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HAWKE'S BAY
REGIONAL COUNCIL

SAFEGUARDING YOUR ENVIRONMENT + KAITIAKI TUKU IHO

Kopuawhara and Opoutama Catchments

Surface Water Quality and Ecology
State of the Environment Report 2009

November 2009
EMT 10/09
HBRC Plan Number 4184

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Resource Management Group
Technical Report

Environmental Science Section

Kopuawhara and Opoutama Catchments Surface Water Quality and Ecology State of the Environment Report 2009

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EXECUTIVE SUMMARY

Hawke's Bay Regional Council (HBRC) monitors water quality of the Kopuawhara and the Opoutama Streams, and flows of the Kopuawhara, and has produced a comprehensive report on the state and trends of water quality for sites within this area, based on data collected between 1998 and 2003 using the river environment classification (REC) (Stansfield 2004).

The present report provides information on the state of the water quality in the two coastal streams Kopuawhara and Opoutama based on the data assessed in the State of the Environment Water Quality / Ecology monitoring programme.

The aim of this study is to analyse the water quality and biomonitoring data collected by HBRC between 1994 and 2008. In particular, the study aims at investigating the following points:

- the state of the Kopuawhara and the Opoutama streams
- assess compliance of the sites with relevant guidelines that are stipulated in either the Regional Resource Management Plan (RRMP), the Resource Management Act (RMA) or with ANZECC (Australia and New Zealand Environment and Conservation Council) water quality guidelines.

The annual contaminant loadings and temporal trends for water quality parameters were not calculated for these sites, as the database was not sufficient for these analyses.

Generally, the physico-chemical water quality showed good compliance with guidelines concerning temperature, pH, nutrient concentrations (DRP and DIN) and ammonia-N in both, the Kopuawhara and Opoutama. Also the periphyton biomass was compliant with the guideline of 120 mg/m² Chlorophyll *a*.

A major problem in both streams was the high fine substrate concentration and low water clarity, often breaching guidelines: Compliance with the least strict guideline of 1.6 m water clarity (RRMP) was 59% in the Kopuawhara and only 15% in the Opoutama (guidelines for fish protection were generally not met). The Opoutama water clarity was more degraded than the Kopuawhara. The catchments are especially sensitive for high suspended matter entering the stream because they lie in soft sedimentary geology. It should be investigated which part of the sediment load has to be accounted for as occurring naturally, and which part can be avoided by better riparian management.

The second major impairment of water quality in the streams is the bacteriological concentration. While *E. coli* concentrations are generally compliant with guidelines in the Kopuawhara, less than half of the samples are complying in the Opoutama. Faecal coliforms are found in high concentrations in almost all samples of both streams. The origin of the elevated *E. coli* concentration in the Opoutama should be investigated especially, and dealt with. It should be clarified, if Opoutama beach at the outlet of the stream is used for contact recreation and if water quality is impaired by this stream.

In terms of biological health using the macroinvertebrate community as indicator, the Kopuawhara showed a healthy community in 2001 and 2002. Since then, the Kopuawhara fails to meet the desired biological quality. The Opoutama has only been sampled once in 2005, with the index showing distinctly poorer ecological health than in the Kopuawhara. Further investigation is recommended.

As well as high sediment, *E. coli* and faecal coliform concentrations, the Opoutama has significantly higher TOC concentration and lower oxygen saturation (only 41% compliant with RMA guideline of 80% saturation) than the Kopuawhara. The Opoutama may be impaired by the intensive sheep and beef farming in its catchment, whereas the Kopuawhara has mainly forestry in its upper catchment and some hill country sheep and beef farming. To improve water quality in these streams, the avoidable part of environmental impact has to be estimated and dealt with, e.g. by enforcing better riparian management.

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1.0 INTRODUCTION

The Hawke's Bay Regional Resource Management Plan (RRMP) has the stated objective of maintaining or enhancing the water quality of surface waters, in order that "it is suitable for sustaining or improving aquatic ecosystems in catchments as a whole, and for contact recreation purposes where appropriate".

Water should maintain a quality, which supports the existing species and the natural character of the ecosystem. Furthermore, resource availability and groundwater recharge have to be safeguarded.

Hawke's Bay Regional Council monitors water quality indicators and river flow at a number of sites throughout the Hawke's Bay region. This document reports on two coastal sites, the Kopuawhara and the Opoutama streams, in the north of the Hawke's Bay Region, that are being monitored for physicochemical, bacteriological and biological data on a long-term basis.

1.1 Aim and Scope of Study

To be aware of the state of the region's environment and changes that occur over time, key environmental indicators are monitored and analysed. This study aims at analysing the water quality and biomonitoring data in two coastal streams, collected by the Hawke's Bay Regional Council between 1994 and 2008. The focus of this investigation will be on:

- the general water quality of the Kopuawhara and Opoutama streams
- their compliance with relevant guidelines that are stipulated in either the Regional Resource Management Plan (RRMP), the Resource Management Act (RMA), or the Australian and New Zealand Environment and Conservation Council (ANZECC)
- ecological indicators
- recommendations for future water quality monitoring and management in these catchments.

2.0 METHODS

2.1 Dataset

The two coastal streams are located in the northern Hawke's Bay, just north and south of the land bridge to the Mahia peninsula. The Kopuawhara stream has been monitored quarterly for physico-chemical, nutrient, microbiological and biological parameters since 1994. The Opoutama stream has been monitored from 1995 to 1997 and from 2004 to 2008, for the same variables except for ecological indicators, which have been sampled only once in 2005.

Table 1: Water quality and flow data used in this study on the Kopuawhara and Opoutama streams. Phy-chem: Physico-chemical variables (temperature, pH, conductivity, dissolved oxygen). Nutrients include DIN (soluble inorganic nitrogen) and DRP (soluble reactive phosphorus). Bacto: bacteriological data (*E. coli* and faecal coliforms). Biom: Biomonitoring (macroinvertebrate and periphyton data).

		Water quality data					Flow data
	HBRC	Record	Parameters				
Monitoring site	Site ID	Period	Phy-Chem	Nutrients	Bacto	Biom	
Kopuawhara	330	1994 - 2008	✓	✓	✓	✓	✓
Opoutama	2125	1995 - 1997 2004 - 2008	✓	✓	✓	n=1	✓

2.2 Flow data

Flow data is available for the Kopuawhara, which is rated at the SOE monitoring site. The recording has several periods of missing data in 1995, 1996, 2000, 2002, and 2003. Flow data for the Opoutama is obtained by correlation with the Kopuawhara, correlation for this time period is $r^2=0.91$ with n=27. Missing flow data affects the Opoutama samples in 1996 only, because SOE monitoring in the Opoutama was interrupted from 1998 to 2003.

Table 2: Flow statistics calculated from the data at the flow recorder site in the Kopuawhara, and calculated from correlation data for the Opoutama.

Flow (L/s)	Kopuawhara Site ID 330	Opoutama Site ID 2125
3× Median	3,296	233
Median	1,099	78
Lower Quartile	527	35
7-day MALF	211	9
Minimum	104	1
Data source	Rated site	Kopuawhara
Data record	1994-2008	1994-2008

2.3 Data analysis

2.3.1 Statistical analysis

Descriptive statistics (mean, median, percentiles and confidence intervals) were used for the analysis of data and full results are given in the appendix. For guidelines and data analysis requiring analysis under specific flow conditions, water quality data was filtered in the following groups:

- year-round at all flows (i.e. all data available)
- under 3* median flow, to remove the potential influence of flood flows
- under median flow
- under the lower quartile (25th percentile) flow, to reflect low river flow conditions

2.3.2 Nutrient loads

Due to a small dataset, nutrient loads have not been calculated for these sites: on a quarterly database (four samples per year) nutrient load calculations are quite uncertain. Additionally, missing flow data for the Kopuawhara and lack of continuous nutrient recording in the Opoutama would have made load estimation unreliable.

2.3.3 Habitat assessments

Together with biological sampling, a stream habitat assessment has been completed in the form of a questionnaire. This assessment provides information on in-stream habitat values and the condition of the riparian zone. The categories used in this report indicate ecological values in interval scores from 1 to 20, 20 representing the best habitat condition. This implies that for example little or no riparian shading would have a low score, but also high periphyton cover or stock having access to most of the stream.

2.3.4 Additional information on SOE monitoring sites

Supporting the data monitored in the field, background information on the rivers and their environment have been collected from several databases. The River Environment Classification for New Zealand (REC Manual, Snelder et al. 2003) gave information on various environmental parameters influencing the characteristics of rivers, such as climate, source of flow, geology, land-cover, and valley-landform.

Information on the potential risk of erosion and sediment entry into streams and rivers were derived from New Zealand Empirical Erosion Model NZeem® (Dymond et al. 2008).

Further information on landcover and landuse has been taken from databases in ArcGIS (ESRI®Arc Map$_{TM}$ 9.3).

3.0 WATER QUALITY IN THE KOPOUWHARA AND OPOUTAMA

3.1 The monitoring sites and their catchments

Photo1: Opoutama

The monitoring sites are shown in Figure 1. The Kopuawhara and the Opoutama are small lowland streams with catchment areas of 68 km² (Kopouwhara), and 14.8 km² (Opoutama). Both streams lie in soft sedimentary geology, and they are influenced by a warm and wet climate (Table 3). They drain north and south of the land bridge to the Mahia peninsula. Mahia peninsula is an attractive recreational area; especially the beaches are a popular attraction.

The small Opoutama Stream (Photo 1) drains south of the Mahia land bridge into the eastern end of Opoutama Beach. The very upper reaches are used for hill country sheep and beef farming, the middle and lower catchment is used for intensive sheep and beef farming, part of the lower-eastern catchment area is scrub.

The Kopuawhara Stream (Photo 2) discharges into the Maungawhio lagoon, which then connects to the sea at Oraka Beach. In the area of its upper catchment down to the SOE monitoring site, the land is primarily used for exotic forestry. Small patches of shrub, and hill country sheep and beef farming are located directly upstream of the monitoring site. Downstream of the monitoring site the dominant land use is intensive sheep and beef, deer and dairy farming. Fish have been monitored (National Fish Database, NIWA) in the Kopuawhara; the records between 1980 and 2007 include following fish: Yelloweye mullet, shortfin eel, longfin eel, banded kokopu, inanga, common bully, giant bully, bluegill bully, redfin bully, mullets, rainbow trout, koura and black flounder. The Kopuawhara is occasionally used for trout fishing (*pers. comm*. Brett Stansfield).

Table 3: Catchments of the Kopuawhara and Opoutama: River Environment classifications.

