Water quality and ecological health for rivers in the Catlins area

Otago Regional Council
Private Bag 1954, 70 Stafford St, Dunedin 9054
Phone 03 474 0827 Fax 03 479 0015
Freephone 0800 474 082
www.orc.govt.nz

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Prepared by Rachel Ozanne

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Foreword

The Otago Regional Council (ORC) carries out regular water quality monitoring as part of its State of Environment programme. It also performs short-term targeted water quality monitoring programmes. This report provides the results from one of these more detailed investigations carried out in the Catlins region.

The Catlins rivers are recognised for retaining historical natural values. All the rivers have a high percentage of native bush in their catchments, and the rivers are considered to have excellent water quality. Farming in the area has traditionally been sheep and beef grazing; however, land use is changing and more intensive farming is now prevalent in the Owaka catchment and is likely to expand.

ORC has a broad range of regulatory and non-regulatory approaches to ensure the water quality in the Catlins region is not only maintained, but also enhanced, where possible. In consultation with the Otago community, ORC is currently putting in place a new water quality strategy and revising its Water Plan to address any water quality issues that may arise from these changes to land use in the Catlins.

The results from this report will be used to guide future policy decisions and will be shared with the community and other stakeholders to promote good practice in order to maintain and enhance water quality in the Catlins region.

Executive summary

The Catlins lies between the Clutha River/Mata-Au to the north-east and the Mataura River to the west. It has the largest remaining area of native forest on the South Island's east coast, and is defined by parallel ranges of hills, which are separated by the valleys of the Owaka, Catlins and Tahakopa rivers, which flow in a south-easterly direction.

The Catlins rivers are recognised for many natural values, including high fish and macroinvertebrate diversity, rare fish, trout spawning and rearing habitat and a significant presence of eels. There is a high percentage of native bush in the catchments and the rivers are considered to have excellent water quality. Until recently, farming in the area has traditionally been sheep and beef grazing; however, land-use is changing and more intensive farming is now prevalent in the Owaka catchment and is likely to expand.

The Catlins' monitoring programme was launched in October 2009. Its objectives were to assess the state of water quality in the Catlins, Owaka, Tahakopa, Maclennan and Tautuku rivers and to determine the ecological health of these rivers

This programme ran from October 2009 to September 2010. Fortnightly water quality sampling was undertaken at ten sites for 12 months. Flow monitoring was undertaken on each river. The water was tested for a range of variables, such as suspended sediment, nutrients and *Escherichia coli* (*E.coli*) bacteria. Substrate analysis, macroinvertebrate sampling and fish sampling were undertaken in late 2009.

The results confirm that the percentage of native bush cover upstream reflects the quality of water downstream. The Tautuku River, which had 91% native bush upstream of the sampling site, had excellent water quality that reflected pre-pastoral conditions. However, the native bush upstream of the Owaka River sites accounted for less than 20% of the landcover. This catchment also had more intensive farming than the other catchments (six dairy farms). Results showed that water quality in the Owaka River was compromised.

The Owaka River is typically well above water quality guideline values for nutrients and is phosphorus limited; the other streams monitored are nitrogen limited. The Owaka upper site was the only site to exceed the stock water drinking guideline of 1000 *E. coli*/100ml.

Substrate analysis showed the presence of bedrock at many sites, but it was prevalent in the Owaka River. Bedrock generally restricts the available habitat for fish and macroinvertebrates; however, the Owaka River still had a high percentage of mayflies, caddisflies and stoneflies (EPT taxa). At all sites, there was minimal fine sediment cover, with the exception of the upper Owaka site (>60% fine sediment cover over the dominant substrate).

The ecological condition of the rivers was good. The percentage of EPT taxa at each site was at least 55%, which indicates that the rivers are very healthy. The condition/density of brown trout was good to excellent, the Owaka River (upper and mid), Tautuku and the Tahakopa upper site were classed as having fish of excellent density and condition. The steeper headwater sites (Catlins) had a lower condition/ density of trout, probably due to scouring flows.

Riparian vegetation was largely absent from the monitored rivers. Riparian vegetation is vital as a mechanism to control sediment input. Most rivers in the Catlins were used to provide stock water, as there is no rural stock-water scheme. This practice has caused the erosion of river banks and the degradation of riparian vegetation.

Water quality and ecological values were combined to summarise each site. The Tautuku, Maclennan and Tahakopa upper were classified as ‘excellent’. The Catlins sites and Tahakopa mid-site were classified as ‘good’, and the three Owaka sites were classed as ‘fair’. No sites were considered to be of poor health.

This targeted 12-month investigation has provided a significant amount of knowledge about rivers in the Catlins area. The results show that all the rivers monitored are in reasonable ecological health. However, it is important to note that the situation could deteriorate unless stock are excluded from water courses or if farming becomes more intensive.

The results will be used to provide baseline data which will help to direct council policy (in line with the Rural Water Quality Strategy). The results are currently being used by the Land Resources team who have started a catchment programme in the Catlins area. This programme aims to establish joint initiatives with land managers to improve river health through best management practices (i.e. fencing and riparian planting).

A series of meetings has already been held with key landowners in the district, and public field-days will be held to communicate the findings of this report to local iwi and landowners. These meetings will signal the start of initiatives with groups of farmers and members of the wider community to encourage changes in practice to improve water quality results.

Contents

1 Introduction

The Catlins rivers are recognised for many natural values, including high fish and macroinvertebrate diversity, rare fish, trout spawning and rearing habitat and a significant presence of eels. The rivers are considered to have excellent water quality as there is a high percentage of native bush in their catchments. Routine State of the Environment (SOE) monitoring has been undertaken at one site on the Catlins River since 1997.

Until recently, farming in the area has traditionally been sheep and beef grazing; however, land-use is changing and more intensive farming is now prevalent in the Owaka catchment and is likely to expand.

This report documents the results of a 12-month investigation of water quality and ecological values in the Catlins. The investigation was undertaken between October 2009 and September 2010 and involved regular testing of surface water and a one-off assessment of aquatic ecological health and substrate analysis. The principal aim of the investigation was to improve understanding of surface water quality within the Catlins and to determine ecological values of the rivers in the region.

This study looks at water quality, habitat condition and ecological values. It does not include the views of the local iwi, community or other stakeholders, nor has there been an assessment of recreational values or socio-economic benefits. The results are anticipated to become part of the future debate of acceptable land-use practices in the Catlins.

Figure 1: The Maclennan River, showing native bush in the catchment

2 Background information

2.1 The Catlins region

The Catlins region largely consists of undulating or lower hill-country. The coast is dominated by sandy bays and cliffs (with slopes of up to 200 m). From there, the land rises steadily from the south-east to north-west, reaching its maximum altitude (720 m) at Mt Pye, in the headwaters of the Tahakopa and Catlins Rivers, and then it falls again, through rolling country, towards the Mataura River (in Southland) and the Clinton lowlands.

The forested ridges provide a contrast to the cleared valleys, where pastoral activities are concentrated. There is little flatland in the Catlins, except in the lower reaches of the principal rivers and streams. Because of the soft rock formation, rivers have become incised and so run in a stable permanent bed. Headwaters of all major rivers rising from within the Catlins have their vegetation intact. The lower reaches exhibit well-developed estuaries.

The Catlins River flows south-eastward. Its total length is 42 km and it shares its estuary with the Owaka River, which flows into the Pacific Ocean at Pounawea, 28 km south of Balclutha. The river's source is to the west of Mt Rosebery, 15 km southwest of Clinton. The Owaka River is 30 km long and flows south-east. Its source is on the slopes of Mt Rosebery.

The Tahakopa River flows south-east through the Catlins. Its total length is 32 km, and it flows into the Pacific Ocean 30 km east of Waikawa, close to the settlement of Papatowai. The river's source is west of Mt Pye, which is 25 km east of Wyndham. The Maclennan River is 17.5 km long and enters the Tahakopa River near Maclennan.

The Tautuku River is 21.5 km long and flows south-east. The river’s source is the Maclennan Range, and it passes over the MacLean Falls on its way to the Tautuku Estuary.

Figure 2: Tautuku, Tahakopa and Catlins catchments, with associated sampling sites

2.2 Climate

The Catlins experiences considerably higher rainfall than most of the South Island's east coast because the climate is modified by the effect of the Pacific Ocean. Heavy rain occurs infrequently, but drizzle is common and 200 days of rain in a year is not unusual. Winds can reach considerable strength, especially on the exposed coast. Most of the South Island's storms develop to the south or south-west, and the Catlins bears the brunt of many of these weather patterns.

Rain days are spread evenly throughout the year. Figure 3 shows that most of the area is classified as having a cool, wet climate.

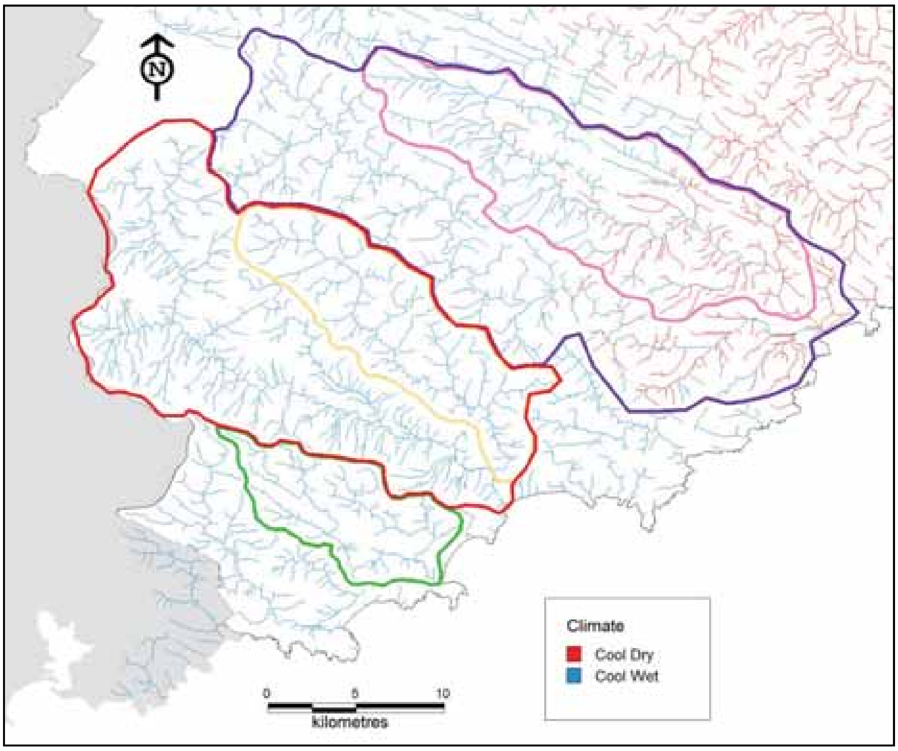


Figure 3: The Catlins area, climate classification, according to REC

Figure 4 shows rainfall data for two rainfall stations. The Waipahi rainfall gauge is located at the top of the Catlins/ Waipahi catchment, and the average annual rainfall, between 1990 and 2010, was 1338mm. The Glenomaru rainfall gauge is located to the north of Owaka, and the average annual rainfall, between 1987 and 2010, was 972mm. (Dunedin's annual average for the same period was 800mm).

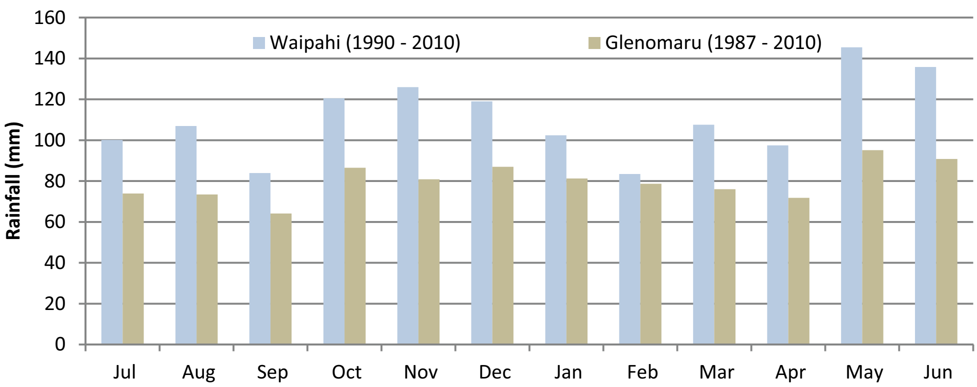


Figure 4: Average monthly rainfall for the Waipahi and Glenomaru rain gauges

2.3 Geology and soils

The Catlins area is distinguished by hill-chains, which run parallel in a south-east/north-west direction and have numerous peaks and sharply ridged crests (Mollmann, 1979). These ranges are composed of Triassic and Jurassic sandstones, mudstones and other related sedimentary rocks.

The Catlins area is known for its distinctive hard sandstones, which are interbedded with softer mudstones, and are the dominant surface rock type. Jurassic-Triassic sediments form the parent material, and sandstones, greywackes, silty mudstones and conglomerates are common. The sediments are folded and form the Southland syncline, a series of forested parallel ridges, which dominate drainage, vegetation and land-use patterns (Mollmann, 1979). The syncline links to similar formations in Nelson, and are offset by the Alpine fault.

There are two broad zonal earth types common in the Catlins, with yellow-brown earth present in less steep valley slopes or bottoms. These soils are greyish-brown friable silt loams, with high leaching capability and low nutrient status.

Podsolised yellow-brown earth variants are present in the hill country and forests. This comprises silt and stony loams that are widespread on wet coastal hills and occur in most other forests at higher altitudes. Figure 5 shows the soils of the Catlins region.

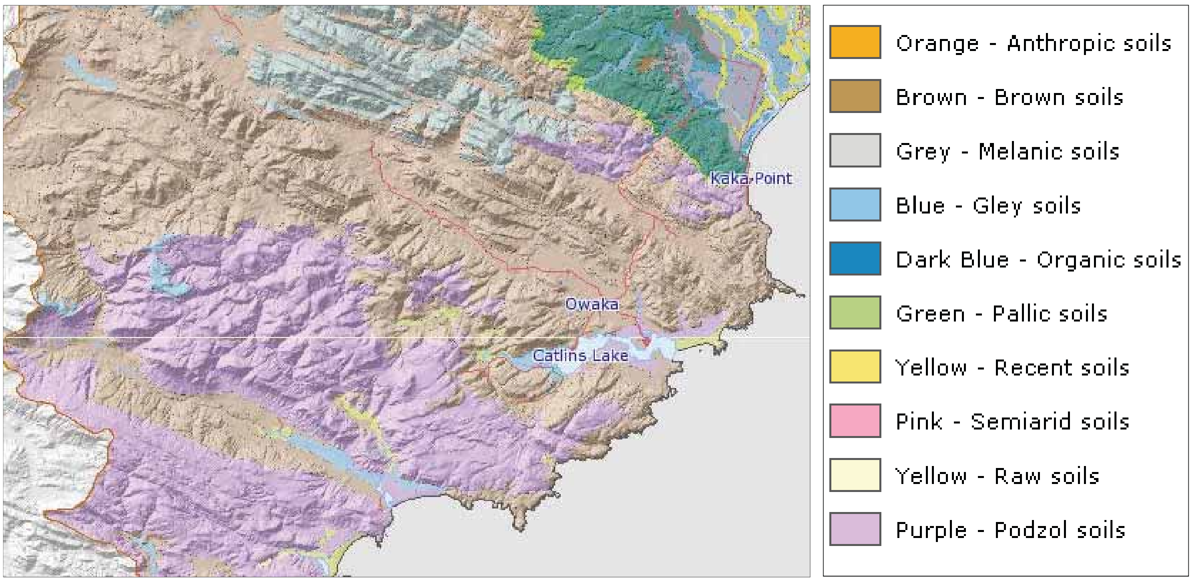


Figure 5: Soils of the Catlins region (Grow Otago)

2.4 Hydrology

Figure 6 shows stream order[1], according to the River Environment Classification System (REC) (Snelder *et al.*, 2003).

The Tahakopa is the only fifth order stream in the area; the main-stem Catlins, Owaka, Maclennan and Tautuku rivers are forth order streams. The majority of watercourses in the area are first and second order streams.

