Site specific (for most species will be relatively small area compared with foraging area).

ACTIVITY	POTENTIAL EFFECT	POTENTIAL CONSEQUENCES	ADDITIONAL INFORMATION	SIGNIFICANCE OF EFFECT		
				SEVERITY	DURATION	EXTENT
			utilised by fishes.			
	2. Increased suspended sediment concentration/ turbidity at the disposal site	Dredge material disposal will increase turbidity as the sediment settles through the water. Additionally, dredge material deposits may be re-suspended into the water column under certain hydrodynamic conditions. Biotic communities (benthic and planktonic) at offshore sites with typically low turbidity may be impacted by elevated suspended sediment concentrations associated with dredging (depending on dredge material type). Impacts would be similar to those of elevated turbidity at the dredging site (see above), with the caveat that offshore communities are typically more sensitive to fine sediments than estuarine communities adapted to high turbidity.	Particles are affected by water currents. The resultant dispersion may cause settlement away from disposal site, depending on local bathymetry, water movement, flocculation, etc. The highest deposition rates will be in the immediate vicinity of the release site. Increased turbidity could impact planktonic animals particularly those that filter and suspension feeders. Most are short-lived (days to months) however so recovery would be relatively rapid. The height of the dredged material pile and the hydrodynamic regime at the site will affect sediment dispersal and redistribution. Obviously, fine particles are more easily resuspended than coarse particles. Coarse sediments at a dredge disposal site are indicative of turbulent water movements capable of removing fine particles. If the dredged materials contained finer mud this would likely disperse and could affect the surrounding sandy communities (potentially reducing grainsize, altering water clarity, affecting suspension feeders, adding organics/ nutrients/ contaminants). Impacts will depend on the sediments to be dredged which are yet to be tested. Previous tests suggest the sediment is dominated by fine sand.	Low-medium	Short-medium term	Site specific/Local (modelling required to determine extent and best location to avoid places like Blueskin Bay).
	3. Reduced water clarity and increased sedimentation effects on plant communities and phytoplankton.	Turbidity associated with dredged material disposal can reduce light penetration at the dredged material area, with potential effects on primary producers.	Dredged material disposal is expected to be periodic during the day, meaning that light limitation is unlikely to be a major problem. Effects on benthic plants are likely to be minor because submerged aquatic vegetation is rare in offshore sand habitats. Primary production in offshore areas is predominantly associated with phytoplankton in the water column. Sensitive areas with significant biogenic habitats have been identified and should be avoided by careful site selection.	Low	Short-term	Site specific/ Local (modelling required to determine extent and location).

ACTIVITY	POTENTIAL EFFECT	POTENTIAL CONSEQUENCES	ADDITIONAL INFORMATION	SIGNIFICANCE OF EFFECT		
				SEVERITY	DURATION	EXTENT
	4. Release of contaminants from dredged benthic sediments	If contaminants are present in sediments at the dredge site, these will be transported to the dredge material disposal site. This could affect the offshore biota through direct toxic effects and bioaccumulation. Due to sediment transport and also the movements of contaminated animals, the influence of contaminated dredged materials will not necessarily be limited to the area of the dredge material disposal site.	Sediments at the dredging site should be tested before the dredging operation commences. Note, muds tend to have greater contaminant loads than sands, due to the greater surface area (per standard volume of sediment) of muds.	Low	Short-term	Site specific/local (extent will depend on dispersal modelling and contaminants present).
	5. Release of nutrients from dredged benthic sediments	This can occur during the disposal of dredged materials.	The dilution of nutrients in the open coastal sea (and the sporadic nature of the disposal schedule) will probably minimise the formation of phytoplankton blooms and associated issues.	Low	Short-term	Site specific/local
	6. Spread of invasive species	Although most invertebrates will not be likely to survive dredging and transport to the dredge material disposal site, there is a possibility of releasing viable algal cysts and sediment microbes at the offshore dredge material disposal site. Transferring and disturbing sediment during dredging can potential spread invasive species through fragmentation.	The release of algal cysts in combination with dredging induced nutrient enrichment could result in harmful algal blooms. The possibility exists, but seems unlikely. A number of invasive species has been reported from the Port Chalmers area. The sea-squirt *Styela* has not yet been recorded but *Undaria* and 25 other new species to New Zealand waters have been recorded from the Otago region. It is highly unlikely that species like *Undaria* would colonise at the proposed disposal site because of the lack of hard substrate, depth and exposure.	Low	Medium-term	Site specific/ Local (extent will depend on dispersal modelling and species present in dredged material).

ACTIVITY	POTENTIAL EFFECT	POTENTIAL CONSEQUENCES	ADDITIONAL INFORMATION	SIGNIFICANCE OF EFFECT		
				SEVERITY	DURATION	EXTENT
Shipping operations	Direct physical disturbance (e.g., scouring and disturbance from boat motion and propellers).	Damage, loss or modification of benthic community.	Communities will already be adapted to ship movement and wake activity. Disturbance during transit of ships will occur but currents are generally relatively strong and communities adapted to repeated disturbance.	Low (cf existing)	Long-term (but communities adapt)	Site-specific
	Effects of wake activity on shoreline communities	Increased wake activity can dislodge and impact intertidal communities.	The potential for increased wake and associated effects on shoreline communities needs to be assessed when information on the new ships is available. If the wake reaching the shore does increase then this can displace some species and communities.	Low	Short-term	Site specific

4. Information gaps/additional studies required

Despite the number of ecological studies undertaken in the Otago Harbour and offshore region, there are gaps in our knowledge which require further studies before a full assessment of potential effects can be made. It will also be important to provide adequate baseline data so that any significant impacts can be monitored and assessed as the project proceeds. Studies required to fill significant information gaps that have been identified at this point and before an overall assessment of potential effects can be made are:

- Confirm sediment types and level of contaminants (to be scoped by Martin Single) at the site to be dredged, associated shipping channels and the proposed disposal site.

- Survey the benthic ecology of the areas within and adjacent to the main channel, to assess their vulnerability to the direct effects of dredging and identify sensitive habitats to increased turbidity.

- Survey the benthic ecology of the proposed disposal site and wider area that may be impacted by disposal of dredged material.

- Observational study to assess the behaviour of birds and mammals to dredging operations.

- Collate further information and data on fisheries through further reviews of catch data and consultation with fishers and other parties.

4.1 Benthic habitat

There have been extensive studies over the years of the benthic environment of the Otago region, particularly the area around Portobello Marine Laboratory. However most of these studies, with the exception of the likes of Rainer (1981), have been restricted spatially or in the species studied. In order to assess the potential effects of dredging, it is essential to have a good understanding of the extent of various habitats and their potential sensitivity to dredging operations. Findings from past studies should be ground-truthed to ensure that the communities have not changed significantly in composition or spatial distribution since the studies were undertaken. Major studies which have been identified at this point are:

- Benthic survey of outer harbour environment

  A survey of benthic habitats in the outer harbour is required to fill gaps in knowledge of spatial distribution and identify areas that are important because of conservation value, sensitivity to operations such as dredging or fisheries value. Habitats/species of particular concern that need to be covered include seagrass distribution, cockle beds, and the ecological areas around Aramoana (DoCs Ecological Protected Area) and unmodified areas around Quarantine and Goat Islands. The survey will need to include mapping the spatial distribution and density of cockles in the area to be affected by dredging. The survey should be coordinated with other cockle surveys that may be undertaken over the summer and the final survey design will be determined once discussions have been held with Southern Clams who already hold some distribution data at locations of interest for commercial gathering.