Site	HBRC Site ID	catchment size (km^2)	REC classes				
			Climate	Source of flow	Geology	dominant land use
Kopuawhara	330	68	warm extremely wet	low elevation	soft sedimentary	exotic forestry, hill country sheep and beef farming
Opoutama	2125	15	warm wet	low elevation	soft sedimentary	intensive sheep and beef farming

Photo 2: Kopuawhara

3.2. Water quality indicators and guidelines

In order to describe the state of the water quality in the Opoutama and Kopuawhara, the physico-chemical and biological values at the monitoring sites are being compared to water quality standards and guidelines. The Hawke's Bay Regional Council's Regional Resource Management Plan (RRMP) and the Resource Management Act (RMA) define several standards and guidelines for water quality in the Hawke's Bay Region, primarily for regulatory purpose. The ANZECC guidelines (2000), the NZ Periphyton guideline (Biggs, 2000) and the MfE guideline for microbiological water quality (2003) are also applicable to these waterbodies. To assess the state of the Wairoa environment, the following physical, chemical, microbiological and biological variables are being analysed in relation the guidelines.

3.2.1 Water temperature

Water temperature influences the aquatic ecosystem in two ways: indirectly, through changes in the physical environment, such as dissolved oxygen and calcium carbonate solubility, conductivity, pH, and the toxicity of chemicals. And directly, by influencing the physiological processes of aquatic organisms, and influencing growth, reproduction, metabolism and mobility and thus the survival of species. A detailed analysis of 88 New Zealand rivers (Quinn and Hickey 1990) identified water temperature as one of the important variables affecting species distribution. Stoneflies (Plecoptera) were largely confined to rivers with temperature maxima between 13 and 19 °C, and mayflies (Ephemeroptera) were less common in rivers with maximum temperatures above 21.5°C. Introduced fish species such as trout usually suffer physiological stress at or above 20ºC. Some New Zealand native fish species (e.g. some bully species or eels) prefer temperatures at or above 20ºC, which is not the case for galaxiid species, the latter preferring cooler temperatures than 20ºC (Richardson et al. 1994). A change in aquatic community composition can be expected from alterations of natural temperature regimes. Thus, in order to protect temperature sensitive fish and macroinvertebrates, certain temperature ranges should not be exceeded.

No temperature standards or trigger values are given in the ANZECC guidelines. The RRMP defines a maximum water temperature of 25ºC, which might not protect site specific aquatic communities, especially in hill country sites. For the Tukituki catchment, a maximum of 19ºC is recommended for the upper catchment and a maximum of 23º C for the lower catchment, to avoid negative effects on trout and macroinvertebrate communities (Ausseil 2008).

For the Opoutama and the Kopuawhara, the 23ºC value is applied, as they are soft sedimentary lowland streams influenced by a warm wet climate.

Nevertheless, compared to large rivers in the lowland, small streams are still dominated by the temperature of the groundwater, and they typically have cooler, more stable water temperatures under natural, shaded conditions, with an aquatic community adapted to these conditions. Thus for comparison, the compliance of both streams with the upper catchment value of 19ºC is also shown in this report.

It has to be taken into consideration, that temperature data in this report consist of spot sampling, not continuous recordings. As temperatures may fluctuate by several degrees each day, these measurements can only be taken as an estimation of the actual temperature regime occurring in the rivers.

3.2.2 Water pH

Not much information exists about the effects of pH on aquatic organisms in New Zealand.

In the ANZECC guidelines (2000), trigger values are defined for pH in upland rivers to lie between 7.3 and 8.0. For lowland rivers, the range of the guideline is slightly lower, i.e. between 7.2 and 7.8. As with temperature data, it has to be taken into consideration that the pH has diurnal and seasonal fluctuations, and the sampling is just a spot measurement. The trigger values of the ANZECC guidelines are defined for daytime sampling. It has to be considered, that carbonate-rich sedimentary rock types of marine origin like limestone tend to be the source of alkalinity in streams, and have a high buffering capacity. Water draining from these areas typically have pH of above 7. As the Kopuawhara and Opoutama each drain a soft sedimentary catchment of marine origin, an upper pH value of 7.8 might not be applicable and will only be discussed in comparison.

Instead, a pH range suitable for fish present in the streams will be used as a guideline in this report. For brown trout a tolerable range of pH 5 to 9.5 and an optimal range of pH 6.7 to 7.8 is suggested by Raleigh et al. (1986). A study by West et al. (1997) indicated that a range of pH 7 to 9.5 should not be toxic for New Zealand native fish. In this report, the guideline for a tolerable pH-range for trout is applied to the Kopuawhara, as it holds trout fishery. The tolerable range for native fish is applied to the Opoutama. As with temperature data, it has to be taken into consideration that the pH has diurnal and seasonal fluctuations, and that the data was recorded from spot measurements, mostly made between 9 am and 5 pm.

3.2.3 Ammonia

Ammonia can be toxic to aquatic organisms, sensitivity in fish being even higher than in macroinvertebrates. Salmonids appear to be especially sensitive to ammonia. In water, ammonia exists in two forms: as un-ionised NH_3 and as the ammonium ion NH_4^+. The toxicity of ammonia is mainly attributed to NH_3, as it easily passes epithelial membranes of aquatic organisms. The proportion in which ammonia forms occur in solution depends primarily on pH and temperature. In the laboratory, total ammonia (i.e. NH_3 plus NH_4^+) is determined and reported, and is signified as NH_4 in this report.

Different guidelines exist concerning the ammonium concentration in surface water: In the ANZECC guidelines, a general trigger value with a 95% protection level for aquatic organisms is defined as 0.035 mg/l unionised ammonia (NH_3) as nitrogen N.

Total ammonia-N (NH_4-N) concentration has been monitored in the Opoutama and Kopuawhara. Because of the pH dependent equilibrium between the ionised and un-ionised ammonia, different trigger values exist for total ammonia-N depending on the pH at the monitoring site. For each monitoring site, the respective trigger value for total ammonia is assigned: For the Kopuawhara, the guideline value for total ammonia-N is 0.78 mg/l at pH 8.1 (95^{th} percentile), for the Opoutama 1.03 mg/l at pH 7.9 (95^{th} percentile) (Table 4).

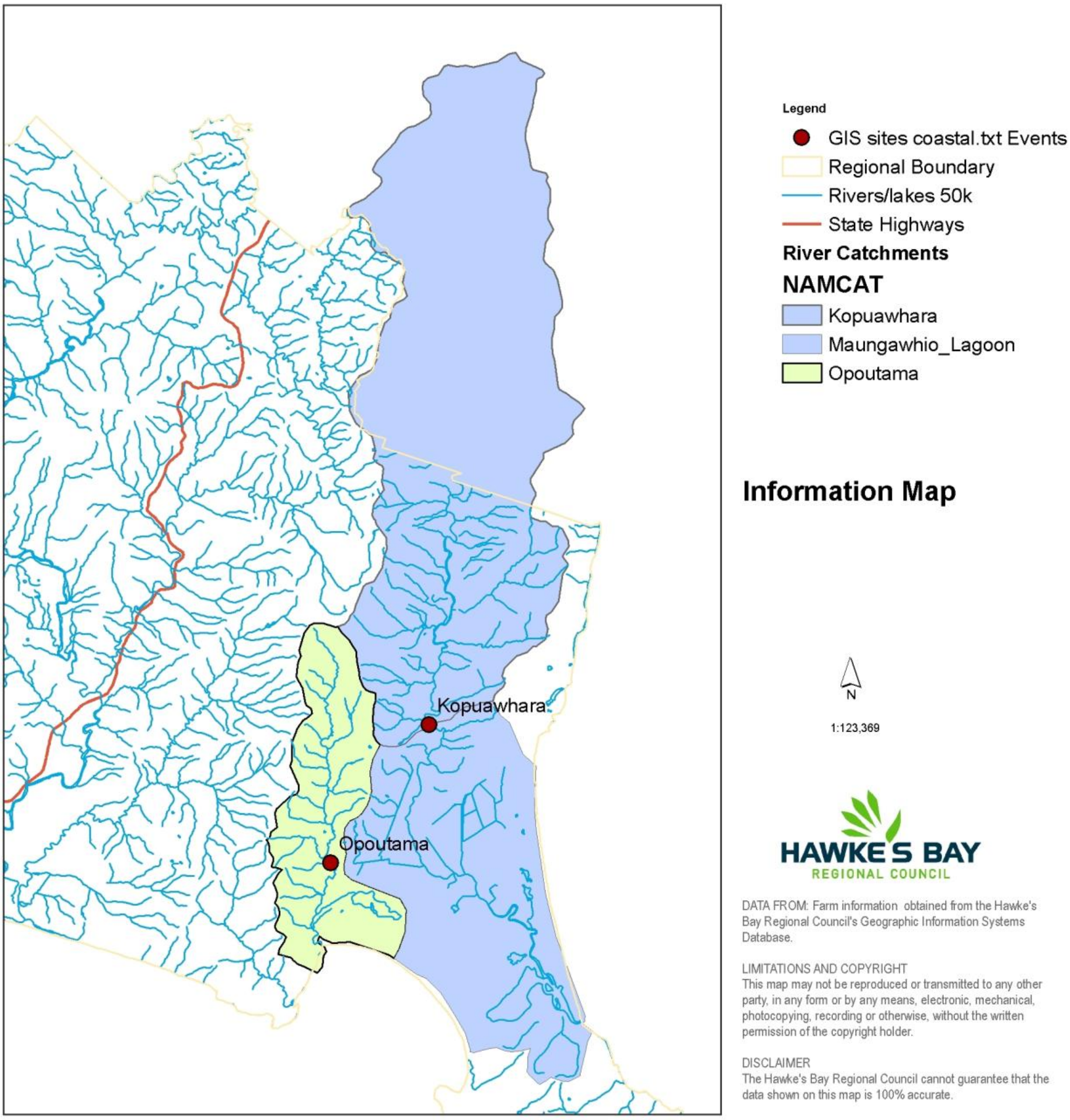

Figure 1: Kopuawhara and Opoutama catchment water quality monitoring sites.

3.2.4 Organic load and oxygen saturation

Total organic carbon (TOC) is an unspecific indicator for the amount of organic matter present in the water, including e.g. matter from decaying vegetation, animals or bacteria. Streams tend to become naturally enriched in organic matter towards the lower catchments. Organic matter can also derive from anthropogenic origins that include wastewater discharges, forest clear cuttings, agricultural practices, or changes in land use. The process of organic matter degradation by bacteria with concomitant consumption of oxygen is measured as biochemical oxygen demand (BOD). Very high organic loads may cause oxygen depletion in water, as heterotrophic bacteria break down the organic matter under the consumption of oxygen. No trigger values exist in New Zealand for BOD or TOC.

Guidelines for dissolved oxygen are recommended by the RRMP, RMA S69 standards for fishery purpose and ANZECC. The ANZECC guidelines give a range between 99% and 103% for upland rivers and 98% to 105% DO for lowland rivers. As an approximation to the natural daily fluctuations of oxygen, ANZECC guidelines are estimated for daytime measurements.

