Otago Estuaries
State of Environment Report 2010

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Chairman's foreword

The high quality of Otago's water and physical environment is a major asset for the region and a vital part of ensuring the region's future prosperity.

Parts of Otago are coming under increasing pressure, as seen in many other areas of the country, from intensive agricultural practices, urbanisation and water discharge practices, which all have the potential to negatively affect the quality of water in the regions lakes, rivers and estuaries.

The Otago Regional Council's Regional Policy Statement and Regional Plan: Water demonstrates the Council's determination to maintain high water quality standards. In addition, the council continues to work closely with farmers, industries and community groups, as part of its aim to ensure water quality does not deteriorate.

Estuaries form the transition zone between marine and river environments and are dynamic areas influenced by tides, waves and the influx of salt water as well as flows of fresh water. The state of the estuary is a reflection of land use practices throughout the river catchment, and the inflow of both seawater and freshwater provides a unique and rich environment for plants and animals. Potential climate change effects, such as sea level rise and more frequent storm events, could also have an impact on the estuarine environment.

This report provides detailed information of the health of seven of Otago's biggest estuaries. Water and habitat quality are discussed and show that they are in very good condition. This information provides a sound baseline for future comparisons, which will help us ensure these areas remain healthy.

Stephen Woodhead
Chairman

Executive summary

This report describes Otago Regional Council's monitoring of seven estuaries for estuarine water and habitat quality. The seven estuaries monitored were: the Catlins, Tokomairiro, Taieri, Kaikorai, Waikouaiti, Shag and Kakanui.

The overall objective of this State of Environment (SOE) report is to provide an assessment of the current state of estuarine health, using the two tools (broad-scale and fine -scale habitat monitoring) provided by the National Estuary Monitoring Protocol, (Robertson *et al.*, 2002), as well as a third component which consisted of water quality monitoring.

The first component - the broad-scale monitoring - produced a habitat map for each estuary which defined the dominant intertidal habitats. This procedure involved a GIS-based methodology. The resulting map is a benchmark indicator for measuring long-term changes in the distribution of various habitats. It also allows for comparison between different estuaries and regions.

Salt marshes were one of the vegetation types monitored, as they are an extremely productive transitional intertidal area between land and salty or brackish water. The Waikouaiti estuary had the greatest percentage cover of saltmarsh. Another important component of estuarine habitat is the amount of soft mud and the rate of sedimentation, both of which indicate whether a change in ecology of an estuary is likely. The Catlins estuary had the highest percentage cover, with soft mud sediments at 29%; the Kaikorai estuary also had a high percentage (21%). Macroalgal blooms were monitored, as they indicate that estuary eutrophication may be taking place. They were present in all estuaries, but at low levels. The Catlins estuary, which had 6.1% macroalgal cover on unvegetated tidal flats, had the highest percentage cover of all the estuaries.

The second component - the fine-scale monitoring - focused on the condition of bottom-dwelling animals and sediment.

The species richness of bottom-dwelling animals was generally low to moderate, which is as expected, as sampling sites are located in predominantly sandy intertidal areas subjected to relatively harsh physical changes, such as regular tidal exposure and variable salinity (Cawthron, 2006). The Shannon-Weiner diversity values highlighted the variation between estuaries and (between) sites.

The concentration of heavy metals (cadmium, chromium, copper, nickel, lead and zinc) was measured in the estuarine sediment. The Otago estuaries were generally all below the ANZECC (2000) ISQG-Low guideline criteria. However, at the upstream site in the Kaikorai estuary, zinc and lead concentrations just exceeded the ANZECC (2000) ISQG-Low guideline criteria.

The ratio of total organic carbon to total nitrogen (TOC:TN) was used to indicate the likely source of organic matter (Cawthron, 2006). Ratios greater than 20 indicate terrestrial sources of organic matter (Kakanui and Shag estuaries); whereas values between four and ten indicate marine algae as the likely source. Most of the sites had a TOC:TN of between 10 and 20.

The third component was water quality monitoring. To compare the estuaries, the key parameters for each estuary were placed into four categories (low, medium, high and very high). The format used to define these categories is the same as that used in Tasmania (Murphy *et al.*, 2003).

The table below shows the categories of turbidity, chlorophyll, nitrite-nitrate nitrogen (NNN) and dissolved reactive phosphorus (DRP) levels assigned to each estuary. The best quality (or lowest concentration) is green; concentrations then increase from yellow to orange and finally to red. The Waikouaiti, Shag and Kakanui estuaries are seen to have the best water quality.

Estuary	***Turbidity NTU***	***Chlorophyll mg/l***	***Nitrite nitrate nitrogen mg/l***	***Dissolved reactive phosphorus mg/l***
Catlins	5.7	2.71	26.5	25
Tokomairiro	5.8	1.66	46	25
Taieri	5.4	1.36	25	25
Kaikorai	10	3.39	56	22
Waikouaiti	2.1	0.99	25	25
Shag	3.2	0.88	48	25
Kakanui	2.5	0.98	40	25

Other parameters monitored include zinc (a toxicity determinand) and those parameters which determine bacterial health. The ANZECC 2000 guideline for total zinc is 0.015mg/l (marine water) and 0.008mg/l for freshwater. The only estuary that exceeds the higher marine guideline value is the Kaikorai estuary. The Tokomairiro, Kaikorai and Kakanui estuaries have the most elevated concentrations of enterococci compared to the other estuaries. The MfE guideline for very safe levels of enterococci (with regard to swimming) is 140cfu/100ml; only the Catlins and the Shag estuaries met this criteria at all times.

The National Estuary Monitoring Protocol, as used in this report, provides a simple, defensible and cost-effective strategy to assess and monitor estuary condition. The baseline monitoring has been undertaken for seven estuaries, and is envisaged that the process will be repeated to monitor any change.

In conclusion the broad-scale monitoring, fine-scale monitoring and water quality monitoring undertaken between 2005/2008 have indicated that all the estuaries are in good health. It is hoped that the knowledge gained from this monitoring will help to protect and sustain Otago's numerous and important estuary systems.

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1. Introduction

Estuary systems play an important role on the coastal interface due to their link between terrestrial, marine and river ecosystems. Estuarine ecosystems provide a productive and high-value habitat for plant (e.g. eelgrass) and animal (e.g. fish, shellfish, wading birds) species. They are also extremely high value as fish nurseries and are highly important to people for their amenity and recreational value. Due to their position at the bottom of the catchment, estuaries tend to integrate and reflect the condition of the catchments that feed them. They receive contaminants from cities, industries, farms and, rivers and streams, and as a result they are under increasing pressure from human activities, which leads to reduced water quality, increased sedimentation, and habitat and species loss.

The estuarine environment is a complex blend of continuously changing habitats. In streams, rivers, and lakes, water quality parameters are more likely to fluctuate within a well-defined range which is largely determined by rainfall and season; whereas frequent changes occur in estuarine physical and chemical parameters with each tidal cycle and with meteorological events. The behaviour of chemical constituents may vary widely from estuary to estuary as characteristics such as topography, circulation and residence time change considerably.

Physical and chemical parameters in estuaries are related to the extent of tidal flushing and stratification. Tidal flushing is the net transport of water (as well as sediments and contaminants) out of an estuary with tidal flow and river flow. Stratification is the layering of the estuary, which is generally associated with the inflow of denser salt water at depth and the outflow of more buoyant fresh water at the surface.

Superimposed on these naturally occurring variations are changes caused by human intervention, including modification of flow, and the input of pollutants such as excess nutrients and toxins. Typical pollution problems in estuaries include nutrient enrichment leading to accelerated eutrophication (excessive plant growth), low dissolved oxygen levels associated with eutrophication and/or flow restrictions, toxins in the water column or sediments (from point source discharges and non-point source run-off), algal blooms (which can be toxic to marine organisms and humans) and the proliferation of invasive species.

Despite their importance, little was known about the condition and functioning of estuaries in the Otago region prior to 2005, and estuarine monitoring in Otago was therefore restricted to only a very small number of water quality parameters or to one-off studies. This report describes Otago Regional Council's monitoring of seven estuaries for estuarine water and habitat quality since 2005. The location of the estuaries are shown in Figure 2-1.

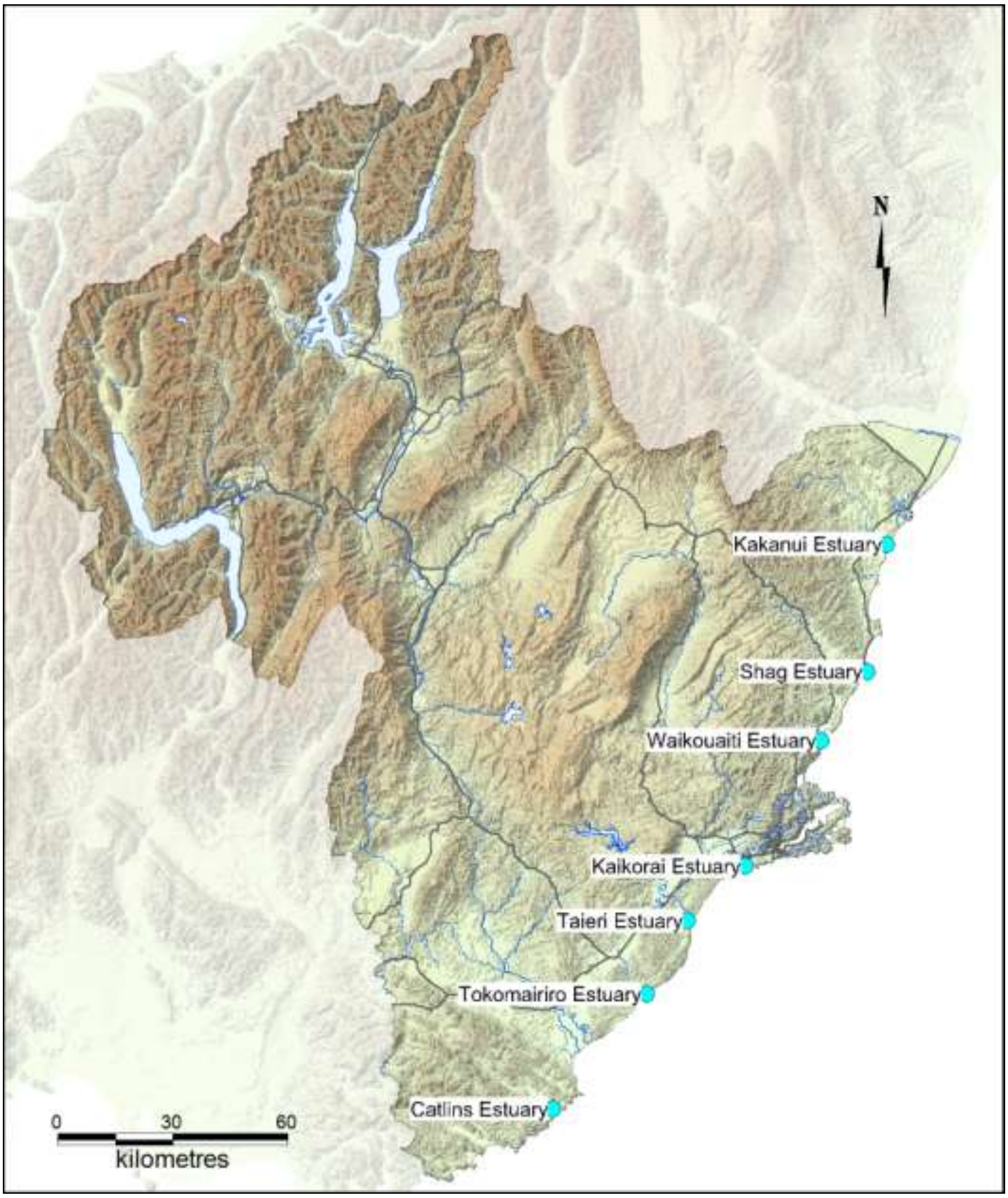

Figure 2-1 Location of estuaries included in the Otago Regional Council monitoring programme

The overall objective of this State of Environment (SOE) report is to provide an assessment of the current state of estuarine health, and a comparison of estuarine health across all the estuaries. Future change can be assessed against these baseline data.

Specifically, this report describes the three main monitoring methods and their results:

- The first and second components consisted of broad-scale habitat mapping and fine-scale environmental monitoring. The protocols are detailed in the National Estuary Monitoring Protocol (Robertson *et al*., 2002).
- The third component consisted of water quality monitoring, which was undertaken over a several years. The results have been used to categorise the key water quality parameters for the seven estuaries

A summary of the characteristics of each of the seven estuaries is presented in Section 2.0. Detailed results of water quality monitoring are presented in Appendices 1.0 and 2.0.

2. Characteristics of the seven estuaries included in the Otago Regional Council estuary monitoring

Estuaries are commonly classified into types according to their particular pattern of water circulation or their physical characteristics. Table 2-1 and Table 2-2 show how the estuaries monitored in Otago fit into these two categories.

Table 2-1 Estuary classification according to water circulation

	Description	***Example***
Highly stratified estuaries	Where the layering between freshwater and saltwater is very distinct. There is a slow but continual up-estuary movement of the salty water on the bottom	Catlins, Kakanui and Waikouaiti
Moderately stratified estuaries	Where mixing of fresh and salt water occurs at all depths. Salinity levels generally increase toward the estuary mouth, although the lower layer is always saltier than the upper layer	Taieri
Vertically mixed estuaries	Where powerful mixing by tides eliminates layering altogether and salinity is a function of the tidal stage. This tidal dominance is usually only observed in small estuaries	Tokomairiro, Kaikorai and Shag

Table 2-2 Estuary classification according to physical characteristics (after Murphy *et al*., 2002)

	Description	***Example***
Barrier or bar estuaries	Estuaries with sandbars across their mouths. Can be permanently-open or seasonally-closed	Shag, Waikouaiti, Kakanui, Taieri, Kaikorai, Catlins Tokomairiro
Coastal inlets	Enclosed marine embayments with wide mouths that lack large riverine inputs but have detectable reduction in salinity due to input from small creeks after heavy rainfall. Generally well mixed and can be hypersaline in summer	
Drowned river valleys	Estuaries with wide river mouths, rocky headlands and deep channels and can be stratified	
River estuaries	Estuaries where fast flowing rivers discharge into the sea with little bar or lagoon development and poor water-mixing	
Coastal lagoons	Saline lagoons with irregular input and infrequent openings to the sea. Incursion by seawater generally occurs only after extreme run-off events or tidal or artificial breaching of the sand barrier. Can be hypersaline in summer	

All the estuaries can be classified into one physical characteristic type (barrier or bar estuaries), the Kaikorai Estuary bar often shuts off the entrance to the estuary.

The following section gives more detail on each of the estuaries.

2.1 Catlins estuary

The Catlins estuary comprises the estuaries of two rivers; the Catlins River and the Owaka River. The estuary is approximately 7.65km long and quite broad in places (up to 1.53km across Catlins Lake) and overall covers slightly in excess of 859ha, excluding deep water (Ryder, 2009). A high percentage of the estuary area is exposed at low water and with the apparently continuously open river mouth, there is a high degree of flushing of the estuary with each tidal cycle. It is apparent that some tracts of the estuary have been reclaimed over past years; particularly at the head of the estuary (Ryder, 2009). Small areas of the remaining estuary are still exposed to stock from time to time. The Catlins estuary is listed as a coastal protection area with Kai Tahu cultural and spiritual values. It is a largely unmodified estuary with minimal development of the main feeder river. A large wetland is located at the head of the estuary, which is an important habitat for waterfowl and for fish breeding. The estuary is an important habitat for marine and freshwater fish such as giant bully, black flounder, brown trout, eels and shellfish. It is also a coastal recreation area with boating, swimming, fishing and walking (Otago Regional Council, 2004).

2.2 Kakanui estuary

The Kakanui estuary is a long (2.2km) and relatively narrow (no more than 230m wide) estuary covering slightly less than 27ha, excluding deep water (Ryder, 2009). The mouth of the estuary is quite mobile. A small percentage of the estuary is exposed at low water. Little of the area has been reclaimed for farming, but some land used for grazing on the true left bank near the mouth can be described as flood plain. Some of this area is being replanted with native trees and shrubs.

The Kakanui estuary is listed as a coastal recreation area in the Regional Plan: Water, as it is important for swimming, walking, fishing, scuba diving, snorkelling and boating (Otago Regional Council, 2004).

2.3 Waikouaiti estuary

The Waikouaiti River has a long and very irregularly shaped estuary covering in excess of 200ha, with a very high percentage of the estuary area being exposed at low water (Ryder, 2007). It is apparent that large tracts of the estuary have been reclaimed over past years, and some areas of the remaining estuary are still exposed to stock from time to time.

In the Regional Plan: Water, the Waikouaiti Estuary is listed as a coastal protection area with Kai Tahu cultural and spiritual values. It is also important for coastal birds such as the eastern bar-tailed godwit and oystercatchers. It is listed as a coastal development area with fishing facilities, recreational facilities and moorings, and is also a coastal recreation area with swimming, walking and surfing (Otago Regional Council, 2004).

2.4 Kaikorai estuary

The Kaikorai Stream has a long and relatively narrow estuary covering slightly in excess of 140ha with a high percentage of the estuary area being exposed at low water (Ryder, 2008). The bar at the estuary mouth is regularly blocked, meaning that a large proportion of the estuary is often inundated for extended time periods. Some tracts of the estuary have been reclaimed over past years, including the golf course and landfills, as well as areas for farming (Ryder, 2008). Some areas of the estuary are exposed to stock from time to time.

The Kaikorai estuary is listed as a coastal protection area in the Regional Plan: Water, as it has Kai Tahu cultural and spiritual values, and estuarine values such as a diversity of species and communities which support a diverse bird population. Up to 50 bird species have been identified in the estuary. There is a wide variety of estuarine plants, such as tall rushland and saltmarsh ribbonwood. It is also a juvenile rearing area for whitebait and breeding area for yellow belly flounder (Otago Regional Council, 2004).

2.5 Taieri estuary

The Taieri River has a long, generally narrow and irregularly shaped estuary that covers in excess of 270ha, with a low percentage of the estuary area being exposed at low water (Ryder, 2008). It is apparent that large areas of what was estuary or flood plain along the margins of the upper estuary have been developed for farming at some time in the past.

The Taieri Estuary is listed as a coastal development area in the Regional Plan: Water, as it has fishing and recreational facilities (Otago Regional Council, 2004).

2.6 Shag estuary

The Shag River has a long and irregularly shaped estuary and covers in excess of 130ha. (Ryder, 2007). A high percentage of the estuary area is exposed at low water. Large areas of what was once estuary or flood plain have been developed for farming. The Shag estuary is listed as a coastal protection area in the Regional Plan: Water (see Section 3.0), and has Kai Tahu cultural and spiritual values. It has an extensive subtidal reef system with luxuriant bladder kelp. There are mudstone wave-cut platforms containing fossils and very good examples of spherical boulders (Katiki concretions). Its estuarine values include large mudflats used for feeding birds which are roosting or stopping over. It is an important whitebait spawning area, and is a habitat for lamprey. The spit is an occasional haul-out location for Hookers sea-lions and Southern elephant seals (Otago Regional Council, 2004).

2.7 Tokomairiro estuary

The Tokomairiro has a long (12.5km) and narrow (370m wide) estuary covering more than 240ha. A small percentage of the estuary area is exposed at low water, indicating that a considerable amount has been reclaimed for farming. The sand bar at the mouth of the estuary has led to rapid siltation within the estuary, and it also limits the tidal range to approximately one metre. The estuary is dominated by a shallow mudflat habitat which acts as sediment trap.

The Tokomairiro Estuary is listed as a coastal protection area in the Regional Plan: Water, as it has Kai Tahu cultural and spiritual, as well as estuarine, value. (Otago Regional Council, 2004).

3. Monitoring requirements

3.1 Resource Management Act 1991

Regional councils are required to undertake environmental monitoring as part of their statutory obligation under the Resource Management Act 1991 (RMA). Part IV, Section 35, directs local authorities to: "Gather such information, and undertake or commission such research, as is necessary to carry out effectively its functions under this Act." Included among the functions is, under Part IV, Section 30 (1)(a): "The establishment, implementation and review of objectives, policies, and methods to achieve integrated management of the natural and physical resources of the region." Integrated management of resources requires a holistic approach, thereby considering the ecosystem as a whole.

For this reason, Otago Regional Council's estuarine programme includes monitoring of both biota and the quality of habitats.

3.2 Regional Coastal Plan for Otago

The Regional Plan: Coast is a statutory document prepared by the Otago Regional Council under Section 64 of the RMA. The plan forms the framework by which the Otago Regional Council undertakes its functions under the RMA in the coastal marine area. Schedule 2.1 of the Regional Plan: Coast includes all estuarine areas along Otago's coast.

Otago is also home to a variety of habitats and areas which contain conservation, cultural or environmental values of regional, national or international importance. Within the Regional Plan: Coast, the different values associated with those areas are recognised and provided for by the identification of areas within the coastal marine area. Three areas have been established:

1. Coastal Protection Area
These areas have been identified on the basis of their biological, physical or cultural values which need to be recognised and provided for.
2. Coastal Development Area
These areas have been developed to varying degrees. The coastal development area provides for the recognition of the facilities and infrastructure in those areas, and the values and uses associated with them.
3. Coastal Recreation Areas
These areas have been identified because of their accessibility by the public, their frequency of use, and the facilities and infrastructure such as yachting clubs, surf life saving clubs and navigational markers associated with them.

Estuaries have been included in the coastal protection area because they are particularly valuable in terms of biological productivity. This productivity results from the continuous flow of nutrients down rivers, the relative shelter compared to the open coast, and the relatively high (in coastal terms) amount of light available. Estuaries provide a benign environment for flora and fauna and are believed to act as both nursery areas and nutrient suppliers for the open coast and deeper ocean waters. Kai Tahu, in accordance with tikanga Maori, have also identified areas that contain important cultural or spiritual values which the Plan recognises.

Regional councils have a duty under the RMA to monitor the state of the environment. These duties are incorporated in the Regional Policy Statement for Otago and the Regional Coastal Plan for Otago. State of the Environment (SOE) monitoring provides the information required to determine whether these objectives are being achieved.

3.3 Need for long-term monitoring

Sustainable management of estuaries requires a knowledge base in order to understand, characterise and track changes Monitoring provides information on how resources are being managed and subsequently the effectiveness of these management practices.

4. Methodology

The monitoring programme had three components:

- The first and second components consisted of broad-scale habitat mapping and fine-scale environmental monitoring. The protocols are detailed in the National Estuary Monitoring Protocol (Robertson *et al*., 2002) and both components were undertaken by Ryder Consulting Ltd.
- The third component consisted of water quality monitoring, which was undertaken over several years by the Otago Regional Council.

4.1 Broad-scale habitat mapping

Broad-scale habitat mapping defines an estuary according to the dominant intertidal habitats. This procedure involves a GIS-based methodology. Colour aerial photographs taken at low tide (maximum scale of 1:10,000) were used to identify habitat features such as substrate and vegetation type. A digital map was produced from the aerial photographs and verified with detailed ground-truthing. The resultant map becomes a valuable benchmark indicator for measuring long-term changes in the distribution of various habitats. It also allows comparison between different estuaries and regions.

4.2 Fine-scale environmental monitoring

Fine-scale monitoring involved measuring a suite of physical, chemical and biological parameters at various sites around the estuary. The parameters measured included those that are known to be indicative of estuary condition and are likely to provide a means for detecting subsequent change (Table 4-1). Monitoring sites (generally a total of 2-4 per estuary) were selected to be representative of different regions of the estuary and suitable for long-term monitoring. Sites were determined using knowledge gained through the broad-scale mapping.

Table 4-1 Parameters measured during fine-scale monitoring

Parameter	*Description*	*Sampling method*
Epifauna	Surface-dwelling animals	All animals observed within a defined area are identified and counted
Infauna	Animals living buried in the sediment	Sediment cores were taken and the invertebrate species within were identified and counted
Sediment	Sediment	The redox discontinuity layer (anoxic layer) was identified and sediments were analysed for physical and chemical parameters (particle size, nutrients, ash free dry weight, trace metals)
Macroalgae	Seaweeds	Percentage coverage was estimated from a defined area

4.3 Water quality

The water quality of the seven coastal estuaries was monitored at least four times between 2006 and 2009. The main aims of the surveys were to:

- add to baseline water quality data.
- determine the status of water circulation/stratification.

In each estuary, samples (NNN, DRP, TN, TP, NH_4 and Enterococci) were collected hourly for six hours during the low tide period. Samples were collected, stored and analysed in accordance with Otago Regional Council's standard procedures (ORC, 2009). The Hydrolab DS5X was also deployed during this period, which continuously recorded temperature, salinity, chlorophyll, turbidity and pH. At hourly intervals the monitor was lowered to obtain depth profiles in order to gauge the extent of tidal stratification.

5. Broad-scale monitoring results

Appendix 1 contains the broad-scale habitat maps (according to the dominant intertidal habitats) for each estuary, and the following section details three of the estuarine habitats (macroalgal cover, saltmarsh habitat and soft mud sediment), and compares the percentage cover of each in each estuary.

5.1 Macroalgal cover

Figure 5-1 shows the percentage cover of potentially nuisance-causing macroalgal beds (e.g. sea lettuce, *Gracilaria sp*. and *Enteromorpha sp*.) on intertidal substrata for each estuary.

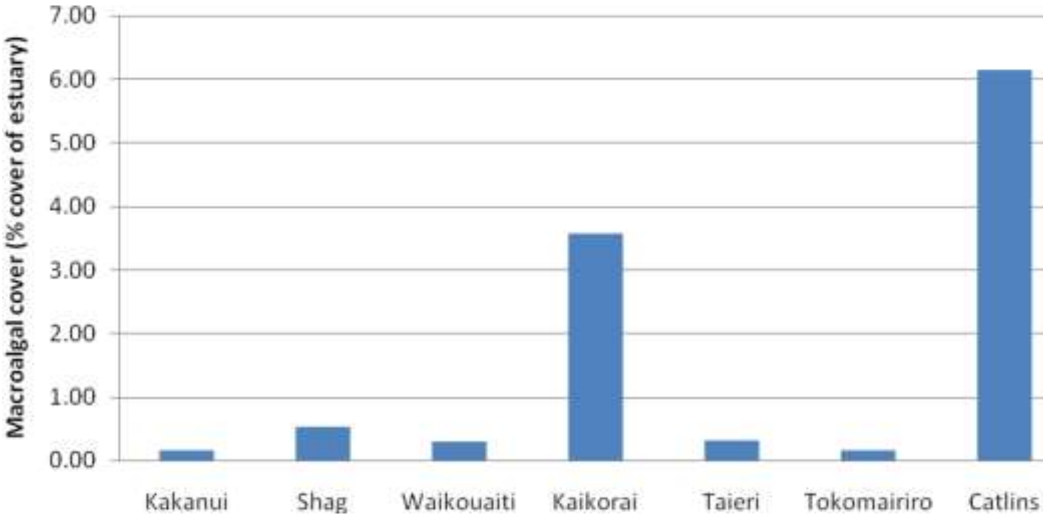

Figure 5-1 Percentage cover of potentially nuisance causing macroalgal beds

Macroalgae were present in all estuaries, but at low levels. The Catlins Estuary, which had 6.1% macroalgal cover on unvegetated tidal flats, had the highest percentage cover of all the estuaries. The ability for macroalgae to thrive is dependent on the availability of nutrients. Section 9.0 shows that the Kaikorai and Tokomairiro estuaries had elevated nutrient levels; nitrogen in particular often exceeded levels that limit phytoplankton blooms (ANZECC, 2000).

5.2 Saltmarsh habitat

Figure 5-2 compares the saltmarsh habitats (i.e. herbfield, reed, rushland, seagrass, sedgeland, shrubland and tussockland) found in the estuaries. Figure 5.2 shows that the Waikouaiti Estuary had the greatest percentage cover of saltmarsh with 40%. The Shag and Tokomairiro estuaries had 30% and 27% coverage, respectively.

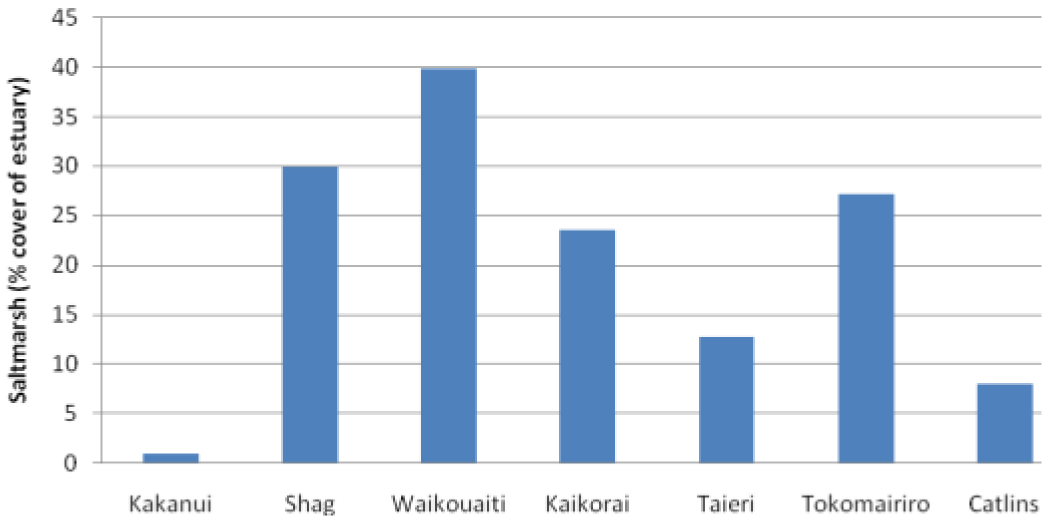

Figure 5-2 Percentage cover of total estuary area as saltmarsh

5.3 Soft mud sediment

Figure 5-3 shows the percentage of soft mud which each estuary contained. The rate of sedimentation and the area of muddy sediments are the most direct measures for assessing whether or not an estuary is moving quickly towards muddiness. Indications of those estuaries which might need more intensive monitoring are those containing large areas of soft mud and show changes in the area of mud over time.

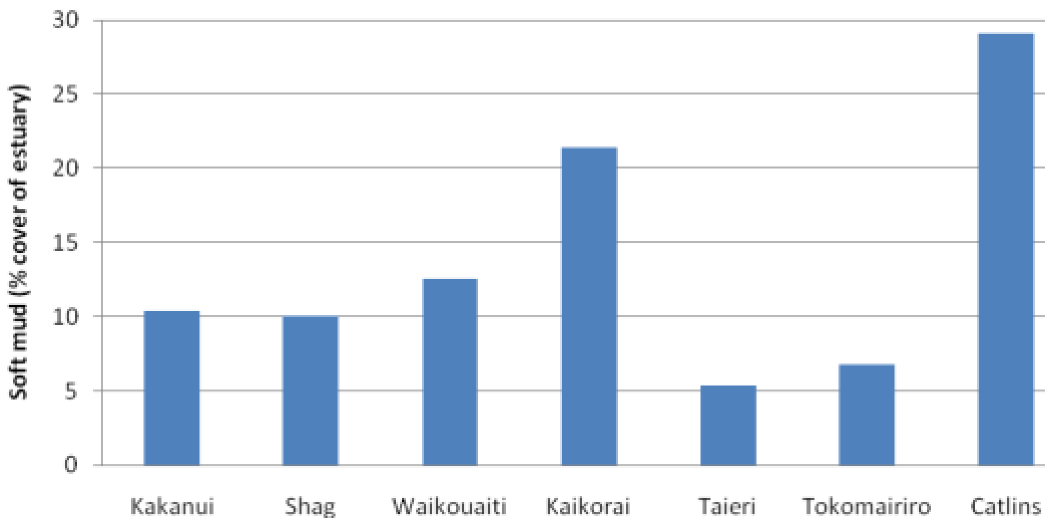

Figure 5-3 Percentage cover of total estuary area as soft mud/sand tidal flats

Figure 5.3 shows that the Catlins Estuary had the highest percentage cover, with soft mud sediments at 29%. The Kaikorai Estuary also had a high percentage (21%). The Kakanui, Shag and Waikouaiti estuaries were more in the medium range at 10%, 10% and 13%, respectively. The Taieri Estuary contained very little soft mud.

6. Fine-scale monitoring results - fauna

Monitoring results provide a baseline measure of species and their abundance. Benthic communities in Otago estuaries vary considerably between sites and estuaries.

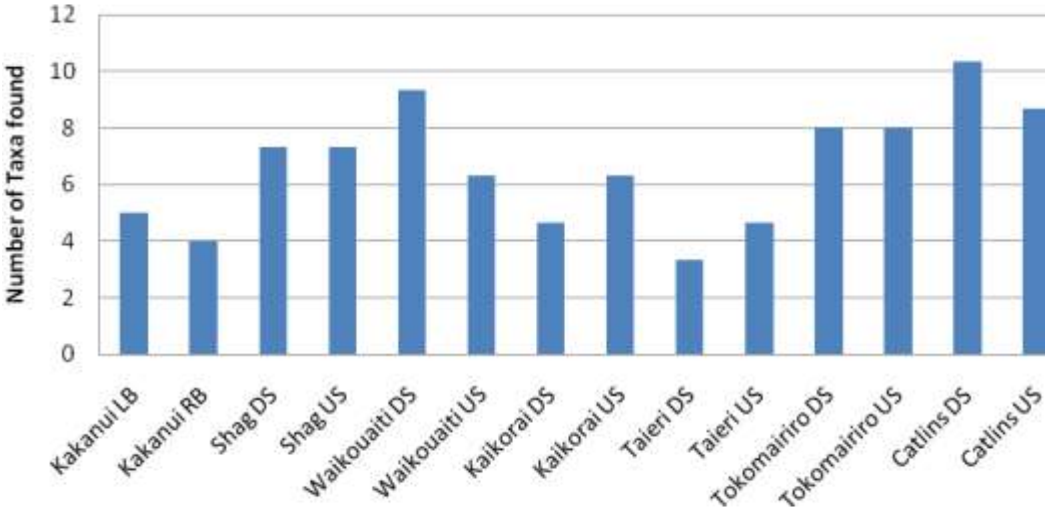

Figure 6-1 Mean number of taxa/community richness in each Otago estuary

Species richness was generally low to moderate. This is to be expected as sampling sites are located in predominantly sandy intertidal areas and are subjected to relatively harsh physical changes, such as regular tidal exposure and variable salinity (Cawthron, 2006).

