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Non-Market Water Values in Southland

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Executive Summary

Background

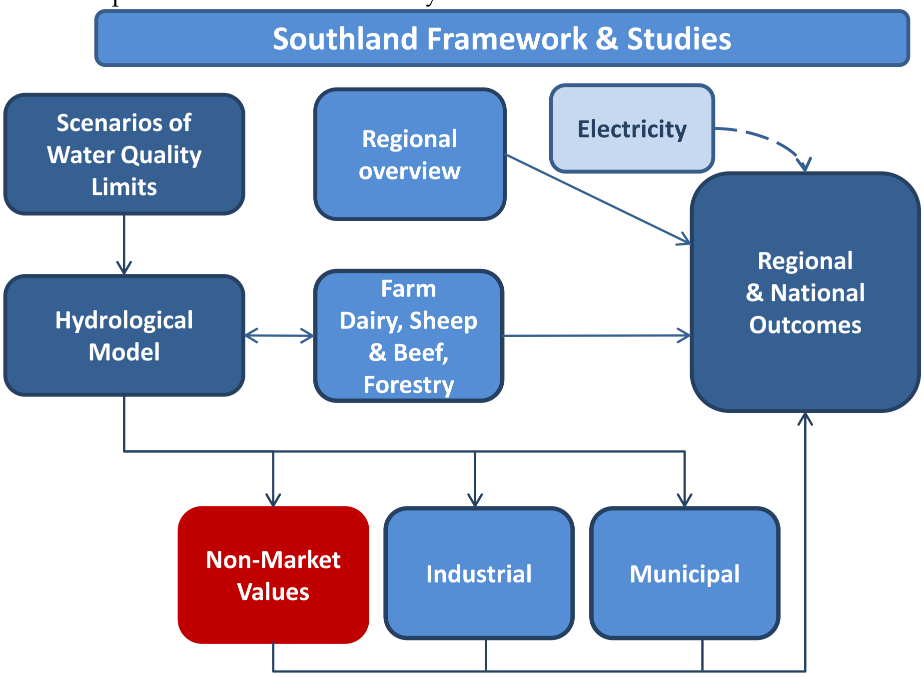
This report provides an analysis and discussion of the non-market values that individuals and communities hold for freshwater in Southland. Non-market values are those that are not usually expressed in monetary terms or associated with commercial activities from which monetary values can be derived. They include recreational uses, scenic qualities, food gathering and the values that people place on natural environments just because they exist.

The context for the report is the Government's proposals for freshwater policy reform and specifically the proposal to introduce limits to manage quality and quantity for fresh water under the National Policy Statement for Freshwater Management (2011). The aim of the report is to provide information that can be used in evaluating the impact of these limits. The scope of this report is limited to the case study region (Southland), but the approach and many of the data may be applicable more widely.

Relationship to Other Studies

This report is part of a series of studies that are examining different aspects of the costs and benefits of limits if applied to Southland (Figure ES1).

Figure ES1 Components of Southland Study



Scenarios of water quality limits have been developed and are used with a hydrological model and a land use model to analyse the impacts that these limits would impose on land use activities (farming and forestry) and their discharges to water. The resulting water quality outcomes are then used in separate studies to examine the implications for municipal and industrial uses of water and the non-market values of water as examined in this study.

This study takes inputs from the hydrological modelling undertaken by Aqualinc and NIWA that is estimating the impacts of quantity and quality limits on water quality at 73 different locations in Southland.

In this study we use scenarios of changes in water quality and we:

- identify the components or attributes of water that enable it to be used or that provide direct value. For example, this would include water clarity, the presence of certain fish species and the absence of pathogens that cause health problems for swimmers. We estimate the relationship between changes in water quality and these **valued attributes**;

- identify non-market values for water and the way in which these values change as a result of changes in water quality. These are **marginal values,** expressed as how total value changes as a result of a small change in a factor that affects that value, for example the change in recreational value of 1 more metre of water visibility;

- compile and make use of **Southland data** that enables us to combine the generic values (applicable to water bodies throughout New Zealand) with the results of the Southland scenario analysis to estimate effects in Southland. For example, this includes data on current levels of recreational activity; and we

- combine the different components to estimate the effects on non-market values.

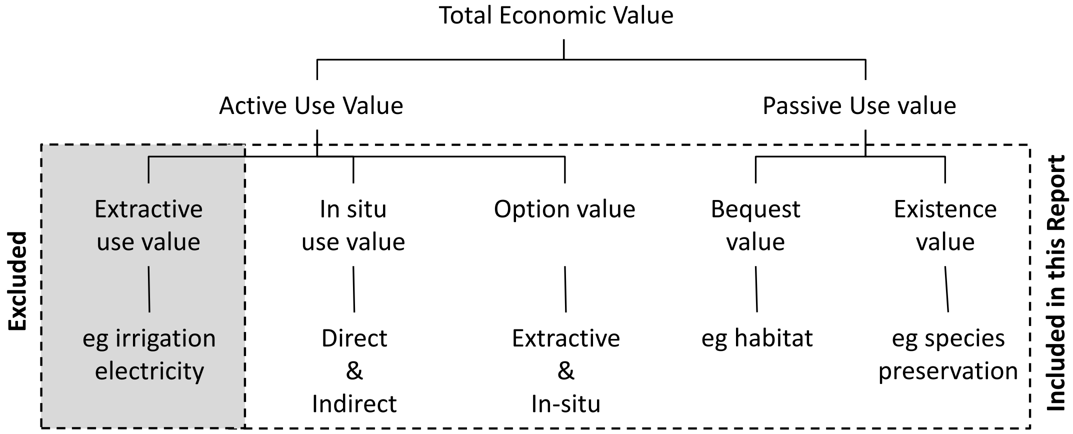
There are significant gaps in the available information which means that we are unable to quantify many non-market values. Those that can be valued are set out below.

Non-Market Values

Non-market values are defined in this study with respect to the concept and components of Total Economic Value (TEV) (Figure ES2). Non-market values exclude the shaded (extractive use values) but include in-situ values (fishing, recreational use), option values and passive use values. We explain the categories more fully below.

A related but different concept used to explore environmental values is that of ecosystem services (provisioning, regulating, cultural and supporting). This concept is a way of understanding or describing how ecosystems function to provide the elements of value, but the TEV concept sets out to capture the full set of values so we are not missing anything by using it as the framework for analysis.

Figure ES2 Total Economic Value (shaded categories are not included in this study)



Source: Adapted from Sharp B and Kerr G (2005) Option and Existence Values for the Waitaki Catchment and EVRI (2009) in Nimmo-Bell (2009) Biodiversity Valuation Manual. A technical manual for MAF BNZ.

The TEV categories are.[1]

- Active use and passive use values, where
    - **active use** values derive from actual use of the water resource via extraction (eg. for irrigation) or for in-stream use for recreation or simply as a back-drop for other activities beside the river. In other words, the physical presence of the water is vital to the realisation of the value. In contrast,
    - **passive use** values are values that pertain more to the fact of existence of the water resource.
- Amongst **active use** values there are those that derive from:
    - **extractive use** of the water that involves taking the water out of the river. This includes use of water for agriculture (irrigation or stock water), municipal use (drinking water and other household uses), industrial use. Hydro-electricity is also included here;
    - **in-situ use** where the water resource may be used directly (eg. swimming) or indirectly (eg. recreation beside the river);
    - **option values** which represent the value of retaining an option to use a resource in the future;
- **Passive use** values, which are independent of the individual's present use of the resource and are variously described as "existence value", the value from knowing that a particular environmental assets exists (eg. endangered species); and "bequest value", the value arising from the desire to bequeath certain resources to one's heirs or future generations (eg. habitat preservation).

[1] Although the categories are changed somewhat, the descriptions are taken largely from Sharp and Kerr (op cit)

In practice people have difficulty in separating out some of these different elements of value, including the components of passive use and the difference between passive use and option values. For practical reasons we group these categories together under the catch-all of existence value. We thus examine:

- In-situ use values – recreational and other uses of water at a particular site;
- Existence values –values that do not require a person to be present at the site.

Despite identifying the different elements of value, studies do not exist that enable us to quantify all of them in monetary terms. We discuss the values identified and the data gaps below, but firstly we examine different perspectives on values of Māori.

The TEV concept isolates individual elements of value. In reaction to this approach, it has been suggested to use that Ngai Tahu see the value of the environment more holistically with values being interlinked and would not differentiate extractive resource use, or its effects, from the other use values because any use can have associated non-market values to both whanau and hapu. This is likely to apply to many other people also. The TEV approach is not attempting to describe how people think about the values of water bodies; most people do not isolate the individual values obtained. What the TEV approach is suggesting is that, if one factor is changed (eg the ability of the water body to provide water for irrigation), but nothing else changes, there is a loss of total value of the water body.

Māori Values

Māori have some additional and distinct values as recognised under the Treaty of Waitangi. There is a legal requirement to address these values in decision-making under the Resource Management Act, the Local Government Act and the Conservation Act.

For Ngai Tahu the values associated with water are numerous and relate directly to many core Ngai Tahu values. Some of these values are likely to be shared by other whanau around the country. These associations show how fundamentally important water is the Ngai Tahu as a taonga.

Specifically for Ngai Tahu as tangata whenua of Southland, in this report we concentrate on the following values that result in different or additional values to those discussed with respect to TEV:

1. The concept of **reciprocity** in which anything taken (food or other resources) is balanced by giving. This means that there is a requirement for restoration to ensure the on-going functioning and wholeness of the environment. This concept is based upon elements of the Māori values of Kaitiakitanga, Mahinga kai, Mauri and Whānaungatanga. Failure to look after the local environment may be seen as a loss of mana. Any deterioration in quality may be reflected in the inability to produce traditional food or other resources iconic to a local environment;

2. The importance of knowledge (**mātauranga**) and the sharing of it with future generations (whakapapa). Management and use of water, and the relationship

with the water body, provides resources for the group but also builds knowledge and provides educational experiences that can be passed on to future generations. Thus there is a marginal increase in knowledge with an increase in water quality because there is an increase in the opportunities for use of a resource that yields opportunities for education;

3. The importance of specific environment and its use to the **cultural identity** of the group. Whānau and hapū are defined with respect to the environment and resources that they relate to, whereby the loss of ability to use a resource reduces their identity as a group.

These concepts would be expected to result in Māori holding and expressing a greater value for sustainable use of water or enhancement of water quality.