The RRMP and the RMA suggest a minimum trigger value of 80% oxygen saturation applying at all river flows. This guideline is used in this report. However it has to be taken into consideration, that oxygen is a parameter with daily fluctuations, like temperature and pH. The data set of the Opoutama and Kopuawhara consist of daytime spot measurements, not continuous recordings.

3.2.5 Water clarity and suspended solids

1.6 m minimum water clarity is defined as the RRMP guideline for recreation waters at flows at or below three times the median flow. Hay et al. (2007) recommend a stricter minimum trigger value for trout, which are drift feeding by sight. Under base flow conditions, 5 m minimum clarity is recommended in rivers important for trout fishery, and 3.5 m in rivers with lesser importance for trout fishery. In the case of the Kopuawhara, with trout present but lesser importance for trout fishery, the 3.5 m guideline has been applied. For the Opoutama no fish records are available, but it discharges into the east end of Opoutama beach, where contact recreation occurs. Thus, the RRMP guideline of 1.6 m minimum water clarity is applied for this stream. For comparison the compliance with the 3.5 m guideline of Hay et al. (2007) for rivers with lesser importance for trout fishery is also shown.

The RRMP guideline defines a maximum suspended solid concentration of 50 mg/l for the Kopuawhara and the Opoutama. This guideline is applied at all flows except flood flows (i.e. flows below three times the median flow).

3.2.6 Bacteriological water quality

E. coli and faecal coliforms (fc) are used as indicators for the presence of pathogens of faecal origin in the water. Both indicators have been assessed in the Opoutama and Kopuawhara. Guideline values for faecal coliforms are defined in the RRMP and allow 200 fc/100 ml in the Kopuawhara and the Opoutama. These guidelines are not intended for contact recreation, but they are set as an achievable goal for land use under best management practices.

For *E. coli* the 2002 MfE microbiological water quality guideline defined a three-mode management system for recreational waters. (The 2003 microbial water quality guidelines): Acceptable: *E. coli* <260/100ml, Alert: *E. coli* <550/100ml and Action: *E. coli* >550/100 ml. For this report, the guidelines for acceptable recreational conditions have been used, i.e. *E. coli* < 260/100ml, to indicate good microbial water quality.

As the *E. coli* is a subset of faecal coliforms, the RRMP guideline for faecal coliforms is more stringent than the MfE guideline for *E. coli*.

3.2.7 DRP, DIN and periphyton biomass

Dissolved reactive phosphorus (DRP) and dissolved inorganic nitrogen (DIN) are bioavailable nutrients which, in high concentrations and together with other factors, may result in undesirable proliferation of periphyton.

The RRMP recommends a maximum DRP concentration of 0.015 mg/l at flows below median flow, which is the value used for this report. The RRMP does not recommend guidelines for nitrogen concentrations, but the ANZECC guidelines suggest a maximum level of 0.167 mg/l DIN for upland sites and 0.444 mg/l DIN for lowland sites. Since the Opoutama and Kopuawhara are lowland streams, the 0.444 mg/l guideline is applied.

Periphyton growth depends on several environmental factors: the availability of nutrients, the length of low flow periods in which growth is undisturbed because the substrate is stable, available sunlight, temperature and biological factors like grazing by invertebrates. Especially long periods of low flows, high nutrient concentrations, and lack of shading are the main factors that can lead to an undesirable proliferation of periphyton, which negatively affects the recreational and aesthetic conditions of a river as well as habitats of aquatic organisms such as fish and invertebrates.

The Kopuawhara and the Opoutama are diatom-dominated streams. After discussions with Dr. Barry Biggs the author of the NZ Periphyton Guidelines (Biggs 2000), Dr. Olivier Ausseil confirmed that the 50 mg/m^2 chlorophyll *a* guideline for the protection of benthic biodiversity apply to river and stream reaches of high biodiversity value (such as in headwater reaches in forest parks). It has been recommended that for slightly enriched rivers (such as the Kopuawhara and Opoutama) a guideline of 120 mg/m^2 chlorophyll *a* be adopted.

3.2.8 Macroinvertebrate communities

Macroinvertebrate communities are used as an indicator of water quality and ecosystem health. The macroinvertebrate community index (MCI) gives an indication of organic enrichment based on presence-absence data of macroinvertebrates found at the monitoring site (Stark 1985). An MCI of 120 and above indicates a healthy macroinvertebrate community and clean water, and is used as a guideline for the Kopuawhara and Opoutama Streams. In the Opoutama the MCI has been assessed only once in 2005.The SQMCI is a community index based on coded abundance data, as opposed to the presence-absence data of the MCI. It is only recommended to compare SQMCI data sampled on the same day, which is the case for the two streams in this report. The SQMCI uses information on shifts in the relative abundance of taxa within the macroinvertebrate community.

Table 4: Summary of recommended guidelines for the Kopuawhara and Opoutama.

Parameter	River flow	Guideline
Temperature (ºC)	All	23
pH (trout tolerance)	All	5.0 – 9.5
pH (native fish)	All	7 – 9.5
DO (% saturation)	All	80
Clarity (m) (contact recreation)	< 3* median	1.6
Clarity (m) (trout-lesser important fishery)	< 3* median	3.5
Suspended solids (mg/l)	All	50
Ammonia-N (mg/l)	All	0.78 / 1.03
Periphyton biomass (mg *Chlo a*/m^2)	All	120
DIN (mg/l)	< Median	0.444
DRP (mg/l)	< Median	0.015
E. coli (/100mL)	All	260
Faecal coliforms (/100mL)	< Median	200
MCI	All	120

3.3 Water quality in the Kopuawhara and Opoutama

3.3.1 Physico-chemical water quality indicators

The results for physico-chemical water quality parameters are summarised in Table 5. The pH in the Kopuawhara and the Opoutama tends to be alkaline, but within a tolerable range for brown trout and native fish (pH<9.5) at all times. Regarding the ANZECC guidelines, which recommend an upper limit of pH 7.8 (like the guideline suggested as the optimal range for brown trout) the Kopuawhara complied only in 20%, and the Opoutama in 78% of the samples taken. As mentioned in section 3.2.2., the Kopuawhara and Opoutama streams drain marine soft sedimentary catchments, and can be expected to be naturally alkaline.

The median stream temperature was 14.3ºC in the Kopuawhara and 12.7ºC in the Opoutama. The 23ºC guideline for lowland sites was met in 100% in the Opoutama and in 96% in the Kopuawhara, where on three occasions, temperatures of 25°C and above have been recorded which indicates high temperature fluctuations that might be harmful for macroinvertebrates and fish. It is recommended that temperatures should not be varied beyond the 20th and 80th percentiles of natural ecosystem temperature distribution (ANZECC 2000), and the Kopuawhara exceeds the 95th percentile of 21ºC.

The upper catchment of this stream is plantation forest, but the forest does not provide shade, as the riparian strip consists of low tussock and shrub, which could explain high temperature extremes. In the Opoutama the highest temperature measured was 22°C, exceeding the 95th percentile of 19.5ºC. Opoutama Stream is in a pastoral catchment with little shading .The 19°C guideline was met in 88% and 93% of the recordings respectively, which suggests that under shaded conditions both streams would have a cool temperature regime of below 19ºC.

Table 5: Summary of physico-chemical water quality parameters for the Kopuawhara and Opoutama.

Parameter	Site ID	Monitoring Site	Average	5th percentile	Median	95th percentile	N. of Samples	% Compliance with standard		Standard/ Guideline
pH	330	Kopuawhara	7.9	7.6	8.0	8.1	40	100		5 to 9.5
	2125	Opoutama	7.6	7.3	7.7	7.9	18	100		7 to 9.5
Temperature (ºC)	330	Kopuawhara	14.1	8.0	14.3	21.0	82	96	88	23 / 19
	2125	Opoutama	12.8	8.0	12.7	19.5	42	100	93	
Water clarity (m) <3* median flow	330	Kopuawhara	2.0	0.5	2.0	3.4	46	59		1.6
	2125	Opoutama	1.0	0.5	1.0	1.9	13	15		
Water clarity (m) < median flow	330	Kopuawhara	2.4	1.1	2.2	3.9	28	7		3.5
	2125	Opoutama	1.1	0.6	1.1	1.9	9	0		
Suspended Solids (mg/l) <3* median flow	330	Kopuawhara	6.7	0.9	4.0	20.5	56	75	96	10 / 50
	2125	Opoutama	9.2	1.5	4.2	33.9	14	79	83	
DO [%]	330	Kopuawhara	88	66	90	111	45	76		80
	2125	Opoutama	79	65	78	99	17	41		
TOC (mg/l)	330	Kopuawhara	2.3	1.1	1.9	5.1	67			no guideline
	2125	Opoutama	4.3	1.8	3.1	6.5	43			

The recreational guideline for water clarity (1.6 m) was only adhered to 15% of the time in the Opoutama, and in 59% of the time in the Kopuawhara. The Kopuawhara, with a record of various native fish species as well as trout, had only 7% compliance with the 3.5 m clarity guideline for rivers with lesser importance for trout fisheries. The Opoutama never met this guideline. Water clarity in the Opoutama improves at lower flows, to a lesser extent than the Kopuawhara (Figure 2).

The low water clarity reflects the streams' sensitivity to erosion, which drain soft sedimentary catchments, and presumably the aggravation of erosion by land use practices, and unfenced streams without riparian buffering.

The RRMP allows a maximum suspended solid concentration of 50 mg/l in the Opoutama and Kopuawhara at all flows. This is kept in 96% of the samples in the Kopuawhara and in 83% of the samples in the Opoutama. Usually, visual clarity provides an indication of the levels of suspended sediment in water. The good compliance of suspended solid concentration with the guideline of 50 mg/l suspended solids contrasts with the low water clarity in both streams.