  The survey would cover the areas of interest using either transects or some stratified sampling of habitat types identified through a preliminary survey of habitat types. Sampling should be sufficiently detailed to describe habitat types and provide a quantitative//semi-quantitative estimate of abundance of major species and communities including seagrasses, cockles and species of particular ecological importance or which may be used for monitoring changes. The survey would be undertaken in two parts:

  1) Preliminary drop-camera survey. Channel-associated communities will be investigated by remote benthic camera deployments in a series of seven transects of approximately 1500 metres lengths perpendicular to the channel spaced about 1 km apart. Deployments will be to the bottom of the channel, the shallow extremes, and either channel floor, slope, or crest depending upon aspect and sampling effectiveness. Deployments in the central and eastern portions of the outer harbour will be located about 1 km apart along approximate contour lines. Intertidal areas not accessible by vessel will be photographed at low tide. Drop camera images would be captured on-demand from the surface as monitored by video feed. The images will be analysed for variables such as substratum, epifauna, epiphytes, infaunal artefacts, and seabed topography. Multivariate analyses will be used to identify principal biotopes based on imagery. A follow-up field-trip to a few sites within each biotope will be conducted to qualitatively evaluate sampling effectiveness and patchiness. Completion of the preliminary drop-camera

survey and brief site-visits will provide the necessary information for the next stage of habitat mapping programme design and costing.

This preliminary survey could be completed by end February 2008.

2) Habitat mapping. It is expected that several sampling methodologies will be required in the final mapping process. These are likely to include sediment grabs, intertidal cores, still photographs, and box dredges and other technology under development. If the channel slopes present a difficult sampling aspect then ROV flyovers or divers may be used. Collections with associated variables will be analysed for multivariate comparison with the full data set. The resulting community data can then used to guide any impact-associated manipulations if they appear warranted.

This more detailed survey should be carried out in late summer and could be completed by June 2008.

- Seagrasses

Seagrasses are particularly important as a high biodiversity habitat and as a feeding and nursery ground for a variety of birds and fish. There are some aerial photographs available from the Port Company and DOC which need to be assessed and if possible major beds identified and mapped.

This work should be completed by the end February 2008 so that the sampling programme for more detailed benthic work can incorporate this component.

- Benthic survey offshore in region of proposed disposal of material

Although only preliminary the most likely option for disposal of dredge material is in 25-30m water depth approximately 3.5 km north-east of the entrance to Otago Harbour. It will be essential that the area is surveyed adequately before final decisions are made to ensure there are no special features important for ecological or fisheries values. Surveys of similar large coastal areas (10-20,000 ha) have been made using a mixture of sidescan to define the habitat type, epibenthic sled or ROV to cover spatial distribution and grab samples to ground truth and sample smaller infauna. Sampling would use stratified random sampling along predefined transects and would be adequate to use as a baseline as well as define the habitats and communities

present and identify species/communities that could be used as indicator species. New technology would be used to characterize the sediments, biochemical and biological features.

A full proposal should be prepared and costed once the location, area of disposal and number of sites is finalised. The field work should be carried in Feb-April 2008 and report could be completed by June 2008.

4.2 Birds and mammals

Birds and mammals are highly mobile. However specific areas are important for nesting and foraging. These areas are relatively well known for the Otago coastline. There may potentially be direct effects of dredging as well as indirect effects through impacts on food availability. Defining areas important for foraging are beyond the scope of this work and can be assessed from existing information. There are potential direct effects of dredging through noise, increased turbidity impacting on feeding and physical disturbance. At this point it is suggested that an observational behavioural study be undertaken to ascertain whether existing maintenance dredging operations have any effects on bird feeding behaviour.

4.3 Fisheries

There is an extensive resource of fisheries information from published research and Ministry of Fisheries sources. This is best augmented by direct discussions with fishery user groups and the Ministry of Fisheries. Additionally, site specific data on sessile shellfish species is likely to be obtained in any benthic surveys.

- Analysis of catch data

  Robust information about commercial fishing activity and recent catches can be obtained from Catch Effort Landing Return data held by the Ministry of Fisheries. This information is important to underpin a fisheries assessment and to place the local fishery in context.

- Further literature review

  There is a large amount of published and "grey" literature on fisheries that is potentially relevant. An initial review has been undertaken, but more literature is potentially available and needs to be located and reviewed. Any

further literature review needs to be well focused and aimed at extracting information that is able to be directly linked to the subject areas within Otago Harbour and the vicinity of the proposed disposal area.

- Local information

  Incomplete local information exists on fisheries for commercial, recreational, charter, customary fisheries. This needs to be obtained through consultation/engagement with the relevant sectors and could form part of the consultation programme.

  These components should be completed over the next 2-3 months.

5. References

Batson, P.B. & Probert, P.K. (2000). Bryozoan thickets off Otago Peninsula. *New Zealand Fisheries Assessment Report* 2000/46: 31 pp.

Bell, J.D. (1999). Results from the Otago and Bluff Harbours Recreational Fishing Surveys 1998. Final research report for the Ministry of Fisheries Project REC9708. J.D. Bell & Associates. 109 p.

Beentjes, M.P.; Bull, B.; Hurst, R.J.; Bagley, N.M. (2002). Demersal fish assemblages along the continental shelf and upper slope of the east coast of the South Island, New Zealand. *New Zealand Journal of Marine and Freshwater Research 36*: 197–223.

Beentjes, M.P.; Cole, R. (2002). Otago Regional Council coastal information: Commercial fisheries. NIWA Client Report CHC2002-009. (Project ORC02504). 47 p.

Boyd, R.O.; Reilly, J.L. (2002). 1999/2000 national marine recreational fishing survey: harvest estimates. Draft New Zealand Fishery Assessment Report.

Bradford, E.; Fisher, D.; Bell, J. (1998). National marine recreational fishing survey 1996: overview of catch and effort results. *NIWA Technical Report 18:* 55 p.

Bradshaw, C.J.A.; Lalas, C.; Thompson, C.M. (2000). Clustering of colonies in an expanding population of New Zealand fur seals (*Arctocephalus forsteri*). *Journal of Zoology (250)*: 105-112.

Dunedin City Council (2006). Otago Harbour Reserves Management Plan. *No.* 66 p.

Emmett, B. (2002). Activities and Potential Environmental Effects Associated with Shellfish Aquaculture in Baynes Sound. A Discussion Document, prepared for Ministry of Sustainable Resource Management, Victoria, British Columbia.