Marginal Values

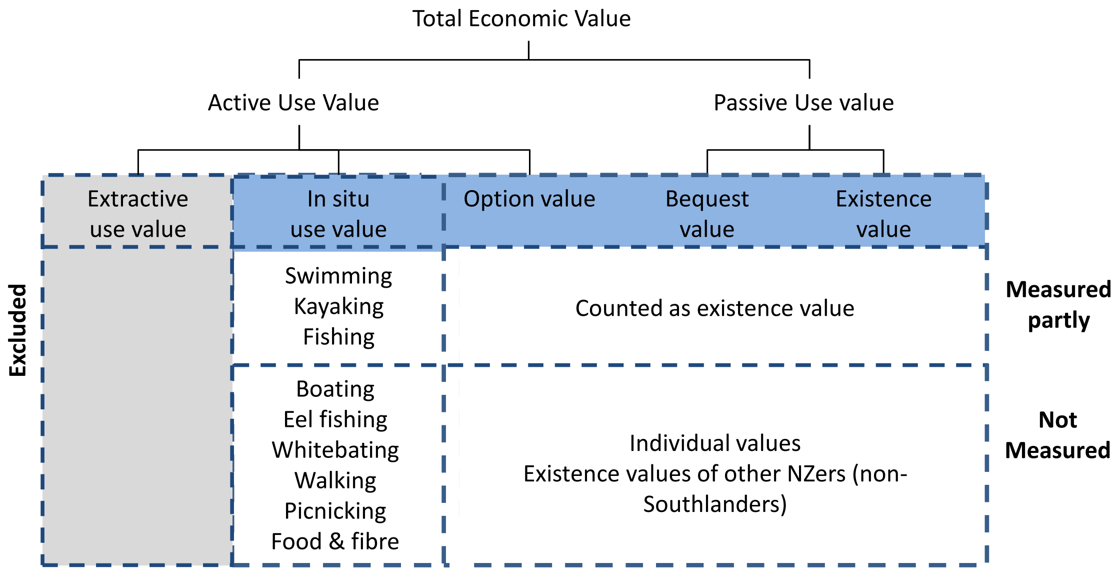
In Table ES1 we summarise the non-market values used in our analysis. These are based on existing literature and studies elsewhere in New Zealand. We use these values to estimate the impacts of changes in water quality in Southland; there were no valuation data available specific to the Southland Region.

Table ES1 Marginal values for use in analysis

Input	Low	Med	High
Value of Water Clarity ($/1m visibility improvement/angler visit)	$10	$10	$20
Value of Domestic Fishing ($/angler-day)	$41	$27	$18
Value of Swimming Visit ($/visit)	$31	$56	$122
Value of Kayaking Visit ($/visit)	$109	$129	$148
Existence value ($/regional household for prevented development)	$47	$53	$56

There are a number of non-market values that are not measured, or only partially measured because of the lack of existing data (see Figure ES3).

Figure ES3 Extent to which components of TEV are measured



We have estimated values for some recreational uses of water bodies, and specifically fishing, kayaking and swimming, but have not provided values for others including whitebating, boating or walking/picnicking. We also do not have estimates of the value of Mahinga kai (traditional food) or other food gathered from water bodies, or of fibre, eg. flax.

Option values are not included specifically, but as noted above, we have not attempted to differentiate between option and existence value, or between existence values and bequest values. Existence values measured include the values accruing to Southlanders, but not to other New Zealanders.

The additional values noted by Māori would be expected to result in greater preferences for (and valuations of) existence and of sustainable uses of water that provide for the passing on of knowledge and/or maintain cultural identity. Thus they will be taken into account to some extent in surveys used to obtain values.[2] The legislative requirement to address these values does not change the values, but suggests that they are considered separately from the valuation exercise discussed in this report.

Policy Analysis

We have used outputs of work by NIWA and Aqualinc as inputs to this study. They analysed the impacts on water quality of quality and quantity limits under 16 separate policy combinations at 73 separate river stretches in Southland and provided results for the year 2037. The results were grouped into five separate broad scenarios (Table ES2): a baseline in 2037 (Scenario A that assumes no additional policy limits) and scenarios B to E with more stringent limits that result in on-farm mitigation actions or cessation of dairy farming (Scenario E).

Table ES2 Scenarios of Average Water Quality Parameters for Southland Water Bodies

		2037 Scenarios				
Parameter	**Unit**	**A**	**B**	**C**	**D**	**E**
N limit	(kg/ha)	60	45 - 60	45 - 60	30	15
P limit	(kg/ha)	1.5 - 2	1 - 2	0.5	0.5 - 2	0.5 - 2
Response		Baseline - no change	64% of farms mitigate	100% of farms mitigate	Stronger mitigation	100% land use change away from dairy

To estimate the aggregate effects we have used a combination of approaches:

- For recreational impacts (swimming and kayaking) we have estimated changes in the number of river sites that are swimmable or suitable for contact recreation based on the *E Coli* levels. The percentage change in number of suitable sites is used to estimate a percentage change in swimming and kayaking activity (and hence in values) (note this ignores the fact that people may shift where they

[2] We have no data on the separate existence values of Māori which might, for example, be used to weight the values to represent the Māori population in Southland versus the study sites. However, views and preferences may differ between Māori populations in different parts of the country, but so will the preferences of all people.

undertake these activities rather than total activity levels changing);[3]

- For fishing we have estimated the change in average phosphorus and nitrogen concentrations across all river sites to estimate the change in the number of fish and in average water clarity. We have used percentage changes in these averages to estimate percentage change in the value of fishing days (water clarity related) and the number of fishing days (related to the number of fish);

- For existence value we have estimated the change in average ecological health (measured using a Macroinvertebrate Community Index, MCI) across all river sites.

The modelling that has provided inputs to our analysis did not include other (non-river) water bodies, ie. lakes and estuaries. This is a limitation to the work, particularly as nutrients are likely to accumulate in estuaries, but are also flushed with sea water. The absence of data for these water bodies does not mean that we have ignored activities; we have used the activity data (recreational numbers and so on) available. However, the water quality impacts if averaged across all sites (including estuaries) would be different from the calculations of averages across river sites only, as described above.

Results

We have modelled the effects of changes in water quality under the individual scenarios on physical attributes of these river sites that enable them to be used and/or valued (eg. water clarity, *E. Coli* levels). We have then used the marginal values in Tables ES1 alongside base data for Southland to estimate the impacts on some non-market values. The results in Table ES3 show the difference between the outcomes of Scenarios B to E 2037 compared with the 2037 baseline (Scenario A).

Table ES3 Summary of Results of Scenario Analysis ($ million per year in 2037)

Value that changes	Scenario B	Scenario C	Scenario D	Scenario E
Water Clarity for Fishing	$0.1 - $0.2	$0.3 - $0.7	$0.3 - $0.7	$0.5 - $1.1
Fishing Days	-$0.1 - $0.0	-$1.2 - -$1.0	-$1.4 - -$1.2	-$2.4 - -$2.2
Swimming Visits	$0.1 - $0.4	$0.0	$0.0 - $0.1	$0.1 - $0.3
Kayaking Visits	$0.1 - $0.1	$0.0	$0.0	$0.0
Existence Value	$0.3 - $0.6	$1.0 - $1.8	$1.0 - $1.9	$1.7 - $3.2
Total	$0.6 - $1.2	$0.2 - $1.2	$0.1 - $1.2	$0.2 - $2.3
Total (ignoring fishing days)	$0.6 - $1.3	$1.2 - $2.4	$1.3 - $2.6	$2.4 - $4.7

Note: results are in 2012 dollars

The values that we have analysed here aggregate to a total annual value of the policy interventions in 2037 (in 2012 dollars) ranging from $0.1 - $2.3 million, with central estimates of $0.4 - $0.8 million per annum. The most significant contributor to value is

[3] It also ignores the fact that many of these sites will not be suitable for swimming or kayaking. Nevertheless the percentage change in the average quality of all river sites is assumed to represent the percentage change in the average quality of all sites suitable for swimming or kayaking

the existence value that accrues to Southland households; this ranges from $0.3 - $3.2 million per annum.[4]

The impacts on fishing are estimated to be in the opposite direction to the other values. Lower nutrient levels because of quality limits is estimated to result in a reduction in fish numbers because of the reduction in growth of food for fish. As we find a positive relationship between fish numbers and fishing days, the number of fishing days is estimated to reduce with lower nutrient levels also. This result depends crucially on the relationship between fish (trout) numbers and fishing days, but although this appears to be a statistically significant relationship, there are other factors that determine the number of fishing days that we are unable to model. We are thus not confident in this value (and the fact that it is negative). If we ignore the fishing values the range of measured non-market values is $0.6 - $4.7 million per annum.

In addition to a number of missing values, the overall level of values reflects the relatively low population of Southland and the scale of changes in water quality that are modelled. The overall results have quantified the value of water quality limits, measured as the change in certain non-market values, as ranging from approximately $10-$112 per household per annum in Southland.

Limitations

The analysis is limited in its scope because there are significant gaps in data and a number of simplifying assumptions.

Data Gaps

Data gaps include the following:

- values of water are missing for a significant number of categories of TEV, as noted in Figure ES2 above. This includes several recreational uses, option values applied to other use categories (including extractive use), and existence values for southland rivers for people outside of Southland;

- relationships between changes in water quality and changes in factors that are valued. For example, we do not know how the water quality changes will affect whitebating or eel fishing;

- the limitation of the analysis to the rivers and streams included in the modelling by NIWA and Aqualinc. This ignores the impacts on estuaries and other wetlands where nutrients and other contaminants may accumulate;

- distinct values expressed by Māori – although we have identified some differences, we are unable to quantify them.

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[4] Existence values for rivers in Southland will be held by people in other parts of New Zealand also, but we do not have data to estimate these

The above data gaps are particularly an issue for Māori because they are linked to core values, including values of whitebaiting or eel fishing. This limits the ability to express or understand the full value of water to Māori. Quantification of Māori market and non-market values requires additional research and the use of culturally appropriate methodologies.

Māori Values

We have noted three distinct differences that apply to Māori values of water bodies. These are the changes to value as a result of reciprocity, knowledge gained from sustainable use and cultural identity from management and use of the water resource. These would be expected to result in increased expressions of existence value and the values of other activities consistent with sustainable use of water. These additional values are taken into account to some limited extent via Māori participation in surveys that have produced measurements of value, but they have not been isolated. The legislative requirement for separate consideration of Māori values is a separate issue from valuation; it has implications both for approaches to decision making and partnership processes that go beyond the issues discussed in this report.

NZ Reputation Risk

We have not analysed any impact on New Zealand's reputation for its pristine environment as a result of impacts on water quality. This is always a difficult consideration when assessing marginal changes in environmental values at a specific site, as the reputational impact is likely to be cumulative as a result of numerous impacts in different locations. However, we note that this is an unvalued component in this study.

Uncertainty

In addition to the data gaps there are uncertainties associated with all of the values used. In all cases the values used have been transferred from different sites in different parts of New Zealand. In particular, we have assumed that the values will transfer to other rivers and to different communities.