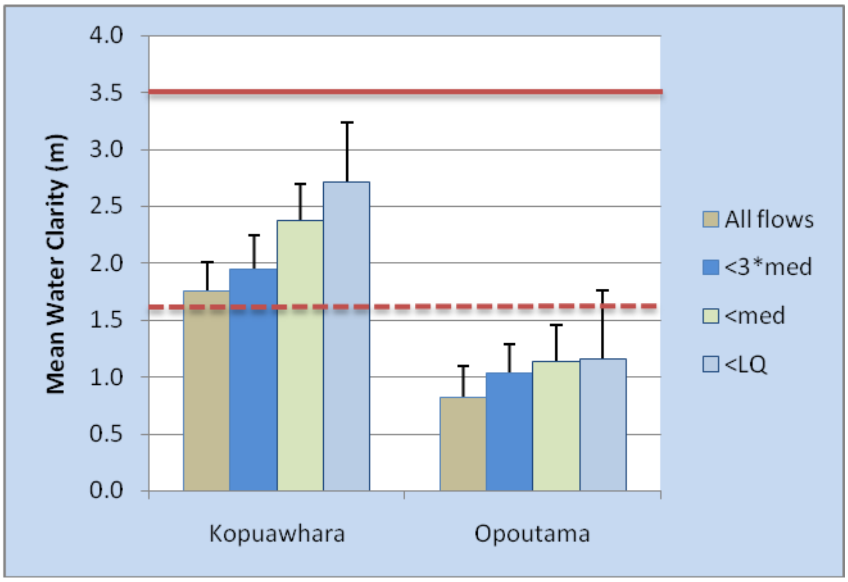

Figure 2: Mean water clarity (m) ± 95% confidence interval under different flow conditions: at all river flows (All flows), below three times median flow (<3*med), below median flow (<med) and below the lower quartile flow (<LQ). The threshold lines indicate the RRMP guideline of 1.6 m for recreational rivers, and the guideline for rivers with lesser importance for trout fishery, 3.5m.

As mentioned in section 3.2.4 organic matter, here expressed as total organic carbon (TOC), generally increases downstream in a river system. Thus, under natural conditions, small headwater streams should have relatively low TOC concentrations. In the case of the two coastal streams, the Opoutama has elevated median TOC concentrations of 3.1 mg/l, clearly higher than the 4.5 times larger Kopuawhara (median: 1.9 mg/l) (Table 5). Elevated TOC levels are an indicator for organic enrichment, which in this case could be attributed to the different types of land use in the catchments of the two sites, as the Opoutama has intensive sheep and beef farming, whereas the Kopuawhara has mainly forestry in its catchment. TOC concentrations in the Kopuawhara are stable at all flows, whereas in the Opoutama TOC increases at low flow, which could indicate an autochthonous origin of algal production.

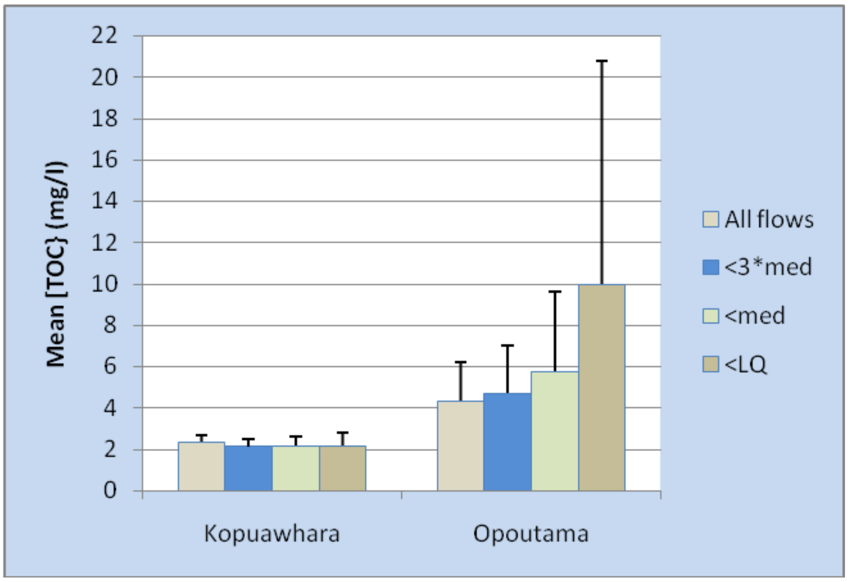

Figure 3: Mean TOC (mg/l) ± 95% confidence interval under different flow conditions: at all river flows (All flows), below three times median flow (<3*med), below median flow (<med) and below the lower quartile flow (<LQ).

In the Kopuawhara, oxygen concentration is compliant with the RRMP guideline only 76% of the time. The median oxygen concentration was 9.8 mg/l, and the lowest value recorded was 4.8 mg/l. At these low oxygen concentrations, negative effects on aquatic biota can be expected. In the Opoutama, in only 41% of the time the oxygen concentrations are compliant with the RRMP guideline. Here, lowest oxygen concentration measured was 6.5 mg/l, the median oxygen concentration was at 9 mg/l. Considering the fact, that minimum oxygen concentrations occur during late night and early morning, and measurements are usually taken during daytime, these measured oxygen levels are likely to be above the actual minimum values occurring in the streams during night time.

Total ammonia-N concentrations (Table 6) were always compliant with the guidelines, and the 95th percentile was well below the trigger value in both, the Kopuawhara and the Opoutama.

Table 6: Ammonia-N concentrations and compliance with pH-dependent trigger values according to ANZECC (2000) for a 95% protection level.

Parameter	Site ID	Monitoring Site	Average	5th percentile	Median	95th percentile	N. of Samples	% Compliance	pH 95th percentile	Ammonia-N trigger value
Ammonia-N [mg/l]	330	Kopuawhara	0.03	0.01	0.02	0.05	67	100	8.1	0.78
	2125	Opoutama	0.07	0.02	0.07	0.10	18	100	7.9	1.03

3.3.2 DRP, DIN and periphyton biomass

DRP concentrations (Table 7) were well below the RRMP guideline levels in the Kopuawhara and Opoutama, a median of 0.002 g/m³ has been measured in both streams, and no exceedances were recorded. Also DIN levels (Table 7) were below the ANZECC recommendation for lower catchments (DIN <0.444 g/m³) at all times.

Table 7: Summary of reactive phosphorus (DRP) and soluble inorganic nitrogen (DIN) at the monitoring sites in the Kopuawhara and Opoutama.

Parameter	Site ID	Monitoring Site	Average	5th percentile	Median	95th percentile	N. of samples	% Compliance with standard	Standard/ Guideline
DRP (g/m³) < median flow	330	Kopuawhara	0.002	0.001	0.002	0.008	31	100	0.015
	2125	Opoutama	0.004	0.001	0.002	0.009	20	100	
DIN (g/m³) < median flow	330	Kopuawhara	0.04	0.02	0.03	0.09	18	100	0.444
	2125	Opoutama	0.19	0.06	0.19	0.26	8	100	

Considering that the Kopuawhara and Opoutama are only small streams that would not naturally have similar nutrient loads to large lowland rivers, it is worth looking at the DIN recommendation for upper catchments for comparison (DIN<0.167 g/m³). This guideline was also always kept in the Kopuawhara, but six out of eight samples in the Opoutama exceeded the guideline.

The DIN concentrations (Figure 4) in the Kopuawhara and the Opoutama are higher at high flows, indicating increased transport of nitrogen into the streams during wet conditions. This pattern is less distinctive regarding the DRP concentration (Figure 5), but it has the same tendency as the DIN, i.e. concentration with stream flow.

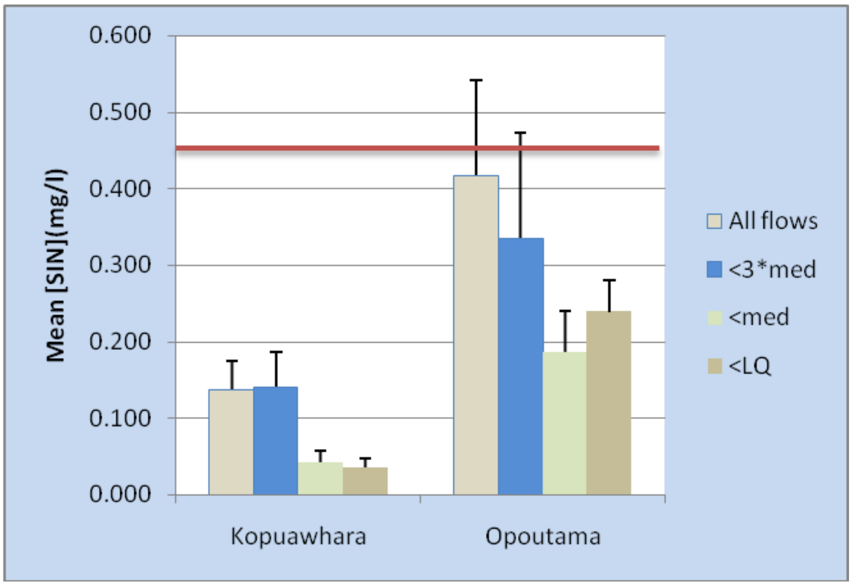

Figure 4: Mean DIN concentrations (mg/l) ± 95% confidence interval under different flow conditions: at all river flows (All flows), below three times median flow (<3*med), below median flow (<med) and below the lower quartile flow (<LQ). The threshold line indicates the ANZECC guideline for lowland sites, 0.444 mg/l DIN.

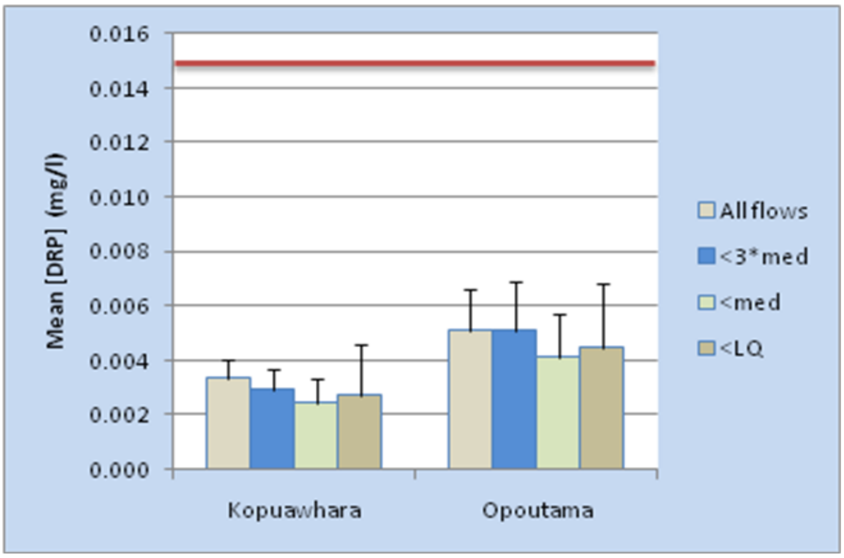

Figure 5: Mean DRP concentrations (mg/l) ± 95% confidence interval under different flow conditions: at all river flows (all flows), below three times median flow (<3*med), below median flow (< Med) and below the lower quartile flow. The threshold line indicates the RRMP guideline for DRP for control of periphyton growth, 0.015 mg/l DRP.

The Opoutama has only been sampled once (2005) for periphyton biomass, so no conclusions can be drawn for this stream.

