Environmental Status of The Near Shore Coastal Environment

April 2005

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Executive Summary

This report presents a comprehensive review of the environmental status of Otago's near shore coastal environment.

There is no current Otago Regional Council (ORC) coastal monitoring programme and therefore the ORC relies on resource consent monitoring to fulfil it's responsibilities under the Resource Management Act (1991), the Regional Policy Statement and the Regional Plan: Coast. The only intensive coastal monitoring undertaken is in the vicinity of Dunedin and is due to the discharge of Green Island and Tahuna WWTP effluent, otherwise coastal monitoring of Otago's coastal marine area (CMA) is limited both temporally and spatially.

A review of coastal monitoring undertaken since the late 1990's is presented with particular regard to water quality, the effects of discharges and possible effects on recreational and food gathering areas. Four main areas are covered:

- Water quality monitoring undertaken as a requirement of resource consents.
- Other monitoring as required by resource consents such as sediment monitoring programmes, ecological programmes, algal monitoring programmes or monitoring for the extent of mussel contamination.
- ORC State of Environment monitoring of the major rivers that discharge into the Otago CMA.
- A review of published research conducted in Otago's CMA over the past 10 years.

There is a need for a coordinated long term water quality and environmental monitoring programme for the whole of the Otago coastline, and the following monitoring and information gathering requirements are recommended:

- That sufficient baseline information is collected to be able to establish water quality classes for the Otago CMA**.**
- That microbiological categories are established for coastal waters in areas where resource consent holders undertake extensive monitoring.
- That additional bacteriological monitoring is undertaken at Kaka Point, Moeraki and McAndrews Bay.
- That bacteriological shellfish flesh sampling is undertaken at Moeraki and Kaka Point.
- That the broad scale mapping element of the protocol developed for assessing and monitoring the condition of New Zealand estuaries is adopted. Initially focusing on estuaries already under some impact, notably the Waikouaiti and Shag estuaries.
- That water quality surveys of the Taieri, Waikouaiti, Kaikorai, Catlins, Shag and Kakanui estuaries are undertaken. Three six hour water quality surveys (over low tide) should be undertaken for each estuary to provide a baseline for the future.

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1. Introduction

The coastal marine area (CMA) of Otago stretches 480km from the Waitaki River in the north to Wallace Point in the south. It exhibits a variety of shorelines along its length including steep cliffs, cobble and gravel delta, and sandy beaches as well as the Dunedin Volcano, now Otago Harbour (ORC 1994).

Rivers ranging in size from the Waitaki and Clutha/Mata-Au to the small rivers of the Catlins coast carry sediment and freshwater to the Otago CMA. Many of these rivers form estuarine wetlands of significant importance to both marine and freshwater wildlife.

There are two main urban areas, Oamaru (population 12,000) and Dunedin (population 114,000), both developed around harbours. There are also many small fishing and holiday communities such as Moeraki, Karitane and Taieri Mouth. The harbour in Dunedin is the only commercial port in Otago.

The high standard of coastal water quality expected in Otago can be affected by discharges of contaminants from both point sources and non point sources as well as accidental spills of contaminants. These discharges may result in decreased recreational and commercial opportunities.

Green Island and Tahuna wastewater effluents which discharge to the CMA south of Dunedin are the primary source of faecal coliforms to Otago's CMA, however other discharges such as stormwater and agricultural runoff will also contribute to the pollution load.

1.1 Coastal Marine Area

Otago's coastal marine area is shown in Figure 1, it extends from the line of mean high water springs, to the limits of the territorial sea at 12 nautical miles (22.2 kilometres), from the Waitaki River in the north to Wallace Beach in the south (ORC 2001).

The Regional Plan: Coast covers the coastal marine area, the coastal marine being:

'the foreshore, seabed, and coastal water, and the air space above the water –
(a) Of which the seaward boundary is the outer limits of the territorial sea:
(b) Of which the landward boundary is the line of mean high water springs, except that where that line crosses a river, the landward boundary at that point shall be whichever is the lesser of –
(c) (i) One kilometre upstream from the mouth of the river; or
(ii) The point upstream that is calculated by multiplying the width of the river mouth by five.'

(Section 2 of the Resource Management Act 1991)

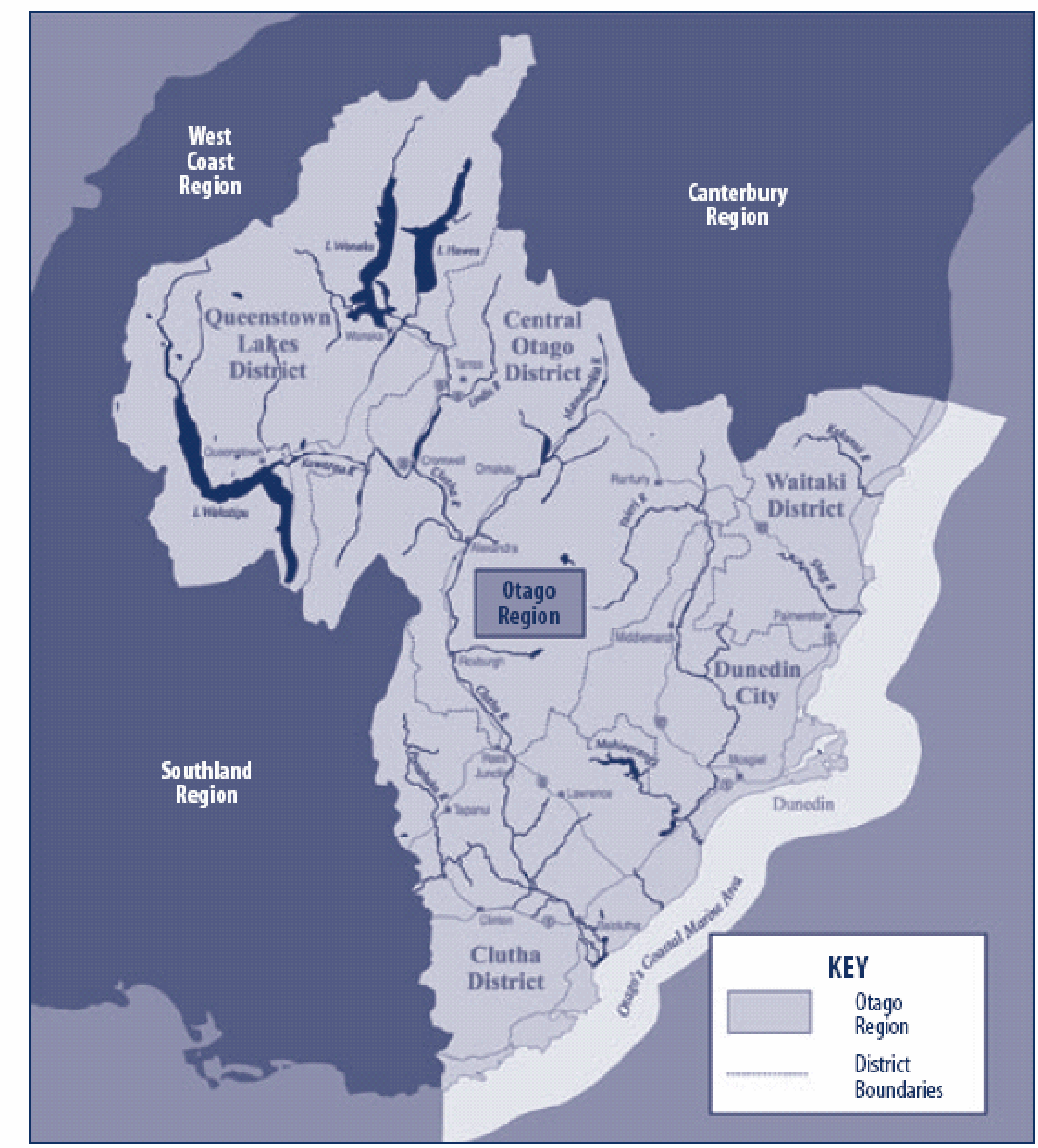

Figure 1.1 The Coastal Marine Area of Otago (ORC 2001)

1.2 Legislative and Policy Framework

The Resource Management (RMA) Act 1991 provides the framework for the management of Otago's natural and physical resources. The Otago Regional Council has the responsibility to monitor the coastal environment and gather information so that it is able to effectively carry out its functions under the RMA (Section 35).

The Regional Policy Statement (RPS) for Otago was prepared under Section 60 of the RMA to provide an overview of the resource management issues of Otago and policies and methods to achieve integrated management of the region's natural and physical resources. Chapter 8 deals with coastal issues, objectives and policies:

Policy 8.5.5

To maintain and where practicable enhance the physical and ecological quality of the coastal environment through:
a) protecting the life-supporting capacity of coastal ecosystems and
b) avoiding as far as practicable or remedying or mitigating the adverse effects, including cumulative effects, of land and water based activities on the coastal marine area through appropriate methods

Policy 8.5.6

To promote a reduction in the adverse effects of contaminant discharges into Otago's coastal waters through:

a) adopting the existing water quality of Otago's coastal waters as a minimum acceptable standard;

b) investigating, and where appropriate, enhancing water quality so that as a minimum standard it is suitable for contact recreation and shellfish gathering where:
i) There is a high public interest in, or use of the water; or
ii) There is a particular Kai Tahu interest in the water; or
iii) There is a particular value to be maintained or enhanced; or
iv) There is a direct discharge containing human sewage; or wastes from commercial or industrial activities; and
c) requiring that all discharges into Otago's coastal waters maintain the standard for the receiving waters after reasonable mixing; and
d) promoting discharges to land where practicable and where there are no significant adverse effects on groundwater or surface water resources, or soil; and
e) preparing contingency responses for accidental pollution spills; and
f) investigating and addressing the effects of diffuse source discharges on coastal water quality; whilst considering financial and technical constraints.

The Regional Plan: Coast was prepared under Section 64 of the RMA and focuses on the sustainable and integrated management of Otago's coastal marine area. It contains a range of objectives relating to coastal water quality (Objectives 10.3.1 to 10.3.6). These objectives aim to maintain or enhance coastal water quality in Otago.

Objective

10.3.1 *To seek to maintain existing water quality within Otago's coastal marine area and to seek to achieve water quality within the coastal marine area that is, at a minimum, suitable for contact recreation and the eating of shellfish within 10 years of the date of approval of this plan.*

10.3.2 *To take into account community, cultural and biological values associated with Otago's coastal marine area when considering the discharge of contaminants into Otago's coastal waters.*

10.3.3 *To safeguard the life-supporting capacity of Otago's coastal marine area*

10.3.4 *To enhance water quality in*
- *a) coastal protection areas; and*
- *b) coastal recreation areas; and*
- *c) areas adjacent to marine mammal or bird sites; and*
- *d) areas where there is a direct discharge containing human sewage; and*
- *e) areas where there is a direct discharge of wastes from commercial, industrial or production activities*

10.3.5 *To consider the adverse effects associated with a discharge of contaminants to the coastal marine area relative to the adverse effects associated with the discharge of the same material to other receiving environments.*

10.3.6 *To reduce the potential for spills or leakage's of hazardous substances and hazardous wastes into the coastal marine area.*

1.3 Monitoring Rationale and Objectives

Issue 10.2.6 of the Regional Plan: Coast recognises that '*there is a lack of knowledge about the current state of Otago's coastal water quality'*. Section 17.2 of the Regional Plan: Coast details the elements that will be monitored to assess the efficiency and effectiveness of the objectives and policies contained within the Plan, these include points 5, 6 and 9 as follows:

5. *The extent to which coastal water quality is maintained and enhanced, in particular in areas where there is:*
- *a) a high public interest in, or use of the water; or*
- *b) a particular Kai Tahu interest in the water; or*
- *c) a particular value to be maintained or enhanced; or*
- *d) a direct discharge containing human sewage; or*
- *e) a direct discharge of wastes from commercial, industrial or production activities.*

6. *Water quality within Otago's coastal marine area with a view to establishing water quality classes*

9. *The nature, extent and effect of the introduction of introduced or exotic plants into the coastal marine area.*

Section 17.3 details the monitoring techniques that are expected to form part of the coastal monitoring programme (these include water quality surveys and surveys of aquatic organisms).

In considering the above, there is a requirement that any coastal monitoring programme

1. Fulfils the Council's responsibilities to monitor the state of the environment as specified under Section 35 of the RMA 1991.
2. Provides high quality, scientifically defensible information on the quality of the region's coastal water quality to other sections of the Council, territorial authorities, stakeholder groups and the general public.

Bearing the above points in mind, it is possible to formulate several specific objectives for the Councils coastal water quality monitoring programme.

1. To improve knowledge and understanding of Otago's coastal water quality.
2. To collect sufficient data to be able to assess the water quality and habitat values of the Otago's coastal environment, with a view to future trend analysis.
3. To assess the efficiency and effectiveness of the objectives and policies set out in the Regional Policy Statement and the Regional Plan: Coast that specifically relate to water quality.

The first two points aim to provide a baseline for coastal water quality, with a view to identifying changes in water quality or ecosystem health in the future and the third point refers to specific objectives and policies already detailed in the Regional Plan: Coast.

2. Coastal Water Quality Issues

The issues associated with discharges as defined by the Regional Plan: Coast are as follows:

Issue
10.2.1 Some discharges and disposal practices cause cultural concern.
10.2.2 Discharges into Otago's coastal marine area can exceed the assimilative capacity of particular areas and reduce the life supporting capacity of coastal waters.
10.2.3 Discharges into Otago's coastal marine area can affect people's health and result in decreased recreational and commercial opportunities for Otago's citizens.
10.2.4 Accidental spills of contaminants into Otago's coastal marine area can have a significant adverse effect on the natural and physical resources of the coast.
10.2.5 The discharge of contaminants into Otago's coastal marine area may, in some cases, have greater adverse effect on the coastal environment than a discharge to other receiving environments.
10.2.6 There is a lack of knowledge about the current state of Otago's coastal water quality.

- The coastal environment is not a closed system and will be affected by coastal, land and river based sources. Longshore drift will also allow contaminants discharging into the sea to the South of Otago to travel up the coast. Table 2.1 lists the main types of marine pollution.

Table 2.1 Major Types of Marine Pollution

Type of Pollution	Effect/Pollutant	Importance in NZ
Agricultural		
• Soil erosion/runoff	Siltation	Major
• Animal waste	Nutrients	Major
• Agricultural runoff	Pesticides/fertilisers	Major
Industrial		
• Industrial effluent	Heavy metals	Slight
• Thermal effluent	Hot water	Slight
• Mining runoff	Sediment, cyanide, heavy metals	Locally important
• Port activities	Fuel leaks, oil spills	Minor but potential
Urban		
• Sewage	Bacteria, soaps, fats, nutrients, ammonia	Major
• Stormwater	Oils, faeces, heavy metals, pesticides	Probably regular
• Landfill leaching	Metals, nutrients, PCSs, toxic waste	Unknown
• Litter	Plastic, glass, metal	Minor, but pervasive

Source (Ridgway and Glasby, 1984, Peake, 1993)

- Land based discharges include both point source (i.e. drains and outfalls) and non point sources (i.e. agricultural runoff, septic tank discharges). These discharges may contain contaminants that affect coastal water quality, such as bacteria, metals, sediment and nutrients.

- Marine based discharges include the disposal of ballast water, rubbish, fuel oil, sewage and other contaminants. Marine pollution tends to be concentrated in estuaries or in the nearshore coastal environment.

2.1 Environmental Incidents

An environmental incident can be defined as 'pollution or an unauthorised activity that may have an adverse effect on the environment'. Environmental incidents are reported to the Otago Regional Council by members of the public.

Between 2000 and 2004 there were 107 reports of pollution to the coastal environment. Figure 2.1 shows that for this period the most common type of reported incident to the Otago Regional Council was oil and fuel spills (34%), followed by 'natural incidents' of foaming, scum, algae and weed. Contaminated stormwater is responsible for 11% of the reported incidents.

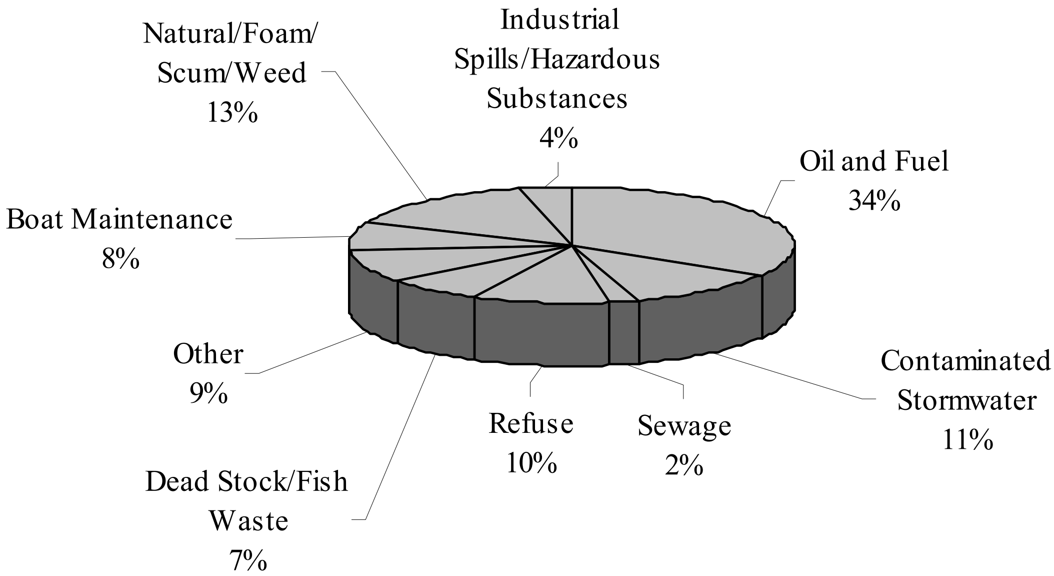

Figure 2.1 Coastal Water Environmental Incidents 2000 to 2004

The incidents reported are generally highly visible, and 81% were located in Otago Harbour, Dunedin. Elsewhere it is likely that there are a large proportion of unreported incidents.