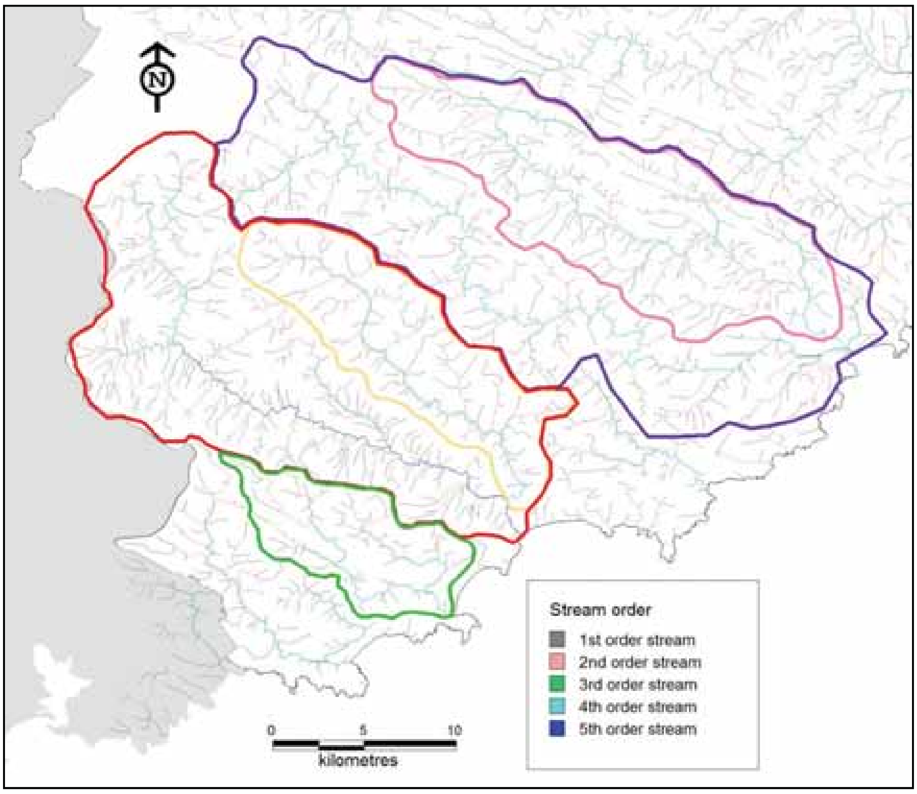


Figure 6: Stream order, according to the River Environment Classification System (REC)

The only long-term hydrological data ORC holds for the area is for the Catlins River. This catchment has an area of roughly 400 km^2 and a high, reliable mean annual rainfall. The lowest flow recorded in the Catlins River at Houipapa is 0.43 m^3/s, while the maximum discharge recorded at the same site is 124 m^3/s. During this monitoring programme, the average daily flow in the Catlins River exceeded 25 m^3/s on ten occasions (Figure 7).

[1] Strahler Order: Hierarchical ordering of streams based on the degree of branching. A first-order stream is an unforked or unbranched stream. Two first-order streams flow together to form a second-order stream, two second-order streams combine to make a third-order stream, etc. (Strahler 1957).

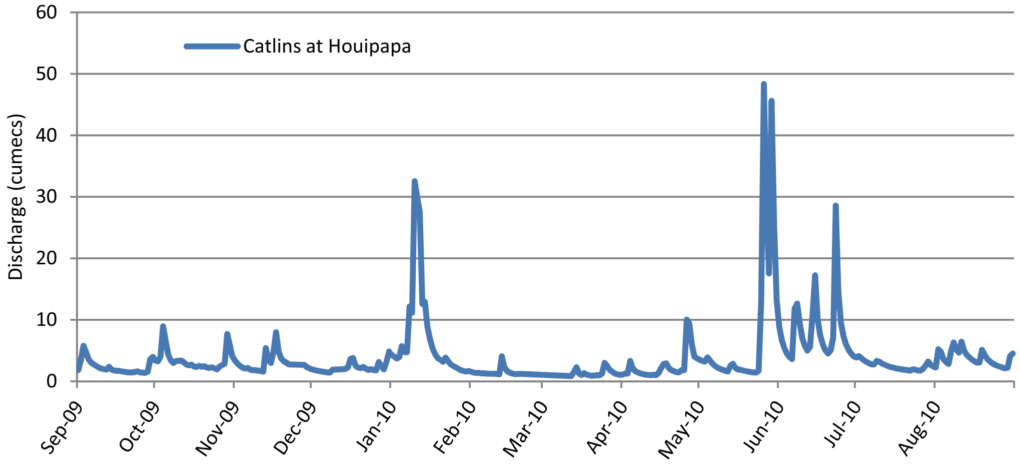


Figure 7: River discharge for the Catlins River at Houipapa (Sep 2009 to Oct 2010)

Compared to North or Central Otago rivers, the Catlins River has a higher frequency of flushing flows. This is shown in Figure 8, in which flows in the Catlins River are compared to those in the Shag River in North Otago (catchment area 714 km^2).

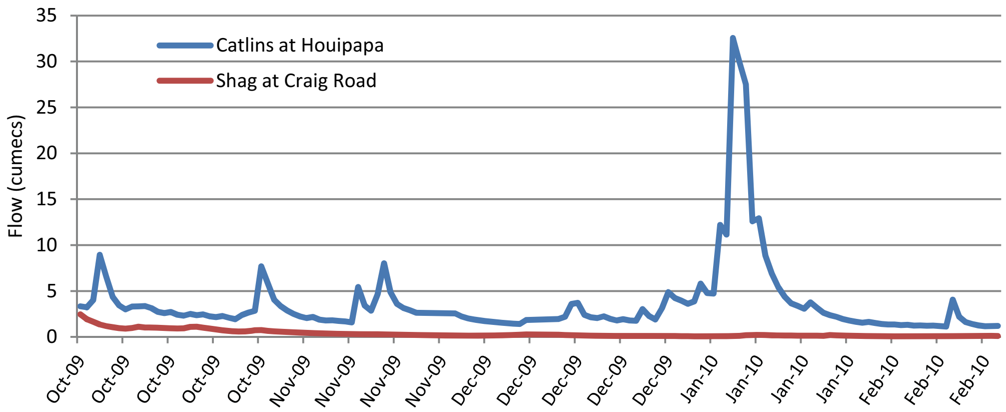


Figure 8: Comparison of river discharges for the Catlins River and the Shag River (North Otago), between October 2009 and February 2010

These larger flows are important for removing algae, flushing nutrients and moving sediment. Rivers with a low frequency of flushing flows are susceptible to algal proliferations, particularly if they contain high nutrient levels.

2.5 Land use

Figure 9 shows the main uses of land in the catchments studied in this report. The Catlins comprises the largest area of native forest on the east coast of the South Island (Elliot *et al.*, 2007), with over 500 km^2 of forest and neighbouring subalpine areas being protected in Catlins Conservation Park (DOC, 2009).

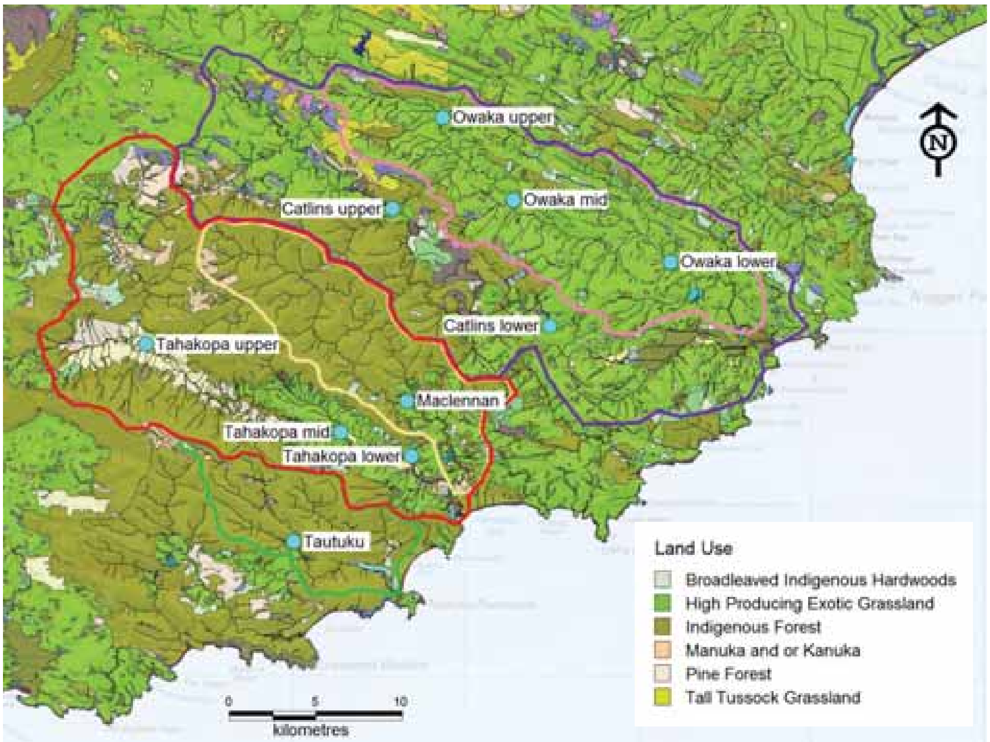


Figure 9: Land use in the Catlins, Owaka, Tahakopa, Maclennan and Tautuku catchments

The forest has rimu, totara, silver beech, matai and kahikatea. Of particular note are the virgin rimu and totara forests in those areas, which were either too rugged or too steep for early settlers to mill. Also of note is an extensive area of silver beech forest, close to the Takahopa River. This is New Zealand's most southerly expanse of beech forest (Buckingham, 1985).

Figure 10 shows the marked differences in land use among the catchments. Both the Tautuku and Maclennan rivers have indigenous forest covering >90% of their catchment area. The Tahakopa catchment is also dominated by indigenous forest (>50%). In contrast, the Owaka catchment is dominated by high producing exotic grassland (>60%).

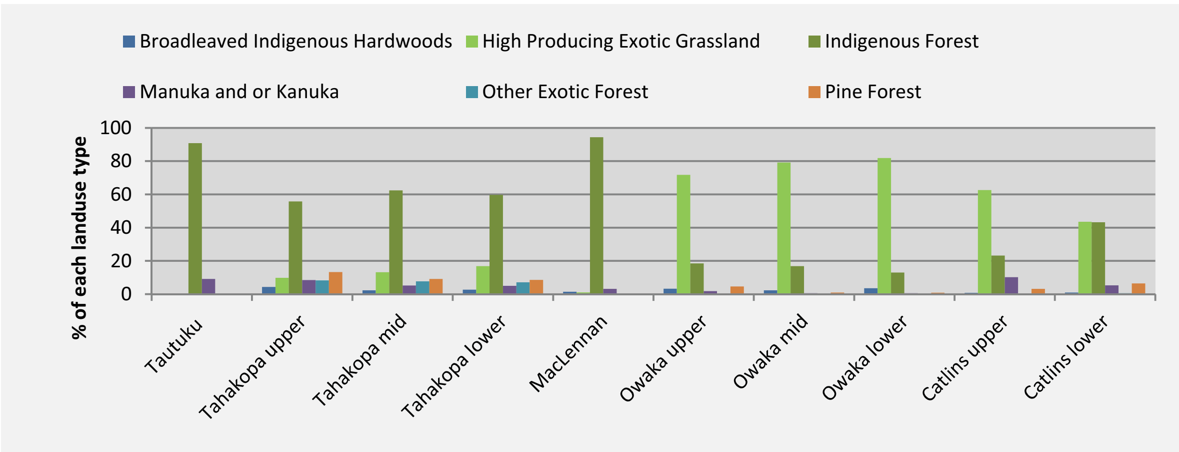


Figure 10: Land-use cover upstream of each sampling site.

On high producing exotic grassland, sheep and beef grazing represents the majority of recorded land use in the catchment, with dairy, deer and forestry being less common forms of agriculture. Dairy farming takes place in the Owaka catchment only, where there are six dairy farms with over 3000 dairy cows.

2.6 Natural values

The Regional Plan: Water for Otago[2] (RPW, 2004) lists many natural values for the Catlins, Tautuku, Tahakopa, Maclennan and Owaka rivers, including high fish and macroinvertebrate diversity, rare fish, trout spawning and rearing habitat and a significant number of eels. All the rivers also have a high degree of naturalness as they are within bushed catchments.

The Catlins, Tautuku, Tahakopa and Owaka rivers support diverse ecosystems. According to the NIWA Freshwater Fish Database, there are numerous species of fish and one species of freshwater crayfish in the catchments (Table 1). Brown trout (*Salmo trutta*) is an introduced species and is also the most common fish in the area.

Table 1: Fish species present in the catchments, according to the NIWA Freshwater Fish Database

Common Name	Species Name	Catlins River	Owaka River	Tahakopa River	Tautuku River
Redfin bully	*Gobiomorphus huttoni*	yes		yes	yes
Longfin Eel	*Auguilla dieffenbachia*	yes	yes	yes	yes
Lamprey	*Geotria australis*	yes		yes	yes
Brown trout	*Salmo trutta*	yes	yes	yes	yes
Giant Kokapu	*Galaxias argenteus*	yes	yes		
Koaro	*Galaxias brevipinnis*	yes			yes
Inanga	*Galaxias maculatus*	yes			
Clutha flathead galaxias	*Galaxias species D*	yes	yes	yes	
Common bully	*Gobiomorphus cotidianus*	yes	yes	yes	
Koara	*Paranephrops*	yes	yes	yes	
Black flounder	*Rhombosolea retiaria*	yes			
Banded Kokapu	*Galaxias fasciatus*		yes		

2.7 Recreational values

Recreational anglers fish the Catlins rivers, with angler days increasing slightly between 2001/2002 and 2007/2008. The Otago region, as a whole, experienced a slight decrease in river angling days over the same period, so the Catlins area does not follow the regional trend. Table 2 below shows angler days over three time periods for the Catlins rivers (Unwin, 1998, 2003 and 2009).

Table 2: Estimated usage (angler days +/- 1 standard error) for the rivers in the Catlins area

River	**Tributary**	**2007/2008**	**2001/2002**	**1994/1995**
Catlins	Catlins	1490 +/- 720	910 +/- 330	4510 +/- 1520
	Owaka	1090 +/- 530	190 +/- 120	1400 +/- 1100
Tahakopa	Maclennan		150 +/- 140	10 +/- 10
	Tahakopa	60 +/- 40	720 +/- 380	1630 +/- 940
Tautuku	Tautuku	30 +/- 30	390 +/- 230	60 +/- 40

[2] Schedule 1A of the Regional Plan: Water for Otago (2004), pg 296.

3 Methods

This section outlines the methods used to collect water chemistry, physical habitat, and ecological values in the catchment.

- The water quality section outlines the sampled analytes, the sampling frequency and guidelines used in the study.
- The biological assessment section outlines the methods used to sample macroinvertebrates and fish.
- The substrate assessment section outlines the key methods used to assess substrate.

3.1 Water quality assessment

Ten sites were sampled on the same day, fortnightly, between October 2009 and September 2010. The sites included one reference site (Tautuku River), three sites on the Tahakopa River, one site on the Maclennan River, three sites on the Owaka River and two sites on the Catlins River. At most sites, continuous flow was monitored, and where it was not, a virtual flow measurement was substituted. Of the sites selected, only the Catlins River lower site (Catlins at Houipapa) was a long-term State of Environment (SOE) monitoring site.

At each river site, water samples were collected for analysis of analytes, including total phosphorus (TP), total nitrogen (TN), nitrite-nitrate nitrogen (NNN), ammoniacal nitrogen (NH_4), dissolved reactive phosphorus (DRP), *Escherichia coli* (*E.coli*) and suspended solids (SS).

3.2 Water quality guidelines

The guideline values have been chosen to reflect the nature of the Catlins catchments. This is because the Catlins is characterised by native forest, particularly around the Maclennan and Tautuku Rivers, which are largely in their unmodified, natural states.

Guideline standards were drawn from three sources (Table 3). The ANZECC (2000) guidelines are referenced for NH_4, TN and TP guideline values, while the biologically available nutrients (DRP and NNN) are referenced against the New Zealand periphyton guidelines (2000). The ANZECC 1992 guidelines are referenced for bacteria.

There are no New Zealand suspended solid guidelines available. However, a study in the Pomahaka River (Roger, 1999) found that 5 NTU was the maximum turbidity value before the growth potential of drift-feeding trout was affected. A regression between SS and turbidity data (R^2=0.78) using data from the Catlins River (at Houipapa) gave a suspended solid value of 6.4 mg/ L (at 5 NTU).

Banded kokopu are more sensitive to elevated SS concentrations than other diadromous species (Rowe, 1997), but the turbidity level at which they reduced their feeding rate was 20NTU, which is well below the figure for trout.