Periphyton biomass in the Kopuawhara is 100% compliant with the guideline of 120 mg/m² chlorophyll *a* for streams that are not pristine and which have a low biodiversity value (Table 8). Comparing the standard for diatom-dominated streams to protect benthic biodiversity (a maximum of 50 mg/m² Chlorophyll *a*), periphyton biomass exceeds the standards in 50% of the samples in the Kopuawhara. For three of the four occasions with high periphyton biomass, accrual periods were longer than 60 days. On the other hand, the accrual period was only 19 days for the high periphyton biomass measurement in 2004 (Table 9). The Kopuawhara stream channel is barely shaded at the monitoring site and elsewhere in its catchment despite the plantation forest. With an adequate riparian buffer strip and thus a shaded stream channel, and a reduction of nutrient transport into the stream, the Kopuawhara might have the potential to also comply with the periphyton guideline to protect benthic biodiversity.

Table 8: Summary of periphyton biomass in the Kopuawhara and Opoutama.

Parameter	Site ID	Monitoring Site	Average	Minimum	Maximum	95% CI	N. of Samples	% Compliance with standard	Standard/ Guideline
Periphyton biomass Chlorophyll a (mg/m2)	330	Kopuawhara	50.4	10	90	0.76	8	100	120
	2125	Opoutama	insufficient data (n=1; 13mg/m3 in 2005)						

Table 9: Chlorophyll *a* concentrations and accrual periods for concentrations of >50 mg/l in the Kopuawhara.

Date	CHLa (mg/m2)	accrual period (d)
4-Sep-98	64.9	64
10-Feb-04	90.0	19
14-Feb-06	90.0	78
27-Feb-07	72.0	111

3.3.3 Nutrient limitation

Periphyton needs both phosphorus and nitrogen for growth, at an average weight ratio of 7.5:1 (Stumm and Morgan 1996 in Wilcock et al 2007). Theoretically, a ratio of <7.5 would thus mean periphyton growth is N-limited; a ratio of > 7.5 growth is P-limited. Under natural conditions, algal growth is also dependent on available light, hydrological, biological and temperature conditions. If these are favourable, low nutrient concentrations may limit algal growth. Ratios between 4 and 20 indicate that nutrient limitation may switch between N and P-limitation, depending on the other conditions. High DIN/DRP ratios of above 20 would mean periphyton is P-limited, low ratios of less than 4 are indicating N-limitations (Ausseil 2008). Therefore, only DIN/DRP data was used for this analysis, that was outside flood flows (flows lower than 3 times median flow) and with low nutrient supply, (i.e. the DRP concentration below the RRMP standard of 0.015 mg/l, and/or DIN concentration below 0.167 mg/l). In the absence of other more accurate methods to indicate nutrient limitation, such as nutrient diffusing substrates, this method is a helpful tool to estimate potential nutrient-limitation conditions (Figure 6).

In the two coastal streams, P-limited conditions seem to be dominating. In the Kopuawhara DIN/DRP ratios were inconclusive at low flows, but at higher flows P-limited conditions prevailed. In the Opoutama, the conditions of nutrient limitation do not seem to change significantly at low flows, phosphorus limitation always dominates. The phosphorus limitation could indicate a relative enrichment of the streams with nitrogen associated with higher intensity agriculture.

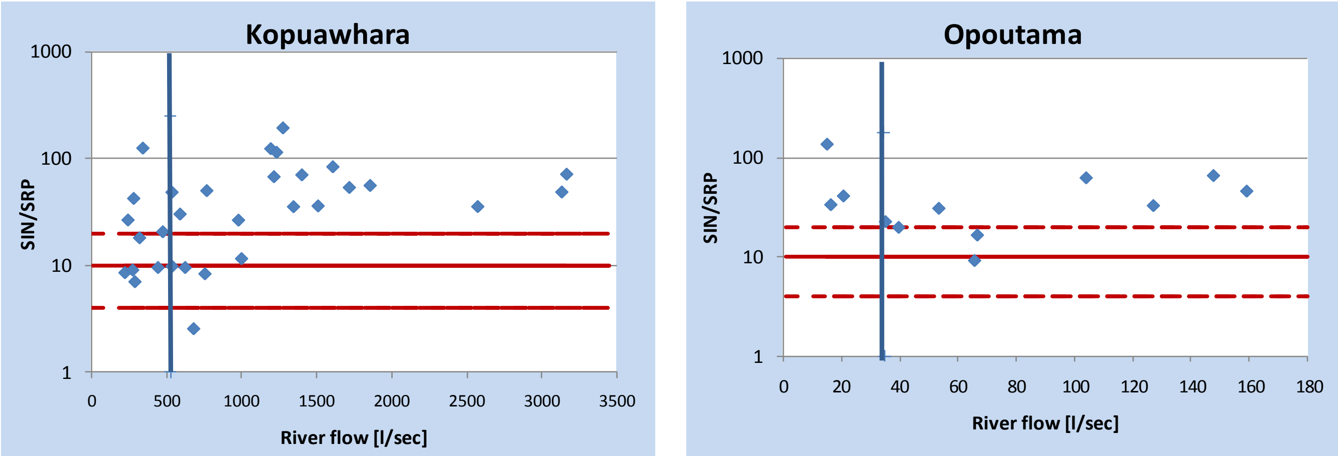

Figure 6: DIN/DRP ratio in the Kopuawhara and Opoutama Streams. Data are for stream flows below 3*median flow and when either or both DIN and DRP are below guideline levels (0.015 mg/l for DRP and 0.167 mg/l for DIN). The vertical blue line indicates the lower quartile flow. Points outside are indicative of limited conditions: P limitation above the upper red lines, N-limitation below the lower red lines.

3.3.4 Microbial water quality

A summary of the microbiological water quality is given in Table 10. Concerning *E. coli* concentrations, the bacteriological water quality was good in the Kopuawhara, and even complied with a swimmable standard (MfE guideline 2003) most of the time at all flows (Figure 7). On the other hand, the faecal coliform guidelines of 200 fc/100ml were exceeded in almost one third of the samples taken in the Kopuawhara. The 200 FC/100 ml criterion is more stringent than the MfE (2003) 260 *E. coli*/100 ml, given that *E. coli* constitute 80-90% of FC. The high coliform concentration may be either explained by the risk of false-positive indication of faecal coliforms in warmer water bodies. Bacteria may occur naturally in soil, or may even replicate in the environment after being excreted from animals (Springthorpe at al. 1993, McLellan 2001, Chao 2003). This has been observed especially in catchments with forestry and with high suspended matter in the water, both of which is the case for the Kopuawhara. Or it may be caused by the transport of bacteria into the stream from the pastoral farming area just upstream of the monitoring site. The cause for the high bacterial concentrations should be investigated. *E. coli* is the better indicator of faecal pollution because it is only originates from the gut of warm-blooded animals (mammals and birds. Faecal coliform includes non-faecal organisms (e.g. *Klebsiella*) so that high compliance of *E. coli* in the Kopuawhara Stream is of greater importance than are the non-compliances for faecal coliform.

Table 10: Summary of microbiological water quality indicated by *E. coli* and faecal coliform concentration in the Kopuawhara and Opoutama.

<table>
<tr><th>Parameter</th><th>Site ID</th><th>Monitoring Site</th><th>Average</th><th>5th percentile</th><th>Median</th><th>95th percentile</th><th>N. of Samples</th><th colspan="2">% Compliance with standard</th><th>Standard/ Guideline</th></tr>
<tr><td rowspan="2">E. coli (/100ml)
All flows</td><td>330</td><td>Kopuawhara</td><td>89</td><td>3</td><td>52</td><td>339</td><td>18</td><td>89</td><td>100</td><td rowspan="2">260 / 550</td></tr>
<tr><td>2125</td><td>Opoutama</td><td>1929</td><td>44</td><td>710</td><td>9200</td><td>39</td><td>38</td><td>49</td></tr>
<tr><td rowspan="2">Faecal coliforms (/100ml)
< median flow</td><td>330</td><td>Kopuawhara</td><td>262</td><td>49</td><td>160</td><td>620</td><td>16</td><td colspan="2">69</td><td rowspan="2">200</td></tr>
<tr><td>2125</td><td>Opoutama</td><td>3098</td><td>99</td><td>1400</td><td>10400</td><td>17</td><td colspan="2">24</td></tr>
</table>

The Opoutama showed high *E. coli* and faecal coliform concentrations, with medians of 9200 *E. coli*/100ml, and 1400 faecal coliforms/100ml, and samples were generally exceeding the level of the "action"-mode of the MfE three-mode management system for recreational waters (*E. coli* >550/100ml). The bacteriological contamination of the Opoutama increases at low flows (Figures 7, 8). The intensive pastoral farming upstream of the monitoring site might be the origin, an assumption which should be investigated. It may be caused by stock access to the stream at all times, with stock either frequenting the stream more often at low flows or the bacterial input being less diluted at low flows.

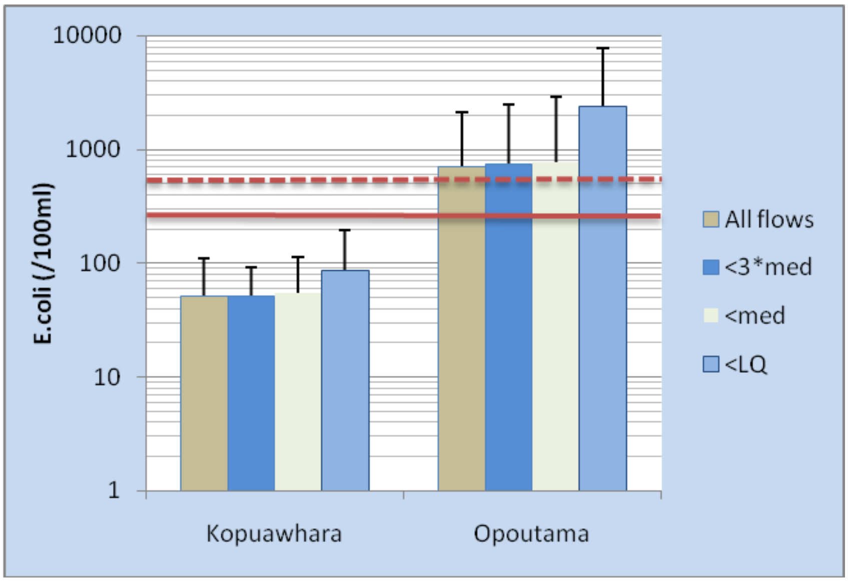

Figure 7: Median *E. coli* concentrations (/100ml) ± 95% confidence interval under different flow conditions: at all river flows (All flows), below three times median flow (<3*med), below median flow (<med) and below the lower quartile flow (<LQ). The threshold lines indicate the MfE guidelines of 260 and 550 *E. coli*/100ml.