2.2 Point Source Discharges

By 2004 the Otago Regional Council had issued a total of 51 resource consents authorising a discharge directly to the coastal environment. Figure 2.2 shows that stormwater discharges are by far the most common type of authorised discharge (68%). However sewage discharges would account for the greatest volume of contaminant discharged to the coastal marine environment.

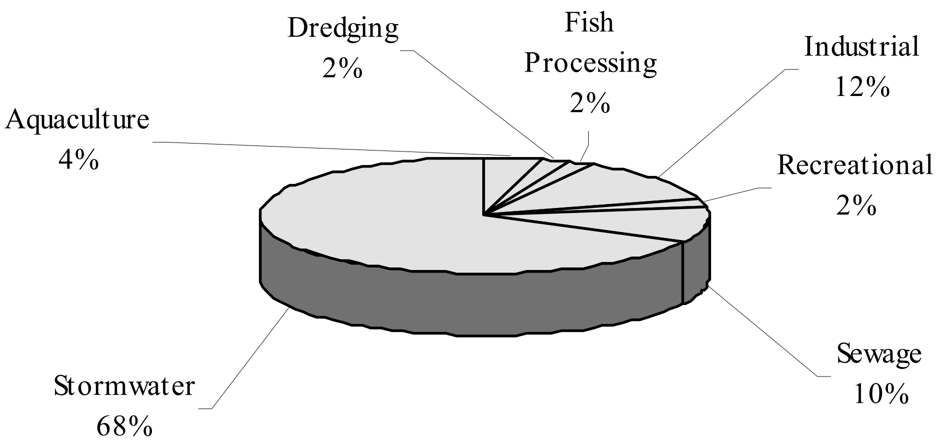

Figure 2.2 Authorised Discharges to Coast (ORC 2004)

The main point source discharges to the coast are listed in Table 2.2, along with details of their consent conditions. Tables 2.3 and 2.4 list the main point sources of contamination (discharges of >400m^3/day and <400m^3/day respectively) that originate inland but are likely to enter the coastal environment.

Table 2.2 Main point sources of contamination in Otago, and associated consent details

1.	Green Island WWTP 97530
Consent: Restricted coastal activity to discharge up to 103680 m^3/day of treated effluent to the Pacific Ocean approx 850m off Waldronville Beach foredune for the purpose of discharge of treated wastewater from the Green Island Wastewater Treatment Plant via an 850m long outfall pipeline, with diffuser	
2.	Tahuna WWTP 2001.380
Consent: To discharge up to 51840 m^3/day average dry weather flow and up to 5,000 litres per second peak weather flow of treated wastewater to the Pacific Ocean at Lawyers Head for the purpose of disposal of wastewater from the Dunedin City Council Tahuna Wastewater Treatment Plant.	
3.	Ravensdown Fertiliser Co-operative Limited 94682
Consent: To discharge up to 816 m^3/day at a rate of up to 14.2 litres per second of gas scrubber effluent into Otago Harbour, adjacent to the Ravensdown Fertiliser Plant Ravensbourne at for the purpose of disposal of superphosphate plant fluoride and odour scrubbers, by Outfall 6A via a multi port diffuser	
4.	Ravensdown Fertiliser Co-operative Ltd 96412
Consent: Discharge wharf washdown water, grey water and miscellaneous discharges from ship unloading to the Ravensbourne Wharf, Otago Harbour for the purpose of ship unloading activities.	
5.	Kaka Point Oxidation Pond CP98301
Consent: Restricted coastal activity to discharge up to 120 m^3/day (dry weather flow) and up to 360,000 litres per day (wet weather flow) of treated sewage effluent to the Pacific Ocean at Port Molyneux for the purpose of discharging Kaka Point oxidation pond effluent.	
6.	WWTP at Portobello 2001.622
Consent: Discharge up to 9 m^3/day of treated wastewater (treatment comprising of a Sequential Batch Reactor and ultra violet disinfection) to the Otago Harbour for the purpose of discharge of treated wastewater from the University of Otago Portobello Marine Laboratory.	

Table 2.3 Main point sources of contamination of >400m^3/day that originate inland but may enter the coastal environment

1.	PPCS
Consent: To discharge up to 20,000 m^3/day of treated meatworks and tannery wastewater and water treatment plant clarifier underflow and filter backwash water into the Koau Branch of the Clutha River/Mata-Au.	
2.	Alliance Pukeuri 98523/98521
Consent: To discharge an average 12,000 m^3/day at a maximum rate of 15,000 cubic metres/day of treated wastewater to water at (1) McEneany Road irrigation race for purpose of discharge of meat processing, tannery & fellmongery wastewater from the Alliance Pukeuri Meat Processing Plant treated by aerated lagoon(s) & clarifier system & (2) the discharge of this wastewater mixed with McEneany Road irrigation water to the Hilderthorpe main irrigation race via a pipeline	
3.	Oamaru WWTP 04088/2002.655
Consent: To discharge up to 7,500 m^3/day (annual average daily flow) of treated effluent from the Oamaru Wastewater Treatment Plant to Landon Creek for the purpose of the treatment and disposal of wastewater from the Oamaru Wastewater Treatment Plant. Location of activity: An area of land at the coastal end of TY Duncan Road, Oamaru	
4.	Waikouaiti Oxidation Ponds DP97107
Consent: Discharge up to 2,000 m^3/day of treated sewage to land by spray irrigation for the purpose of disposal of oxidation pond effluent from the Waikouaiti and Karitane Domain	

Table 2.4 Main point sources of contamination of $<400m^3$/day that originate inland but are likely to enter the coastal environment

5.	Warrington Oxidation Pond 96531_V1
Consent: To discharge up to 250 m^3/day of treated domestic effluent to land for the purpose of disposal of treated domestic effluent from the Warrington township wastewater treatment pond at the base of Warrington Spit.	
6.	Mainland Poultry, Waikouaiti 2000.499, 2000.499A, 99515
Consent: Discharge up to 150 m^3/week of processing wastewater to land to dispose of wastewater from egg grading and processing at a poultry farm. Consent: Discharge up to 3.9 m^3/day of septic tank effluent to land for the purpose of disposal of effluent from staff facilities at a poultry farm operation Consent: To discharge leachate to land in a manner in which it may enter water from a poultry farm landfill	
7.	Otago Salmon Hatchery Trust CP2000.511
Consent: Discharge up to 25 m^3/day day of wastewater to Thompsons Creek for the purpose of discharge of wastewater from a salmon hatchery at Port Chalmers Wastewater Treatment Plant, adj to SH88, Sawyers Bay.	
8.	Fairfield Landfill 93540
Consent: To discharge up to 103 m^3/day of landfill leachate to groundwater by seepage through the 21 hectares area being the base of the landfill bounded by the leachate for the purpose of controlling landfill leachate at the Fairfield Landfill adjacent to the Kaikorai Estuary approximately 1 km off Old Brighton Road.	
9.	Seacliff WWTP DP95883
Consent: Discharge up to 43.2 m^3/day of treated domestic sewage to land at a rate of up to 0.5 litres per second from the township of Seacliff	
10.	Otago Peninsula Trust 96445
Consent: To discharge up to 12 m^3/day of treated sewage effluent to land in circumstances which will result in the contaminant entering the Pacific Ocean at Taiaroa Head, Otago Peninsula to dispose of sewage disposal from a visitor centre.	
11.	Otago Aquaculture Ltd 2005.100
Consent: Discharge sea water onto the Karitane Beach, at its southern end, for the purpose of disposal of treated paua farm waste water, immediately north of the northern boundary of the Puketeraki Coastal Protection Area	
12.	Southern Abalone Ltd 2004.856
Consent: Discharge water used in an onshore paua farm to an unnamed stream flowing into the Pacific Ocean at the north end of Park Road, Warrington	
13.	Green Island Landfill 3839
Discharge to sewer, but may impact surface waters. Consent: To discharge landfill and composting facility leachate to groundwater within a 38 ha area bounded by a leachate collection drain and the taking of groundwater and leachate from within the 38 ha landfill area, including the leachate collection drain, and the diversion and taking of 'dirty' stomwater from the working area within the landfill.	

2.3 Non Point Source Discharges

Non point source or diffuse pollution comes from a variety of sources and results from rain or snow gathering contaminants as it moves through or across land cover. The contaminants of concern include those listed in Table 2.1.

Otago has experienced considerable modification of land cover and intensification of agriculture. This has had implications for the coastal environment as the volume of runoff has increased, and the volume of contaminants being discharged has increased accordingly. Runoff contaminants of significance include sediment eroded from the land, nutrients entrained in farm runoff and bacteria sourced from farm stock. Non point source discharges affects coastal water mainly through the discharge of the contaminants via estuaries, the most obvious sign of coastal contamination is the discolouration of coastal waters. The type of land use is critical in the amount of contaminant reaching waterways, higher intensity land use such as dairying, is more likely to adversely affect water quality than lower intensity land uses such as sheep farming. Table 2.5 shows river catchment and associated land use cover.

Table 2.5. Land use by catchment (hectares)

Catchment	MSB	PS	PB	D	DDS	DF	GP	Total Ha
Kakanui	38717	31772	3674	1588	886	3049	167	89587
L. Waitaki	9696	12330	3001	10469	536	795	535	46955
Waianakarua	13624	15282	1786		123	958	384	46288
Shag	27045	23053	5213	260		230	12	71728
Waikouaiti	22598	11097	1263	483	46	0	26	42897
Otago Penin.	3735	5652	774	508	295	163	45	26887
Kaikorai	232	823	331	144	67	82	115	6100
Leith	160	427	57	327	209	98	4	5936
Taieri	257987	149070	17769	11237	1117	2701	1157	569000
Coastal	7587	8054	812	1421	118	589	2	39478
Catlins	16835	6397	2216	828		0.9		40394
S. Catlins	13289	5534	1976			87		62164

MSB; Mixed Sheep/Beef, PS;Primarily Sheep, PB; Primarily Beef, D; Dairying, DDS; Dairy Dry Stock, DF; Deer Farming
Source: Agribase 2000

2.4 Shipping

Issues 8.3.7 and 8.3.8 of the Regional Policy Statement for Otago state that:

Issue

8.3.7 *'The discharge of ballast water into Otago's coastal marine area has the potential to result in contamination and in the introduction of exotic unwanted organisms'.*

8.3.8 *'Otago's coastal environment is threatened by pollution spills both on the land and in the water and by maritime shipping disasters'*

Most of Otago's shipping activity is based in Otago Harbour. In 2004 the majority of ship visits were fishing boats (189) and container vessels (191). Cruise boats accounted for 21 ship visits and other types of cargo included oil (22), LPG (19), Fertiliser (17), Cement (14), Cars (10) and Logs (10). In total ship visits for 2004 numbered 525.

There is always the potential that commercial shipping may cause pollution, in particular from the discharge of ballast waters, oil and fuel spills and spillage of cargo when onloading and offloading at port.

Table 2.5 lists the fuel depots available for shipping in Otago. These sites are high risk as they have the potential to cause major coastal pollution.

Table 2.5 Hydrocarbon Risks in Otago's Coastal Marine Area

Location	**Potential Source of Hydrocarbons**
Oamaru	Diesel pumps, port activities
Moeraki	3 diesel pumps on wharf
Karitane	1 diesel pump on jetty
Carey's Bay	3 pumps on jetty
Dunedin	Diesel pumps, port activities, shipping
Taieri Mouth	3 diesel pumps on wharf

3. Resource Consent Monitoring

Otago Regional Council's state of environment (SOE) water quality monitoring programme does not include estuary or coastal water monitoring. The majority of environmental data is provided through resource consent holder monitoring undertaken in relation to discharges of industrial or municipal wastewater to the coast.

3.1 Resource Consent Monitoring for Shellfish Gathering and Contact Recreation

The Otago Regional Council does not have a regional bacteria water quality monitoring programme for recreational shellfish gathering or for contact recreation and relies on the results of resource consent monitoring for an insight into the state of Otago's coastal water quality and whether it is suitable for either activity.

Shellfish feed by filtering hundreds of litres of water per day, removing plankton and detritus from the water. Due to this method of feeding, the shellfish also tend to accumulate pathogens (i.e. bacteria and viruses) that are present in the water. Contaminated shellfish (i.e. those that have accumulated pathogens) have the potential to cause illness when ingested.

Table 3.1 Guideline Values For Contact Recreation, Shellfish Gathering and Shellfish Flesh

Date	Guideline	Allowable Concentration
MfE/MoH June 2003	Surveillance/ Green Alert/Amber Action/Red	*'No single sample greater than 140 enterococci/100ml)* *'Single sample over 140 enterococci'* *'Two consecutive samples over 280 enterococci'*
MfE/MoH June 2003	The Recreational Shellfish Gathering Bacteriological Guideline Value	*'The median faecal coliform content of samples taken over a shellfish gathering season shall not exceed a Most Probable Number (MPN) of 14 per 100ml, and not more than 10% of samples should exceed an MPN of 43/100ml (using a five-tube decimal dilution test).*
Department of Health 1995	The Microbiological Reference Criteria For Food	*'A faecal coliform concentration of 230MPN/100 gm represents an acceptable level and values above it are marginally acceptable or unacceptable in terms of the sampling plan. Values above 330 MPN/100gm are unacceptable in terms of the sampling plan and detection of one or more samples exceeding this level would be cause for rejection of the lot.*

Contact recreation monitoring is also a critical indicator as faecal coliform and enterococci bacteria are associated with the gut of humans, mammals and birds and the level of these in water provides an indication of the level of contamination and whether the water is suitable for contact recreation.

Water quality standards for the purposes of contact recreation and shellfish are detailed in Table 3.1. The current microbiological guidelines applicable to contact recreation in marine waters include a 'traffic light' warning system. (Surveillance/Green Mode, Alert/Amber Mode and Action/Red Mode). The New Zealand Marine Bathing Study showed that enterococci were the indicator that most closely correlated with health effects, therefore it is the preferred indicator in marine waters. Faecal coliforms and *E. coli* are useful when used as an indicator in addition to enterococci.

The following consents require monitoring for values associated with shellfish or contact recreation.

i) Green Island WWTP: It is a requirement that Dunedin City Council undertake shoreline faecal coliform monitoring enterococci monitoring and faecal coliform analysis of Blackhead Point mussels.

Table 3.2 Monitoring Requirements for Green Island WWTP

Beach	**Monitoring Requirements**
Black Head Beachlands Westwood,	Faecal coliform analyses of shoreline water Weekly: Dec-Mar, Monthly: Apr-Nov
Blackhead St Clair	Enteroccoci analysis of shoreline samples Weekly: Dec-Mar, Monthly: Apr-Nov
Blackhead Pt	Faecal coliform analysis of mussels Over 6 weeks (Jan – Mar)

Table 3.3 Green Island Wastewater Treatment Plant. Faecal coliform (MPN/100ml) and Enteroccoci (Ent/100ml) in Receiving Waters and Faecal coliform concentration in Mussel Flesh (MPN/100gm)

Location	**Blackhead**			**Beachlands**	**Westwood**	**St Clair**
Analysis	**FC**	**Ent**	**Mussel Flesh FC**	**FC**	**FC**	**Ent**
Median	2	10	18	1	1	10
Minimum	1	10	18	1	1	10
Maximum	97	20	23	25	13	160

The location of monitoring sites is shown in Figure 3.1 and results of monitoring for 2003-2004 are given in Table 3.3. All 2003/2004 results are below relevant guideline levels other than one enterococci at St Clair.

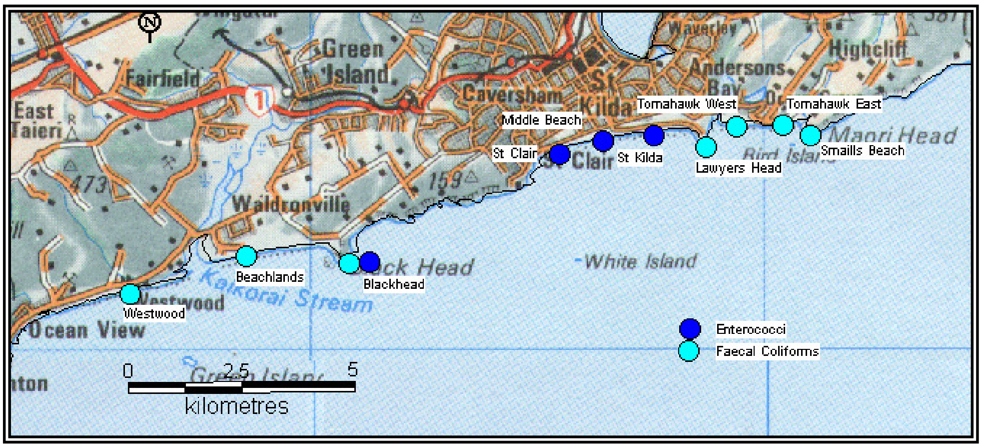

Figure 3.1 Dunedin City Council Weekly Monitoring Sites for Faecal Coliforms and Enterococci during the Bathing Season (1 Nov to 31 March)

ii) Tahuna WWTP: It is a requirement that Dunedin City Council undertake faecal coliform and enterococci monitoring of beach waters detailed in Table 3.4 at weekly intervals from 1 November to 31 March (inclusive) and at monthly intervals from April to October (inclusive).

Table 3.4 Faecal Coliform and Enterococci Monitoring at Dunedin Beaches

Beach	**Monitoring Requirements**
St Clair Beach Middle Beach St Kilda Beach	Enterococci in accordance with Section D (Marine Recreational Waters) of the June 2003 Ministry for the Environment/Ministry of Health Recreational Water Quality Guidelines.
Lawyers Head Beach Tomahawk Beach West Tomahawk Beach East Smaills Beach	Faecal coliforms in accordance with Section F (Recreational Shellfish-gathering Waters) of the June 2003 Ministry for the Environment/Ministry of Health Recreational Water Quality Guidelines.