Fenaughty, J.M.; Bagley, N.M. (1981). W.J. Scott New Zealand Trawl Survey South Island East Coast. Fisheries Management Division, Ministry of Agriculture and Fisheries, Wellington. *Fisheries Technical Report No. 157:* 224 p.

Fisher, D.; Bradford, E. (1998). National marine recreational fishing survey 1996: catch and effort results by fishing zone. Final Research Report for Ministry of Fisheries Research Project REC9701. NIWA. 36 p.

Gales, N.J.; Mattlin, R.H. (1997). Summer diving behaviour of lactating New Zealand sea lions, *Phocarctos hookeri*. *Canadian Journal of Zoology 75*: 1695-1706.

Graham, D.H. (1938). Fishes of Otago Harbour and adjacent seas with additions to previous records. *Transactions and Proceedings of the Royal Society of New Zealand 68:* 399–419.

Graham, D.H. (1940). Breeding habits of fishes of the Otago Harbour and adjacent seas. *Transactions and Proceedings of the Royal Society of New Zealand 69:* 361–372.

Grove, S.L. (1995). Subtidal soft-bottom macrofauna of the upper Otago Harbour. MSc, Marine Science. University of Otago.

Grove, S.L. & Probert, P.K. (1999). Sediment macrobenthos of Upper Otago Harbour, New Zealand. *New Zealand Journal of Marine and Freshwater Research 33*: 469-480.

Gust, N.; Inglis, G.J.; Peacock, L.; Miller, S.; Floerl, O.; Hayden, B.J.; Fitridge, I.; Johnston, O.; Hurren, H. (2006). Rapid nationwide delimitation surveys for *Styela clava*. NIWA Client Report: CHC2006-24. Prepared for Biosecurity New Zealand Project ZBS2005-32. *No.* 81 p.

Harcourt, R.G.; Schulman, A.M.; Davis, L.S.; Trillmich, F. (1995). Summer foraging by lactating female New Zealand fur seals (*Arctocephalus forsteri)* off Otago Peninsula, New Zealand. *Canadian Journal of Zoology 73*: 678-690.

Hitchmough, R.; Bull, L.; Cromarty, P. (2005). New Zealand Threat Classification System lists. No. 134 p.

James, G.D. (1970) Mesh selection studies on flatfish in relation to the Otago trawl fishery. *New Zealand Journal of Marine and Freshwater Research 4*: 229–240.

Jones, E.J. (2006). Bryozoan thickets on Otago shelf, New Zealand : a quantitative assessment of the epibenthos using underwater photography. MSc thesis, University of Otago.

Lalas, C. (1983). Comparative feeding ecology of New Zealand marine shags (*Phalacrocoracidae*). Unpublished PhD thesis, University of Otago, Dunedin.

Lalas, C. (1977). Food and feeding behaviour of the black-fronted tern, *Childonias hybrida albostriatus*. MSc in Zoology, University of Otago, Dunedin, 164 p.

Lalas, C. (1979). Seasonal movements of Black-fronted terns. *Notornis 26*: 69-72.

Lalas, C. (1983). Comparative feeding ecology of New Zealand marine shags (*Phalacrocoracidae*). Unpublished PhD thesis, University of Otago, Dunedin.

Marchant, S.; Higgins, P.J. (1990). Handbook of Australian, New Zealand and Antarctic Birds. Vol. 1. Oxford University Press, Melbourne.

Mattern, T.; Ellenberg, U.; Houston, D.M.; Davis, L.S. (2007). Consistent foraging routes and benthic foraging behaviour in yellow-eyed penguins. *Marine Ecology Progress Series 343*:295-306.

Ministry of Fisheries (2007a). Draft Hector's and Maui's Dolphin Threat Management Plan. Available from http://www.fish.govt.nz/en-nz/Consultations/hector/default.htm

Ministry of Fisheries (2007b). A description of the fishery and biology of most commercially harvested species throughout New Zealand fisheries waters, including waters off the Otago Coast is available at http://www.fish.govt.nz/en-nz/default.htm and then by following the links to recent fishery plenary reports on individual species.

Moore, P.J. (1999). Foraging range of the Yellow-eyed penguin *Megadyptes antipodes*. *Marine Ornithology 27*: 49-58.

Paavo, B.L.; Probert, P.K. (2005). Infaunal assemblages in coastal sediments at dredge spoil disposal sites at Otago, New Zealand. Final Report for Port Otago Ltd. (POL). No. 111 p.

Paavo, B.L. (2006). Soft-sediment benthos of Aramoana and Blueskin Bay (Otago, New Zealand) and effects of dredge-spoil disposal. PhD thesis, University of Otago.

Pawson, M. (2004). The cockle *Austrovenus stutchburyi* and chlorophyll depletion in a southern New Zealand inlet. MSc thesis, University of Otago.

Peterman, R.M. (2004). Possible solutions to some problems facing fisheries researchers and managers. *ICES Journal of Marine Science 68:* 1331–1343.

Probert, P.K.; Batham, E.J. & Wilson, J.B. (1979). Epibenthic macrofauna off southeastern New Zealand and mid-shelf bryozoan dominance. *New Zealand Journal of Marine and Freshwater Research 13*: 379-392.

Probert, P.K. & Wilson, J.B. (1984). Continental shelf benthos off Otago Peninsula, New Zealand. *Estuarine, Coastal and Shelf Science 19*: 373-391.

Probert, P.K. (1990a). Assessment of Environmental Effects of the Disposal of Dredge Spoil. Univord Consulting Service. No. 15 p.

Probert, P.K. (1990b). Marine environmental implications of a proposed extension to the reclamation at Observation Point, Port Chalmers. No. p.

Probert, P.K. (1990c). Marine environmental implications of proposed extensions to Port Chalmers Container Terminal. No. p.

Rainer, S.F. (1981). Soft-bottom benthic communities in Otago Harbour and Blueskin Bay, New Zealand. *New Zealand Oceanographic Institute Memoir 80*: 38 pp.

Ralph, P.M. & Yaldwyn, J.C. (1956). Seafloor animals from the region of Portobello Marine Biological Station, Otago Harbour. *Tuatara 6*: 57-85.

Raffaelli, D. (1979). The grazer-algae interaction in the intertidal zone on New Zealand rocky shores. *Journal of Experimental Marine Biology and Ecology 38: 81-100.*

Roper, D.S.; Jillett, J.B. (1981). Seasonal occurrence and distribution of flatfish (Pisces: Pleuronectiformes) in inlets and shallow water along the Otago coast. *New Zealand Journal of Marine and Freshwater Research 15(1)*: 1-13.

Sagar, P.M.; Shankar, U.; Brown, S. (1999). Numbers and distribution of waders in New Zealand, 1983-1994. *Notornis 46*: 1-44.

Sagar, P.; Beentjes, M.P.; Sykes, J. (2002). Otago Regional Council coastal information: Seabirds and marine mammals. *No.* 47 p.