Figure 6-1 shows that mean species richness per core ranged from 3.3 (Taieri Estuary downstream site) to 10.3 (Catlins Estuary downstream site); while Figure 6-2 shows that the mean abundance ranged from 8 (Kakanui Estuary right bank) to 362 (Kakanui left bank). The habitat composition at the two sites in the Kakanui was very different; which is reflected in the difference in the mean number of animals between the sites.

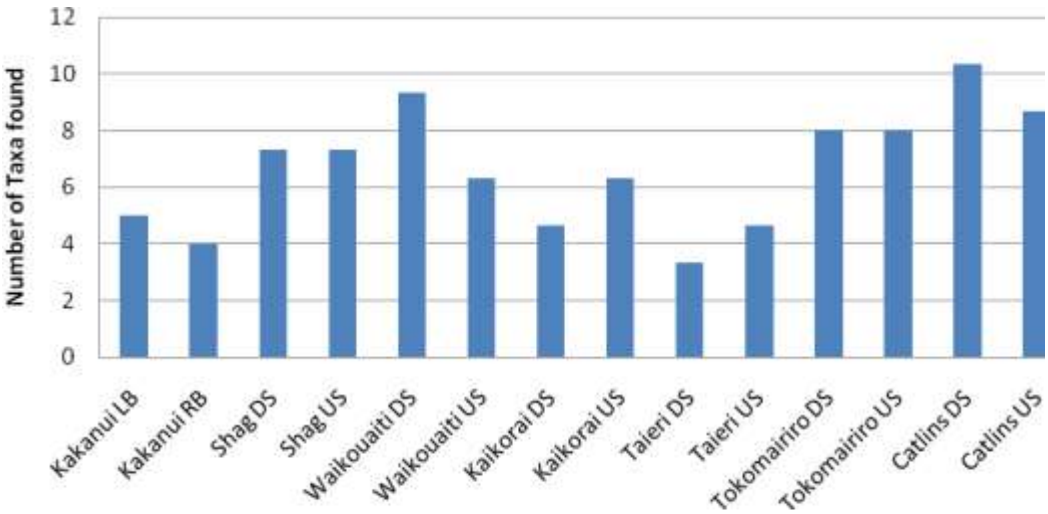

Figure 6-2 Mean number of animals in each Otago estuary

The Shannon-Weiner diversity values highlight the variation between estuaries and (between) sites (Figure 6-3). Even though estuary samples may be equally rich in species, they could be very uneven in species makeup, with perhaps one species contributing most of the abundance. The Shannon Weiner diversity index takes this into consideration, and the higher the index, the higher the uncertainty of composition. There are currently no relevant thresholds for defining New Zealand estuaries in relation to the Shannon-Weiner index.

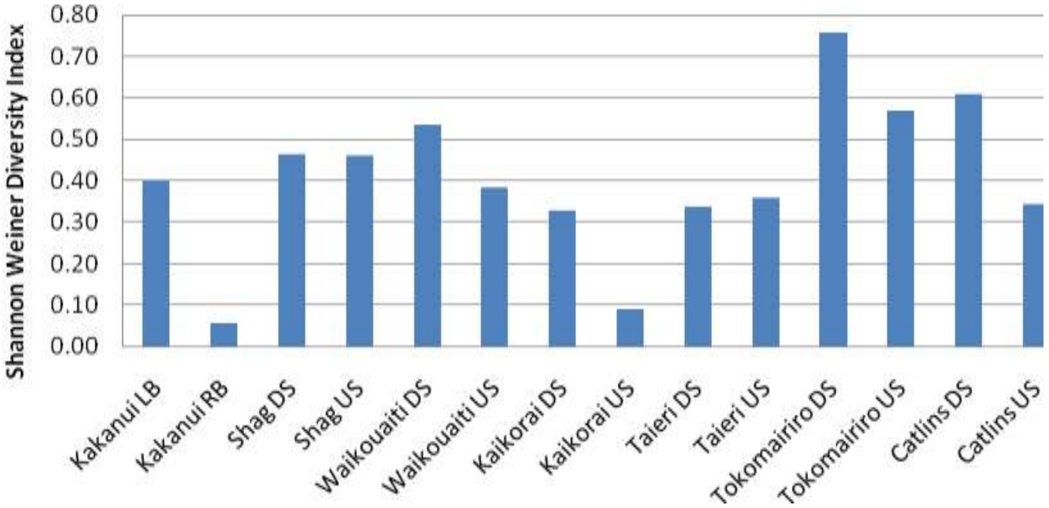

Figure 6-3 Average Shannon-Weiner diversity values for three cores (two sites in each estuary).

Although there was significant variation in the communities across the estuaries, there was also a common general species assemblage present.

Figure 6-4 shows the summary results of a multi-dimensional analysis which groups sites according to species composition. Sites with similar characteristics are plotted closely together; while those with very different characteristics are plotted well apart. The first principal component explained 38% of the total variance in the data and was highly correlated with Amphipoda (*Phoxocephalid* at 11.7%) and Polychaeta (*Spionidae* 2.3%, *Nephtyidae* 2.1% and *Glyceridae* at 1.7%). The second principal component explained 30% of the variance in data and was highly correlated with Amphipoda (*Gammaridae* at 8.1%), Polychaetea (*Spionidae* at 1.7%, *Glyceridae* at 2.1% and *Phoxocepahlid* at 3.5%) and Bivalvia (*Veneridae* at 2.1%).

Three distinct groups are shown. The sites bounded by the red circle were dominated by amphipods (Phoxocephalidae) and polychaetes (particularly *Nephtyidae*). The sites bounded in blue are more diverse, but dominated by amphipods (*Gammaridae*); while the sites bounded in green were the most diverse, with an abundance of polychaetes (*Glyceridae*, *Nephtyida* and *Spionidae*), amphipods (*Phoxocephalidae*) and bivalves (*Veneridae*)

The Waikouaiti and Catlins downstream sites had high numbers of bivalvia (*Veneridae*) compared to the other sites.

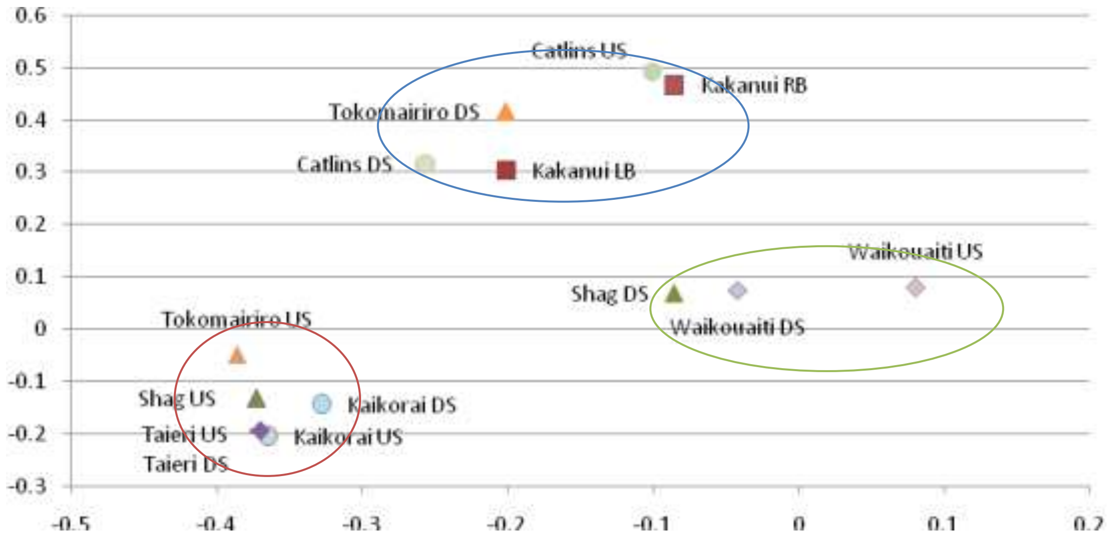

Figure 6-4 Principal components analysis. The benthic communities found at the sites bounded by red are markedly different from the other estuarine sites

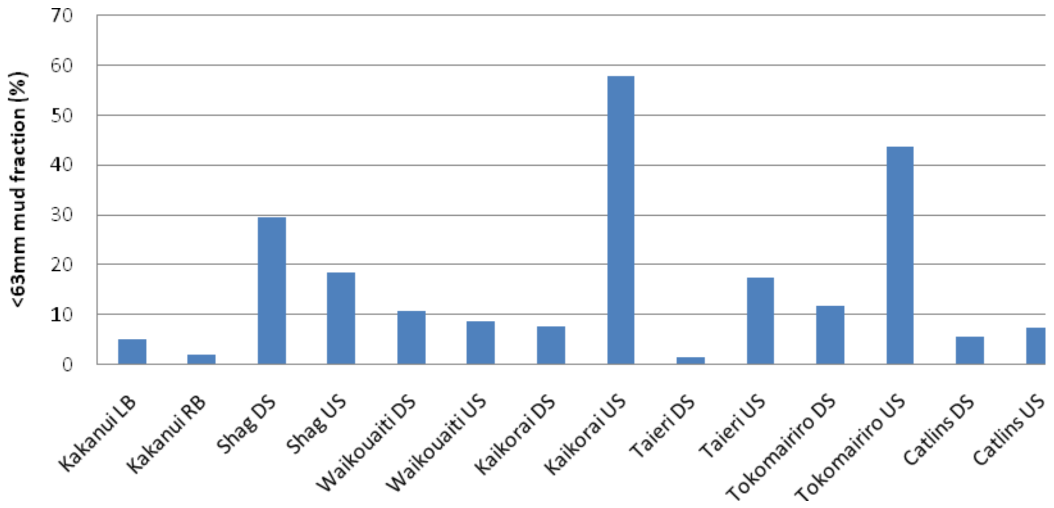

Figure 6-5 Percentage of sediment of <63µm particle fraction size

Figure 6-5 shows that the Kaikorai, Tokomairiro, Shag and Taieri estuaries had the highest percentage of the <63µm sediment particle fraction. It is interesting to note that these estuaries correlate with the estuaries with the least diverse benthic communities (Figure 6-4), which indicates that habitat is a prime factor in the variation in benthic communities between estuaries.

7. Fine-scale monitoring results – trace elements in sediments

Estuaries provide ideal conditions for accumulating sediment which may have elevated trace element concentrations. For each trace element and organic compound, ANZECC has derived a low interim sediment quality guideline value (ISQG-Low) and a high interim sediment quality guideline value (ISQG-High). These are shown in Table 7-1. The ISQGs relate to the toxic impact of trace elements and organic compounds on sediment-dwelling organisms.

Table 7-1 ISQG sediment guideline values

	Arsenic	Cadmium	Chromium	Copper	Nickel	Lead	Zinc
ISQG Low (mg/kg)	20	1.5	80	65	21	50	200
ISQG High (mg/kg)	70	10	370	270	52	220	410

The results presented in Table 7-2 below are the average values from two sites within each estuary.

Table 7-2 Nutrient and heavy metal contamination in the estuaries monitored

	Kakanui	Shag	Waikouaiti	Kaikorai	Taieri	Tokomairiro	Catlins
Total Nitrogen	0	0.1	0.1	0.1	0.1	0.1	0.1
Total Phosphorus	255	523.5	466	705	450	380	240
Arsenic	4.8	10.1	6.5	0	0	3.7	5
Cadmium	0	0	0	0.1	0	0.1	0
Chromium	4.4	10.4	5.8	18.7	5.1	6.6	5.9
Copper	1.9	4.5	4.7	12	3.2	3.9	3.9
Nickel	4.6	6.9	6	9.2	4.8	5.1	4.8
Lead	5.9	5.2	4.2	27.4	3.7	4.2	2.1
Zinc	14.4	31.9	26.3	127	19.5	26.5	17

Detectable levels of trace elements in sediments can either be due to natural processes or the result of anthropogenic activities. Figure 7-1 to 7.6 show the mean concentration of various trace metals for each estuarine site.

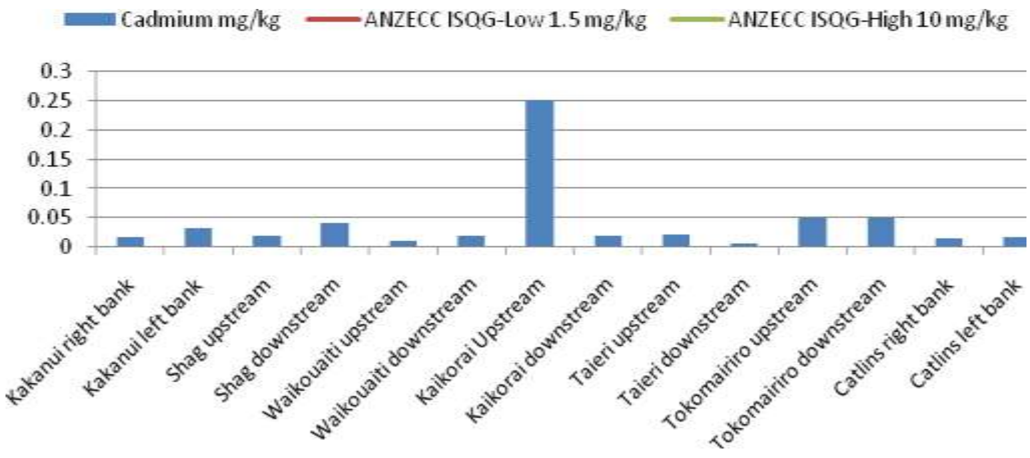

Figure 7-1 Mean concentration of cadmium (mg/kg) for each estuary site

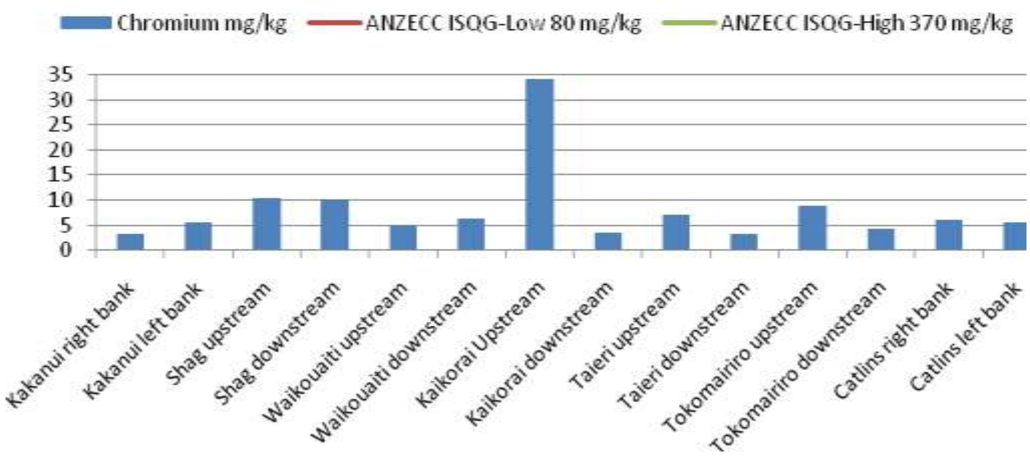

Figure 7-2 Mean concentration of chromium (mg/kg) for each estuary site

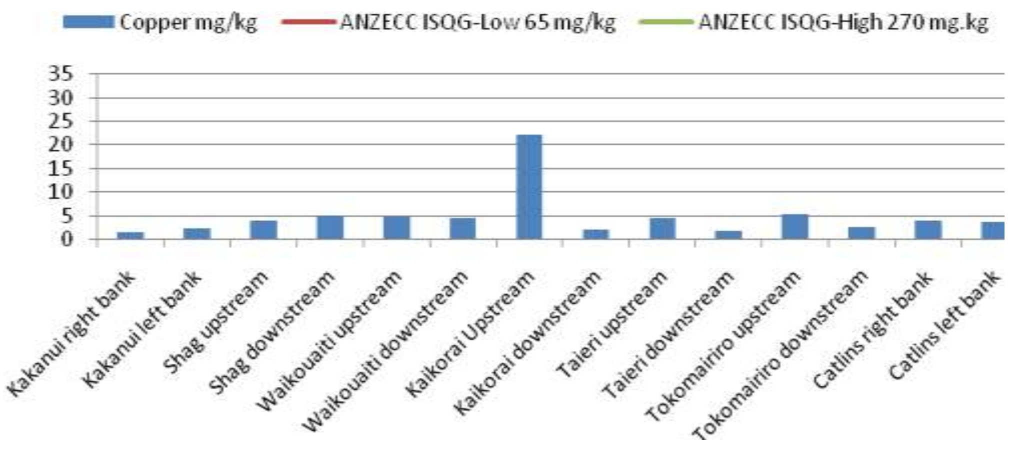

Figure 7-3 Mean concentration of copper (mg/kg) for each estuary site

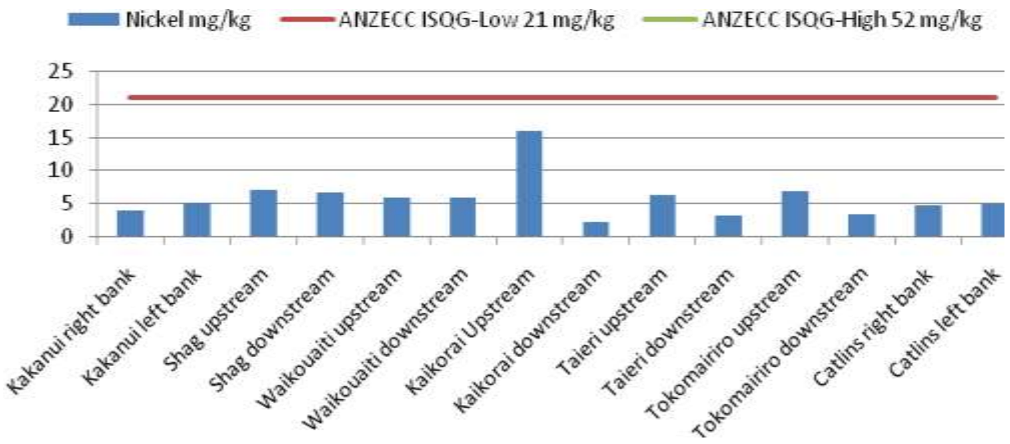

Figure 7-4 Mean concentration of nickel (mg/kg) for each estuary site

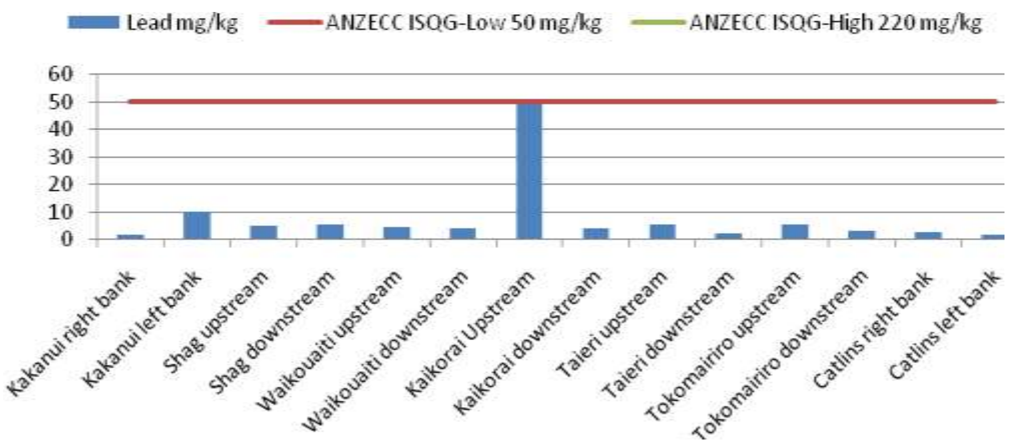

Figure 7-5 Mean concentration of lead (mg/kg) for each estuary site

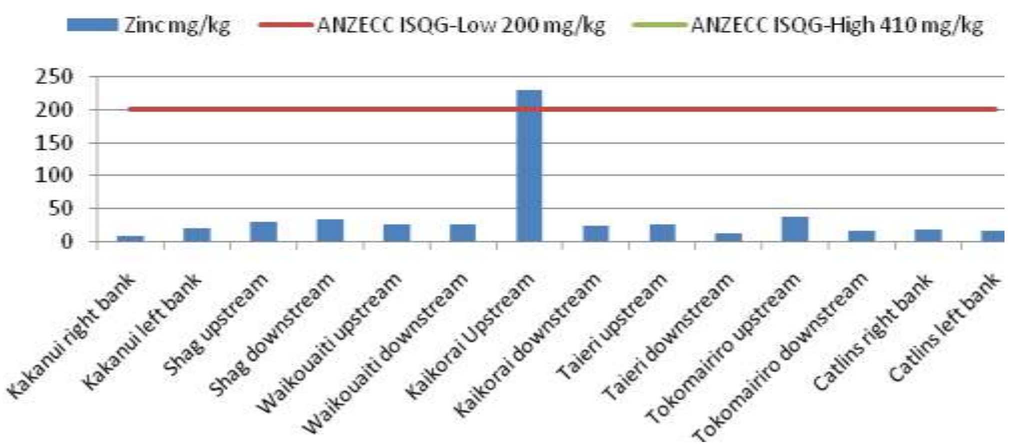

Figure 7-6 Mean concentration of zinc (mg/kg) for each estuary site

The level of heavy metals (cadmium, chromium, copper, nickel, lead and zinc) in the Otago estuaries were generally all below the ANZECC (2000) ISQG-Low guideline criteria. However, at the upstream site in the Kaikorai Estuary, zinc and lead concentrations just exceeded the ANZECC (2000) ISQG-Low guideline criteria.

8. Fine-scale monitoring results - sediment organic carbon and nutrients

Total organic carbon, total nitrogen and total phosphorus are indicators which are commonly used to assess organic matter and nutrient levels (National Estuary Monitoring Protocol indicators Robertson *et al.*, 2002). Figure 8-1 shows the percentage of total organic carbon in each estuary.

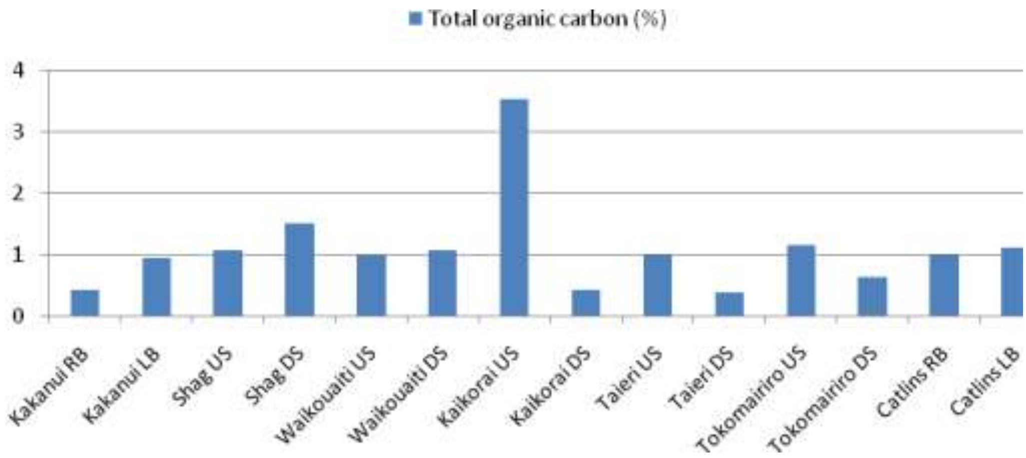

Figure 8-1 Percentage of total organic carbon for each estuary

The ratio of TOC:TN can be used to indicate the likely source of organic matter (Cawthron, 2006). Ratios greater than 20 indicate terrestrial sources of organic matter; whereas values between four and ten indicate marine algae as the likely source (Meyers 1994). Well-flushed estuaries (residence time 2-3 days), shallow (<2m mean depth) and sandy estuaries (Cawthron, 2006), typical of those in Otago, are more likely to have low sediment TN and TOC concentrations, but could still experience macroalgal blooms. This is likely to occur when the rate of nutrient supply (particularly nitrogen) to the algae is high enough to trigger excessive growth. Table 8-1 gives the ratios of TOC:TN for each estuary.

Table 8-1 TOC:TN ratios for each estuary

Estuary	TN g/100g	TOC %	Ratio TOC:TN
Kakanui right bank	0.065	0.42	6.5
Kakanui left bank	0.025	0.95	37.9
Shag upstream	0.05	1.08	21.6
Shag downstream	0.09	1.50	16.7
Waikouaiti upstream	-	0.99	-
Waikouaiti downstream	0.07	1.07	15.3
Kaikorai Upstream	0.25	3.53	14.1
Kaikorai downstream	0.025	0.42	16.8
Taieri upstream	0.076	1.00	13.2
Taieri downstream	0.025	0.39	15.6
Tokomairiro upstream	0.093	1.16	12.45
Tokomairiro downstream	0.061	0.63	10.35
Catlins right bank	0.094	1.00	10.6
Catlins left bank	0.076	1.11	14.5

The estuary sites with a TOC:TN ratio greater than 20, indicating a terrestrial source of organic matter are the Kakanui estuary (left bank) and the Shag estuary (upstream). Those with lowest TOC:TN ratio are the Kakanui estuary (right bank) and the Catlins estuary (right bank), indicating that marine algae is the likely source of organic matter.

9. Water quality

In this section the physical and chemical aspects of estuaries are discussed. Where applicable the parameter under investigation is plotted against salinity.

9.1 Salinity

The salinity of seawater in the open ocean is remarkably constant at about 35 parts per thousand (ppt). Salinity in an estuary, however, varies according to location, tidal fluctuations and the volume of freshwater run-off.

Salinity levels in estuaries are generally highest near the mouth of a river where ocean water enters, and lowest upstream, where freshwater flows in. However, actual salinities at specific locations in the estuaries vary through the tidal cycle and with seasons.

Variations in salinity produce changes in species composition, distribution and abundance in an estuary. Estuarine organisms have different tolerances and responses to salinity changes. For example, benthic organisms are able to tolerate changing salinities, but salinities outside an acceptable range will affect growth and reproduction.

Salinity is also important because it affects chemical conditions within the estuary, particularly dissolved oxygen levels. The amount of dissolved oxygen (solubility) decreases with increasing salinity. The solubility of oxygen in seawater is about 20 percent less than in freshwater of the same temperature.

Humans can affect the salinity of estuaries as the shoreline areas are developed. Abstracting water from a river for irrigation can reduce the fresh water flow into an estuary, making it more saline, and tidal barriers may decrease the salinity of areas that were once saltmarshes.

Table 9-1 Salinity results for each estuary

Salinity ppt	*Median*	*Maximum*	*Minimum*
Catlins estuary	24.23	34.23	8.22
Kaikorai estuary	11.25	33.45	0.45
Kakanui estuary	17.22	33.68	0.12
Shag estuary	17.21	34.14	0.97
Taieri estuary	21.7	34.92	0.29
Tokomairiro estuary	15.65	31.64	4.16
Waikouaiti estuary	23.13	33.94	0.72

In order to see whether the estuaries stratified, water quality profile monitoring was undertaken. Examples of the stratification status of all estuaries are shown graphically in Appendix 2. The only estuaries that stratify regularly (at the sampling location) are the Catlins, Kakanui and Waikouaiti estuaries. The Taieri estuary stratifies, but not to such a marked extent. The Shag, Kaikorai and Tokomairiro estuaries do not stratify.

9.2 Tides, current speed, and direction

Water levels and current velocities in estuaries vary with the tide, but also with weather conditions and with the amount of river flow and run-off entering the rivers. This needs to be considered when interpreting changes in physical and chemical parameters.

Changes in water volume in the estuary change the concentration of dissolved and suspended materials in the water. During periods of high run-off due to storms, the amount of suspended sediment in the water tends to increase because of erosion in the watershed.

Depending on the pollutant source, bacterial levels may also increase as run-off increases. Conversely, turbidity levels may increase during periods of low water volume because of the action of wind and waves on muddy bottom sediments at low tide.

9.3 Weather

Meteorological conditions can be valuable in interpreting water quality data and explaining changes in water quality parameters. For example, thermal stratification of estuaries may occur after a period of high temperatures and light winds. This in turn may lead to decreased mixing and decreased dissolved oxygen levels at depth. High winds may lead to increased suspended solids, and high rainfall may decrease salinity and increase contaminant concentrations.

9.4 Temperature

Water temperature is a critical factor in determining where marine organisms live and how well they thrive. For example, each species of phytoplankton has an optimal temperature for survival. Growth rates of estuarine plants and cold-blooded animals generally increase with temperature, up to the thermal optimum. Shifts in temperature cause variations in phytoplankton abundance and species composition. Organisms are limited to certain temperature ranges and may be more susceptible to disease or poisoning from toxins when the temperature rises. Human activities such as sewage discharges can upset the temperature balance in an estuary. Because cold water is denser than warm water, there may be distinct layers of water of different temperatures, with the warmer water on top and the colder water on the bottom.

Temperature is a critical factor influencing many other biological and chemical processes in an estuary. Cold water holds more oxygen than warm water. For example, water at 0ºC can contain up to 14.6mg of oxygen per litre of water, but at 20ºC it can hold a maximum of only 9.2mg of oxygen per litre. The rates of metabolism and photosynthesis increase as water temperature rises.

Table 9-2 Temperature results for each estuary

Temperature	*Median*	*Maximum*	*Minimum*
Catlins estuary	14.61	23.8	8.44
Kaikorai estuary	15.46	22.36	4.16
Kakanui estuary	15.79	21.5	5.11
Shag estuary	15.61	20.26	10.65
Taieri estuary	16.07	23.15	4.07
Tokomairiro estuary	13.83	18.28	7.48
Waikouaiti estuary	14.83	19.71	4.06

Table 9-2 shows that the maximum temperature in five of the estuaries reached 20 ºC. However temperatures did not remain at this level for long periods, generally being an indicator of the river temperature at low tide, rather than the mixed estuary.

9.5 Dissolved oxygen

Dissolved oxygen (DO) is supplied to estuarine waters through two natural processes:

- diffusion of atmospheric oxygen into the water
- photosynthesis by phytoplankton and aquatic macrophytes (seaweeds and seagrasses), which results in production of oxygen.

Mixing of surface waters by wind and waves increases the rate of absorption of atmospheric oxygen into the water. DO levels are influenced by temperature and salinity. The solubility of oxygen, or its ability to dissolve in water, decreases with increasing temperature and salinity (Figure 9.3). DO levels in an estuary vary seasonally, with the lowest levels occurring during the late summer months when temperatures climb to their highest levels of the year.

DO is removed from the water by aerobic respiration and bacterial decomposition. As a result, Do levels in an estuary may vary widely because of differences in the amount of DO produced by plants. Bacteria, fungi and other organisms affect DO levels in an estuary because they consume DO while breaking down organic matter.

DO depletion may occur in an estuary when many plants die and decompose, or when run-off or poorly treated wastewater containing large amounts of organic matter enters the estuary. In some estuaries, large nutrient inputs, normally from sewage inputs, stimulate phytoplankton blooms. When these organisms decompose, the surrounding water becomes depleted of DO and, in severe cases, may lead to anoxic conditions that kill bottom-dwelling organisms. Shallow, well-mixed estuaries are less susceptible to this phenomenon because wave action and circulation patterns can easily supply the deeper waters with DO.

Generally DO levels of greater than 4mg/l indicate an adequate supply of DO to support marine species growth and activity; while levels from 1-3mg/l indicate hypoxic conditions which are detrimental to marine life. DO below 1mg/l indicates anoxia. Table 9-3 shows the median, maximum and minimum DO levels recorded during monitoring. The Kaikorai estuary had the lowest level of DO, recording just 4.02mg/l, but the median value was 9.46mg/l indicating an adequate supply of DO.

Table 9-3 Dissolved oxygen results for each estuary

DO mg/l	*Median*	*Maximum*	*Minimum*
Catlins estuary	9.22	11.69	7.8
Kaikorai estuary	9.46	11.98	4.02
Kakanui estuary	9.03	13.00	5.82
Shag estuary	9.33	12.31	6.7
Taieri estuary	8.46	12.33	3.5
Tokomairiro estuary	9.69	13.68	7.34
Waikouaiti estuary	8.65	13.44	4.22

9.6 pH

The pH of coastal sea water is usually 7.8, or slightly higher. River waters have pH values generally in the pH range 7.3 to 8.4.

pH is important because most aquatic organisms are adapted to live in pH levels of between 5.0 and 9.0. The pH level in an estuary will tend to remain fairly constant because the chemical components of seawater resist large changes in pH; dissolved carbonate minerals present in seawater tend to minimise or buffer pH changes by reacting with the ions that change pH. Biological activity, however, may significantly alter pH levels in an estuary.

The process of photosynthesis removes carbon dioxide (CO_2) from the water. Since CO_2 becomes carbonic acid when dissolved, the removal of CO_2 results in a higher pH. Therefore, as algal populations increase during the growing season, pH levels tend to rise. During large increases in the populations of planktonic algae (blooms), pH levels may increase significantly.