Table 3: Physico-chemical and microbiological analytes and guideline values

Analyte	Unit	Guideline value	Ecological effect
NH_4	mg/l	<0.9*	High levels of ammonia are toxic to aquatic life, especially fish. The level of total ammonia in water should be less than 0.9mg/l to be safe for fish. Ammonia in waterways comes from either waste waters or animal wastes (dung and urine).
TN	mg/l	<0.614*	Encourages the growth of nuisance aquatic plants. These plants can choke up waterways and out-compete native species. High levels can be a result of runoff and leaching from agricultural land.
NNN	mg/l	<0.295**	The biologically available component of TN, an excess of this nutrient may cause nuisance algal growths.
TP	mg/l	<0.033*	Encourages the growth of nuisance aquatic plants which can choke up waterways and out-compete native species. High levels can be a result of either waste water or, more often, runoff from agricultural land
DRP	mg/l	<0.026**	The biologically available component of TP, an excess of this nutrient may cause nuisance algal growths
E.Coli	cfu/100ml	<126*** <1000 **** (^1) <260 (^2)260-550 (^3) <550	*E. coli* bacteria are used to indicate the risk to human health and to stock from drinking water contaminated with harmful micro-organisms (e.g. from human or animal faeces).
SS	mg/l	<6.4^^	Suspended solids smother larger substrate, reducing available habitat for macroinvertebrates and fish. Nutrients may attach to sediments. High levels may affect clarity and photosynthesis. High levels would also make it difficult for fish and other animals to see their prey.
*ANZECC & ARMCANZ (2000), **Biggs (2000), ***ANZECC (1992), ****ANZECC (1992) stock water guideline ^MfE/ MoH (2003) - ^1 = acceptable level, ^2 = alert level, ^3 = action level, ^^Cawthron (1999)/ ORC 2010: This value is based on taking the 5 NTU (turbidity) guideline recommended by Cawthron (1999) as the value that compromises trout growth potential and then applying the NTU value to a regression equation that was based on turbidity and SS data from the Catlins River near Houipapa.			

3.3 Biological assessment

3.3.1 Macroinvertebrates

Aquatic macroinvertebrates are organisms that live on or within the bottom substrate (e.g. rocks, gravels, sands, silts and organic matter, such as macrophytes, or organic debris, such as logs and leaves), in rivers and streams. Examples include insect larvae (e.g. mayflies, stoneflies, caddisflies and beetles), aquatic oligochaetes (worms), snails and crustaceans (e.g. amphipods and crayfish). These macroinvertebrates are a useful means of assessing the biological health of a river because they are found everywhere and have different tolerances to temperature, dissolved oxygen, sediment and chemical pollution. Thus, the presence or absence of taxa can provide insight into long-term changes in water quality.

Macroinvertebrate communities were sampled at nine sites in December 2010. (The Tahakopa lower site was too deep.) At each site, three Surber[3] samples (250 µm; 0.062 m^2) were collected using Protocol C3: Hard-bottomed, quantitative sampling of stream macroinvertebrate communities (Stark *et al*., 2001). Samples were preserved in 90% ethanol in the field and returned to a laboratory to be processed.

In the laboratory, the samples were passed through a 500 µm sieve to remove fine material. The sieve contents were then placed in a white tray, and macroinvertebrates were identified under a dissecting microscope (10-40X), using the key conceived by Winterbourn *et al.* (2000).

[3] Surber samplers have a horizontal frame that sits on the stream bed (to quantify the sampling area) and a net attached to the horizontal frame. The bottom sediments (and invertebrates) in the frame are stirred up and flow downstream into the net.

While there are no guideline values currently in place for macroinvertebrate community indices, the commonly accepted categories are summarised in Table 4. The indices often used to measure stream health are summarised below:

- **Species richness**: The total number of species (or taxa) collected at a sampling site. In general, high species richness is considered ‘good’; however, mildly impacted or polluted rivers with slight nutrient enrichment can have higher species richness than un-impacted, pristine streams.
- ***Ephemeroptera Plecoptera* and *Trichoptera (EPT)* richness**: This index is the sum of the total number of *Ephemeroptera* (mayflies), *Plecoptera* (stoneflies) and *Trichoptera* (caddisflies) species collected. These groups of insects are often the most sensitive to organic and mineral pollution; therefore, low numbers might indicate a polluted environment. In some cases, the percentage of EPT species compared to the total number of species found at a site can give an indication of their importance in the overall community.
- **Macroinvertebrate Community Index (MCI)**: This index assesses the organic enrichment of stony or hard-bottomed streams by sampling the riffle habitats of macroinvertebrates. The pollution tolerance scores of all species found at a site are added. Species very sensitive to pollution score highly; whereas more pollution tolerant species receive a low score.
- **Quantitative Macroinvertebrate Community Index (SQMCI)**: The QMCI uses the same method as the MCI scores but gives each taxon a score based on the abundance of that taxon in the community. Scores range from 0 (severely polluted) to 10 (very clean).

Table 4: Criteria for aquatic macroinvertebrate health, according to different macroinvertebrate indices

Macroinvertebrate index	Poor	Fair	Good	Excellent
Total species	<10	15-20	20-30	>30
Total EPT species	<5	5-15	15-20	>20
MCI	<80	80-99	100-119	>120
QMCI	<4	4-5	5-6	>6

3.3.2 Fish communities

The nine sites were electro-fished to see how fish species composition and density varied. A 100 m^2 reach was fished at each of the 15 sites. The reach was isolated by placing top and bottom stop nets across its width.

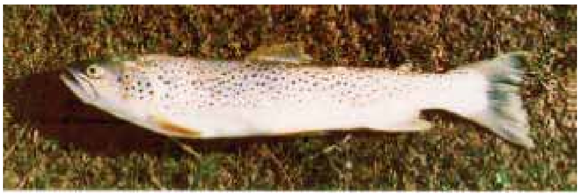
Each site was fished by three-pass downstream electric-fishing, using a pulsed DC Kainga EFM300 backpack electroshocker. A 15-minute rest period between electric-fishing passes was used to allow fish to settle. The backpack operator used a sieve dip net, while another team member used a pole net immediately below the electroshocker. A third member carried buckets for fish collection. Fish from each pass were kept separate, counted and then released, after the third electric fishing pass. At each site, native fish were identified and counted; trout, on the other hand, were counted, weighed in grams, and then measured from the tip of the snout to the caudal fork.

At each site, trout were weighed and measured so that their condition could be assessed. The aim was to collect 20 trout from each site, however this was not possible at all sites. Calculating trout condition is important as it indicates the relationship between a trout's length and weight, and is unrelated to age.

The formula for trout condition is:

$$K = \frac{10^N W}{L^3}$$

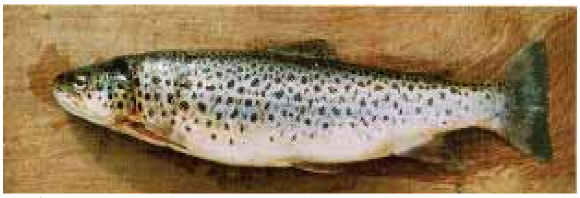
Where K is the Condition Factor; W is the weight of the fish in grams (g), L is the length of the fish in millimetres (mm) and N equals 5. This formula produces the K values (condition values). A photographic representation is shown in Figure 11.



Extremely poor K = 0.78

Poor K = 0.95

Fair K = 1.19



Good K = 1.36

Excellent K = 1.66

Exceptional K = 2.02

Figure 11: Photo representation of trout with different condition factors (Barnham and Baxter, 1998)

Table 5: K-value of fish condition (Barnham and Baxter, 1998)

K value	Condition	Comments
1.6	**Excellent**	trophy class fish
1.4	**Good**	well-proportioned fish
1.2	**Fair**	acceptable to many anglers
1	**Poor**	long and thin
0.8	**Extremely poor**	resembling a Barracuda, big head and narrow, thin body

3.3.3 Substrate assessment

Substrate was assessed at the nine sites during baseline summer flows in December 2009. Substrate or particle size of the riverbed is important in determining which biological communities inhabit a river. Cobble and gravel streambeds provide a different habitat to sand or silt laden streams because their interstices are larger and provide greater through flow and oxygenation.

All sites other than the Tahakopa lower were assessed for substrate size in run and riffle reaches. For each site, two riffles and two runs were chosen for a cross-sectional survey. The substrate size of ten randomly selected particles was measured while wading across the stream's cross section. The second narrowest axis of each particle was measured. These measurements were assessed against the Wentworth scale, shown in Table 6.

Table 6: Wentworth scale

Score	Substrate type	Size
7	Bedrock	>400mm
6	Boulder	>256-4000mm
5	Cobble	>64 to 256mm
4	Pebble	>16 to 64mm
3	Gravel	>2 to 16mm
2	Sand	>0.063 to 2mm
1	Silt	<0.063mm

From the substrate measurements, the Substrate Index (SI) was calculated. This index, proposed by Harding *et al.* (2009), was based on the Wentworth scale; however, it was originally a modified form of the SI used by Jowett and Richardson (1990).

The following formula was used to calculate the SI.

Substrate index (SI) = SI = 0.08% bedrock + 0.07% boulder+0.06% cobble +0.05%pebble +0.04% gravel +0.03% sand and silt

A streambed consisting entirely of bedrock will have an SI = 0.08*100% bedrock (i.e. 8), while a sandy bottom stream will have an SI = 0.03*100% sand (i.e. 3).

A modified Brusven Index (BSI) method (1977) was also used to characterise the bed substrate. This index generates a three-digit code, which describes both the substrate size and the degree of embeddedness by fine sediment.

The following formula was used to get the BSI.

Brusven index (BSI) = DS.F
D = the dominant substrate class based on the Wentworth scale
S = the substrate surrounding the dominant substrate based on the Wentworth scale
F = the percentage of fine sediment surrounding the dominant substrate (D). This is based on a 0-9 scale with 0 indicating no fine sediment and 9 indicating >90% fine sediment.

For each of the ten randomly selected particles, the degree of substrate embeddedness and compactness was noted. The definitions of embeddedness and compactness are given in Table 7.

Table 7: Scores for the degree of embeddedness and compactness

Score	Substrate embeddedness	Substrate compactness
1	Not embedded, the substrate on top of the bed	Loose, easily moved substrate
2	Slightly embedded, >25% of the particle is buried or attached to the surrounding substrate	Mostly loose, little compaction
3	Firmly embedded, approximately 50% of the substrate is embedded or attached to the surrounding substrate	Moderately packed
4	Heavily embedded, >66% of the substrate is buried	Tightly packed substrate

Embeddedness is an indication of how much of the dominant substrate is buried by finer sediment. Compactness is a measure of how tightly packed substrate is. Under certain conditions (e.g. frequent flash flows or sedimentation), substrate can become highly compacted. When this happens, bed substrate can become very stable, which adversely affects steam biological health by reducing or eliminating interstitial spaces, the habitat used by macroinvertebrates and fish.

4 River water quality

This section provides an assessment of the intensive monitoring of rivers undertaken during the 12 months of this study, and compares this period to the long-term SOE monitoring data.

One problem with water quality data is the confounding effect of varying river flow conditions at the time of sampling. To acknowledge this variable, water quality data was flow adjusted. Each graph has two bars presented throughout this section. The blue column shows the median value for all data (regardless of flow conditions), and the beige column represents times of lower flow (i.e. when the river has its highest recreational use (e.g. fishing and swimming)). Throughout this report, the term 'lower flow' refers to 'below median flows'.

4.1 Nutrients

The extent and opportunity for plant growth depends largely on the time of year. Median flow is used to represent the growing season because flows above median flow usually occur outside of the summer and are therefore not generally conducive to periphyton growth.

The two main nutrients available for plant growth are NNN and DRP; these are shown in Figure 12 and Figure 13. In Figure 12, it is obvious that the Tautuku has very little available NNN. At lower flows, the Catlins, Maclennan and Tahakopa rivers also drop below the New Zealand periphyton guideline level.

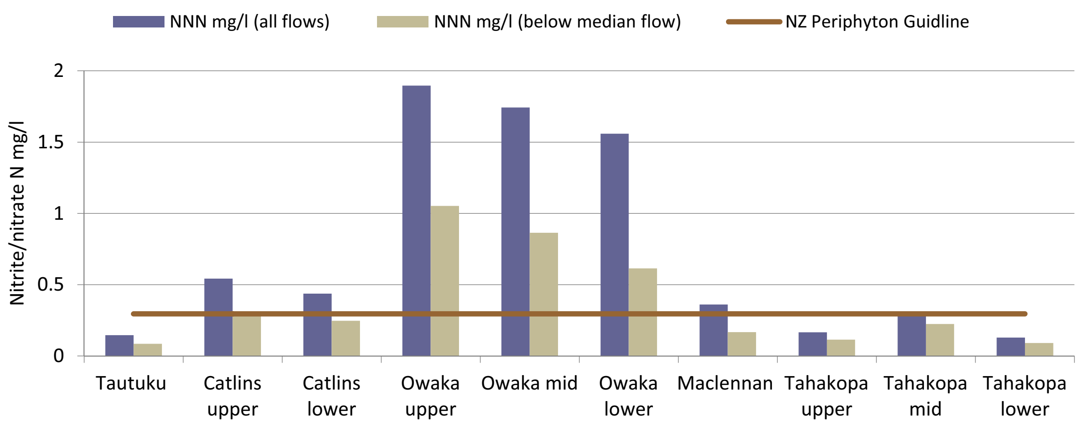


Figure 12: Median nitrite-nitrate-nitrogen concentration at each river site over the sampling period

DRP levels were generally below guideline levels, except the upper Owaka, which exceeded the New Zealand periphyton guideline concentration at both flow scenarios.

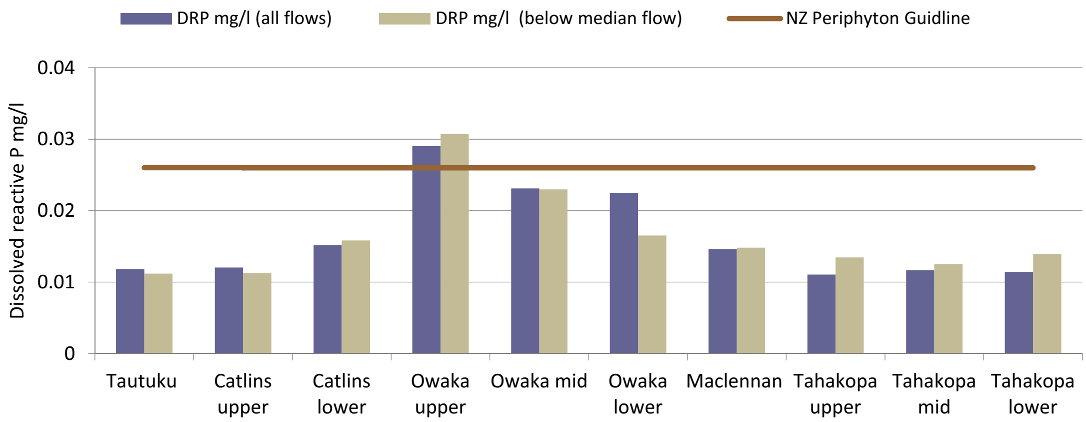


Figure 13: Median dissolved reactive phosphorus concentration at each river site over the sampling period

Redfield (1963) published data that indicated a molar ratio of N:P of 16:1 is required for periphyton growth. At a recent workshop held by NIWA, it was suggested that a ratio of <4:1 reflects N limitation, while a ratio of >20:1 indicates P limitation (Wilcock *et al.*, 2007).Figure 14 shows the NNN:DRP ratio for each site.

Figure 14 shows that using the Redfield ratio, the Tautuku, Catlins lower, Maclennan, Tahakopa upper and Tahakopa lower sites were N limited, although none were below the NIWA threshold of <4:1. The Catlins upper, and all the Owaka sites, were P limited with a ratio of >20:1.

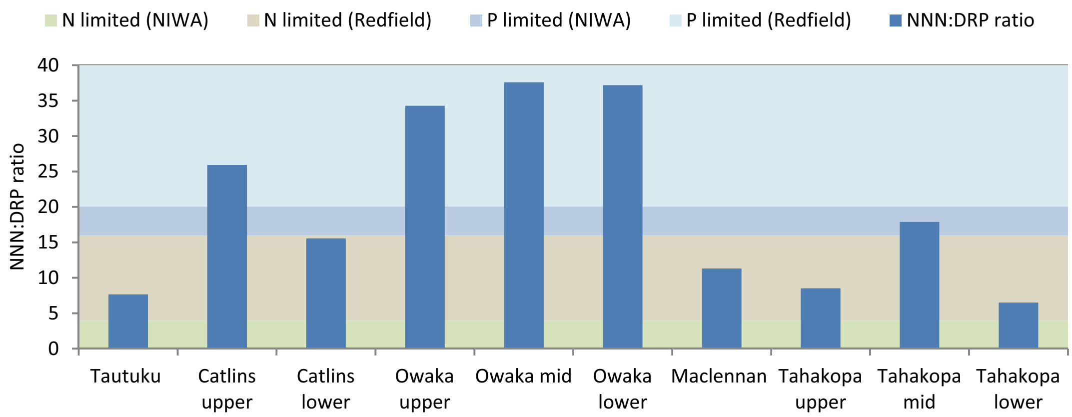


Figure 14: NNN:DRP ratio. The green area indicates N limitation (NIWA); the brown area indicates N limitation (Redfield 1963); the dark blue area indicates P limitation (Redfield, 1963), and the light blue area indicates P limitation (NIWA).