South Pacific Aluminium (1981). Proposed aluminium smelter at Aramoana.

Teirney, L.D.; Kilner, A.R.; Millar, R.B.; Bradford, E.; Bell, J.D. (1997). Estimation of recreational harvests from 1991–92 to 1993–94. *New Zealand Fisheries Assessment Research Document 97/15:* 43 p.

Waugh, S.; Filippi, D.; Fukuda, A.; Suzuki, M.; Higuchi, H.; Setiawan, A.; Davis, L. (2005). Foraging of royal albatrosses, *Diomedea epomophora*, from the Otago Peninsula and its relationships to fisheries. *Canadian Journal of Fisheries and Aquatic Sciences 62(6)*: 1410-1421.

Wood, A.C.L. (2005). The macrofaunal communities with bryozoan thickets on Otago shelf, south-eastern New Zealand. MSc thesis, University of Otago.

Würsig, B.; Duprey, N.; Weir, J. (2007). Dusky dolphins (*Lagenorhynchus obscurus*) in New Zealand waters: Present knowledge and research goals. DOC Research & Development Series 270. No. 28.

6. Bibliography

Agnew, P. (2004). Mating behaviour and population trends of blue penguins (*Eudyptula minor*) at Taiaroa Head, Otago Peninsula.

Anon. (1991). Otago Harbour Planning Study Stage One. Pollution Report. ORC and DCC Joint Discussion Series No. 4. Otago Regional Council/ Dunedin City Council.

Anon. (1991). Otago Harbour Planning Study Stage One. Report of the Ecosystems and Physical Systems Working Group. ORC and DCC Joint Discussion Series No. 8. Otago Regional Council/ Dunedin City Council.

Armstrong, J.H. (1988). Reproduction in the paddle-crab *Ovalipes catharus* (Decapoda: Portunidae) from Blueskin Bay, Otago, New Zealand. *New Zealand Journal of Marine and Freshwater Research 22*: 529-536.

Barker, M.F.; Scheibling, R.; Mladenov, P.V. (1992). Seasonal changes in population structure of the fissiparous asteroids *Allostichaster insignis* (Farquhar) and *Coscinasterias calamaria* (Gray). *In*: Scalera-Liaci, L.; Canicatti, C. (eds). *Echinoderm Research 1991*, pp. 191 - 196, A.A. Balkema.

Batham, E.J. (1956). Ecology of Southern New Zealand sheltered rocky shore. *Transactions of the Royal Society of New Zealand 84(2)*: 447-465.

Batson, P.B. (2000). The Otago Shelf bryozoan thickets: aspects of their distribution, ecology and sedimentology. Thesis. University of Otago.

Batson, P.B.; Probert, P.K. (2000). Bryozoan thickets off Otago Peninsula. New Zealand Fisheries Assessment Report No. 31 p.

Beentjes, M.P. (1984). Aspects of feeding in *Chione stutchburyi* with emphasis on differences in shore height. Thesis. University of Otago.

Beentjes, M.P. (2003). Review of flatfish catch data and species composition. New Zealand Fisheries Assessment Report 17. 22 p.

Beentjes, M.P.; Cole, R. (2002). Otago Regional Council coastal information : commercial fisheries.

Bell, J.D. (2000). Results from the Otago and Bluff Harbours recreational fishing survey 1998 : final research report for the Ministry of Fisheries project REC9708 No. 109.

Bell, R.E. (1994). Marine recreational fishing along the Otago coastline : a report to the Otago Regional Council No. 30 p.

Berkenbusch, K.; Rowden, A.A. (1998). Population dynamics of the burrowing ghost shrimp *Callianassa filholi* on an intertidal sandflat in New Zealand (Decapoda: Thalassinidea). *Ophelia 49(1)*: 55-69.

Berkenbusch, K.; Rowden, A.A. (1999). Factors influencing sediment turnover by the burrowing ghost shrimp *Callianassa filholi* (Decapoda: Thalassinidea). *Journal of Experimental Marine Biology and Ecology 238(2)*: 283-292.

Berkenbusch, K.; Rowden, A.A.; Probert, P.K. (2000). Temporal and spatial variation in macrofauna community composition imposed by ghost shrimp *Callianassa filholi* bioturbation. *Marine Ecology Progress Series 192*: 249-257.

Borland, C. (1950). An ecological study of *Benhamina obliquata* (Sowerby), a basommatophorous pulmonate, in Otago Harbour. *Transactions of the Royal Society of New Zealand 78(4)*: 385-393.

Bradshaw, C.J.A.; Lalas, C.; McConkey, S.D. (1998). New Zealand sea lion predation on New Zealand fur seals. *New Zealand Journal of Marine and Freshwater Research 32(1)*: 101-104.

Bradshaw, C.J.A.; Lalas, C.; Thompson, C.M. (2000). Clustering of colonies in an expanding population of New Zealand fur seals (*Arctocephalus forsteri*). *Journal of Zoology (250)*: 105-112.

Breen, P.A.; Carbines, G.; Kendrick, T.H. (1999). Stock assessment of cockles in Papanui and Waitati Inlets, Otago Harbour and Purakanui, Otago. Final Research Report for Ministry of Fisheries Research Project COC9701.

Brett, T. (1999). The Commercial Fishing Industry in Otago & Southland. In Sorrell, P. (eds). The Cyclopaedia of Otago and Southland 1999, pp. 749–753. Dunedin City Council, Dunedin.

Brewin, B.I. (1946). Ascidians in the vicinity of the Portobello Marine Biological Station, Otago Harbour. *Transactions of the Royal Society of New Zealand 76*: 87-131.

Brewin, B.I. (1952). Seasonal changes in microplankton in the Otago Harbour during the years 1944-45. *Transactions of the Royal Society of New Zealand 79(3-4)*: 614-627.

Bricelj, V.M.; Malouf, R.E.; de Quillfeldt, C. (1984). Growth of juvenile *Mercenaria mercenaria* and the effect of resuspended bottom sediments. *Marine Biology 84(2)*: 167-173.

Brough, J.F. (1979). Macroplankton of Otago Harbour surface waters. Thesis. University of Otago.

Brown, M.T.; Hodgkinson, W.M.; Hurd, C.L. (1999). Spatial and temporal variations in the copper and zinc concentrations of two green seaweeds from Otago Harbour, New Zealand. *Marine Environmental Research 47(2)*: 175-184.

Chatterton, T.D.; Williams, B.G. (1994). Activity patterns of the New Zealand cancrid crab *Cancer novaezelandiae* (Jacquinot) in the field and laboratory. *Journal of Experimental Marine Biology and Ecology 178(2)*: 261-264.

Clayton, S.M. (1982). A biologically-defined wave exposure scale for the Otago Peninsula. Thesis. University of Otago.

Cooke, R.R.M.; Hurd, C.L.; Lord, J.M.; Peake, B.M.; Raven, J.A.; Rees, T.A.V. (2004). Iron and zinc content of *Hormosira banksii* in New Zealand. *New Zealand Journal of Marine and Freshwater Research 38(1)*: 73-85.