The occurrence of the different forms of ammonia depend on pH. At the pH of average seawater, ~ 95% of ammonia is in the cationic form NH_4, but if pH rises to ~ 9.5 then about half the ammonia will be in the toxic form NH_3.

Table 9-4 pH results for each estuary

pH	*Median*	*Maximum*	*Minimum*
Catlins estuary	8.12	8.71	6.77
Kaikorai estuary	7.95	8.3	6.03
Kakanui estuary	7.86	9.47	4.99
Shag estuary	8.01	8.56	6.31
Taieri estuary	8.04	8.37	7.25
Tokomairiro estuary	8.43	9.55	6.61
Waikouaiti estuary	7.99	8.85	7.35

Table 9-4 shows the range of estuarine pH conditions encountered during monitoring. The Tokomairiro estuary had a maximum pH level of 9.55. However, as this level was only present briefly on one sampling occasion, it is unlikely that ammonia toxicity was present.

9.7 Toxic contaminants

As a result of estuarine and coastal development, contaminants, including heavy metals, can enter estuaries. Many of these are persistent, bioaccumulate and incorporate into sediments.

Figure 9-1 shows total zinc plotted against salinity. Many of the estuaries have elevated levels of zinc, but the Shag estuary has noticeably higher concentrations of zinc at lower salinities; while the Catlins Estuary shows elevated zinc concentrations at higher salinities. The ANZECC 2000 guideline for total zinc is 0.015mg/l (marine water) and 0.008mg/l for freshwater. Table 9-5 shows that the total zinc concentrations in all estuaries exceeded both guideline values at some point. The median total zinc concentration in the Shag estuary met the freshwater guideline value and it is only the median zinc concentration in the Kaikorai estuary that did not meet the higher marine guideline value.

Table 9-5 Total zinc (mg/l) results for each estuary

Total Zinc mg/l	*Median*	*Max*	*Min*
Catlins estuary	0.014	0.265	0.006
Kaikorai estuary	0.017	0.097	0.0025
Kakanui estuary	0.0065	2.14	0.0025
Shag estuary	0.008	0.455	0.0025
Taieri estuary	0.014	0.136	0.0025
Tokomairiro estuary	0.0065	0.327	0.0025
Waikouaiti estuary	0.0065	0.395	0.0025

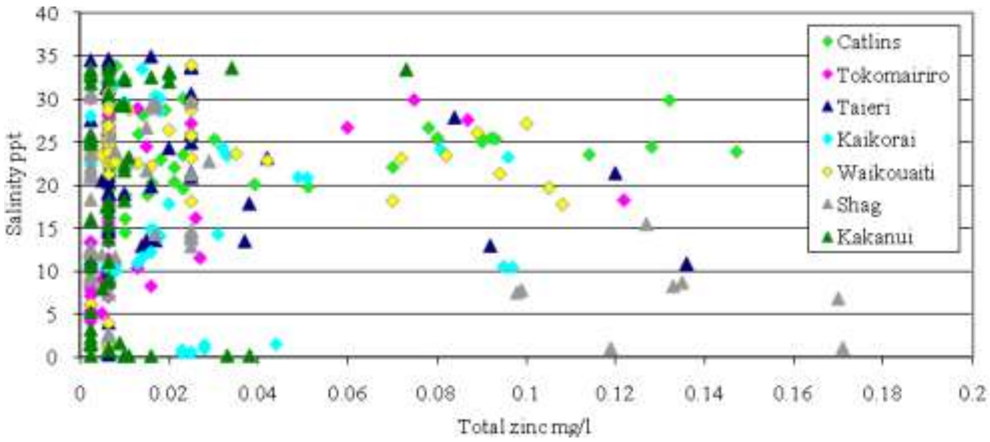

Figure 9-1 Catlins, Tokomairiro, Taieri, Kaikorai, Waikouaiti, Shag and Kakanui estuaries. Total zinc mg/l plotted against salinity (outliers not shown)

9.8 Nutrients

Nitrogen (N) and phosphorus (P) are key water quality parameters in estuaries as they influence plant growth, oxygen concentrations, water clarity and sedimentation rates. The rate of biological productivity or eutrophication will in part depend on nutrients. N is essential in protein and DNA synthesis in organisms and photosynthesis in plants. P is essential in metabolic processes. N species of interest in estuaries are nitrate (NO_3), nitrite (NO_2), ammonia (NH_3) and ammonium (NH_4). Nutrients are not in themselves a threat to marine life, but can contribute to excessive plant growth, low DO and eutrophication.

In marine systems, N is generally the limiting nutrient to plant growth. The amount of dissolved inorganic forms present (NNN, ammonia) is particularly important as they are available for biological uptake and indicate the likelihood of eutrophication (Ward *et al.*, 1998). P is monitored as it is generally the limiting nutrient in freshwater systems, although both P and silica have been found to be limiting in some situations (Deeley and Paling, 1999).

Table 9-6 Nutrient results for each estuary

Median values mg/l	***NH4***	***NNN***	***TN***	***DRP***	***TP***
Catlins estuary	0.02	0.0265	0.34	0.025	0.025
Kaikorai estuary	0.02	0.056	0.615	0.022	0.0355
Kakanui estuary	0.02	0.04	0.285	0.021	0.025
Shag estuary	0.02	0.048	0.35	0.025	0.025
Taieri estuary	0.02	0.025	0.25	0.025	0.025
Tokomairiro estuary	0.02	0.046	0.4	0.025	0.025
Waikouaiti estuary	0.01	0.025	0.28	0.025	0.025

Maximum values mg/l	***NH4***	***NNN***	***TN***	***DRP***	***TP***
Catlins estuary	0.21	0.191	0.73	0.025	0.055
Kaikorai estuary	0.5	1.43	2.24	0.075	0.417
Kakanui estuary	0.28	0.473	1.16	0.061	0.144
Shag estuary	0.12	0.364	0.88	0.025	0.085
Taieri estuary	0.18	0.3	0.65	0.025	0.075
Tokomairiro estuary	0.82	1.32	1.56	0.045	0.26
Waikouaiti estuary	0.22	0.227	0.66	0.031	0.089

Figure 9-2 shows TP plotted against salinity. The Tokomairiro and Kaikorai estuaries had elevated concentrations of TP compared to the other estuaries. The ANZECC guideline for TP (based on data from SE Australia) is 0.03mg/l; this value was only exceeded in the Kaikorai estuary. Table 9.6 indicates that the median TP concentrations in all but the Kaikorai estuary met this guideline value.

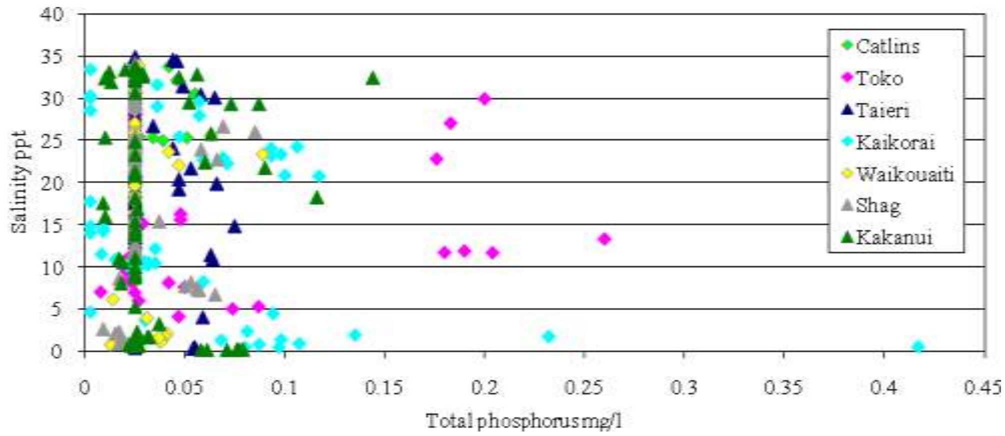

Figure 9-2 Catlins, Tokomairiro, Taieri, Kaikorai, Waikouaiti, Shag and Kakanui estuaries. Total phosphorus mg/l plotted against salinity

Figure 9-3 shows DRP plotted against salinity. The Kakanui, Tokomairiro and Kaikorai estuaries had elevated concentrations of DRP compared to the other estuaries. There are no specific ANZECC guidelines for DRP in SE Australia, the range being 0.005 to 0.015mg/l (based on other Australian regions). Table 9-6 shows that all the estuaries had median values that exceeded this guideline.

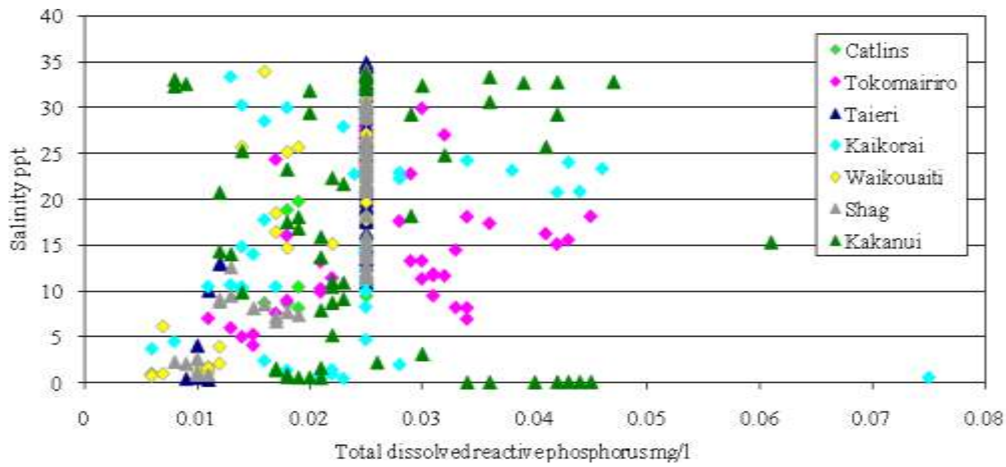

Figure 9-3 Catlins, Tokomairiro, Taieri, Kaikorai, Waikouaiti, Shag and Kakanui estuaries. Dissolved reactive phosphorus mg/l plotted against salinity

Figure 9-4 shows TN plotted against salinity. It can be seen that the Tokomairiro, Kaikorai and Shag estuaries had elevated concentrations of TN compared to the other estuaries. The ANZECC guideline for TN (based on data from SE Australia) is 0.3mg/l. Table 9.6 indicates that the median DRP concentrations in the Catlins, Kaikorai, Shag and Tokomairio estuaries exceeded this guideline value.

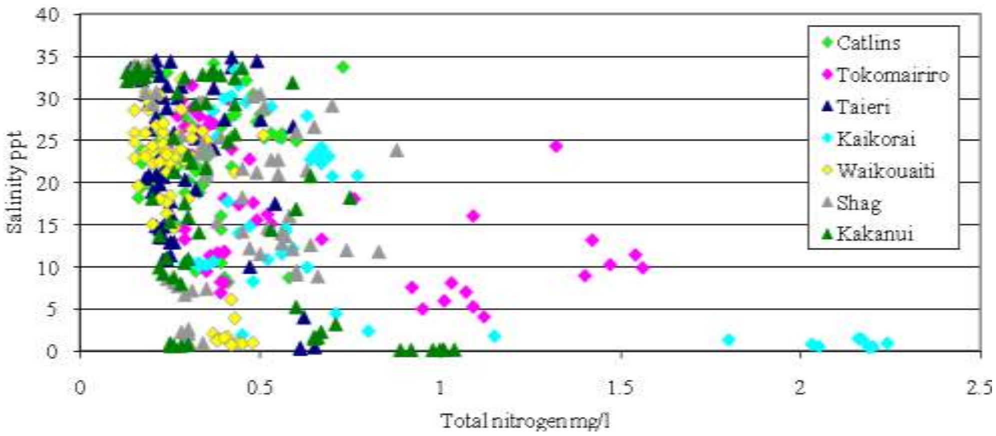

Figure 9-4 Catlins, Tokomairiro, Taieri, Kaikorai, Waikouaiti, Shag and Kakanui estuaries. Total nitrogen mg/l plotted against salinity

Figure 9-5 shows NNN plotted against salinity. Again, the Tokomairiro and Kaikorai estuaries had elevated concentrations of NNN compared to the other estuaries. The ANZECC guideline for NNN (based on data from SE Australia) is 0.015mg/l. Table 9-6 indicates that the median NNN concentrations in all estuaries exceeded this guideline value, especially when predominantly fresh water was present.

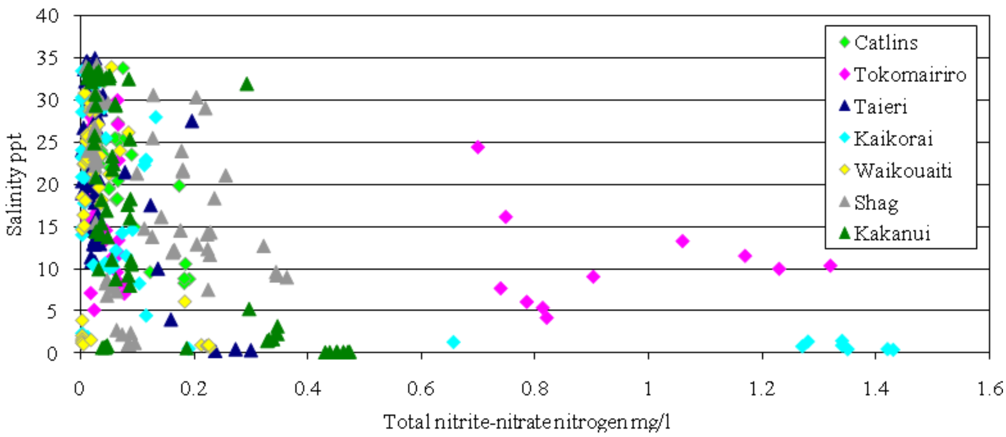

Figure 9-5 Catlins, Tokomairiro, Taieri, Kaikorai, Waikouaiti, Shag and Kakanui estuaries. Nitrite nitrate nitrogen mg/l plotted against salinity

Figure 9-6 shows NH_4 plotted against salinity. The Tokomairiro and Kaikorai estuaries had elevated concentrations of NH_4 compared to the other estuaries; however, the Shag and Catlins estuaries also show some elevated results. The ANZECC guideline for NH_4 (based on data from SE Australia) is 0.015mg/l. Table 9-6 indicates that the Waikouaiti estuary met this guideline level; while median NH_4 concentrations in all the other estuaries only just exceeded this guideline value.

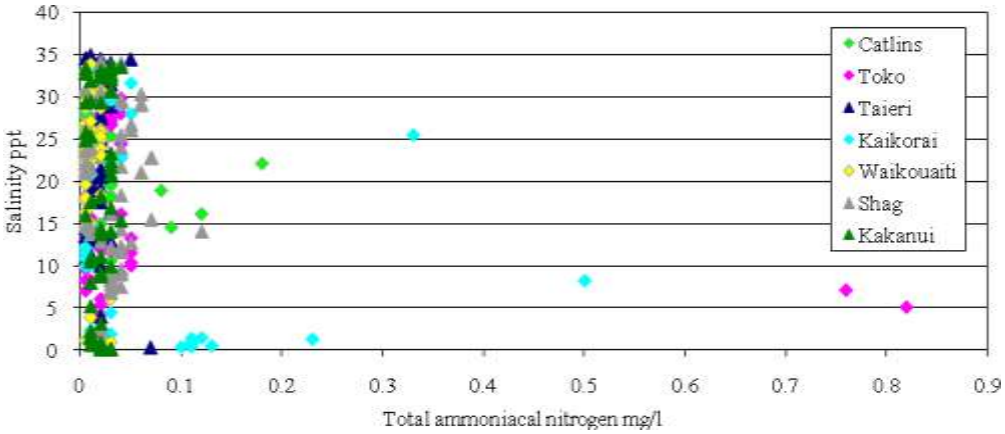

Figure 9-6 Catlins, Tokomairiro, Taieri, Kaikorai, Waikouaiti, Shag and Kakanui estuaries. Ammoniacal nitrogen mg/l plotted against salinity

9.9 Pathogens (indicator bacteria)

A healthy, balanced estuary naturally has bacteria that play a role in biological processes, and are essential members of a functioning ecosystem. However, the presence of pathogens (viruses, bacterial and protozoans that cause disease) are of concern in areas where waters are used for swimming, boating, shellfishing or other contact recreation activities. The potential levels of pathogens in estuaries are tracked by monitoring indicator bacteria, commonly faecal coliforms, Escherichia coli and enterococci, all of which are bacteria normally prevalent in the intestines and faeces of warm blooded animals. The presence of coliform bacteria is not a problem in itself, but they indicate the possible presence of harmful bacteria and the contamination of water by sewage or livestock. Pathogens can enter water systems in several ways: directly from boats, from septic tanks which are not working properly, from sewage treatment plants, from domestic animals and livestock.

Table 9-7 Bacteria results for each estuary

Enterococci mpn/100ml	***Median***	***Maximum***	***Minimum***	***Count***
Catlins estuary	5	110	2	78
Kaikorai estuary	54	12500	1	50
Kakanui estuary	36	3800	2	95
Shag estuary	16	98	0.5	73
Taieri estuary	5	320	0.5	75
Tokomairiro estuary	36.5	330	5	46
Waikouaiti estuary	10	280	1	74

Escherichia coli cfu/100ml	***Median***	***Maximum***	***Minimum***	***Count***
Catlins estuary	10	80	2	78
Kaikorai estuary	315	6800	1	58
Kakanui estuary	90	920	2	100
Shag estuary	56	410	0.5	73
Taieri estuary	10	280	0.5	75
Tokomairiro estuary	20	150	5	46
Waikouaiti estuary	28	1500	1	74

As estuaries can either be predominantly salt water or freshwater depending on the state of tide, both enterococci (the indicator bacteria for salt water) and *Escherichia coli* (the indicator bacteria for freshwater) are discussed.

Figure 9-7 shows enterococci plotted against salinity. The Tokomairiro, Kaikorai and Kakanui estuaries had the most elevated concentrations of enterococci compared to the other estuaries; however, all these high values were taken at low tide when the water was predominantly river water. The MfE guideline for very safe levels of enterococci (with regard to swimming) is 140cfu/100ml. Table 9-7 indicates that only the Catlins and the Shag estuaries met this criteria at all times. The MfE guideline for satisfactory levels of enterococci (with regard to swimming) is between 140 and 280cfu/100ml. Table 9-7 indicates that in addition to the Catlins and Shag estuaries, the Waikouaiti Estuary met this criteria at all times.

The median concentrations of bacteria in the seven estuaries indicate that generally they all met the MfE guideline for very safe levels of enterococci.

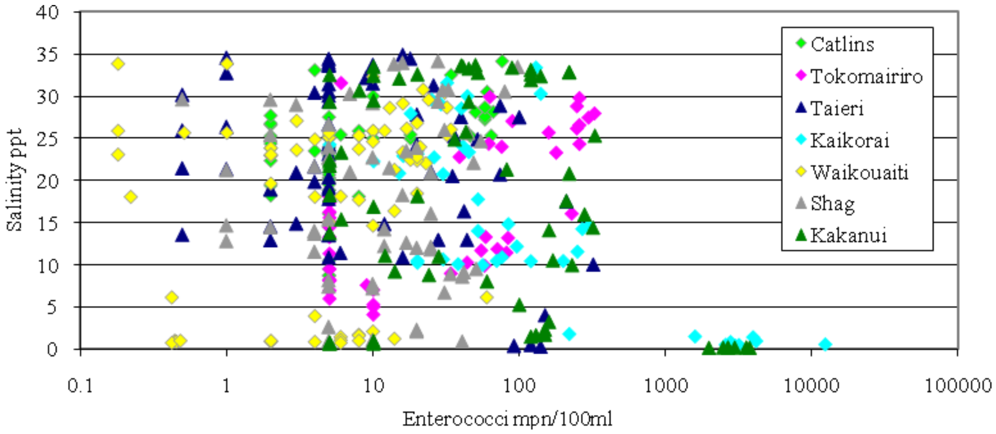

Figure 9-7 Catlins, Tokomairiro, Taieri, Kaikorai, Waikouaiti, Shag and Kakanui estuaries. Enterococci cfu/100ml plotted against salinity

Figure 9-8 shows *Escherichia coli* plotted against salinity. This graph is useful when looking at the low salinity ranges. The Kaikorai and Kakanui estuaries had the most elevated concentrations of *Escherichia coli* compared to the other estuaries, at all states of tide. The MfE guideline for very safe levels of *Escherichia coli* (with regard to swimming) is 260cfu/100ml. Table 9-7 indicates that only the Catlins and the Tokomairiro estuaries met this criteria at all times. The MfE guideline for satisfactory levels of *Escherichia coli* (with regard to swimming) is between 260 and 550cfu/100ml. Table 9-7 indicates that in addition to the Catlins and Tokomairiro estuaries, the Shag and Taieri estuaries met this criteria at all times.

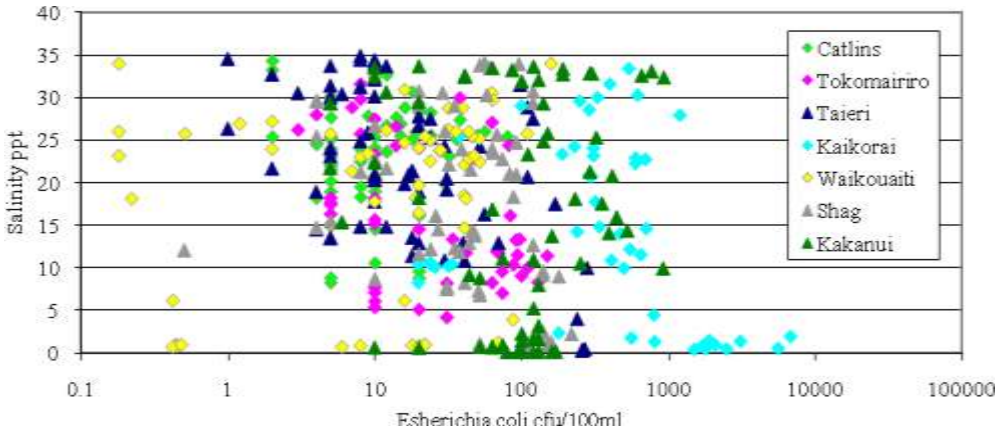

Figure 9-8 Catlins, Tokomairiro, Taieri, Kaikorai, Waikouaiti, Shag and Kakanui estuaries. Esherichia coli cfu/100ml plotted against salinity.

The median concentrations of bacteria in all the estuaries (other than the Kaikorai) indicate that generally they all met the MfE guideline for very safe levels of *Escherichia coli.*

As a general rule of thumb, it is encouraged to avoid swimming and collecting shellfish during heavy rain and for up to two days afterwards. If these rainfall events are avoided, it is likely that elevated levels of bacteria (often associated with rainfall and run-off from the land) will also be avoided.

9.10 Suspended solids, turbidity, and chlorophyll

Suspended solids are the material suspended in the water column, and turbidity refers to the clarity of the water (i.e. the ability of water to transmit light). Turbidity is influenced by the level of suspended solids. Life in estuaries depends on plant production for much of its energy; plants, in turn, depend on sunlight for photosynthesis. When the water is too turbid, too much light is diffused and not enough reaches plants that need it, and production decreases. Turbidity also affects fish and aquatic life by clogging fish gills and the feeding apparatus of bottom dwelling-animals with suspended particles, by obscuring the vision of fish as they hunt for food and by smothering bottom-dwelling animals.

Elevated levels of suspended material and turbidity occur naturally through erosion, storm run-off and with plant growth on a seasonal basis. However, these parameters also indicate degraded water quality if the elevated levels are caused by erosion due to development, organic material due to nutrient enrichment or uncontrolled discharges.

Table 9-8 Suspended solid results for each estuary

Suspended Solids mg/l	*Median*	*Maximum*	*Minimum*
Catlins estuary	28	95	11
Tokomairiro estuary	22	120	9
Taieri estuary	19.5	115	6
Kaikorai estuary	18.5	270	5
Waikouaiti estuary	3.94	45	1.5
Shag estuary	12	36	1.5
Kakanui estuary	8	50	0.5

Table 9-9 Turbidity results for each estuary

Turbidity NTU	*Median*	*Maximum*	*Minimum*
Catlins estuary	5.7	31.2	1.3
Tokomairiro estuary	5.8	62.8	0.9
Taieri estuary	5	28.1	0.9
Kaikorai estuary	10	85	1.5
Waikouaiti estuary	1.9	31.7	0.1
Shag estuary	3.2	163.8	0.1
Kakanui estuary	2.5	223.1	0.2

Table 9-10 Chlorophyll results for each estuary

Chlorophyll mg/l	*Median*	*Maximum*	*Minimum*
Catlins estuary	3.55	9.43	0.08
Tokomairiro estuary	1.66	7.86	0.59
Taieri estuary	1.36	4.89	0.38
Kaikorai estuary	3.39	5.91	0.05
Waikouaiti estuary	0.99	14.62	0.46
Shag estuary	0.88	21.18	0.06
Kakanui estuary	0.2	9	0.98

Figure 9-9 shows suspended solids plotted against salinity. There is considerable scatter in all estuaries, but the Shag, Kaikorai and Tokomairiro estuaries had the most elevated concentrations of suspended solids compared to the other estuaries.

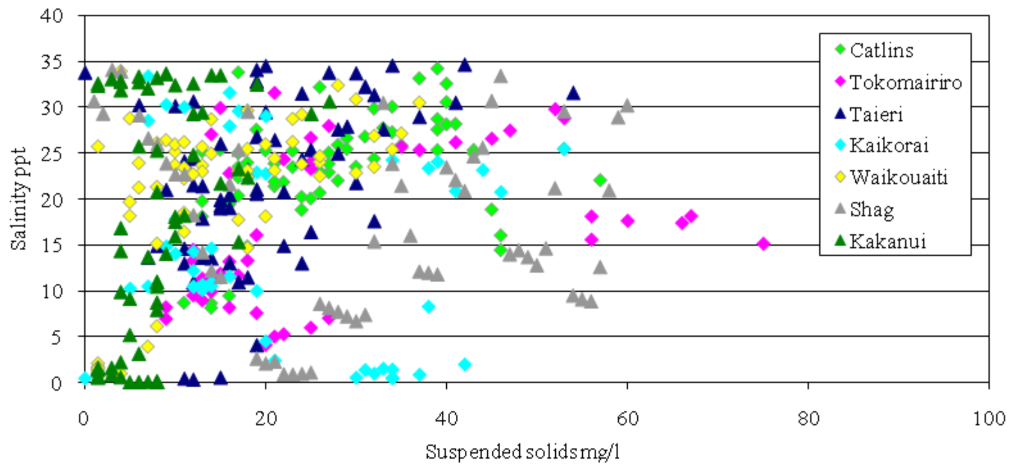

Figure 9-9 Catlins, Tokomairiro, Taieri, Kaikorai, Waikouaiti, Shag and Kakanui estuaries. Suspended solids mg/l plotted against salinity

Figure 9-10 shows turbidity plotted against salinity. The Shag, Kaikorai and Tokomairiro estuaries have elevated levels of turbidity compared to the other estuaries. The ANZECC guideline for turbidity (based on data from SE Australia) is 0.5NTU to 10NTU. Table 9-9 indicates that the median turbidity levels in all the estuaries met this guideline level.

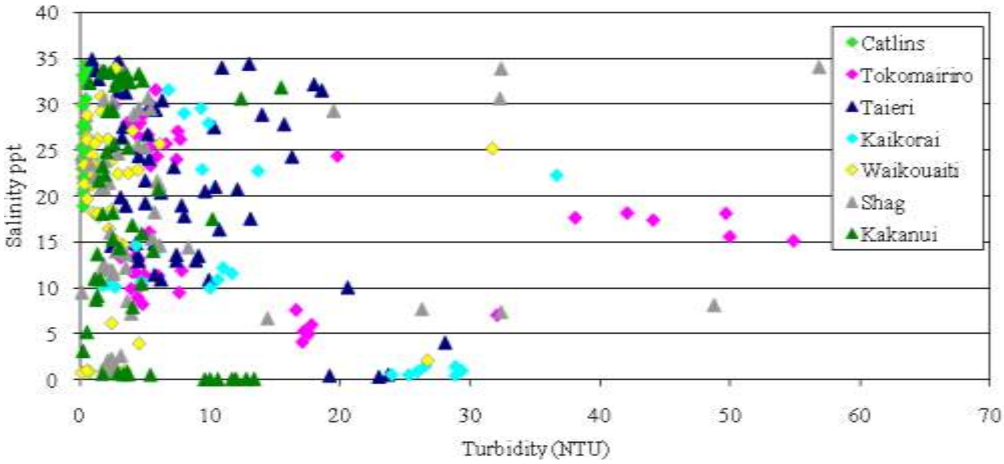

Figure 9-10 Catlins, Tokomairiro, Taieri, Kaikorai, Waikouaiti, Shag and Kakanui estuaries. Turbidity NTU plotted against salinity

Chlorophyll is included in this section, as algal blooms contribute to the turbidity of the water and increase the suspended solids (ANZECC 2000). Figure 9-11 shows chlorophyll plotted against salinity. The Shag estuary has noticeably elevated concentrations of chlorophyll compared to the other estuaries. The ANZECC guideline for chlorophyll (based on data from SE Australia) is 0.004mg/l. Table 9-10 indicates that the median concentration of chlorophyll in all the estuaries easily exceeded this extremely low guideline level.

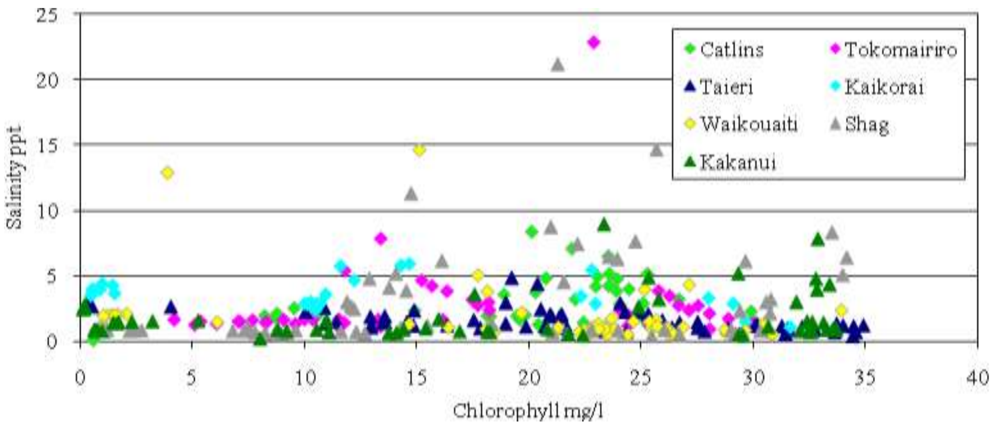

Figure 9-11 Catlins, Tokomairiro, Taieri, Kaikorai, Waikouaiti, Shag and Kakanui estuaries. Chlorophyll plotted against salinity

10. Discussion

10.1 Broad-scale monitoring

The presence of macroalgal blooms indicate that estuary eutrophication may be taking place. Decaying macroalgae blooms can accumulate on shorelines, depleting the sediment of oxygen and causing nuisance odours (Stevens *et al.*, 2008). The cause of the macroalgal blooms is complex and estuaries can vary in their susceptibility to the problem.

Results from the monitoring show that macroalgae were relatively scarce in the Shag and Waikouaiti estuaries and nuisance growths that could be attributed to enrichment were relatively minor and generally confined to back waters. *Enteromorpha* and *Cladophora* were present during summer, but they decreased in size over winter. Macroalgae were generally scarce in the Taieri, Kakanui and Kaikorai estuaries. Nuisance growths that could be attributed to enrichment were not evident anywhere within the estuaries. Macroalgae in the Catlins estuary were relatively scarce. Slightly downstream from the Hina Hina yacht club, *Gracilaria chilensis* and *Ulva lactuca* were present. This may be partially encouraged by nutrification, but it is also in a very sheltered embayment.

Monitoring indicated that salt marshes were well established (>20%) on four of the estuaries (Waikouaiti, Tokomairiro, Shag and Kaikorai). A salt marsh is a transitional intertidal area between land and salty or brackish water, which is dominated by halophytic (salt tolerant) herbaceous plants. Salt marshes are extremely productive habitats as they produce large quantities of plant detritus that serves a broad food chain of organisms from bacteria to mammals.

Marshes also act as buffers for the mainland by slowing and absorbing storm surges, thereby reducing erosion of the coastline. They are important for spawning, nursery and refuge habitat for many fish and shellfish species, as well as nesting, feeding and resting areas for birds and wildlife.

The main control on an estuary's ecology is its physical configuration: depth, pattern of subtidal (submerged at all stages of the tide) and intertidal (emerges from the water at low tide) habitats, and the nature of the substrate (mud, sand, or some mixture of the two). Soft mud is therefore another important indicator of estuary health. Estuaries fill with sediments eroded from two sources: the land; delivered mainly by rivers and streams during floods which fill in the upper reaches; and marine sands, washed in through the mouth on a regular basis by tides and waves which fill the lower reaches.

If there is a change in sediment run-off from the land, then the physical nature of the estuary will also change, and chances in the ecology will inevitably follow. A coarse indication of which estuaries should be targeted for more intensive monitoring are those with large areas of soft mud and changes in the area of mud over time. The Catlins estuary had the highest percentage cover with soft mud sediments at 29%; the Kaikorai estuary also had a high percentage (21%).

10.2 Fine-scale monitoring

The soft sediments in estuaries contain microbes, plants and animals that live in, burrow through, move across, sit on top of, stick together, eat, excrete in and mix the muds, silts and sands that cover the floor of estuaries. Some of these are well known and obvious (for example shellfish); others are less so (for instance, bacteria).