Table 3.5 Results for Faecal Coliform (MPN/100ml) and Enterococci (Ent/100ml) Monitoring at Dunedin Beaches July 2003 to June 2004

Location	**St Clair**	**Middle Beach**	**St Kilda**	**Lawyers Head**	**Tomahawk West**	**Toma. East**	**Smaill's Beach**
	Ent	Ent	Ent	FC	FC	FC	FC
Median	10	10	10	130	9400	7100	140
Maximum	160	270	830	45000	59000	67000	16000

Figure 3.1 and Table 3.4 shows the location of monitoring sites and Table 3. gives results for 2003/4. The results show that median enterococci results at Dunedin beaches are extremely low, however at some point during 2003/2004 all the beaches exceeded the surveillance/green mode of 140 enterococci/100ml and St Kilda exceeded the action red mode of 280 enterococci/100ml day.

The faecal coliform results from Lawyers Head, Tomahawk West and East and Smaills Beach were extremely high, reflecting the discharge from Lawyers Head.

iii) Green Island WWTP: It is a requirement that a shoreline shellfish (mussel) monitoring programme is undertaken in order to assess the status of coastal faecal contamination with respect to the DCC's coastal water outfalls.

Sites are sampled at quarterly intervals and Table 3.6 details the sites monitored in 2003/2004. Figure 3.2 details site locations.

Table 3.6 Median faecal coliform (n = 4) concentrations in seawater (MPN/100ml) and mussel flesh (MPN/100gm) for the period July 2003 to April 2004. Highlighted cells show exceedences of guideline levels.

Site	Water	Flesh
	2003/2004	2003/2004
Victory Beach (N control site)	26.75	3350
Allans Beach (Belmont end)	9.4	230
Hoopers Inlet Mouth (water only)	1.8	N/A
Sandfly Bay (NE	3	137.5
Sandfly bay (SW – mussels and water)	9.5	405
Boulder Bay (NE)	66	765
Smaills Beach/Maori Head	240	5000
Tomahawk Creek (water only)	41	N/A
Lawyers Head (Beach on St Kilda side)	635	1045
Second Beach (NW)	25.4	78
Blackhead (Beach end)	58.9	220
Brighton (Sports ground)	1.9	19
Bruces Rocks (N end)	1.8	18
Taieri Mouth (Livingston Park)	1.9	45
Akatore (N – southern control site)	1.9	255

Table 3.6 shows the 2003/4 median results for faecal coliforms in water. Since the commissioning of the Green Island upgrade (June 2000) then there has been a marked decrease at all sites. However sites at Sandfly Bay (SW), Boulder Bay, Smaills Beach Tomahawk Creek, Second Beach, Blackhead and Lawyers Head failed to meet guidelines, as well as the northern control site Victory Beach. For surveys up to June 2000 the median faecal coliform concentration in water at all sites was above the shellfish gathering guideline of 14 MPN/100ml.

Table 3.6 also shows the 2003/4 median results for faecal coliform concentrations in shellfish. Since the commissioning of the Green Island upgrade (June 2000) the median faecal coliform concentration in shellfish at all monitored sites has decreased significantly, however sites at Sandfly Bay SW, Boulder Bay, Smaills Beach, Lawyers Head and both control sites failed to meet guideline values.

The most probable source of contamination is the Lawyers Head outfall, however discharges from stormwater drains and local streams during rain events are likely to be responsible for some increases in faecal coliform contamination.

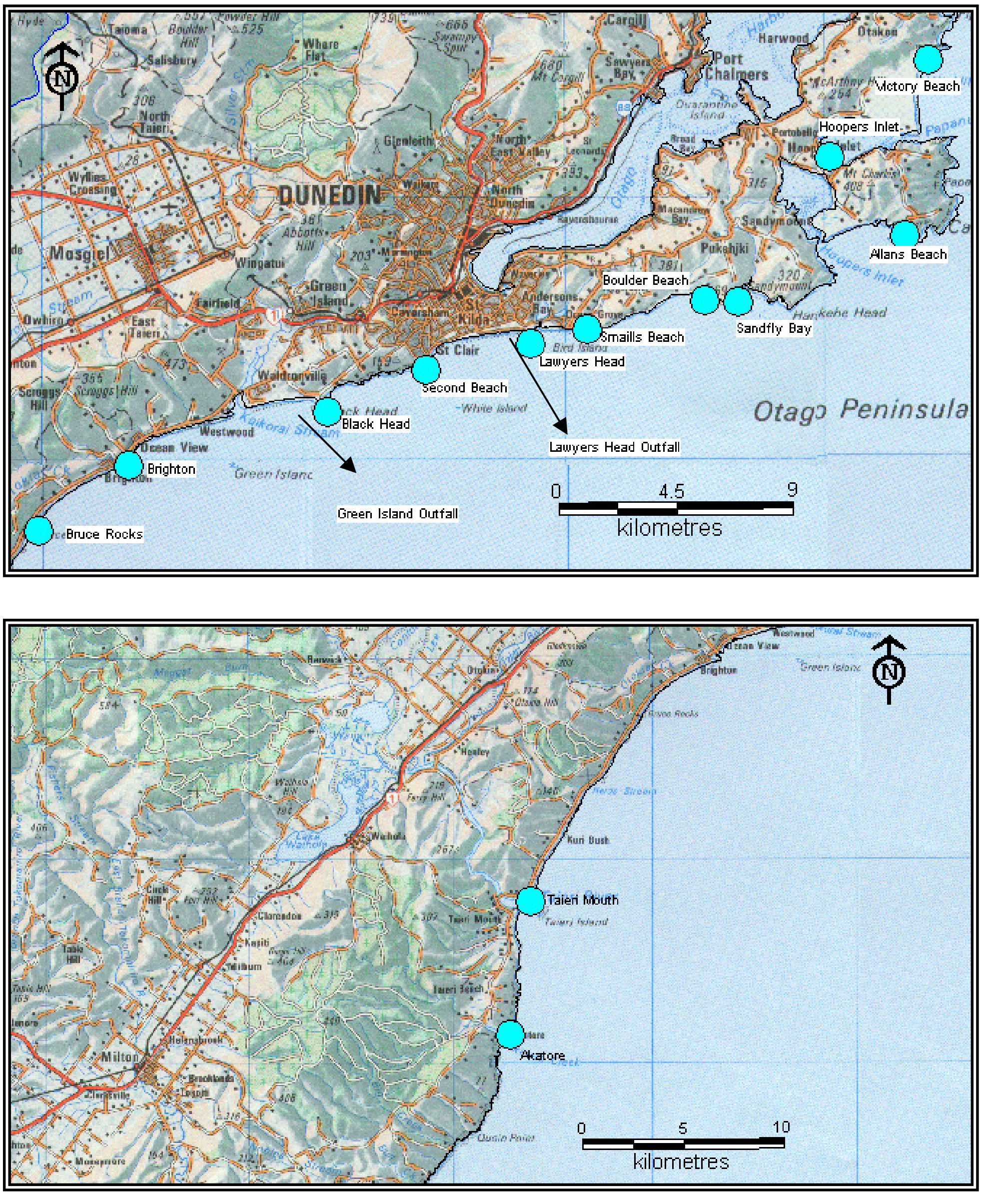

Figure 3.2 Dunedin City Council Shellfish Monitoring Sites. Sampling carried out quarterly

iv) ***Kaka Point Oxidation Pond:*** ***It is a requirement that faecal coliform monitoring is undertaken in the receiving water 100 metres either side of the outfall.***

Sampling is undertaken six monthly and one of the sampling occasions coincides with the December / January / February peak loading on the oxidation pond and peak holiday use of the coastal area.

Table 3.7 Results for 2004 faecal coliform (MPN/100ml) and enterococci monitoring (Ent/100ml) 100m north and 100m south of Kaka Point Oxidation Pond .

Date	**Site**	**Enterococci**	**Faecal Coliforms**
11/8/04	100m north	5	10
	100m south	5	<10
18/2/04	100m north	<10	59
	100m south	<10	27
5/2/01	*100m north*		*1700*
	100m south		*430*

There have been occasional high faecal coliform bacteria concentrations measured at these locations i.e. on 5th February 2001, results of which are also included in Table 3.7.

The 'Cultural Impact Assessment on the Wastewater Discharges from the Clutha District Council Operated Treatment Plants' prepared by Kai Tahu ki Otago comments that 'during summer when visits to the beach are more common and the population of Kaka Point much higher, faecal coliform concentrations in the water can potentially be far too high for safe water contact. All the rocky points and adjacent beaches in this area (including the point) are favoured areas to harvest kai moana.'

Iwi have rated the upgrading at Kaka Point as third on their priority list, after Milton and Lawrence as it adversely impacts on their ability to harvest and enjoy shellfish and other food sources.

v) ***Seacliff WWTP: It is a requirement that faecal coliform monitoring is undertaken immediately seaward of the land disposal area.***

At five regular intervals over a one month period during December to April each year, a representative sample of seawater is collected at three evenly spaced sites (north, middle and south) immediately seaward of the land disposal area. These samples are analysed for faecal coliforms/enterococci to verify that effluent which reaches coastal waters is achieving suitable dilution such that shoreline enterococci do not exceed contact recreation limits of 140/100ml.

Table 3.8 Enterococci concentrations in seawater at Seacliff for the period March-April 2004.

Date	**Enterococci Concentrations n/100ml**		
	Shore 1	**Shore 2**	**Shore 3**
09/03/04	2	<3	2
23/03/04	<3	2	<3
25/03/04	<3	<3	<3
26/03/04	<3	2	<3
02/04/04	29	20	6

Table 3.8 shows that enterococci concentrations in seawater off Seacliff are extremely low, indicating that the land disposal system of Seacliff effluent is not affecting the coastal environment.

Weekly water quality monitoring for faecal coliforms at Dunedin beaches (Blackhead, Beachlands and Westwood) in 2003/4 showed that all results were below relevant guideline levels, However the faecal coliform results from Lawyers Head, Tomahawk West and East and Smaills Beach were extremely high, reflecting the discharge from Lawyers Head.

Enterococci monitoring at Dunedin beaches (Blackhead, Middle Beach, St Kilda and St Clair) showed that whilst the median results were within guideline levels, at some point during 2003/4 the beaches at St Clair, Middle Beach and St Kilda exceeded the surveillance/green mode of 140 enterococci/100ml.

The water quality at the majority of Dunedin's popular bathing beaches is reasonably good for bathing purposes, but will be reduced to a poorer quality following heavy rainfall.

Quarterly mussel monitoring showed that median faecal coliform concentration guideline standards for shellfish flesh were exceeded at Victory Beach, Sandfly Bay (SW), Boulder Bay, Smaills Beach, Lawyers Head and Akatore over the 2003/4 period. However, shellfish at Allan's Beach, Hoopers Inlet, Sandfly Bay (NE), Second Beach, Blackhead, Brighton, Bruces Rocks and Taieri Mouth met the guideline for faecal coliforms.

In general shellfish faecal coliform concentrations have decreased since the 2000 Green Island WWTP upgrade, but there are still occasionally guideline failures which probably reflect the discharge from Lawyers Head.

The frequency of sampling undertaken by the Dunedin City Council in relation to the Tahuna and Green Island WWTP effluent outfalls is such that microbiological categories for coastal waters could be developed in this limited area.

This microbiological category combined with a detailed sanitary inspection category (a measure of how susceptible a water body is to faecal contamination) would enable a grade to be determined for recreation suitability.

Table 3.9 Contact Recreation Microbiological Assessment Categories

Class	Enterococci n/100ml	Classification
A	Sample 95 percentile <40	Very Good
B	Sample 95 percentile 41-200	Good
C	Sample 95 percentile 201-500	Fair
D	Sample 95 percentile >500	Poor

To enable further coastal water classification it is recommended that one site to the south of Dunedin, one site to the north of Dunedin and one site in Dunedin Harbour is sampled on a weekly basis over the bathing season. It is suggested that the sites are Kaka Point, Moeraki and McAndrews Bay.

Although the majority of sampling is undertaken in the vicinity of Dunedin, the extra sites will give a better geographical spread of sites along Otago's coastline. It is recommended that the sites are sampled weekly over the summer period in order to comply with the Microbiological Guidelines for Marine Waters and to provide adequate monitoring for meeting Objective 10.3.1 of the Regional Plan: Coast.

3.2 Resource Consent Monitoring - Shellfish Contaminants

Guideline permissible levels of metals in shellfish are detailed in Table 3.10 and the normal dietary intake requirements for zinc are detailed in Table 3.11.

Table 3.10 Heavy Metal Concentrations for NZ and US FDA guidelines for adults (expressed as mg/kg dry weight)

Mg/kg dry wt	Cu	Zn	Pb	Cd	Cr	Ni
Food Regs/NZ DoH	150	2000	10	5		
US FDA			4.2		11	80
Australia NZ food standards code			2	2		

Table 3.11 Normal dietary Intake Requirement s for Zinc (mg/day)

	7-12m	1-3	4-6	7-10	11-14		15-18		19-50+		Pregnancy
Gender					M	F	M	F	M	F	
mg/day	5.6	5.5	6.5	7.5	12	10.3	13	10.2	9.4	6.5	7.3-13.3

Source: World Health Organisation (WHO, 2001)

Heavy metals are generally not eliminated from the aquatic ecosystem by natural processes. Shellfish and particularly filter feeders such as bivalve molluscs are particularly prone to accumulating heavy metals such as copper, cadmium, chromium, mercury, zinc, lead, arsenic and nickel.

i) ***Dunedin City Council: Although not a requirement of either the Tahuna WWTP consent or the Green Island WWTP consent, the DCC tests shellfish for a range of heavy metals on a six monthly basis.***

Figure 3.2 shows the DCC shellfish and microbiological monitoring sites. At these sites shellfish are also tested for heavy metal concentrations. 2004 monitoring results revealed that metal concentrations were low relative to food consumption guidelines.

Results show all sites had similar concentrations of copper, nickel and zinc. Even elevated levels of metals at various sites on various sampling occasions were below guideline levels for food (Australia New Zealand Food Standards Code). Small peaks in lead and chromium at the Lawyers Head site are probably due to the effects of the discharge but are well below relative food consumption guidelines.

ii) ***Ravensdown Fertiliser Cooperative Limited: It is a requirement that investigations into the chemical contamination of blue mussels is undertaken at two yearly intervals (in February).***

The monitoring sites are located on the intertidal rock wall between the point where outfall 6a crosses the shoreline and a point 150 metres to the northwest. Five samples, each containing five adult blue mussels *(Mytilus edulis aoteanus)* are collected and the flesh analysed for fluoride, copper, cadmium, chromium and zinc. Three control sites are also monitored.

Table 3.12 Metals and Flouride in Blue Mussels 1996-2002 (mg/kg wet weight)

Year	Cadmium	Chromium	Copper	Zinc	Flouride
1996	0.12	0.40	0.7	19.6	0.90
1998	0.10	0.40	1.2	18.0	0.90
2000	0.05	0.40	0.7	15.4	0.96
2002	0.05	0.23	0.9	15.6	0.88

Results from the 2000 survey showed that concentrations of copper, cadmium and zinc concentrations were below the Australia New Zealand Food Standard Code guidelines and chromium concentrations were at or below the level of detection. Flouride levels were also below the now revoked Food and drug Regulations standard of 15mg/kg wet weight.

iii) Dunedin City Council has undertaken human enterovirus monitoring of shellfish since October 2002 (although not a requirement of consent conditions for either Tahuna WWTP or Green Island WWTP).

The presence of enterovirus' in shellfish and receiving water is likely to provide stronger evidence of the presence of sewage wastewater than the presence of faecal coliforms alone. Three rounds of enterovirus testing have revealed no detectable concentrations of these viruses in shellfish or seawater collected from Akatore, Black Head, Second Beach, Lawyers Head, Boulder Beach and Victor Beach sites. Apart from at Lawyers Head in April 2004 viruses in shellfish samples were below detectable limits.

3.3 Resource Consent Monitoring - Whole Effluent Toxicity

i) Ravensdown Fertiliser Cooperative Limited: It is a requirement that whole effluent toxicity testing is undertaken annually using three test organisms.

The testing is carried out on three test organisms, a marine bacterium (Microtox *Vibrio fischeri*), a marine algae (*Minutocellus polymorphus*) and a marine amphipod (*Chaetocorophium lucasi*) by the National Institute of Water and Atmospheric Research (NIWA) in Hamilton.

A dilution requirement of 500 to 650 times is generally required to avoid adverse effects on aquatic life. The Ravensdown diffuser at outfall 6A provides a dilution of 517 times (Ravensdown, 1983), suggesting that there should be no effect from the effluent.
The sensitivity of the test organisms varied at different toxicity dilutions, and it is probable that at higher concentrations the acidity component of the effluent would have a significant effect in its own merit.

3.4 Resource Consent Monitoring - Nutrients

The following consents require monitoring for nutrients:

i) Green Island WWTP: It is a requirement that nutrient monitoring is undertaken.

The primary focus of the offshore component of the water quality monitoring is to investigate whether or not nutrients in the wastewater discharge contribute significantly to algal blooms in the area.

Three nutrient and phytoplankton surveys were undertaken during 2003/4. Nutrient levels at the Westwood and Blackhead sites were not elevated and were generally within the background range that is typical for coastal waters in this area. Even though the wastewater discharge is a significant source of nutrients to the Otago coastal environment, high initial dilution renders the concentration of nutrients to background levels within a short distance of the outfall.

Elevated nutrient concentrations are likely to be restricted to the immediate outfall area (probably <1500m from the outfall), as nutrient concentrations in the receiving environment are reduced to background levels at 2000m from the outfall.

ii) ***Green Island WWTP: It is a requirement that ammonia monitoring is undertaken (water samples from Black Head and Westwood on a monthly basis from February to April)***

The diffuser supports an array of flora and fauna including various fish species, crayfish, anemones, sea squirts and seaweeds which would suggest that there are no toxic effects occurring. It is likely that dilution in the local coastal environment varies with sea conditions, in particular current speed. Dilution of the effluent once it leaves the diffuser is rapid with samples taken from as little as 1m from the diffuser ports comfortably meeting the ANZECC 2000 guidelines for 95% levels of protection (Table 3.13), as well as meeting US EPA acute and chronic criteria for ammonia.