Corfield, J.; Hickey, C. (2004a). Fluoride discharge from fertiliser manufacture: multivariate statistical analysis of sediment impacts. NIWA Client Report HAM2004-124. Prepared for Ravensdown Fertiliser Co-Operative Ltd.

Corfield, J.H.; Hickey, C. (2004b). Ravensbourne discharge to Otago Harbour: supplementary multivariate analysis of benthic communities. NIWA Client Report HAM2004-124. Prepared for Ravensdown Fertiliser Co-Operative Ltd.

Crump, R.G.; Barker, M.F. (1985). Sexual and asexual reproduction in geographically separated populations of the fissiparous asteroid *Coscinasterias calamaria* (Gray). *Journal of Experimental Marine Biology and Ecology 88(2)*: 109-127.

Depledge, M.H.; Lundebye, A.K. (1996). Physiological monitoring of contaminant effects in individual rock crabs, *Hemigrapsus edwards*: The ecotoxicological significance of variability in response. *Comparative Biochemistry and Physiology 113C(2)*: 277-282.

Deverall, K.R. (1979). The distribution and abundance of *forsterygion nigripinne* (Cuv. and Val. 1836) in Otago Harbour. Thesis. University of Otago. 100 p.

Dobbinson, S.J.; Barker, M.F.; Jillett, J.B. (1989). Experimental shore level transplantation of the New Zealand cockle *Chione stutchburyi*. *Journal of Shellfish Research 8(1)*: 197-212.

Douglas, G. Siene fishing in the Otago Harbour. *Bearings 2(3)*: 12-19.

Dunedin City Council (2006). Otago Harbour Reserves Management Plan. No. 66 p.

Ellis, J.; Cummings, V.; Hewitt, J.; Thrush, S.; Norkko, A. (2002). Determining effects of suspended sediment on condition of a suspension feeding bivalve (*Atrina zelandica*): results of a survey, a laboratory experiment and a field transplant experiment. *Journal of Experimental Marine Biology and Ecology 267*: 147-174.

Fea, N.I.; Harcourt, R.; Lalas, C. (1999). Seasonal variation in the diet of New Zealand fur seals (*Arctocephalus forsteri*) at Otago Peninsula, New Zealand. *Wildlife Research 26(2)*: 147-160.

Featherston, D.W.; McKinnon, A.D.; Ellison, C.R. (1979). *Bothriocephalus scorpii* in red cod. *New Zealand Journal of Zoology 6(4)*: 647.

Fisher, D.; Bradford, E. (1999). National marine recreational fishing survey 1996: catch and effort results by fishing zone No. 44 p.

Forrest, B.; Brown, S.; Taylor, M.; Hurd, C.; Hay, C. (2000). The role of natural dispersal mechanisms in the spread of *Undaria pinnatifida* (Laminariales, Phaeophyceae). *Phycologia 39*: 547-553.

Franklin, T.J. (1999). The reef fish assemblages associated with macroalgal dominated reefs along the Karitane shoreline, East Otago. Thesis. University of Otago.

Fyfe, J.; Israel, S.A.; Chong, A.; Ismail, N.; Hurd, C.L.; Probert, K. (1999). Mapping marine habitats in Otago, Southern New Zealand. *Geocarto International 14(3)*: 15-26.

Gales, N.J.; Mattlin, R.H. (1997). Summer diving behaviour of lactating New Zealand sea lions, *Phocarctos hookeri*. *Canadian Journal of Zoology 75*: 1695-1706.

Gales, R.P. (1984). Comparative breeding ecology of seabirds on the Otago coast. Thesis. University of Otago.

Graham, D.H. (1938). Fishes of Otago Harbour and adjacent seas with additions to previous records. *Transactions of the Royal Society of New Zealand 68*: 399-419.

Graham, D.H. (1939). Food of the fishes of Otago Harbour and adjacent sea. *Transactions of the Royal Society of New Zealand 68*: 421-436.

Graham, D.H. (1940). Breeding habits of the fishes of Otago Harbour and adjacent seas. *Transactions of the Royal Society of New Zealand 69*: 361-372.

Graham, D.H. (1956). A treasury of New Zealand fishes (2nd ed.). Reed, Wellington, 424 p.

Grant, J.; Thorpe, B. (1991). Effects of suspended sediments on growth, respiration, and excretion of the soft-shell clam (*Mya arenaria*). *Canadian Journal of Fisheries and Aquatic Science 48*: 1285-1292.

Grove, S.L. (1995). Subtidal soft-bottom macrofauna of the upper Otago Harbour. Thesis. University of Otago.

Grove, S.L.; Probert, P.K. (1999). Sediment macrobenthos of upper Otago Harbour, New Zealand. . *New Zealand Journal of Marine and Freshwater Research 33*: 469-480.

Grundy, R.G. (1985). The behaviour of dissolved silica within Blueskin Bay and its tributary waters. Thesis. University of Otago.

Gust, N.; Inglis, G.J.; Peacock, L.; Miller, S.; Floerl, O.; Hayden, B.J.; Fitridge, I.; Johnston, O.; Hurren, H. (2006). Rapid nationwide delimitation surveys for *Styela clava*. NIWA Client Report: CHC2006-24. Prepared for Biosecurity New Zealand Project ZBS2005-32. No. 81 p.

Hamel, J. (1991). Birdlife on Otago Harbour. *In*: Otago Harbour Planning Study, Stage One. Report of the Ecosystems and Physical Systems Working Group, pp. 129-152, ORC & DCC Joint Discussion Series, Dunedin.

Hamel, J. (1991). Taiaroa Head and its bird population. *In*: Otago Harbour Planning Study, Stage One. Report of the Ecosystems and Physical Systems Working Group, pp. 170-173, ORC & DCC Joint Discussion Series, Dunedin.

Harcourt, R.G.; Schulman, A.M.; Davis, L.S.; Trillmich, F. (1995). Summer foraging by lactating female New Zealand fur seals (*Arctocephalus forsteri)* off Otago Peninsula, New Zealand. *Canadian Journal of Zoology 73*: 678-690.

Harwood, N.J.; Lokman, P.M. (2006). Fecundity of banded wrasse (*Notolabrus fucicola*) from Otago, Southern New Zealand. *New Zealand Journal of Marine and Freshwater Research 40*: 467-476.

Hawkins, A.J.S.; James, M.R.; Hickman, R.W.; Hatton, S.; Weatherhead, M. (1999). Modelling of suspension-feeding and growth in the green-lipped mussel *Perna canaliculus* exposed to natural and experimental variations of seston availability in the Marlborough Sounds, New Zealand. *Marine Ecology Progress Series 191*: 217-232.

Hayward, B.W.; Grenfell, H.; Cairns, G.; Smith, A.M. (1996). Environmental controls on benthic foraminiferal and the camoebian associations in a New Zealand tidal inlet. *Journal of Foraminiferal Research 26(2)*: 150 - 171.