Benthic communities reflect the influence of contaminants, oxygen levels, physical changes in habitat and shifts in temperature or salinity (Cawthron, 2006). Species have lifespans ranging from several months to years, so their health reflects exposure to stresses over a long period, particularly as most species are fairly immobile. A change in habitat, due for example to increased pollution, may mean a shift from a community dominated by larger longer-lived species to a community dominated by smaller shorter-lived species (Cawthron, 2006).

The fauna of the Shag, Waikouaiti, Kaikorai and Taieri estuaries were representative of typical estuarine animals found in healthy environments (Morton and Miller, 1973). Mud crabs, mud snails, polychaete worms and amphipods are a feature of all estuaries in the Otago region and densities of these animals are as one would expect. Shellfish, such as cockles, are present in the Shag and Waikouaiti. In the Taieri and Kaikorai estuaries, shellfish are relatively scarce.

The Kakanui estuary had a low number of fauna species, but those present were representative of typical estuarine animals found in healthy environments (Morton and Miller, 1973). Densities of polychaete worms and amphipods were slightly lower than one would expect. Shellfish, such as cockles, were scarce in the inlet. Mud crabs and mud snails were notably absent from the lower estuary, probably due to the absence of suitable habitat. Mud crab burrows were, however, evident in mud banks along the margins of the upper estuary

In the Catlins estuary fauna is again representative of typical estuarine animals found in healthy environments. Shellfish, such as cockles, were common in the inlet, especially near Pounawea. Mud crabs and mud snails did not feature prominently in any of the cores sampled, but mud crab burrows were common at both sites, and mud snails (*Amphibola crenata*) were abundant (up to $50/m^2$), especially in the upper estuary (Catlins Lake).

10.3 Sediments

Various trace elements will be found naturally within the minerals which comprise the sediments. Natural weathering and erosion of rock and soils release trace elements into the waterways where they can be deposited onto the sediments in estuarine and coastal areas.

Agricultural activities involve the application to land of some materials that contain significant concentrations of one or more trace elements. There can be some loss of these elements from farms to the wider environment, including to freshwater and marine sediments (Environment Waikato, 2009). Examples of these losses include: land clearance, which may result in increased weathering and erosion; zinc sulphate applications, which are used extensively to protect against liver damage that causes facial eczema in both cattle and sheep; application of superphosphate fertilisers, which contain significant amounts of several trace elements as impurities, most notably cadmium and fluorine; copper and zinc, which are applied to horticultural areas in fungicide formulations; and urban stormwater run-off, which can transport many trace elements (including lead, copper and zinc)into waterways.

Trace elements tend to precipitate out and accumulate onto sediments in areas where there is a sudden change of redox conditions, salinity or pH, or where water velocities slow. Estuaries provide many of these conditions, making them prime candidates for accumulating sediment that may have elevated trace element concentrations.

The Shag and Waikouaiti estuaries showed little evidence of contamination of the sediments. The Shag estuary had slightly higher levels of metals than the Waikouaiti estuary, but none of the parameters examined exceeded the ANZECC (2000) ISQG – low trigger levels.

Levels of heavy metals usually associated with urban and road run-off (Zn, Cu, Fe) were low. The sediments within each estuary reflected the geology of their respective catchments, with the Shag estuary having a higher proportion of very fine sediment. There were extensive patches of anoxic sediment in both inlets, but nothing that would not be expected in moderately enriched estuaries.

The levels of contaminants at the Taieri River estuary were considerably lower than at, for example the Kaikorai estuary (Stewart, 2008). This is likely to be a reflection of the more remote location of this estuary. As can be expected, levels of heavy metals associated with urban and road run-off (Zn, Cu, Fe) were very low. The Taieri estuary had a lower proportion of very fine sediment compared with some other Otago estuaries (Stewart 2008) and there were patches of anoxic sediment within the inlet, consistent with moderately enriched estuaries.

The Kakanui River estuary showed higher levels of contamination on the left bank, when compared to the right bank, however, levels were very low and are most likely a factor of the left bank being less well flushed rather than stormwater run-off. The sediments had a high proportion of moderately fine sediment but very little silt or mud. Patches of anoxic sediment were present, as would be expected in a moderately enriched estuary.

There was some evidence of contamination of the sediments within the Kaikorai Stream estuary. The estuary had relatively high levels of heavy metals, with both lead and zinc slightly exceeding the ANZECC (2000) ISQG - Low trigger levels at the upstream site. There was a high proportion of very fine sediment, especially upstream of the Taieri Mouth Road bridge; the estuary also has patches of anoxic sediment.

There was little evidence of contamination of the sediments within the Catlins estuary. The estuary had very low levels of heavy metals, with no contaminants exceeding the ANZECC (2000) ISQG - Low trigger levels at the either fine-scale site. The sediments within the estuary reflect the geology of the Catlins and Owaka River catchments, with there being a high proportion of very fine sediment, especially in Catlins Lake and along the lower reaches of the Owaka River. There were also patches of anoxic sediment within the estuary.

Organic matter in estuarine sediments is rich in nutrients derived from two sources: land run-off, which transports organic matter to the coastal environment; and near-shore processes, which generate organic carbon (such as algal biomass and aquatic plant growth) that is deposited in sediments.

Significant changes in benthic community structure can occur when sediments accumulate high levels of organic matter. For example, the organic content can play an important role in determining redox (reduction-oxidation) potential of sediments.

The organic matter in coastal sediments plays an important role in determining the fate and toxicity of metals and organic compounds in the marine environment. Metals are generally more mobile under oxidising conditions and therefore can be released into the water column overlaying the sediments, where they will be more bio-available to organisms. Organic compounds can also adsorb metals and other organic matter, thereby concentrating them into sediments and making them less bioavailable.

The upstream site in the Kaikorai estuary had the highest percentage of organic carbon, and a relatively high TOC:TN ratio, indicating a terrestrial source of organic matter. The Kakanui right bank had a low percentage of organic carbon. The TOC:TN ratio for the Kakanui was very low (6.5), which indicates a marine source of organic carbon.

10.4 Water quality

ANZECC (2000) default trigger values for physical and chemical stressors in estuarine waters (slightly disturbed ecosystems) contain no New Zealand data, and the guidelines recommend that regional specific trigger values are used in preference to the ANZECC (2000) values. A useful exercise was to categorise the key parameters for the seven monitored estuaries. The format used to define these categories is the same as that used in Tasmania (Murphy *et al*., 2003). Table 10-1 divides each parameter into four categories (low, medium, high and very high).

Table 10-1 Categories of turbidity, chlorophyll, nitrite-nitrate nitrogen and dissolved reactive phosphorus levels.

Category	*Turbidity NTU*	*Chlorophyll mg/l*	*Nitrite-nitrate nitrogen mg/l*	*Dissolved reactive phosphorus mg/l*
Low	0 to 4	0 to 2	0 to 20	0 to 5
Medium	>4 to 10	>2 to 5	>20 to 50	>5 to 15
High	>10 to 20	>5 to 10	>50 to 100	>15 to 30
Very High	>20	>10	>100	>30

Table 10-2 shows each estuary and the category for each parameter (the median results from all sampling occasions was taken to derive the category). Table 10-3 shows the individual sampling occasion results

Table 10-2 Categories of turbidity, chlorophyll, nitrite nitrate nitrogen and dissolved reactive phosphorus levels. The median results for all sampling occasions are categorised for each estuary

Estuary	*Turbidity NTU*	*Chlorophyll mg/l*	*Nitrite-nitrate nitrogen mg/l*	*Dissolved reactive phosphorus mg/l*
Catlins estuary	5.7	2.71	26.5	25
Tokomairiro estuary	5.8	1.66	46	25
Taieri estuary	5.4	1.36	25	25
Kaikorai estuary	10	3.39	56	22
Waikouaiti estuary	2.1	0.99	25	25
Shag estuary	3.2	0.88	48	25
Kakanui estuary	2.5	0.98	40	25

Table 10-3 Categories of turbidity, chlorophyll, nitrite-nitrate nitrogen and dissolved reactive phosphorus levels. The median results for each sampling occasion are categorised for each estuary

Estuary	*Number of sampling occasions*	*Turbidity NTU*	*Chlorophyll mg/l*	*Nitrite-nitrate nitrogen mg/l*	*Dissolved reactive phosphorus mg/l*
Catlins estuary	11*	3	4	1	
		5	5	7	
		2	1	2	11
				1	
Tokomairiro estuary	7*	1	4	1	
		4	3	1	1
		1		4	3
		1		1	3
Taieri estuary	10*	3	8	3	
		3	1	6	1
		2			9
		1		1	
Kaikorai estuary	7*	1		2	
		1	4	1	2
		2		1	5
		1		4	1
Waikouaiti estuary	12*	8	8	5	
		2	1	6	4
					9
				1	
Shag estuary	10*	5	5	1	
		2	2	4	3
		1	2	1	7
		1		4	
Kakanui estuary	11*	8	8	1	
		2	2	6	3
		1		2	6
				2	2

*Where individual sample numbers did not add up to total sampling occasions, there was no result available.

Turbidity is influenced by the level of suspended solids. Life in estuaries depends on plant production for much of its energy; plants, in turn, depend on sunlight for photosynthesis. When the water is too turbid, too much light is diffused and not enough reaches plants that need it, and production decreases. Turbidity also affects fish and aquatic life by clogging fish gills and the feeding apparatus of bottom dwelling-animals with suspended particles, by obscuring the vision of fish as they hunt for food and by smothering bottom-dwelling animals.

Although ANZECC (2000) suggests turbidity is not a very useful indicator for estuarine and marine waters, Ward *et al.*, (1998) valued its use as an indicator because it is easily measured in the field. ANZECC (2000) guidelines provide a range of default trigger values for SE Australian estuaries (0.5 to 10 NTU), the values vary due to site specificity and regional variability. This range encompasses the low (0 to 4NTU) and medium (4.1 to 10NTU) used for the estuary categorisation. Three of the seven estuaries studied had median turbidity values in the low category.

High chlorophyll concentrations indicate that there is an algal bloom, which will contribute to the turbidity of the water and increase suspended solids (ANZECC 2000). Average and median chlorophyll concentrations were very low for most estuaries. This is reflected in the low category of 0 to2µg/l, which is lower than the ANZECC trigger value of 4µg/l. Of the seven estuaries monitored, only the Kaikorai had a median concentration of chlorophyll of more than 3µg/l.

Nitrogen and phosphorus are key water quality parameters in estuaries as they influence plant growth, oxygen concentrations, water clarity and sedimentation rates. Table 10.3 shows that a broad range of NNN categories were recorded in most estuaries. All the estuaries recorded median NNN concentrations in the high category on at least one sampling occasion, the Kaikorai estuary reaching this level on four sampling occasions. None of the estuaries had median NNN values that fell in the low category of <20µg/l (which is slightly higher than the ANZECC estuarine trigger value of 15µg/l). The medium to high NNN values recorded are probably a function of natural riverine input (for example, ANZECC default trigger values are 0.444mg/l for New Zealand lowland rivers), rather than excessive anthropogenic input.

Like NNN, a broad range of DRP concentrations were recorded. The Tokomairiro, Kakanui and Kaikorai estuaries had concentrations that fell into the high category on at least one occasion, the Tokomairiro estuary reaching this level on three sampling occasions. None of the estuaries had median values that fell into the low or medium categories.

The Tokomairiro estuary had a high maximum concentration of NH_4 (0.82mg/l). The ANZECC guideline for NH_4 (based on data from SE Australia) is 0.015mg/l. The Waikouaiti estuary meets this guideline level; while median NH_4 concentrations in all the other estuaries only just exceeded this guideline value.

The presence of pathogens (viruses, bacterial and protozoans that cause disease) are of concern in areas where waters are used for swimming, boating, shellfishing or other contact recreation activities There were no exceedences of the MfE/MoH surveillance/green mode level (>260 cfu/100ml) for *E. coli* in the Catlins and Tokomairiro estuaries, and the Taieri and Shag estuaries did not exceed the MfE/MoH alert/amber mode level (>550 cfu/100ml) for *E. coli.* However, there were significant bacteria concentrations found in the Kaikorai estuary. On five sampling occasions (out of eight), bacteria levels exceeded 550cfu/100ml. Significant bacteria concentrations were also found in the Waikouaiti estuary on one sampling occasion (out of 12), but this was due to significant rainfall prior to the sampling event.

Perhaps the most reliable indicator of pathogen concentration within estuarine waters is the concentration of enterococci, which are found only in the gut of warm blooded animals. The Catlins and the Shag estuaries recorded maximum enterococci levels within the MfE/MoH 2003 surveillance/green mode level for enterococci (>140 enterococci/100ml); however, the Kaikorai, Kakanui, Taieri and Tokomairiro estuaries exceeded the action /red level for enterococci (>280 enterococci/100ml) on at least one sampling occasion.

As a result of estuarine and coastal development, contaminants such as heavy metals can enter estuaries. Many of these are persistent, bioaccumulate and incorporate into sediments.

Zinc was the only metal monitored, as it was intended to be used as an indicator for the presence of other metals. In every estuary, the total zinc concentration exceeded both guideline values at some point during the monitoring period. Only the Shag estuary met the ANZECC freshwater guideline for zinc (0.008mg/l) and only the Kaikorai estuary exceeded the marine ANZECC 2000 trigger value (0.015mg/ll). It is likely that the source of this zinc is mainly stormwater run-off from the urban catchment.

The Catlins estuary had levels of zinc just below the guideline level. The geological map of the South Island (Figure 10-1) shows the Catlins is formed on volcaniclastic deposits (which are part of the Murihiku terrain). The other estuaries are generally dominated by schist. This difference in geology accounts for natural variation in metal concentrations in water.

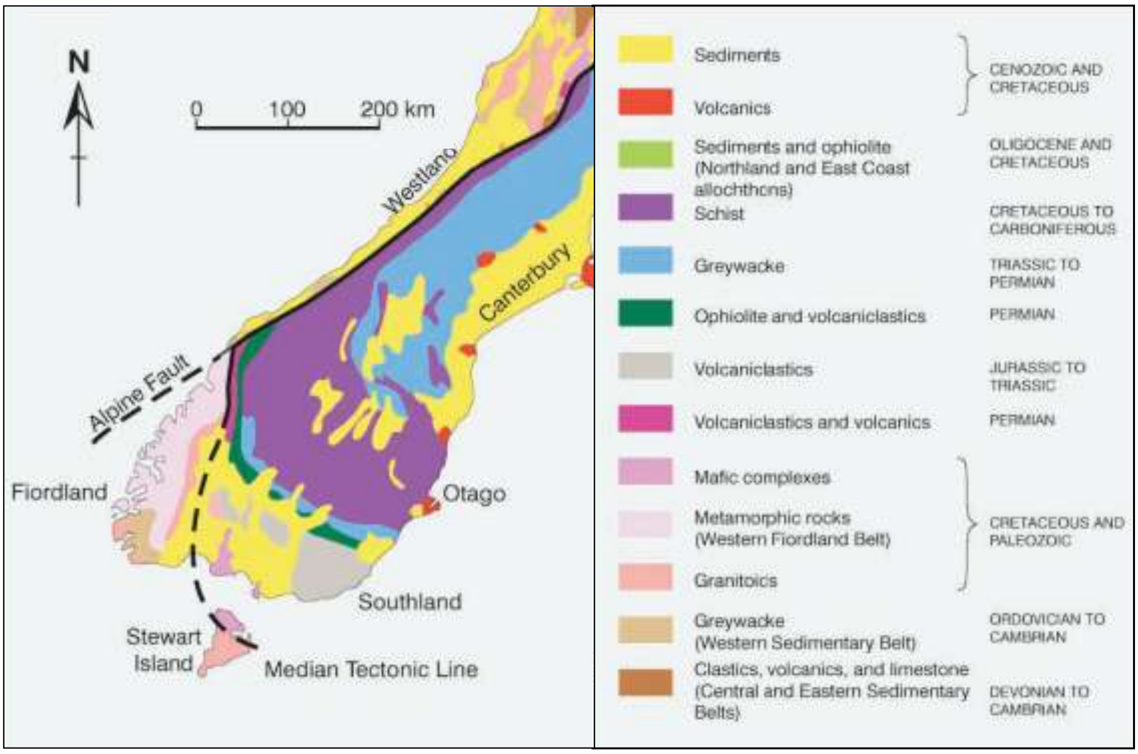

Figure 10-1 Geology of the South Island (GNS)

11. Conclusion

All the estuaries appear to be in good health. The fine-scale monitoring indicated that the fauna of the estuaries are generally representative of typical estuarine animals found in healthy environments (Morton and Miller, 1973). Mud crabs, mud snails, polychaete worms and amphipods are a feature of all estuaries in the Otago region and densities of these animals are as one would expect in healthy estuaries.

The fine-scale monitoring also showed that only the Kaikorai estuary had some evidence of contamination of the sediments. The estuary had some elevated concentrations of heavy metals, with both lead and zinc slightly exceeding the ANZECC (2000) ISQG - Low trigger levels at the upstream site.

The broad-scale monitoring indicated that the estuaries all had a healthy suite of estuarine flora, mainly dominated by herbfields and grassland. Macroalgae was relatively scarce and where present confined to backwaters.

The water quality monitoring has enabled estuaries to be catagorised according to their DRP, NNN, turbidity and chlorophyll *a* levels. Using the same format that was used to define categories for estuaries in Tasmania (Murphy *et al.*, 2003), the following can be noted:

- The Catlins, Tokomairiro and Taieri estuaries have low chlorophyll, medium turbidity and NNN, and high DRP concentrations
- The Kaikorai estuary has medium turbidity and chlorophyll levels and high NNN and DRP levels
- The Waikouaiti and Shag estuaries have low turbidity and chlorophyll, medium NNN and high DRP levels

The National Estuary Monitoring Protocol provides a simple, defensible and cost-effective strategy to assess and monitor estuary condition. The baseline monitoring has been undertaken for seven estuaries, and it is envisaged that the process will be repeated in the future to monitor any change.

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Appendix A - Broad-scale habitat mapping

The following maps were generated by Ryder Consulting Ltd. More clarity and detail is available on GIS files stored at the ORC offices in Dunedin.