Definition of 'Redfield ratio':

The optimal N/P ratio for phytoplankton growth, the 'Redfield ratio', is 16:1 (based on molecular concentrations). Large differences from 16 at low N/P ratios can be an indication of potential nitrogen limitation; whereas, large differences at high N/P ratios can suggest potential phosphorus limitation of the primary production of phytoplankton.

Definition of 'molar concentration':

Molar concentration = $c_i = n_i / V$, where c_i is defined as the amount of a constituent n_i, divided by the volume of the mixture V

Definition of 'nutrient limitation':

A limiting nutrient is defined as that element in shortest supply relative to demands for plant growth. Adding a limiting nutrient will stimulate plant growth (i.e. net primary productivity) more than adding any other element. Co-limitation by two or more nutrients is possible.

The Tautuku site had the lowest concentrations of DRP (Figure 13); however, all sites, except the Owaka upper site, had concentrations of DRP well below the New Zealand periphyton guideline level of 0.026mg/l. The Tautuku site also had the lowest concentration of NNN. The only sites to exceed the New Zealand periphyton guideline (at median flow) for NNN were the three Owaka sites (Figure 12).

The excessive growth of algae or macrophytes is only possible if nutrients, particularly NNN and DRP, which are biologically available for plant uptake, are available. If one of these nutrients is in low supply, then plant growth is restricted. The Tautuku, Catlins lower, Maclennan, Tahakopa upper and Tahakopa lower sites were N limited, and the Catlins upper, and all the Owaka sites were P limited (Redfield ratio of >20:1). However, sites can also switch nutrient limitation at different times of the year (co-limitation). Figure 15 shows that the Tahakopa mid-site exhibits P limitation (NNN:DRP>20) mainly during the winter months, or exhibits N limitation (NNN:DRP between four and 20) mainly during the summer months, which suggests the river is N limited.

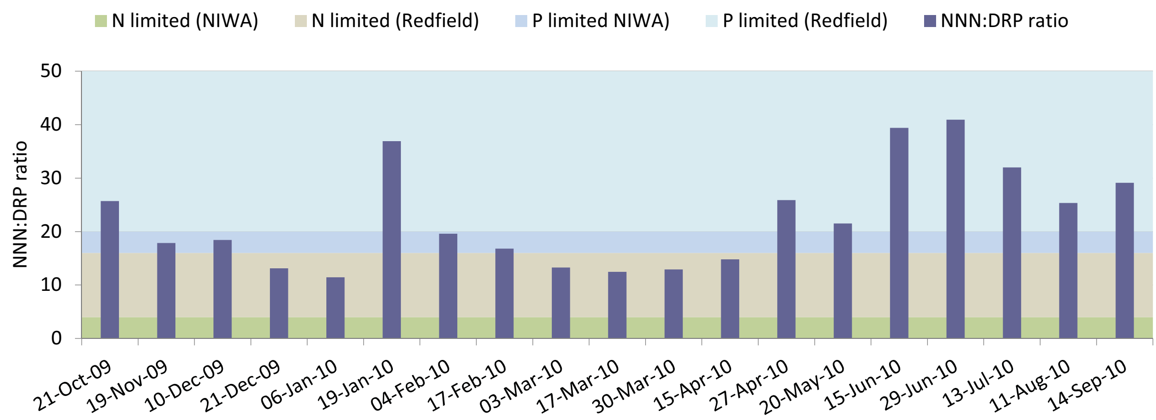


Figure 15: NNN:DRP ratio at Tahakopa mid-site

N limitation was present during the summer at most sites, except for the three Owaka River sites, which showed consistent P limitation. This may be why the rivers in this study had no excessive algae or macrophyte growth during the study period. Filamentous algae were absent, and only a thin film of light brown algae was present on the substrate at each site. Although the Owaka was not N limited, it did not show any sign of nuisance algae growths.

TN concentrations followed exactly the same pattern at NNN. The Tautuku site had the lowest median concentration at both flow scenarios. Concentrations were well below the guideline at both flow rates in the Tautuku, Tahakopa upper and Tahakopa lower sites.

At lower flows, TN concentrations were only above the guideline value in the Owaka River (Figure 16). At all flows, the Catlins River also exceeded guideline concentrations.

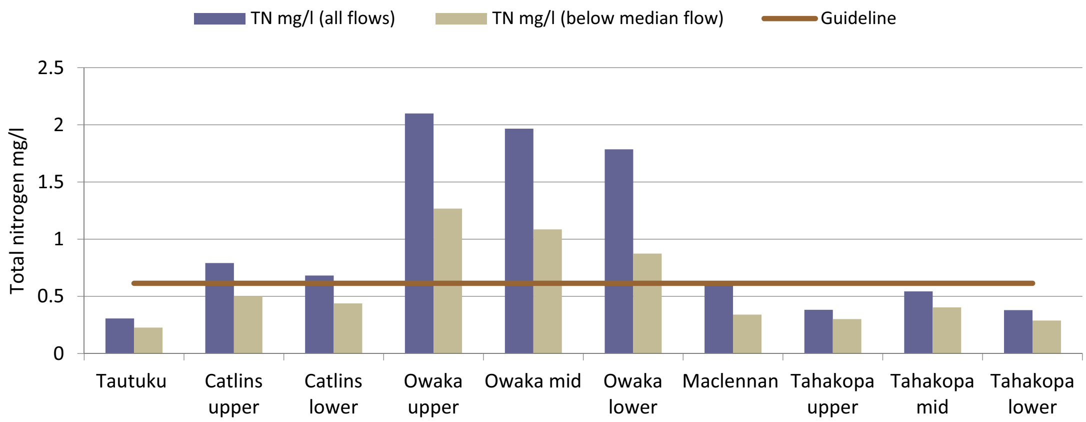


Figure 16: Median total nitrogen concentration at each river site over the sampling period

At all flows, TP concentrations were below the guideline level at Tautuku, Tahakopa upper and the Tahakopa lower sites. At lower flows, all sites, except for the Owaka River, had median concentrations below the guideline level (Figure 17).

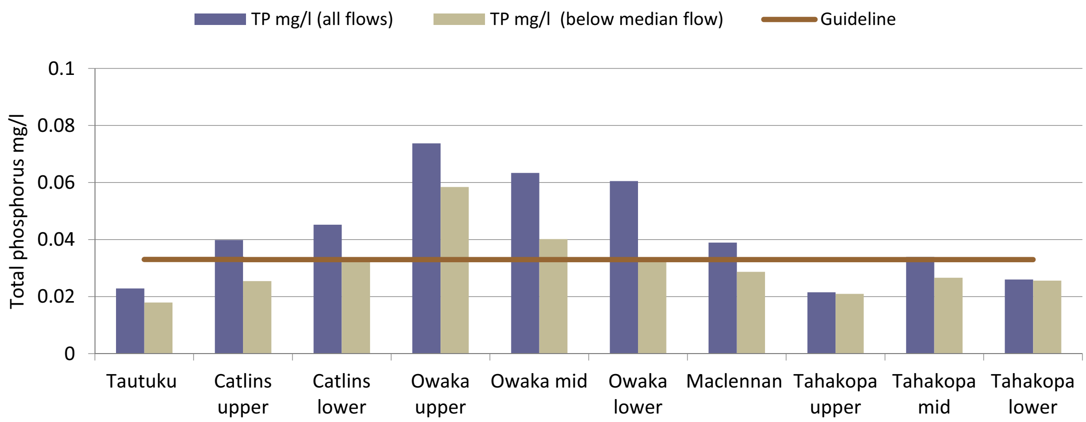


Figure 17: Median total phosphorus concentration at each river site over the sampling period

NH_4 was the only parameter that did not exceed guideline levels (0.9 mg/l) at any of the river sites (Figure 18).

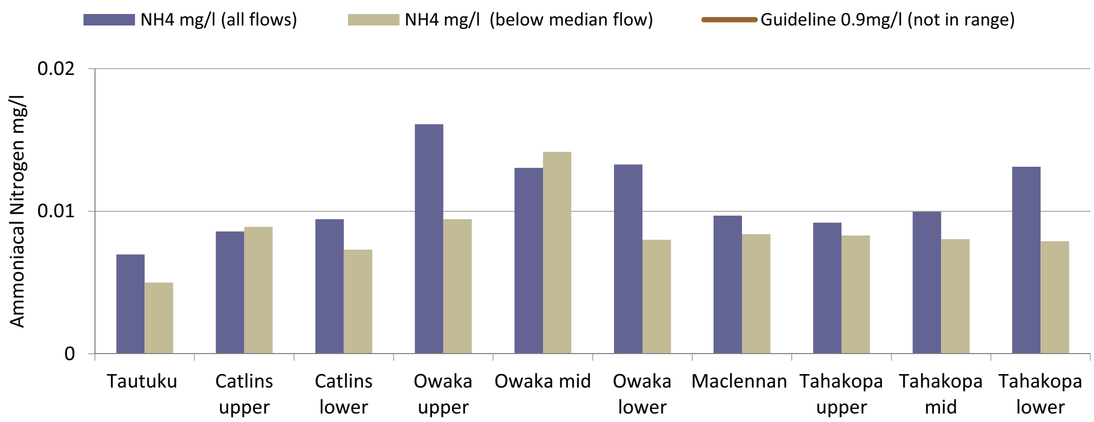


Figure 18: Median ammoniacal nitrogen concentration at each river site over the sampling period

4.2 Bacteria

Two guideline values are shown for bacteria; the first is the ANZECC 1992 seasonal median of 126cfu/100ml, used as an indicator for the suitability of contact recreation; the other is the ANZECC 1992 stock water drinking water guideline of 1000 cfu/100 ml.

Figure 19 shows that the Tautuku River meets the 126 cfu/100 ml criteria, as do the Tahakopa upper and lower sites and the Maclennan. All the other sites exceeded this concentration; in particular, the Catlins upper site and the Owaka River had high median concentrations of bacteria at median flows. The Owaka upper and mid-sites exceeded the stock water drinking guideline. Higher concentrations of bacteria generally occur when flows are high; however, at all the sites monitored, the bacteria concentrations were similar at both flows.

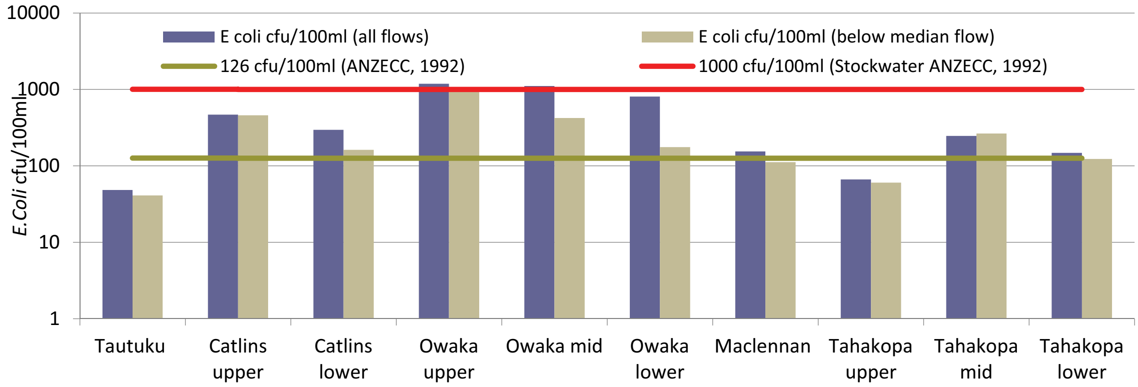


Figure 19: Median *E.coli* concentration at each river site over the sampling period

4.3 Suspended solids

SS concentrations at lower flows were well below the guideline value at all sites, except for the Owaka Upper and Tahakopa mid-sites. However, at all flows, most sites have high sediment concentrations, particularly the Owaka and Catlins rivers. The Tahakopa mid-site also had high levels of suspended solids (Figure 20).

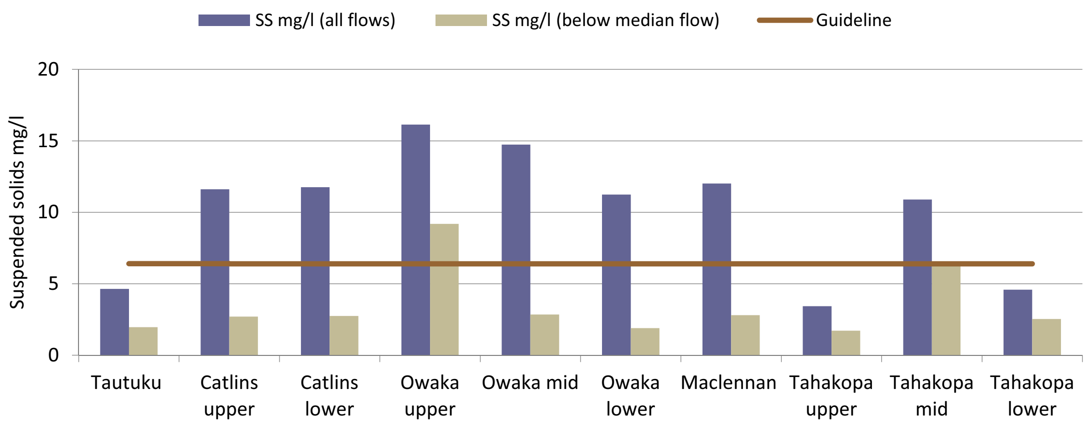


Figure 20: Median suspended solid concentration at each river site over the sampling period

4.4 Comparison of water quality between sites

Table 8 ranks the river sites from best (1) to worst (10) for each parameter: the higher the score (maximum score 70), the poorer the water quality. Typically, all the waterways, except the Owaka, had nutrient and bacteria concentrations below the guideline values.

Table 8: To compare sites, the median concentration of each contaminant (at lower flows) is ranked from best (1) to poorest (10). Where cells are shaded brown, the median value exceeded guideline standards.

Rank		NH4	DRP	*E.Coli*	NNN	SS	TN	TP	
	Guideline values	0.9 mg/l	0.026 mg/l	126 mg/l	0.295 mg/l	6.4 mg/l	0.614 mg/l	0.033 mg/l	Total Score
1	Tautuku	1	1	1	1	3	1	1	9
2	Tahakopa upper	6	4	2	3	1	3	2	21
3	Tahakopa lower	3	5	4	2	4	2	4	24
4	Maclennan	7	6	3	4	7	4	6	37
5	Catlins lower	2	7	5	6	6	6	7	39
6	Tahakopa mid	5	3	7	5	9	5	5	39
7	Catlins upper	8	2	9	7	5	7	3	41
8	Owaka lower	4	8	6	8	2	8	8	44
9	Owaka mid	10	9	8	9	8	9	9	62
10	Owaka upper	9	10	10	10	10	10	10	69

The median values (at lower flows) were also assessed against water quality guidelines (Table 3) chosen to protect local instream standards. Table 9 shows how the grade was derived for each site. NH_4 was not included in this assessment, as all sites passed the guideline value for this parameter. An excellent classification meant that the six other variables met guideline values; a score of 4 or 5 was given a ‘good’ classification; a score of 2 or 3 meant the site was classified as ‘fair’, and a score of 1 or less was classed as ‘poor’.

Table 9 shows that the Tautuku, the Maclennan, and the Tahakopa (upper and lower) sites had excellent water quality; while the three Owaka sites had poor water quality.

Table 9: The median concentration of each contaminant (at lower flows) is compared to the guideline value. The brown cells indicate that guideline concentration is exceeded.

	DRP	*E.Coli*	NNN	SS	TN	TP	
Guideline values	<0.026mg/l	<126 cfu/100ml	<0.295mg/l	<6.4mg/l	<0.614mg/l	<0.033mg/l	Grade
Tautuku	0.011	41	0.086	1.97	0.227	0.018	Excellent
Catlins upper	0.011	459	0.292	2.70	0.503	0.025	Good
Catlins lower	0.016	162	0.246	2.75	0.438	0.032	Good
Owaka upper	0.031	1023	1.053	9.19	1.268	0.058	Poor
Owaka mid	0.023	423	0.864	2.84	1.085	0.040	Poor
Owaka lower	0.017	176	0.615	1.90	0.874	0.033	Poor
Maclennan	0.015	112	0.168	2.81	0.341	0.029	Excellent
Tahakopa upper	0.013	60	0.115	1.72	0.301	0.021	Excellent
Tahakopa mid	0.013	265	0.224	6.28	0.404	0.027	Good
Tahakopa lower	0.014	123	0.091	2.53	0.288	0.026	Excellent

4.5 Comparison of long-term and project water quality monitoring

The Catlins lower site has been monitored since January 2000 as part of the ORC State of the Environment (SOE) monitoring programme. Seasonal Kendall analysis was undertaken for the site, using data between 2002 and 2010 (over six seasons, as ORC monitors bi-monthly). The trend test calculates the probability of getting a trend slope at least as big as measured, if there was a trend at all. This is the p-value. If the p-value is small enough, there is a statistically significant trend. P-values of 0.05 or less are conventionally regarded as indicating that a trend is statistically significant at the 95.0% confidence level (i.e. unlikely to be due to chance).