Table 3.13 ANZECC 2000 Guidelines – Toxicity to ammonia of a range of marine species

Species	Toxicity
Marine Fish	3 species, 44-68 hr LC_{50}, 8.8 mg/l (*Pagrus major*); 21.4 mg/l (*Salmor salar)* and 44.9 mg/l (*Fundulus heteroclitus*)
Marine Crustacean	15 species, 24-96 hr LC_{50}, ranges from 18.69 mg/l (*Penaeus semisulcatus*) to 264 mg/l (brine shrimp *Artemia salina*)
Marine Molluscs	2 species, 48-96 hr LC_{50}, (*Argopectin irradians*), 77.2 mg/l and 42.8 mg/l for *Anadara granosa.*
Marine Rotifer	1 species, 24-96 hour EC_{50}, (*Brachionus plicatus)*

LC_{50} – Median Lethal Concentration, EC_{50} – Median Effective Concentration

3.5 Chlorophyll *a* Monitoring

The following consents require chlorophyll *a* monitoring:

i) Green Island WWTP: It is a requirement that chlorophyll a monitoring is undertaken.

The trigger value for possible adverse effects in coastal waters is 1 chlorophyll (based on ANZECC 2000 guidelines for NSW Australia).

Chlorophyll *a* is analysed in order to see whether the effluent is causing or contributing to nuisance phytoplankton blooms in the area.

During 2003/4 chlorophyll *a* levels were low at both the Blackhead and Westwood offshore sites and ranged between 0.9 and 1.8 µg/L. The dominant phytoplankton taxa were *Skeletonema* spp. and *Pseudo-nitzschia* spp., which are generally non-toxic.

The area typically features low chlorophyll *a* concentrations and is not naturally prone to algal blooms. Some toxin-forming algal species are likely to be present occasionally, however it appears that the existing discharge is unlikely to significantly increase the adverse effects of naturally occurring nuisance or toxic phytoplankton blooms.

ii) Ravensdown Fertiliser Cooperative Limited: It is a requirement that monitoring of macroalgae is undertaken at two yearly intervals (in February).

The monitoring sites are 25m, 350m and 1,000 metres to the northeast of outfall 6a and 350 metres southwest of outfall 6a. The total percentage cover of algae and the percentage cover of dominant species of algae is determined within a $0.25m^2$ quadrant every 5 metres along each of two parallel 100 metres transects. The two transects are located 30 metres apart. Three control sites are also monitored.

Shallow subtidal areas are extensive in the Upper Otago Harbour and the presence of dense beds of benthic red macroalgae is a feature of the biology of this part of the harbour. Dominant algae in the shallow subtidal areas are *Lenormandia chauvinii* and two species of *Ceramiales*. *Lenormandi* has increased in abundance at all stations except 250W since 1996, whilst *Ceramiales* has decreased. The reason for the change is unknown.

3.6 Resource Consent Monitoring - Sediments

Table 3.14 Australian and New Zealand Environment and Conservation Council Interim Sediment Quality Guidelines, High and Low values for Organic Compounds and Metals in Sediment mg/kg dry weight (ANZECC, 2000; Long and Morgan, 1991). Shaded cells show results from Green Island WWTP.

Metal	ANZECC Low Trigger	ANZECC High Trigger	Minimum for GI WWTP	Maximum for GI WWTP 2002
Arsenic	20	70	2.8	4.7
Cadmium	1.5	10	<0.01	0.01
Chromium	80	370	1.7	5.5
Copper	65	270	1.4	3.3
Lead	50	220	1.34	2.88
Mercury	0.15	1	<0.01	0.02
Nickel	21	52	2.1	5.7
Zinc	200	410	7.4	18.7

The following consents require sediment monitoring:

i) ***Green Island WWTP: It is a requirement that subtidal sediment surveys for heavy metals is undertaken. (This survey is undertaken in conjunction with the Green Island WWTP consent requirement for benthic invertebrate monitoring)***

Samples were taken 10m. 50m, 250, 500m, 1000m and 2000m distance from each side of the outfall along a transect running approximately west and east of the outfall and parallel to the shore. In addition, samples were taken from a single location at Akatore to the south and Victory beach to the North to function as controls.

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000) establish guidelines for sediment quality based on the recognition that sediments are an important sink for contaminants that may affect benthic communities. These are shown in Table 3.14, along with results from 2002.

In 2003/2004 arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc were considerably lower than ANZECC 2000 trigger values. For mercury and cadmium most of the values were below the laboratory detectable limits. The Akatore site which is well away from wastewater outfalls recorded higher results than nearby sites, this suggests the metals may be from a natural geological source. Whether the site is upcurrent or downcurrent of the outfall has no bearing on metal concentrations, however concentrations of metals (other than copper and mercury) decrease with distance from the outfall.

ii) ***Ravensdown Fertiliser Cooperative Limited: It is a requirement that investigations into sediment quality is undertaken at two yearly intervals (in February) at the same sites sampled for benthic biota.***

Five replicate samples of sediment, each consisting of five cores 60 mm diameter and 50 mm deep were be collected at each site from the same locations sampled for benthic biota (25W, 25E, 350E, 1000E, 350W). Sediment grain size distribution was determined on one sample per site and fluoride, phosphorus, cadmium, chromium copper and zinc concentrations were determined on each replicate sample. Three control sites were also monitored.

Table 3.14 gives guideline values and Table 3.15 shows that none of the monitoring stations exceeded the value over the time period.

Table 3.15 2002 Sediment Results (mg/kg dry weight)

Metal	Impact Sites				Control Sites		
	25E	**350E**	**1000E**	**350W**	**E**	**F**	**G**
Cadmium	0.14	0.14	0.04	0.03	0.06	0.14	0.11
Chromium	16.8	21.8	10.1	16.8	23	20	18.2
Copper	12.8	16.4	5.8	9.8	17.8	12.3	14
Zinc	70.4	86.6	36.2	80.8	111.6	137.8	136.2
Flouride	189.6	186.0	129.8	176.6	161.6	157.2	161.6
Phosphorus	1109	1133	583	1072	752	722	762

Between 1984 and 2002 the mean concentrations of all contaminants was below guideline levels at all stations. In 2002 cadmium, chromium, copper and zinc were all below the ISQG Low guideline levels (Table 3.14). There is no guideline value for flouride in sediments and the 2002 results show that concentrations in the same year were not statistically different between control sites and the works impact sites. There is no guideline value for phosphorus in sediments, the 2002 results indicate that total phosphorus concentrations were higher at 25W, 25E, 350W and 350E than the control sites and indicates that works derived total phosphorus is present in sediments near the works.

iii) Ravensdown Fertiliser Cooperative Limited: Although not a requirement of consent conditions, a baseline sediment survey was undertaken on 30 August 2004 around stormwater outfalls 3,4 and 6.

Six samples were collected from each site, three samples at 20m and three samples at 50m from the stormwater outfalls at 45, 90 and 135 degree angles to the shore. Samples were tested for cadmium, chromium, copper, zinc, total phosphorus and fluoride concentrations.

Outfall 6 sample results showed an exceedence of the ANZECC ISQG-Low trigger value for cadmium in the 20mW and 50mW samples which may cause some adverse biological effects. The NIWA tentative ISQG-Low trigger value for flouride (500 mg/kg dry weight) was exceeded in all samples. Average concentrations of cadmium, chromium, zinc, phosphorus and fluoride were higher than concentrations recorded in the 2004 harbour environment monitoring study (Bioresearches, 2004a). No adverse effects are expected as a result of the concentrations of chromium, copper, zinc and phosphorus recorded in sediments within 50m of the outfall. Concentration of fluoride in the sediments within 50m of Outfall 6 is likely to cause some adverse biological effects.

Outfall 4 sample results showed that the ANZECC ISQG-Low trigger value for copper was exceeded in the 20mE sample which may cause some adverse biological effects. The NIWA tentative ISQG-Low trigger value for fluoride (500 mg/kg dry weight) was exceeded in all samples which may also cause some adverse biological effects. It should be noted that this outfall is closest to Outfall 5 that used to drain an area that produced copper sulphate up until 1983.

Outfall 3 sample results show that the NIWA tentative ISQG-Low trigger value for fluoride (500 mg/kg dry weight) was exceeded in all samples except the 50m 90º sample. No adverse effects are expected as a result of metal or fluoride concentrations within 50m of Outfall 3.

3.7 Benthic Invertebrate Monitoring

The following consents require benthic invertebrate monitoring.

i) Green Island WWTP: It is a requirement that subtidal sediment surveys for benthic macrofauna abundance are undertaken. (This survey is undertaken in conjunction with the Green Island WWTP consent requirement for subtidal sediment monitoring for heavy metals)

Samples were taken 10m. 50m, 250, 500m, 1000m and 2000m distance from each side of the outfall along a transect running approximately west and east of the outfall and parallel to the shore. In addition, samples were taken from a single location at Akatore to the south and Victory beach to the North to function as controls.

As heavy metal concentrations in all sediment samples are well below the appropriate sediment guidelines, adverse effects on benthic ecology due to metal contamination would not be expected. Akatore had the highest concentration of metals, but benthic community structure was broadly similar to that found elsewhere. Fauna found was typical of an extremely physically disturbed environment (characterised by exposure to strong currents and a mobile sediment bed), with a common core of species exhibiting a patchy distribution.

The 2004 results emphasise the highly variable nature of the benthic communities off the Otago coast. This variation is evident in numbers of benthic animals, benthic community and background sediment concentrations of metals at different locations.

Table 3.16 compares trends in benthic marine communities found around wastewater outfalls at Green Island, New Zealand and overseas. The predicted nearby effects are for a reduced number of species and animals compared to nearby sites, when at Green Island numbers actually increase.

Table 3.16 Summary of trends in benthic marine communities observed around wastewater outfalls in New Zealand and overseas, with the observed trends seen at Green Island (Ryder 2004)

	Proximity to Outfall		
Biological Parameter	**Close**	**Intermediate**	**Distant**
	PREDICTED EFFECT		
Number of species	Low	Increased greatly	Increased
Number of animals	Reduced	Increased greatly	Increased
Variability	Reduced	Increased	Unchanged
Pollution intolerant species	Absent	Reduced Numbers	Present
	OBSERVED EFFECT AT GREEN ISLAND (relative to other nearby sites)		
	10-50m	250-1000m	2000m
Number of species	Slightly higher	Increased slightly	Increased slightly
Number of animals	Increased	Increased	Increased
Variability	Slightly reduced	Slightly reduced	Slightly reduced
Pollution Intolerant Species	Absent	Present	Absent

ii) Ravensdown Fertiliser Cooperative Limited: It is a requirement that monitoring of the structure of soft bottom macrobenthic communities is undertaken at two yearly intervals (in February).

The monitoring sites are 25m, 350m and 1,000 metres to the northeast of outfall 6a and 350 metres southwest of outfall 6a. Five sediment cores, 150 mm diameter and 200 mm long are taken at each site. The fresh samples are sieved through a 0.5 mm sieve and all living fauna removed for identification and counting. The number of taxa and the Shannon-Weiner diversity index are determined for each core and the data subjected to a multi variate analysis. Three control sites are also monitored.

Small polychaete worms and amphipods were the most abundant groups in the study area. Small amphipods and crustaceans such as the sand crab and burrowing crab were also abundant as were common molluscs. Echinoderms were present in small numbers. The Ravensbourne Works discharges in 2002 were not causing significant adverse effect on benthic fauna diversity.

iii) Waikouaiti Oxidation Pond: It is a requirement that an annual investigation of benthic invertebrates is undertaken in the tidal flat shoreline.

Once per year, a low tide ecological survey of the Waikouaiti Beach, or the most adjacent Waikouaiti Estuary tidal flat to the land disposal field (or both depending on results of nitrate plume investigations) is undertaken, there is also a control site and a site within the leachate plume. The ecological survey assesses whether groundwater seepage is causing adverse impacts to coastal ecosystems.

The 2003 survey indicates that the variety of invertebrates found within the core samples was typical of those found inhabiting exposed sandy shores in New Zealand

(Morton and Miller 1973) and previous surveys of Waikouaiti beach. Taxonomic diversity was similar for low and mid beach zones and slightly lower in the upper beach zone.

iv) Warrington Oxidation Pond: It is a requirement that an annual investigation of benthic invertebrates is undertaken in the tidal flat shoreline.

Once per year in the summer holiday period (December / January) a survey is carried out to ascertain any observable impacts on areas that might be affected by leachate from the land disposal area of Warrington Oxidation pond effluent. Seven 1 square metre quadrats are examined on a transect running from the sub-tidal channel to spring high tide across the tidal flats. Each quadrat is examined for epifauna and flora (diversity and abundance) and a photograph taken. An 8 cm core to 20 cm depth is taken and sieved through a 1 mm sieve and then the diversity and abundance of retained macroinvertebrates recorded. General sediment characteristics (including colour, consistency and smell) is noted for each of the cores. In addition the low water site is quantitatively examined on the basis of 30 replicates of 13 cm diameter cores to 15 cm depth sieved through a 1 mm mesh sieve.

The 2003 survey highlighted that one transect (3) had an extensive layer of blackened, odourous sand running parallel to the beach for at least 20m, this appeared consistent with the main effluent leachate plume identified by Greenwood (1999).

Beach fauna was similar to that found in previous surveys, however diversity was much greater in the zone of blackened sand suggesting infauna was responding to enrichment. Generally clean sands, lack of algal cover, and dominance of cockles indicate that enrichment is mild and localised.

v) Alliance Pukeuri: It is a requirement that annual assessment of benthic biota in the marine sediment is undertaken adjacent to the discharge point.

Once per year a survey is carried out to assess benthic biota in the marine sediments adjacent to the discharge points. Six transects were established off the North Otago Coast in the vicinity of the Pukeuri outfall (from 3000 northeast to 5000 southwest of the outfall). Samples were taken along the transects at 25m, 50m, 100m and 200m from the high tide mark.

The 2002 survey results show that fauna is typical of an extremely physically disturbed environment with a common core of species (dominated by polychaetes and amphipods) exhibiting a patchy distribution, there was a high variation both between locations on the coast and at locations in 2001 and 2002. There was no clear association between benthic communities and the location of outfalls along the coast and the benthic communities are likely to be primarily structured by the effects of disturbance.

3.8 Resource Consent Monitoring - Rocky Shore Ecological Values

i) Green Island WWTP: It is a requirement that annual ecological monitoring of rocky shore sites is undertaken.

The monitoring assesses the impacts of both the Green Island WWTP discharge and the Tahuna WWTP which discharges effluent at Lawyers Head. Monitoring sites include Victory Beach, Allan's Beach, Boulder Beach, Lawyers Head (Impact Site), Second Beach, Black Head (Impact Site), Brighton, Akatore

Taxonomic richness reflects the health of the intertidal community and generally the index increases with better water quality, greater habitat diversity and habitat stability.

There were some evidence of subtle differences between inter-tidal communities at the impact site and at other sites, but the overall similarities in species between sites was very high. Variation between samples collected from individual sites was often greater than the variation between sites, emphasising the natural variability present. This suggests that any effects of wastewater outfalls are no more than minor in comparison to the natural variation between sites and years.

The 2004 intertidal survey revealed diverse and healthy ecological communities along the Otago coast that are consistent with those found in other studies (e.g. Morton and Millar 1968, Probert 1988, Gering 1990).

3.9 Resource Consent Monitoring - Dunedin Harbour Water Quality

Table 3.17 ANZECC Default Trigger Values for Marine Water. (* indicates the trigger values applying to slightly-moderately disturbed systems)

Metal	Trigger Values for Marine Water (µg/l)			
	Level of Protection (% species)			
	99%	95%	90%	80%
Cadmium	0.7*	5.5	14	36
Chromium	0.14	4.4*	20	85
Copper	0.3	1.3*	3	8
Lead	2.2	4.4*	6.6	12
Nickel	7*	70	20	560
Zinc	7	15*	23	43

i) Ravensdown Fertiliser Cooperative Limited: It is a requirement that water quality meets the standard of water classes CR and SG of the 3rd Schedule for the Resource Management Act (1991) outside the 50m mixing zone.

On a weekly basis a sample from the mid point of the mixing zone boundary is analysed for conductivity, temperature, pH, total fluoride, total phosphorus and tubidity.

Conductivity and temperature were within normal range. Total phosphorus was below the ANZECC trigger level of 30 mg/l, turbidity was generally stable at about 2 NTU, but occasionally peaked. pH had one result which was below the low ANZECC guideline of pH 7.0 and fluoride concentrations at the mixing zone were below the (South African) guideline of 5 mg/l.

Table 3.18 Summary Results for Outfall 6A Water quality monitoring at the Mixing Zone Boundary (Nov 1999-May 2003)

	Cond	**Fluoride**	**pH**	**Temp**	**Total P**	**Turb**
	mS/cm	**mg/l**		**ºC**	**mg/l**	**NTU**
Number	165	165	165	165	165	165
Average	51	1.57	7.91	13.1	0.064	2.63
95% C.I.	0.8	0.06	0.03	0.5	0.022	0.55
Minimum	8.3	0.4	6.54	6.5	0.002	0.27
Maximum	57.8	4.67	8.27	19.5	1.45	40.4

4. Non Resource Consent Monitoring

4.1 Dunedin Harbour Sediment Monitoring (post 1999)

The guidelines shown in Table 4.1 define an ISQG-low trigger value and an ISQG-High level. Concentrations below the trigger value are unlikely to have an adverse effect on benthic invertebrates. Concentrations above the ISQG-High indicate that sediments are highly contaminated. Sediments with levels between the two can be described as moderately contaminated.

Table 4.1 Recommended Sediment Quality Criteria for Heavy Metals, ISQG Trigger Values (mg/kg)

	Copper	Chromium	Nickel	Zinc	Lead	Cadmium
ISQG-low	65	80	21	200	50	1.5
ISQG-high	270	380	52	410	220	10

Source: ANZECC 2000 based on National Oceanographic and Atmosperic Administration (NOAA) National Status and Trends Programme in the US.

i) In 2004 sediment was analysed for metals and enterococci at 19 sites in the Upper Harbour (DCC 2005).

A summary of sediment quality results are shown in Table 4.2 and a comparison with previous studies at three specific sites (near Orari stormwater outfall, near Portobello outfall and a control site) is shown in Table 4.3. Depth of sampling is unknown, samples were collected either on foot or by boat using a day grab.