1 Introduction

1.1 Context for this Report

This report provides background information and analysis on non-market values of fresh water. Non-market values are those that generally are not expressed in monetary terms or associated with commercial activities from which monetary values can be derived. They include recreational uses, scenic qualities, food gathering and the values that people place on natural environments. The study aims to provide information that can be used to evaluate the costs and benefits of limits to protect quality and quantities in fresh water bodies. The analysis in this report is limited to a case study region (Southland), but the approach and many of the data will be applicable more widely.

Fresh water is increasingly being recognised as one of New Zealand's key economic assets, including as an input to agriculture, for electricity generation and as a site for commercial recreational activities.[5] However, it is also recognised that water quality is declining in some catchments, with potential risks for the economy, recreational and cultural uses of water, and for fresh water habitats. In addition, there is competition for water resources in some parts of the country and some current over-allocation.

Some of the potential conflicts and trade-offs were identified in a recent report by the Parliamentary Commissioner for the Environment (Table 1) that focussed on the impacts on water quality of discharges of nutrients, sediment and pathogens, particularly from agriculture. Other sources of discharge include wastewater systems (including septic tanks) and industry. The impacts include those on algal blooms, habitats for fish and other organisms, water clarity and suitability of water bodies for recreational use.

Table 1 Environmental and Health Impacts of Water Pollution

Cause	Effects
Nutrients (nitrogen and phosphorus)	• Nitrates can make water unsafe to drink and kill sensitive organisms (eg. young trout and salmon); • Ammonia is highly toxic to fish • Excessive growth of large plants (macrophytes), periphyton and phytoplankton. Periphyton can carpet the bottom of waterways, with impacts on habitats and degrading water recreation and fishing. • Algal blooms that can be toxic, including via organisms that eat it (eels, shellfish) • Oxygen depletion as a result of excessive plant growth
Sediment	• Damage to plants when suspended in moving water; • Damage to gills and delicate body parts of invertebrates and fish; • Increasing turbidity thus reducing visibility (for people and animals) and reducing light for plants • Smothering beds of water bodies, reducing habitat for plants, invertebrates and fish • Changing water flows
Pathogens	• Health risks for people and animals, including diarrhoea, loss of milk production, miscarriage and death

Source: Parliamentary Commissioner for the Environment (2012) Water quality in New Zealand: Understanding the Science

[5] Ministry for the Environment (2013) Freshwater reform 2013 and beyond. Wellington. Ministry for the Environment

These issues are the backdrop to the Government's proposals for reform of the freshwater management system.[6] Part of the reforms include the establishment of a National Objectives Framework to support the setting of freshwater objectives and limits as required by the National Policy Statement Freshwater Management [7] and ensuring these will provide for the values that the community consider important.

The work described in this report is part of a wider stream of work that, to the extent possible, is examining the total costs and benefits of water quality and quantity limits. These limits would protect or enhance some uses and values of water by ensuring that discharges or takes do not prevent freshwater objectives being met. This may mean that other uses or activities are constrained (extractive uses and activities that affect water quality and quantity). This report addresses the impacts of changes in values that are not readily measured in monetary terms. This excludes uses of water for agriculture (irrigation and stock water), hydro-electricity, industrial and domestic uses, but includes recreational use and the continued existence of valued ecosystems. We explain the categories in more detail in Section 2.

1.2 Components of the Study and Structure of this Report

The overall project is aiming to provide inputs to the assessment of the costs and benefits of national policy settings on water quantity and quality. A case study region, Southland, has been selected in which to assess the impacts initially, with the intention being to extend the analysis to the country as a whole in the future.

The work is being undertaken alongside other studies (Figure 1). Scenarios of water quality limits have been developed and are used with a hydrological model and a land use model to analyse the impacts that these limits would impose on land use activities (farming and forestry) and their discharges to water. The resulting water quality outcomes are then used in separate studies to examine the implications for municipal and industrial uses of water and the non-market values of water as examined in this study.

This study takes inputs from the hydrological modelling undertaken by Aqualinc and NIWA that is estimating the impacts of quantity and quality limits on water quality at 73 different locations in Southland.

In this study we use scenarios of changes in water quality and we:

- identify the components or attributes of water that enable it to be used or that provide direct value. For example, this would include water clarity, the presence of certain fish species and the absence of pathogens that cause health problems for swimmers. We estimate the relationship between changes in water quality and these **valued attributes**;

[6] ibid

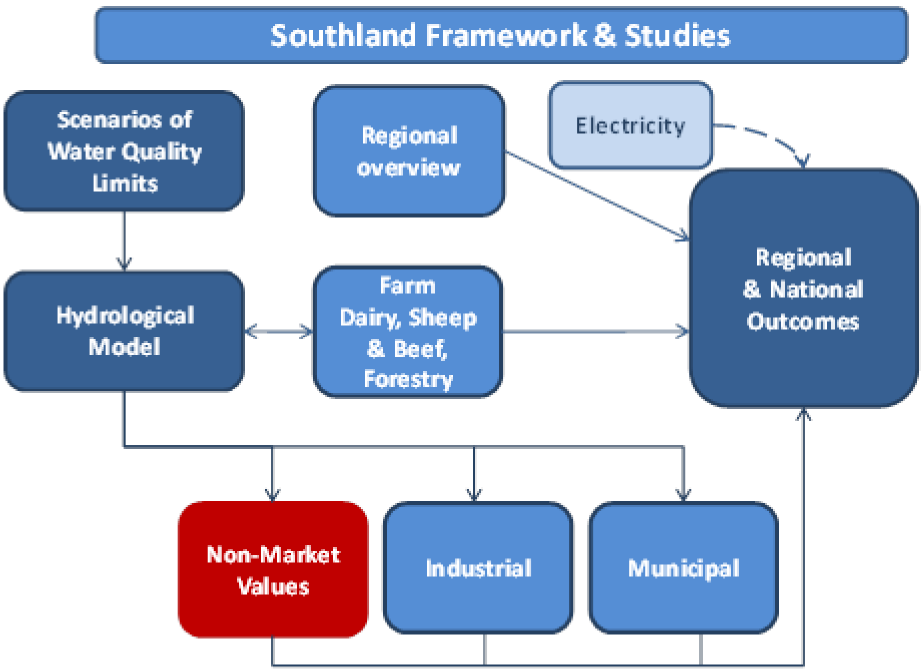
[7] National Policy Statement Freshwater Management 2011 Issued by notice in the Gazette on 12 May 2011

- identify non-market values for water and the way in which these values change as a result of changes in water quality. These are **marginal values,** expressed as how total value changes as a result of a small change in a factor that affects that value, for example the change in recreational value of 1 more metre of water visibility;

- compile and make use of **Southland data** that enables us to combine the generic values (applicable to water bodies throughout New Zealand) with the results of the Southland scenario analysis to estimate effects in Southland. For example, this includes data on current levels of recreational activity; and we

- combine the different components to estimate the effects on non-market values.

Figure 1 Relationship of this study to other studies



In this report, we start by defining the values that are being considered in this report and the use of benefit transfer methodologies to make us of values defined from studies in other geographical locations (Section 2). We then discuss and present monetary values relating to water use in New Zealand and identify values that we will use in analysis (Section 3). This is followed by a presentation of background material on Southland that is used to estimate what values are relevant and how they might be used. We use the values to analyse the impacts of possible changes to water quality in Southland (Section 4).

2 Categories of Value

2.1 Overview

The overall methodology for the study is outlined above (Section 1.2). In this section we describe the way in which we have defined the values for analysis and the approach used to collect data relating to these values. We are looking to identify values reported in studies that can be used to quantify the relative preferences of people for non-market uses of water than can be compared with the uses that are more readily expressed in monetary terms, such as the input of water to agriculture.

We start by defining non-market values: the values that are addressed in this report and those that are out of scope, but addressed in other reports. We also discuss Māori perspectives on values as they pertain to fresh water. We discuss the issues relating to monetary valuation of the environment and the extent to which we can use values from studies in some other part of the country to apply to the case study region of Southland.

2.2 Non-Market Values of Water

The topic for this report is non-market valuation; the term is used here as a reasonably general catch-all to include all sources of value that are not covered by other studies. Thus, pragmatically, our definition of non-market values is based initially on exclusion of:

- Agricultural use of water, including irrigation and stock water;
- Industrial water use;
- Domestic water use, including all extractions for reticulated supply to households and industry;
- Hydro-electricity.

Rivers and waterways are used as a sink for pollutants, but this value is taken into account via the other components. The value of the sink to agricultural land users is some proportion of the surplus from farming, and other studies are taking these surpluses into account. The cost of supplying the sink function is the loss of non-market values that are being considered in this study.

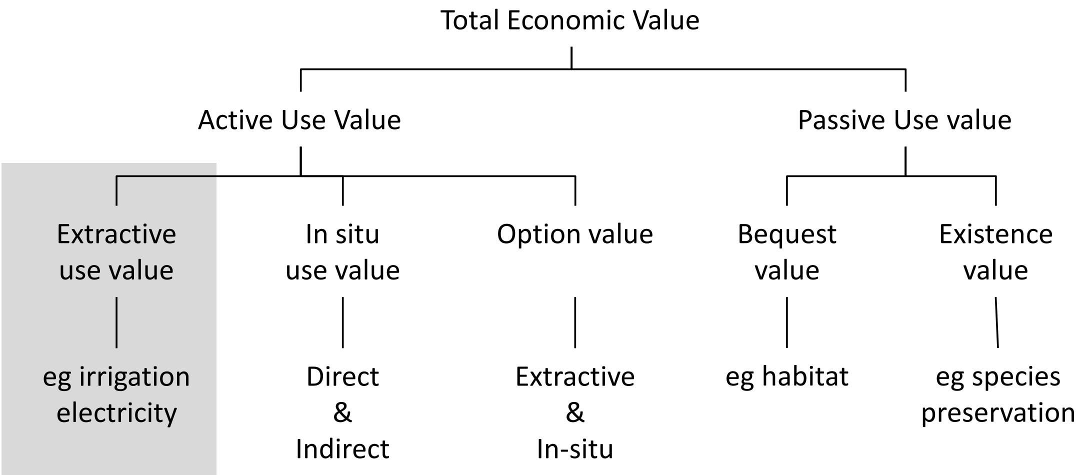
To ensure that we cover all relevant non-market values we attempt to define the set of values inclusively also. We use the Total Economic Value (TEV) concept to ensure that a relatively comprehensive list of values is developed.

2.3 Total Economic Value

Total Economic Value (TEV) is used to classify the full range of values that people derive from the environment. In Annex 1 we also discuss the linkages between TEV and a different but related concept of Ecosystem Services: the Ecosystem Services framework aids in identifying the services the ecosystem provides (provisioning, regulating, cultural and supporting), while TEV outlines the value that result. These are not mutually exclusive concepts, and it is the TEV concept that is used in this report to ensure that we capture the full range of values.

There are many different classifications of TEV, and one is shown in Figure 2; of the categories shown, the extractive use values (shaded in the figure) are excluded.