Catlins estuary

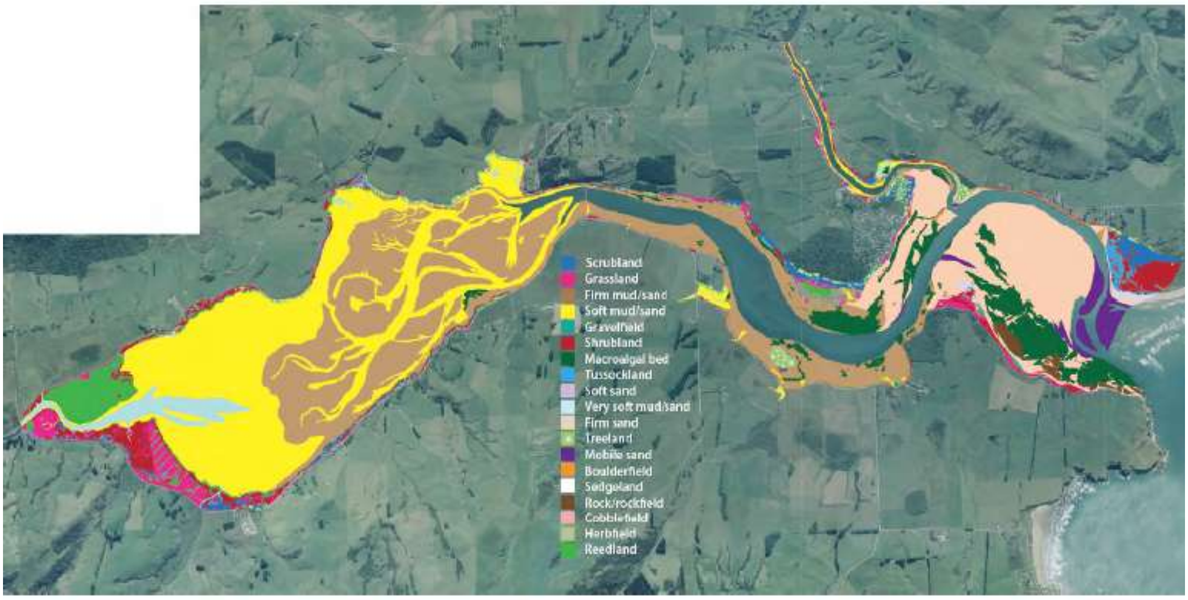

Figure A-1 GIS habitat map of Catlins estuary

Kakanui estuary

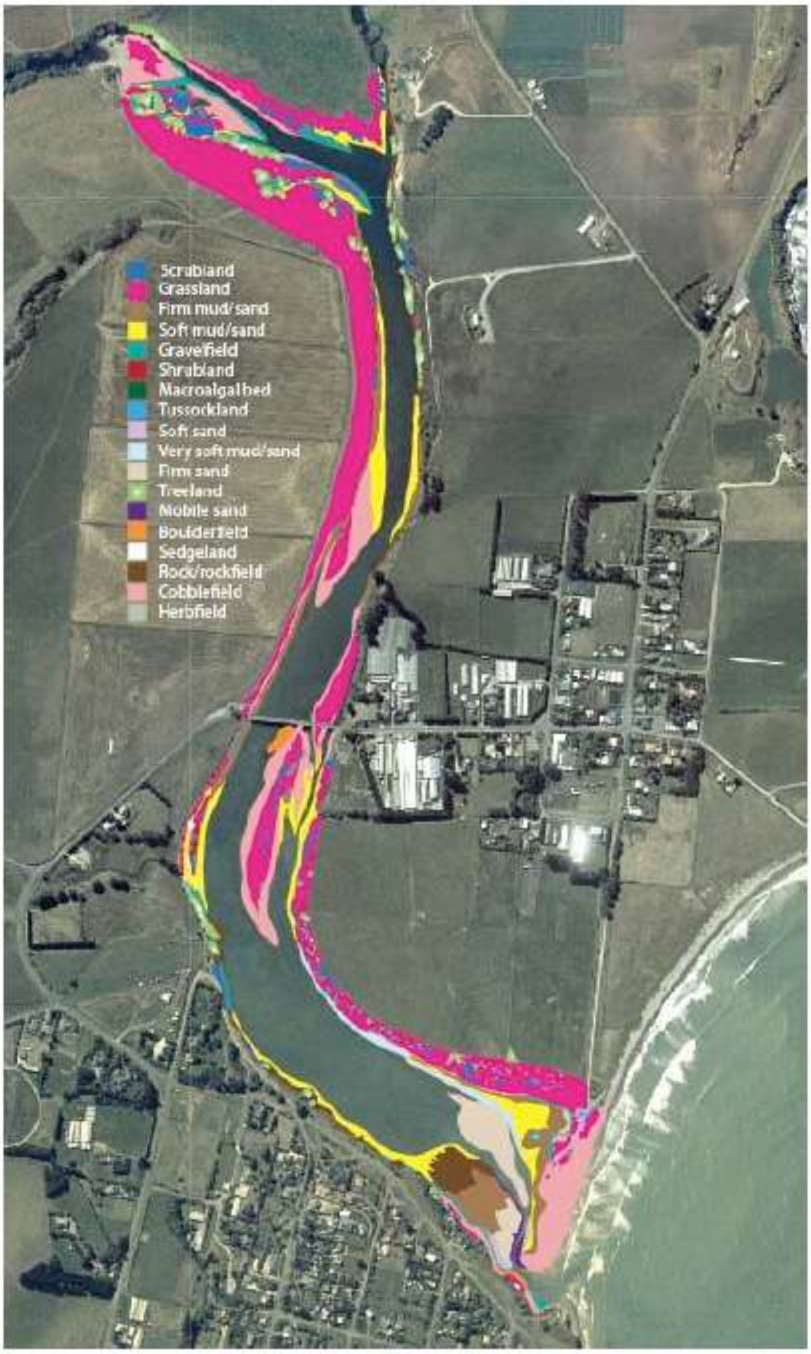

Figure A-2 GIS habitat map of Kakanui estuary

Waikouaiti estuary

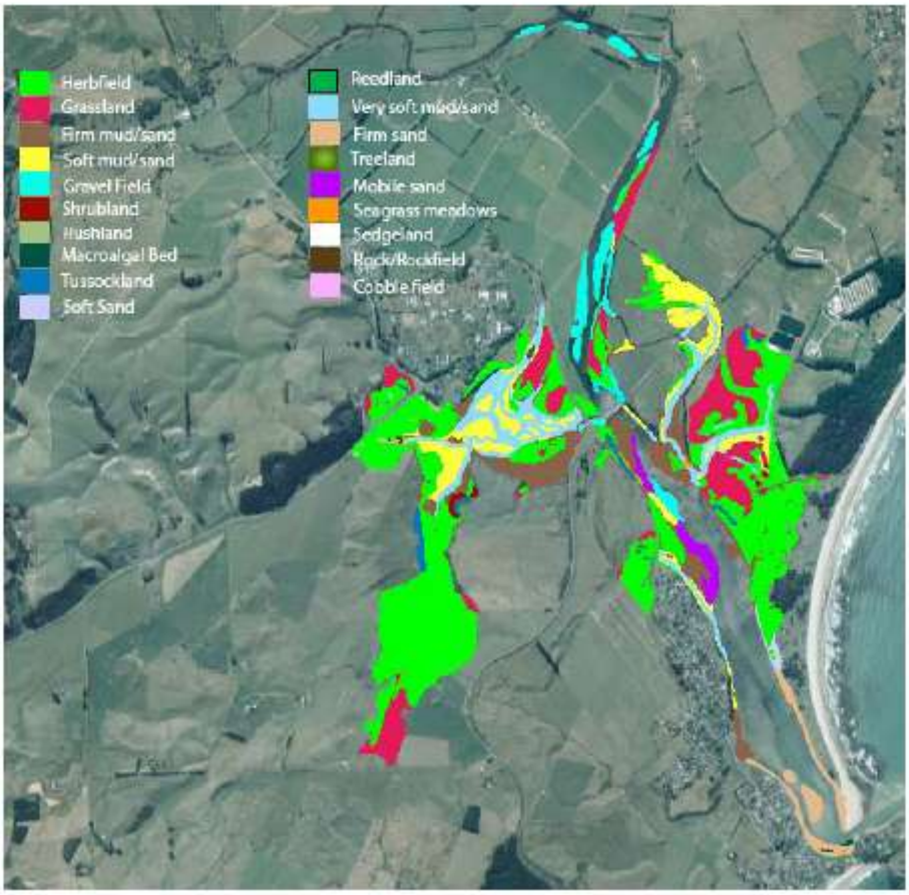

Figure A-3 GIS habitat map of Waikouaiti estuary

Shag estuary

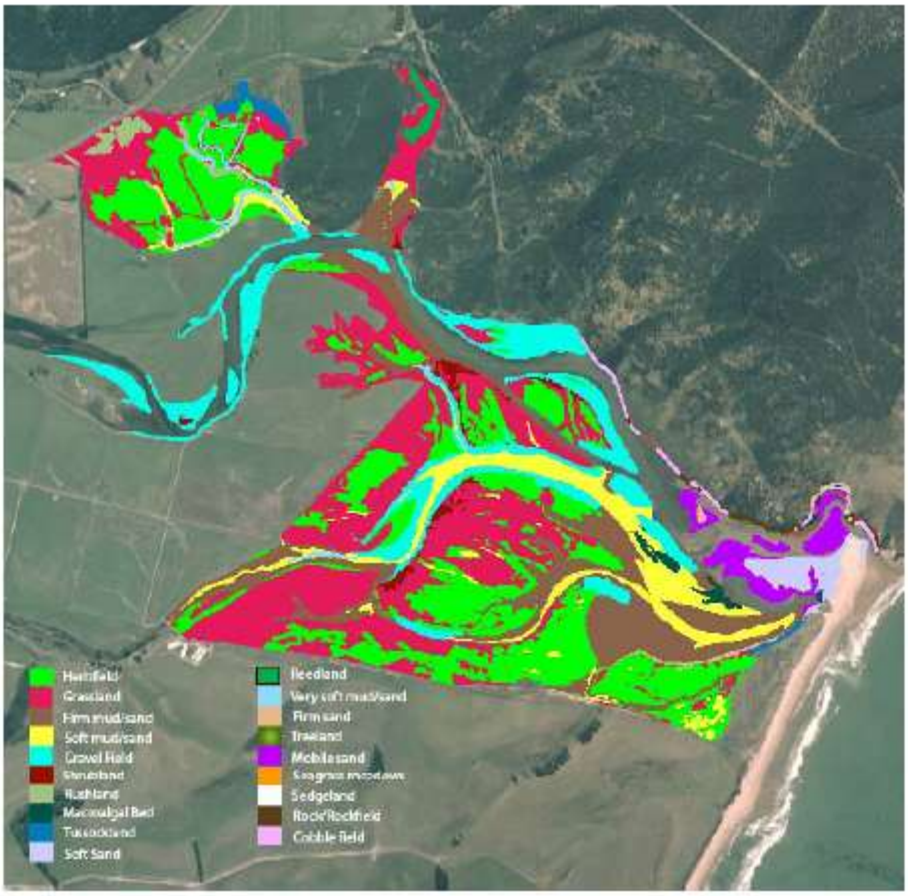

Figure A-4 GIS habitat map of Shag estuary

Kaikorai estuary

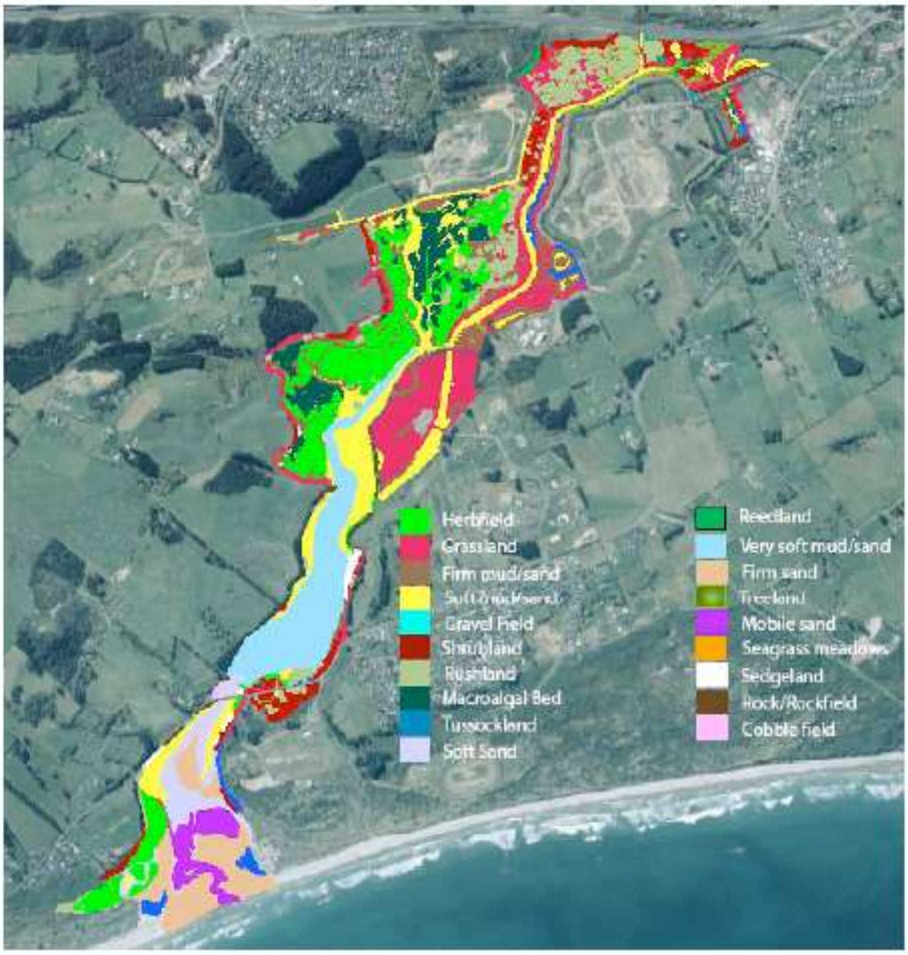

Figure A-5 GIS habitat map of Kaikorai estuary

Taieri estuary

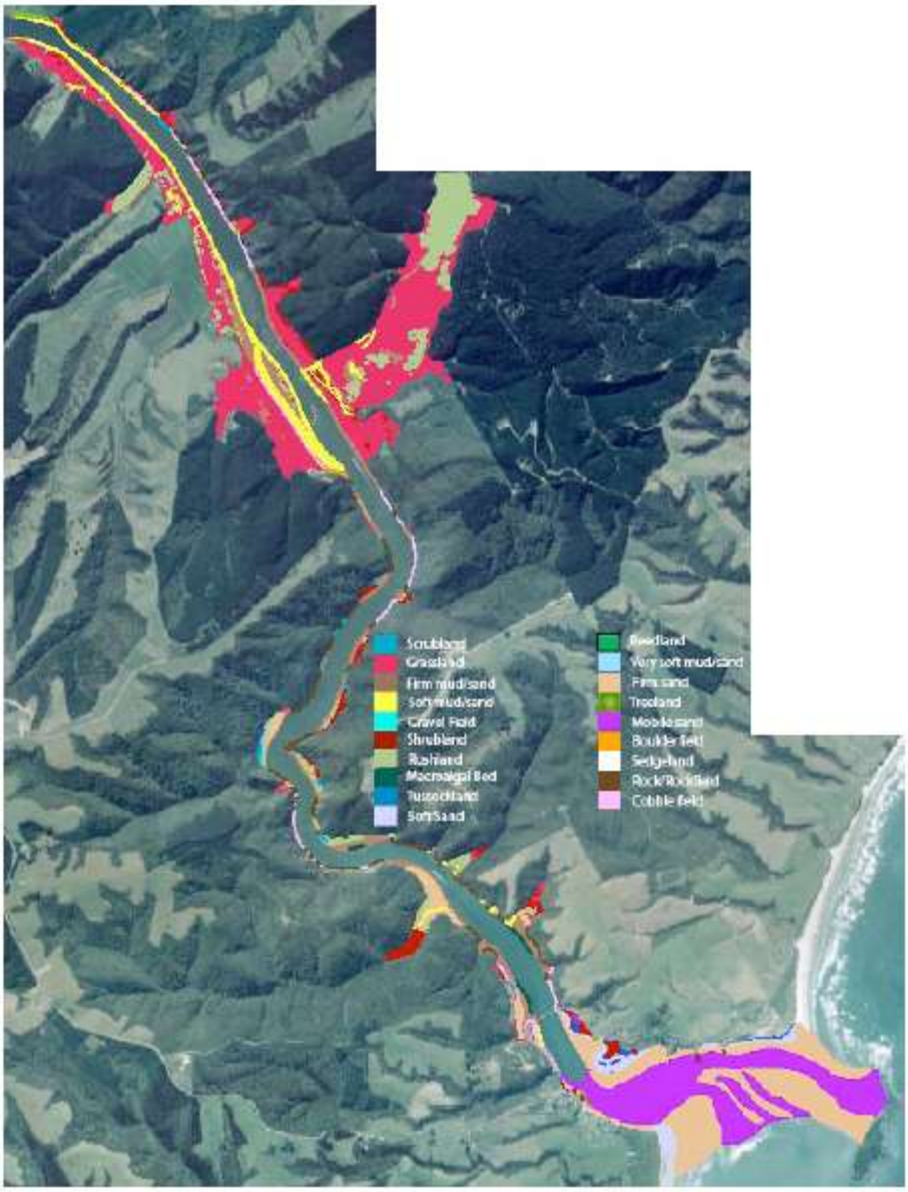

Figure A-6 GIS habitat map of Taieri estuary

Tokomairiro estuary

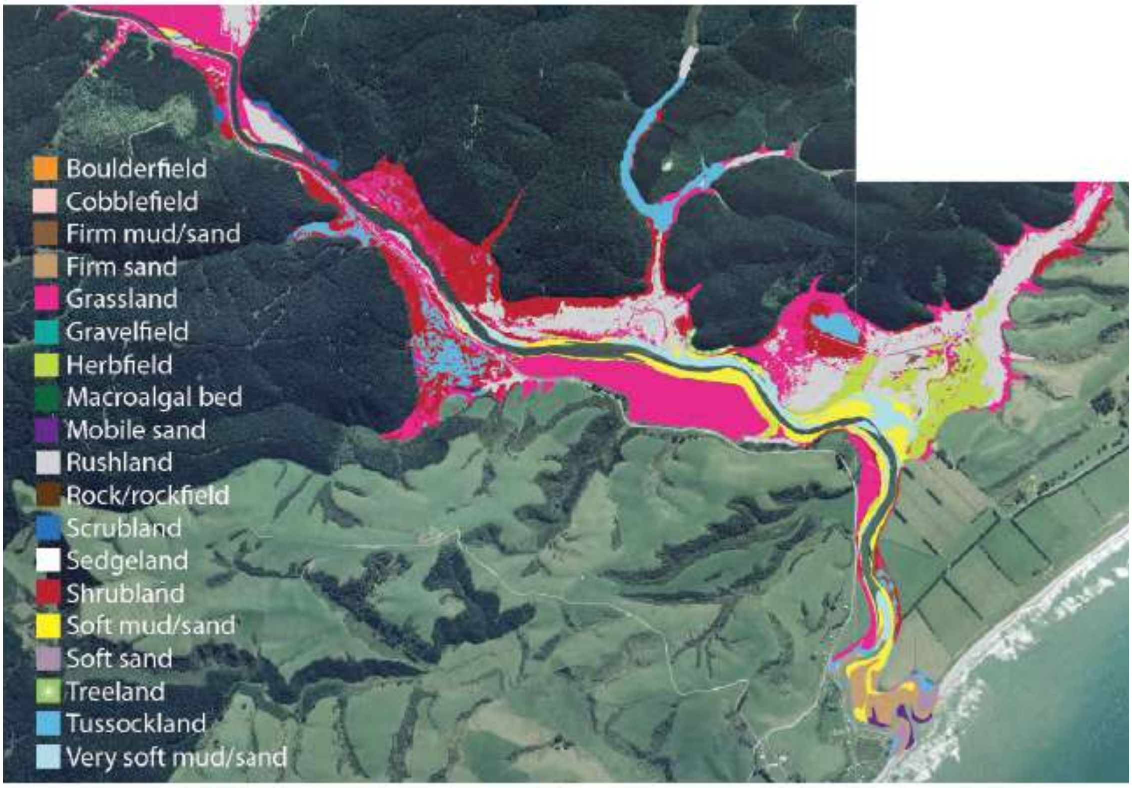

Figure A-7 GIS habitat map of Tokomairiro estuary

Appendix B - Stratification status

Stratification (i.e. the layering of the estuary.), is generally associated with the inflow of denser salt water at depth and the outflow of more buoyant fresh-water at the surface. Stratification can also occur when seasonal heating causes a sharp differential or thermocline so that the warm surface layer is isolated from the colder bottom layer.

In stratified estuaries, bacteria is more likely to be elevated in the surface waters, rather than in the more saline bottom waters. Profile monitoring showed that vertical stratification was very distinct in three of the river estuaries (Catlins, Kakanui and Waikouaiti) and less distinct in the Taieri, Shag, Kaikorai, and Tokomairiro estuaries. Figures A2 to A7 show each estuary over a six-hour time-frame, with salinity and depth indicating the stratification status.

The figure below shows an example of stratification in the Catlins estuary. The figure clearly shows the denser salt water forming a layer underneath the more buoyant freshwater at a depth of about 3m.

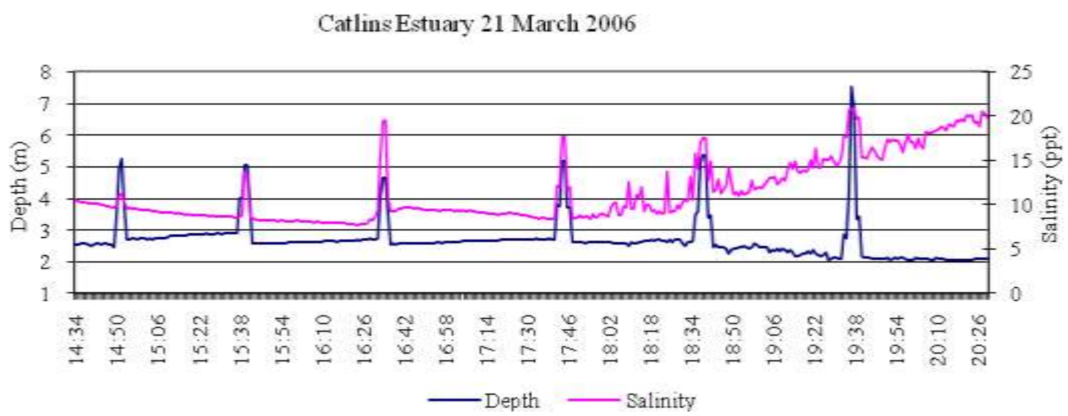

Figure B-1 Catlins estuary, 21 March 2006. The estuary was stratified

The figure below shows an example of stratification in the Waikouaiti estuary. The figure clearly shows that salinity increased with depth (i.e. when the water quality probe was lowered at hourly intervals, salinity increased).

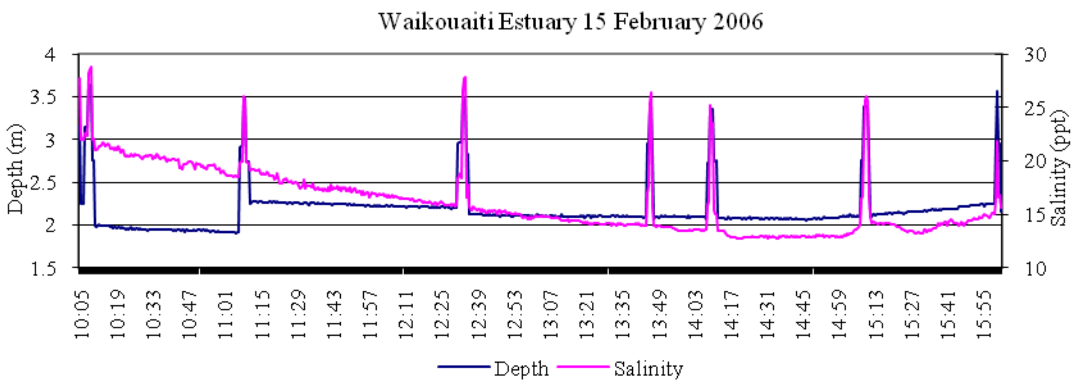

Figure B-2 Waikouaiti estuary, 15 February 2006. The estuary was stratified

The figure below shows an example of stratification in the Kakanui estuary. The figure indicates that salinity increased rapidly at depths of over 3m, meaning stratification of saline and fresh-water.

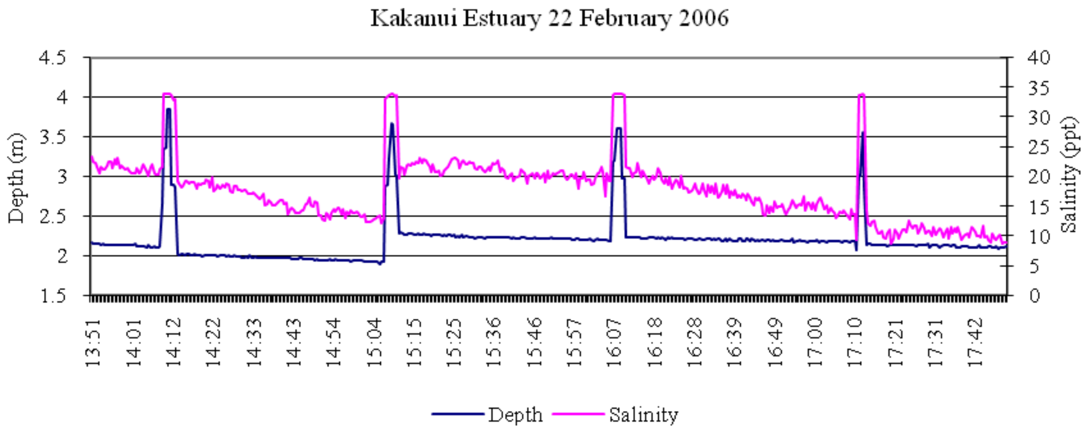

Figure B-3 Kakanui estuary, 22 February 2006. The estuary was stratified

The figure below shows an example of moderate stratification in the Taieri estuary on the 31st January 2006. The figure indicates that salinity did not generally increase with depth, although it could be argued that some stratification of saline and freshwater occurred at low tide.

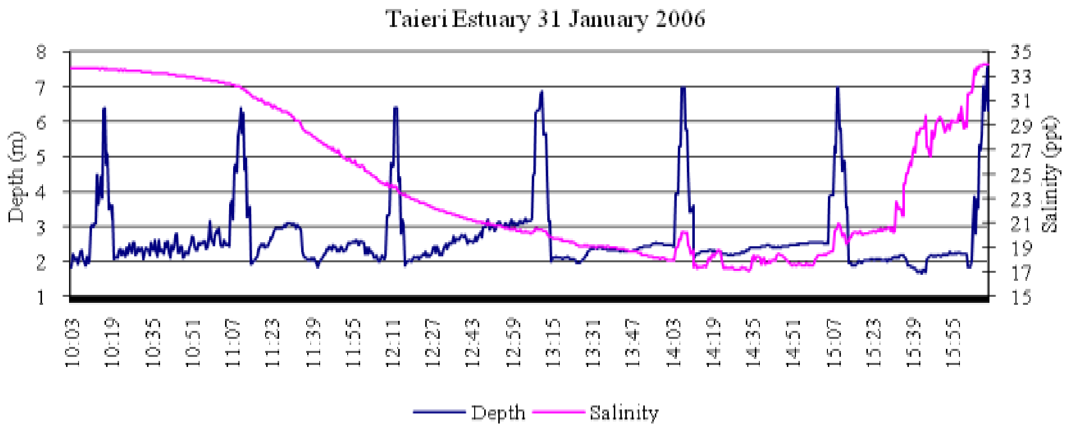

Figure B-4 Taieri estuary, 31 January 2006. The estuary was moderately stratified

The figure below shows an example vertical mixing in the Kaikorai estuary on 14 November 2007. The figure shows the time series, which does not record a marked increase in salinity when the water quality probe was lowered at hourly intervals, suggesting that the estuary was not stratified, probably due to its shallowness.

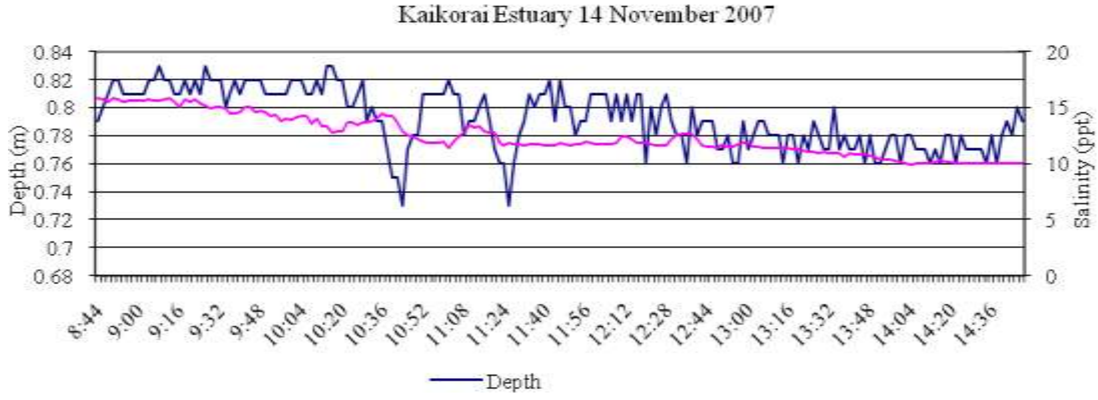

Figure B-5 Kaikorai estuary, 14 November 2007. The estuary was vertically mixed

The figure below shows an example vertical mixing in the Tokomairiro estuary on 8 May 2008. The figure shows the time series, which does not record a marked increase in salinity when the water quality probe was lowered at hourly intervals, suggesting that the estuary was not stratified. Again, this is probably due to its shallowness.

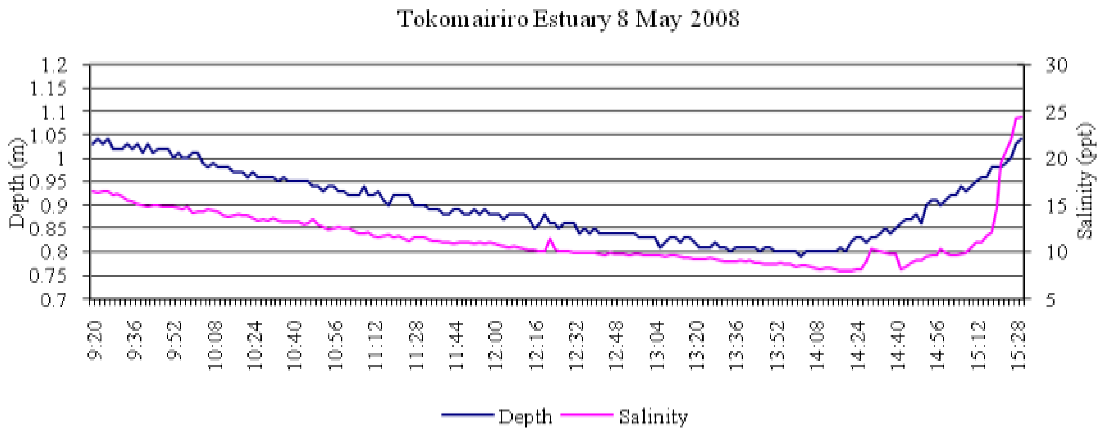

Figure B-6 Tokomairiro estuary, 8 May 2008. The estuary was vertically mixed

The figure below shows an example of vertical mixing in the Shag estuary on 20 April 2006. The figure shows the time series, which does not record a marked increase in salinity when the water quality probe was lowered at hourly intervals, suggesting that the estuary is not stratified, probably due to its shallowness.

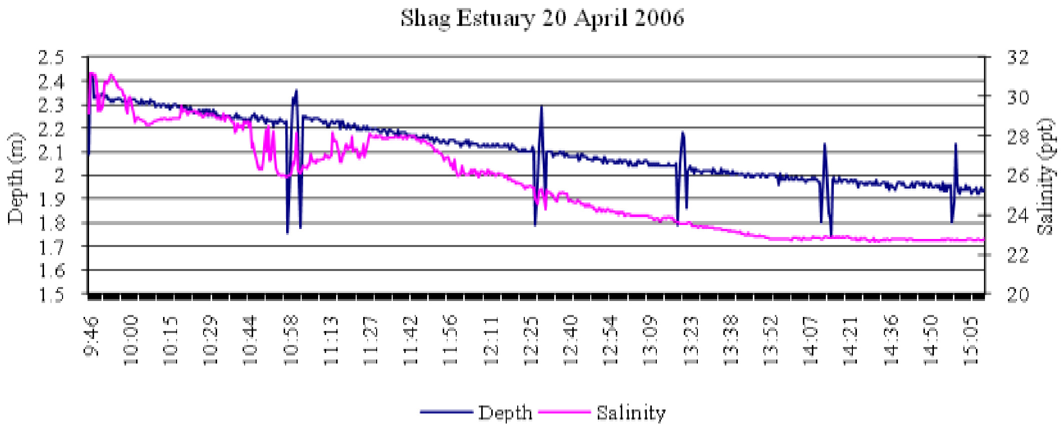

Figure B-7 Shag estuary, 20th April 2006. The estuary was vertically mixed

Appendix C - Water quality results

Catlins estuary - laboratory results

Catlins	Time	NH4 mg/l	Chl mg/l	DRP mg/l	Ent cfu /100ml	E.coli cfu /100ml	F.coli cfu /100ml	NNN mg/l	SS mg/l	TN mg/l	TP mg/l	TZn mg/l
03/02/05	06:00	0.08	7700	0.025	5	31	50	0.049	30	0.61	0.025	0.02
03/02/05	07:00	0.06	8690	0.024	5	5	10	0.049	38	0.47	0.025	0.04
03/02/05	08:00	0.1	10000	0.009	5	10	27	0.007	43	0.58	0.025	0.03
03/02/05	09:00	0.09	11700	0.025	5	5	10	0.009	47	0.57	0.025	0.02
03/02/05	10:00	0.11	14800	0.025	5	10	15	0.019	54	0.41	0.025	0.07
03/02/05	11:00	0.17	16300	0.025	5	5	5	0.013	57	0.44	0.025	0.06
03/02/05	12:00	0.21	15000	0.025	5	10	5	0.013	55	0.41	0.025	0.07
03/02/05	13:00	0.13	15000	0.025	5	10	25	0.008	63	0.33	0.025	0.08
03/02/05	14:00	0.18	12900	0.025	5	5	5	0.011	57	0.32	0.025	0.07
03/02/05	15:00	0.08	11100	0.018	5	10	5	0.014	45	0.33	0.025	0.01
03/02/05	16:00	0.12	9300	0.025	5	20	10	0.03	46	0.39	0.025	0.01
03/02/05	17:00	0.09	8560	0.025	5	10	10	0.037	46	0.39	0.025	0.01
21/03/06	14:30	0.03	4670	0.019	5	10	35	0.184	13	0.39	0.025	0.0065
21/03/06	15:30	0.03	4250	0.018	5	20	35	0.191	14	0.58	0.025	0.0065
21/03/06	16:30	0.03	4390	0.019	5	5	45	0.182	14	0.41	0.025	0.0065
21/03/06	17:30	0.02	5640	0.016	5	5	10	0.182	11	0.4	0.025	0.0065
21/03/06	18:30	0.02	7360	0.025	5	20	5	0.122	16	0.32	0.025	0.0065
21/03/06	19:30	0.02	9170	0.025	5	5	10	0.094	18	0.27	0.025	0.0065
21/03/06	20:30	0.03	5340	0.019	5	30	32	0.173	13	0.34	0.025	0.051
28/03/06	07:30	0.03	11400	0.025	5	10	25	0.065	17	0.19	0.025	0.021
28/03/06	08:30	0.03	10800	0.025	5	10	15	0.049	16	0.17	0.025	0.023
28/03/06	09:30	0.03	9980	0.025	8	4	4	0.062	13	0.22	0.025	0.0065
28/03/06	10:30	0.03	10100	0.025	2	8	8	0.064	11	0.16	0.025	0.0065
28/03/06	11:30	0.03	10600	0.025	2	8	8	0.049	16	0.2	0.025	0.0065
28/03/06	12:30	0.02	13500	0.025	2	8	8	0.032	17	0.17	0.025	0.0065
28/03/06	11:31		16400		2	2	2	0.044	20	0.24	0.025	0.03
03/04/06	12:00	0.005	15100	0.025	5	5	15	0.027	11	0.27	0.025	0.0065
03/04/06	13:00	0.01	14600	0.025	5	5	5	0.026	19	0.22	0.025	0.0065
03/04/06	14:00	0.005	13600	0.025	5	5	10	0.065	23	0.22	0.025	0.0065
03/04/06	15:00	0.005	13500	0.025	5	10	20	0.035	18	0.19	0.025	0.0065
03/04/06	16:00	0.005	13900	0.025	5	5	5	0.039	17	0.21	0.025	0.0065
03/04/06	17:00	0.005	15200	0.025	5	5	5	0.023	21	0.17	0.025	0.0065
03/04/06	18:00	0.005	16700	0.025	5	5	5	0.026	17	0.23	0.025	0.0065
07/11/06	10:20	0.005	13900	0.025	5	5	5	0.025	27	0.27	0.025	0.265
07/11/06	11:20	0.005	12500	0.025	5	5	5	0.025	28	0.27	0.025	0.021
07/11/06	12:20	0.01	11700	0.025	5	10	5	0.025	24	0.3	0.025	0.016
07/11/06	13:20	0.01	11600	0.025	5	5	5	0.025	24	0.29	0.025	0.015
07/11/06	14:20	0.01	11900	0.025	5	5	5	0.025	25	0.34	0.025	0.039
07/11/06	15:30	0.005	14200	0.025	5	5	5	0.025	27	0.22	0.025	0.018
07/11/06	16:20	0.005	18200	0.025	10	5	5	0.034	34	0.27	0.025	0.023
01/02/07	06:00	0.005	18100	0.025	10	10	5	0.025	24	0.19	0.025	0.129
01/02/07	07:00	0.005	16900	0.025	5	5	9	0.04	32	0.28	0.025	0.132
01/02/07	08:00	0.005	14900	0.025	2	12	12	0.025	29	0.39	0.025	0.078

Catlins estuary - laboratory results

Catlins	Time	NH4 mg/l	Chl mg/l	DRP mg/l	Ent cfu /100ml	E.coli cfu /100ml	F.coli cfu /100ml	NNN mg/l	SS mg/l	TN mg/l	TP mg/l	TZn mg/l
01/02/07	09:00	0.005	14300	0.025	2	4	4	0.025	32	0.35	0.025	0.128
01/02/07	10:00	0.005	13400	0.025	2	32	32	0.025	26	0.35	0.025	0.0065
01/02/07	11:00	0.005	13300	0.025	4	12	12	0.025	30	0.29	0.025	0.114
01/02/07	12:00	0.005	13300	0.025	2	8	8	0.025	27	0.28	0.025	0.147
07/02/07	11:30	0.005	13800	0.025	5	10	5	0.03	11	0.25	0.025	0.0065
07/02/07	12:30	0.005	13500	0.025	5	5	5	0.089	23	0.34	0.025	0.023
07/02/07	13:30	0.005	12300	0.025	5	5	5	0.021	22	0.32	0.025	0.0065
07/02/07	14:30	0.005	12000	0.025	5	10	5	0.021	26	0.35	0.025	0.0065
07/02/07	15:30	0.005	12000	0.025	5	5	5	0.025	21	0.32	0.025	0.0065
07/02/07	16:30	0.005	13000	0.025	5	10	5	0.051	21	0.42	0.025	0.0065
07/02/07	17:30	0.005	14800	0.025	5	5	5	0.033	13	0.33	0.025	0.0065
22/04/08	07:00	0.03	23600	0.025				0.074	17	0.73	0.042	0.008
22/04/08	08:00	0.03	20500	0.025				0.041	26	0.46	0.046	0.01
22/04/08	09:00	0.03	17700	0.025	58	38	38	0.065	34	0.49	0.025	0.006
22/04/08	10:00	0.02	18900	0.025	64	46	46	0.063	43	0.51	0.034	0.093
22/04/08	11:00	0.03	17000	0.025	46	80	80	0.066	39	0.56	0.051	0.09
22/04/08	12:00	0.02	15300	0.025	18	36	36	0.065	43	0.6	0.039	0.09
22/04/08	13:00	0.02	16100	0.025	6	24	24	0.06	29	0.42	0.025	0.092
23/04/08	07:30	0.005	20500	0.025				0.026	47	0.27	0.029	0.077
23/04/08	08:30	0.02	17500	0.025				0.067	77	0.49	0.048	0.078
23/04/08	09:30	0.02	15600	0.025	110	70	70	0.093	95	0.55	0.041	0.08
23/04/08	10:30	0.02	16200	0.025	92	40	40	0.086	77	0.42	0.028	0.08
23/04/08	11:30	0.02	16300	0.025	46	44	44	0.075	75	0.47	0.027	0.081
23/04/08	12:30	0.02	15800	0.025	20	62	62	0.08	73	0.48	0.034	0.023
23/04/08	13:30	0.02	16300	0.025	18	50	52	0.078	53	0.55	0.027	0.08
11/02/09	08:00	0.02	18700	0.025	76	2	4	0.025	39	0.37	0.025	0.0065
11/02/09	09:00	0.02	19800	0.025	34	12	50	0.025	40	0.37	0.025	0.02
11/02/09	10:00	0.005	16900	0.025	60	18	24	0.025	40	0.48	0.055	0.0065
11/02/09	11:00	0.005	18600	0.025	66	20	88	0.025	41	0.5	0.025	0.0065
11/02/09	12:00	0.005	22000	0.025	58	14	16	0.025	39	0.41	0.025	0.0065
11/02/09	13:00	0.005	15100	0.025	50	24	44	0.025	40	0.43	0.025	0.014
11/02/09	14:00	0.005	16800	0.025	58	16	8	0.025	39	0.52	0.025	0.019
10/03/09	08:00	0.01	13500	0.025	8	15	15	0.025	15	0.25	0.025	0.0065
10/03/09	09:00	0.01	13900	0.025	10	18	23	0.025	17	0.34	0.025	0.0065
10/03/09	10:00	0.01	13800	0.025	10	19	27	0.025	35	0.56	0.025	0.0065
10/03/09	11:00	0.01	14000	0.025	8	56	56	0.025	28	0.53	0.025	0.013
10/03/09	12:00	0.01	14300	0.025	2	15	15	0.025	31	0.31	0.025	0.0065
10/03/09	13:00	0.02	16000	0.025	2	9	9	0.025	33	0.29	0.025	0.0065
10/03/09	14:00	0.03	18200	0.025	4	2	2	0.025	37	0.24	0.025	0.0065
	MAX	0.21	23600	0.025	110	80	88	0.191	95	0.73	0.055	0.265
	MIN	0.005	4250	0.009	2	2	2	0.007	11	0.16	0.025	0.006
	MEDIAN	0.02	13950	0.025	5	10	10	0.0265	28	0.34	0.025	0.0135
	MEAN	0.03	13851	0.02	15.15	15.63	19.35	0.05	32.24	0.36	0.03	0.04
	COUNT	81	82	81	78	78	78	82	82	82	82	82

Catlins estuary - field results

Catlins	Time	Temp Deg C	Cond mS/cm	DO %	DO mg/l	pH pH	Sal mg/l	Turb NTU	Chla mg/l
3/02/05	06:00	20.7	22.6		8.1			3.5	
3/02/05	07:00	21	24.6		8.4			3.1	
3/02/05	08:00	20.5	27.9		8			2.2	
3/02/05	09:00	21.1	33.8		8.3			1.6	
3/02/05	10:00	19.3	40.2		8.9			1.3	
3/02/05	11:00	18	44.2		9.4			1.4	
3/02/05	12:00	20	42.1		8.7			1.3	
3/02/05	13:00	21.3	38.8	110	8.6		25.3	1.7	
3/02/05	14:00	23.3	34.5	101.5	7.8		22.1	1.9	
3/02/05	15:00	23	29.9	106	8.4		18.9	2.1	
3/02/05	16:00	23.6	25.9	101	7.8		16.1	2.9	
3/02/05	17:00	23.8	23.6	99	7.8		14.5	3.8	
21/03/06	14:30	14.69	17.87	107.2	10.34	8.11	10.52	5.8	1.89
21/03/06	15:30	14.87	15.03	107.5	10.44	8.16	8.73	6.8	1.77
21/03/06	16:30	15.04	14.22	108.9	10.57	8.17	8.22	6.5	1.93
21/03/06	17:30	14.98	15.1	108.6	10.52	8.21	8.77	5.9	2.1
21/03/06	18:30	14.87	16.31	118.1	11.43	8.29	9.53	4.5	2.51
21/03/06	19:30	14.61	24.58	121	11.38	8.41	14.9	3.9	2.32
21/03/06	20:30	14.27	31.82	118.8	10.91	8.34	19.82	2.8	1.99
28/03/06	07:30	12.86	32.68	100.6	9.49	7.83	20.41	7	1.27
28/03/06	08:30	12.86	31.48	97.2	9.21	8.04	19.58	8	1.63
28/03/06	09:30	12.82	29.39	96.9	9.27	8.04	18.14	8.1	1.93
28/03/06	10:30	12.85	29.56	97	9.27	8.04	18.26	7.2	1.88
28/03/06	11:30	12.97	31.29	98.8	9.35	8.07	19.45	4.4	1.93
28/03/06	12:30	12.99	35.54	104.2	9.67	8.12	22.41	7.3	1.42
28/03/06	11:31	13.08	39.67	107.7	9.71	8.16	25.33	6.8	1.67
3/04/06	12:00	21.02		106.4	9.6	7.48			1.84
3/04/06	13:00	14.23	42.82	102.2	8.95	7.95	27.59	3.5	0.86
3/04/06	14:00	14.77	39.61	104.2	9.16	8.04	25.29	4.4	1.24
3/04/06	15:00	15.21	37.83	107.2	9.41	8.09	24.02	5.7	2.79
3/04/06	16:00	15.58	37.14	111.1	9.71	8.12	23.54	6.3	4.21
3/04/06	17:00	15.45	37.68	111.3	9.73	8.12	23.91	4.4	4.74
3/04/06	18:00	15.13	39.3	113.1	9.88	8.16	25.07	3.1	2.87
7/11/06	10:20	12.02	39.3	100.3	9.14	8.53	25.09	6.1	1.72
7/11/06	11:20	12.52	35	103.9	9.52	8.57	22.05	8.4	3.19
7/11/06	12:20	13.32	32.5	106.4	9.7	8.59	20.28	7.4	3.72
7/11/06	13:20	14.04	30.5	108.1	9.79	8.57	18.88	6.8	3.55
7/11/06	14:20	13.69	32.3	112.7	10.2	8.65	20.11	5.6	8.34
7/11/06	15:30	13.62	36.3	121.1	10.78	8.71	22.96	3.1	4.16
7/11/06	16:20	13.15	46.2	114.7	9.88	8.61	30.08	8.4	1.44
1/02/07	06:00	15.85		99.9	9.75	7.67			0.08
1/02/07	07:00	14.08	45.98	94.5	7.99	8.03	29.88	7	2.26
1/02/07	08:00	14.4	41.53	94.1	8.07	8	26.66	8.6	3.19
1/02/07	09:00	14.58	38.41	95.7	8.29	7.98	24.44	12.2	3.96
1/02/07	10:00	14.56	36.42	97.7	8.54	7.98	23.03	13.4	4.93
1/02/07	11:00	14.65	37.18	98.4	8.56	7.98	23.56	11.6	5.13