Since 2002, DRP has significantly increased in the Catlins River ($p=<0.05$).

A Mann-Whitney (W) test was conducted on data taken between 2002 and October 2009, and then that taken after October 2009 (the sampling period for this report). The hypothesis was that the two sample medians would be equal.

As the data contained significant departures from normality, tests that compared standard deviations were invalidated. Therefore, in all cases, the Mann-Whitney W test was used as an alternative to the t-test to compare the medians of the two samples. This test is constructed by combining the two samples, sorting the data from smallest to largest, and comparing the average ranks of the two samples in the combined data. Where the P-value is less than 0.05, there is a statistically significant difference between the medians at the 95.0% confidence level.

The samples taken between October 2009 and September 2010 show that DRP and TP are significantly higher than in the period January 2002 to September 2009. The difference is shown in Figure 21.

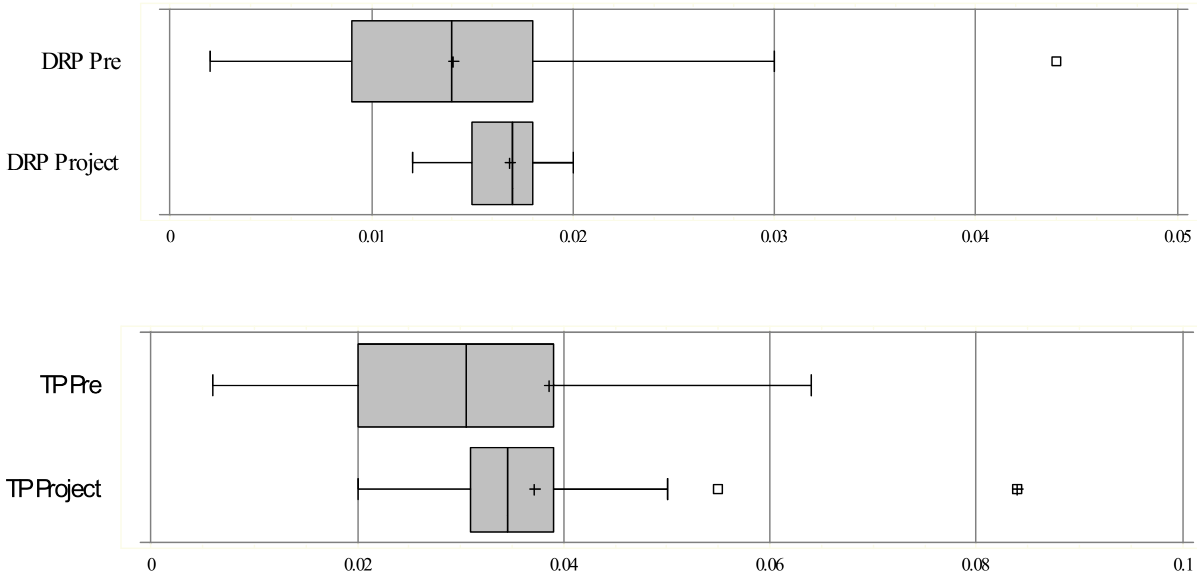


Figure 21: The concentration of DRP and TP pre October 2009 is significantly lower than post October 2009.

5 Biological health

5.1 Macroinvertebrate communities

Three Surber samples were collected from each site in December during base-flow conditions. Macroinvertebrate health indices show that the highest MCI values were found in the Maclennan and Tahakopa river sites. All these sites had a combination of mayfly species (*Deleatidium* sp., *Coloburiscus humeralis*, and *Nesameletus*). The stonefly, *Zerlandoperla*, was abundant in the Maclennan River (Figure 22). The Tahakopa sites had an abundance of cased caddis (*Olinga*, *Pycnocentrodes* and *Helicopsyche*).

Figure 22: Stoneflies at the Maclennan River site

The three Owaka river sites obtained fair MCI scores, due to the presence of mayflies (particularly the *Deleatidium* species) (Figure 23). Compared to the other sites, the Owaka River had fewer caddis species, such as *Olinga*, *Helicopsyche* or *Bareoptera roria.*

The Catlins and the Tautuku sites obtained good MCI scores, due to the presence of mayflies. (All sites had plenty of *Deleatidium* species, and the upper Catlins site had an abundance of *Coloburiscus humeralis*) and organic pollution sensitive caddisflies (such as the *Olinga* species and *Bareoptera roria* (Figure 23)).

The Maclennan and the Tahakopa sites had excellent MCI scores, because each had a large number of mayflies (the *Nesameletus* species), stoneflies (particularly the *Zelandoperla* species) and caddisflies (the *Helicopsyche* and *Olinga* species) (Figure 23).

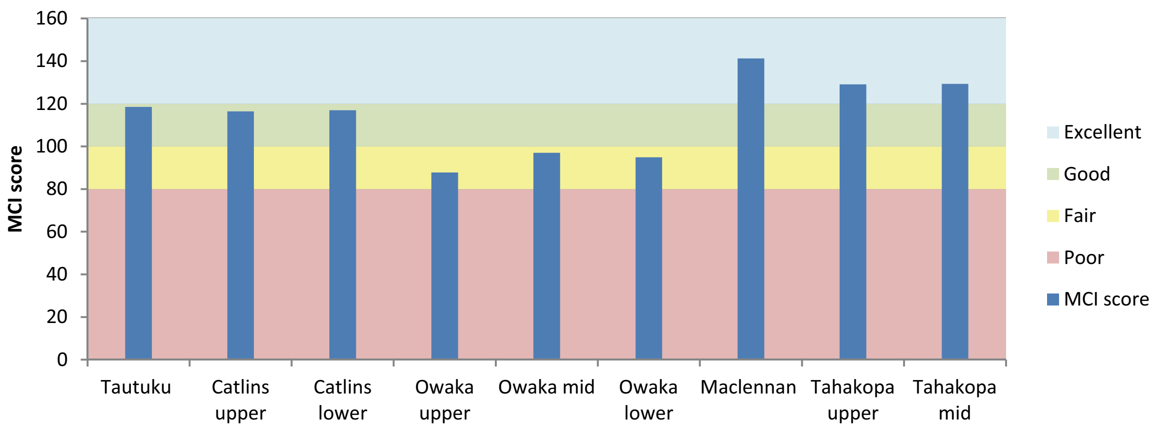


Figure 23: Macroinvertebrate Community Index (MCI) values for all rivers

QMCI indices provide different patterns for macroinvertebrate community structure. The Tahakopa upper, Tautuku and Maclennan sites had the highest QMCI scores (Figure 24) as they supported a large number of mayflies (primarily *Deleatidium*) and stoneflies (particularly the *Zelandoperla* species in the Maclennan River) and caddisflies (such as the *Olinga*, *Helicopsyche* and *Pycnocentrodes* species).

These sites were closely followed by the Catlins sites, the Owaka and the Tahakopa mid-sites. These sites had a QMCI score of 'good' and also contained relatively large numbers of mayflies and caddisflies (Figure 24).

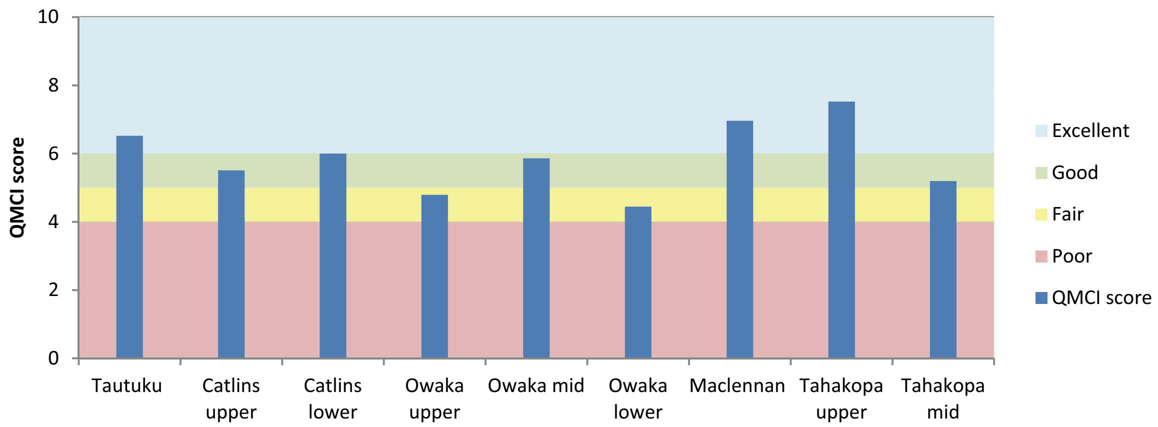


Figure 24: Quantitative Macroinvertebrate Community Scores (SQMCI) for all rivers

The Owaka upper and lower sites had a QMCI score of 'fair' (Figure 24). This is because there were fewer mayflies, stoneflies and caddisflies than at the other sites. The only caddisfly found in any quantity was the *Pycnocentrodes* species, which is more tolerant of poorer quality water than are some of the other species.

The EPT taxa follow similar trends to the MCI and QMCI graphs. The total number of EPT taxa at the Tautuku site were enough to place this site in the 'good' category. Otherwise, the other sites were all categorised as 'fair', except the Owaka mid-site, which was classed as 'poor'. (Figure 25).

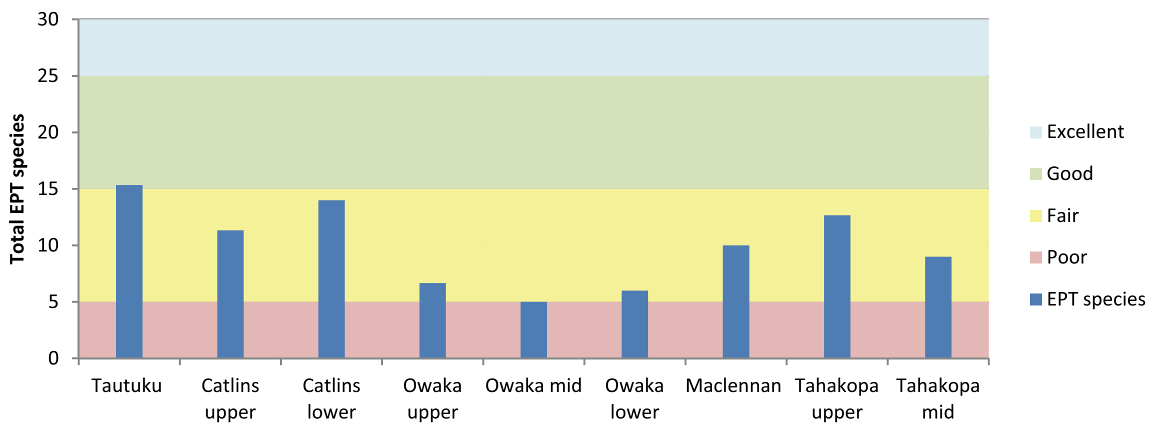


Figure 25: Total number of Ephemeroptera (Mayflies), Plecoptera (Stoneflies) and Trichoptera (Caddisflies) (EPT) species found in each river

When the EPT data were expressed as a percentage of the total number of species, however, it is quite a different story. All sites had a very high proportion of EPT taxa and represent very healthy rivers (Figure 26). The lowest scoring site was the Owaka upper site, which had 61% EPT taxa; the Tahakopa upper site had 94% EPT taxa; and the Tautuku site had 83% EPT taxa. The Owaka sites and Tahakopa sites had the lowest percentage of EPT species, but the community was dominated by mayflies, stoneflies and caddisflies, rather than dipterans, worms, molluscs and crustaceans.

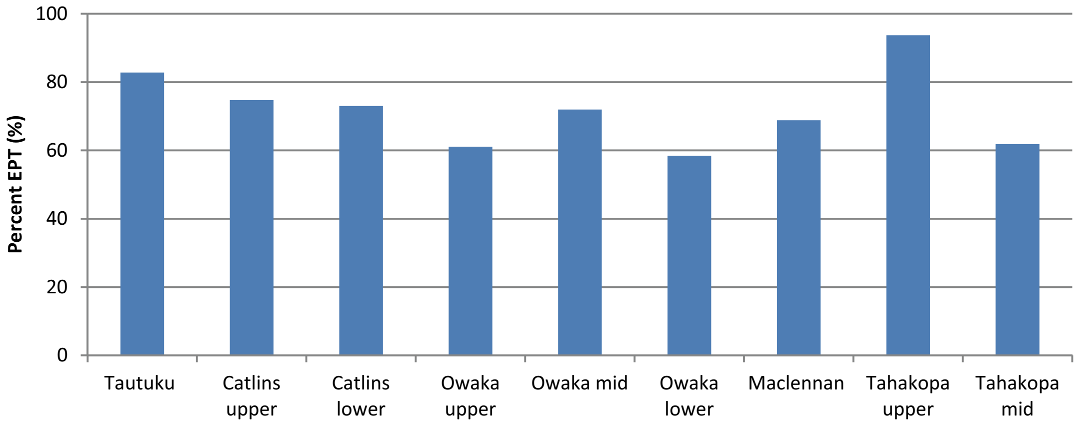


Figure 26: Percentage of macroinvertebrate community comprising *Ephemeroptera* (mayflies), *Plecoptera* (stoneflies) and *Trichoptera* (caddisflies) (EPT) found in each river

5.2 Fish communities

Electric fishing for density data was completed at nine sites in December 2010. The Tahakopa lower site could not be fished due to its depth and width. At each of the nine sites, a known area was fished (normally 100 m^2) and between three and seven species were present at each site, although ten species were caught in total (Figure 27). These included brown trout, longfin eel, lamprey, common bully, upland bully, bluegill bully, redfin bully, inanga, koaro and black flounder. Freshwater crayfish were also found in some rivers, but these were not included in the fish diversity graph.

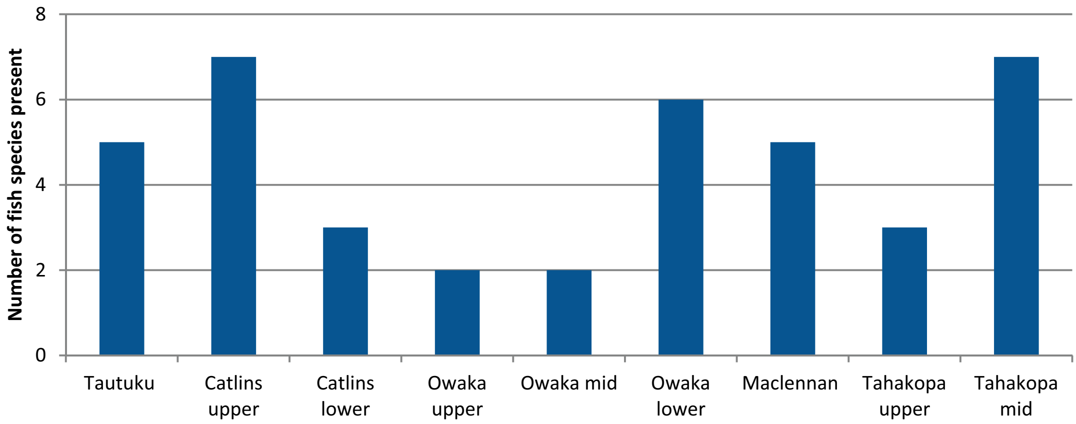


Figure 27: Number of fish species found at each sampling site

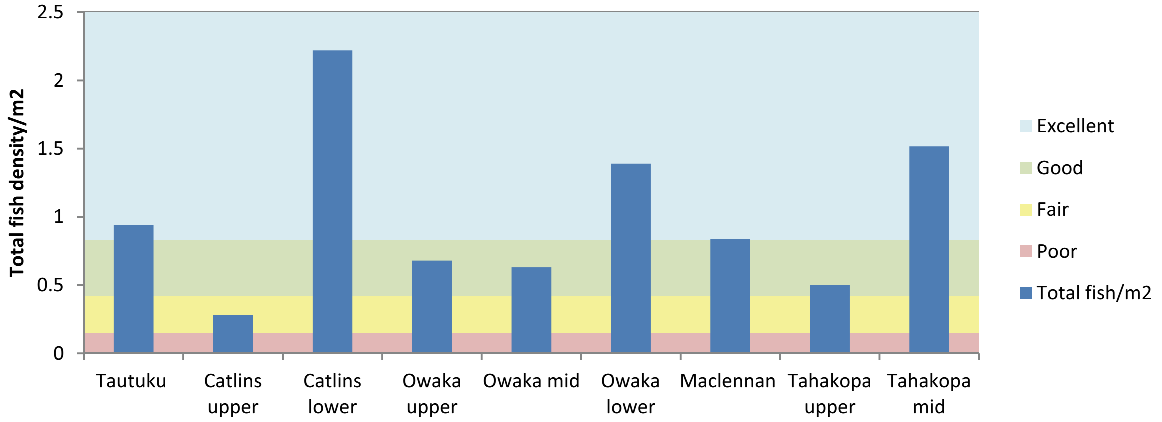


Figure 28: Total fish density (m^2) at each sampling site

A known area was sampled (normally 100 m^2), and the density data showed that total fish density was highly variable between sites (Figure 28). Fish densities for this study were compared to densities calculated from the New Zealand Freshwater Fish Database (NZFFD), using all sites in the south-eastern corner of New Zealand. The Catlins lower site and the Tahakopa mid-site had the highest total densities of fish, with 2.22 and 1.52 fish/m^2, respectively, while the Catlins upper and Tahakopa upper sites had the lowest fish densities, with 0.28 and 0.50 fish/m^2, respectively (Figure 28).