Hayward, B.W.; Hollis, C.J. (1994). Brackish water foraminifera in New Zealand: A taxonomic and ecologic review. *Micropaleontology 40(3)*: 185-222.

Haywood, G.J. (2004). Some effects of river discharges and currents on phytoplankton in the sea off Otago, New Zealand. *New Zealand Journal of Marine and Freshwater Research 38(1)*: 103-114.

Heiss, W.M.; Smith, A.; K, P.P. (2000). Influence of the small intertidal seagrass *Zostera novazelandica* on linear water flow and sediment texture. *New Zealand Journal of Marine and Freshwater Research 34(4)*: 689-694.

Hewitt, J.; Norkko, J. (2007). Incorporating temporal variability of stressors into studies: An example using suspension-feeding bivalves and elevated suspended sediment concentrations. *Journal of Experimental Marine Biology and Ecology 341*: 131-141.

Hitchmough, R.; Bull, L.; Cromarty, P. (2005). New Zealand Threat Classification System lists. No. 134 p.

Inglis, G.; Gust, N.; Fitridge, I.; Floerl, O.; Woods, C.; Hayden, B.; Fenwick, G. (2006). Dunedin Harbour (Port Otago and Port Chalmers) Baseline survey for non-indigenous marine species (Research Project ZBS2000/4). No. 104 p.

Irwin, C.R. (2004). The impacts of harvesting and the sustainability of a New Zealand littleneck clam (*Austrovenus stutchburyi*) fishery in Papanui and Waitati inlets, New Zealand. Thesis. University of Otago.

Ismail, N. (2001). Ecology of eelgrass, *Zostera novazelandica* Setchell, in Otago Harbour, Dunedin, New Zealand. Thesis. University of Otago.

James, G.D. (1970). Mesh selection studies on flatfish in relation to the Otago Trawl Fishery. *New Zealand Journal of Marine and Freshwater Research 4(3)*: 229-240.

Jillett, J.B. (1976). Zooplankton associations off Otago Peninsula, southeastern New Zealand, related to different water masses. *New Zealand Journal of Marine and Freshwater Research 10(4)*: 543-557.

Jones, E.J. (2006). Bryozoan thickets on Otago shelf, New Zealand: a quantitative assessment of the epibenthos using underwater photography. Thesis. University of Otago.

Lalas, C. (1977). Food and feeding behaviour of the black-fronted tern, *Childonias hybrida albostriatus*. Thesis. MSc in Zoology, University of Otago, Dunedin. 164 p.

Lalas, C. (1983). Comparative feeding ecology of New Zealand marine shags (*Phalacrocoracidae*). Thesis. Unpublished PhD thesis, University of Otago, Dunedin.

Lalas, C. (1991). Marine mammals of Otago harbour. *In*: Otago Harbour Planning Study, Stage One. Report of the Ecosystems and Physical Systems Working Group, pp. 165-169, ORC & DCC Joint Discussion Series, Dunedin.

Lalas, C. (1991). Seabirds associated with Otago Harbour. *In*: Otago Harbour Planning Study, Stage One. Report of the Ecosystems and Physical Systems Working Group, pp. 153-164, ORC & DCC Joint Discussion Series, Dunedin.

Lalas, C.; Bradshaw, C.J.A. (2003). Expectations for population growth at new breeding locations for the vulnerable New Zealand sea lion (*Phocarctos hookeri*) using a simulation model. *Biological Conservation 114(1)*: 67-78.

Lalas, C.; Harcourt, R. (1995). Pup production of the New Zealand fur seal on Otago Peninsula, New Zealand. *Journal of the Royal Society of New Zealand 25(1)*: 81-88.

Lalas, C.; Ratz, H.; McEwan, K.; McConkey, S.D. (2007). Predation by New Zealand sea lions (*Phocarctos hookeri*) as a threat to the viability of yellow-eyed penguins (*Megadyptes antipodes*) at Otago Peninsula, New Zealand. *Biological Conservation 135(2)*: 235-246.

Ludmerer, A. (2002). New Zealand sea lions (*Phocarctos hookeri*): abundance estimates and habitat utilization on the Otago Peninsula. Thesis. University of Otago.

McClatchie, S., Jillett, J.B. & Gerring, P. (1991). Observations of gulls foraging on beach-stranded plankton in Otago Harbour, New Zealand. *Limnology and Oceanography 36(6)*: 1195-1200.

McClatchie, S.; Hutchinson, D.; Nordin, K. (1989). Aggregation of avian predators and zooplankton prey in Otago shelf waters, New Zealand. *Journal of Plankton Research 11(2)*.

McClatchie, S.; Kawachi, R.; Dalley, D.E. (1990). Epizoic diatoms on the euphausiid *Nyctiphanes australis* : Consequences for gut pigment analyses of whole krill. *Marine Biology 104(2)*: 227-232.

Michael, K.P.; Cranfield, H.J. (2001). A summary of the fishery, commercial landings, and biology of the New Zealand queen scallop, *Zygochlamys delicatula* (Hutton, 1873). New Zealand Fisheries Assessment Report 2001/68. 24 p. *No.* 24 p.

Miller, S.M. (1998). Effects of human disturbance on eelgrass, *Zostera novazelandica*, and the associated benthic macrofauna at Harwood, Otago Harbour, New Zealand. Thesis. University of Otago.

Ministry of Fisheries (2007). Draft Hector's and Maui's Dolphin Threat Management Plan. Available from http://www.fish.govt.nz/en-nz/Consultations/hector/default.htm.

Ministry of Fisheries Science Group (Comps.). (2006). Report from the Fishery Assessment Plenary, May 2006: stock assessments and yield estimates. 875pp http://home.niwa.co.nz/science/groups/fisheries/plenary/.

Mitchell, C.P. (1980). Intertidal distribution of six trochids at Portobello, New Zealand. *New Zealand Journal of Marine and Freshwater Research 14(1)*: 47-54.

Mladenov, P.V. (1998). Nuisance Sea Tulip Aggregations in Otago Harbour - Background Report: Prepared for Port Otago Ltd. No. 8 p.

Moore, P.J. (1999). Foraging range of the Yellow-eyed penguin *Megadyptes antipodes*. *Marine Ornithology 27*: 49-58.

Murdoch, R.C. (1985). Determination of zooplankton distribution by patterns of water circulation off Otago Peninsula. Thesis. University of Otago.

Murdoch, R.C. (1989). The effects of a headland eddy on surface macro-zooplankton assemblages north of Otago Peninsula, New Zealand. *Estuarine, Coastal & Shelf Science 29(4)*: 361-383.

Navarro, J.M.; Widdows, J. (1997). Feeding physiology of *Cerastoderma edule* in response to a wide range of seston concentrations. *Marine Ecology Progress Series 152*: 175-186.

New Zealand Commission for the Environment (1981). Proposed aluminium smelter at Aramoana: environmental impact audit.