Table 4.2 Contaminant levels (mg/kg for metals, MPN/100ml for enterococci) in sediments in the Upper Harbour Basin. 2004

	Cu	Cr	Mn	Ni	Zn	Fe	Pb	Cd	Ent
Max	168	46.9	339	18.6	**1130**	30700	**227**	1.64	490
Min	6.5	16.8	144	8.6	98.2	12300	38.4	0.29	80
Median	28.4	15.3	187	11.9	270	17700	72.75	0.36	130
Mean	47.1	27.9	199	12.8	359.6	20362	82.94	0.49	202

Source: Dunedin City Council 2005

Iron is present in quite significant concentrations, but due to its low toxicity there are no upper limits set for iron in the ANZEEC 2000 guidelines. Manganese concentrations vary widely, but there are no guideline values.

Nickel concentrations are quite high in places but levels do not exceed ISQG-low trigger levels (21 mg/kg), chromium concentrations also do not exceed ISQG-low trigger levels (80 mg/kg).

At the Portobello stormwater shows levels of copper that exceed the ISQG-low level trigger value (65 mg/kg), and Andersons Bay inlet also shows elevated copper concentrations (although they do not exceed the ISQG-low trigger values). Cadmium concentrations exceed ISQG-low trigger levels (1.5 mg/kg) at the Portobello stormwater outfall and zinc contamination is highest at Portobello stormwater outfall although zinc

ISQG-low trigger values (200 mg/kg) are exceeded over a wide area of the Upper Harbour Basin. ISQG-low trigger values for lead (50 mg/kg) are also exceeded over substantial areas of the Upper Harbour.

Table 4.3 Lead, zinc and copper concentrations in sediment. (ORC, 1998, ORC 2000, DCC 2004)

	Control Site			Near Orari Stormwater Outlet			Near Portobello Stormwater Outlet		
	1998	**2000***	**2004**	**1998**	**2000***	**2004**	**1998**	**2000***	**2004**
Lead	19	33	19.2	200	209	43	410	449	227
Zinc	110	159	119	190	332	157	1300	1285	1130
Copper	17	22	15.2	20	41	18.2	210	305	168

*concentrations (mg/kg) averaged for top 10cm of core samples

There are no ANZECC 2000 guideline values for enterococci in sediments, however the maximum number of enterococci in any one water sample for secondary contact in marine waters is 450-700 enterococci/100ml. If the MfE guideline were to be used (<140 enterococci/100ml) the area of non compliance would be wider.

ii) In 1999 sediment was analysed for lead, zinc and copper at three sites in the Upper Harbour Basin. (ORC 2000)

Sediment cores were taken from the vicinity of the Portobello stormwater outlet, the Orari stormwater outlet and a control site in the Upper Harbour.

Heavy metal results showed similar metal concentrations in the lower core sections with elevated levels in the upper core. The control site had metal concentrations below the ISQG-low levels. Orari Street had levels of lead and zinc exceeding the ISQG-high value at 3cm and 8cm but copper concentrations remained below the ISQG-low level. Portobello Road had metal concentrations greater than both the ISQG-low guideline values (lead above 16cm, zinc above 17cm, copper above 12cm) and the ISQG-High level (lead and zinc at 12cm and copper at 10cm)

A 160m transect from the Portobello site had sediment analysis undertaken every 10m. Concentrations of lead, zinc and copper were above the ISQG-low level for almost the entire length of the transect, only copper concentrations dropped below the ISQG-low at 130m. ISQG-high levels were exceeded for lead up to 90m from the site and for zinc up to 120m from the site. ISGQ-high levels were also exceeded for copper for up to 18m from the site and then from 40-60m from the site. . However it is interesting to note that lead levels have dropped dramatically in the sediment at the stormwater outfall sites. This probably reflects the removal of lead from petrol by the early 1990's.

The above studies show that the Portobello Road stormwater outlet is having significant adverse effects on the eastern corner of the upper Harbour basin. The extent of contamination is about a 160 m radius from the outlet with an approximate depth of 0.2 m. The low energy waters characteristic of this area are unable to dilute the stormwater significantly before contaminants settle out or adsorb onto the underlying sediments. The sedimentation rate is estimated to be around 3-3.5 mm/year with the depth of contamination traced to the installation of the stormwater outfall in the 1960s.

4.2 Recreational Water Quality Monitoring

The current microbiological guidelines applicable to marine and freshwater systems include a 'traffic light' warning system. (Surveillance/Green Mode, Alert/Amber Mode and Action/Red Mode) as shown in Table 4.4.

Table 4.4 Surveillance, alert and action levels for marine waters (Ministry of Environment/Ministry of Health 2003)

Action Levels	Enterococci/100ml
Surveillance/Green Mode	No single sample over 140 enterococci
Alert/Amber Mode	Single sample over 140 enterococci
Action/Red Mode	Two consecutive samples over 280 enterococci

Recreational water quality monitoring undertaken (Post 2000) include the following:

i) Dunedin City Marine Recreational Project. Bacteriological Water Quality For Harbour and Coastal Areas For Contact Recreation. 2000

Sites at MacAndrew Bay, St Kilda, St Clair, Blackhead and Brighton were sampled up to three times weekly in February, March and April 2000. Results from the survey are given in Table 4.5. The Amber/Alert Mode of the MfE/MoH guidelines was exceeded at all beaches during the survey period, but only St Kilda exceeded the Action/Red Mode level of 280 enterococci/100ml, however no follow up sample was taken within 24 hrs.

Table 4.5 Enterococci Results (Public Health South 2000)

	McAndrew Bay	St Kilda	St Clair	Blackhead	Brighton
No Samples	15	15	15	15	15
Maximum	145	464	213	195	230
samples > 140	1	3	2	2	1

ii) MacAndrew Bay Recreational Water Quality Survey

Enterococci sampling was undertaken in MacAndrew Bay in 2001 to determine the risk to bathers from Roger's Creek and stormwater outfalls. Results from the beach areas are given in Table 4.6. The Alert/Amber Mode of the MfE/MoH guidelines was exceeded once at south beach and twice at NE Beach, but generally beach samples were below the Surveillance/Green Mode of the guidelines (Table 4.4).

Table 4.6 MacAndrew Bay Enterococci Results (Public Health South 2001)

	Mid Beach 2	South Beach 3	NE Beach 4	Combined
No samples	4	15	15	34
Maximum	20	270	160	270
Median	10	33	20	20

5. Otago Regional Council Monitoring

5.1 Estuaries

There is no current ORC coastal estuarine monitoring programme however a survey of six estuaries was undertaken in 2003/2004 details of which are given in Table 5.2.

Table 5.1 Guideline Values For Possible Adverse Effects Due To Nutrients (ANZECC 2000)

	Form	Estuaries (mg/l)	Coastal Waters (mg/l)
Nitrogen	NO_3-N	0.015	0.005
Phosphorus	TP	0.03	0.025

* based on ANZECC 2000 guidelines for SE Australia (slightly disturbed ecosystems).

The aim of the estuary monitoring undertaken during summer 2004/05 was to assess the baseline nutrient and bacterial status of Otago's main estuaries. As the estuaries were monitored over one tidal cycle, sampling ranged from predominantly freshwater to mainly marine water. To accommodate this indicator bacteria monitored were faecal coliform, enterococci and *Escherichia coli.*

Table 5.2 Estuary Monitoring 2004/2005, Selected Nutrient and Bacteriological Results

Estuary	NO_3-N	Total N	Total P	E Coli cfu/100ml		FC MPN/100ml	
	Median	Median	Median	Median	Range	Median	Range
Kakanui	0.022	0.27	0.025	41	5-96	26.5	8-130
Waikouaiti	0.008	0.43	0.0245	395	5-1500	505	45-2100
Taieri	0.027	0.36	0.025	10	5-31	21.5	5-45
Shag	0.015	0.275	0.026	295	150-410	300	180-460
Catlins	0.014	0.41	0.025	10	5-31	10	5-27

Phosphorus, nitrogen and ammonia play a major role in the primary production of coastal ecosystems, ammonia may also be toxic to aquatic life in certain concentrations dependent on water temperature and pH. The measurement of these nutrients provides an insight into the impact of adjacent catchment land use practices.

Table 5.2 gives a range of nutrient concentrations above which problematic plant growth may occur. However many other factors will interact to determine whether this is a possibility (i.e. light, turbidity, temperature). Median nitrate levels were high compared to guideline values, but typical for estuaries whose catchments have been modified. Median phosphorus levels were below ANZECC guideline levels for estuaries. Exceedence of the MfE/MoH surveillance/green mode level (>260 cfu/100ml) for *E.coli* in freshwaters is marked in both the Shag and Waikouaiti estuaries, however levels in the other estuaries were low. Contact recreation guideline exceedences for *E. coli* and enterococci are probably the result of intensive farming in the catchments and associated runoff during rainfall. This was almost certainly the case for the Waikouaiti estuary, which had experienced a high level of rainfall just prior to sampling.

Estuaries are good indicators of the health of their catchment and often act as a sink for contaminants such as metals and nutrients. Estuaries also provide a unique habitat for a range of animals and plants. They are breeding grounds for birds, fish, shellfish and invertebrates and often support diverse plant communities. They are also important in mahinga kai (food gathering) areas and support a range of recreational activities.

The life supporting capacity of Otago's coastline is required to be monitored to address Objective 10.3.3 of the Regional Plan: Coast. A protocol has been developed by the Cawthron Institute for assessing and monitoring the condition of New Zealand estuaries, this protocol would address this objective. The Otago Regional Council contributed to the development of this national protocol, with the Kaikorai Estuary forming one of the nine estuaries that were monitored (Cawthron 2002).

Monitoring of the dominant characteristics of the estuarine benthic intertidal habitat is undertaken at two levels:

(i) Broad-scale mapping of habitat (e.g., dominant substrate and vegetation) using aerial photographs at a scale of 1:10,000. Broad-scale mapping enables assessment of changes over time, identification of special areas and spread of invasive species.

(ii) Monitoring of fine-scale variables at 2-4 sites over at least 3 years that reflect important aspects of overall estuary condition (e.g., biodiversity, contamination, toxicity, enrichment). This involves annual physical-chemical and biological sampling of sediment grain size, nutrients, heavy metals, organic matter, chlorophyll *a* and species abundance (infauna, epifauna, microalgae and macroalgae).

Section 3.2.6 details benthic invertebrate monitoring undertaken as part of consent compliance conditions. Some of the studies have been undertaken in potentially the most susceptible sites for pollution in Otago's CMA and overall there is no strong evidence that life supporting capacity is reduced. Therefore it is not recommended that routine benthic invertebrate monitoring of estuaries is undertaken.

It is recommended that the Council implement the broad scale mapping element of the Cawthron protocol, initially focusing on estuaries already under some impact, notably the Waikouaiti and Shag estuaries.

It is also recommended that Council implement intensive water quality surveys of major estuaries (to include the Taieri, Waikouaiti, Kaikorai, Catlins, Shag and Kakanui). Data provided will provide a baseline for the future. Three six hour water quality surveys (over low tide) should be undertaken to incorporate the tidal flushing and stratification regimes of the estuaries.

5.2 State Of Environment Freshwater Monitoring

The Otago Regional Council State of Environment Monitoring programme monitors the quality of most of the major rivers that discharge into the Otago Coastal Marine Area.

Table 5.3 details the freshwater sites and the results for bacterial contamination (2000 to 2005).

Table 5.3 Otago Regional Council's seaward SOE freshwater monitoring sites

River	Site	Flow 00-04	E. coli Results 00 to 05	
		Mean m^3/sec	Median	Range
Kakanui River	Pringles	3.03	35	8-440
Shag River	Goodwood	1.46	89	4-2000
Waianakarua	Browns Pump	1.7 #	21	1-190
Waikouaiti River	Orbell's	0.401*	56	8-1800
Blueskin Bay	Careys Creek	n/a	105	19-610
Blueskin Bay	Waitati Stream	n/a	120	2-650
Water of Leith	Dundas Street	0.80	385	82-10500
Kaikorai Stream	Townleys Rd	n/a	270	38-9700
Taieri River	Allanton	104.42	115	15-1700
Tokomairiro	Tokoiti	0.68**	1500	370-7900
Clutha	Balclutha	564.8	42	10-1100
Catlins	Houipapa	4.24	140	40-1500

* South Branch at Lawsons, ** West Branch only, # Estimated data

Median *E. coli* results are above the Ministry of Environment/Ministry of Health (MfE/MoH) June 2003 acceptable/green mode guideline level of 260 E.coli/100mls in the Water of Leith and Kaikorai, the Tokomairiro is above the alert/red mode level of 550 E.coli/100ml. The Tokomairiro has a median total nitrogen concentration of 0.915 mg/l which is above the ANZECC 2000 default trigger guideline (0.614 mg/l). Although not strictly a coastal issue, it is recommended that the SOE monitoring site at Tokomairiro is moved as it is not the role of the SOE monitoring programme to measure the quality of effluent.

Figure 5.1 clearly shows that the Tokomairiro at Tokoiti has the poorest water quality. This is due to the poor water quality downstream of Milton sewage treatment works.

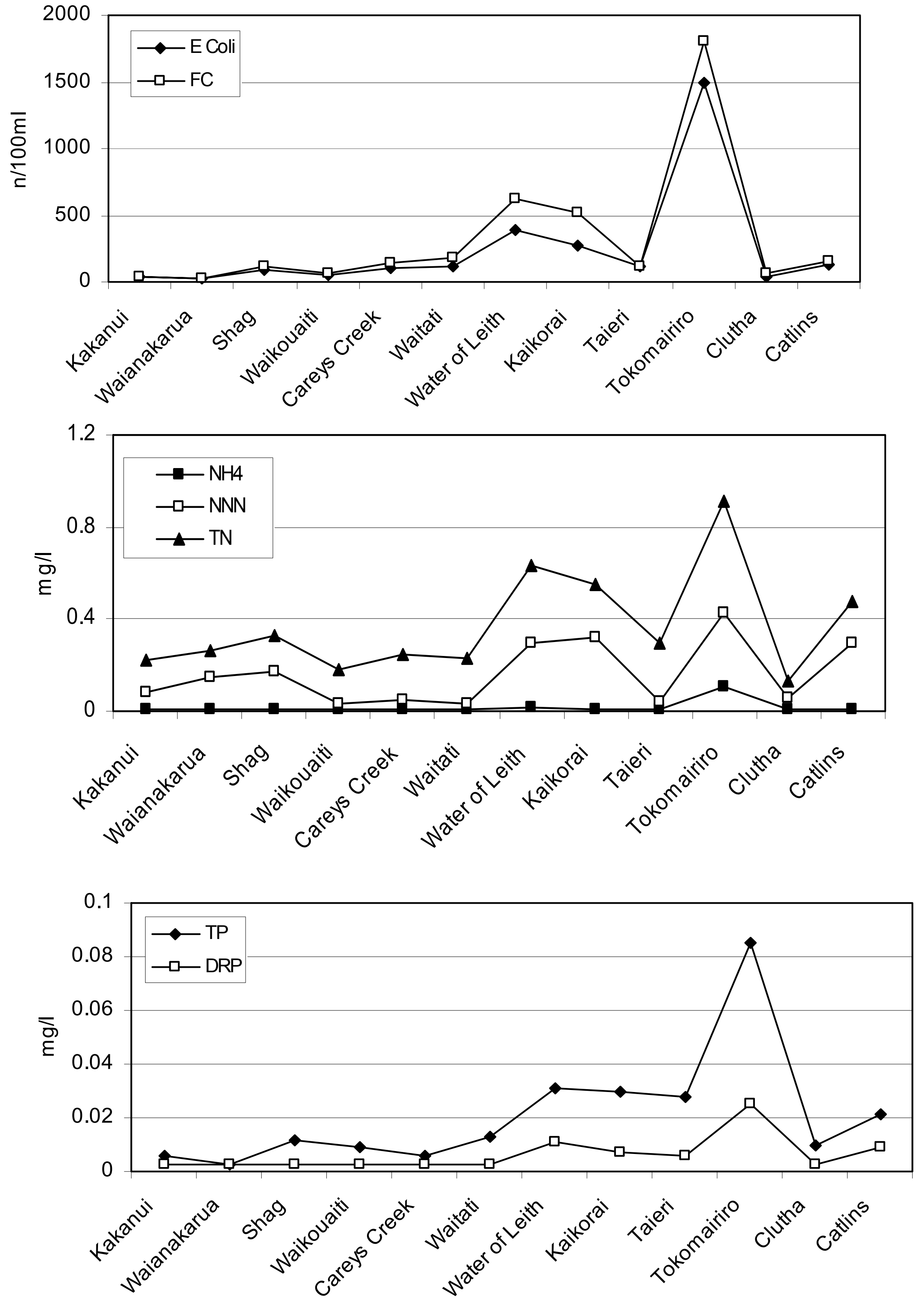

Figure 5.1 Median water quality results 2000 to 2005 taken from freshwater State of Environment monitoring sites located closest to the coast. Results are displayed from the Kakanui River in the North of Otago to the Catlins River in the South of Otago.

6. Discussion

The objective of this report has been to provide a comprehensive review of recent coastal water quality in Otago's CMA.

The primary aim was to assess the spatial and temporal variation in water quality with respect to contact recreation and shellfish standards in areas where there is high public use of water.

The Otago Regional Council relies heavily on resource consent monitoring for coastal water quality information. However not only is this monitoring temporally and spatially limited, the information is not collated to look at the broad picture, rather every consent is assessed for compliance purposes per se. There is clearly a need for a coordinated long term water quality and environmental monitoring programme for the whole of the Otago coastline to avoid, remedy or mitigate adverse effects.

Water classification is the most appropriate technique for overall management of Otago's coastal water quality as it allows different objectives to be applied to different areas. In the Third Schedule of the RMA, eleven water quality classes are identified as shown in Table 6.1. The classes specified are appropriate to Otago, but have not been implemented due to a lack of monitoring to date. Ideally Class AE standards should apply to all coastal waters, Class SG standards to all waters where shellfish are collected or could be taken if water quality was improved, Class CR standards to all waters where bathing occurs or could potentially occur if water quality was improved and Class F water to all coastal waters.