5.2.1 Native fish

Native fish densities were also compared to densities calculated from the New Zealand Freshwater Fish Database (NZFFD), using all sites in the south-eastern corner of New Zealand.

The Catlins lower, the Owaka lower and the Maclennan sites had high densities of longfin eels, which placed them in the 'excellent' category. This represents the top 25% of native fish densites in the Catlins region (Figure 29). The Tautuku and Tahakopa mid-sites fell into the 'good' category, mainly because of high densities of longfin eels, lamprey and redfin bullies. The remaining sites had native fish densities in the 'fair' category, with the exception of the Owaka upper site that fell into the 'poor' category, as only one longfin eel was caught.

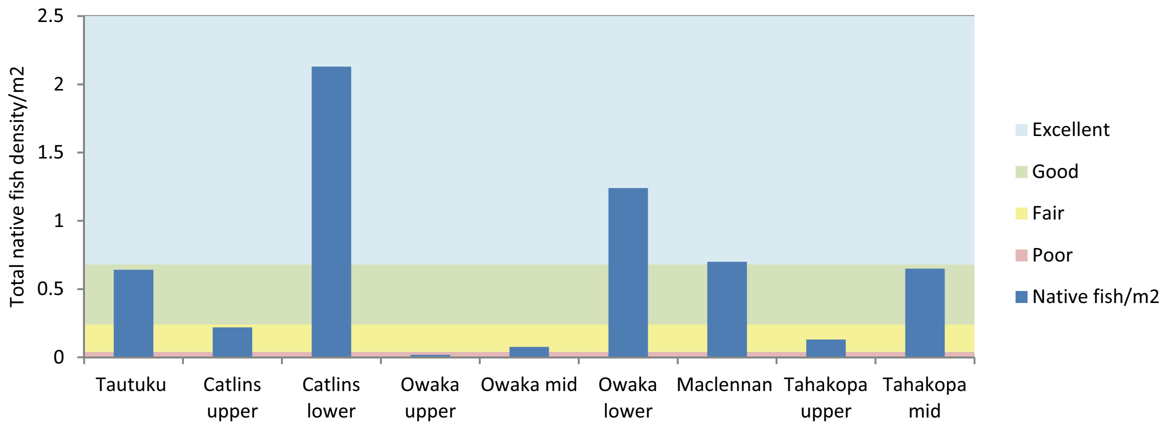


Figure 29: Native fish density (m^2) relative to native fish density quartiles for the entire Catlins region

The Catlins lower site had the highest longfin eel density, the Tahakopa mid-site had the highest lamprey, common bully and redfin bully densities. The Owaka lower site had abundant native fish, with the highest density of inanga and a high density of common bully and longfin eels. Native fish densities tended to be higher closer to the coast; densities decreased with distance upstream.

5.2.2 Brown trout

Brown trout were present at all sites. At each site, the condition factor for brown trout (K) was determined (Figure 11). This standardised measure is commonly used to assess the health of trout.

Based on trout condition alone, the Owaka mid and Owaka lower sites fell into the 'excellent' category. The trout in the Owaka upper, Maclennan, Tahakopa upper and Tautuku rivers were in good condition. The Tahakopa mid-site and both the Catlins sites had trout in poor condition (Figure 30).

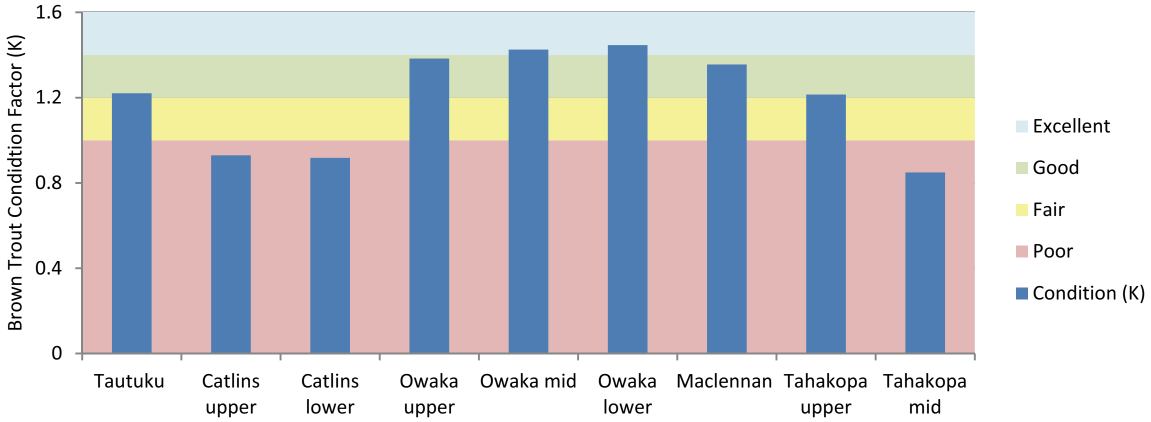


Figure 30: Median brown trout condition factor

When trout density was considered, the Tautuku, Owaka (upper and mid) and Tahakopa upper sites had the highest densities of trout considered to be 'excellent', based on data from the NZFFD (Figure 31). The Catlins lower, Owaka lower, Maclennan and Tahakopa mid-sites had good densities of trout, and the Catlins upper site had fair densities of trout (Figure 31).

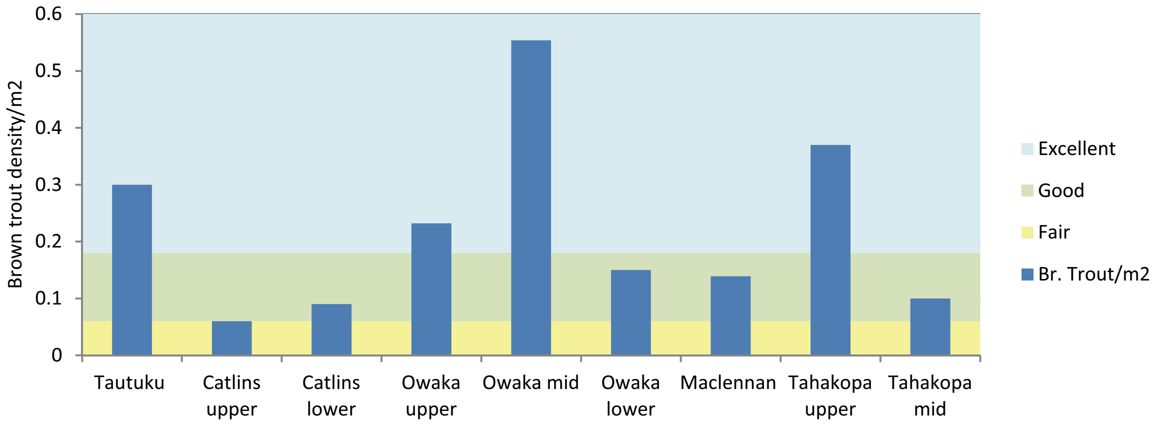


Figure 31: Brown trout density (m^2) relative to trout density quartiles for the Catlins area

Assessing a river for brown trout condition or density alone can give conflicting results. For example, the condition of brown trout at the Owaka sites was found to be best, but in terms of density per m^2, the brown trout at the Tautuku, Owaka mid and Tahakopa upper sites were found to be in the best (Figure 30 and Figure 31).

A high quality trout river needs to contain high densities of excellent condition fish. To give an accurate idea of the quality of the brown trout fishery at each site, the condition of the trout in each river, along with the trout's density per m^2, was assessed (Figure 32).

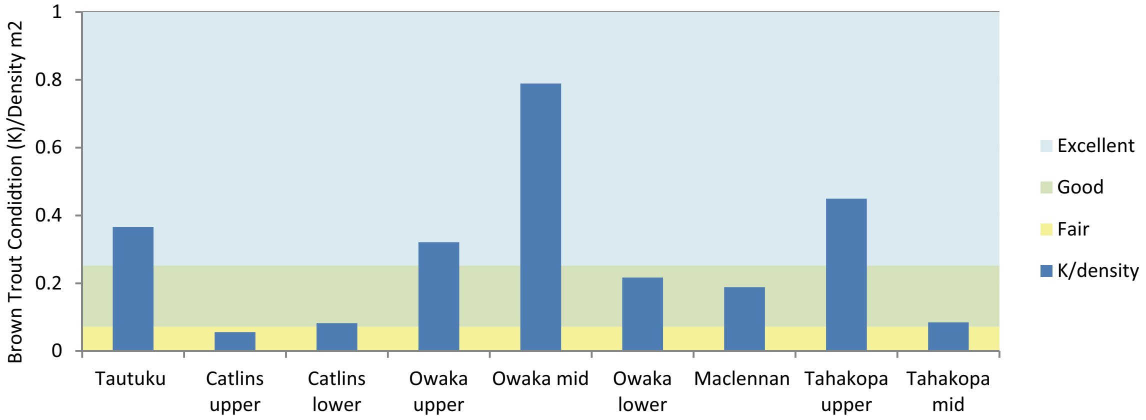


Figure 32: Brown trout density and condition factor index

Figure 32 shows how each site perfoms as a brown trout fishery. The Tautuku, Owaka mid and upper and the Tahakopa upper sites rank as the four best, because they carry high numbers of excellent/good condition trout. The Owaka lower and the Maclennan sites carried excellent/good condition trout, but at lower densities. The Catlins sites and Tahakopa mid-sites carried fish in poor condition at fair/ good densities.

6 Substrate assessment

Assessments of the substrate were conducted at nine of the sites. (The lower Tahakopa site was too deep to assess (Table 10)). The assessment included estimations of fine sediment cover (<2 mm), measurement of the longest axis of 40 pieces of substrate and estimations of compactness and embeddedness. The substrate index and modified Brusven substrate index were also calculated.

Table 10: Summary results of physical habitat assessment in the nine rivers

Site	Median particle size based on the Wentworth Scale	Substrate Index	Brusven Index	Estimated fine sediment cover (%)	Average Compactness	Average Embeddedness
Tautuku	64 to 250mm	5.65	54.1	5	1	1
Catlins upper	64 to 250mm	5.45	64.1	5	2.3	1.8
Catlins mid	64 to 250mm	5.52	54.1	8	2.2	1.7
Owaka upper	<2 to 16mm	5.75	78.6	60	2.8	2.6
Owaka mid	16 to 64mm	5.35	47.2	20	1.9	1.8
Owaka lower	16 to 64mm	4.95	45.3	32	1.7	1.7
Maclennan	16 to 64mm	5.7	54.1	7	1.4	1.6
Tahakopa upper	64 to 250mm	5.8	54.1	12	1.25	1
Tahakopa mid	16 to 64mm	4.65	43.2	21	2.1	1.4

The Catlins sites had the largest substrate size, with a median Wentworth particle size of between 250 and 400 mm. The substrate index at these sites was greater than 6, and the fine sediment cover was low (between 5% and 8%). The Owaka upper and mid-sites, as well as the Tahakopa upper site, had a substrate index of at least 5.3. For the Owaka sites, this is high and was due to the presence of bedrock.

The Brusven index shows that the Owaka upper site had bedrock as the dominant substrate (7 as first digit), the Owaka mid-site also had substantial amounts of bedrock (7 as second digit). Most sites were dominated by cobbles or pebbles (5 or 4 as first digit); only the Catlins sites had boulders (6 as first digit) as the dominant substrate.

The sites with more than 20% fine sediment cover were the Owaka sites and the Tahakopa mid-site; the sites with least sediment cover were the Tautuku site and the Catlins upper site. There were four sites with average compaction scores of greater than 2, which translates to loose substrate with little compaction. Of these sites, the substrate at the Owaka upper site was the most compact (highest average score). The only site with an average embeddedness of greater than 2 (depicting that >25% of the substrate is buried or attached to the surrounding substrate) was the Owaka upper site. At the other sites, the substrate was on top of the bed.

The sites can be ranked for substrate by ranking the categories (other than the BSI) from 1 to 9, with 1 being the best and 9 being the worst, and then adding the scores in each category. The results are shown in Table 11 (with the lowest ranked river first).

Table 11: Total substrate score for each site, based on ranking each index from 1 to 9, and then adding the individual scores to calculate the total

Site	Substrate Index	Fine sediment	Compactness	Embeddedness	Total score
Tautuku	6	1	1	1	9
Maclennan	3	3	3	4	13
Tahakopa upper	4	5	2	2	13
Catlins lower	1	4	7	5	17
Catlins upper	2	1	8	7	18
Tahakopa mid	9	7	6	3	25
Owaka mid	7	6	5	8	26
Owaka lower	8	8	4	6	26
Owaka upper	5	9	9	9	32

Table 11 shows that the Tautuku site had the best substrate and scored 9, while the Owaka sites had the poorest substrate and hence the highest total scores. The Owaka upper site scored highly for compactness and embeddedness, due to the high proportion of bedrock.

7 Summary of water quality, physical habitat and ecological monitoring

This study looked at mutiple stressors (chemical, physical and community structure) to provide a broad ecological assesment for each site. Each site was graded as 'excellent', 'good', 'fair' or 'poor' for water quality, physical habitat, macroinvertebrate (MCI) and trout fishery values. An overall grade was then calculated for each site. The results are summarised in Table 12.

Table 12 Summary of categories for water quality, substrate, MCI and trout condition-related density for each river

Site	Overall grade	Water quality	Physical habitat	MCI score	Trout density/ condition
Tautuku	excellent	excellent	excellent	good	excellent
Maclennan	excellent	excellent	excellent	excellent	good
Tahakopa upper	excellent	excellent	good	excellent	excellent
Tahakopa mid	good	good	fair	excellent	good
Catlins upper	good	good	good	good	fair
Catlins lower	good	good	fair	good	good
Owaka mid	Fair	poor	fair	fair	excellent
Owaka lower	Fair	poor	fair	fair	good
Owaka upper	Fair	poor	poor	fair	excellent
Tahakopa lower	n/a	excellent	n/a*	n/a*	n/a*

*n/a river was too wide and deep to assess effectively

8 Discussion

This section discusses the results from the water quality monitoring, substrate analysis and ecological monitoring derived from the macroinvertebrate and fish sampling. Where appropriate, we linked water quality and physical habitat; specifically, we sought to find out where agricultural development had had adverse effects on ecological values.

8.1 River water quality

Water quality results are frequently reported as being above or below the ANZECC guidelines (2000). The guidelines set default trigger values for slightly disturbed (modified) river ecosystems in New Zealand. An exceedance of the trigger value is an 'early warning' mechanism to alert resource managers of a potential problem (or emerging change) that should be followed up. The ANZECC guidelines cannot be expected to represent a local threshold for water quality.

Therefore, in this study, we adopted guidelines which are more appropriate for conditions in the Catlins: the New Zealand periphyton guidelines, give recommended concentrations for NNN and DRP, the ANZECC (1992) guidelines give more appropriate guidelines for bacteria that specifically apply to reacreational health and we have also used a suspended solid guideline to protect fishery values.

By applying these guidelines, we found that the Tautuku, Maclennan and Tahakopa (upper and lower) sites had the best water quality. To establish this, we compared the median values taken at lower flows to those guidelines recommended as appropriate to protect local instream standards (Table 3). Table 9 shows how the grade was derived for each site. NH_4 was not included in this assessment, as all sites had concentrations below the guideline for this parameter. An 'excellent' classification meant all of the six variables met guideline values, a score of 5 gave a 'good' classification, a score of 3 or 4 meant the site was classified as 'fair', and 2 or less meant the water quality of the site was 'poor'.