Catlins estuary - field results continued

Catlins	Time	Temp Deg C	Cond mS/cm	DO %	DO mg/l	pH pH	Sal mg/l	Turb NTU	Chla mg/l
1/02/07	12:00	14.69	37.63	97.5	8.45	7.99	23.88	7.9	3.82
7/02/07	11:30	16.24		101.9	9.72	7.63		1.7	1.71
7/02/07	12:30	16.54	37.12	96.8	8.1	8.06	23.52	4	6.47
7/02/07	13:30	16.9	34.82	100.8	8.46	8.09	21.9	4.3	7.05
7/02/07	14:30	17.6	33.16	104.4	8.7	8.1	20.74	4	4.79
7/02/07	15:30	17.79	34.16	108.5	8.99	8.14	21.44	3.3	5.07
7/02/07	16:30	17.95	34.88	119.4	9.82	8.23	21.94	3.4	7.45
7/02/07	17:30	17.52	39.51	113.5	9.23	8.17	25.22	2.3	6.5
22/04/08	07:00	11.22	51.36	102.2	9.15	8.69	33.82	6	1.39
22/04/08	08:00	10.1	49.18	99.2	9.19	8.46	32.22	11.9	2.23
22/04/08	09:00	8.68	42.43	100	9.87	8.52	27.31	17	3.85
22/04/08	10:00	8.45	39.74	100.8	10.13	8.57	25.38	23.9	4.08
22/04/08	11:00	8.44	39.71	100.8	10.13	8.56	25.36	31.2	6.49
22/04/08	12:00	8.47	39.25	102.2	10.29	8.55	25.03	27.7	5.93
22/04/08	13:00	8.52	39.89	101.8	10.2	8.54	25.49	15.4	5.67
23/04/08	07:30		35.4	102.6	11.69	8.64			0.09
23/04/08	08:30		35.4	102.6	11.69	8.64			0.09
23/04/08	09:30		35.4	102.6	11.69	8.64			0.09
23/04/08	10:30		35.4	102.6	11.69	8.64			0.09
23/04/08	11:30		35.4	102.6	11.69	8.64			0.09
23/04/08	12:30	9.34	35.4	102.6	11.69	8.64			0.09
23/04/08	13:30	9.38	39.91	102.9	10.11	8.5	25.5		6.08
11/02/09	08:00	14.09	51.92	100.4	8.2	6.84	34.23	1.6	0.95
11/02/09	09:00	14.38	49.68	97.1	7.96	6.81	32.59	2.1	0.93
11/02/09	10:00	14.78	46.96	97.8	8.05	6.77	30.59	3.6	1.64
11/02/09	11:00	15.33	43.68	101.9	8.43	6.77	28.21	5.6	3.7
11/02/09	12:00	15.97	42.84	104.9	8.6	6.79	27.61	6.6	4.61
11/02/09	13:00	16.23	43.62	107.4	8.72	6.82	28.17	5	4.98
11/02/09	14:00	16.18	44.42	110.7	8.97	6.84	28.75	3.1	6.7
10/03/09	08:00	11.76	39.78	99.6	9.06	7.07	25.41	3.5	4.42
10/03/09	09:00	11.92	39.26	100	9.09	7.08	25.04	7.1	5.49
10/03/09	10:00	11.98	40.46	101.6	9.17	7.09	25.9	8.7	9.43
10/03/09	11:00	11.94	40.52	101.9	9.21	7.09	25.94	7.3	7.34
10/03/09	12:00	11.81	41.78	101.3	9.13	7.11	26.84	5.8	4.68
10/03/09	13:00	11.88	43.07	101.4	9.07	7.11	27.77	10	2.64
10/03/09	14:00	12.16	50.48	105.6	9.07	7.09	33.17	6.8	1.41
	MAX	23.8	51.92	121.1	11.69	8.71	34.23	31.2	9.43
	MIN	8.44	14.22	94.1	7.8	6.77	8.22	1.3	0.08
	MEDIAN	14.61	37.18	102.6	9.22	8.115	24.23	5.7	2.715
	MEAN	14.93	36.23	104.17	9.41	8.00	23.28	6.56	3.26
	COUNT	77	79	75	82	70	66	73	70

Tokomairiro estuary - laboratory results

Toko	Time	NH4 mg/l	Chl mg/l	DRP mg/l	Ent cfu /100ml	E.coli cfu /100ml	F.coli cfu /100ml	NNN mg/l	SS mg/l	TN mg/l	TP mg/l	TZn mg/l
30/08/06	12:35	0.02	4430	0.012	5	31	70	0.734	25	1.03	0.042	0.0025
30/08/06	13:30	0.76	3660	0.011	10	10	110	0.019	27	1.07	0.008	0.0025
30/08/06	14:30	0.02	3180	0.013	5	10	91	0.786	25	1.01	0.027	0.0025
30/08/06	15:30	0.82	2110	0.014	10	20	55	0.025	21	0.95	0.074	0.005
30/08/06	16:30	0.02	2340	0.015	10	31	77	0.821	20	1.12	0.047	0.0025
30/08/06	17:30	0.02	2780	0.015	10	10	73	0.814	22	1.09	0.087	0.0025
30/08/06	18:30	0.03	4220	0.017	9	10	36	0.74	19	0.92	0.05	0.0025
13/12/06	14:35	0.005	10300	0.028	5	5	35	0.025	60	0.48	0.025	0.0065
13/12/06	15:35	0.005	10500	0.045	5	5	14	0.016	67	0.4	0.025	0.122
13/12/06	16:35	0.005	10100	0.034	5	10	15	0.025	56	0.76	0.025	0.0065
13/12/06	17:35	0.01	9860	0.036	5	5	5	0.025	66	0.44	0.025	0.252
13/12/06	18:30	0.005	8960	0.041	5	5	36	0.025	87	0.52	0.048	0.327
13/12/06	19:30	0.01	8420	0.043	5	10	10	0.013	56	0.49	0.048	0.0065
13/12/06	20:30	0.01	8550	0.042	5	10	15	0.021	75	0.53	0.029	0.0065
09/01/07	13:00	0.005	8330	0.033	5	20	77	0.046	12	0.29	0.025	0.0065
09/01/07	14:00	0.005	7320	0.029	5	97	85	0.045	12	0.29	0.025	0.0065
09/01/07	15:00	0.005	5880	0.03	5	150	140	0.058	13	0.36	0.023	0.0065
09/01/07	16:00	0.005	4690	0.031	5	74	130	0.065	12	0.35	0.021	0.0065
09/01/07	17:00	0.01	4250	0.034	5	63	160	0.081	16	0.4	0.019	0.016
09/01/07	18:00	0.005	3720	0.034	5	74	170	0.078	9	0.39	0.025	0.0065
09/01/07	19:00	0.005	3570	0.033	5	130	170	0.07	9	0.39	0.023	0.0065
17/04/08	06:00	0.02	17900	0.025				0.019	27	0.27	0.025	0.0065
17/04/08	07:00	0.03	17500	0.025				0.019	25	0.29	0.025	0.0065
17/04/08	08:00	0.02	16500	0.025				0.02	37	0.27	0.025	0.0065
17/04/08	09:00	0.02	15800	0.025	260	14	18	0.021	22	0.24	0.025	0.0065
17/04/08	10:00	0.02	14900		180	10	12	0.023	25	0.31	0.025	0.0065
17/04/08	11:00	0.02	16100	0.025	76	20	20	0.022	25	0.42	0.025	0.0065
17/04/08	12:00	0.03	18200	0.025	6	8	8	0.02	21	0.31	0.025	0.0065
08/05/08	09:30	0.04	9670	0.018	230	84	84	0.749	19	1.09	0.025	0.026
08/05/08	10:30	0.05	8250	0.021	84	92	92	1.06	16	1.42	0.025	0.0025
08/05/08	11:30	0.05	7060	0.022	82	94	94	1.17	15	1.54	0.025	0.027
08/05/08	12:30	0.05	6440	0.021	58	110	110	1.23	14	1.56	0.025	0.0025
08/05/08	13:30	0.04	5680	0.018	34	100	100	0.903	13	1.4	0.025	0.005
08/05/08	14:30	0.05	4910	0.021	44	88	88	1.32	12	1.47	0.025	0.013
08/05/08	15:30	0.04	9510	0.017	62	82	82	0.7	22	1.32	0.025	0.015
12/02/09	08:40	0.04	15900	0.025	260	8	6	0.025	52	0.28	0.025	0.075
12/02/09	09:40	0.04	15800	0.025	250	7	10	0.025	53	0.31	0.025	0.013
12/02/09	10:40	0.04	15300	0.025	330	4	8	0.025	120	0.33	0.025	0.0065
12/02/09	11:40	0.03	14900	0.025	300	10	16	0.025	47	0.36	0.025	0.087
12/02/09	12:40	0.03	14700	0.025	260	14	20	0.025	45	0.35	0.025	0.06
12/02/09	13:40	0.02	14100	0.025	250	3	6	0.025	41	0.33	0.025	0.0065
12/02/09	14:40	0.01	13700	0.025	160	8	2	0.025	35	0.33	0.025	0.0065
25/03/09	08:15	0.03	9890	0.032	90	63	110	0.067	14	0.37	0.183	0.025
25/03/09	09:15	0.03	6010	0.032	59	70	71	0.069	17	0.38	0.204	0.0025
25/03/09	10:15	0.03	5970	0.031	55	42	65	0.067	14	0.4	0.18	0.0025

Tokomairiro estuary - laboratory results continued

Toko	Time	NH4 mg/l	Chl mg/l	DRP mg/l	Ent cfu /100ml	E.coli cfu /100ml	F.coli cfu /100ml	NNN mg/l	SS mg/l	TN mg/l	TP mg/l	TZn mg/l
25/03/09	11:15	0.02	6170	0.031	71	68	71	0.066	15	0.4	0.19	0.0025
25/03/09	12:15	0.01	6390	0.03	63	38	68	0.066	15	0.41	0.2	0.0025
25/03/09	13:15	0.02	6620	0.03	59	34	50	0.068	18	0.67	0.26	0.0025
25/03/09	14:15	0.02	7590	0.029	39	48	48	0.068	16	0.47	0.176	0.0025
	MAX	0.82	18200	0.045	330	150	170	1.32	120	1.56	0.26	0.327
	MIN	0.005	2110	0.011	5	3	2	0.013	9	0.24	0.008	0.0025
	MEDIAN	0.02	8330	0.025	36.5	20	66.5	0.046	22	0.4	0.025	0.0065
	MEAN	0.05	9155.71	0.03	75.89	41.28	61.59	0.25	30.69	0.62	0.05	0.03
	COUNT	49	49	48	46	46	46	49	49	49	49	49

Tokomairiro estuary - field results

Toko	Time	Temp Deg C	Cond mS/cm	DO %	DO mg/l	pH pH	Sal mg/l	Turb NTU	Chla mg/l
30/08/06	12:35	8.45	14.15	108.2	11.96	8.16	8.18	20	1.35
30/08/06	13:30	8.76	12.37	115	12.71	8.44	7.09	32.1	1.51
30/08/06	14:30	8.98	10.65	117.9	13.05	8.57	6.05	17.8	1.35
30/08/06	15:30	9.32	9.032	121.4	13.41	8.73	5.08	17.6	1.27
30/08/06	16:30	9.57	7.46	123.9	13.68	8.88	4.16	17.1	1.66
30/08/06	17:30	9.53	9.465	121.6	13.34	8.75	5.34	17.2	1.52
30/08/06	18:30	9.59	13.29	113.9	12.3	8.54	7.65	16.6	1.61
13/12/06	14:35	16.32	28.75	116.8	10.17	8.92	17.7	38.1	2.76
13/12/06	15:35	16.43	29.5	121.4	10.52	9.06	18.22	42.1	2.38
13/12/06	16:35	16.95	29.45	117.5	10.08	9.09	18.18	49.7	2.99
13/12/06	17:35	17.08	28.39	113.1	9.72	9.09	17.46	44.1	3.2
13/12/06	18:30	17.17	26.72	106.4	9.19	9.09	16.33	62.8	3.84
13/12/06	19:30	16.86	25.7	104.5	9.11	9.1	15.65	50	4.24
13/12/06	20:30	16.29	25.03	101.2	8.95	9.09	15.2	54.9	4.66
09/01/07	13:00	16.96	24.05	131.9	11.56	9.09	14.55	4.1	1.1
09/01/07	14:00	17.35	22.25	135.2	11.84	9.23	13.36	4.2	1.15
09/01/07	15:00	17.63	19.24	136.5	12.03	9.31	11.4	6	1.26
09/01/07	16:00	18.03	16.35	139.7	12.35	9.4	9.56	7.6	1.33
09/01/07	17:00	18.17	14.24	141.1	12.53	9.49	8.24		1.44
09/01/07	18:00	18.28	12.26	142.7	12.74	9.55	7.02		1.53
09/01/07	19:00	18.13	14.3	145.6	12.94	9.52	8.28	4.8	1.48
17/04/08	06:00	12.8	43.44	84.3	7.57	8.41	28.04	3.6	0.93
17/04/08	07:00	12.58	41.63	81.3	7.39	8.47	26.74	5.2	1.18
17/04/08	08:00	12.37	39.78	80.1	7.38	8.43	25.41	5.4	1.23
17/04/08	09:00	12.3	38.37	80.7	7.49	8.41	24.4	5.9	1.2

Tokomairiro estuary - field results continued

Toko	Time	Temp Deg C	Cond mS/cm	DO %	DO mg/l	pH pH	Sal mg/l	Turb NTU	Chla mg/l
17/04/08	10:00	12.38	36.91	81.4	7.59	8.4	23.37	5.4	0.96
17/04/08	11:00	12.6	37.9	84.9	7.85	8.43	24.07	7.4	2.36
17/04/08	12:00	13.83	48.39	101.2	8.7	8.62	31.64	5.8	0.59
08/05/08	09:30	7.9	26.44	88	9.51	8.34	16.14	5.3	1.64
08/05/08	10:30	7.53	22.1	87.4	9.71	8.26	13.26	4.5	1.66
08/05/08	11:30	7.48	19.41	88.6	9.96	8.18	11.51	4.9	1.68
08/05/08	12:30	7.53	17	89.9	10.2	8.13	9.97	3.9	1.68
08/05/08	13:30	7.64	15.52	90.9	10.35	8.11	9.04	4.4	1.65
08/05/08	14:30	7.7	17.59	89.5	10.08	8.14	10.34	4.7	1.67
08/05/08	15:30	10.51	38.41	98.2	9.48	8.69	24.43	19.8	1.97
12/02/09	08:40	15	45.95	92.6	7.63	6.65	29.86	5.6	1.31
12/02/09	09:40	15.16	44.6	89.6	7.4	6.64	28.88	4.8	1.73
12/02/09	10:40	15.53	43.43	89.1	7.34	6.62	28.03	4.6	2.13
12/02/09	11:40	15.66	42.74	89.5	7.38	6.61	27.53	4.3	2.74
12/02/09	12:40	15.86	41.52	92.3	7.62	6.62	26.65	4.4	2.75
12/02/09	13:40	15.93	40.96	95.1	7.86	6.62	26.25	7.7	3.48
12/02/09	14:40	16.36	40.27	100.8	8.28	6.64	25.76	6.6	3.86
25/03/09	08:15	12.53	42.16	86.6	7.83	6.69	27.12	7.5	2.38
25/03/09	09:15	12.45	19.77	92.3	9.25	6.68	11.74	4.3	1.42
25/03/09	10:15	12.98	19.82	90.3	8.94	6.73	11.77	4	5.41
25/03/09	11:15	13.5	20.07	94.5	9.24	6.66	11.94	7.8	2.68
25/03/09	12:15	13.92	46.14	92.1	7.98	6.76	30	2.6	1.36
25/03/09	13:15	13.91	22.28	100.8	9.69	6.82	13.37	3.1	7.86
25/03/09	14:15	14.04	36.2	111.8	10.1	6.88	22.87	0.9	2.32
	MAX	18.28	48.39	145.6	13.68	9.55	31.64	62.8	7.86
	MIN	7.48	7.46	80.1	7.34	6.61	4.16	0.9	0.59
	MEDIAN	13.83	25.7	100.8	9.69	8.43	15.65	5.8	1.66
	MEAN	13.34	27.38	104.48	9.88	8.16	17.04	14.07	2.15
	COUNT	49	49	49	49	49	49	47	49

Taieri estuary - laboratory results

Taieri	Time	NH4 mg/l	Chl mg/l	DRP mg/l	Ent cfu /100ml	E.coli cfu /100ml	F.coli cfu /100ml	NNN mg/l	SS mg/l	TN mg/l	TP mg/l	TZn mg/l
31/01/05	06:00	0.09	18200		10	10	45	0.015	62	0.4	0.025	0.025
31/01/05	07:00	0.14	16200		5	10	27	0.024	35	0.37	0.025	0.025
31/01/05	08:00	0.11	16000		5	31	20	0.015	45	0.4	0.025	0.025
31/01/05	09:00	0.12	19500	0.025	5	10	5	0.020	42	0.29	0.025	0.12
31/01/05	11:00	0.18	12200	0.025	10	10	10	0.033	49	0.34	0.025	0.025
31/01/05	12:00	0.18	12300		5	10	20	0.038	42	0.32	0.025	0.025
31/01/05	12:00	0.14	14300	0.025	5	10	23	0.029	57	0.35	0.025	0.025
31/01/05	13:00	0.08	12000	0.025	5	5	5	0.025	49	0.33	0.025	0.025
31/01/05	14:00	0.06	8750	0.025	5	20	30	0.033	25	0.36	0.025	0.01
31/01/05	15:00	0.04	7200	0.025	5	5	32	0.025	28	0.38	0.025	0.02
31/01/05	16:00	0.04	6750	0.025	5	10	23	0.038	9	0.36	0.025	0.005
31/01/05	17:00	0.1	9240	0.025	5	20	20	0.038	37	0.41	0.025	0.01
15/12/05	08:10	0.04	18000	0.025	5	5	5	0.055	18	0.21	0.025	0.0065
15/12/05	09:10	0.03	13800	0.025	5	3	20	0.039	12	0.18	0.025	0.0065
15/12/05	10:10	0.02	10400	0.025	0.5	9	9	0.033	15	0.26	0.025	0.0065
15/12/05	11:10	0.02	8120	0.025	1	18	28	0.024	13	0.25	0.025	0.0065
15/12/05	12:10	0.02	6650	0.025	3	17	25	0.023	9	0.19	0.025	0.0065
15/12/05	13:10	0.02	6870	0.025	0.5	18	23	0.078	12	0.26	0.025	0.0065
15/12/05	14:10	0.03	11700	0.025	0.5	10	10	0.036	6	0.23	0.025	0.0065
31/01/06	10:10	0.03	77300	0.025	5	10	15	0.006	30	0.14	0.025	0.0065
31/01/06	11:10	0.03	20300	0.025	9	10	35	0.008	31	0.17	0.025	0.0065
31/01/06	12:10	0.02	13400	0.025	20	52	40	0.006	24	0.2	0.025	0.0065
31/01/06	13:10	0.02	48700	0.025	35	31	55	0.008	19	0.18	0.025	0.0065
31/01/06	14:10	0.01	10400	0.025	5	20	40	0.003	16	0.21	0.025	0.0065
31/01/06	15:10	0.02	10400	0.025	25	10	35	0.024	19	0.21	0.025	0.0065
31/01/06	16:10	0.03	14600	0.025	5	10	14	0.014	19	0.2	0.025	0.0065
21/02/06	13:15	0.05	16100	0.025	5	10	5	0.009	20	0.25	0.046	
21/02/06	14:15	0.03	13100	0.025	5	5	5	0.017	24	0.28	0.049	
21/02/06	15:15	0.02	12400	0.025	5	5	5	0.012	10	0.27	0.065	
21/02/06	16:15	0.02	10700	0.025	5	20	10	0.005	19	0.59	0.034	
21/02/06	17:15	0.01	11300	0.025	5	5	36	0.003	11	0.37	0.044	
21/02/06	18:15	0.02	6110	0.025	5	31	25	0.005	15	0.32	0.047	
21/02/06	19:15	0.01	8200	0.025	5	10	40	0.003	16	0.29	0.047	
10/08/06	08:00	0.02	6410	0.025	210	170	360	0.123	32	0.54	0.025	0.092
10/08/06	09:00	0.02	4090	0.011	320	280	370	0.136		0.47	0.025	0.084
10/08/06	10:00	0.02	818	0.01	150	240	240	0.159	19	0.62	0.059	
10/08/06	11:00	0.02	490	0.01	120	270	270	0.273	15	0.65	0.055	0.042
10/08/06	12:00	0.23	223	0.011	140	260	260	0.237	12	0.61	0.054	0.038
10/08/06	13:00	0.07	235	0.009	92	260	260	0.300	11	0.61	0.025	0.037
10/08/06	14:00	0.02	8190	0.025	100	120	120	0.196	33	0.5	0.025	0.136
30/01/07	05:50	0.03	18000	0.025	10	98	91	0.023	54	0.24	0.025	0.017
30/01/07	06:50	0.03	15000	0.025	74	110	220	0.035	37	0.24	0.025	0.0065
30/01/07	07:50	0.03	11200	0.025	74	110	130	0.031	22	0.23	0.025	0.0065
30/01/07	08:50	0.03	8770	0.025	42	56	74	0.030	25	0.25	0.025	0.0065
30/01/07	09:50	0.03	7270	0.012	44	70	80	0.034	16	0.25	0.025	0.0065

Taieri estuary - laboratory results continued

Taieri	Time	NH4 mg/l	Chl mg/l	DRP mg/l	Ent cfu /100ml	E.coli cfu /100ml	F.coli cfu /100ml	NNN mg/l	SS mg/l	TN mg/l	TP mg/l	TZn mg/l
30/01/07	10:50	0.03	8260	0.012	28	40	50	0.022	24	0.26	0.025	0.0065
30/01/07	11:50	0.02	16000	0.025	20	20	20	0.031	29	0.21	0.025	0.014
06/02/07	10:30	0.02	16200	0.025	5	5	5	0.025	20	0.19	0.025	0.015
06/02/07	11:30	0.02	12100	0.025	5	5	5	0.025	18	0.21	0.025	0.0065
06/02/07	12:30	0.01	8570	0.025	5	10	5	0.025	13	0.25	0.025	0.0065
06/02/07	13:30	0.01	6840	0.025	5	5	15	0.025	14	0.23	0.025	0.0065
06/02/07	14:30	0.01	6470	0.025	5	41	15	0.025	12	0.23	0.025	0.0065
06/02/07	15:30	0.005	8850	0.025	5	5	5	0.025	13	0.22	0.025	0.0065
06/02/07	16:30	0.02	13700	0.025	5	30	18	0.025	12	0.2	0.025	0.0065
11/12/07	08:35	0.01	18500	0.025	1	2	2	0.025	19	0.22	0.025	0.0025
11/12/07	09:30	0.01	16500	0.025	1	1	1	0.025	21	0.2	0.025	0.016
11/12/07	10:30	0.01	11300	0.025	2	4	6	0.025	15	0.2	0.025	0.016
11/12/07	11:30	0.01	8110	0.025	3	8	8	0.025	8	0.21	0.025	0.0025
11/12/07	12:30	0.01	5950	0.025	2	20	22	0.025	11	0.25	0.025	0.006
11/12/07	13:30	0.005	5760	0.025	0.5	18	22	0.025	7	0.22	0.025	0.0025
11/12/07	14:30	0.005	8100	0.025	2	4	4	0.025	11	0.22	0.025	0.0025
30/10/08	08:00	0.005	14100	0.025	1	1	1	0.011	42	0.21	0.044	0.025
30/10/08	09:00	0.005	14600	0.025	4	6	8	0.013	41	0.22	0.058	0.025
30/10/08	10:00	0.01	11700	0.025	4	2	2	0.017	30	0.23	0.053	0.025
30/10/08	11:00	0.01	5870	0.025	12	12	12	0.018	22	0.23	0.075	0.025
30/10/08	12:00	0.005	4470	0.025	16	30	30	0.019	17	0.24	0.064	0.025
30/10/08	13:00	0.01	5910	0.025	6	18	22	0.018	18	0.25	0.063	0.025
30/10/08	14:00	0.01	7130	0.025	4	16	16	0.018	15	0.22	0.066	0.025
10/02/09	08:00	0.01	16300	0.025	16	8	12	0.025	115	0.42	0.025	0.025
10/02/09	09:00	0.02	15400	0.025	18	8	12	0.025	34	0.49	0.025	0.062
10/02/09	10:00	0.02	12000	0.025	26	8	12	0.025	32	0.37	0.025	0.025
10/02/09	11:00	0.02	11600	0.025	40	24	24	0.025	28	0.4	0.025	0.025
10/02/09	12:00	0.02	9360	0.025	36	24	28	0.025	25	0.32	0.025	0.025
10/02/09	13:00	0.02	10500	0.025	52	8	24	0.025	28	0.35	0.025	0.025
10/02/09	14:00	0.01	17900	0.025	10	12	12	0.025	27	0.42	0.025	0.025
	MAX	0.23	77300	0.025	320	280	370	0.3	115	0.65	0.075	0.136
	MIN	0.005	223	0.009	0.5	1	1	0.0025	6	0.14	0.025	0.0025
	MEDIAN	0.02	11200	0.025	5	10	20	0.025	19.5	0.25	0.025	0.014
	MEAN	0.04	12132	0.02	25.87	38.65	48.44	0.04	24.80	0.30	0.03	0.02
	COUNT	75	75	71	75	75	75	75	74	75	75	67

Taieri estuary - field results

Taieri	Time	Temp Deg C	Cond mS/cm	DO %	DO mg/l	pH pH	Sal mg/l	Turb NTU	Chla mg/l
31/01/05	06:00		46.8					1.6	
31/01/05	07:00		41.8					2	
31/01/05	08:00		46.3					2	
31/01/05	09:00		50					1.2	
31/01/05	11:00	16	33		9.1			1.8	
31/01/05	12:00		32.9					2	
31/01/05	12:00	16	38.9		8.5			1.9	
31/01/05	13:00	17.5	32.6		7.5			2	
31/01/05	14:00	19	23.9		6.6			2.3	
31/01/05	15:00	19.5	20.5		4.6			2.3	
31/01/05	16:00	20	19.3		3.6			2.3	
31/01/05	17:00	19.8	25.4		3.5			2.3	
15/12/05	08:10	13.15	51.3			8.12	33.75		1.3
15/12/05	09:10	13.94	46.9			8.18	30.56		1.38
15/12/05	10:10	14.93	40.5			8.2	25.95		1.61
15/12/05	11:10	16.02	34.1			8.18	21.37		1.91
15/12/05	12:10	16.17	33.4			8.2	20.94		2.07
15/12/05	13:10	16.12	34.2			8.18	21.46		2.08
15/12/05	14:10	14.9	46.4			8.2	30.18		1.27
31/01/06	10:10	16.83	51.1	120.2	7.86	7.98	33.64	12.7	0.72
31/01/06	11:10	16.83	49.1	116.6	7.65	8.05	32.19	18	1.11
31/01/06	12:10	18.25	38.2	114.5	7.7	8.1	24.29	16.3	2.26
31/01/06	13:10	18.8	32.9	112.2	7.63	8.1	20.53	9.6	2.47
31/01/06	14:10	19.08	30.6	113.4	7.74	8.09	18.97	7.8	2.97
31/01/06	15:10	19.03	33.5	112.8	7.62	8.09	21.01	10.4	1.92
31/01/06	16:10	16.74	51.6	120.6	7.88	8.08	34.01	10.9	1.21
21/02/06	13:15	23.15	52.19	113.7	7.53	7.95	34.44	13	0.38
21/02/06	14:15	16.4	48.12	120.6	8.08	8.04	31.44	2.9	0.56
21/02/06	15:15	16.4	46.26	118.4	7.97	8.06	30.08	5.4	1.17
21/02/06	16:15	17.16	41.6	118	7.99	8.07	26.72	5.2	1.44
21/02/06	17:15	17.61	37.9	118.6	8.09	8.09	24.07	5.3	2.93
21/02/06	18:15	18.39	30.98	121.5	8.4	8.12	19.23	5	4.89
21/02/06	19:15	18.25	32.64	121.2	8.34	8.11	20.38	6.2	4.41
10/08/06	08:00	6.06	28.5	97.4	10.78	7.96	17.54	13.1	1.63
10/08/06	09:00	5.21	17.1	97	11.52	7.9	10.04	20.6	2.27
10/08/06	10:00	4.52	7.2	94.6	11.9	7.56	4.03	28.1	2.66
10/08/06	11:00	4.07	1	94.5	12.33	7.26	0.51	23.7	2.69
10/08/06	12:00	4.12	0.6	94.6	12.33	7.26	0.29	23	2.94
10/08/06	13:00	4.22	0.8	94.7	12.32	7.25	0.4	19.2	2.81
10/08/06	14:00	8.3	42.7	99.2	9.74	8.02	27.52	10.3	1.04
30/01/07	05:50	13.72	48.24	96.9	8.18	7.88	31.53	18.6	0.98
30/01/07	06:50	14.12	44.61	96.1	8.18	8	28.88	14	0.96
30/01/07	07:50	15.12	33.12	93.9	8.23	8	20.72	12.1	1.14
30/01/07	08:50	15.85	26.75	93.5	8.29	7.99	16.35	10.7	1.23
30/01/07	09:50	16.38	21.65	92.5	8.29	7.93	12.96	8.9	1.22
30/01/07	10:50	16.78	21.65	94.3	8.39	7.94	12.96	7.4	1.07

Taieri estuary - field results continued

Taieri	Time	Temp Deg C	Cond mS/cm	DO %	DO mg/l	pH pH	Sal mg/l	Turb NTU	Chla mg/l
30/01/07	11:50	15.03	43.17	100.5	8.46	8.01	27.84	15.7	0.76
06/02/07	10:30	15.12	45.34	101.1	8.4	8.02	29.41	5.8	0.58
06/02/07	11:30	16.01	36.62	101.7	8.62	8.06	23.16	7.2	0.78
06/02/07	12:30	16.89	28.94	103.2	8.86	8.15	17.83	8	1.02
06/02/07	13:30	17.43	22.46	103.2	9.02	8.14	13.49	9.1	1.42
06/02/07	14:30	18	18.42	103.8	9.1	8.14	10.87	9.9	2.59
06/02/07	15:30	18	22.6	105.4	9.1	8.14	13.58	7.4	1.48
06/02/07	16:30	17.38	38.3	104.2	8.53	8.1	24.35	4.5	0.74
11/12/07	08:35	13.77	49.9	102.6	8.65	8.21	32.75	1.4	0.9
11/12/07	09:30	15.58	41.13	101.5	8.63	8.32	26.38	3.2	1.05
11/12/07	10:30	16.83	30.59	100.6	8.67	8.36	18.96	3.5	1.34
11/12/07	11:30	17.56	24.56	100.1	8.72	8.36	14.88	4.3	2.37
11/12/07	12:30	17.94	21.59	99.7	8.72	8.35	12.93	4.5	1.9
11/12/07	13:30	17.89	22.58	100.7	8.79	8.35	13.57	4.4	1.93
11/12/07	14:30	17.98	24.07	102.5	8.87	8.37	14.56	2.4	1.47
30/10/08	08:00	11.07	52.39	106.6	9.44	7.81	34.58	3	0.71
30/10/08	09:00	11.17	46.75	104.3	9.46	7.87	30.44	6.3	0.82
30/10/08	10:00	11.9	34.53	103	9.72	7.92	21.7	5	1
30/10/08	11:00	12.51	24.51	102.3	9.95	7.93	14.85	5.7	1.21
30/10/08	12:00	12.99	18.47	101.8	10.03	7.91	10.9	6.2	1.38
30/10/08	13:00	13.08	19.27	101.9	10	7.92	11.42	5.7	1.52
30/10/08	14:00	13.13	31.91	104.5	9.71	7.93	19.87	3.1	1.13
10/02/09	08:00	14.91	52.85	106.3	8.51	7.45	34.92	0.9	1.22
10/02/09	09:00	15	52.25	105.2	8.42	7.44	34.48	2.8	1.14
10/02/09	10:00	15.4	47.9	103.7	8.4	7.42	31.28	3.5	1.17
10/02/09	11:00	15.94	42.74	100.9	8.27	7.4	27.53	3.3	1.48
10/02/09	12:00	16.28	39.66	99.2	8.19	7.37	25.32	4.5	2.09
10/02/09	13:00	16.43	39.07	99.7	8.23	7.36	24.9	2.6	2.25
10/02/09	14:00	15.4	51.24	107	8.54	7.42	33.73	1.2	1.36
	MAX	23.15	52.85	121.5	12.33	8.37	34.92	28.1	4.89
	MIN	4.07	0.6	92.5	3.5	7.25	0.29	0.9	0.38
	MEDIAN	16.07	34.2	102.55	8.46	8.04	21.7	5.35	1.36
	MEAN	15.16	34.57	104.62	8.61	7.96	22.05	7.46	1.61
	COUNT	70	75	56	63	63	63	68	63