Figure 2 Total Economic Value (shaded categories are not included in this study)



Source: Adapted from Sharp B and Kerr G (2005) Option and Existence Values for the Waitaki Catchment and EVRI (2009) in Nimmo-Bell (2009) Biodiversity Valuation Manual. A technical manual for MAF BNZ.

It is a modification of an example that has been developed specifically to address the values associated with water; the general ideas that are represented are as follows.[8]

- There are active use and passive use values, where
    - **active use** values derive from actual use of the water resource via extraction (eg. for irrigation) or for in-stream use for recreation or simply as a back-drop for other activities beside the river. In other words, the physical presence of the water is vital to the realisation of the value. In contrast,

    - **passive use** values are values that pertain more to the fact of existence of the water resource.

- Amongst **active use** values there are those that derive from:
    - **extractive use** of the water that involves taking the water out of the river. This includes use of water for agriculture (irrigation or stock water), municipal use (drinking water and other household uses), industrial use (eg. cooling, washing, inputs to food and drink production). Hydro-electricity is generally non-extractive and does not remove the water (although this is clearly not the case with the Manapori hydro scheme),[9] but it renders it unavailable for use over

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[8] Although the categories are changed somewhat, the descriptions are taken largely from Sharp and Kerr (op cit)

[9] The water is diverted from the Waiau river system to the the Manapouri Hydro-Electric Power Scheme on the western arm of Lake Manapouri. It results in the diversion of up to 90% of the flow in

certain stretches of a river and will generally alter the waterway significantly;

  - **in-situ use** where the water resource may be used directly (eg. swimming) or indirectly (eg. recreation beside the river);

  - **Option values** which represent the value of retaining an option to use a resource in the future. They represent the value of not foreclosing options. Quasi-option value is a term used to describe the welfare gain associated with delaying a decision when there is uncertainty about the payoffs of alternative choices, and when at least one of the choices involves an irreversible commitment of resources. Quasi-option value stems from the value of information gained by delaying an irreversible decision to develop a natural environment; it is not a value that individuals attach to changes in the natural resource;

- **Passive use** values, which are independent of the individual's present use of the resource and are variously described as "existence value", the value from knowing that a particular environmental assets exists (eg. endangered species); and "bequest value", the value arising from the desire to bequeath certain resources to one's heirs or future generations (eg. habitat preservation).

Although these categories of value are widely discussed in the literature, in practice it may not always be possible to separate them out. Passive uses, in particular, are often combined into a single existence value category.[10] Sharp and Kerr[11] note, for example, that disentangling use and existence values in existing studies may be impossible and that survey respondents in studies to estimate values may not be able to separate out the values associated with non-use from use values.

In this report, following Sharp and Kerr, we have grouped all passive or non-uses into the single category of existence value and included option value within this also. Although option value includes values placed on retaining options for extractive and other more direct uses, the value tends to be enhanced through non-use and increase in the same way as existence values. Our treatment of existence value is that it is a measure of the value of an environmental attribute that is related to the existence of the environmental attribute, and that increases in value with its ecological health.

Some uses are readily identified, including extractive uses and in-stream uses that include recreational use, food gathering and navigation/transport. In general the extractive uses are commercial and have values that can be measured through market prices; in contrast in-stream uses tend to be non-market values that require alternative valuation techniques. The TEV concept is useful as a reminder that values accrue to people that do not visit the water body but who benefit from knowledge of its existence

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the catchment to its discharge point in Doubtful Sound (www.es.govt.nz/media/12553/water-quantity-issues-and-options-paper.pdf) .

[10] Sharp and Kerr (op cit)

[11] Sharp B and Kerr G (2005) Option and Existence Values for the Waitaki Catchment

also, and that there are values in retaining options for future use, where this future use may be any one (or combinations) of the other uses.

We thus examine:

- In-situ use values – recreational and other uses of water at a particular site;

- Existence values – the values that do not require a person to be present at the site.

Before examining how data relating to these values can be collected, we first discuss the relevance of this categorisation to Māori.

2.4 Māori Values

Understanding Māori values pertaining to water is an important element of this work. It recognises that such understanding is also a statutory requirement in the Resource Management Act 1991 (RMA), the Conservation Act and the Local Government Act.

In addition, the specific relationship of tangata whenua to local environs is increasingly being recognised in Treaty Settlements via Statutory Acknowledgements. For example, the relationship of Ngai Tahu to the environment is acknowledged in a number of Statutory Acknowledgements agreed under the Ngai Tahu Claims Settlement Act 1998 (Box 1).

Box 1 Ngai Tahu Statutory Acknowledgements

The Ngai Tahu Claims Settlement Act 1998 includes Statutory Acknowledgements that recognise Ngäi Tahu's mana in relation to a range of specified sites and areas, and specifically the cultural, spiritual, historical and traditional association with these areas. They recognise the centrality of the concept of mauri (an essence that binds the physical and spiritual elements of all things together) to Ngäi Tahu's value of the environment.

The statutory areas include the four main stem rivers in Southland (Waiau, Aparima, Oreti, and Mataura), Te Anau-au (Lake Te Anau), Moturua (Lake Manapouri), Lake Hauroko, Manawapopore/Hikuraki (Mavoa Lakes), Uruwera (Lake George) and Waituna Wetland.

The purposes of Statutory Acknowledgements are to achieve cooperation and good faith between councils and Ngai Tahu, and:

- to ensure that Ngäi Tahu's particular association with certain significant areas in the South Island are identified, and that Te Runanga o Ngai Tahu is informed when a proposal may affect one of these areas;[12] and
- to improve the implementation of RMA processes, in particular by requiring consent authorities to have regard to Statutory Acknowledgements when making decisions on the identification of affected parties.

Statutory Acknowledgements do not override the existing consent process, but they recognise that Ngai Tahu has particular interests and associations that need to be taken into account in decisions.

Source: Ngäi Tahu Statutory Acknowledgements. A Guide for Local Authorities.

Māori perspectives on water management are also found in policy at national, regional and local levels. They were addressed specifically by the Land and Water Forum which

[12] The Council must send a summary of the resource consent application to Te Runanga o Ngai Tahu

included a summary of some of the issues that affected world views and relationships to water.[13]

Harmsworth & Tipa[14] noted with respect to environmental monitoring, that when monitoring environmental attributes that are important to tangata whenua, it was important for methods to be grounded in the beliefs, values and practices of Māori. In this section we discuss (albeit briefly) how Māori see water, how they interact with water and how key cultural concepts relate to water.

Māori conceptualise water as an undivided entity and as part of a system of lakes, rivers, lagoons, swamps, their associated beds, and adjoining lands. An integrated and holistic approach to water valuation is necessary to give effect to the principle of water being an undivided entity. A starting point is to identify values.

Table 2 Core Ngāi Tahu whānui values and uses relating to the freshwater environment

Core Value	Description	Relationship to Cultural Use of freshwater environment
Whakapapa	Whakapapa (genealogy) is about the relationships of all life forms to each other as well as the atua (gods). Whakapapa describes bonds, relationships, and connections. All things are linked by whakapapa.	Water has its own whakapapa and Māori link to this whakapapa. Whakapapa is also central to passing on knowledge through the generations.
Whānaungatanga	The interrelationship of Māori with their ancestors, their whānau, hapū and iwi as well as the natural resources within their tribal boundaries. This genealogical relationship is one of the foundations upon which the Māori culture is based.	Sustainable management seeks to sustain the health, wealth and well-being of the natural environment while sustaining communities dependent upon it. In a catchment it is water that makes and maintains connections between different waterbodies and entities within a catchment.
Te Ao Māori	The environment is viewed as a whole – not as divided parts.	This holistic view of the freshwater environment requires consideration of the whole catchment. A catchment constitutes soils, water, flora, fauna and the relationships between them.
Mauri	Mauri is a central component of the Māori perspective on the environment. It can be defined as the life principle, life supporting capacity, or life force present in all things.	Protecting the mauri of a resource is the fundamental management principle for Māori. Māori treasure the mauri of freshwater and may experience cultural offence and distress when the mauri is degraded.
Wairua	Spiritual connection/wellbeing.	Ngāi Tahu, like other Māori, use different ways to feel spiritually connected with their takiwā. This spiritual connection can occur by gathering kai with whānau at a traditional fishing place that they know have been named by their tūpuna, and utilised by successive generations of their whānau; being able to contribute the kai that their takiwā is renowned for, to ceremonies. Being denied these opportunities can impact on spiritual wellbeing.

[13] Land and Water Forum. (2012). Second Report of the Land and Water Forum: Setting Limits for Water Quality and Quantity, and Freshwater Policy- and Plan-Making Through Collaboration
[14] Harmsworth, G.R. & Tipa, G. (2006). Māori environmental monitoring in New Zealand: progress, concepts and future direction. Report for the Landcare Research ICM web site.

Core Value	Description	Relationship to Cultural Use of freshwater environment
Kaitiakitanga	The exercise of guardianship by manawhenua of an area and resources in accordance to tikanga Māori (customs and rules).	Kaitiakitanga governs the way humans interact with the environment. The notions of sharing and maintaining balance with nature underpin cultural uses and practices. Balance requires respect to be shown when interacting with the environment; and use of the resource (within limits) afforded by healthy ecosystems. Māori continue to have a duty to protect the natural world.
Tino Rangatiratanga	Tino Rangatiratanga is the right to make decisions for your own people concerning the resources within your takiwā.	This means determining what, from a cultural perspective, represents satisfactory aquatic conditions and appropriate use.
Mahinga kai	Mahinga kai encompasses the resource harvested, the ability to access the resource, the site where gathering occurs, the act of gathering and using the resource, and the good health of the resource.	Mahinga kai is considered to be the principle 'environmental indicator' in natural systems. If mahinga kai is not present, or is unsafe to harvest, then, that natural system is under stress and requires remedial action. The state of freshwater is important as a medium for sustaining and accessing mahinga kai. Ideally streams will sustain healthy and diverse koiora/life.
Manaakitanga	The support, caring and hospitality shown to guests.	The ability to manaaki visitors by supplying kai sourced locally means that the activities of fishing, eeling and gathering foods creates and maintains whānau and hapū ties and reinforces identity. Conversely the inability to manaaki guests and sustain whāungatanga can lead to cultural loss.
Te Reo	Language. Te Reo contains knowledge and is another expression of culture and identity.	Stories, waiata and Te Reo that pertain to particular uses, and these uses sustain the culture. When a valued species disappears from a local ecosystem or the activities associated with a species decrease, the associated Te Reo drops away.

Source: Tipa G (2011). Our Uses: Cultural Use in Murihiku. Report prepared for Environment Southland.

Two values from Table 2 that are fundamental to Ngai Tahu are *Whakapapa* and *Whānaungtanga*.