Appendix 1 details the minimum standards of water quality for each class. Under s69 of the RMA, Otago Regional Council may set more stringent standards and also develop new classes and standards.

Table 6.1 Water Quality Classes

Class	Objective
Class AE	Water managed for aquatic ecosystem purposes
Class F	Water managed for fishery purposes
Class FS	Water managed for fish spawing purposes
Class SG	Water managed for gathering or cultivation of shellfish for human consumption
Class CR	Water managed for contact recreation purposes
Class WR	Water managed for water supply purposes
Class I	Water managed for irrigation purposes
Class IA	Water managed for industrial abstraction
Class NS	Water managed for in its natural state
Class A	Water managed for aesthetic purposes
Class C	Water managed for cultural purposes

To address Objective 10.3.1 of the Regional Plan: Coast, the Otago Regional Council could also consider instigating a shoreline coastal monitoring programme for water quality and shellfish. This would enable a more extensive grading of coastal waters (other than in the immediate vicinity of Dunedin). The Microbiological Water Quality

Guidelines (Ministry of Environment/Ministry of Health 2003) grade beaches according to their suitability for recreation. The grading is based on two aspects; the microbiological quality of the water and the sanitary inspection category (based on the source of microbiological contamination), this assessment is detailed in Table 7.2

Table 6.2 Grades for Recreational Suitability (MfE/MoH 2003)

Sanitary Inspection Category	Microbiological Assessment Category Enterococci/100ml			
	A	B	C	D
	≤ 40	41-200	201-500	≥500
Very Low	Very Good	Very Good	Follow Up**	Follow Up**
Low	Very Good	Good	Fair	Follow Up**
Moderate	Follow Up*	Good	Fair	Poor
High	Follow Up*	Follow Up*	Poor	Very Poor
Very High	Follow Up*	Follow Up*	Follow Up*	Very Poor
* Unexpected result requiring investigation ** Implies non sewage source of contamination				

In order to obtain a grade for recreational suitability 20 samples are required per site per bathing season, Dunedin City Council collect sufficient water quality data during the bathing season to enable the development of microbiological categories for coastal waters in the vicinity of Dunedin. Grades for recreational suitability are also able to be developed in this limited area.

It is proposed that water quality sampling should be undertaken at Kaka Point, Moeraki and McAndrews Bay, and that shellfish monitoring should also be undertaken at Kaka Point and Moeraki. Extensive shellfish sampling is undertaken by Southern Clams Limited in Blueskin Bay and Purakanui, and the Otago Regional Council has obtained this data.

The spatial and temporal variation in the life supporting capacity of Otago's coastal waters also needs addressing. Generally this is done through the monitoring of benthic invertebrates. In Otago resource consent conditions require that benthic invertebrates are monitored to assess the impact of discharges. Sampling is therefore already undertaken in 'hotspots', and no strong evidence of reduced life supporting capacity has been noted. It is appropriate to rely on this regime of monitoring without extending the monitoring programme.

There is a need to establish baseline estuary monitoring, as estuaries are good indicators of the health of their catchment. If dominant estuarine habitats are defined, and boundaries established, the data becomes a valuable benchmark indicator for measuring change (MfE Confirmed Indicaors for the Marine Environment, ME6 2001). It is suggested that this broadscale mapping initially be undertaken on the Shag and Waikouaiti estuaries as they are already under some impact. Water quality monitoring should also be undertaken over a half tide (encompassing low tide) to establish a baseline water quality for selected estuaries.

7. Recommendations

Issue 10.2.6 of the Regional Plan: Coast recognises that '*there is a lack of knowledge about the current state of Otago's coastal water quality'*. In order to address this the following monitoring is recommended

- That sufficient baseline information be collected to be able to implement water quality classes to the Otago CMA**.**
- That microbiological categories be established for coastal waters in areas where resource consent holders undertake extensive monitoring. The additional monitoring be undertaken at Kaka Point, Moeraki and McAndrews Bay.
- Shellfish sampling be undertaken at Moeraki and Kaka Point.
- That the broad scale mapping element of the protocol Cawthron Institute developed for assessing and monitoring the condition of New Zealand estuaries, be adopted. Initially focusing on estuaries already under some impact, notably the Waikouaiti and Shag estuaries.
- That water quality surveys of the Taieri, Waikouaiti, Kaikorai, Catlins, Shag and Kakanui estuaries be undertaken. Three six hour water quality surveys (over low tide) should be undertaken during the summer months for each estuary to provide a baseline for the future.

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Appendix 1 - Third Schedule Water Quality Classes

Note: The standards listed for each class apply after reasonable mixing of any contaminant or water with the receiving water and disregards the effect of any natural perturbations that may affect the water body.

1. Class AE Water (being water managed for aquatic ecosystem purposes)

i) The natural temperature of the water shall not be changed by more than 3º Celcius.

ii) The following shall not be allowed if they have an adverse effect on aquatic life
  a) Any pH change
  b) Any increase in the deposition of matter on the bed of the water body or coastal water.
  c) Any discharge of a contaminant into the water.

iii) The concentration of dissolved oxygen shall exceed 80% of saturation concentration

iv) There shall be no undesirable biological growths as a result of any discharge of a contaminant to the water.

2. Class F Water (being water managed for fishery purposes)

1) The natural temperature of the water –
  i) shall not be changed by more than 3º Celcius; and
  ii) shall not exceed 25º Celcius
2) The concentration of dissolved oxygen shall exceed 80% of saturation concentration.
3) Fish shall not be rendered unsuitable for human consumption by the presence of contaminants.

3. Class FS Water (being water managed for fish spawning purposes)

1) The natural temperature of the water shall not be changed by more than 3º Celcius. The temperature of the water shall not adversely affect the spawning of the specified fish species during the spawning season.
2) The concentration of dissolved oxygen shall exceed 80% of saturation concentration.
3) There shall be no undesirable biological growths as a result of any discharge of a contaminant to the water.

4. Class SG Water (being water managed for the gathering or cultivating of shellfish for human consumption)

1) The natural temperature of the water shall not be changed by more than 3º Celcius.
2) The concentration of dissolved oxygen shall exceed 80% of saturation concentration.
3) Aquatic organisms shall not be rendered unsuitable for human consumption by the presence of contaminants.

5. Class CR Water (being water managed for contact recreation purposes)

1) The visual clarity of the water shall not be so low as to be unsuitable for bathing
2) The water shall not be rendered unsuitable for bathing by the presence of contaminants.

3) There shall be no undesirable biological growths as a result of any discharge of a contaminant to the water.

6. Class WS Water (being water managed for water supply purposes)

1) The pH of surface waters shall be within the range 6.0 to 9.0 units.
2) The concentration of dissolved oxygen in surface waters shall exceed 5 grams per cubic metre.
3) The water shall not be rendered unsuitable for treatment (equivalent to coagulation, filtration, and disinfection) or unsuitable for irrigation.
4) The water shall not be tainted or contaminated so as to make it unpalatable or unsuitable for consumption by humans after treatment (equivalent to coagulation, filtration, and disinfection), or unsuitable for irrigation.
4) There shall be no undesirable biological growths as a result of any discharge of a contaminant to the water.

7. Class I Water (being water managed for irrigation purposes)

1) The water shall not be tainted or contaminated so as to make it unsuitable for the irrigation of crops growing or likely to be grown in the area to be irrigated.
2) There shall be no undesirable biological growths as a result of any discharge of a contaminant to the water.

8. Class IA Water (being water managed for industrial abstraction purposes)

1) The quality of the water shall not be altered in those characteristics which have a direct bearing upon its suitability for the specified industrial abstraction.
2) There shall be no undesirable biological growths as a result of any discharge of a contaminant to the water.

9. Class NS Water (being water managed in its natural state)

The natural quality of the water shall not be altered.

10. Class A Water (being water managed for aesthetic purposes)

The quality of the water shall not be altered in those characteristics which have a direct bearing upon the specified aesthetic values.

11. Class C Water (being water managed for cultural purposes)

The quality of the water shall not be altered in those characteristics which have a direct bearing upon the specified cultural or spiritual values.

Appendix 2 - Coastal Otago Research (1995 to 2005)

1. SHELLFISH

Trace metal levels in two New Zealand scallop species, *Pecten novaezelandiae* and *Chlamys deliculata*. Master's thesis, University of Otago, at Dunedin, New Zealand. Ashoka, S. (1999).

Samples of two New Zealand scallop species, *Pecten novaezelandiae* and the Queen Scallop, *Chlamys deliculata*, were analyzed for the trace metals Cd, Cu, Fe and Zn. *P. novaezelandiae* were collected from six sites around the South Island, while Queen Scallops were sampled from the Otago Coastal Shelf. Frew *et al.* (1996) found that oysters in the Subtropical Convergence Zone had elevated Cd levels, and the results of the study indicate that this is also true for both the scallop species investigated. Stewart Island, the Otago Coast and the Chatham Islands are all located in Subtropical Convergence waters, and the Cd levels of scallop samples from these sites were significantly elevated compared to levels found in samples from the other sites.

Aspects of growth and condition in *Austrovenus stutchburyi* (Finlay, 1927) (Bivalvia: Veneridae) at Waitati Inlet: Influence of shore height and distance from the mouth. Master's Thesis, University of Otago, Dunedin, New Zealand. Cameron, T.B. (1997).

The population dynamics and growth parameters of bivalve species are known to vary along environmental gradients including shore height and distance from the mouth of an inlet, estuary or harbour. This is thought to be due partly to seston concentration and time available for feeding which also vary along these two directional gradients. Patterns of distribution, growth and condition along these gradients (shore height and distance) of *Austrovenus stutchburyi,* the New Zealand little neck clam was carried out at Waitati Inlet, north of Dunedin.

At Waitati Inlet decreased shell growth rate, lighter colouration and declining condition was noted with increasing shore height and increasing distance from the sea, however other factors such as salinity may be operating to override the expected patterns.

Modern and ancient *Zygochlamys debicatula* shellbeds in New Zealand, and their sequence stratigraphic implications. *Sedimentary Geology* 122 (1-4): 267-284. Orpin, A.R., Gammon, P.R., Naish, T.R., Carter, R.M. (1998).

The scallop *Zygochlamys delicatula* is an indicator species for a carbonate shell-ground facies which occurs on the sediment-starved outer shelf and upper slope around southern New Zealand. The modern distribution of *Z. delicatula* is restricted to areas where sea summer surface temperatures are less than ca. 15º C. Its occurrence in Late Pliocene and Pleistocene strata in North Island has, therefore, been taken to indicate a northward-expanded range during former glacial intervals.

Stirling, D.J. (2001). Survey of historical New Zealand shellfish samples for accumulation of gymnodimine. *New Zealand Journal of Marine and Freshwater Research* 35 (4): 851-857.

In 1994 a major biotoxin event occurred along the east coast of the South Island, New Zealand. Gymnodimine, a unique bioactive spiroimine, was isolated and characterised from Foveaux Strait dredge oysters (*Tiostrea chilensis* = *Ostrea chilensis*) collected during this outbreak.

Liquid chromatographic-mass, spectrometric analysis for gymnodimine was undertaken on 217 samples (eight species of shellfish) between 1993-99. Of these gymnodimine was detected at 37 of the 63 sites sampled from around New Zealand and in 155 samples, covering six species of shellfish. Gymnodimine is not limited to *T. chilensis* and can occur in other shellfish species over much of New Zealand. Gymnodimine is a possible cause of the numerous historical biotoxin screen-positive results.

Shell lesions in New Zealand *Haliotis* spp. (Mollusca, Gastropoda). *Journal of Shellfish Research* 17 (3): 805 811. Grindley, R.M., Keogh, J.A., Friedman, C.S. (1998).

Shell lesions are reported in the three New Zealand species of *Haliotis* (*Haliotis iris* Martyn, 1784, *Haliotis australis* Gmelin, 1791, and *Haliotis virginea virginea* Gmelin, 1791). The lesions are described as blisters of conchiolin, and occasionally nacreous material, forming on the inside of the abalone shell near the apex. Lesions were most prevalent in populations in the Catlins region of South Otago and off the northeast coast of Stewart Island, although they were found throughout the southern New Zealand range of *H. iris*, including offshore islands. The mean shell length of lesion-bearing H. iris was significantly ($p < 0.05$) less than that of non-lesion-bearing *H. iris* at 4 of 11 locations sampled.

2. BRYOZOANS

The Otago shelf bryozoan thickets: aspects of their distribution, ecology and sedimentology. Master's Thesis, University of Otago, Dunedin, New Zealand. Batson, Peter B. (2000).

The mid- to outer-continental shelf off Otago Peninsula is inhabited by a conspicuous and abundant suite of frame-building bryozoans. A dredge survey of 56 mid to outer continental shelf sites off Otago Peninsula (45 to 120m in depth) was used to map the distribution of frame-building bryozoan species.

The distribution of frame-building bryozoans ranged from 65m to 120m in depth off Otago Peninsula, and occurred in thicket-forming quantities from 75m to 100m. The ecological influence of bryozoans on the Otago shelf is probably significant. They may enhance local biodiversity, compete with other taxa, and function as a major conduit of energy and nutrients from the water column to the benthos. Bryozoans are a major source of biogenic sediment on the Otago shelf, especially from 75m to 90m, where they often comprise over a quarter of the mass of the gravel fraction of sediments.

Effects of oyster dredging on the distribution of bryozoan biogenic reefs and associated sediments in Foveaux Strait, southern New Zealand. *Continental Shelf Research* 23 (14-15): 1337-1357. Cranfield, H.J., Manighetti, B., Michael, K.P., Hill, A. (2003).

Foveaux Strait has been commercially fished for oysters for over 100 years, focusing principally upon bryozoan biogenic reefs that once covered large areas of the strait.

Fishers dredged the biogenic reefs for their oysters, damaging the framework structure, removing epifauna and exposing associated sediments, which were then reworked and transported down-current in the strong tidal flow. By 1999 none of the original bryozoan biogenic reefs remained.

Communities dominated by byssally attached *Modiolus* appear to provide the early framework and shelter for development of new patch reefs. However, the recent discovery of regenerating colonies of the reef-building bryozoan *Cincitipora* in eastern Foveaux Strait suggests that bryozoan patch reefs may also be capable of re-establishing where conditions are suitable. It is thought that careful management could reverse much of the deleterious effect of fishing.

Stable isotope composition of modern bryozoan skeletal carbonate from the Otago Shelf, New Zealand. ***New Zealand Journal of Marine and Freshwater Research*** **34 (2): 331-351. Crowley, S.F.; Taylor, P.D. (2000).**

The oxygen ($\delta^{18}O$) and carbon ($\delta^{13}C$) isotope ratios of 10 species of living Bryozoa collected from the Otago Shelf, New Zealand were analysed to assess the extent to which isotopic equilibrium (relative to inorganic equilibrium isotope fractionation) is attained during the precipitation of skeletal calcium carbonate.

The data reveal that whereas eight species of Bryozoa synthesize skeletal carbonate in apparent oxygen isotope equilibrium with respect to environmental conditions, two species (*Celleporina grandis* and *Hippomonavella flexuosa*) yield $\delta^{18}O$ (HCO_2) values which indicate significant disequilibrium oxygen isotope fractionation during calcification. This disequilibrium is probably related to kinetic factors associated with diffusion-controlled transport of HCO_3 to the site of calcite precipitation.

Bathymetric distributions of modern populations of some common Cenozoic Bryozoa from New Zealand, and paleodepth estimation. ***New Zealand Journal of Geology and Geophysics*** **47 (1): 57-69. Taylor, P.D., Gordon, D.P., Batson, P.B. (2004).**

The bathymetric distributions of four readily identifiable and common species (*Cinctipora elegans, Attinopora zealandica, Diaperoecia purpurascens,* and *Celleporaria emancipata*) plus one distinctive ecological group of bryozoans (tube-building symbionts of hermit crabs) were investigated as potential paleodepth indicators in the Cenozoic (where they dominate many fossil assemblages).

A localised analysis of occurrences and abundances of *Cinctipora elegans* and *Diaperoecia purpurascens* off Otago Peninsula was also conducted. This analysis confirmed that these species occur over a large depth range on the Otago shelf. In *C. elegans*, colony abundance peaked strongly between 75 and 100 m off Otago Peninsula, a relatively narrow depth range. Despite their wide bathymetric distributions, several of the species surveyed here may eventually prove useful as paleodepth indicators because of their morphological plasticity which, by analogy with other bryozoans, is probably a response to environmental variables, some correlated with depth.

3. SEAWEED

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

In the Northern Hemisphere, brown seaweeds in the Order Fucales have been used extensively as bio-monitors of heavy metal contamination in sea water. Iron (Fe) and zinc (Zn) concentrations in the intertidal fucalean seaweed *Hormosira banksii* was monitored at three sites in Otago, south-eastern New Zealand and two sites at Leigh, north-eastern New Zealand.

There was no evidence of Zn or Fe contamination at any site studied. Zn levels for *H. banksii* from Otago Harbour followed a trend similar to an earlier study of *Ulva* sp. and the Fe content reflected patterns previously observed in sea water. Thus, as for Northern Hemisphere fucalean seaweeds, *H. banksii* is potentially useful as a biomonitor for heavy metals in seawater. Despite low Zn and Fe levels it is thought that these trace elements do not limit the growth of *H banksii.*

The influence of sessile epifauna on the ecology and physiology of the giant kelp. *Macrocystis pyrifera* (L.) C. Agardh. PhD Thesis, University of Otago, Dunedin, New Zealand, 178 pp. Hepburn, C. (2003).

The influence of sessile epifauna on the growth, nitrogen physiology and biomechanical properties of *Macrocystis pyrifera* was investigated over three years (1998-2001) in a shallow subtidal environment at Harrington Point in Otago Harbour, New Zealand.

Macrocystis pyrifera showed a clear seasonal pattern of light limited growth during winter and a period of nitrogen limited growth during the summer and autumn. At no time was there any clear evidence of a reduction in the growth of *M. pyrifera* resulting from high levels of colonization by epifauna.