Table 9 shows that the Tautuku site had excellent water quality, as did the Maclennan, and the Tahakopa (upper and lower) sites. These sites had a high percentage of indigenous forest upstream. In contrast, the rivers with the poorest water quality were the Owaka sites. These had the highest percentage of exotic grassland (71-81%). The Owaka valley is predominantly used for sheep and beef farming, although there is some deer farming and six dairy farms. Dairy wintering also occurs in the valley.

8.1.1 Nutrients

Nuisance algae growths can be common in rivers affected by excessive nutrient contamination. Instream values, such as swimming and angling, are two activities that can be adversely affected by nuisance algae growths.

The Owaka sites had median NNN and TN concentrations well above guideline values (Figure 12 and Figure 16). Elevated nutrient concentrations were also present at lower flows when rivers and streams are most likely to be used for angling and contact recreation. TP was also above guideline values at each site, but DRP only exceeded the guideline at the Owaka upper site. N limitation was present during the summer at most sites, except for the three Owaka River sites, which showed consistent P limitation.

Despite elevated nutrient concentrations, abundant algal growth was not evident at any of the Owaka sites, nor at any of the other rivers monitored. This may be due to nutrient limitation, but the wet summer (with no low flows) probably meant that optimal conditions for prolific algae growth were not present.

Elevated nutrient concentrations in the Owaka River suggest that it is receiving a larger nutrient input than the other rivers in the Catlins. The reason of this is unknown, but it could be due to the direct deposition of effluent (related to stock access), inappropriate dairy effluent application on saturated soils, dairy wintering or even fertiliser application.

8.1.2 Bacteria

The suitability of water for recreational activities (such as swimming) is assessed by the level of *E. coli* bacteria in a water sample. Although most *E. coli* are harmless, elevated levels are used to indicate the presence of faecal pollution, which may pose a threat to human health as it contains other pathogenic organisms.

The suitability of water for stock drinking is assessed in a similar way. The same indicator bacteria is used, but at a different threshold (1000 *E. coli* per 100ml water), as described in the ANZECC (1992). This is a useful measure for the rivers with rural catchments, as these catchments are likely to provide drinking water for stock.

In the Catlins rivers, bacteria are most likely to enter the water because of land-use practices, particularly the practice of allowing stock access to water. This practice is prevalent in the area as there is no rural water supply or riparian fencing. Another source of *E.coli* may be dead animals in watercourses. We saw this often during the study period (Figure 33).

Figure 33 Dead animals in waterways in the Catlins area

Bacteria concentrations at both flows are important, as recreation is more likely to occur during periods of low flows and stock need to be able to drink at any time. The rivers with low bacteria concentrations were the Tautuku, Maclennan and Tahakopa upper and lower sites.

However, the Catlins upper and all the Owaka sites had median *E coli* concentrations well above the 126 *E coli*/100 ml guideline. The Catlins catchment is purely sheep and beef farmed, whereas the Owaka has dairy farms in its catchment.

The Owaka River returned unusual results for bacteria during the sampling. The upper site, which was expected to have the best water quality, had the most elevated bacteria results. The Kruskall-Wallis test showed a statistically significant difference in the medians at the 95% confidence level. This is shown in Figure 34 (below).

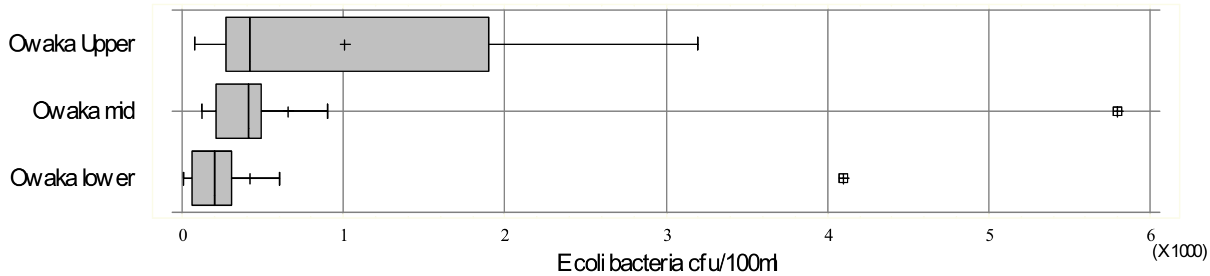


Figure 34 Bacteria concentrations at the three Owaka River sites

The cause of the elevated concentrations is unknown, but the most logical causes would be from dead animals in the water upstream (Figure 33), access of stock to the river (Figure 38), dairy wintering or a direct discharge of effluent (e.g. offal pit, septic tank and irrigation of effluent).

8.1.3 Suspended solids

Suspended solids are the concentration of inorganic and organic matter held in the water column of a river. SS are typically fine particulate matter, such as clay, and all rivers carry SS under natural conditions.

Increased concentrations of SS can lead to alterations to the physical state of the river, such as reduced penetration of light, temperature changes or infilling of interstitial spaces when solids are deposited. SS can also cause chemical alterations such as the entrainment (and release from the sediment) of contaminants such as heavy metals, pesticides, bacteria and nutrients, especially phosphorus. Finally increased concentrations of SS can cause biological alterations such as a reduction in the rate of photosynthesis (due to a reduction in light) for periphyton, and macrophytes.

We used an effects-based guideline for SS of 6.4 mg/l (Table 3). At lower flows, the only site to exceed the 6.4 mg/l value was the Owaka upper site. When all flows were included, both Catlins sites, all the Owaka sites, the Maclennan and Tahakopa mid-sites had high concentrations of SS (Figure 20). SS that enters the river during high flows will settle out as flows recede and then have potential significant ecological effects over a prolonged period.

Observations in the field suggest that unfenced rivers and eroding banks are an issue at every site except the Tautuku.

8.1.4 Summary of river water quality

- The NH_4 concentration (an indicator of raw effluent in waterways) was well below the guideline value at all sites.
- The DRP concentration at lower flows exceeded the guideline concentration at the Owaka upper site. The three Owaka sites exceeded the NNN guideline concentration at lower flows.
- Algal growth was possibly limited by NNN, except at the Owaka sites, where DRP is likely to be the limiting nutrient.
- Bacteria concentrations were significantly elevated in the Owaka River.
- Bacteria concentrations were also elevated at the Catlins sites, which have no dairy farming in their catchments.
- The SS concentration (at lower flows) was higher than the guideline value at only the Owaka upper site, although at all flows, most sites were affected.

8.2 Substrate

With the exception of the Owaka upper and mid-sites, the sites show a very similar substrate composition. The Owaka sites contain a greater proportion of bedrock (Figure 35).

Figure 35 Presence of bedrock at the Owaka upper site

The presence of bedrock means that these sites are less likely to retain organic material (leaves, twigs), which is essential to macroinvertebrates as a food supply. Large amounts of stable substrate, such as bedrock, restricts the habitat available to macroinvertebrates and provides more surface area for algal growths to settle and grow on. However, this did not occur at the Owaka sites.

Although bedrock dominated the Owaka sites, fine sediment was visible in areas where bedrock was absent (Figure 37). The only sampling site with a median substrate size of less than 16 mm was the Owaka upper site. Generally, most of the sites sampled had substrate in good to excellent condition.

The Tautuku, the Catlins and the Tahakopa upper sites had the largest median substrate class. This similarity in substrate-size class was probably due to frequent flushing flows reducing fine sediment build up.

Figure 36: Good substrate size at the Catlins upper site. The median substrate size was 64-250 mm, but frequent emergent boulders were also present.

Figure 37 Substrate size at the Owaka mid- and lower sites. The median substrate size was 16-64 mm, but deposition of sediment was also apparent.

Susbstrate analysis showed that no sites monitored had more than 10% deposition/ sedimentation. Excessive sedimentation can cause degraded macroinvertebrate and fishery values because of a loss of habitat availability (as fine sediment fills in interstitial spaces between larger substrate).

In the Catlins, river-bank collapse (Figure 38), caused by stock grazing in riparian zones, is a major source of sediment, as is collapsed banks and pugging (due to stock access).

Appropriate riparian management is vital to maintaining the quality and ecological values of rivers and streams. Healthy riparian zones reduce and buffer the impact of land-based processes by reducing erosion (i.e. by slowing down the speed of overland water flow before it reaches the river) and filtering inputs of sediment, nutrients and bacteria in overland flow. Riparian zones also protect banks from erosion and buffer the impact of floods. Riparian zones are also instrumental in preventing nuisance plant growths, primarily by maintaining lower summer maximum water temperatures and reducing light levels.

Figure 38: Examples of stock access, bank erosion and unfenced rivers in the Catlins area

Some of the sites had excellent riparian vegetation; examples shown in Figure 39. However, most of the other sites had no riparian vegetation; examples shown in Figure 40.

Figure 39: Examples of good riparian vegetation in the Catlins area

Figure 40: Examples of poor riparian vegetation in the Catlins area

Freshly ploughed paddocks are another source of sediment. If no buffer strip is available to prevent sediment runoff, sediment is free to travel overland and enter the nearest watercourse. The volume of silt exported from a ploughed paddock is enough to disrupt the ecological balance of the receiving water course. An example of the discolouration instream caused by sediment runoff is shown in Figure 41.

Figure 41 The two top photographs show the result of inappropriate land management (insensitive ploughing) which caused a considerable volume of sediment to be carried to the local river (bottom left photograph). The photograph in the bottom right hand corner shows the same river without sediment.

8.2.1 Summary of substrate and riparian vegetation

- The Owaka upper and mid-sites had substantial amounts of bedrock, which limits the habitat available for macroinvertebrates.
- The amount of fine sediment instream corresponded well to the amount of riparian vegetation.
- The sources of fine sediment are probably due to stock trampling river banks, although insensitive ploughing followed by rainfall can export large volumes of sediment to the river.

8.3 Ecological instream values

The relationships between ecology, substrate and water quality are complex. Table 12 shows degraded water quality does not neccessarily relate to degraded ecological values. Factors, such as the shallowness of the river in the reach monitored or the velocity of the water during periods of high flow, may account for anomolies. Examples are:

- the Owaka river, which had poor water quality but good to excellent fishery values
- the Tautuku site, which had excellent water quality, physical habitat structure and fishery values, but the macroinvertebrate community was classified as ‘good’
- the Maclennan site, which had excellent water quality, macroinvertebrate community and physical habitat structure, but the trout condition-related density was classified as ‘good’.

MCI values for this study show the majority of rivers fall into the ‘excellent’ and ‘good’ categories. The exception was the Owaka River, which at all three sites was classed as ‘fair’ (Figure 23). According to Stark *et al.* (2001), this suggests probable moderate pollution. However, every site had abundant mayfly communities, including the Owaka River. When compared to the other sites, the water quality and physical habitat in the Owaka was poor; however, one species of pollution sensitive mayfly (*Deleatidium*) accounted for between 58% to 72% of all macroinvertebrate species found in the river. The Owaka River also supported some of the highest densities of trout in excellent condition.

The Catlins lower and Tahakopa mid sites were classified as ‘good’ to ‘fair’ in all respects (with the exception of the excellent MCI classification for the Tahakopa mid-site). The brown trout fishery at the Catlins and Tahakopa (mid-site) was not as good as the other sites; this is probably because these rivers were steep with a scouring water velocity (the substrate had little fine sediment or algae which suggests a high scouring action). The trout at these sites may also be limited by a lack of flood refuge habitat.

The highest densities of native fish were generally found in rivers dominated by larger substrate (Catlins lower site, Maclennan, Tautuku, Tahakopa mid). Coarse substrate and good intersistitial space are important for native fish species because they are benthic dwelling and use the riverbed for shelter, foraging and nesting (Jowett and Boustead, 2001). However, the Owaka lower site is the exception to this rule as it had a much smaller substrate size. However, it also had a much lower density of brown trout (0.15 brown trout/m^2), compared to the upper Owaka sites, (0.55 to 0.67 brown trout/m^2), which would increase the survival chance of native fish.

8.3.1 Summary of ecological instream values

- This study has shown that the rivers in the Catlins area generally have good water quality and high ecological values.
- Mayflies were abundant at every site.
- MCI values in the study showed the majority of rivers fall into the 'excellent' and 'good' categories.
- The highest densities of native fish were generally found in rivers dominated by larger substrate.
- The brown trout fishery was classified as 'fair' at the Catlins and Tahakopa (mid-site). However, it ranged from 'good' to 'excellent' at the other sites.

9 Conclusions

- Results from this study show that all the rivers monitored are in reasonable ecological health.
- The percentage of native bush cover upstream reflects the quality of water downstream. The Tautuku River, which had 91% native bush upstream of the sampling site, had excellent water quality and reflects pre-pastoral conditions. Native bush upstream of the Owaka River sites only accounts for up to 20% of landcover, with a much higher percentage of pastoral land use. Water quality at the Owaka sites was compromised.
- Typically, the Owaka River was well above water quality guideline values for nutrients and was P limited; the other rivers monitored were N limited.
- The Owaka upper and mid-sites were the only sites to exceed the stock water drinking guideline of 1000 *E. coli*/100ml.
- The ecological condition of all the rivers was good. The percentage of mayflies, caddisflies and stoneflies (EPT taxa) at each site was at least 55%, which indicates very healthy rivers.
- The condition/density of brown trout was generally ‘good’ to ‘excellent’. The steeper headwater sites had a lower condition/ density of trout, probably due to scouring flows.
- Substrate analysis showed that bedrock was evident at many sites, but was prevalent in the Owaka River. The presence of bedrock generally restricts the habitat available for fish and macroinvertebrates.
- Substrate at most sites tended to be clean pebbles and cobbles; fine sediment cover was limited, except at the upper Owaka site, which had more than 60% fine sediment cover over the dominant substrate.
- Riparian vegetation is largely absent from the rivers monitored. Riparian vegetation is vital as a mechanism to control sediment input. Most rivers in the Catlins are used to provide stock water. Allowing stock access to rivers obviously accelerates bank erosion and degrades riparian vegetation.
- Water quality and ecological values were combined to summarise each site. The Tautuku, Maclennan and Tahakopa upper sites were classified as ‘excellent’. The Catlins sites and Tahakopa mid-site were classified as ‘good’ and the three Owaka sites were classified as ‘fair’. No sites were considered to be in poor health.
- The ecological health of the sampled rivers will deteriorate if poor land management practices, such as stock being given free access to watercourses, are allowed to continue. If farming becomes more intensive, then the situation could worsen.
- Results from this study will be used to provide baseline data to help direct council policy, in line with the Rural Water Quality Strategy.