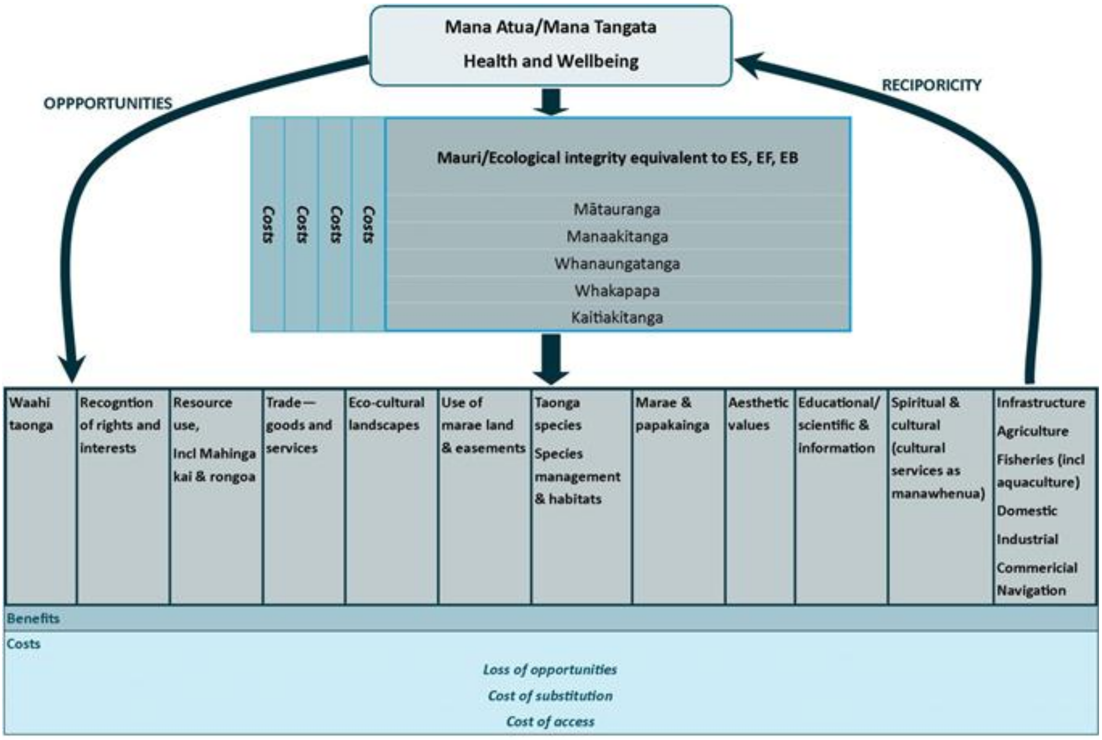
- **Whakapapa** describes bonds, relationships, and connections. Water is the medium flowing through a catchment that makes connections. Rivers connect the entire landscape – ki uta ki tai – from the mountains to coastal environments. Manipulating flows, diverting waters, and dewatering river reaches, breaks connections and results in cultural impacts – even cultural loss.

- **Whānaungtanga** – In Ngāti Hokopu v Whakatane DC (C168/02), the Environment Court stated that:
  Of all the values of tikanga Māori, whānaungatanga is the most pervasive. It denotes the fact that in the traditional Māori thinking relationships are everything – between people; between people and the physical world; and between people and the atua (spiritual entities).[15]

[15] Māori Custom and Values in New Zealand Law NZ Law Commission, paragraph 130 citing an unpublished paper written for the Commission by Joseph Williams ("He Aha Te Tikanga Māori".

These two values also highlight the challenges in undertaking a non-market valuation – Māori would contend that you cannot put a value on these (and other) core values. The challenge is therefore to understand how tangata whenua conceptualise the relationships between these values, as the first step in identifying what components can be valued. An example of an alternative conceptualisation is provided in Figure 3.

Figure 3: Tangata whenua economic valuation framework



Source: Te Ao Marama Incorporated

This alternative valuation framework was based on a number of primary principles that an economic valuation would be expected to provide for. It would:

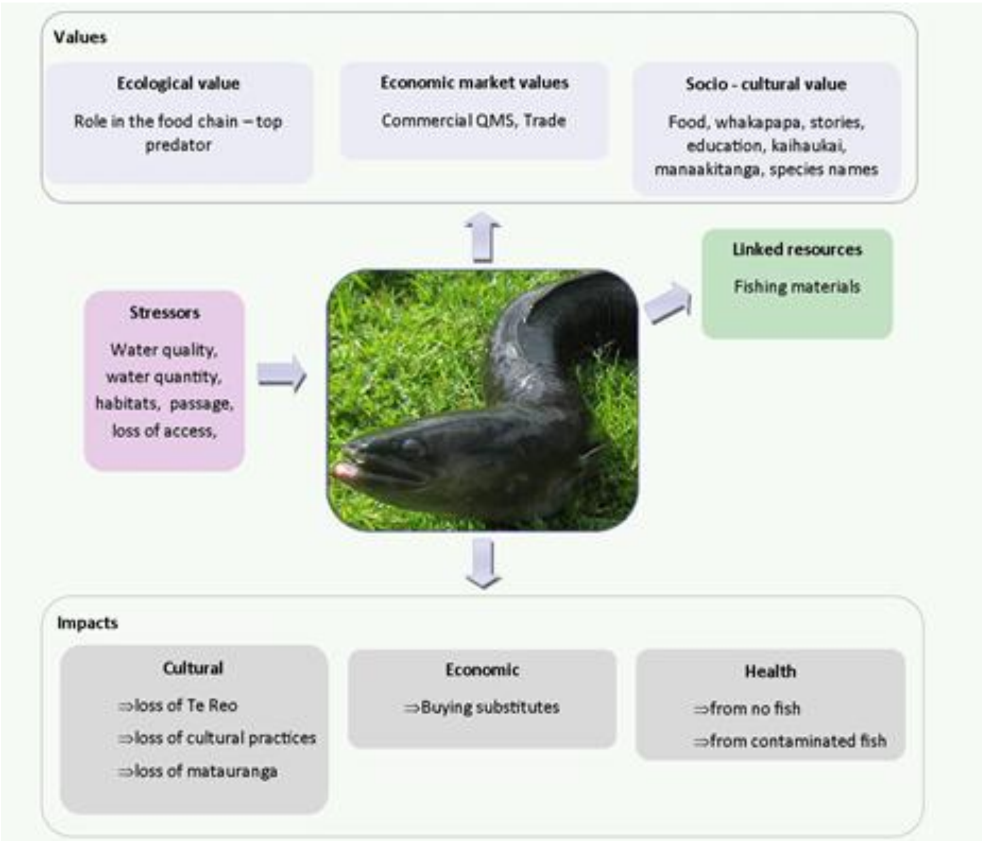
1. use terminology that better enables "flaxroots" tangata whenua participation in the discussion. Whanau may not be engage with more conventional TEV depictions;
2. recognise the wide breadth of cultural interests;
3. includes the indigenous concept of reciprocity, which includes costs and benefits, opportunities and responsibilities;
4. recognises the interconnectedness of biotic and abiotic factors and that there is no sense in which some values are less tangible than others;
5. supports the use of interdisciplinary methodologies, including Mātauranga Māori.

The framework also recognises:

- existing theories sourced from international literature (including concepts of cultural landscapes, cultural keystone species and eco-cultural attributes;[16]
- the LAWF cultural framework—Mana Atua/Mana Tangata Model; and
- the growing emphasis in literature and research of health and wellbeing, including the cultural determinates.

A conceptualisation, however, is only the first step. The next step would be to work with tangata whenua to identify dimensions that can be measured, quantified and valued. For example, the value of a particular taonga species, in this case eels (tuna)is illustrated in Figure 4, and from this the impact of environmental change can be also be depicted (Figure 5). By progressing from a conceptualisation of values and the interrelationship between values, it is possible to start to understand (and potentially quantify) how these values change with incremental changes in water quality.

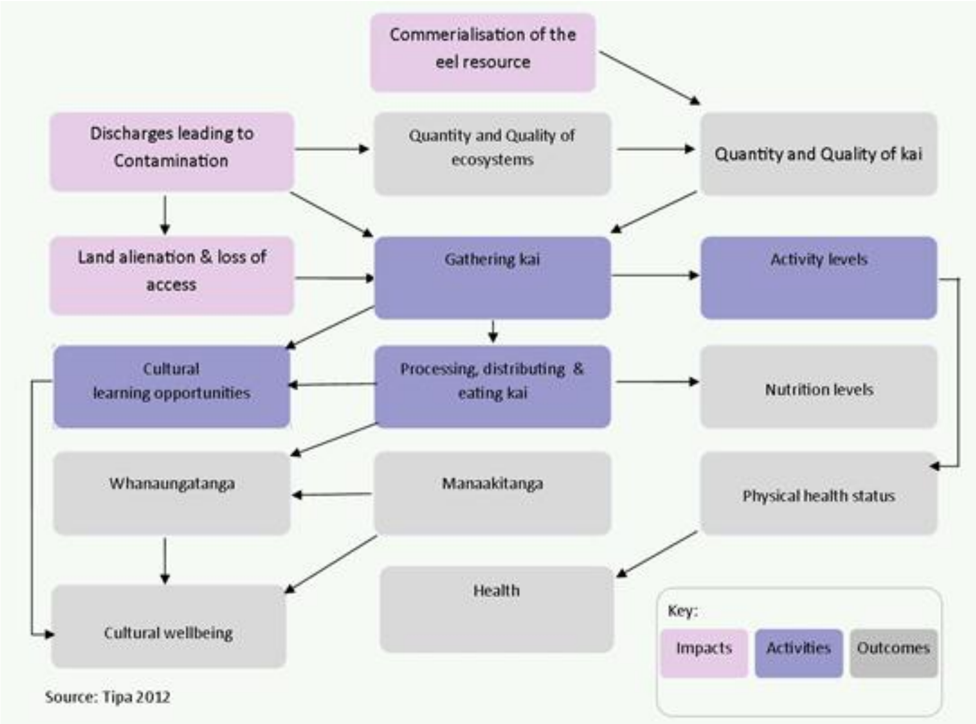
Figure 4 The significance of eels as a taonga species



Source: Gail Tipa

[16] See for example: Martinez, D. (1995) Karuk tribal module of mainstem salmon watershed analysis: Karuk ancestral lands and people as reference ecosystem for eco-cultural restoration in collaborative ecosystem management. Unpublished report. On file with: U.S. Department of Agriculture, Forest Service, Klamath National Forest, 1312 Fairlane Road, Yreka, CA 96097. Contract #43-91W8-5-7017.; Garibaldi, A. and N. Turner. (2004) Cultural keystone species: implications for ecological conservation and restoration. Ecology and Society 9(3): 1. [online] URL: http://www.ecologyandsociety.org/vol9/iss3/art1

Figure 5 An illustration of the impacts resulting from environmental change on mahinga kai



Source: Gail Tipa

These figures also introduce the commercial interests of Māori, which has been excluded from the wider economic valuation project conducted within Southland. Any valuation needs to recognise the growing Māori market economy.