Provision of ammonium to *M. pyrifera* by hydroids during a period of nitrogen limitation at Harrington Point and the apparent lack of deleterious effects resulting form their presence suggests that diminutive, translucent hydroids that commonly live on the surface of seaweed may have a mutualistic relationship with their seaweed substrata.

Variations in the alginate content and composition of *Durvillaea Antarctica* and *D. willana* from southern New Zealand. *Journal of Applied Phycology* 12 (3-5): 317-324. Kelly, B.J.; Brown, M.T. (2000).

The brown seaweeds *Durvillaea Antarctica* and *D. willana* are dominant components of the lower littoral and upper sublittoral of exposed rocky shores in southern New Zealand. Tissue samples of both species, harvested from a site on the southeast coast of the South Island over a period of 2 years, were analysed for alginate content and composition.

Individuals of both species were further separated into different blade (lamina and palm) and stipe (cortex and medulla) fractions to assess variation within the thallus. On average, the alginate content and frequency of mannuronic acid (F sub(m)) was higher in *D. Antarctica* than in *D. willana*. Blades contained more alginate than stipes, laminae and stipes were rich in mannuronic acid whereas holdfasts were rich in guluronic acid. Variations in composition are considered to reflect the functional differences of the tissue, giving flexibility to blade and stipe and rigidity to the holdfast. Despite fluctuations in content and composition between collection times, no seasonal trends in either component were apparent.

4. FISH

Accumulation of Po-210 by spiny dogfish (*Squalus acanthias*), elephant fish (*Callorhinchus milii*) and red gurnard (*Chelodonichthys kumu*) in New Zealand shelf waters. *Marine and Freshwater Research* 48 (3): 229-234. Bellamy, P., Hunter, K.A. (1997).

Concentrations of the natural radionuclide Po-210 were measured in the livers of 81 individual specimens of three fish species, the spiny dogfish (*Squalus acanthias*), elephant fish (*Callorhinchus milli*) and the red gurnard (*Chelodonichthys kumu*) which were collected from waters of the Otago continental shelf, New Zealand. Separate measurements showed that only a negligible fraction of the Po-210 was supported by decay of the Pb-210 parent (Po-210/Pb-210 activity ratios were 15, 134 and 5.9 respectively for the three species) indicating that direct uptake of Po-210 into the liver balances losses from excretion and radioactive decay.

The reef fish assemblages associated with macroalgal dominated reefs along the Karitane shoreline, East Otago. Master's thesis, University of Otago, Dunedin, New Zealand. Franklin, T.J. (1999).

The reef fish community off the coast of Karitane was examined using an Underwater Visual Census (UVC). Some cool temperate species were also observed, while no warm temperate or sub-Antarctic species were seen. The trend of decreasing species richness of fish assemblages with increasing latitudes due to the absence of warm temperate species and endemic species is supported here. Fish species of Karitane also appear to reach larger sizes than that recorded in warmer waters of New Zealand. The cold coastal waters characteristic of Otago is suggested as a determining factor in Karitane's reef fish community composition

Temporal variation in the fish assemblage from summer to winter was detected with a reduced number of species seen. It is suggested that an offshore migration to waters of a more consistent temperature may occur during the winter.

Larval *Anisakis* (Nemotoda) from inshore fish species, South Island, New Zealand. Master of Science thesis, University of Otago, Dunedin, New Zealand. Hassall, M.L. (2000).

Larval *Anisakis* are parasitic nematodes that infect fish and humans if live larvae are consumed in uncooked fish products. This study aimed to establish the risk of *Anisakis* as a source of human infection in New Zealand commercial fish and ensure processing methods reduce any chance of infection. The fish species Tarakihi (*Nemadactylus marcopterus*), Red cod (*Pseudophyvis bachus*), Red gurnard (*Chelidonichthys kumu*), Monkfish (*Kathetostoma giganteum*) and Arrow squid (*Nototodarus solanii*) caught from waters off the east coast of the South Island, New Zealand were surveyed for *Anisakis* larvae.

Anisakis larvae were found in all species surveyed with the highest intensity of infection in Tarahiki and the lowest in Arrow squid. Overall infection with larval *Anisakis* in fish fillets was low in commercial New Zealand species. Following recommended storage practices, storing fish on ice and gutting as soon as possible after capture will reduce and eliminate chances of larval *Anisakis* infection.

Comparative dispersal of larvae from demersal versus pelagic spawning fishes. *Marine Ecology-Progress Series* 252: 255-271. Hickford, M.J.H.; Schiel, D.R. (2003).

Ichthyoplankton surveys on the east coast of the South Island, New Zealand were conducted to ascertain whether certain types of reef fish larvae more likely to be dispersed on an exposed temperate coast and whether larval dispersal is more strongly associated with taxa that have pelagic eggs.

Analyses was undertaken based on 492 plankton net samples collected perpendicular to the shore (0.05, 2, 4 and 6 km offshore) and parallel to the shore (0.05, 0.1, 0.3. and 1 km alongshore) from a rocky reef environment. 60 taxa were caught belonging to 32 families but 11 taxa accounted for 97 % of all larvae collected.

It was found that reef fish larvae that hatch from non-pelagic eggs are not retained mostly or exclusively near reefs on exposed coasts. Broad-scale dispersal of fish larvae may provide benefits in terms of predator avoidance, re-colonisation of habitats and risk-spreading, but it carries with it the increased risk of unfavourable advection that may delay or even prevent recruitment.

Age and growth of red cod (*Pseudophycis bachus*) off the southeast coast of South Island, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 30 (2): 151-160. Horn, P.L. (1996).

Age determination of Red Cod was undertaken using the bands in sectioned otoliths. The technique was validated by examining the state of otolith margins over a 1-year period, and by following the progression of length modes in length-frequency distributions (for age classes 0+ to 3+). Von Bertalanffy growth parameters are estimated for Red Cod off the south-east coast of the South Island. Few fish appear to live longer than 4 years. Because of the few age classes in the population at any time, age distributions may be obtained for most of a sample using length modes.

Demersal fish assemblages off Southern New Zealand. Master's thesis, University of Otago, Dunedin, New Zealand. Jacob, W. (1995).

Demersal fishery trawls were conducted in an area bounded by 46-54ºS and 165-180ºE on the Snares Shelf, Aucklands Shelf, Bounty Plateau, Pukaki Rise and Campbell Plateau restricted to depths of less than 1000m. The environmental parameters recorded in the analysis were sediment type, depth, temperature, latitude and longitude.

Identification of fish assemblages and their relation to environmental parameters revealed depth and temperature as environmental parameters most correlated with the distribution patterns of the species. Shallow water assemblages were dominated by species from the families Gemplyidae, Squalidae, Triakidae, and Moridae, mainly represented by *Thrysites atun*, *Squalus acanthias*, *Galeorhinus australis*, and *Pseudophycis bachus* respectively. Deep water assemblages were dominated by Chimaeridae, Argentinidae, Merlucciidae and Macrouridae, mainly represented by *Hydrolagus novaezelandiae, Argentina elongata*, *Microtones novaezelandiae*, and *Lepidorhynchus denticulatus,* respectively. Merucciidae, Macrouridae, and Gampylidae often dominated the total catch weight. Topography, oceanographic features, and sampling strategy within the study area may be among other factors determining species assemblages.

Age, growth and feeding ecology of five co-occurring fishes in southern New Zealand. PhD thesis, University of Otago, Dunedin, New Zealand, 166 pp. Jaing, W. (2002).

The age, growth and the feeding ecology of five co-occurring fish at Karitane and Cape Saunders, southern New Zealand was investigated, species involved were blue cod (*Parapercis colia*) banded wrasse (*Latris lineata*), spotty (*Notolabrus celidotus*), moki (*Latirdopsis ciliaris*) and trumpeter (*Latris lineata*). For each species, age and growth were estimated with respect to sex and geographical area.

Findings suggest that management measures need to take into consideration geographic differences in fish growth, trophic interaction (as co-occurring fishes interact through predation), and partition resources along trophic, temporal and spatial gradients. The detection of the impact of oyster dredging on the diet and growth of blue cod suggests that biogenic reefs are important habitats for reef species, particularly young fish. Hence, such habitats may need to be protected from damage by bottom fishing gear, such as oyster dredging.

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.; McClatchie, S. (1999).

Side-scan sonar data was collected off the coast of Otago, New Zealand for 21 days during 1994 to 1996 using a 130 kHz Klein 595 digital side-scan sonar. A total of 2198 schools were detected. Of these, 348 schools of barracouta (*Thyrsites atun*), 67 schools of jack mackerel (*Trachurus murphyi*), and 17 schools of slender tuna (*Allothunnus fallai*) were identified. Barracouta schools were significantly smaller than schools of jack mackerel or slender tuna, but the size of schools was not related to state of tide, location, water depth, salinity, temperature, or density of krill. Fish schools were detected throughout daylight hours but dispersed at night. Analysis of stomach contents revealed barracouta, jack mackerel and slender tuna were feeding on krill, *Myctophanes australis*, and fish schools occurred in areas with high densities of *N. australis*. Variability in the abundance of *N. australis* was related to salinity; catches were highest in a band of low-salinity water which was present in the study area following periods of high river runoff.

A side-scan sonar study of pelagic schooling fish off Otago, New Zealand. Published PhD thesis, University of Otago, Dunedin, New Zealand, 229 pp. O'Driscoll, R. (1997).

A Klein 595 side-scan sonar with an effective frequency of 130 Hz was used to study the distribution of pelagic schooling fish off the coast of Otago, New Zealand at small (kilometre) spatial scales.

Acoustic data were collected off Otago on 21 days during the late summer and autumn of 1994, 1995, and 1996. A total of 2,198 fish schools were detected. Of these, 348 schools of barracouta (*Thyrsites atun*), 67 schools of jack mackerel (*Trachurus murphyi*), and 17 schools of slender tuna (*Allothunnus fallai*) were identified. Net catches of krill were highest in a band of low salinity surface water which was present in the study area following periods of high river flow. There was no clear association between the occurrence of seabirds and fish schools. The distribution of planktivorous seabirds was determined by the distribution of krill, but the spatial structure of seabird aggregations was related to physical hydrography.

Feeding and schooling behaviour of barracouta (*Thyrsites atun*) off Otago, New Zealand. *Marine and Freshwater Research* 49(1): 19-24. O'Driscoll, R.L. (1998b).

To test the hypothesis that fish in schools forage more successfully than individual fish, an analysis was made of the stomach contents of barracouta (*Thyrsites atun*), a facultatively schooling species of fish, in a wild fish population. Schooling (n=29) and non-schooling (n=86) barracouta were captured during a side-scan sonar survey of pelagic fish off the coast of Otago, New Zealand. The proportion of fish with empty stomachs was lower and the mean wet mass of gut contents was higher in barracouta from schools. The increase feeding success of fish in schools was due to increased consumption of krill, *Nyctiphanes australis.* In regions where the density of krill in net tows was high (>1000 individuals km^{-1} tow length) or moderate (100-1000 individuals km^{-1}), the mean wet mass of krill in the stomachs of schooling barracouta was 2-4 times higher than in the stomachs of non-schooling barracouta. Few schools of barracouta were observed in areas with low densities of krill (<100 individuals km^{-1}). Schooling by barracouta seems to be a feeding strategy to exploit surface swarms of krill.

An investigation into the spatial and temporal distribution patterns of ichthyoplankton off the Otago coast, south-eastern New Zealand. Master's thesis, Dunedin, New Zealand. Parsons, M.J. (1999).

Seasonal and spatial distribution patterns of ichthyoplankton were investigated off Otago, south-eastern New Zealand. Concurrent surface and sub-surface (10m depth) tows were carried out in two areas representative of the inshore (Blueskin Bay), and mid-shelf (Mid-shelf), environments at monthly intervals from 22 February 1996 to 3 March 1997.

Overall, more larvae were found in Blueskin Bay than in the Mid-shelf area, and more larvae were collected in sub-surface tows than at the surface. Seasonal peaks in total larval abundance were recorded in autumn and winter in the Blueskin Bay area, and in spring and late summer in the Mid-shelf area. These peaks in abundance reflected the seasonal nature of spawning off the Otago coast. Sprat (*Sptrattus* spp.) and flatfish (Pleuronectidae) larvae dominated the winter inshore larval catch. Lanternfish

(Myctophidae) larvae were most abundant in the Mid-shelf area in spring when Southland Current water was close to shore. Scorpionfish (Scorpaenidae) larvae were the most abundant larvae in late summer in the Mid-shelf area.

5. KRILL

The distribution and ecology of *Nyctiphanes australis* in coastal Otago waters. PhD Thesis, University of Otago, Dunedin, New Zealand 101 pp. Haywood, G.J. (2002).

The euphausiid *Nyctiphanes australis* G.O. Sars is endemic to the coastal waters of Australia and New Zealand. Like other euphausiids, it is an important trophic link between primary production and the upper trophic levels in the marine ecosystem, transferring carbon from phytoplankton, detritus and small crustaceans to larger animals.

Sampling was carried out between May 1996 and April 1998 on a survey transect (45º 48.3' S, 170º 45.5' E to 45º51.8' S, 170º 55.2' E) that crossed the Southland Current at right angles, the shortest distance to the shelf break. Eight stations, approximately 2 km apart, were surveyed on 16 occasions. Although the sampling sites were 50 km from the Taieri River and 90 km from the Clutha River, the subsurface hydrological signature of riverine input to nearshore neritic waters could be observed in temperature and salinity cross-sectional views of the survey transect. Chlorophyll α concentrations indicated that primary productivity increased on the inner continental shelf where the Southland Current and river water mixed.

6. PROTOZOA

Grazing by protozoa in marine coastal and oceanic ecosystems off New Zealand. *New Zealand Journal of Marine and Freshwater Research* 30 (3): 313-324. James, M.R., Hall, J.A., Barrett, D.P. (1996).

Uptake rates for ciliates and flagellates grazing on bacteria and picophytoplankton were measured in different water masses around South Island, New Zealand, in April 1992. Fluorescent particles were used to established uptake rates for major ciliate taxa, phytoflagellates, and heterotrophic flagellates. Protozoan grazing had little impact on the bacterial population, removing < 5% of the population per day. Heterotrophic flagellates and ciliates selected picophytoplankton in preference to bacterial-sized particles, both groups removing 6-32% of the picophytoplankton population per day. Highest removal rates for picophytoplankton were found in coastal waters and for bacterial populations in sub-Antarctic waters. This difference was attributed to differences in community composition and taxa-specific clearance rates.

7. SEALS

Geographic and temporal variation in the condition of pups of the New Zealand fur seal (*Arctocephalus forsteri*): evidence for density dependence and differences in the marine environment. *Journal of Zoology* 252: 41-51. Bradshaw, S.J.A, Davis, L.S., Lalas, C., Harcourt, R.G. (2000).

The geographic and temporal variation in pup condition in 20 colonies of New Zealand fur seals *Arctocephalus forsteri* around South Island, New Zealand was investigated during three consecutive breeding seasons, 1996-98 (n = 6856 pups).

A morphometric index of pup condition was best estimated by comparing all pups in all years using least-squares linear regression of the log (e)-transformed measurements of length vs. mass. Condition varied significantly among years and colonies, but not between sexes. Seasonal changes in pup densities at colonies were estimated and the relationship between pup density and condition was investigated. Pup density explained a significant proportion of the variation in pup condition in 1996 and 1998, suggesting that condition is partly density-dependent. Geographic differences in pup condition were also found. The 1998 El Niño coincided with a reduction in pup condition. A morphometric index of pup condition seems to be useful as an indicator of spatial and temporal variation in the marine environment.

Summer foraging behaviour of a generalist predator, the New Zealand fur seal (*Arctocephalus forsteri*). *Wildlife Research* 28(6): 599-601. Harcourt, R.G., Bradshaw, C.J.A., Davis, L.S. (2001).

This study examined the dive behaviour of 20 lactating New Zealand fur seals (*Artocephalus forsteri*) breeding at Fuchia Gully (Ohinepuha, 45 degrees 52'S, 170 degrees 44'E), Otago Peninsula, New Zealand, over five consecutive austral summers (199394-1997/98).

Annual variation in dive behaviour was examined, (1) long duration with many dives of medium depth (LONG); (2) short duration with few, shallow dives (SHALLOW); and (3) short duration consisting of long, deep dives and long surface intervals and bottom times (DEEP). Diving was primarily nocturnal, and bout type varied significantly with time of day. The proportion of LONG bouts was greatest at dusk and near dawn, SHALLOW bouts predominated during the night, and DEEP bouts were of importance near dawn.

The high degree of flexibility in foraging behaviour of the New Zealand fur seal means that, inevitably, analyses of dive behaviour will have low statistical power. Changes in foraging behaviour may only be useful to detect very large changes in resource availability. Alternatively, very large sample sizes may be able to detect more subtle changes.

Prey of Hooker's sea lions *Phocarctos hookeri* based at Otago Peninsula New Zealand. *Marine Mammal Research in the Southern Hemisphere Vol. 1 status, ecology and medicine*. M. Hindell and C. Kemper (Eds.), Surrey, Beatty & Sons, Chipping Norton. Pg. 130-136. Lalas, C. (1997).

8. PHYTOPLANKTON

Size fractionated phytoplankton standing stocks and primary production during austral winter and spring 1993 in the Subtropical Convergence region near New Zealand. *New Zealand Journal of Marine and Freshwater Research* 31 (2): 201-224. Bradford-Grieve, J.M., Change, F.H., Gall, M., Pickmere, S., Richards, F. (1997)

Size-fractionated phytoplankton standing stocks and potential primary production (PPP) off the west and east coasts of South Island, New Zealand, were evaluated in austral winter and spring 1993.

These are the first size-fractionated primary production data to be reported from the southern Subtropical Convergence (STC) and in oceanic New Zealand waters. Picophytoplankton (< 2 mu m) formed > 30% of integrated chlorophyll *a* and daily PPP in most water types and seasons, except when the 20-200 mu m size class dominated in west coast waters in spring and in the STC in winter and spring. In subtropical and STC waters, PPP was 30% higher than at similar latitudes in the North Atlantic Ocean.