Kaikorai estuary - laboratory results

Kaikorai	Time	NH4 mg/l	Chl mg/l	DRP mg/l	Ent cfu	E.coli cfu	F.coli cfu	NNN mg/l	SS mg/l	TN mg/l	TP mg/l	TZn mg/l
06/12/04	11:07	0.15		0.043	220	560	780	0.104	78	1.15	0.232	
01/02/05	12:35	0.13		0.075	12500	5600	148000	0.19	270	2.05	0.417	
04/04/05	13:39	0.33		0.025		38	560	0.044	53	0.38	0.047	
07/06/05	13:21	0.23		0.018		810	1100	0.656	31	1.8	0.068	
01/08/05	13:45	0.5		0.025		20	20	0.103	38	0.48	0.059	
03/10/05	12:35	0.03		0.008		800	800	0.115	20	0.71	0.094	
12/12/05	12:15	0.01		0.016		180	180	0.0025	21	0.8	0.081	
20/12/05	11:30	0.01	2610	0.044	15	290	720	0.0025	41	0.77	0.1	0.049
20/12/05	13:30	0.01	1280	0.038	20	310	610	0.0025	44	0.69	0.093	0.096
20/12/05	14:30	0.01	1380	0.034	5	230	650	0.012	34	0.67	0.106	0.032
20/12/05	15:30	0.01	1300	0.043	41	310	640	0.0025	39	0.67	0.093	0.081
20/12/05	16:30	0.005	1300	0.046	45	190	660	0.005	38	0.65	0.098	0.033
25/12/05	12:30	0.01	1090	0.042	30	300	700	0.006	46	0.7	0.117	0.051
08/02/06	10:45	0.03		0.028		6800	6800	0.012	42	0.45	0.135	
27/02/06	08:00	0.01	2480	0.013	130	540	540	0.0025	7	0.43	0.0025	0.014
27/02/06	09:00	0.005	2620	0.014	140	620	620	0.0025	9	0.42	0.0025	0.017
27/02/06	10:00	0.01	3140	0.015	52	470	0.5	0.0025	10	0.44	0.0025	0.018
27/02/06	11:00	0.01	2970	0.014	84	340	340	0.0025	9	0.47	0.0025	0.016
27/02/06	12:00	0.01	3590	0.018	44	330	330	0.0025	11	0.4	0.0025	0.018
27/02/06	13:00	0.005	4170	0.016	52	320	320	0.006	10	0.41	0.0025	0.02
27/02/06	14:00	0.005	4020	0.016	40	290	290	0.0025	7	0.37	0.0025	0.018
03/04/06	12:50	0.005		0.006		98	98	0.0025	12	0.42	0.03	
07/06/06	11:02	0.08		0.025		230	230	0.3	16	0.81	0.0025	
10/10/07	08:20	0.07	2580	0.013	80	200	200	0.23	15	0.68	0.016	0.015
10/10/07	09:10	0.08	1690	0.01	100	140	140	0.253	14	0.65	0.026	0.016
10/10/07	10:20	0.07	1660	0.011	70	170	170	0.237	15	0.66	0.027	0.02
10/10/07	11:10	0.06	3630	0.013	9	71	71	0.172	28	0.61	0.054	0.018
10/10/07	12:10	0.05	4840	0.015	3	86	86	0.161	28	0.62	0.017	0.014
10/10/07	13:10	0.05	5100	0.013	1	60	60	0.164	28	0.63	0.011	0.023
10/10/07	14:10	0.04	7020	0.01	3	57	57	0.198	19	0.57	0.025	0.01
14/11/07	08:40	0.005	7760	0.025	240	470	470	0.05	12	0.51	0.0025	0.014
14/11/07	09:40	0.005	6990	0.025	300	710	720	0.091	14	0.57	0.009	0.017
14/11/07	10:40	0.005	7270	0.025	270	240	240	0.073	12	0.57	0.009	0.031
14/11/07	11:40	0.005	6690	0.025	250	650	660	0.08	16	0.56	0.008	0.014
14/11/07	12:40	0.005	6880	0.025	96	550	550	0.062	12	0.59	0.035	0.016
14/11/07	13:40	0.005	6210	0.025	76	410	430	0.055	14	0.52	0.015	0.013
14/11/07	14:40	0.005	6750	0.025	56	500	230	0.031	19	0.63	0.022	0.008
12/12/07	09:00	0.05	12600	0.025	32	400	500	0.024	16	0.44	0.036	0.008
12/12/07	10:00	0.03	12100	0.025	25	250	270	0.021	17	0.46	0.057	0.01
12/12/07	11:00	0.04	10000	0.025	29	100	200	0.041	20	0.53	0.036	0.007
12/12/07	12:00	0.05	6190	0.023	18	1200	1700	0.132	16	0.63	0.057	0.0025
12/12/07	13:00	0.04	5720	0.024	26	700	800	0.114	20	0.64	0.059	0.0025
12/12/07	14:00	0.04	4870	0.028	16	600	600	0.115	19	0.66	0.069	0.008
12/12/07	15:00	0.03	5110	0.028	10	600	600	0.112	18	0.67	0.071	0.0025
16/10/08	09:00	0.01	5750	0.014	20	32	38	0.057	5	0.35	0.031	0.007
16/10/08	10:00	0.01	5940	0.014	38	26	28	0.051	13	0.33	0.027	0.008

Kaikorai estuary - laboratory results

Kaikorai	Time	NH4 mg/l	Chl mg/l	DRP mg/l	Ent cfu	E.coli cfu	F.coli cfu	NNN mg/l	SS mg/l	TN mg/l	TP mg/l	TZn mg/l
16/10/08	11:00	0.01	6110	0.013	30	24	26	0.043	13	0.37	0.03	0.008
16/10/08	12:00	0.01	6080	0.014	120	24	27	0.023	12	0.29	0.026	0.097
16/10/08	13:00	0.01	6260	0.014	200	34	50	0.022	12	0.3	0.028	0.0025
16/10/08	14:00	0.01	6210	0.017	70	20	36	0.041	7	0.31	0.032	0.006
16/10/08	15:00	0.01	6230	0.011	20	24	24	0.045	14	0.33	0.035	0.095
25/02/09	08:00	0.11	1140	0.022	4000	3100	3600	1.28	34	2.17	0.098	0.028
25/02/09	09:00	0.11	823	0.022	4200	2100	2600	1.34	32	2.24	0.107	0.028
25/02/09	10:00	0.11	2650	0.021	2800	1700	2300	1.27	37	2.03	0.087	0.023
25/02/09	11:00	0.11	1510	0.021	3200	2500	2700	1.35	34	2.19	0.08	0.025
25/02/09	12:00	0.11	1010	0.021	2600	1800	2200	1.42	30	2.2	0.097	0.025
25/02/09	13:00	0.1	1310	0.023	3000	1500	1800	1.43	34	2.19	0.081	0.023
25/02/09	14:00	0.12	1330	0.022	1600	1900	2200	1.34	33	2.16	0.079	0.044
	MAX	0.5	12600	0.075	12500	6800	148000	1.43	270	2.24	0.417	0.097
	MIN	0.005	823	0.006	1	20	0.5	0.0025	5	0.29	0.0025	0.0025
	MEDIAN	0.02	4505	0.022	54	315	485	0.056	18.5	0.615	0.0355	0.017
	MEAN	0.05	4499.23	0.02	740.52	734.90	3299.51	0.24	27.03	0.79	0.06	0.02
	COUNT	58	48	58	50	58	58	58	58	58	58	48

Kaikorai estuary - field results

Kaikorai	Time	Temp Deg C	Cond mS/cm	DO %	DO mg/l	pH pH	Sal mg/l	Turb NTU	Chla mg/l
06/12/04	11:07	14.9		56	4.02		1.8	40	
01/02/05	12:35	22		92.4	7.23	7.45	0.57	85	
04/04/05	13:39	12.5		117.8	10.71		25.5	6.9	
07/06/05	13:21	4.16		88.4	11.43	7.48	1.36	13	
01/08/05	13:45	8.63		81.9	9.08	7.44	8.29	12	
03/10/05	12:35	14.7		95.5	9.52		4.5	7.8	
12/12/05	12:15	20.7		98.1	8.72		2.4	8.9	
20/12/05	11:30	19.5		42.4	4.05		20.9		
20/12/05	13:30	20.9		61.3	5.48		23.2		
20/12/05	14:30	21.6		54.7	4.9		24.3		
20/12/05	15:30	21.9		59.1	4.99		24.1		
20/12/05	16:30	22.3		60	5.14		23.4		
25/12/05	12:30	19.8		54.1	4.84		20.8		
08/02/06	10:45	15.79		77.3	7.05	6.71	1.97		
27/02/06	08:00	15.89	50.85			7.47	33.45		
27/02/06	09:00	18.14	46.61			8.06	30.34		
27/02/06	10:00	18.17	23.3			8.06	14.05		
27/02/06	11:00	18.51	24.52			7.99	14.86		
27/02/06	12:00	18.63	46.25			8.06	30.07		
27/02/06	13:00	19.13	28.89			7.32	17.8		
27/02/06	14:00	18.86	44.22			7.95	28.6		
03/04/06	12:50	17.56		83.1	7.67	7.6	3.7	8.43	

Kaikorai estuary - field results continued

Kaikorai	Time	Temp Deg C	Cond mS/cm	DO %	DO mg/l	pH pH	Sal mg/l	Turb NTU	Chla mg/l
07/06/06	11:02	8.4		88.1	9.69		4.7	10	
10/10/07	08:20								
10/10/07	09:10								
10/10/07	10:20								
10/10/07	11:10								
10/10/07	12:10								
10/10/07	13:10								
10/10/07	14:10								
14/11/07	08:40	12.18		103.8	11.98	7.01		45.5	0.05
14/11/07	09:40	12.2	24.21	91.9	9.04	8	14.65	4.3	5.91
14/11/07	10:40	12.25	23.66	104.8	10.32	8.18	14.28	6	5.8
14/11/07	11:40	11.91	19.53	103.5	10.45	8.11	11.58	11.7	5.74
14/11/07	12:40	12.45	20.48	111.4	11.06	8.27	12.2	11	4.66
14/11/07	13:40	13.01	18.49	114.3	11.31	8.27	10.92	10.6	3.59
14/11/07	14:40	13.78	17.04	117.3	11.48	8.3	9.99	10	2.89
12/12/07	09:00	16.31	48.39	96.7	7.81	8.06	31.64	6.8	1.1
12/12/07	10:00	18.44	45.64	116.4	9.13	8.15	29.64	9.3	1.52
12/12/07	11:00	19.28	44.89	101.3	7.84	8.18	29.09	8	2.89
12/12/07	12:00	20.55	43.38	116.8	8.89	8.2	27.99	9.9	3.31
12/12/07	13:00	22.36	36.09	130.9	9.93	8.26	22.79	13.7	5.45
12/12/07	14:00	21.76	36.31	151.1	11.58	8.26	22.95	9.4	2.88
12/12/07	15:00	21.62	35.4	137.5	10.61	8.23	22.31	36.7	3.46
16/10/08	09:00	12.96	17.46	95.6	9.47	7.52	10.26	1.8	3.01
16/10/08	10:00	12.69	17.22	85.1	8.49	7.53	10.11	2.7	2.84
16/10/08	11:00	12.44	18.12	95.9	9.59	7.63	10.68	4.7	2.9
16/10/08	12:00	12.63	17.76	106.7	10.63	7.79	10.45	2.2	2.51
16/10/08	13:00	13.04	17.79	115.6	11.41	7.95	10.47	1.5	2.38
16/10/08	14:00	13.24	17.81	117	11.5	7.95	10.49	1.5	2.64
16/10/08	15:00	13.29	17.86	117.4	11.52	8.02	10.51	1.5	2.88
25/02/09	08:00	11.63	2.631	72.6	7.67	6.03	1.42	28.9	4.27
25/02/09	09:00	11.94	1.801	74.2	7.81	6.13	0.96	29.4	4.42
25/02/09	10:00	12.61	1.602	82.4	8.55	6.18	0.85	26	3.94
25/02/09	11:00	13.49	0.9792	92.6	9.44	6.25	0.51	25.3	3.86
25/02/09	12:00	14.62	1.011	104	10.34	6.3	0.53	24	3.99
25/02/09	13:00	15.46	0.8632	105.8	10.33	6.31	0.45	28.9	3.5
25/02/09	14:00	16.55	2.805	112.7	10.69	6.38	1.51	26.6	3.66
	MAX	22.36	50.85	151.1	11.98	8.3	33.45	85	5.91
	MIN	4.16	0.8632	42.4	4.02	6.03	0.45	1.5	0.05
	MEDIAN	15.46	20.005	96.3	9.455	7.95	11.25	10	3.385
	MEAN	15.83	23.94	95.13	8.94	7.58	14.00	15.94	3.43
	COUNT	51	34	44	44	40	50	37	28

Waikouaiti estuary - laboratory results

Waikouaiti	Time	NH4 mg/l	Chl mg/l	DRP mg/l	Ent cfu /100ml	E.coli cfu /100ml	F.coli cfu /100ml	NNN mg/l	SS mg/l	TN mg/l	TP mg/l	TZn mg/l
30/11/04	06:00	0.22	14300	0.02	27	200	82	0.013	10	0.35	0.022	0.016
30/11/04	07:00	0.11	9800	0.03	82	410	280	0.006	13	0.36	0.026	0.031
30/11/04	08:00	0.15	9450	0.03	99	250	430	0.009	14	0.52	0.02	0.023
30/11/04	09:00	0.2	10800	0.025	100	310	330	0.011	33	0.5	0.033	0.025
30/11/04	10:00	0.07	6150	0.015	180	1500	580	0.006	20	0.37	0.026	0.281
30/11/04	11:00	0.06	5400	0.014	200	1300	860	0.007	31	0.45	0.029	0.395
30/11/04	12:00	0.05	4650	0.011	280	1200	2100	0.008	16	0.66	0.029	0.03
30/11/04	13:00	0.04	3770	0.01	170	1400	1100	0.009	12	0.41	0.027	0.044
30/11/04	14:00	0.03	3350	0.009	260	810	1100	0.008	18	0.48	0.023	0.008
30/11/04	15:00	0.02	2540	0.007	100	380	590	0.006	17	0.32	0.021	0.005
30/11/04	16:00	0.06	4820	0.012	60	86	220	0.005	20	0.38	0.016	0.009
30/11/04	17:00	0.16	10500	0.023	10	5	45	0.009	45	0.46	0.02	0.005
15/02/06	10:05	0.03	22900	0.031	23	41	50	0.012	14	0.26	0.047	
15/02/06	11:05	0.02	10000	0.017	20	41	41	0.0025	11	0.25	0.025	
15/02/06	12:10	0.005	7620	0.017	14	20	64	0.005	11	0.24	0.025	
15/02/06	13:10	0.005	7800	0.018	10	41	68	0.0025	18	0.26	0.025	
15/02/06	14:10	0.02	8100	0.018	5	52	64	0.009	10	0.35	0.025	
15/02/06	15:10	0.01		0.019	5	5	50	0.011	13	0.27	0.025	
15/02/06	16:00	0.01	14000	0.022	5	5	64	0.006	8	0.2	0.025	
01/03/06	09:05	0.02	17000	0.025	22	16	16	0.007	30	0.18	0.025	0.0065
01/03/06	10:00	0.01	15400	0.025	16	20	20	0.017	24	0.2	0.025	0.0065
01/03/06	11:00	0.02	13700	0.025	17	32	32	0.017	23	0.22	0.025	0.0065
01/03/06	12:00	0.02	12600	0.025	21	20	20	0.069	26	0.28	0.025	0.0065
01/03/06	13:00	0.01	12700	0.025	20	52	52	0.005	18	0.2	0.025	0.0065
01/03/06	14:00	0.01	12800	0.025	18	24	24	0.006	26	0.22	0.025	0.013
01/03/06	15:00	0.02	12100	0.025	20	44	48	0.011	30	0.26	0.025	0.042
30/03/06	09:10	0.02	14700	0.025	11	24	40	0.0025	18	0.13	0.025	0.0065
30/03/06	10:00	0.02	14700	0.025	13	32	40	0.025	14	0.15	0.025	0.0065
30/03/06	11:00	0.02	13500	0.025	10	36	36	0.025	10	0.15	0.025	0.0065
30/03/06	12:00	0.02	13000	0.025	4	24	24	0.025	14	0.15	0.025	0.0065
30/03/06	13:00	0.01	12900	0.025	3	28	28	0.025	13	0.18	0.025	0.035
30/03/06	14:00	0.02	13800	0.025	2	8	8	0.025	13	0.15	0.025	0.0065
30/03/06	15:00	0.02	17300	0.025	2	2	2	0.025	6	0.23	0.025	0.0065
18/01/07	08:00	0.01	1000	0.012	10	140	210	0.0025	1.5	0.37	0.041	0.0065
18/01/07	09:00	0.01	775	0.011	8	100	190	0.0025	1.5	0.41	0.04	0.0065
18/01/07	10:00	0.01	436	0.011	6	120	150	0.0025	1.5	0.38	0.038	0.0065
18/01/07	11:00	0.005	339	0.01	14	70	84	0.0025	1.5	0.38	0.037	0.0065
18/01/07	12:00	0.01	451	0.011	6	110	140	0.005	1.5	0.44	0.038	0.0065
18/01/07	13:00	0.01	611	0.011	8	120	140	0.018	1.5	0.4	0.037	0.0065
18/01/07	14:00	0.01	3200	0.012	4	88	100	0.0025	7	0.43	0.031	0.0065
04/04/07	10:00	0.005	15200	0.025				0.025	11	0.26	0.089	0.0065
04/04/07	11:00	0.005	10600	0.025				0.025	17	0.26	0.025	0.0065
04/04/07	12:00	0.005	11800	0.025				0.05	6	0.43	0.025	0.0065
04/04/07	13:00	0.02	11300	0.025				0.025	18	0.31	0.025	0.072
04/04/07	14:00	0.005	11200	0.025				0.025	10	0.2	0.042	0.0065

Waikouaiti estuary - laboratory results continued

Waikouaiti	Time	NH4 mg/l	Chl mg/l	DRP mg/l	Ent cfu /100ml	E.coli cfu /100ml	F.coli cfu /100ml	NNN mg/l	SS mg/l	TN mg/l	TP mg/l	TZn mg/l
04/04/07	15:00	0.01	13000	0.025				0.084	11	0.34	0.025	0.0065
20/04/07	09:00	0.005	19200	0.025				0.025	5	0.28	0.025	0.011
20/04/07	10:00	0.005	16300	0.025				0.025	9	0.31	0.025	0.02
20/04/07	11:00	0.005	9600	0.025				0.025	21	0.2	0.025	0.0025
20/04/07	12:00	0.005	9680	0.025				0.025	32	0.24	0.025	0.005
20/04/07	13:00	0.005	9150	0.025				0.025	12	0.29	0.025	0.008
20/04/07	14:00	0.005	8320	0.025				0.025	11	0.25	0.025	0.016
19/03/08	06:30	0.01	15500	0.025	31	63	55	0.025	37	0.22	0.025	0.0065
19/03/08	07:30	0.005	14500	0.025	20	1.2	91	0.025	32	0.21	0.025	0.0065
19/03/08	08:30	0.005	14100	0.025	32	46	46	0.025	18	0.23	0.025	0.0065
19/03/08	09:30	0.005	13600	0.025	10	16	16	0.025	26	0.23	0.025	0.0065
19/03/08	10:30	0.005	13500	0.025	8	28	28	0.025	24	0.24	0.025	0.0065
19/03/08	11:30	0.02	14800	0.025	8	22	29	0.025	34	0.31	0.025	0.0065
19/03/08	12:30	0.01	17500	0.025	10	10	10	0.025	28	0.28	0.025	0.0065
21/04/08	08:00	0.04	17800	0.025				0.025	43	0.49	0.025	0.0065
21/04/08	09:00	0.01	16500	0.025	6	14	20	0.025	29	0.32	0.025	0.0065
21/04/08	10:00	0.01	15000	0.025	12	6	6	0.025	28	0.28	0.025	0.0065
21/04/08	11:00	0.01	14600	0.025	14	4	6	0.025	25	0.35	0.025	0.0065
21/04/08	12:00	0.01	14100	0.025	6	2	2	0.018	25	0.36	0.025	0.0065
21/04/08	13:00	0.03	14000	0.025	2	10	12	0.012	27	0.35	0.025	0.0065
21/04/08	14:00	0.03	16600	0.025	2	2	2	0.025	29	0.32	0.025	0.0065
07/05/08	09:00	0.005	15000	0.025	34	12	12	0.016	8	0.23	0.025	0.089
07/05/08	10:00	0.005	13900	0.025	16	9	11	0.034	11	0.24	0.025	0.082
07/05/08	11:00	0.005	13700	0.025	14	7	10	0.023	8	0.24	0.025	0.094
07/05/08	12:00	0.005	12100	0.025	2	20	23	0.032	5	0.16	0.025	0.105
07/05/08	13:00	0.005	11400	0.025	6	19	22	0.038	5	0.3	0.025	0.07
07/05/08	14:00	0.005	11100	0.025	8	10	13	0.035	17	0.24	0.025	0.108
07/05/08	15:00	0.01	16900	0.025	3	2	2	0.031	35	0.23	0.025	0.1
27/04/09	09:30	0.005	11500	0.025	24	64	90	0.017	18	0.19	0.025	0.025
27/04/09	10:30	0.005	11000	0.025	32	40	62	0.016	23	0.19	0.025	0.025
27/04/09	11:30	0.005	10400	0.025	12	44	56	0.011	20	0.18	0.025	0.025
27/04/09	12:30	0.005	9890	0.025	2	48	64	0.012	21	0.18	0.025	0.025
27/04/09	13:30	0.005	9160	0.025	4	42	54	0.008	20	0.22	0.025	0.025
27/04/09	15:30	0.01	17500	0.016	1	160	4	0.054	4	0.18	0.027	0.025
27/04/09	14.30	0.005	13200	0.014	1	110	30	0.013	1.5	0.51	0.063	0.025
09/06/09	09:30	0.02	389	0.006	8	22	24	0.212	4	0.44	0.014	0.0025
09/06/09	10:30	0.02	379	0.006	2	18	22	0.222	3	0.44	0.016	0.0025
09/06/09	11:30	0.02	372	0.006	4	20	28	0.223	1.5	0.45	0.016	0.0025

Waikouaiti estuary - laboratory results continued

Waikouaiti	Time	NH4 mg/l	Chl mg/l	DRP mg/l	Ent cfu /100ml	E.coli cfu /100ml	F.coli cfu /100ml	NNN mg/l	SS mg/l	TN mg/l	TP mg/l	TZn mg/l
09/06/09	12:30	0.02	329	0.006	2	8	8	0.224	1.5	0.45	0.019	0.0025
09/06/09	13:30	0.02	302	0.006	6	6	6	0.227	1.5	0.42	0.013	0.0025
09/06/09	14:30	0.03	503	0.007	2	22	22	0.225	1.5	0.48	0.02	0.0025
09/06/09	15:30	0.03	3350	0.007	60	16	16	0.183	8	0.42	0.014	0.0025
	MAX	0.22	22900	0.031	280	1500	2100	0.227	45	0.66	0.089	0.395
	MIN	0.005	302	0.006	1	1.2	2	0.0025	1.5	0.13	0.013	0.0025
	MEDIAN	0.01	11650	0.025	10	28	40	0.025	14	0.28	0.025	0.0065
	MEAN	0.02	10451	0.02	30.93	136.34	140.86	0.03	16.10	0.31	0.03	0.03
	COUNT	87	86	87	74	74	74	87	87	87	87	80

Waikouaiti estuary - field results

Waikouaiti	Time	Temp Deg C	Cond mS/cm	DO %	DO mg/l	pH pH	Sal mg/l	Turb NTU	Chla mg/l
30/11/04	06:00		36.1					1.9	
30/11/04	07:00		26.1					2.7	
30/11/04	08:00		26.3					3	
30/11/04	09:00		31.9					8.7	
30/11/04	10:00		17.2					6.2	
30/11/04	11:00		15.5					6	
30/11/04	12:00	15.5	12.8		9			8.1	
30/11/04	13:00	15.8	11.1		8.3			5.2	
30/11/04	14:00		10.1		8.6			4.9	
30/11/04	15:00		8.37					4.5	
30/11/04	16:00	18.3	14.6		8.4			4.4	
30/11/04	17:00	17.7	28.7		8			3.2	
15/02/06	10:05	15.8	35.09	92	6.58	7.73	22.09	2	0.69
15/02/06	11:05	16.58	29.89	95.6	6.88	7.82	18.5	2.4	0.73
15/02/06	12:10	16.85	26.85	105.2	7.63	7.88	16.42	2.2	1.05
15/02/06	13:10	17.54	24.24	113	8.16	7.91	14.67	3.3	1.27
15/02/06	14:10	18.32	39.43	137	9.51	8.24	25.16	31.7	3.93
15/02/06	15:10	19.26	40.18	190.6	13.06	8.33	25.69	6.1	1.6
15/02/06	16:00	19.71	24.94	159.4	10.96	8.31	15.13	2.7	14.62
01/03/06	09:05	15.44	47.32	78.8	5.38	7.89	30.86	1.6	0.5
01/03/06	10:00	15.7	45.06	82.6	5.67	7.91	29.21	1.6	0.46
01/03/06	11:00	16.08	40.91	88.7	6.15	7.9	26.22	2.1	0.53
01/03/06	12:00	16.47	37.84	94.3	6.58	7.91	24.03	2.5	0.58
01/03/06	13:00	16.46	35.56	93.4	6.58	7.88	22.42	2.9	0.82
01/03/06	14:00	16.56	35.69	101.4	7.13	7.95	22.51	3.7	0.84
01/03/06	15:00	16.33	36.15	104.3	7.35	7.99	22.84	4.4	1.04
30/03/06	09:10								
30/03/06	10:00	12.04	44.34			7.99	28.69		
30/03/06	11:00	12.46	40.56			7.99	25.96		
30/03/06	12:00	12.79	39.12			7.98	24.94		

Waikouaiti estuary - field results continued

Waikouaiti	Time	Temp Deg C	Cond mS/cm	DO %	DO mg/l	pH pH	Sal mg/l	Turb NTU	Chla mg/l
30/03/06	13:00	13.46	37.34			8.02	23.67		
30/03/06	14:00	14.26	36.38			8.05	22.99		
30/03/06	15:00	14.95	37.69			8.19	23.92		
18/01/07	08:00	16.41	3.824	84.2	8.05	7.68	2.08	26.7	2.08
18/01/07	09:00	16.81	3.126	86.2	8.19	7.56	1.69	2.4	2.02
18/01/07	10:00	17.1	2.631	90.5	8.56	7.69	1.42	2	2.02
18/01/07	11:00	17.53	2.256	95.9	9	7.79	1.21	2.1	1.96
18/01/07	12:00	17.89	1.966	100.4	9.36	7.88	1.05	2.7	1.92
18/01/07	13:00	18.12	2.933	108.3	10.03	8.22	1.58	2.3	1.95
18/01/07	14:00	19.05	7.025	140.7	12.61	8.85	3.91	4.5	12.88
04/04/07	10:00	14.15	36.94	85.4	7.5	7.73	23.39	1.3	1.06
04/04/07	11:00	14.42	36.45	90.5	7.93	7.88	23.05	0.8	1.04
04/04/07	12:00	15.35	33.89	98.5	8.56	7.92	21.25	0.9	0.76
04/04/07	13:00	14.74	36.54	99.9	8.69	7.99	23.11	0.9	1.31
04/04/07	14:00	14.58	37.38	97.2	8.46	7.98	23.7	0.9	1.7
04/04/07	15:00	17.12	40.89	164	13.33	8.49	26.2	1.3	0.99
20/04/07	09:00	11.12	44.47	88.9	8.06	7.91	28.79	0.5	0.6
20/04/07	10:00	11.23	41.17	90.5	8.31	8.07	26.41	0.5	0.61
20/04/07	11:00	11.59	38.39	97.3	8.97	8.09	24.42	0.9	0.48
20/04/07	12:00	12.1	37.1	102.6	9.42	8.13	23.51	0.9	0.5
20/04/07	13:00	12.68	35.97	108.4	9.88	8.15	22.71	0.9	0.57
20/04/07	14:00	12.98	35.3	112.6	10.23	8.19	22.23	1	0.66
19/03/08	06:30	14.83	46.84	49.9	4.22	8.05	30.51	4.3	1.36
19/03/08	07:30	16.24	41.84	88	7.4	8.4	26.88		1.04
19/03/08	08:30	16.34	39.86	93.1	7.88	8.4	25.46		0.96
19/03/08	09:30	16.52	38.75	98.9	8.38	8.42	24.67		1.49
19/03/08	10:30	17.03	37.52	105.3	8.88	8.44	23.8		0.91
19/03/08	11:30	17.34	39.73	119	9.88	8.54	25.38		1.48
19/03/08	12:30	17.09	49.41	129.8	10.38	8.64	32.39		0.72
21/04/08	08:00								
21/04/08	09:00								
21/04/08	10:00								
21/04/08	11:00								
21/04/08	12:00								
21/04/08	13:00								
21/04/08	14:00								
07/05/08	09:00	8.89	40.77	85.4	8.45	8.37	26.11	0.5	0.96
07/05/08	10:00	8.61	36.96	84.8	8.59	8.41	23.41	0.3	0.91
07/05/08	11:00	8.72	34	88.4	9.06	8.45	21.32	0.3	1.05
07/05/08	12:00	8.85	31.62	90.2	9.32	8.45	19.68	0.5	2.16
07/05/08	13:00	8.96	29.42	93.3	9.7	8.46	18.16	1	3.78
07/05/08	14:00	9.12	28.79	98.2	10.2	8.5	17.74	1.4	5.03
07/05/08	15:00	9.81	42.2	112.7	10.85	8.7	27.15	4	4.29
27/04/09	09:30	13	45.66	87.6	7.76	7.79	29.65		0.81
27/04/09	10:30	13.06	44.41	87.9	7.82	7.85	28.74		0.86
27/04/09	11:30	13.34	40.55	92.8	8.34	7.83	25.96		0.83

Waikouaiti estuary - field results continued

Waikouaiti	Time	Temp Deg C	Cond mS/cm	DO %	DO mg/l	pH pH	Sal mg/l	Turb NTU	Chla mg/l
27/04/09	12:30	13.6	36.57	98.8	8.99	7.86	23.13		0.92
27/04/09	13:30	14.48	29.33	109.6	10.11	7.94	18.1	1.3	0.92
27/04/09	15:30	15.67	51.51	108.9	9.13	8.05	33.94	2.7	2.34
27/04/09	14.30	14.34	40.22	129	11.08	8.16	25.72	1.1	1.13
09/06/09	09:30	4.06	1.818	102	13.16	7.35	0.97	3.4	1.14
09/06/09	10:30	4.06	1.699	101.6	13.11	7.42	0.9	1.8	0.96
09/06/09	11:30	4.11	1.581	102.1	13.17	7.43	0.84	0.7	0.87
09/06/09	12:30	4.35	1.608	103.3	13.23	7.44	0.85	1.9	0.86
09/06/09	13:30	4.4	1.358	102.9	13.18	7.47	0.72	0.1	0.82
09/06/09	14:30	4.65	1.827	104.5	13.28	7.52	0.97	0.5	0.96
09/06/09	15:30	6.06	10.78	113.5	13.44	8.08	6.13	2.4	1.44
	MAX	19.71	51.51	190.6	13.44	8.85	33.94	31.7	14.62
	MIN	4.06	1.358	49.9	4.22	7.35	0.72	0.1	0.46
	MEDIAN	14.83	35.97	98.8	8.645	7.99	23.13	2.1	0.99
	MEAN	13.76	29.09	102.62	9.15	8.04	19.51	3.33	1.72
	COUNT	71	79	61	66	67	67	63	61

Shag estuary - laboratory results

Shag	Time	NH4 mg/l	Chl mg/l	DRP mg/l	Ent cfu /100ml	E.coli cfu /100ml	F.coli cfu /100ml	NNN mg/l	SS mg/l	TN mg/l	TP mg/l	TZn mg/l
02/12/04	06:00	0.05	695	0.014	40	410	460	0.012	9	0.22	0.026	0.002
02/12/04	07:00	0.01	1670	0.011	36	340	320	0.008	16	0.25	0.017	0.001
02/12/04	08:00	0.01	790	0.017	64	330	360	0.015	9	0.28	0.027	0.002
02/12/04	09:00	0.01	510	0.015	36	290	350	0.01	8	0.26	0.021	0.001
02/12/04	10:00	0.01	240	0.017	48	330	310	0.015	8	0.27	0.026	0.002
02/12/04	11:00	0.01	176	0.014	12	200	270	0.019	10	0.32	0.038	0.028
02/12/04	12:00	0.02	454	0.019	36	290	240	0.019	12	0.47	0.031	0.016
02/12/04	13:00	0.01	167	0.015	25	150	340	0.016	8	0.31	0.026	0.008
02/12/04	14:00	0.01	176	0.016	55	300	290	0.015	6	0.41	0.027	0.008
02/12/04	15:00	0.02	151	0.016	41	310	240	0.014	5	0.25	0.022	0.006
02/12/04	16:00	0.01	346	0.016	10	200	230	0.014	4	0.27	0.023	0.006
02/12/04	17:00	0.01	165	0.015	23	200	180	0.013	13	0.36	0.037	0.007
16/02/06	10:05	0.005	49800	0.025	14	52	60	0.009	18	0.16	0.025	
16/02/06	11:10	0.03	29900	0.025	30	120	120	0.028	22	0.18	0.025	
16/02/06	12:05	0.04	12300	0.025	28	120	130	0.025	30	0.2	0.025	
16/02/06	13:00	0.02	70100	0.025	28	56	64	0.028	30	0.19	0.025	
16/02/06	14:00	0.04	7270	0.025	16	96	100	0.009	21	0.15	0.025	
16/02/06	15:00	0.02	9250	0.025	6	76	76	0.028	27	0.23	0.025	
20/04/06	10:00	0.06	18400	0.025	10	20	23	0.019	33	0.7	0.025	0.016
20/04/06	11:00	0.05	15800	0.025	5	10	64	0.025	36	0.65	0.069	0.015
20/04/06	12:00	0.05	15100	0.025	31	30	100	0.022	21	0.6	0.085	0.0025
20/04/06	13:00	0.04	14300	0.025	5	63	95	0.013	36	0.36	0.058	0.008
20/04/06	14:00	0.07	13900	0.025	5	10	85	0.029	29	0.55	0.066	0.011
20/04/06	15:00	0.07	13200	0.025	10	74	150	0.025	34	0.53	0.025	0.029
04/10/06	07:20	0.04	5620	0.025	16	88	92	0.236	5	0.45	0.025	0.0025
04/10/06	08:20	0.04	5860	0.025	12	46	46	0.229	5	0.45	0.025	0.017
04/10/06	09:20	0.04	5970	0.025	12	35	38	0.224	12	0.47	0.025	0.0025
04/10/06	10:20	0.04	6100	0.025	4	20	20	0.228	14	0.5	0.025	0.008
04/10/06	11:20	0.04	8080	0.025	4	12	12	0.18	15	0.45	0.025	0.015
04/10/06	12:20	0.04	11200	0.025	2	4	4	0.127	34	0.39	0.025	0.0025
04/10/06	13:20	0.04	16500	0.025	2	4	4	0.048	28	0.33	0.025	0.017
10/01/07	13:30	0.02	1270	0.01	5	130	290	0.063	1.5	0.3	0.009	0.0065
10/01/07	14:30	0.02	834	0.009	20	220	280	0.073	3	0.3	0.015	0.426
10/01/07	15:30	0.02	548	0.008	20	140	200	0.088	4	0.28	0.017	0.0065
10/01/07	16:30	0.02	463	0.01	10	110	210	0.085	1.5	0.29	0.017	0.45
10/01/07	17:30	0.02	446	0.011	41	150	180	0.083	1.5	0.29	0.017	0.119
10/01/07	18:30	0.02	451	0.01	5	52	210	0.084	3	0.34	0.019	0.171
10/01/07	19:30	0.02	572	0.01	10	160	190	0.095	3	0.3	0.019	0.455
24/01/07	12:30	0.03	4800	0.016	41	10	100	0.046	13	0.24	0.017	0.135
24/01/07	13:30	0.03	4550	0.015	5	41	70	0.044	13	0.26	0.053	0.133
24/01/07	14:30	0.03	4290	0.018	10	31	77	0.054	12	0.27	0.05	0.099
24/01/07	15:30	0.03	3990	0.017	10	51	77	0.063	7	0.31	0.057	0.0065
24/01/07	16:30	0.03	3890	0.017	31	52	180	0.046	14	0.29	0.065	0.17
24/01/07	17:30	0.04	5240	0.019	5	31	68	0.225	10	0.35	0.056	0.098
24/01/07	18:30	0.07	9820	0.025	5	5	5	0.026	29	0.38	0.037	0.127