To assist with undertaking future valuations, tangata whenua have been active in developing tools enabling them to record sites and resources of significance and to assess their current state.[17] The data from these assessments would improve valuations, including with tangata whenua as decision-makers on what cultural values are appropriate to measure and quantify.

In examining these, our particular concern is with how these values change with incremental changes in water quality. Key issues that result in different or additional values to those discussed with respect to non-market values are:

1. The concept of **reciprocity** in which anything taken (food or other resources) is balanced by giving. This means that there is a requirement for restoration to ensure the on-going functioning and wholeness of the environment. This concept is based upon elements of the Māori values of Kaitiakitanga, Mahinga kai, Mauri and Whānaungatanga. Failure to look after the local environment is a source of loss of mana. Any deterioration in quality may be reflected in the inability to produce traditional food or other resources iconic to a local environment;

[17] Nelson K and G T Tipa (2012) Cultural indicators, monitoring frameworks & assessment tools. Report for Water Wheel Project.

2. The importance of knowledge (**mātauranga**) underpinning the management of lands and waters within a tribal area (takiwa) and the sharing of it with future generations (whakapapa). Management and use of water, and the relationship with the water body, provides resources for the group but also builds knowledge and provides educational experiences that can be passed on to future generations. Thus there is a marginal increase in knowledge with an increase in water quality because there is an increase in the opportunities for use of a resource that yields opportunities for education. Generation and application of mātauranga comes from being able to interact safely with waters and resources as tūpuna (ancestors) did;

3. The importance of a specific environment and its use to the **cultural identity** of the group. This concept is based upon elements of the Māori values of Manaakitanga, Wairua and Mahinga kai. Whānau and hapū are defined with respect to their takiwa. The loss of ability to use a resource may affect the environs and resources at the core of their cultural identity. Substitution is not a valid management response for environmental degradation. Identity is place-specific, and cultural practice / use specific. Cultural identity is a fundamental component that underpins wellbeing.

These concepts would be expected to result in Māori holding and expressing a greater value for sustainable use of water or enhancement of water quality.

2.5 Monetary Valuation

2.5.1 Assumptions

In this study we convert as many values as possible into monetary values. The fundamental aim of this approach is not to put a dollar value on water, but to express the impact of marginal changes in environmental quality in terms of the trade off against other things that people value:[18] what would people be willing to give up to gain improved water quality? We are using money as a way to measure relative preferences for different uses of water to assist in identifying which uses of water provide the greatest wellbeing benefits to the community.

Wellbeing refers to the total benefits that people obtain from all that they value, including but not limited to consumption of goods and services, participation in individual or communal activities, their environment, health and overall contentment with their life and actions.

We use money as the means for valuing changes in wellbeing. The main reason for doing so is that we already have some expressions of relative contribution to wellbeing using money. When people purchase items they are making expressions of their relative preference for one item of consumption over another. If someone spends money on a day trip to a recreational site, for example, it provides a measure of the relative value of that trip because the money spent could have been used for something else. Money is

[18] Turner RK, Paavola J, Cooper P, Farber S, Jessamy V and Georgiou S (2003) Valuing nature: lessons learned and future research directions. Ecological Economics 46: 493-510.

being used here to express the relative preference for a particular recreational visit compared with other options. The approach is trying to reproduce what would happen if markets could be established for these different uses.

Building on this, valuation techniques for non-market uses of water use a mix of revealed and stated preference techniques to estimate relative values.

- Revealed preference techniques observe how people behave and use the results as a measure of relative preferences, as with the recreational trip example above.

- Stated preference techniques rely on surveys in which people are asked to state their relative preferences, often in terms of willingness to pay. The more sophisticated approaches use choice experiments in which a clear payment method is shown and trade-offs are demonstrated, ie. having more of one thing means having less of another.

Some studies have noted differences in expressions of willingness to pay (WTP) for something and willingness to accept compensation (WTA) for its loss.[19] The appropriate approach to use depends on the distribution of property rights, with WTP appropriate where an individual has no right to the benefits from a resource and WTA appropriate when rights exist.[20] The approach matters because studies suggest large differences between results in stated preference studies depending on whether questions are eliciting WTP or WTA. However, in the analysis here, and in most environmental policy decisions, the decision being made are regarding an improvement in environmental quality for which, arguably, there is no current right; this is almost by definition here as the government is considering whether or not to introduce policy measures to improve quality and is using a cost benefit approach to evaluate this choice. On this basis it can be argued that WTP is the most appropriate measurement approach. However, there may be instances where, for strongly held preferences, income constraints mean that these preferences cannot be full demonstrated, and we address this briefly below.

2.5.2 Income Constraints

When using monetary valuation of environmental benefits, peoples' expressions of value are limited by their disposable income, in the same way as they are when purchasing consumption goods in conventional markets. We thus treat the environment as a consumption item for which individuals can choose to purchase if they can afford to and prefer it to other items.

We do not treat all decision choices in this way; there are, for example, ethical issues that constrain some options. Ethical stances are taken towards species extinction (or at least for some, often larger organisms), and Turner et al[21] suggest that there will be

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[19] See for example Pearce DW and Turner RK (1990) Economics of Natural Resources and the Environment. Harvester Wheatsheef.

[20] Pearce D, Atkinson G and Mourato S (2006) Cost-Benefit Analysis and the Environment. Recent Developments. OECD.

[21] Turner RK, Paavola J, Cooper P, Farber S, Jessamy V and Georgiou S (2003) Valuing nature: lessons learned and future research directions. Ecological Economics 46: 493-510.

constraints to substitutability with respect to cultural values that may be on a completely different “moral” plane. They also note that the appropriate context for economic valuation is conditioned, among other things, by the scale of environmental changes, and that monetary valuation is most meaningful when considering small, marginal, changes in the conditions of natural assets. However, mostly environmental damage is along a continuum of effects in which many human activities have some effects on the environment and we are inevitably involved in making trade-offs. The extent to which people make these trade-offs appears to differ with relative wealth.

The approach of assuming the environment is like a consumption item appears to be consistent with behaviour. For example, analysis of environmental protection across countries finds that nations choose to protect the environment more when they are more wealthy. At low national income levels (less developed countries) there tends to be deteriorating environmental quality as per capita incomes increase, but above a certain level this changes, such that the environment improves with wealth—this is the inverted-U shape or Environmental Kuznets Curve.[22] Grossman and Kruger[23] were some of the original authors to note this effect, including showing the relationship between GDP per capita and levels of water quality in different countries. They note that “*as nations or regions experience greater prosperity, their citizens demand that more attention be paid to the noneconomic aspects of their living conditions. The richer countries which tend to have relatively cleaner urban air and relatively cleaner river basins, also have more stringent environmental standards and stricter enforcement of their environmental laws than the middle-income and poorer countries, many of which still have pressing environmental problems to address.*”[24]

This relationship is not universally agreed and there are other studies that suggest that it does not apply, at least to some environmental issues such as biodiversity protection.[25] More recent studies applied specifically to water quality have raised some questions about the (political) mechanisms by which the relationship functions but have not questioned the underlying link between wealth and demand for water quality.[26]

These results tend to suggest that individuals will also be more likely to place relatively less value on water quality when their incomes are low. People will sacrifice environmental quality for income until the point at which they are sufficiently wealthy, or their other more basic needs are met, and the marginal benefits of additional wealth are not as great as the dis-benefits of environmental destruction.

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[22] It is named after Kuznets who hypothesised that income inequality first rises and then falls as economic development proceeds - Kuznets S (1955) Economic growth and income inequality. American Economic Review, 49: 1-28..

[23] Grossman GM and Krueger AB (1995) Economic Growth and the Environment. Quarterly Journal of Economics, 110(2): 353-377

[24] Grossman and Kruger (op cit), p372

[25] Mills JH and Waite TA (2009) Economic prosperity, biodiversity conservation, and the environmental Kuznets curve. Ecological Economics 68 (2009) 2087–2095

[26] Paudel KP, Lin C-YC and Pandit M (2011) "Estimating the Environmental Kuznets Curve for Water Pollutants at the Global Level: Semiparametric and Nonparametric Approaches." Manuscript; Granda C, Pérez LG and Muñoz JC (2008) The Environmental Kuznets Curve for Water Quality: An Analysis of its Appropriateness Using Unit Root and Cointegration Test. Lect. Econ., 69 (Jul-Dec): 221-244

When aggregating values across the community it means that the expressed values of higher income people tend to be given greater weight because their expressions of value are higher. When applying this approach to environmental issues this might appear to be unfair, but it simply reflects the observation that lower income people express a preference for other consumption items over the environment at a lower price than do higher income individuals. Although this is likely to be the most significant effect with income (preferences differ with income), we acknowledge that there may be some individuals for whom income constraints limit their ability to express their preferences. For these individuals there may be a very significant difference between expressions of willingness to pay and willingness to accept compensation in a way that suggests that WTP may not adequately reflect relative preferences. We do not know if these people are a significant proportion of the population.

We also note that, in comparison with the general population, Māori appear to be "more willing to pay for environmental improvements, regardless of income".[27]

Thus, as a general rule, income affects willingness to pay, but this does not invalidate the results. It reflects relative preferences. This issue raises the related concept of the distribution of benefits and how these are treated in this analysis. We turn briefly to these issues below.

2.5.3 Distributional Issues

The benefits of land use activities that result in water quality impacts may be enjoyed by a more limited number of people than the environmental impacts (or benefits of quality improvements) which are more widely distributed across the community.[28] The efficiency argument that is widely used in public policy economics (the Kaldor-Hicks efficiency criterion)[29] is that these distributional effects do not matter; what matters is that the nation (or region) as a whole is better off.[30] If land use activities produce wealth but damage the environment, we could redistribute this wealth and all people could be better off. For example, all those that valued the environment could be compensated for their losses. However, the principle does not state that compensation must be paid, only that it *could* be paid.[31] The underlying assumption is that there may be numerous policies and projects, all of which will make some people better off and others worse off, but in aggregate across all projects/policies, all are made better off.

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[27] Awatere S (2005) Can non-market valuation measure indigenous knowledge? Australian Agricultural and Resource Economics Society Conference, February 9-11, Coff's Harbour, Australia

[28] The financial benefits of land use activities will flow to other people as those whose incomes increase will spend more, thus increasing incomes for others, but not everyone will gain

[29] Kaldor N (1939) 'Welfare propositions of economics and interpersonal comparisons of utility', Economic Journal 49: 549–52; Hicks JR (1939) 'Foundations of welfare economics', Economic Journal 49:696–712.