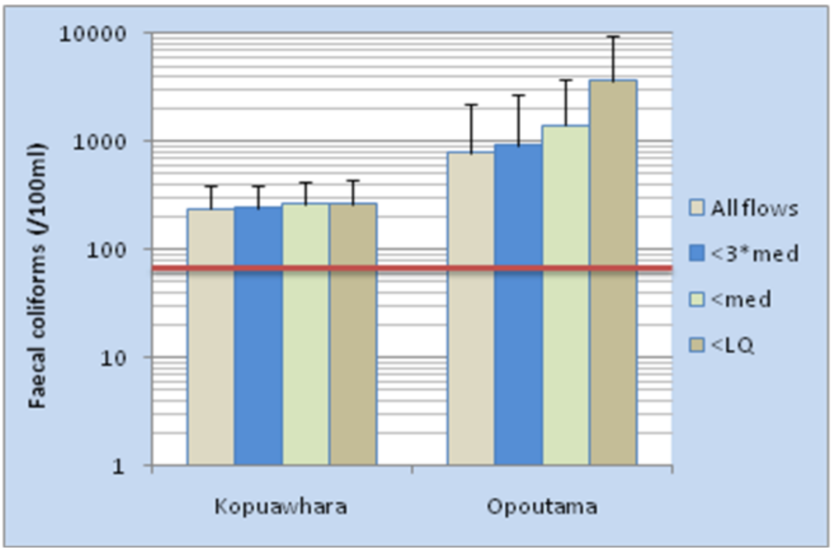

Figure 8: Median faecal coliforms concentrations (/100ml) ± 95% confidence interval under different flow conditions: at all river flows (All flows), below three times median flow (<3*med), below median flow (<med) and below the lower quartile flow (<LQ). The threshold line indicates the RRMP guideline of 200 fc/100ml.

3.3.5 Biological monitoring

The MCI values (macroinvertebrate presence/absence data) (Figure 9) for the Kopuawhara showed good ecosystem health and clean water in the years 2001 and 2002, whereas between 2004 and 2008 the MCI was below the water quality and habitat value of 120, indicating disturbance of the macroinvertebrate community. Within the period 1998 to 2009 three changes occurred in service providers that determined the macroinvertebrate taxa. The years of change-over are shown as arrows and lines in Figure 9: the first institute for taxa determination until 2002 was Watercare Services Ltd., the second until 2006 Cawthron Institute, the third from 2007 onward was Landcare Research. Changes in the macroinvertebrate indices do not follow a pattern that might be caused by differences in taxonomic determination between the institutes.

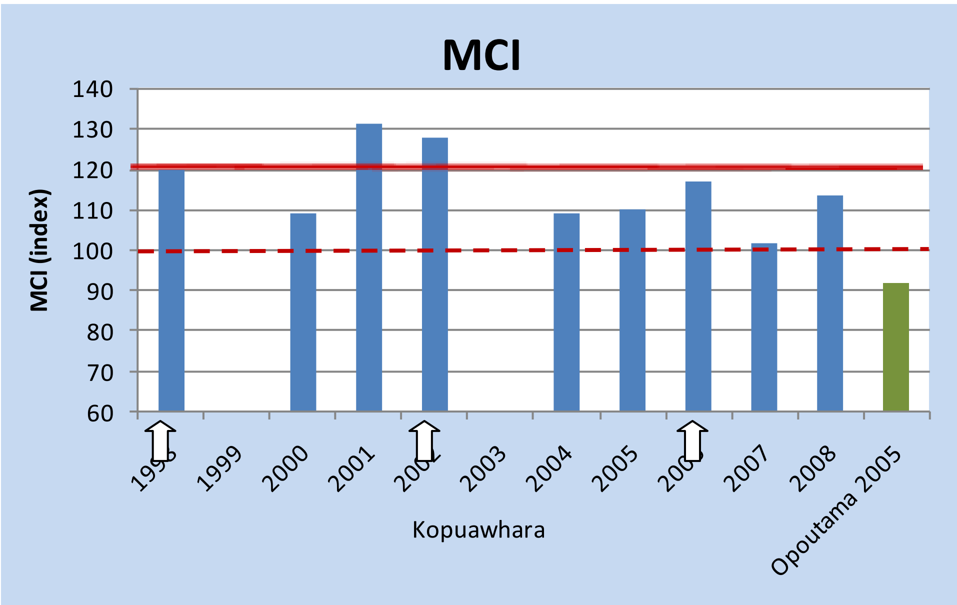

Figure 9: MCI values for the Kopuawhara and Opoutama (2005). White arrows indicate changes in service providers that determined taxa.

The SQMCI (coded abundance) (Figure 9) never reached the highest threshold indicating clean water. In 2007 and 2008 the index value was just above 4, indicating only fair water quality with probable pollution. In these years, the percentage of Ephemeroptera and Trichoptera taxa (no Plecoptera found) of the macroinvertebrate community was lower than in the preceding years, and Diptera were more abundant.

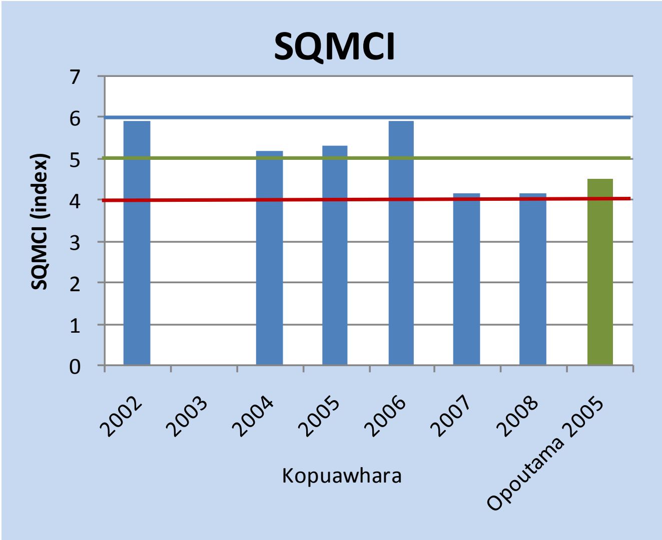

Figure 10: SQMCI values for the Kopuawhara and the Opoutama (2005)

3.3.6 Habitat assessment

Stream habitat has been monitored once a year in the Kopuawhara from 2000 until 2008, and in three years (2005, 2007, 2008) in the Opoutama. In the stream habitat assessment forms, values are given for habitat quality parameters, with highest values always expressing higher in-stream quality. For example a high value for streamside vegetation means high coverage by vegetation, whereas a high value for stock access to the stream means stock has no access, so that a high value always implies better quality for stream habitat. For easier interpretation, the graph has been coloured, indicating good habitat quality in green shading, poor conditions in red shading. Values for the assessed time period have been averaged (Figure 11).

The Kopuawhara had moderate habitat diversity with occasional riffle/pool occurrences. Macrophytes were present only in half of the assessment occasions. Periphyton cover was generally absent until 2003. From 2004 onwards, periphyton cover was visible, but on less than 20% of the surface area. Stock had access to almost the entire assessed stream area, and there is a high potential for sediment input into the stream. Streamside vegetation is incomplete, breaks are common, and the stream is poorly shaded.

According to the habitat assessment, the Opoutama has poor habitat diversity at the monitoring site. Macrophytes were present in 2005, absent in 2007 and abundant in 2008. There was no periphyton visible in 2005 and 2007, but a periphyton cover of more than 50% of the surface in 2008. As in the Kopuawhara, stock at the Opoutama has unlimited access to the stream, and there is a potential of sediment input to the stream. During 2005 and 2007 the streamside vegetation was recorded as being incomplete, which worsened to even more frequent gaps in the vegetation in 2008. The stream is poorly shaded within the assessed reach.

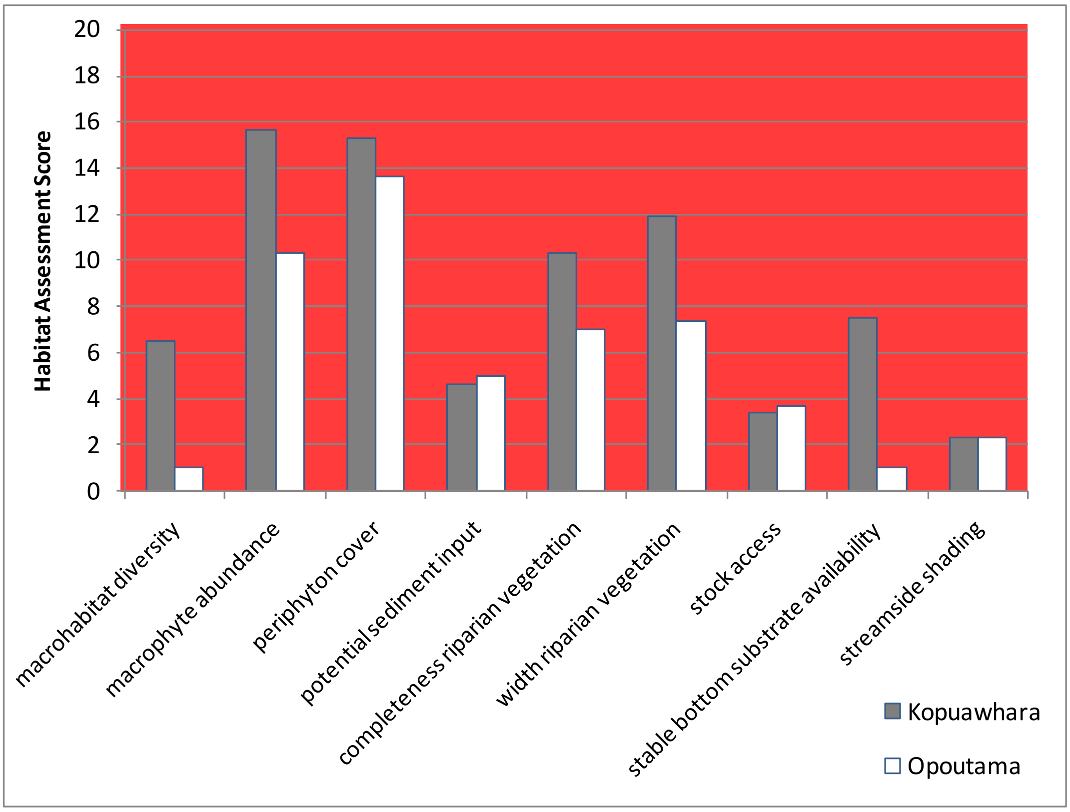

Figure 11: Habitat Assessment Scores for the Kopuawhara and Opoutama averaged from annual assessments.

3.3.7 Comparison with national figures

In 2008, NIWA prepared a report to the Ministry for the Environment with a summary of Regional Council water quality data between 1996 and 2002. Median values for key water quality parameters for New Zealand are given in this report. The rivers were categorized into five broad categories: upland / lowland rivers (source of flow according to the River Environment Classification REC), and predominant natural, pastoral or urban land use in the catchment.