Nicholson, C.M.; Lewis, G.D. & Loutit, M.W. (1989). A survey of human pathogenic bacteria and viruses in cockle beds at Otakou, Otago Harbour, New Zealand. *New Zealand Journal of Marine and Freshwater Research 23*: 529-532.

NIWA Science (2006). Bumper year for Otago Harbour salmon. National Centre for Fisheries & Aquaculture Update No. 19 Available from http://www.niwascience.co.nz.

O'Driscoll, R.L. (1998). Description of spatial pattern in seabird distributions along line transects using neighbour K statistics. *Marine Ecology Progress Series 165*: 81-94.

O'Driscoll, R.L. (1998). Feeding and schooling behaviour of barracouta (*Thyrsites atun*) off Otago, New Zealand. *Marine and Freshwater Research 49*: 19-24.

O'Driscoll, R.L.; McClatchie, S. (1998). Spatial distribution of planktivorous fish schools in relation to krill abundance and local hydrography off Otago, New Zealand. *Deep-Sea Research Part II: Topical Studies in Oceanography 45(7)*: 1295-1325.

O'Driscoll, R.L.; Renner, M.; Austin, F.J.; Spencer, H.G. (1998). Distribution of seabirds in coastal waters off Otago, New Zealand. *New Zealand Journal of Marine and Freshwater Research 32(2)*: 203-213.

Paavo, B.L.; Probert, P.K. (2005). Infaunal assemblages in coastal sediments at dredge spoil disposal sites at Otago, New Zealand. Final Report for Port Otago Ltd. (POL). No. 111.

Pankhurst, N.W.; Boyden, C.R.; Wilson, J.B. (1980). The effect of a fluoride effluent on marine organisms. *Environmental Pollution, Series A 23*: 299-312.

Partridge, T.R.; Wilson, J.B. (1975). The ecology of Aramoana, Otago Harbour. University of Otago; Dunedin Metropolitan Regional Planning Authority, Dunedin, N.Z. 103 p.

Paulin, M.; Roberts, C.D. (1990). Report on the fishes of Otago Harbour and adjacent waters.

Peake, B.M.; Marsden, I.D.; Islay, D.; Bryan, A.M. (2006). Spatial and Temporal variations in trace metal concentrations in the cockle, *Austrovenus stutchburyi* from Otago, New Zealand. *Environmental Monitoring and Assessment 115(1-3)*: 119-144.

Perriman, L.; Steen, H. (2000). Blue penguin (*Eudyptula minor*) nest distribution and breeding success on Otago Peninsula, 1992 to 1998. *New Zealand Journal of Zoology 27*: 269-275.

Pfannkuche, J. (1998). The optical properties of Otago waters. Thesis. University of Otago.

Pfannkuche, J. (2002). Optical properties of Otago Shelf Waters: South Island New Zealand. *Estuarine, Coastal and Shelf Science 55*: 613-627.

Probert, P.K. (1975). Report to the Otago Harbour Board on the marine environmental implications of the proposed reclamation for container terminal development at Port Chalmers: Phase 2. Appended to the Environmental Impact Report on Port Chalmers reclamation and container terminal development. Otago Harbour Board.

Probert, P.K. (1990). Assessment of Environmental Effects of the Disposal of Dredge Spoil. Univord Consulting Service. No. 15 p.

Probert, P.K. (1990). Marine environmental implications of a proposed extension to the reclamation at Observation Point, Port Chalmers.

Probert, P.K. (1990). Marine environmental implications of proposed extensions to Port Chalmers Container Terminal.

Probert, P.K. (1991). Marine Biology and Ecology. *In*: Otago Harbour Planning Study, Stage One. Report of the Ecosystems and Physical Systems Working Group, pp. 104-128, ORC & DCC Joint Discussion Series, Dunedin.

Probert, P.K.; Batham, E.J. (1979). Epibenthic macrofauna off southeastern New Zealand and mid-shelf bryozoan dominance. *New Zealand Journal of Marine and Freshwater Research 13(3)*: 379-392.

Probert, P.K.; Wilson, J.B. (1984). Continental shelf benthos off Otago Peninsula, New Zealand. *Estuarine, Coastal and Shelf Science 19(3)*: 373-391.

Quinn, J.M. (1978). The hydrology and plankton of Otago Harbour. Thesis. University of Otago.

Rainbow, P.S.; Emson, R.H.; Smith, B.D.; Moore, P.G.; Mladenov, P.V. (1993). Talitrid amphipods as biomonitors of trace metals near Dunedin, New Zealand. *New Zealand Journal of Marine and Freshwater Research 27*: 201-207.

Rainer, S.F. (1969). Marine benthic ecology in Otago. Macrofauna of deposit substrata in the Otago Harbour and Blueskin Bay. Thesis. University of Otago.

Rainer, S.F. (1981). Soft-bottom benthic communities in Otago Harbour and Blueskin Bay, New Zealand. *New Zealand Oceanographic Institute Memoir 80*.

Ralph, P.M.; Yaldwin, J.C. (1956). Seafloor animals from the region of Portobello Marine Biological Station, Otago Harbour. *Tuatara (6)*: 57-85.

Ratz, H.; Darby, J.T. (2004). Survival and breeding of yellow-eyed penguins (*Megadyptes antipodes*), at two locations on Otago Peninsula, South Island, New Zealand, 1991–96. *New Zealand Journal of Zoology 31*: 133-147.

Ren, J.S.; Ross, A.H.; Schiel, D.R. (2000). Functional descriptions of feeding and energetics of the pacific oyster *Crassostrea gigas* in New Zealand. *Marine Ecology Progress Series 208*: 119-130.

Robertson, C.J.R. (1993). Timing of egg laying in the Royal Albatross (*Diomedea epomophora*) at Taiaroa Head 1937 - 1992. *Conservation Advisory Science Notes No. 50 Department of Conservation, Wellington No.* 8 p.

Robertson, C.J.R. (2001). Effects of intervention on the royal albatross population at Taiaroa Head, Otago, 1937-2001. *DOC Science Internal Series 23 No.* 13 p.

Robertson, D.A. (1973). Planktonic eggs and larvae of some New Zealand marine teleosts. Thesis. University of Otago.

Robertson, D.A. (1980). Hydrology and quantitative distribution of planktonic eggs of some marine fishes off the Otago Coast, southeastern New Zealand. *Fisheries Research Bulletin (21)*: 69 pp.

Robinson, W.E.; Wehling, W.E.; Morse, M., P. (1984). The effect of suspended clay on feeding and digestive efficiency of the surf clam *Spisula solidissima* (Dilwyn). *Journal of Experimental Marine Biology and Ecology 74(1)*: 1-12.

Roper, D.S.; Jillett, J.B. (1981). Seasonal occurrence and distribution of flatfish (Pisces: Pleuronectiformes) in inlets and shallow water along the Otago coast. *New Zealand Journal of Marine and Freshwater Research 15(1)*: 1-13.

Royds Garden Consultants (1990). Environmental Impact Assessment: Observation Point Reclamation. Unpublished report to Port Otago Ltd.