[30] The Kaldor crtitrion is that there is a net gain to the community if "the winners" can fully compensate "the losers" for their loss and still have a gain for themselves. Under the Hicks criterion there will be a net gain from the change, if the losers cannot bribe the winners to prevent the change occurring, before the change is made, eg. if the amount the recreationalists would be willing to pay to avoid the pollution was insufficient, if it was paid to those that benefit from being able to pollute, to obtain their agreement not to do so.

[31] Johansson P (1991) 'An Introduction to Modern Welfare Economics', Cambridge University Press, Cambridge

This approach does not differentiate between types of distribution, ie. between environmental and financial costs and benefits; nor does it necessarily examine whether distribution has occurred afterwards. In contrast, adopting an approach which requires that all policy interventions are of benefit to everyone, or at least not detrimental, can lead to a policy stalemate in which there are few policies that can ever be adopted.[32]

The underlying analytical approach is still appropriate, but it is important to note that the benefits of introducing water quality limits may be more widely distributed across the community than are their costs. The whole community is likely to benefit as a result of improvements in water quality because all (or very many) appear to place a value on the recreational opportunities or the existence values of a natural environment. The financial costs from any necessary reduction in activities that cause pollution are more narrowly borne by those undertaking the activities, and those who otherwise would benefit from the spillovers. These equity considerations may be an appropriate additional consideration by decision makers.

2.5.4 Community Values

Studies that obtain estimates of willingness to pay for environmental attributes are measuring the stated preferences of individuals. A number of authors, eg. Sagoff,[33] have suggested that people might state different levels of preference if responding as members of a group rather than as individuals. This can reflect a number of issues, including the greater willingness to incur a cost if others face the same cost, thus ensuring no change in relative income. Suggestions have been made for studies to use values derived through collective discussions, rather than surveys of individuals,[34] although the methodological difficulties are clear, including those of obtaining representative samples of people.[35]

Community preferences will not necessarily lead to different outcomes. For example, just as Marsh found that individuals state a willingness to pay for cleaner water, they also have a willingness to pay to protect jobs in the dairy industry.[36] Community values extend to social and financial considerations in addition to environmental and cultural factors.

The absence of community values is a possible limitation to the analysis, and this is based on the infancy of the discipline and the absence of studies. We have not, for

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[32] Indeed, this kind of stalemate was the background to the adoption of the Kaldor-Hicks efficiency criterion in the first place, rather than the stricter Pareto criterion (no one can be made worse off).

[33] Sagoff M (1988) The Economy of the Earth. Cambridge University Press. Cambridge.

[34] See, for example, Wilson MA and Howarth RB (2002) Discourse-based valuation of ecosystem services: establishing fair outcomes through group deliberation. Ecological Economics, 41:431-443; Lo AY and Spash CL (2011) Articulation of Plural Values in Deliberative Monetary Valuation; Beyond Preference Economisation and Moralisation. Munich Personal RePEc Archive Paper No. 30002.

[35] Turner RK (2006) Limits to CBA in UK and European Environmental Policy: Retrospects & Future Prospects. CSERGE Working Paper EDM 06-17

[36] Marsh D (2010) Water Resource Management In New Zealand: Jobs or Algal Blooms? Presented at the Conference of the New Zealand Association of Economists Auckland 2 July 2010

example, identified studies that show the difference between community and individual values.

2.6 Implications and Benefit Transfer

In this section we have defined non-market values with reference to the TEV concept and explained how Māori values might differ. We have also set out why we are using monetary valuation to organise this information about relative values. The work under this study is not developing new (primary) data on values of water but is making use of results in existing studies. We use non-market values estimated at individual water bodies (study sites) to identify values that can be used more generally. This is known as the benefit transfer approach.[37] Sharp and Kerr define the role of the benefit transfer method as follows:

> *Despite lack of precision, benefit transfer is the only available indicator of non-market values in the absence of a site-specific study. It is an approach that is generally accepted as providing order of magnitude estimates of values that indicate whether further, site-specific valuation work is warranted.*

A summary of values taken from water valuation studies is included in Annex 2 of this report; this builds on a summary of values previously provided by Covec and others.[38] This list represents potential study sites for benefit transfer; the study sites that are used must be considered in terms of how closely their location, resource (including the presence of substitutes) and affected population match that of the policy site.

Sharp and Kerr[39] define three principal methods of transferring benefits from a study site to a policy site:

- direct transfer—the specific values are transferred;
- benefit function transfer—the valuation function is transferred;
- meta-analysis—where many study cases are available, regression analysis can be applied to the results to identify statistically the relationship between site attributes and value.

The direct transfer approach is the most crude yet the most readily applicable. It involves taking the mean values estimated at the study sites and applying them to the policy site – no adjustment is made to these values to reflect policy site characteristics.[40] For example, the estimated recreational value per visit from a study conducted at one New Zealand location could be directly applied to a visit in another catchment. To do so assumes that all factors of importance that determine that value are the same or very similar, eg. the aesthetic value of the site, the amenities that are present and the same or similar socio-economic characteristics.

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[37] Sharp B and Kerr G (2005) Option and Existence Values for the Waitaki Catchment. Report Prepared for Ministry for the Environment; Barbera M.G (2010) Benefit transfer approaches, Auckland Council
[38] Denne T, Scarpa R and Beville S (2011) Gap Analysis of Freshwater Economic Valuation Information. Report to Ministry for the Environment. Covec.
[39] Sharp B and Kerr G, op cit.
[40] Sharp B and Kerr G, op cit.

In contrast, the benefit function transfer and meta-analysis methods involve the transfer of a function (or equation) rather than a value. This equation would then be populated with local parameter values, eg. the value of a fishing trip might be a function of the number of fish in the river (and thus the chances of catching a fish), water visibility and some other aesthetic parameters. As such, these approaches are regarded as more accurate than a direct value transfer.

In practice the difference between direct transfer and benefit function transfer is not that clear; direct transfer may simply be transfer of a benefit function with a very simple functional form (equation). Thus what is transferred may sit on a continuum of complexity, depending on the existing understanding of the factors that determine value and the availability of input values to solve any equation.

In the next Section we bring together data in published studies that can be used as measures of the non-market values of water and water environments.

3 Values for Benefit Transfer

3.1 Marginal Values

In this section we identify values that might be used to apply to the Southland case study. The focus is on marginal values which are measures of how much total value changes as a result of a small incremental change in a factor affecting value. Because we are examining the effects of changes in water quality, which in some cases may be relatively small, the analysis focuses on how values change as a result rather than on total values.

As discussed above, this study is not undertaking primary research on the values of different uses of water in Southland. Rather it is using data that have been collated from other studies in other parts of New Zealand and is "transferring" these data to Southland. Before we examine the data from these New Zealand studies in Sections 3.3 and 3.4 below, we firstly discuss the relative size of non-market values as identified in international studies.

Annex 3 provides substantial detail on the identification of these values. We begin with a discussion of the relative magnitude of market and non-market values, consider the wealth of literature dealing with composite values, and conclude by exploring individual elements of TEV for benefit transfer.

3.2 Relative Values

A review of international water valuation literature, particularly that in which values have been applied to policy decisions, has identified a number of useful summaries. Below we present the findings of these studies as a way to identify the more significant values that have been identified elsewhere and to gain an understanding of the relative magnitude of non-market values compared to market values.

3.2.1 Water Framework Directive

Published in 2000, the EU Water Framework Directive (WFD) calls for all surface waters to achieve "good ecological status" except where the costs to do so are disproportionate to the benefits. Accordingly, the majority of cost-benefit analyses focus on improvements to water quality, estimating the total value of an improvement rather than each individual component of TEV.

Hanley et al[41] split "good ecological status" into ecology (fish, plants, insects & birds), aesthetics (litter & sewage), and river bank erosion. They found that willingness-to-pay for improvements from 'fair' to 'good' for each of these attributes were very similar across categories, averaging £12.50 for the River Wear and £46.6 for the River Clyde. Nocker *et al.* assessed the relative importance of benefits of the WFD (Table 3).

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[41] Hanley, N., Wright, R.E. & Alvarez-Farizo, B (2006) Estimating the economic value of improvements in river ecology using choice experiments: an application to the Water Framework Directive. Journal of Environmental Management 78: 183-193

Table 3 Summary values of the EU Water Framework Directive in three countries

Benefits of the WFD	UK	Netherlands	France
Use Values			
Avoided costs to water supply			28%
Formal recreation		16%	3%
Informal recreation	6%		
Fish	13%	-6%	
Amenity	24%	42%	
CO_2 storage, air quality	35%	33%	
Non-use Values			
Biodiversity/Bequest	21%	17%	9%
Protect Groundwater sources			60%
Total	**100%**	**100%**	**100%**

Source: Adapted from Nocker, L.D., Broekx, S., Liekens, I., Gorlach, B., Jantzen, J. & Campling, P. (2007) Costs and Benefits associated with the implementation of the Water Framework Directive, with a special focus on agriculture, Final Report. Study for DG Environment – Final Version

The key things to note are the significant contribution estimated for water ecosystems capture of CO_2 (sequestration) and capture of air pollutants. We are unaware of any studies that have assessed these benefits in New Zealand and they are not taken into account in calculating NZ's GHG emission commitments. Amenity values are an additional high value category, although the linkages between this and both informal recreation and bequest value are likely to be high; we discuss this further below.

A report published by the UK's Department for Environment, Food and Rural Affairs (Defra) summarised the present value of achieving the objectives of the WFD in England, Wales, Northern Ireland and Scotland. The relative size of the benefit from each river standard is presented in Table 4. This suggests a very different pattern of benefits, with over 50% of measured benefits being angling-related.

Table 4: Relative share of benefits for WFD river standards

Rivers Standard	Type of Benefit	Average Share of Benefits
Discharge of Oxidisable Material	Angling	25%
Acid	Angling	6%
Phosphorus	Non-use value	49%
Ammonia	Angling	19%
Water Resources	Environmental	Not possible to estimate
Morphology	Environmental	Not possible to estimate

Source: Adapted from Defra (2007) Draft partial regulatory impact assessment of environmental quality standards for implementation of the water framework directive in the UK.

As part of a cost-benefit analysis of implementing the WFD in the Netherlands, a comprehensive assessment of the benefits of improved water quality was conducted. Ruijgrok (2007) used a WTP for non-use values of €11/household/year for biodiversity, and €5/household/year for the bequest value for cleaner waters.

Table 5: Present Value benefits of the WFD in the Netherlands (€ million, 100 year period at 4%)

	Achievement of 'Good' Status					
	Limited		Substantial		Maximum	
Use Values						
Fishing	-86	-5%	-282	-6%	-948	-19%
Health for Bathers	2	0%	6	0%	17	0%
Recreation	254	15%	711	16%	873	17%
Amenity	704	42%	1,900	42%	2,309	46%
Regulation Functions (climate, air)	554	33%	1,496	33%	1,818	36%
Non-Use Values						
Biodiversity	265	16%	715	16%	869	17%
Bequest	0	0%	29	1%	78	2%
Total Values	**1,693**	**100%**	**4,575**	**100%**	**5,016**	**100%**

Not Accounted for: Clean Drinking Water, Agriculture, Flood Protection, Shipping, Food Safety.
Source: Ruijgrok (2007) in Nocker et al. (op cit)

Again we observe a substantially different split, with non-use values averaging around 17% of total value.