These national values are used for comparison with the key water quality parameters in the coastal streams. In order to compare the figures, the two coastal sites had to be placed into the general categories used in the NIWA report. The Opoutama falls into the lowland pastoral category whereas the Kopuawhara is a lowland stream with predominantly exotic forest in its catchment, which thus falls into the "natural" category according to the NIWA classification.

Table 11: Comparison of water quality statistics for Kopuawhara and Opoutama with national figures (1997-2002). Green shading indicates better water quality than the median, red worse water quality.

Site	DRP (mg/l, median)		DIN (mg/l, median)		*E. coli* (/100ml, 95th percentile)		Clarity (m, median)	
	National median	Coastal Site	National median	Coastal Site	National median	Coastal Site	National median	Coastal Site
Kopuawhara	0.01	0.002	0.163	0.03	515	339	2.2	2.0
Opoutama	0.014	0.002	0.55	0.19	1542	9200	1.2	1.0

In both the Kopuawhara and the Opoutama, nutrient concentrations (DIN and DRP) were lower compared to the national median. *E. coli* concentrations were lower than the national 95^{th} percentile in the Kopuawhara, whereas the Opoutama markedly exceeded the national 95^{th} percentile. Water clarity is a little below the national median in the Kopuawhara and in the Opoutama, but within the natural range of variation.

4. DISCUSSION AND RECOMMENDATIONS

4.1 Conclusions

Kopuawhara

The Kopuawhara shows good compliance with environmental guidelines concerning pH, ammonia-nitrogen and nutrient concentrations (DIN, DRP). The temperature generally complied with the guideline, and was usually well below 19ºC, with an average of 14ºC. On several occasions temperatures of 25ºC and above were recorded in the Kopuawhara, which indicate high temperature fluctuations that might be harmful for macroinvertebrates and fish. High temperature maxima are likely to occur in this stream because the channel is not shaded upstream of the monitoring site, with only tussock and occasional shrubs in the riparian zone of the pasture. But even in the upper reaches, the Kopuawhara is poorly shaded in spite of plantation forest because the riparian zone in this area consists mainly of tussock and low scrub. Dissolved oxygen concentrations in the Kopuawhara are below the 80% guideline in one quarter of the samples.

Various native fish species as well as trout have been recorded since 1980 and the Kopuawhara is currently used for occasional trout fishing (pers. comm. Brett Stansfield). The stream has only a 7% compliance the 3.5 m clarity guideline for rivers with lesser importance for trout fisheries. Water clarity was below contact recreation guidelines (1.6 m) in over 40% of the samples. Due to the soft sedimentary geology, the streams in this region are susceptible to sediment input into the channel. The lack of a riparian buffer zone as well as unrestricted stock access is likely to exacerbate this condition. The suspended solid concentration generally complied with the RRMP guideline of 50 mg/l. This is in contrast to the low compliance with water clarity in the streams. It is recommended that the guideline levels should be reassessed in order to address the specific problems in these streams. Lower water clarity and higher suspended solid concentrations are natural to a certain degree in soft sedimentary rock catchment streams, but these streams are especially sensitive to further erosion due to intensive land use practices. In order to assess the additional impact of land use a value has to be found, that records sedimentation above the natural background. It seems that the RRMP guideline for suspended solids does not adequately reflect the potential land-use impact, as it does not correlate with the low compliance with water clarity guidelines.

E. coli concentrations were compliant with the MfE guideline for swimmable standards in 89% of the time, but faecal coliform concentrations were above guideline levels in one third of the samples taken, although no intensive pastoral farming occurs in the catchment. It has to be acknowledged that (1) the FC guideline is quite stringent by comparison with that for *E. coli*, and (2) the FC test result may include non-faecal bacteria.

The periphyton biomass in the Kopuawhara complied with the guideline of 120 mg/m² Chlorophyll *a* for enriched rivers with a low biodiversity value. This finding is supported by the habitat assessment, where periphyton was generally absent until 2003, and visible, but on less than 20% of the surface in the following years.

The Kopuawhara has the potential of a macroinvertebrate community index of above 120, indicating a healthy community and clean water, as recorded in the years 2001 and 2002. The MCI indicated an impaired community health from 2004 onwards, the same year, in which periphyton cover has been recorded in the habitat assessment. It should be observed, whether there is a declining trend occurring in this river as soon as enough continuous data for statistical analysis is available. The cause for the low SQMCI and MCI values in more recent years should be investigated.

Opoutama

The water quality in the Opoutama was within guidelines for water temperature, pH and ammonia-nitrogen. Soluble phosphorus and nitrogen concentrations complied with guidelines at all times, but they were higher than in the Kopuawhara. Soluble nitrogen concentrations in the Opoutama stream were more than four times the concentration of the Kopuawhara. Only spot sampling temperature measurements have been taken in the coastal streams, and it is likely that maximum temperatures have not been captured. Nevertheless, the water temperature has large amplitude, as temperatures of up to 22ºC have been recorded, although the average temperature was only 12.8ºC. This can be explained by the fact, that the stream channel is not shaded. Concerning water clarity and bacteriological concentrations, water quality of the Opoutama is more degraded compared to the Kopuawhara: in 85% of the samples, water clarity is lower than the contact recreation guideline, and the *E. coli* guideline is only met in 49% of the samples. The RRMP guideline of 200 faecal coliforms/ 100ml was met in less than one quarter of the samples. Dissolved oxygen low, meets the guidelines in only 41%, and organic carbon concentration is significantly higher than in the Kopuawhara.

No periphyton data is available, and only one macroinvertebrate sample has been taken in 2005. This sample showed an MCI of 92, thus the macroinvertebrate community indicates clearly poorer ecological health in the Opoutama than in any recorded year in the Kopuawhara. The cause of this should be investigated, especially more macroinvertebrate samples should be taken to be able to draw conclusions. Whether this is due to lower water quality or because of a different stream bottom substrate (no stable bottom substrate and very poor habitat diversity) can only be clarified with more macroinvertebrate assessments for comparison.

Like the Kopuawhara, the Opoutama lacks riparian vegetation, but the different land use is most likely aggravating circumstances in the Opoutama: the catchment is hill country and intensive pastoral farming, as opposed to plantation forest in the catchment of the Kopuawhara. This finding is consistent with a study by Larned et al. (2004), in which water quality of urban and pastoral low-elevation streams were found to have distinctly lower water quality compared to native and plantation forest low-elevation streams. *E. coli*, dissolved nitrogen and phosphorus concentrations were found to be 2-7 times higher, and median water clarity 40-60% lower in pastoral low-elevation streams than in streams with forest in the catchment (Larned et al. 2004).

Load calculations and trend analysis were not possible because sampling was only quarterly and, in addition, there were missing water quality and flow data.

Table 12: Summary of environmental information on the Kopuawhara and Opoutama. WW: warm wet; SS: soft sedimentary; L: low; EF: exotic forestry; P: pastoral; LG: low gradient.

		Environmental information							
SiteID	Monitoring site	CA [km2]	Climate	Geology	Source of flow	Landcover	Valley landform	Erosion risk (incl. tributaries)	Dominating Landcover
330	Kopuawhara	68	WW	SS	L	EF	LG	0	Exotic forestry, hill country sheep & beef
2125	Opoutama	15	WW	SS	L	P	LG	0	intensive and hill country sheep & beef

Table 13: Summary of percentage compliance of water quality parameters with guidelines for the Kopuawhara and Opoutama.

		Physico-chemical water quality						Water clarity, suspended solids			bacteriol. water quality		biol. water quality	
Site ID	**Monitoring Site**	**Temperature**	pH standard (a)	Ammonia-N	Dissolved oxygen	SRP	SIN	Water clarity (contact recreation)	Water clarity (trout fishery)	Suspended solids	E. coli	Faecal coliforms	Periphyton biomass	MCI
330	Kopuawhara	96	100 [(a)]	100	76	100	100	59	7	96	100	69	100	33
2125	Opoutama	100	100 [(a)]	100	41	100	100	15	0	83	49	24	ND	n=1

4.2. Recommendations

4.2.1 Management implications

Elevated fine substrate concentrations, as occurs in both the Opoutama and the Kopuawhara Streams, affect the ecological integrity several ways: e.g. aquatic invertebrate communities are affected by changes in habitat, such as reducing interstitial velocity, limiting interstitial space, or particles adhering to filter structures of organisms (reviewed in Castro-Vasconcelos & Melo 2008). Niyogi et al. (2007) indicated that invertebrate species richness has a linear negative relationship with fine-sediment cover. Fine sediment loads are increased in areas with grazed pasture compared to tussock or native grassland (Matthaei et al. 2006, review Wood & Armitage 1997), and riparian vegetation reduces fine substrate entry into the stream, significantly (Stone et al. 2005). As the sensitivity of the two coastal sites to impairment by sediment input due to the soft sedimentary geology is naturally high, management should aim towards protection against further sediment loads entering the streams e.g. by enhancement of best management practices for riparian buffers in pastoral areas.

High *E. coli* concentrations occur especially in the Opoutama, but guidelines were also exceeded in the Kopuawhara. The source of the contamination in both streams should be identified and measures for amelioration should be taken. Again, best management practices in riparian management could prevent further impairment in catchments with pastoral farming as the Opoutama.

4.2.2 Further monitoring

Both coastal streams show impairments in water quality concerning low oxygen, low water clarity, high bacteriological concentrations, and disturbed macroinvertebrate communities.

Further monitoring is recommended with emphasis on the following aspects:

- The underlying database, i.e. quarterly sampling frequency, with additional gaps in water quality and/or flow data during the monitoring period renders nutrient load and trend analysis impossible. Monitoring frequency, i.e. monthly versus quarterly, should be reconsidered.
- Not enough biological data is available in the Opoutama: macroinvertebrates have been sampled only once in 2005. More macroinvertebrate data is also necessary to investigate the cause of low macroinvertebrate indices in recent years in the Kopuawhara.
- Reconsider guidelines, especially from the aspect of different environmental regional backgrounds. Some guidelines seem contradictory (see suspended solid concentration and water clarity), or not appropriate to the potential values of the ecosystem (e.g. temperature guideline of 23ºC for a small stream). The ANZECC DO guidelines are not very helpful.
- Undertake diurnal temperature and oxygen monitoring to capture the entire range, as temperature and oxygen levels tend to reach thresholds that may seriously affect aquatic organisms in unshaded streams.
- It is recommended to that the faecal coliform concentration data be analysed – the origin of the faecal coliforms and the informative value for water quality reports should be reviewed.
- The Opoutama carries a high load of *E. coli*. It should be reassessed, if the river mouth, which discharges into the western end of Opoutama beach, is used for contact recreation. If this is the case, bacteriological levels in the estuary should be monitored more closely.