Royds Garden Consultants (1990). Environmental Impact Assessment, Boiler Point Reclamation. Unpublished report to Port Otago Ltd.

Royds Garden Consultants (1990). Environmental Impact Assessment, Dredging and Dredge Spoil Relocation, Port Otago. Unpublished report to Port Otago Ltd.

Sabetian, A. (1998). Effect of Dredge Spoil Disposal on Benthos and Sediments. Unpublished Report to Probert, K. & A.G. Smith.

Safi, K.; Hewitt, J.; Talman, S.G. (2007). The effect of high inorganic seston loads on prey selection by the suspension-feeding bivalve, *Atrina zelandica*. *Journal of Experimental Marine Biology and Ecology 344*: 136-148.

Sagar, P.; Beentjes, M.P.; Sykes, J. (2002). Otago Regional Council coastal information: Seabirds and marine mammals. No. 47 p.

Schembri, P.J. (1988). Bathymetric distribution of hermit crabs (Crustacea Decapoda Anomuia) from the Otago region, south eastern New Zealand. *Journal of the Royal Society of New Zealand 18*: 91-102.

Shin, P.K.S.; Yau, F.N.; Chow, S.H.; Tai, K.K.; Cheung, S.G. (2002). Responses of the green-lipped mussel *Perna viridis* (L.) to suspended solids. *Marine Pollution Bulletin 45*: 157–162.

Sinner, J.; Forrest, B.; Taylor, M. (2000). A strategy for managing the Asian kelp *Undaria*: final report. Cawthron Report 578, 119 pp. Prepared for Ministry of Fisheries.

Skoeld, M.; Barker, M.F.; Mladenov, P.V. (2002). Spatial variability in sexual and asexual reproduction of the fissiparous seastar *Coscinasterias muricata*: The role of food and fluctuating temperature. *Marine Ecology Progress Series 233*: 143-155.

Smillie, R.H.; Hunter, K.; Loutit, M. (1981). Reduction of chromium (VI) by bacterially produced hydrogen sulphide in a marine environment. *Water Research 15(12)*: 1351-1354.

South Pacific Aluminium (1981). Proposed aluminium smelter at Aramoana.

Stevenson, M.L.; Beentjes, M.P. (2002). Inshore trawl survey of the Canterbury Bight and Pegasus Bay, December 2000-January 2001 (KAH0014, CMP0001). NIWA Technical Report 112. 97 p.

Stewart, B.; Keogh, J.; Fletcher, D.; Mladenov, P. (1992). Biomass survey of the New Zealand little neck clam (*Chione stutchburyi*) in Papanui and Waitati inlets, Otago during 1991/1992. Unpublished report, Marine Science and Aquaculture Research Centre, University of Otago, Dunedin.

Street, B. (1996). The southern queen scallop fishery. *Seafood New Zealand 4*: 35–38.

Stuart, M.D.; Hurd, C.L.; Brown, M.T. (1999). Effects of seasonal growth rate on morphological variation of *Undaria pinnatifida* (Alariaceae, Phaeophyceae). *Hydrobiologia 398/399*: 191-199.

Swanson, K.M. (1979). The Marine Fauna of New Zealand: Ostracods of the Otago Shelf. *Memoirs of the New Zealand Oceanographic Institute 78*: 56 pp.

Taylor, M.; MacKenzie, L. (2001). Delimitation survey of the toxic dinoflagellate *Gymnodinium catenatum* in New Zealand. Cawthron Report 661, 12 pp. Prepared for Ministry of Fisheries.

Taylor, P.D.; Schembri, P.J.; Cook, P.L. (1989). Symbiotic associations between hermit crabs and bryozoans from the Otago region, southeastern New Zealand. *Journal of Natural History 23*: 1059-1085.

Thrush, S. (1980). Some effects of chromium rich tannery effluent on benthic macrofauna. Thesis. University of Otago. 97 p.

Thrush, S. (1988). The comparison of macrobenthic recolonization patterns near and far away from crab burrows on a sublittoral sand flat. *Journal of Marine Research (46)*: 669-681.

Voice, A.J. (1975). The invertebrate ecology and the *Chione stutchburyi* population on the intertidal sand flats at Aramoana, Otago Harbour, New Zealand. Thesis. University of Otago. p.

Walsh, R.S.; Hunter, K.A. (1992). Influence of phosphorus storage on the uptake of cadmium by the marine alga *Macrocystis pyrifera*. *Limnology and Oceanography 37(7)*: 1361-1369.

Watson, S.L. (1992). Coastal zone management in Otago Harbour, New Zealand: Use of a Geographic Information System for a survey and appraisal of the Portobello area. Thesis. Otago University. 94 p.

Watters, P.A. (1964). Distribution of *Amphibola crenata* (Pulmonata) in the Dunedin area with notes on the probable origin of the species. *Transactions of the Royal Society of New Zealand 4*: 117-134.

Waugh, S.; Filippi, D.; Fukuda, A.; Suzuki, M.; Higuchi, H.; Setiawan, A.; Davis, L. (2005). Foraging of royal albatrosses, *Diomedea epomophora*, from the Otago Peninsula and its relationships to fisheries. *Canadian Journal of Fisheries and Aquatic Sciences 62(6)*: 1410-1421.

Westerskov, K. (1969). The macrobenthos of Blueskin Bay, Otago. Thesis. University of Otago.

Wilson, B. (1984). Recruitment, growth and community development in fouling organisms in Otago Harbour. Thesis. University of Otago.

Wing, S.; Irwin, C.; Granger, G. (2002). Biomass survey and yield estimates for New Zealand little neck clam *Austrovenus stutchburyi*, in Papanui and Waitati Inlets, Otago. Final Report for the Ministry of Fisheries research Project COC2001/02. *No.* 52 p.

Witman, J.D. (1974). Sedimentological and ecological studies of Blueskin Bay estuary. Thesis. University of Otago.

Wood, A.C.L. (2005). The macrofaunal communities associated with bryozoan thickets on Otago shelf, south-eastern New Zealand. Thesis. University of Otago.

Würsig, B.; Duprey, N.; Weir, J. (2007). Dusky dolphins (*Lagenorhynchus obscurus*) in New Zealand waters: Present knowledge and research goals. DOC Research & Development Series 270. No. 28 p.

Zeldis, J.R. (1983). Ecology of *Munida gregaria* (Fabricius) (Decapoda, Anomura). Thesis. University of Otago.

Zeldis, J.R. (1985). Ecology of *Munida gregaria* (Fabricius) (Decapoda, Anomura). Distribution and abundance, population dynamics and fishery considerations. *Marine Ecology Progress Series 22*: 77-99.

Zeldis, J.R. (1989). A fishery for *Munida gregaria* in New Zealand: ecological considerations.

Zeldis, J.R.; Jillett, J.B. (1982). Aggregation of pelagic *Munida gregaria* (Fabricus) (Decapoda, Anomura) by coastal fronts and internal waves. *Journal of Plankton Research 4(4)*: 839-857.