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. Haywood, G.J. (2004).**

Major rivers on the south-eastern coast, South Island, New Zealand create plumes that are deflected north between the Southland Current and the coast. Surveys of the continental shelf water mass off the Otago coast over a 2-year period, May 1996-April 1998, confirmed that when the Southland Current surfaced it contained less chlorophyll *a* than mixed water subject to terrestrial influence, implying that river-borne nutrients stimulated primary production in the mixed water. The greatest boost occurred in winter when diatom abundance increased. The band of chlorophyll-rich water extended through the photic zone and was several kilometres wide suggesting that riverine influence on marine biomass is substantial. In summer, the Southland Current often lay beneath oceanic water, with no increase in chlorophyll *a* concentration in the overlying water, due possibly to heavy grazing by zooplankton. In summer 1997-98, seawater temperatures were higher and phytoplankton biomass lower than in summer 1996-97, consistent with a strong El Niño event in the Pacific Ocean.

Mixotrophic and heterotrophic nanoflagellate grazing in the convergence zone east of New Zealand. ***Aquatic Microbial Ecology*** **20 (1): 83-93. Safi, K.A.; Hall, J.A. (1999).**

Nanoflagellate grazing was investigated in the subtropical convergence region off the east coast of the South Island, New Zealand, in the summer of 1995. Clearance rates were estimated using 0.5 mu m fluorescently labelled beads and fluorescently labelled bacteria to represent bacterial populations and 1.0 mu m fluorescently labelled beads representing picophytoplankton populations. Nanoflagellate grazing by mixotrophs was on average lower than heterotrophic nanoflagellate clearance rates per individual for all prey types, and both heterotrophic and mixotrophic nanoflagellates showed a preference for picophytoplankton-sized particles over bacteria-sized particles when grazing on artificial prey. Despite lower clearance rates per individual, higher numbers of mixotrophic nanoflagellates meant that they contributed 57 % of measured grazing impact on picophytoplankton-sized particles, 40% of grazing on bacteria-sized particles and 55% of grazing on stained bacteria per day.

9. CRUSTACEANS

Mexicope sushara sp nov., the first New Zealand record of the isopod crustacean family Acanthasipidiidae (Asellota). ***Zootaxa*** **489: 1-11. Bruce, N.L. (2004).**

Mexicope sushara sp. nov. is recorded from south-eastern New Zealand coastal waters, the first record of the genus from the Pacific and the first record of Acanthaspidiidae from New Zealand. The species is from the continental shelf, taken in association with a bryozoan colony at a depth of 80 metres on the Otago shelf, south-eastern South Island. The distinguishing characters are a rostral spine and prominent and acute pre-ocular lobes; these characters in conjunction with stalked eyes separate the species from all others in the family.

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

Heart rates and midgut gland wet weight/dry weight (WW/DW) ratios of rock crabs (*Hemigrapsus edwardsi*) were measured in individuals collected along a contaminant gradient in Otago Harbour, New Zealand. Median heart rates decreased by 15-20% while midgut gland WW/DW ratios increased by 25-30% with increasing contamination of field sites. Intra and inter-individual variability in heart rate increased markedly at the most severely contaminated sites, as did inter-individual variability in midgut gland WW/DW ratio. The findings are discussed in the context of the use of the biomarker approach to address ecotoxicological problems.

10. SEDIMENT

Sediment transport in and around Bluff Harbour. Master's thesis, University of Otago, Dunedin, New Zealand. Gabites, B. (2001).

Strong water flows are often found through the entrances of tidal inlets as a large amount of water floods into and them ebbs out through a small entrance area. Due to differing current strengths, different sized particles are eroded and transported into areas where they are able to settle out, resulting in gradual changes in the distribution of sediments within tidal inlets. As such, the direction of sediment transport within a tidal inlet can be inferred from the changes in the sediment distributions.

75 samples were collected from Bluff Harbour and Awarua Bay using a $0.1m^2$ Day Grab sampler on board a boat, and by hand using a small spade. The sedimentological analyses performed on the sediments of Bluff Harbour and Awarua Bay show that Bluff Harbour is dominated by flood-tidal currents resulting in a net transport of sedimentary material into Bluff Harbour from Foveaux Strait.

Sediment macrobenthos of upper Otago Harbour, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 33 (3): 469-480. Grove, S.L.; Probert, P.K. (1999).

Sediment macrobenthos of the Upper Otago Harbour, south-eastern New Zealand, was surveyed in 1993. Replicate samples (0.1 m(2) sieved on I-mm mesh) were taken using a diver-operated suction sampler from 15 stations, including some suspected to be contaminated. Multivariate analysis of abundance data was used to examine patterns of benthic community structure and their relationship to environmental variables: sediment grain size, organic content, heavy metal concentration (V, Cr, Mn, Co, Ni, Cu, Zn, Cd, Pb), sea-floor temperature, dissolved oxygen concentration, water depth, and macro-algal content. Samples from Sawyers Bay, an area previously identified as impacted by sewage and industrial waste, were set apart from all other stations. A combination of percent sand, macro-algal content, water depth, and chromium concentration correlated best with the observed community structure.

PAH Toxicity in the Upper Otago Harbour Basin: An Investigation using an Acute Static Sediment Amphipod Bioassay. Master's thesis, University of Otago, Dunedin, New Zealand. Moore, D.W. (2001)

Undertook an acute exposure bioassay experiment using an amphipod *(Paracorophium excavatum)*. Six sites were monitored, including 2 control sites (Papanui Inlet and Hoopers Inlet) and 4 impact sites: (Broad Bay, Macandrew Bay, Orari Street and Portobello Road). The top 2-3 cm of sediment was sampled and the key finding of 4-day and 10-day acute static sediment bioassay was that there was no significant decrease in survival rates for any of the sites measured relative to the control sites. This suggests that sediment appears to be non-toxic to acute exposure for this species however it does not take into account chronic exposure and is limited to one single species.

11. OCEAN CURRENTS AND WAVES

Variability in the southland current, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 30 (1): 1-17. Chiswell, S.M. (1996).

Current meter moorings were deployed in six locations around the South Island, New Zealand, in 1993 to monitor the Southland Current. Off the eastern shelf of the South Island, the Southland Current is unidirectional, but variable in speed. Flows south of Stewart Island, over the Snares Plateau, are more isotropic and considerably weaker.

Currents off Oamaru are correlated with those off Nugget Point, and the dispersion relationship calculated between them indicates phase and group propagation to the north-east along the coast comparable to that expected for coastally-trapped waves (CTW). Currents in Foveaux Strait are strongly wind-driven, but currents over the Snares Plateau show almost no coherence with the Invercargill wind.

Wave hindcast for the New Zealand region: nearshore validation and coastal wave climate. *New Zealand Journal of Marine and Freshwater Research* 37 (3): 567-588. Gorman, R.M., Bryan, K.R., Lang, A.K. (2003).

The wave generation model WAM (Wave Model) was implemented over a domain covering the south-west Pacific and Southern Oceans. The model was used to hindcast the generation and propagation of deep-water waves incident on the New Zealand coast over a 20-year period (1979-98), using winds from the European Centre for Medium-Range Weather Forecasts (ECMWF).

The hindcasts were compared with data from wave buoy deployments at eight representative sites around the New Zealand coast. With appropriate interpolation and correction for the effects of limited fetch and sheltering by land, the hindcast was found to provide a satisfactory simulation of wave conditions at sites on exposed coasts.

Remote topographic forcing of a baroclinic western boundary current: An explanation for the Southland Current and the pathway of the subtropical front east of New Zealand. ***Journal of Physical Oceanography*** **32 (11): 3216-3232. Tilburg, C.E., Hurlburt, H.E., O'Brien, J.J., Shriver, J.F. (2002).**

The Southland Current is a western boundary current adjacent to the South Island of New Zealand and flows along a segment of the Southern Hemisphere subtropical front (STF). The physical mechanisms that govern the behaviour of this current and other portions of the STF and sub-Antarctic front (SAF) were investigated using one regional and three global ocean simulations.

Currents associated with the SAF flow along the southern edge of the Campbell Plateau, a large submarine platform southeast of New Zealand. In contrast, the location of the Southland Current and the pathway of the STF east of New Zealand are due to remote forcing of upper-ocean currents by topographically constrained abyssal currents.

12. WATER CHEMISTRY

Partitioning of Chemical Contaminants in Urban Stormwater. PhD Thesis, University of Otago, Dunedin, New Zealand. Brown, J.N. (2002)

Undertook an examination of PAHs (and three metals) in urban stormwater. The Portobello Road stormwater drain and the Water of Leith were sampled over nine rainfall events between November 1998 and March 2001. It was found that PAH, Pb, Cu and Zn levels rose significantly during a storm event and were correlated with SS levels. Road debris was found to be the major source of the contaminants in stormwater.

Concentrations of PAHs and metals at Portobello Road were high when compared to those reported for stormwater elsewhere in NZ and internationally and the old DCC gasworks site appears to be contributing PAHs during baseflows. While the contaminant concentrations in the stormwater frequently exceeded the relevant water quality guidelines, the levels in the bioavailable truly dissolved phase indicate that acute toxic impacts were unlikely. Areas of localised sedimentation contamination (notably in the vicinity of stormwater drains) are likely to exhibit chronic effects on benthic organisms.

Labile forms of iron in coastal seawater: Otago Harbour, New Zealand. ***Marine and Freshwater Research*** **512(3): 193-203. Croot, P.L.; Hunter, K.A. (2000).**

The horizontal distribution and speciation of iron in the Otago Harbour, New Zealand was investigated on six occasions from April to November 1993. The only important freshwater source of iron in the harbour, the Water of Leith, appeared to be a major source of iron to Otago Harbour only under conditions of high stream flow. However, the influence of the Water of Leith was often detectable down harbour by the presence of more reactive labile iron phases. Prolonged periods of strong winds also appeared to supply large concentrations of reactive iron to the eater column, possibly by mixing and re-suspension of sediment material from below the redox boundary.

Experiments on natural samples from Otago Harbour revealed that at pH 4.0, ascorbic acid was able to reduce Fe(III) oxyhydroxides more effectively than was hydroxylamine hydrochloride. This difference may reflect either different mechanisms for the reduction of iron oxyhydroxides or differences in the crystallinity of these oxyhydroxides.

Trace metal distributions across the continental shelf near Otago Peninsula, New Zealand. *Marine Chemistry* 62 (3-4): 185-201. Croot, P.L.; Hunter, K.A. (1998).

The distributions of the trace metals iron (Fe), copper (Cu) and cadmium (Cd) along with hydrological parameters (salinity, temperature and reactive phosphate) across the New Zealand continental shelf near Otago Peninsula have been studied. This is a region in which the Subtropical Convergence (STC), a major oceanic from separating subtropical and sub-Antarctic waters, is uniquely located close to land, permitting an examination of the influence of terrestrial sources of Fe and Cu on oceanic waters containing excess micronutrients.

Reactive silicate in shelf waters near Otago Peninsula, New Zealand. *Marine and Freshwater Research* 46 (2): 427-433. Hawke, D.J. (1995).

Reactive Si data from 19 monthly occupations of two transects near Otago Peninsula in 1986-87 showed low surface values (less than or equal to 1 mu M) during spring and summer, and high values (>4 mu M) in winter. Concentrations were greatest after flooding in the Clutha River, 100 km south of the study area. In spring and early summer, concentrations were lowest inshore at the surface. Vertical gradients across the Southland Front, a near-horizontal thermal front outcropping near the shelf break, were calculated and compared with phosphorus gradients from the same samples. Nine of 21 Si gradients were negative (i.e. concentrations decreased with depth), whereas only 1 of 24 phosphorus gradients was negative. This implies that riverine Si flux is important in establishing Si gradients across the Southland Front.

The optical properties of Otago Waters. Master's thesis, University of Otago, Dunedin, New Zealand. Pfannkuche, J. (1998).

The optical properties and concentrations of optically active water components were measured at 37 stations on the Otago coast. For the broad-band (PAR), diffuse light attenuation decreased 15-fold (K_d = 0.76 to 0.05 m^{-1}) and reflection 7-fold (R = 11.95 to 1.45%) from the most turbid harbour water to the clearest oceanic sites 30km offshore. The K_d values therefore suggested that Otago shelf waters were appreciably clearer than first thought.

Aspects of marine chemistry in Doubtful Sound and Coastal Otago. Master's thesis, University of Otago, Dunedin, New Zealand. Walls, D.J. (1995).

Cruises were undertaken in Doubtful Sound in February and August 1994 and along a fixed transect off the Otago coast in May, June, September and November 1994. Conductivity and temperature measurements were measured using a CTD probe. Discrete water samples were also collected and later analyzed for dissolved oxygen, chlorophyll and nutrients (phosphate, silicate, and total oxidized nitrogen). The results from Doubtful Sound confirm the presence of a large freshwater layer overlying more saline dense water. The lowest salinities were recorded at the head of the fiord and these increased seaward with a reduction in the thickness of this freshwater layer.

Nitrate and phosphate concentrations are very low in the surface freshwater layer. Silicate concentration is almost the inverse of this having highest concentrations in the surface freshwater suggesting variation in nutrient concentrations within the top 75m of the water column. The concentrations are higher in August, which is brought about by the reversal of the summer thermocline which allows the entrainment of nutrient-rich deep water to shallower depths. Temperature and salinity measurements for the transect off the Otago Coast indicate a seasonal dependence and together with T/S plots enable the water to be classified into neritic, Southland Current, and Sub-Antarctic waters. Phosphate and nitrate levels generally increased with depth and distance offshore indicating that the Sub-Antarctic water is the major source of these nutrients to the inshore waters. Silicate levels were variable with depth and distance offshore. The N:P ratio calculated from the data for all the cruises off the Otago Coast suggests that this parameter may be a useful signature for the different water bodies.

13. MARINE ENVIRONMENTAL STUDIES

Marine environmental studies along the Oamaru coastline. Master's thesis, University of Otago, Dunedin, New Zealand. Loveridge, C.J. (1998).

Environmental investigations were conducted in the nearshore Oamaru region. The sampling programme was designed to enable identification of environmental changes which were attributable to the commissioning of a new Sewerage Scheme in the area. Sampling began in June 1994 and was completed in March 1996. Parameters which were measured included: surface water currents, surface nutrient characteristics, benthic community structure, indicator organism distributions.

Surface nutrient levels were high (factor 2-5 times) relative to other parts of the Otago coast. All nutrient levels were derived from land sources. Silicate levels were not influenced by presence of coastal discharges. The concentrations of all other nutrients measured (nitrate, nitrite, phosphate) were strongly related to coastal outfall proximity. The Pukeuri Alliance Meatworks discharge is affecting nutrient levels over a large area (~400-800m). N/P ratios in the area were between 2 and 10, and were seasonal as was the distribution of most of the nutrients measured.

The benthic community was sparse (20-50 individuals) and composed of a few (8-15) families of small individuals. Stations close to the shore were significantly different from those further out both in terms of families present ($t=1.90$; $p<0.03$) and number of individuals ($R=0.559$; $p<0.018$) which could be related to removal of sewerage from this area.

14. ECOLOGICAL COMMUNITIES

Coastal oceanography sets the pace of rocky intertidal community dynamics. ***Proceedings of the National Academy of Sciences of the United States of America*** **100 (21): 12229-12234. Menge, B.A., Lubcheno, J., Barcken, M.E.S., Chan. F., Foley, M.M., Friedenburg, T.L., Gaines, S.D., Hudson, G., Krenz, C., Leslie, H., Menge, D.N.L., Russell, R., Webster, M.S. (2003).**

The structure of ecological communities reflects a tension among forces that alter populations. Marine ecologists previously emphasized control by locally operating forces (predation, competition, and disturbance), but newer studies suggest that inputs from large-scale oceanographically modulated subsidies (nutrients, particulates, and propagules) can strongly influence community structure and dynamics. On New Zealand rocky shores, the magnitude of such subsidies differs profoundly between contrasting oceanographic regimes. Community structure, and particularly the pace of community dynamics, differ dramatically between intermittent upwelling regimes compared with relatively persistent down-welling regimes.

Top-down and bottom-up regulation of New Zealand rocky intertidal communities. *Ecological Monographs* 69 (3): 297-330. Menge, B.A., Daley, B.A., Lubchenco, J., Sanford, E., Dahlhoff, E., Halpin, P.M., Hudson, G., Burnaford, J.L. (1999).

The effects and rates of predation, grazing, and recruitment on rocky intertidal community dynamics at upwelling and non-upwelling sites on the South Island of New Zealand was investigated. Comparative experiments studies were done at each of two sites on both the east and west coasts of the South Island. Benthic community structure, maximal wave force, nearshore sea surface temperature, air temperature at low tide, nutrient concentrations, survival of mussels, rates and effects of predation, rates and effects of limpet grazing, recruitment of mussels and barnacles, and RNA:DNA rations (a growth index) of mussels were quantified

15. BIRDS

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

Foraging ranges of Yellow-eyed penguins *Megadyptes antipodes* were estimated off the south-east coast of the South Island, New Zealand during three breeding seasons, 1990/91, 1991/92, 1992/93. At the main study area – Boulder Beach on the Otago Peninsula – 14 penguins were radio-tracked for two- to three-week periods during the three stages of the breeding seasons. Birds at Otago Peninsula foraged over the continental shelf, which is mostly 40-80m deep and 30 km wide. Foraging time was also measured using dive recorders during the 1993/94 and 1994/95 breeding seasons.

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

The occurrence, abundance, and distribution of seabirds was studied in a physically dynamic region off the coast of Otago, New Zealand. Eleven line-transect surveys were conducted in late summer and autumn of 1994-96, when surface swarms of "krill", *Nyctiphanes australis*, were present in the study area. Twenty species of seabird were recorded. The abundance and occurrence of species varied between sitting and flying counts. The most numerous species were sooty shearwaters (*Puffinus griseus*), red-billed gulls (*Larus novaehollandiae*), black-billed gulls (*L. bulleri*), and black-backed gulls (*L. dominicanus*). Spatial similarity matrices revealed strongest association between red- and black-billed gulls.

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