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APPENDIX 1: SUMMARY OF DATA AT ALL RIVER FLOWS/YEAR ROUND

Kopuawhara	pH	TEMP (^{o}C)	DO (mg/l)	SDO (%)	BD (m)	TURB (ntu)	SS (mg/l)	TN (mg/l)	NH_3-N (mg/l)	SIN (mg/l)	SRP (mg/l)	TP (mg/l)	FC (/100ml)	*E.coli* (/100ml)	TOC (mg/l)	CHLa (mg/m^2)	MCI (Unit)	EPTTaxa number	Taxa number
Average	7.9	14.1	9.5	88	1.8	6.4	15.7	0.35	0.027	0.14	0.003	0.016	235.744	88.8	2.3	50.4	113	9	17
Min	7.3	7.0	4.8	53	0.1	0.0	0.5	0.07	0.003	0.01	0.001	0.001	0.5	0.5	0.8	10	92	4	6
5%ile	7.6	8.0	7.1	66	0.5	0.6	1.0	0.10	0.005	0.02	0.001	0.002	19	2.6	1.1	10	96	4	6
10%ile	7.7	8.5	7.4	69	0.5	0.8	1.5	0.12	0.005	0.02	0.001	0.003	27	7.9	1.2	11	101	4	7
Median	8.0	14.3	9.8	90	1.8	2.1	4.0	0.30	0.015	0.08	0.002	0.011	148	52.0	1.9	57	112	9	19
90%ile	8.1	19.5	11.5	105	3.0	12.0	23.4	0.60	0.035	0.29	0.008	0.028	560	184.0	3.9	90	128	14	24
95%ile	8.1	21.0	12.1	111	3.2	20.5	31.8	0.68	0.050	0.34	0.009	0.046	650	338.5	5.1	90	129	15	25
Max	8.1	26.3	14.2	123	4.4	100	394.0	1.84	0.470	0.43	0.016	0.128	860	500.0	7.9	90	131	17	27
StDev	0.2	4.6	1.7	15	1.02	13.4	48.9	0.29	0.062	0.12	0.003	0.020	231	125.0	1.4	34.1	12	4	7
95% CI	0.057	0.996	0.388	4.389	0.247	3.106	11.1	0.084	0.015	0.037	0.00074	0.0045	70.7	57.8	0.33	23.7	7.18	2.84	4.9
n	40	82	74	45	65	71	74	45	67	43	68	74	41	18	67	8	10	9	9

Opoutama	pH	TEMP (^{o}C)	DO (mg/l)	SDO (%)	BD (m)	TURB (ntu)	SS (mg/l)	TN (mg/l)	NH_3-N (mg/l)	SIN (mg/l)	SRP (mg/l)	TP (mg/l)	FC (/100ml)	*E.coli* (/100ml)	TOC (mg/l)	CHLa (mg/m^2)	MCI (Unit)	EPTTaxa number	Taxa number
Average	7.6	12.8	9.1	79	0.8	19.6	23.0	0.65	0.067	0.42	0.005	0.071	2226.54	1928.5	4.3				
Min	7.1	6.9	6.0	57	0.1	3.2	1.5	0.26	0.005	0.02	0.001	0.013	54	19.0	1.6	13	92	4	13
5%ile	7.3	8.0	6.5	65	0.1	3.9	1.5	0.28	0.018	0.11	0.001	0.020	64.4	43.7	1.8				
10%ile	7.4	9.0	7.1	68	0.2	4.4	1.5	0.31	0.027	0.16	0.001	0.022	82	51.8	2.0				
Median	7.7	12.7	9.2	78	0.9	7.4	6.0	0.65	0.066	0.36	0.002	0.036	770	710.0	3.1				
90%ile	7.9	18.3	10.7	95	1.5	44.3	62.9	0.95	0.100	0.73	0.011	0.091	4040	3112.0	5.1				
95%ile	7.9	19.5	11.9	99	1.9	77.2	84.2	1.00	0.105	0.75	0.012	0.170	10400	9200.0	6.5				
Max	8.0	22.0	12.4	103	2.0	180	114.0	1.05	0.130	0.76	0.023	1.117	20000	20000.0	43.0	13	92	4	13
StDev	0.2	3.6	1.6	13	0.56	33.4	32.5	0.25	0.031	0.26	0.005	0.167	4599	4498.8	6.2				
95% CI	0.108	1.097	0.549	5.970	0.268	10.8	15.0	0.119	0.014	0.126	0.002	0.050	1481.8	1411.9	1.849				
n	18	42	33	17	17	37	18	17	18	16	43	43	37	39	43	1	1	1	1

APPENDIX 2: STREAM HABITAT ASSESSMENT FORM

STREAM/RIVER…...…………….
EASTING……………..……………...
NORTHING.……………..…………
SITE- ID ……………………………..
DATE…………………………………
ASSESSOR………………………….
WIDTH of the stream…………….…

STREAM HABITAT ASSESSMENT

Determine the condition of the stream channel and riparian zone at which you are standing and up to 100m upstream and downstream. Estimate the average condition over that distance and select ONE of the scoring categories for each characteristic.

I. Adjacent landuse

Q1 Dominant land-use pattern beyond the immediate streamside vegetative buffer zone.

	L	R	
Undisturbed native forest, wetland			40
Disturbed native forest, Tussock grassland			30
Non production exotic forest			25
Production forest			20
Retired Pasture			15
Extensive pastoral farming e.g. Beef, sheep and deer on hill country			10
Intensive pastoral farming e.g. Dairy on easy contour			5
Horticultural /Urban / Industrial			1

II. Vegetation

Q2 Width of stream and bankside vegetation on both sides that buffers the effect of deleterious land use patterns (average riparian zone)

>30 m wide		30
5-30m		20
1-5m		5
0m		1

Q3 Structure of streamside vegetation

	L	R	
Trees with dense groundcover e.g. Tussock, toetoe, ferns, flax, rushes			20
Trees with no or light groundcover			15
Tall grasses with patchy trees and groundcover scrub			10
Patchy trees, groundcover grazed			5
Grazed Pasture, grasses to stream edge			1

Q4 Type of streamside vegetation

	L	R	
Native trees like, Manuka, Kowhai, Hebe, Cabbage Tree etc., wetland			30
Native trees with different exotic species			25
Willows, Poplars, Rank, tall native grass			15
Pinus Radiata, Conifers in general >10 years			10
Gorse, Blackberry, Broome, high grasses, plantation forests< 10 years			5
Pasture grasses and weeds			1

Q5 Age of the trees and the vegetation

	L	R	
High > 60			10
Medium 21-60			5
Low 0.1-20			1

Q6 Streamside shading

50% or more		20
30 – 49%		10
10 – 29%		5
Little or no shading		1

Q7 Completeness of bank and streamside vegetative buffer

Completely intact		30
Occasional breaks i.e. 1-10 gaps in reach		20
Breaks common i.e. 11-20 gaps in reach		10
Breaks frequent i.e. 20+ gaps in reach		5
Buffer absent		1

Q8 Periphyton cover on suitable substrates (as filamentous or mat forming growths >3mm thick). This excludes bryophytes and mosses.

Periphyton not visible on hand held stones		20
Visible on bed covering few surfaces, <20% cover		10
Visible on bed covering many surfaces, 20-50% cover		5
Visible on bed covering most surfaces, >50% cover		1

Q9 Macrophyte abundance

Macrophytes generally absent and stony substrate and / or low growing chara/bryophyte. Moss communities dominant		20
Submerged and or emergent macrophytes present		10
Submerged macrophytes abundant		5
Emergent macrophytes abundant		1

III. Stability (Bank, Channel)

Q10 Bank Stability

Bank stable, no evidence of erosion or bank failure Infrequent, small areas of erosion (10%)		20
Moderate frequency of erosion areas (11-30%)		10
Unstable, many eroded areas (>30% eroded)		1

Q11 Channel stability and complexity

Stable natural stream width little or no enlargement of islands, point bars (sediment movement), and/or no channelisation		20
Some new increase in sediment movement mostly from coarse gravel and/or some channelisation present.		10
Moderate movement of gravel, coarse sand, pools partially filled with silt and/ or channelisation obvious.		5
Heavy deposits of fine material, most pools filled with sediment and/or extensive channelisation		1

IV. Disturbances caused by stock management

Q12 Stock Access

Stock do not have access to the stream or it's banks		20
Stock only have access to a small part of the stream		10
Stock have access to most of the stream		5
Stock have access to the entire stream		1

Q13 Stock damage

None		20
Low		10
Modest		5
High		1

V. Other external disturbances

Q14 What is the potential for the **input of sediments** to your stream e.g. from stock trampling, stock crossings, surface runoff, farm roads, slips erosion, gravel extraction?

No potential		20
Low potential		10
Moderate potential		5
High potential		1

Q15 What is the potential for the **input of contaminants** to your stream e.g. from spray drift, sprayer washings, sheep dips, effluent ponds, silage pits dumps, oil and foam, dead animals etc.?

No contamination		20
Low contamination		10
Moderate contamination		5
High contamination		1

Q16 Is there any **artificial drainage** entering the stream e.g. tile, mole, storm water & open drains which have the vegetation dredged?

No artificial drainage		20
Sparse artificial drainage		10
Moderate amount of drainage		5
Extensive drainage networks		1

Q17 Are there any **natural drainage pathways within 200m** of you (e.g. where run-off is directed into a gully or ephemeral type channel and then into a stream- a large amount of run-off enters the stream at one point)

No natural drainage pathways within 100m		20
1 natural drainage pathway within 100m		10
2-3 natural drainage pathways within 100 m		5
> 3 natural drainage pathways within 100m		1

VI. Stream/Riverbottom habitat diversity

Q18 Hydraulic indicators of instream macrohabitat diversity measured by different frequency of flow types.

Frequent occurrence of riffle/ bends/pools. Excellent diversity of habitat.		20
Common occurrence of riffle/bend/pools. Good diversity of habitat.		10
Occasional occurrence of riffle/ bends/ pools. Moderate diversity.		5
Infrequent or absence of riffle/ bends/ pools. Essentially a straight run. Poor diversity of habitat		1

Q19 Stable bottom substrate availability.

> 50% cobble, gravel, submerged logs, undercut banks, bedrock or other stable habitat (diverse and stable)		20
30-50% cobble, gravel or other stable habitat (adequate habitat)		10
10-30% cobble, gravel or other stable habitat. Habitat availability less than desirable		5
< 10% cobble, gravel or other stable habitat. Lack of habitat is obvious		1

Q20 Embeddedness of dominant coarse substrate

Difficult to move		20
Moderate amount of effort		10
Easy to move		1