Shag estuary - laboratory results continued

Shag	Time	NH4 mg/l	Chl mg/l	DRP mg/l	Ent cfu /100ml	E.coli cfu /100ml	F.coli cfu /100ml	NNN mg/l	SS mg/l	TN mg/l	TP mg/l	TZn mg/l
15/11/07	08:50	0.02	7860	0.025	80	29	52	0.128	7	0.5	0.025	0.0025
15/11/07	09:50	0.01	5610	0.025	20	39	68	0.178	5	0.88	0.025	0.0025
15/11/07	10:50	0.01	6390	0.025	13	45	76	0.18	8	0.63	0.025	0.0025
15/11/07	11:50	0.03	8030	0.025	25	26	48	0.142	8	0.58	0.025	0.0025
15/11/07	12:50	0.03	6930	0.025	25	24	58	0.165	8	0.59	0.025	0.0025
15/11/07	13:50	0.03	7310	0.025	20	0.5	1	0.163	9	0.74	0.025	0.0025
15/11/07	14:50	0.04	6980	0.025	25	38	52	0.162	8	0.83	0.025	0.005
22/01/08	09:30	0.005	15100	0.025	17	64	64	0.025	6	0.33	0.025	0.0025
22/01/08	10:30	0.005	12900	0.025	49	32	32	0.025	9	0.35	0.025	0.0025
22/01/08	11:30	0.005	12900	0.025	25	92	96	0.025	14	0.35	0.025	0.0025
22/01/08	12:30	0.005	14100	0.025	55	92	100	0.025	11	0.34	0.025	0.0025
22/01/08	13:30	0.005	15600	0.025	45	68	68	0.025	14	0.28	0.025	0.007
22/01/08	14:30	0.005	18500	0.025	33	20	28	0.025	25	0.21	0.025	0.0025
22/01/08	15:30	0.005	19900	0.025	98	61	61	0.025	12	0.17	0.025	0.0025
13/11/08	08:45	0.12	8650	0.025	4	48	48	0.223	16	0.56	0.025	0.025
13/11/08	09:45	0.01	9060	0.025	2	27	42	0.176	20	0.53	0.025	0.025
13/11/08	10:45	0.01	8530	0.025	4	48	84	0.126	16	0.57	0.025	0.025
13/11/08	11:45	0.02	7940	0.025	1	44	52	0.205	18	0.56	0.025	0.025
13/11/08	12:45	0.005	8980	0.025	1	4	12	0.112	20	0.52	0.025	0.025
13/11/08	13:45	0.005	12500	0.025	1	8	8	0.099	24	0.49	0.025	0.025
13/11/08	14:45	0.02	18500	0.025	0.5	4	8	0.038	33	0.34	0.025	0.025
23/03/09	08:30	0.04	5790	0.013	51	140	140	0.345	11	0.6	0.025	0.0025
23/03/09	09:30	0.04	5590	0.012	42	140	140	0.346	11	0.6	0.025	0.0025
23/03/09	10:30	0.04	5370	0.012	34	180	180	0.364		0.66	0.025	0.0025
23/03/09	11:30	0.05	6740	0.013	17	120	120	0.323	12	0.64	0.025	0.0025
23/03/09	12:30	0.06	9430	0.025	7	83	83	0.256	15	0.55	0.025	0.0025
23/03/09	13:30	0.06	10800	0.025	3	35	35	0.22	19	0.51	0.025	0.017
23/03/09	14:30	0.06	11000	0.025	7	58	58	0.204	17	0.48	0.025	0.0025
	MAX	0.12	70100	0.025	98	410	460	0.364	36	0.88	0.085	0.455
	MIN	0.005	151	0.008	0.5	0.5	1	0.008	1.5	0.15	0.009	0.001
	MEDIAN	0.02	6980	0.025	16	56	83	0.048	12	0.35	0.025	0.007
	MEAN	0.03	9073.21	0.02	21.76	96.42	120.88	0.10	14.58	0.41	0.03	0.04
	COUNT	73	73	73	73	73	73	73	72	73	73	67

Shag estuary - field results

Shag	Time	Temp Deg C	Cond mS/cm	DO %	DO mg/l	pH pH	Sal mg/l	Turb NTU	Chla mg/l
02/12/04	06:00	14	2.16		7.8			3.1	
02/12/04	07:00	14.3	5.11		7.6			3	
02/12/04	08:00	14.5	1.89		7.6			2.9	
02/12/04	09:00	15	1.98		7.5			2.5	
02/12/04	10:00	15.4	1.01		6.7			3.3	
02/12/04	11:00	16	0.765		7			4.1	
02/12/04	12:00		1.71					3.2	
02/12/04	13:00	16.8	0.669		7.2			3.6	
02/12/04	14:00	17	0.711		7			2.6	
02/12/04	15:00	17	0.719		7.1			2.3	
02/12/04	16:00	17.1	0.625		7.35			2	
02/12/04	17:00	16.8	0.644		6.8			4.8	
16/02/06	10:05	15.76	51.33	106.6	7.09	7.87	33.8	12.5	4.35
16/02/06	11:10	16.73	47.13	112.7	7.51	7.99	30.72	32.3	2.12
16/02/06	12:05	16.89	45.28	154.9	10.38	8.17	29.37	19.5	2.3
16/02/06	13:00	17.3	51.78	138.7	8.96	8.11	34.14	56.9	6.39
16/02/06	14:00	17.23	51.55	163.1	10.56	8.2	33.96	32.4	5.05
16/02/06	15:00	16.91		125.3	8.91	8.32		93.1	0.06
20/04/06	10:00	12.69	45.01	117.5	10.28	7.76	29.18		0.59
20/04/06	11:00	12.99	41.55	119.2	10.52	7.75	26.68		0.52
20/04/06	12:00	13.37	40.64	125.2	11.01	7.74	26.02		0.84
20/04/06	13:00	13.71	37.73	128.8	11.39	7.71	23.95		0.79
20/04/06	14:00	14.19	36.04	137	12.08	7.75	22.76		0.8
20/04/06	15:00	14.55	36.04	140.6	12.31	7.8	22.76		0.78
04/10/06	07:20	10.97	29.65	88.1	8.66	7.98	18.32	5.7	1.27
04/10/06	08:20	10.74	23.63	87.7	8.93	7.95	14.27	3.2	1.01
04/10/06	09:20	10.65	20.6	88.6	9.15	7.9	12.28	3.5	0.69
04/10/06	10:20	10.89	19.56	92.6	9.55	7.91	11.6	2.5	0.73
04/10/06	11:20	11.39	34.52	90.5	8.65	8.04	21.69	5.9	0.56
04/10/06	12:20	11.41	39.82	97.9	9.15	8.12	25.44	5	0.38
04/10/06	13:20	11.8	45.56	102	9.2	8.14	29.58	5.4	0.37
10/01/07	13:30	15.52	4.941	96.9	9.39	8.27	2.71	3.1	0.82
10/01/07	14:30	15.64	4.008	100.6	9.78	8.38	2.18	2.1	0.77
10/01/07	15:30	15.65	4.341	101.4	9.83	8.38	2.37	2.4	0.79
10/01/07	16:30	15.73	1.859	104.6	10.21	8.51	0.99	2.8	0.8
10/01/07	17:30	15.74	1.821	106.5	10.39	8.53	0.97	2.8	0.79
10/01/07	18:30	15.66	1.952	105.8	10.34	8.48	1.04	2.5	0.8
10/01/07	19:30	15.59	2.195	105.3	10.3	8.52	1.18	2.2	0.84
24/01/07	12:30	18.74	14.92	111.6	9.78	7.85	8.66	3.6	0.66
24/01/07	13:30	19.24	14.21	118.3	10.29	8.01	8.22	48.8	0.61
24/01/07	14:30	19.83	13.5	124.8	10.75	8.13	7.78	26.3	0.66
24/01/07	15:30	20.08	12.7	128.9	11.09	8.23	7.29	3.9	0.78
24/01/07	16:30	20.26	11.85	129.1	11.1	8.26	6.78	14.4	0.78
24/01/07	17:30	20.1	12.99	123.8	10.64	8.33	7.47	32.4	1.06
24/01/07	18:30	19.6	25.41	117.2	9.7	8.22	15.45	5.5	1.18

Shag estuary - field results continued

Shag	Time	Temp Deg C	Cond mS/cm	DO %	DO mg/l	pH pH	Sal mg/l	Turb NTU	Chla mg/l
15/11/07	08:50	11.58	46.91	93.6	8.44	8.16	30.55	1.8	2.98
15/11/07	09:50	11.77	37.68	95.8	8.98	8.23	23.92	1.9	6.29
15/11/07	10:50	11.89	34.29	95.7	9.08	8.19	21.53	2.2	4.53
15/11/07	11:50	12.13	26.38	95.2	9.29	8.11	16.1	2.3	6.13
15/11/07	12:50	12.19	20.45	97.5	9.74	8	12.18	1.7	2.47
15/11/07	13:50	12.36	20.24	98.6	9.83	7.99	12.05	2.3	2.63
15/11/07	14:50	12.6	19.97	101	10.03	8.01	11.87	2.5	2.98
22/01/08	09:30	19.73	37.14	97.7	7.75	8.48	23.53	0.8	6.44
22/01/08	10:30	19.77	35.16	100.4	8.03	8.51	22.14	1.1	7.43
22/01/08	11:30	19.59	33.46	106.4	8.59	8.56	20.95	1.6	8.73
22/01/08	12:30	18.44	38.81	97.4	7.86	8.47	24.72	2.9	7.62
22/01/08	13:30	17.91	40.14	101.6	8.24	8.52	25.66	4.4	14.64
22/01/08	14:30	16.92	47.19	95.6	7.67	8.44	30.76	5.2	3.2
22/01/08	15:30	15.48	50.9	103	8.36	8.47	33.48	3.3	8.31
13/11/08	08:45	16.05	23.3	105.8	9.59	7.03	14.05	2.7	5.16
13/11/08	09:45	16.52	24	112.2	10.05	7.34	14.51	8.3	3.85
13/11/08	10:45	17.23	22.85	120.8	10.71	7.41	13.75	3.5	4.07
13/11/08	11:45	17.76	21.5	128	11.29	7.48	12.87	163.8	4.77
13/11/08	12:45	17.88	24.32	131.4	11.43	7.53	14.72	6.1	11.29
13/11/08	13:45	16.75	33.91	135.1	11.55	7.56	21.26	6.1	21.18
13/11/08	14:45	15.34	45.63	139.5	11.66	7.14	29.63	4.5	6.11
23/03/09	08:30	11.74	16.38	90.7	9.35	6.31	9.58	0.1	0.82
23/03/09	09:30	11.98	15.73	95	9.78	6.4	9.17		0.64
23/03/09	10:30	12.52	15.37	98.4	10.01	6.42	8.94		0.56
23/03/09	11:30	13.13	21.21	94.7	9.3	6.52	12.67	1.8	0.6
23/03/09	12:30	13.14	33.56	94.5	8.81	6.66	21.02	1.8	0.64
23/03/09	13:30	13.74	44.75	93.5	8.18	6.73	28.99	4.1	0.88
23/03/09	14:30	13.85	46.53	95.9	8.31	6.75	30.28	2.5	0.78
	MAX	20.26	51.78	163.1	12.31	8.56	34.14	163.8	21.18
	MIN	10.65	0.625	87.7	6.7	6.31	0.97	0.1	0.06
	MEDIAN	15.615	23.075	104.6	9.325	8.01	17.21	3.2	0.88
	MEAN	15.30	23.89	109.95	9.30	7.88	17.84	10.88	3.06
	COUNT	72	72	61	72	61	60	65	61

Kakanui estuary - laboratory results

Kakanui	Time	NH4 mg/l	Chl mg/l	DRP mg/l	Ent cfu /100ml	E.coli cfu /100ml	F.coli cfu /100ml	NNN mg/l	SS mg/l	TN mg/l	TP mg/l	TZn mg/l
01/02/05	06:00	0.12	9300	0.025	10	10	35	0.02	32	0.37	0.025	0.01
01/02/05	07:00	0.28	15900	0.025	5	96	95	0.019	50	0.36	0.025	0.025
01/02/05	08:00	0.07	6300	0.018	5	74	150	0.026	20	0.28	0.025	0.005
01/02/05	09:00	0.07	5020	0.017	10	41	86	0.029	20	0.25	0.025	0.005
01/02/05	10:00	0.08	6370	0.018	5	63	77	0.025	26	0.27	0.025	0.005
01/02/05	11:00	0.1	6450	0.018	5	52	80	0.024	27	0.26	0.025	0.005
01/02/05	12:00	0.07	4650	0.018	5	41	130	0.022	26	0.17	0.025	0.005
01/02/05	13:00	0.06	6150	0.009	10	41	110	0.014	19	0.21	0.025	0.005
01/02/05	14:00	0.04	7270	0.011	5	20	73	0.018	30	0.23	0.025	0.005
01/02/05	15:00	0.1	6370	0.015	5	10	35	0.02	21	0.28	0.025	0.005
01/02/05	16:00	0.04	4970	0.02	10	10	64	0.027	19	0.27	0.025	0.005
01/02/05	17:00	0.05	5120	0.008	5	10	41	0.013	18	0.26	0.025	0.005
08/02/05	12:09	0.1		0.025		5	98	0.039	24	0.43	0.0025	
11/04/05	13:10	0.02		0.011	20	84	85	0.045	3	0.23	0.009	
14/06/05	13:05	0.01		0.007		5	4	0.107	0.5	0.22	0.006	
14/06/05	13:05	0.01		0.007		5	4	0.107		0.22	0.006	
16/08/05	13:15	0.19		0.025	20	7	8	0.121	13	0.25	0.025	
12/10/05	12:08	0.005		0.008		42	42	0.033	4	0.26	0.024	
05/12/05	12:25	0.02		0.025	12	28	37	0.029	19	0.25	0.025	
10/01/06	12:52				9	48						
08/02/06	12:30	0.03		0.025	14	22	26	0.007	31	0.17	0.058	
22/02/06	14:00	0.04	9640	0.025	82	290	700	0.038	11	0.26	0.025	
22/02/06	15:00	0.03	6350	0.013	160	390	690	0.035	9	0.33	0.025	
22/02/06	16:00	0.03	4460	0.012	220	410	820	0.026	8	0.64	0.025	
22/02/06	17:00	0.02	2850	0.012	320	520	780	0.026	4	0.53	0.025	
22/02/06	18:00	0.03	2940	0.014	230	910	840	0.031	4	0.22	0.025	
22/02/06	19:00	0.03	2780	0.012	240	620	940	0.028	7	1.16	0.036	
22/02/06	20:00	0.02	3100	0.013	210	580	890	0.034	7	0.7	0.049	
07/03/06	08:41				43	340						
22/03/06	13:30	0.03	5810	0.025	45	86	91	0.015	8	0.19	0.025	0.02
22/03/06	14:30	0.03	6130	0.025	15	130	170	0.018	7	0.13	0.025	0.02
22/03/06	15:30	0.03	8640	0.025	20	41	95	0.011	12	0.18	0.025	0.016
22/03/06	16:30	0.04	8210	0.025	10	63	75	0.013	15	0.16	0.025	0.073
22/03/06	17:30	0.03	8150	0.025	41	10	120	0.013	14	0.16	0.025	0.0065
22/03/06	18:30	0.03	6660	0.025	40	120	120	0.014	9	0.45	0.025	0.0065
22/03/06	19:30	0.03	7030	0.025	50	20	110	0.013	9	0.16	0.025	0.034
29/03/06	07:30	0.02	1300	0.008	120	760	760	0.027	3	0.13	0.012	0.02
29/03/06	08:30	0.03	2010	0.009	120	650	650	0.044	1.5	0.15	0.029	0.0065
29/03/06	09:30	0.02	2030	0.008	140	920	920	0.029	1.5	0.16	0.01	0.0065
29/03/06	10:30	0.03	1660	0.008	120	720	720	0.028	1.5	0.23	0.012	0.0065
29/03/06	11:30	0.02	1710	0.008	310	720	720	0.027	1.5	0.26	0.017	0.0065
29/03/06	12:30	0.02	1740	0.008	120	660	660	0.03	1.5	0.14	0.016	0.0065
29/03/06	13:30	0.03	2010	0.009	110	440	440	0.028	3	0.27	0.019	0.0065
19/04/06	13:20	0.01		0.005	2	12	12	0.02	3	0.36	0.021	
15/06/06	10:15	0.02		0.033		450	450	0.27	1.5	0.53	0.051	

Kakanui estuary - laboratory results continued

Kakanui	Time	NH4 mg/l	Chl mg/l	DRP mg/l	Ent cfu /100ml	E.coli cfu /100ml	F.coli cfu /100ml	NNN mg/l	SS mg/l	TN mg/l	TP mg/l	TZn mg/l
11/10/06	11:30	0.02	5010	0.03	10	41	55	0.084	10	0.43	0.144	0.01
11/10/06	12:30	0.02	9240	0.025	5	10	27	0.049	19	0.29	0.047	0.01
11/10/06	13:30	0.03	8850	0.022	5	10	5	0.057	18	0.31	0.06	0.01
11/10/06	14:30	0.02	8970	0.029	5	5	20	0.061	25	0.32	0.073	0.01
11/10/06	15:30	0.01	9090	0.02	10	20	30	0.06	13	0.35	0.052	0.01
11/10/06	16:30	0.03	10400	0.023	5	5	10	0.055	15	0.35	0.09	0.01
11/10/06	17:30	0.02	6500	0.029	5	20	15	0.087	11	0.75	0.116	0.01
22/11/06	11:00	0.02	360	0.018	5	63	110	0.044	1.5	0.3	0.022	0.0065
22/11/06	12:00	0.02	304	0.018	10	52	64	0.041	1.5	0.25	0.024	1.53
22/11/06	13:00	0.02	332	0.021	5	20	64	0.186	1.5	0.28	0.026	2.14
22/11/06	14:00	0.02	289	0.02	10	63	68	0.042	1.5	0.25	0.023	0.248
22/11/06	15:00	0.01	309	0.019	5	10	35	0.037	4	0.26	0.027	0.239
22/11/06	16:00	0.02	501	0.018	10	74	110	0.046	3	0.25	0.024	0.0065
22/11/06	17:00	0.03	632	0.019	10	63	10	0.045	4	0.6	0.026	0.0065
05/12/06	11:10				12	44	44					
08/01/07	11:45				40	50	76					
31/01/07	06:30	0.02	7130	0.019	20	230	230	0.036	10	0.2	0.025	0.0065
31/01/07	07:30	0.02	6320	0.021	5	160	160	0.047	7	0.22	0.025	0.0065
31/01/07	08:30	0.02	5590	0.022	12	74	96	0.054	8	0.24	0.025	0.0065
31/01/07	09:30	0.02	4590	0.022	24	52	56	0.061	8	0.26	0.025	0.0065
31/01/07	10:30	0.02	3720	0.023	14	44	50	0.083	5	0.23	0.025	0.0065
31/01/07	11:30	0.04	9570	0.061	6	6	40	0.036	17	0.25	0.025	0.0065
31/01/07	12:30	0.03	15000	0.036	8	12	16	0.025	27	0.27	0.025	0.0065
20/02/07	11:55				16	44	54					
20/03/07	12:45				14	40	100					
23/01/08	08:00	0.005	8140	0.042	220	300	400	0.05	4	0.36	0.056	0.0025
23/01/08	09:00	0.005	8410	0.047	220	290	320	0.05	4	0.34	0.029	0.0025
23/01/08	10:00	0.005	11900	0.036	89	190	230	0.031	6	0.37	0.02	0.0025
23/01/08	11:00	0.005	12300	0.039	52	190	190	0.024	6	0.39	0.028	0.0025
23/01/08	12:00	0.005	10800	0.042	45	140	140	0.026	12	0.43	0.087	0.009
23/01/08	13:00	0.005	11200	0.041	43	150	180	0.024	6	0.43	0.063	0.0025
23/01/08	14:00	0.005	13300	0.032	36	140	160	0.023	12	0.41	0.025	0.0025
18/02/08	12:30				330	280	280					
21/02/08	08:00	0.01	3960	0.014	330	320	350	0.086	8	0.26	0.01	0.0025
21/02/08	09:00	0.01	4530	0.018	210	350	370	0.082	10	0.29	0.009	0.006
21/02/08	10:00	0.005	4570	0.021	280	440	270	0.086	10	0.3	0.01	0.0025
21/02/08	11:00	0.01	3570	0.022	170	250	250	0.089	8	0.29	0.019	0.0025
21/02/08	12:00	0.01	3210	0.021	60	130	150	0.086	8	0.28	0.018	0.005
21/02/08	13:00	0.01	3350	0.023	28	120	130	0.088	8	0.3	0.017	0.0025
21/02/08	14:00	0.03	8910	0.018	6	110	120	0.055	17	0.3	0.025	0.011
10/03/08	12:45				58	210	300					
24/02/09	08:00	0.03	78	0.045	2700	100	330	0.473	8	1.04	0.079	0.0025
24/02/09	09:00	0.03	77.3	0.043	3600	160	310	0.47	8	1.01	0.077	0.038
24/02/09	10:00	0.03	73.7	0.044	2500	170	360	0.462	8	1.01	0.076	0.011
24/02/09	11:00	0.03	71.7	0.042	3000	130	340	0.451	7	1	0.076	0.033

Kakanui estuary - laboratory results continued

Kakanui	Time	NH4 mg/l	Chl mg/l	DRP mg/l	Ent cfu 100ml	E.coli cfu 100ml	F.coli cfu 100ml	NNN mg/l	SS mg/l	TN mg/l	TP mg/l	TZn mg/l
24/02/09	12:00	0.03	66.7	0.04	3800	120	300	0.45	8	0.98	0.071	0.01
24/02/09	13:00	0.02	54	0.036	2000	94	300	0.438	6	0.92	0.061	0.01
24/02/09	14:00	0.02	44.2	0.034	2700	79	310	0.43	5	0.89	0.058	0.016
11/03/09	08:00	0.02	1590	0.03	160	130	130	0.346	6	0.71	0.037	0.0025
11/03/09	09:00	0.01	1240	0.026	150	100	120	0.346	4	0.67	0.026	0.0025
11/03/09	10:00	0.01	778	0.021	150	120	120	0.338	3	0.65	0.032	0.0025
11/03/09	11:00	0.01	745	0.017	130	130	140	0.331	1.5	0.66	0.031	0.009
11/03/09	12:00	0.01	709	0.017	120	100	120	0.328	1.5	0.65	0.026	0.0025
11/03/09	13:00	0.01	1410	0.022	100	120	140	0.296	5	0.6	0.025	0.0025
11/03/09	14:00	0.01	1580	0.02	120	100	140	0.292	4	0.59	0.013	0.0025
	MAX	0.28	15900	0.061	3800	920	940	0.473	50	1.16	0.144	2.14
	MIN	0.005	44.2	0.005	2	5	4	0.007	0.5	0.13	0.0025	0.0025
	MEDIAN	0.02	4620	0.021	36	90	120	0.04	8	0.285	0.025	0.0065
	MEAN	0.03	4981.15	0.02	280.01	170.51	220.39	0.10	10.42	0.39	0.03	0.06
	COUNT	92	82	92	95	100	98	92	91	92	92	75

Kakanui estuary - field results

Kakanui	Time	Temp Deg C	Cond mS/cm	DO %	DO mg/l	pH pH	Sal mg/l	Turb NTU	Chla mg/l
01/02/05	06:00	14	24.9					2.1	
01/02/05	07:00	15	40.9					1.9	
01/02/05	08:00	16.8	17.8					0.95	
01/02/05	09:00	18.9	15.8					1.1	
01/02/05	10:00	19	18.7					0.85	
01/02/05	11:00	19	18.8					0.8	
01/02/05	12:00	20	14.1		8			0.75	
01/02/05	13:00	20.5	18.3		13			1.1	
01/02/05	14:00	20.5	21.3		11.25			1.1	
01/02/05	15:00	20.5	18.8		12			1.2	
01/02/05	16:00	21	14.8		10			1.5	
01/02/05	17:00	21.5	15.6		12			1.2	
08/02/05	12:09	21.18		94.4	7.63	7.61		2.9	
11/04/05	13:10	13.82		94.5	8.7	7.71		0.45	
14/06/05	13:05	5.11		87.2	11	7.16		0.55	
14/06/05	13:05								
16/08/05	13:15	8.43		85.8	8.12	7.44		2	
12/10/05	12:08	7.9			10			4.7	
05/12/05	12:25	19.42		81.3	6.89	7.4		1.9	
10/01/06	12:52								
08/02/06	12:30	16.8		66		4.99		2.5	
22/02/06	14:00	18.15	33.96	98.2	6.73	7.76	21.3	2.8	0.58
22/02/06	15:00	18.3	23.35	99.8	7.12	7.64	14.08	5.6	0.66
22/02/06	16:00	18.58	33.24	86.5	5.92	7.66	20.8	6	0.94

Kakanui estuary - field results continued

Kakanui	Time	Temp Deg C	Cond mS/cm	DO %	DO mg/l	pH pH	Sal mg/l	Turb NTU	Chla mg/l
22/02/06	17:00	18.42	23.84	88	6.25	7.63	14.4	3	0.92
22/02/06	18:00	17.99	16.97	88.6	6.51	7.67	9.95	223.1	
22/02/06	19:00								
22/02/06	20:00								
07/03/06	08:41								
22/03/06	13:30	14.48	50.58	84	7.07	7.89	33.25	3.6	0.91
22/03/06	14:30	15.07	48.97	86.2	7.22	7.97	32.07	2.7	0.8
22/03/06	15:30	14.89	49.69	79.3	6.65	7.94	32.6	2.8	0.78
22/03/06	16:30	14.86	50.93	71.4	5.96	7.89	33.51	2.3	0.9
22/03/06	17:30	14.83	50.95	81.4	6.8	7.93	33.52	1.9	0.92
22/03/06	18:30	14.84	51.11	76.7	6.4	7.93	33.64	1.8	0.98
22/03/06	19:30	15.03	51.16	106.9	8.88	8.08	33.68	1.7	0.94
29/03/06	07:30	14.32	50.37	72.3	6.12	7.75	33.1	3.3	1.42
29/03/06	08:30	14.52	49.7	70.9	5.99	7.81	32.6	4.8	1.48
29/03/06	09:30	14.71	49.38	71.1	5.99	7.79	32.37	0.7	1.52
29/03/06	10:30								
29/03/06	11:30								
29/03/06	12:30								
29/03/06	13:30								
19/04/06	13:20	14.36		58.1	5.82	6.73		1.21	
15/06/06	10:15	5.3		63.1	7.9	6.42		2.55	
11/10/06	11:30	11.2	49.47	83.7	7.4	8.09	32.44	3.8	0.82
11/10/06	12:30	11.13	49.56	85.8	7.6	8.24	32.5	3.5	0.73
11/10/06	13:30	12.52	35.5	101.1	9.29	8.35	22.38	1.9	0.46
11/10/06	14:30	12.53	45.19	102.2	8.98	8.34	29.31	2.1	0.47
11/10/06	15:30	12.83	45.43	97.2	8.49	8.37	29.48	2.5	0.51
11/10/06	16:30	13.87	34.6	108.1	9.67	8.41	21.74	1.4	0.56
11/10/06	17:30	14.15	29.55	107.1	9.72	8.41	18.25	2.5	0.73
22/11/06	11:00	15.51	1.478	98.9	9.71	8.04	0.78	2.9	0.8
22/11/06	12:00	15.82	1.394	101.5	9.91	8.26	0.74	1.7	0.84
22/11/06	13:00	16.39	1.177	119.8	11.56	9.3	0.62	5.4	0.89
22/11/06	14:00	16.77	1.225	116.6	11.19	9.15	0.65	3.3	0.87
22/11/06	15:00	17.03	1.253	122	11.59	9.47	0.66	3.7	0.85
22/11/06	16:00	17.44	1.779	120.7	11.37	9.34	0.95	3.6	0.8
22/11/06	17:00	16.55	27.55	117.5	10.24	8.7	16.89	4	0.77
05/12/06	11:10								
08/01/07	11:45								
31/01/07	06:30	16.08	29.35	84.9	7.41	7.79	18.12	1.7	0.76
31/01/07	07:30	16.05	22.83	83.5	7.49	7.76	13.74	1.3	0.66
31/01/07	08:30	15.93	18.72	82.4	7.54	7.64	11.07	1.1	0.71
31/01/07	09:30	15.81	15.12	83.2	7.73	7.55	8.79	1.2	0.91
31/01/07	10:30	15.73	15.76	83.6	7.76	7.57	9.19	1.3	0.8
31/01/07	11:30	15.79	25.3	85.7	7.65	7.82	15.38	2.5	1
31/01/07	12:30	15.66	47.03	101.2	8.26	8	30.64	12.4	1.13
20/02/07	11:55								
20/03/07	12:45								

Kakanui estuary - field results continued

Kakanui	Time	Temp Deg C	Cond mS/cm	DO %	DO mg/l	pH pH	Sal mg/l	Turb NTU	Chla mg/l
23/01/08	08:00	16.05	49.99	88.2	7.11	8.39	32.81	3	3.97
23/01/08	09:00	16.12	50.03	91.4	7.35	8.41	32.85	3.5	7.88
23/01/08	10:00	16.2	50.75	92.9	7.44	8.42	33.37	4.5	4.37
23/01/08	11:00	16.55	49.92	93.6	7.47	8.42	32.76	3.1	4.81
23/01/08	12:00	17.57	45.19	119.7	9.56	8.5	29.31	2.5	5.21
23/01/08	13:00	17.95	40.29	112.5	9.11	8.48	25.77	2.6	3.22
23/01/08	14:00	18.17	39.01	111.9	9.07	8.46	24.86	2	2.65
18/02/08	12:30								
21/02/08	08:00	16.78	39.64	80.7	8.83	8.27	25.31	3.68	4.9
21/02/08	09:00	17.01	28.53	80.8	9.22	8.27	17.56	10.2	3.6
21/02/08	10:00	17.51	26.17	73.8	8.43	8.11	15.96	4.75	1.7
21/02/08	11:00	18.3	17.86	87.7	10.19	8.09	10.52	4.69	0.9
21/02/08	12:00	19.12	13.85	98.1	11.38	8.26	8	4.02	0.2
21/02/08	13:00	19.24	18.57	110.2	12.53	8.42	10.97	1.53	1.6
21/02/08	14:00	18.82	36.84	104.4	11.12	8.47	23.32	1.71	9
10/03/08	12:45								
24/02/09	08:00	12.49	0.3707	93.1	9.73	6.22	0.18	13.4	2.76
24/02/09	09:00	12.48	0.3668	93.3	9.74	6.23	0.18	12.8	2.7
24/02/09	10:00	12.47	0.3492	94.5	9.87	6.22	0.17	12	2.64
24/02/09	11:00	12.51	0.3395	94.9	9.91	6.23	0.17	11.7	2.66
24/02/09	12:00	12.58	0.3176	95.6	9.97	6.23	0.15	10.6	2.57
24/02/09	13:00	12.59	0.2819	95.6	9.97	6.24	0.14	10	2.5
24/02/09	14:00	12.63	0.2452	97	10.1	6.25	0.12	9.6	2.46
11/03/09	08:00	11.85	5.817	91.8	9.59	6.11	3.21	0.2	1.54
11/03/09	09:00	11.71	4.199	95.2	10.03	6.25	2.29		1.51
11/03/09	10:00	11.63	3.13	97.9	10.37	6.29	1.69		1.47
11/03/09	11:00	11.55	3.015	100.3	10.65	6.3	1.63		1.38
11/03/09	12:00	11.67	2.728	102.9	10.91	6.34	1.47		1.44
11/03/09	13:00	12.15	9.315	109.2	11.19	6.58	5.25	0.5	1.61
11/03/09	14:00	12.93	48.73	108.9	9.28	6.8	31.89	15.5	3.02
	MAX	21.5	51.16	122	13	9.47	33.68	223.1	9
	MIN	5.11	0.2452	58.1	5.82	4.99	0.12	0.2	0.2
	MEDIAN	15.79	23.595	93.45	9.025	7.855	17.225	2.5	0.98
	MEAN	15.41	25.78	92.98	8.88	7.68	17.14	6.31	1.81
	COUNT	85	76	72	78	72	64	81	63