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Appendix 1

Water quality results

Catlins River (mid) at Houipapa hydro site					E2244800	N5410300	
Date	NH4	DRP	*E.Coli*	NNN	SS	TN	TP
	g/m3-N	g/m3-P	cfu/100ml	g/m3-N	g/m3	g/m3-N	g/m3-P
21-Oct-09	0.005	0.013	180	0.309	5	0.48	0.032
19-Nov-09	0.005	0.016	260	0.386	7	0.49	0.033
10-Dec-09	0.01	0.015	150	0.177	2.5	0.39	0.036
21-Dec-09	0.005	0.018	210	0.206	4	0.31	0.032
06-Jan-10	0.01	0.012	450	0.245	9	0.5	0.038
19-Jan-10	0.01	0.017	140	0.438	4	0.53	0.036
04-Feb-10	0.005	0.016	64	0.194	3	0.36	0.03
17-Feb-10	0.01	0.015	180	0.24	1.5	0.44	0.036
03-Mar-10	0.01	0.018	130	0.204	1.5	0.36	0.033
17-Mar-10	0.01	0.017	120	0.185	4	0.47	0.039
30-Mar-10	0.01	0.017	330	0.189	1.5	0.41	0.03
15-Apr-10	0.005	0.02	180	0.246	1.5	0.41	0.031
27-Apr-10	0.02	0.015	1200	0.572	28	1.12	0.084
20-May-10	0.005	0.016	120	0.385	1.5	0.52	0.026
15-Jun-10	0.01	0.015	100	0.604	17	0.88	0.055
29-Jun-10	0.005	0.02	44	0.64	3	0.66	0.02
11-Aug-10	0.005	0.015	74	0.436	14	0.73	0.043
14-Sep-10	0.005	0.02	62	0.442	7	0.6	0.033
13-Jul-10	0.005	0.018	38	0.514	1.5	0.67	0.02
median	**0.005**	**0.016**	**140**	**0.309**	**4**	**0.49**	**0.033**
Catlins River (upper) at Chloris Pass Rd					E2235700	N5417100	
Date	NH4	DRP	*E.Coli*	NNN	SS	TN	TP
	g/m3-N	g/m3-P	cfu/100ml	g/m3-N	g/m3	g/m3-N	g/m3-P
21-Oct-09	0.005	0.009	280	0.318	3	0.5	0.023
19-Nov-09	0.005	0.014	290	0.427	5	0.51	0.021
10-Dec-09	0.02	0.011	520	0.241	2.5	0.49	0.031
21-Dec-09	0.005	0.014	900	0.217	3	0.33	0.025
06-Jan-10	0.005	0.009	440	0.285	8	0.55	0.029
19-Jan-10	0.01	0.014	210	0.528	3	0.65	0.031
04-Feb-10	0.005	0.011	170	0.277	1.5	0.46	0.022
17-Feb-10	0.005	0.01	210	0.29	1.5	0.5	0.024
03-Mar-10	0.005	0.012	80	0.23	1.5	0.43	0.023
17-Mar-10	0.01	0.011	1800	0.202	3	0.5	0.03
30-Mar-10	0.01	0.013	210	0.233	1.5	0.44	0.021
15-Apr-10	0.01	0.016	530	0.269	4	0.49	0.031
27-Apr-10	0.02	0.01	1700	0.646	20	1.1	0.066
20-May-10	0.005	0.011	80	0.471	4	0.62	0.021
15-Jun-10	0.005	0.013	150	0.791	13	1.02	0.045
29-Jun-10	0.005	0.016	51	0.774	11	0.82	0.022
13-Jul-10	0.005	0.013	35	0.629	3	0.77	0.015
11-Aug-10	0.01	0.01	130	0.388	31	0.86	0.067
14-Sep-10	0.01	0.014	24	0.486	4	0.63	0.022
median	**0.005**	**0.012**	**210**	**0.318**	**3**	**0.51**	**0.024**

Appendix 1
Water quality results continued

Maclennan River at top of Kahuika School Road					E2236537	N5405994	
Date	NH4	DRP	*E.Coli*	NNN	SS	TN	TP
	g/m3-N	g/m3-P	cfu/100ml	g/m3-N	g/m3	g/m3-N	g/m3-P
21-Oct-09	0.005	0.01	130	0.018	1.5	0.19	0.019
19-Nov-09	0.005	0.013	110	0.011	1.5	0.14	0.017
10-Dec-09	0.005	0.012	100	0.012	2.5	0.17	0.025
21-Dec-09	0.005	0.015	240	0.006	1	0.09	0.022
06-Jan-10	0.01	0.009	62	0.0025	3	0.27	0.022
19-Jan-10	0.005	0.012	65	0.032	1.5	0.12	0.025
04-Feb-10	0.02	0.014	58	0.034	3	0.15	0.027
17-Feb-10	0.005	0.015	110	0.268	1.5	0.53	0.039
03-Mar-10	0.01	0.018	62	0.19	3	0.39	0.035
17-Mar-10	0.01	0.017	170	0.218	4	0.49	0.038
30-Mar-10	0.01	0.018	110	0.187	1.5	0.42	0.031
15-Apr-10	0.01	0.02	130	0.32	1.5	0.41	0.034
27-Apr-10	0.02	0.015	170	0.549	22	1.06	0.068
20-May-10	0.005	0.016	86	0.388	7	0.5	0.024
15-Jun-10	0.01	0.015	300	0.622	17	0.9	0.054
29-Jun-10	0.005	0.019	36	0.626	41	0.65	0.023
13-Jul-10	0.005	0.018	42	0.513	1.5	0.66	0.019
11-Aug-10	0.01	0.015	110	0.439	14	0.72	0.044
14-Sep-10	0.005	0.019	28	0.443	7	0.6	0.033
median	**0.005**	**0.015**	**110**	**0.218**	**3**	**0.42**	**0.027**
Owaka River (mid) at Tahatika					E2242710	N5417610	
Date	NH4	DRP	*E.Coli*	NNN	SS	TN	TP
	g/m3-N	g/m3-P	cfu/100ml	g/m3-N	g/m3	g/m3-N	g/m3-P
21-Oct-09	0.01	0.019	490	1.07	7	1.3	0.04
19-Nov-09	0.005	0.022	410	1.61	10	1.69	0.037
10-Dec-09	0.02	0.017	720	0.739	2.5	1.06	0.047
21-Dec-09	0.005	0.017	450	0.571	3	0.69	0.03
06-Jan-10	0.01	0.016	570	0.92	7	1.13	0.04
19-Jan-10	0.02	0.026	900	1.49	6	1.61	0.049
04-Feb-10	0.02	0.024	270	0.76	3	1.01	0.04
17-Feb-10	0.02	0.034	420	0.854	1.5	1.03	0.052
03-Mar-10	0.02	0.027	260	0.709	3	0.91	0.047
17-Mar-10	0.02	0.024	420	0.625	1.5	0.84	0.038
30-Mar-10	0.01	0.022	260	0.637	1.5	0.87	0.035
15-Apr-10	0.01	0.03	440	0.72	1.5	0.96	0.041
27-Apr-10	0.02	0.03	5800	1.98	43	2.58	0.133
20-May-10	0.005	0.02	210	1.31	1.5	1.39	0.028
15-Jun-10	0.01	0.021	240	2.64	17	2.69	0.072
29-Jun-10	0.01	0.027	120	1.97	5	2	0.031
13-Jul-10	0.005	0.025	120	1.72	3	2.03	0.027
11-Aug-10	0.02	0.022	140	1.75	19	2.19	0.072
14-Sep-10	0.01	0.027	200	1.55	9	1.86	0.05
median	**0.01**	**0.024**	**410**	**1.07**	**3**	**1.3**	**0.04**

Appendix 1
Water quality results continued

Owaka River (lower) at Katea Road					E2251800	N5414000	
Date	NH4	DRP	*E.Coli*	NNN	SS	TN	TP
	g/m3-N	g/m3-P	cfu/100ml	g/m3-N	g/m3	g/m3-N	g/m3-P
21-Oct-09	0.01	0.019	200	1.03	6	1.3	0.048
19-Nov-09	0.005	0.02	310	1.43	6	1.52	0.03
10-Dec-09	0.01	0.011	580	0.524	2.5	0.78	0.03
21-Dec-09	0.005	0.014	220	0.334	1.5	0.5	0.028
06-Jan-10	0.01	0.016	380	0.631	3	0.88	0.036
19-Jan-10	0.01	0.023	600	1.41	4	1.56	0.046
04-Feb-10	0.01	0.012	61	0.392	3	0.72	0.032
17-Feb-10	0.005	0.017	170	0.62	1.5	0.87	0.036
03-Mar-10	0.01	0.023	180	0.445	1.5	0.67	0.042
17-Mar-10	0.01	0.017	11	0.424	1.5	0.69	0.036
30-Mar-10	0.005	0.018	62	0.427	1.5	0.73	0.034
15-Apr-10	0.01	0.025	120	0.629	1.5	0.88	0.036
27-Apr-10	0.04	0.034	4100	0.91	22	1.55	0.118
20-May-10	0.005	0.018	60	1.2	1.5	1.38	0.03
15-Jun-10	0.01	0.023	270	2.66	21	2.7	0.084
29-Jun-10	0.01	0.025	210	2.14	3	2.17	0.028
13-Jul-10	0.005	0.021	44	1.78	4	1.99	0.027
11-Aug-10	0.01	0.022	250	1.98	11	2.31	0.052
14-Sep-10	0.01	0.025	190	1.57	9	1.84	0.046
median	**0.01**	**0.02**	**200**	**0.91**	**3**	**1.3**	**0.036**

Owaka River (upper) at Purekireka					E2238600	N5422400	
Date	NH4	DRP	*E.Coli*	NNN	SS	TN	TP
	g/m3-N	g/m3-P	cfu/100ml	g/m3-N	g/m3	g/m3-N	g/m3-P
21-Oct-09	0.005	0.025	360	1.35	14	1.59	0.06
19-Nov-09	0.005	0.027	300	1.67	13	1.73	0.049
10-Dec-09	0.02	0.034	1800	0.961	8	1.19	0.062
21-Dec-09	0.01	0.038	3200	0.948	9	1.08	0.064
06-Jan-10	0.01	0.025	2400	1.03	10	1.24	0.056
19-Jan-10	0.01	0.028	500	1.61	12	1.66	0.062
04-Feb-10	0.01	0.031	1900	0.961	7	1.16	0.053
17-Feb-10	0.01	0.029	2900	0.909	5	1.09	0.05
03-Mar-10	0.01	0.032	420	0.948	5	1.12	0.05
17-Mar-10	0.005	0.031	420	0.786	4	1	0.051
30-Mar-10	0.01	0.031	290	0.798	1.5	1.02	0.044
15-Apr-10	0.01	0.036	590	0.904	8	1.13	0.06
27-Apr-10	0.02	0.028	2600	1.98	39	2.61	0.147
20-May-10	0.005	0.031	180	1.47	20	1.66	0.079
15-Jun-10	0.02	0.026	700	2.86	16	2.89	0.07
29-Jun-10	0.01	0.032	130	2.17	9	2.31	0.049
13-Jul-10	0.06	0.044	78	1.82	7	2.16	0.041
11-Aug-10	0.02	0.027	270	2.1	24	2.48	0.08
14-Sep-10	0.01	0.032	160	1.77	14	2.07	0.066
median	**0.01**	**0.031**	**420**	**1.35**	**9**	**1.59**	**0.06**

Appendix 1
Water quality results continued

Tahakopa River (lower) at Mouats Saddle					E2236700	N5402800	
Date	NH4	DRP	*E.Coli*	NNN	SS	TN	TP
	g/m3-N	g/m3-P	cfu/100ml	g/m3-N	g/m3	g/m3-N	g/m3-P
21-Oct-09	0.01	0.01	320	0.24	3	0.44	0.024
19-Nov-09	0.005	0.014	270	0.253	4	0.41	0.024
10-Dec-09	0.02	0.008	390	0.151	6	0.38	0.024
21-Dec-09	0.01	0.015	600	0.203	4	0.34	0.028
06-Jan-10	0.01	0.009	600	0.138	9	0.4	0.035
19-Jan-10	0.02	0.01	260	0.38	4	0.53	0.038
04-Feb-10	0.01	0.016	56	0.215	3	0.41	0.03
17-Feb-10	0.01	0.014	120	0.014	1.5	0.2	0.023
03-Mar-10	0.005	0.018	180	0.011	1.5	0.12	0.027
17-Mar-10	0.005	0.012	130	0.022	3	0.27	0.027
30-Mar-10	0.01	0.014	52	0.024	1.5	0.25	0.022
15-Apr-10	0.005	0.018	96	0.023	4	0.21	0.033
27-Apr-10	0.02	0.01	48	0.021	5	0.46	0.031
20-May-10	0.005	0.015	16	0.032	1.5	0.18	0.021
15-Jun-10	0.02	0.009	34	0.129	6	0.42	0.024
29-Jun-10	0.005	0.017	6	0.136	1.5	0.22	0.014
13-Jul-10	0.005	0.015	10	0.101	1.5	0.25	0.016
11-Aug-10	0.01	0.009	8	0.085	6	0.45	0.025
14-Sep-10	0.005	0.017	25	0.074	1.5	0.2	0.022
median	**0.01**	**0.014**	**96**	**0.101**	**3**	**0.34**	**0.024**
Tahakopa River (upper) at Tahakopa Valley Bridge					E2221420	N5409240	
Date	NH4	DRP	*E.Coli*	NNN	SS	TN	TP
	g/m3-N	g/m3-P	cfu/100ml	g/m3-N	g/m3	g/m3-N	g/m3-P
21-Oct-09	0.005	0.01	60	0.222	1.5	0.34	0.02
19-Nov-09	0.005	0.015	170	0.215	4	0.27	0.018
10-Dec-09	0.005	0.01	150	0.156	3	0.35	0.026
21-Dec-09	0.005	0.015	190	0.163	3	0.23	0.023
06-Jan-10	0.005	0.01	240	0.156	7	0.33	0.028
19-Jan-10	0.005	0.014	97	0.327	3	0.41	0.037
04-Feb-10	0.01	0.015	22	0.141	1.5	0.32	0.018
17-Feb-10	0.01	0.012	42	0.081	1.5	0.25	0.019
03-Mar-10	0.005	0.016	150	0.077	1.5	0.2	0.022
17-Mar-10	0.01	0.01	100	0.036	1.5	0.32	0.023
30-Mar-10	0.02	0.028	20	0.079	1.5	0.29	0.019
15-Apr-10	0.005	0.012	56	0.039	1.5	0.25	0.025
27-Apr-10	0.02	0.008	50	0.045	4	0.44	0.023
20-May-10	0.005	0.014	12	0.105	1.5	0.26	0.017
15-Jun-10	0.01	0.007	22	0.162	5	0.44	0.022
29-Jun-10	0.005	0.017	24	0.459	1.5	0.48	0.011
13-Jul-10	0.005	0.014	1	0.228	1.5	0.39	0.013
11-Aug-10	0.01	0.008	4	0.11	3	0.47	0.018
14-Sep-10	0.005	0.016	20	0.266	1.5	0.45	0.022
median	**0.005**	**0.014**	**50**	**0.156**	**1.5**	**0.33**	**0.022**

Appendix 1
Water quality results continued

Tahakopa River (mid) at Tahakopa					E2232700	N5404200	
Date	NH4	DRP	*E.Coli*	NNN	SS	TN	TP
	g/m3-N	g/m3-P	cfu/100ml	g/m3-N	g/m3	g/m3-N	g/m3-P
21-Oct-09	0.005	0.01	290	0.257	19	0.42	0.023
19-Nov-09	0.005	0.014	380	0.25	2.5	0.33	0.019
10-Dec-09	0.01	0.009	330	0.166	2.5	0.37	0.028
21-Dec-09	0.005	0.015	420	0.197	4	0.29	0.026
06-Jan-10	0.005	0.009	370	0.103	8	0.39	0.029
19-Jan-10	0.01	0.011	200	0.406	5	0.49	0.039
04-Feb-10	0.01	0.013	150	0.255	4	0.41	0.026
17-Feb-10	0.005	0.011	270	0.185	1.5	0.34	0.025
03-Mar-10	0.005	0.015	350	0.199	3	0.32	0.029
17-Mar-10	0.01	0.013	290	0.162	6	0.38	0.03
30-Mar-10	0.01	0.015	240	0.194	1.5	0.44	0.026
15-Apr-10	0.005	0.016	320	0.237	5	0.4	0.03
27-Apr-10	0.02	0.01	460	0.259	20	0.73	0.051
20-May-10	0.01	0.015	210	0.323	6	0.47	0.026
15-Jun-10	0.01	0.01	110	0.394	20	0.71	0.045
29-Jun-10	0.01	0.015	55	0.614	4	0.63	0.018
13-Jul-10	0.01	0.014	46	0.448	3	0.62	0.019
11-Aug-10	0.01	0.011	86	0.279	11	0.6	0.035
14-Sep-10	0.01	0.015	90	0.437	4	0.6	0.025
median	**0.01**	**0.013**	**270**	**0.255**	**4**	**0.42**	**0.026**
Tautuku River at Maclean Falls					E2229967	N5397831	
Date	NH4	DRP	*E.Coli*	NNN	SS	TN	TP
	g/m3-N	g/m3-P	cfu/100ml	g/m3-N	g/m3	g/m3-N	g/m3-P
21-Oct-09	0.005	0.008	31	0.018	1.5	0.14	0.013
19-Nov-09	0.005	0.011	42	0.008	2.5	0.11	0.013
10-Dec-09	0.005	0.005	30	0.013	2.5	0.23	0.017
21-Dec-09	0.005	0.012	54	0.008	1	0.08	0.015
06-Jan-10	0.005	0.005	24	0.01	3	0.18	0.015
19-Jan-10	0.005	0.007	18	0.031	1.5	0.18	0.029
04-Feb-10	0.005	0.01	64	0.028	1.5	0.15	0.019
17-Feb-10	0.005	0.011	32	0.02	1.5	0.15	0.014
03-Mar-10	0.005	0.019	370	0.179	4	0.26	0.027
17-Mar-10	0.005	0.009	100	0.009	1.5	0.19	0.019
30-Mar-10	0.005	0.018	40	0.179	1.5	0.32	0.02
15-Apr-10	0.005	0.016	26	0.196	1.5	0.3	0.023
27-Apr-10	0.02	0.011	120	0.131	12	0.45	0.035
20-May-10	0.005	0.016	16	0.263	4	0.37	0.021
15-Jun-10	0.005	0.013	40	0.229	6	0.39	0.028
29-Jun-10	0.005	0.019	2	0.381	3	0.41	0.015
13-Jul-10	0.005	0.019	66	0.355	3	0.49	0.018
11-Aug-10	0.005	0.016	2	0.297	3	0.43	0.021
14-Sep-10	0.005	0.019	14	0.327	4	0.43	0.024
median	**0.005**	**0.012**	**32**	**0.131**	**2.5**	**0.26**	**0.019**