3.2.2 The United States

The US Environmental Protection Agency (EPA) used a meta-analysis of willingness-to-pay (WTP) studies to estimate the value of improvements in water quality at a national level. Benefits to navigation reflect the reduced cost of waterway maintenance arising from the removal of sediment build-up. Water storage capacity is similarly increased by the removal of sediment. Water treatment plants face lower costs for a reduction in sediment. These three avoided costs represent the market benefits of the effluent guidelines. Non-market benefits include recreation, fishing and biodiversity. The following table presents the range of estimated annual benefits:

Table 6: Annual Benefits of Water Quality Improvement (2008 US $million)

Benefit Category	Low	Mid	High
Navigation	$1-$3	$1-$3	$1-$3
Water Storage	$1-$3	$1-$4	$2-$4
Drinking Water	$1-$2	$1-$2	$1-$2
WTP	$56-$110	$210-$413	$430-$843
Total	**$59-$118**	**$214-$422**	**$434-$852**

Source: EPA (2009) Environmental Impact and Benefits Assessment for Final Effluent Guidelines and Standards for the Construction and Development Category.

Across all options and scenarios, the benefits to navigation average 1.1% of total monetised benefits, water storage 1.2%, drinking water 0.8%, and non-market WTP 97.0%.[42] Although these results are specified for an improvement in water quality, they indicate the scale of non-market water values at a national level for the US. The relative

[42] EPA was unable to quantify some additional benefits such as improved market values of nearby properties, benefits to fishing, and reduced cost of flood damages.

composition of water values in Southland will differ, mostly due to the increased significance of water in agriculture.

Johnson et al. (2003) conducted a meta-analysis on 20 studies which distinguished use and non-use values for improvements in water quality in the US.[43] They found that a $1 increase in use values is associated with a 0.67% increase in non-use values, indicating that an increase in use of a water resource enhances non-use values.

Clearly, the proportion of estimated non-use values varies wildly, with values between 16% and 69% in the studies surveyed. For studies which assessed similar components of value for changes in water quality, we averaged the relative proportions of use and non-use values and obtained the relative proportions shown in Table 7.

The proportion of non-use to use values will depend on a number of factors, such as the number of households nearby, its popularity for recreation, and any industrial uses. However, it is unlikely that using a fixed percentage of use (or market) value is a useful or accurate way to estimate non-use and/or non-market values.

Table 7: Relative components of TEV

Values	Share of TEV
Use:	
Recreation	12%
Fish	-5%
Amenity	42%
CO_2 Storage, Air Quality	34%
Non-Use:	
Biodiversity	16%
Bequest	1%

3.3 Absolute Values

Annex 3 reviews a number of studies that have produced values for specific uses of water. We summarise the key results here.

3.3.1 Composite Values

In the literature review it is clear that people have difficulty in distinguishing different components of TEV, and with a shift towards greater use of choice modelling, survey questions have tended to ask people their values for changes in a composite of water quality attributes. Such work is especially common for estimates of household WTP for cost-benefit analysis under the WFD.[44]

[43] Johnston RJ, Besedin EY & Wardwell R F (2003) Modeling relationships between use and nonuse values for surface water quality: A meta-analysis. *Water Resources Research* 39 (12): 1-9

[44] See for example, Hanley N, Colombo S, Tinch D, Black A & Aftab A (2006) Estimating the Benefits of Water Quality Improvements under the WFD: are Benefits Transferable? European Review of Agricultural Economics 33 (3): 391-413, HanleyN & Black AR (2005) Cost-Benefit Analysis and the Water Framework Directive in Scotland. Integrated Environmental Assessment and Management 2 (2): 156-165. Bateman, IJ, Brouwer R, Davies H, Day BH, Deflandre A, Di Falco S, Georgiou S, Hadley D, Hutchins M, Jones AP, Kay D, Leeks G, Lewis M, Lovett AA, Neal C, Posen P, Rigby D, Turner RK and

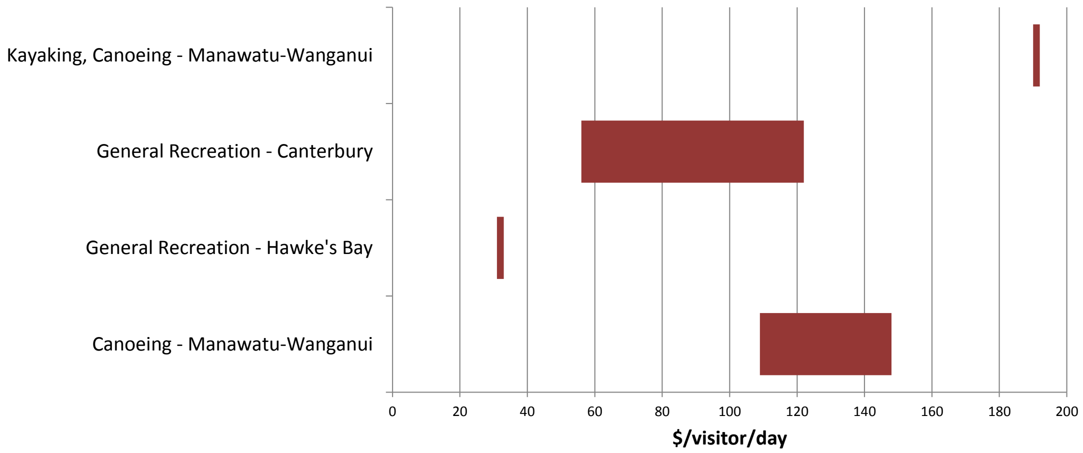
A common approach for valuing improvements in water quality is to conduct surveys which ask respondents their WTP for various 'bundles' of attributes, such as an improvement from poor to moderate in the categories of clarity, biodiversity, and bankside vegetation.

While combined values may be useful for estimating TEV, some issues arise when attempting to identify specific values for elements of TEV. First, combined values often estimate a specific subset of TEV, which may overlap with the individual values identified above. This makes benefit transfer from combined values difficult. Also, combined values are typically estimated for a marginal change in water quality, and therefore ignore values which are independent of water quality.

3.3.2 Recreation Values

Table 8 presents a summary of the recreation values identified for fresh water bodies in New Zealand.

Table 8: Recreation values in New Zealand (2012 dollars)



Sources: Meyer (1994), Cocklin, Fraser & Harte (1994), Harris & Meister (1981) & Sandrey (1986).

According to Kerr (2003), the highest value here ($190/visit) is from a study that has been discredited. We use the range of values to $148/visit only.

Although caution is required when using these site-specific values for benefit transfer, we consider these results transferable in the absence of more suitable studies.

The key driver of recreational benefits is the quality and quantity of water for swimming and boating. When we conduct our scenario analysis in Section 4, we consider changes in water quality (clarity, *E. coli* levels) on the number and value of recreational uses (the scenarios studied do not vary in quantity). The following values (Table 9) are suitable for use in benefit transfer.

Kerry R (2006) Analysing the Agricultural Costs and Non-Market Benefits of Implementing the Water Framework Directive. Journal of Agricultural Economics 57 (2): 221-237

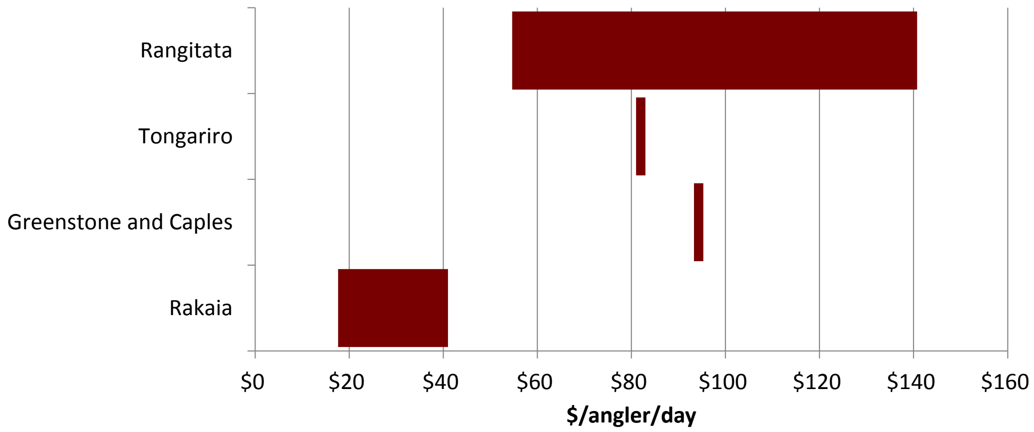
Table 9 Recreational Values for Benefit Transfer

Value	Value (Range)	Unit
Recreational visit	$56 ($31-$122)	Per visit
Visibility for recreation	$82	Per 4m change in clarity ($0 for less than 4m)
Change in water quality from non-swimmable to swimmable	$43	Per household
Canoeing/Kayaking	$129 ($109-$148)	Per visit

Fishing

New Zealand's trout and salmon fishing is world-renowned. A survey of studies on the value of sport fishing yielded the range depicted in Figure 6

Figure 6 New Zealand recreational fishing values



Sources: Table 30 Recreational fishing values.

The range of values is relatively large ($18 to $141/angler /day); given the absence of site-specific values for Southland rivers, values at the low end of the range might be the *most* appropriate to use for benefit transfer as we are more confident that these represent a value of fishing as opposed to any values of the location.

Caution is required when transferring these values to other rivers, as values did not correspond well with quality of fishing ratings. Alternatively, we can consider the site-specific components of total fishing value. The results from Beville & Kerr's (in prep) study of site-specific preferences are presented in Table 10.

Using the generic 2012 values, we obtain the following possible fishing values for benefit transfer (Table 11).

Table 10: Impact of marginal changes in site-specific factors on fishing values (mean WTP) at North Canterbury Rivers ($/angler/day) – 2008 values (Dec 2012 values in parentheses)

Parameter	Generic	Mainstem-braided	Back-country	Lowland	Lake
Improved water visibility (1m)	8.86 (9.74)	17.85 (19.62)	13.06 (14.36)	10.77 (11.84)	10.26 (11.28)
Bag limit (1 more trout)	31.64 (34.78)	36.61 (40.24)	55.81 (61.35)	30.67 (33.71)	34.84 (38.3)
Catch rate (1 more trout)	18.39 (20.21)	23.29 (25.6)	36.51 (40.13)	21.77 (23.93)	16.98 (18.66)
Trout size (per lb)	28.81 (31.67)	43.66 (47.99)	56.13 (61.7)	27.56 (30.29)	25.26 (27.77)
Didymo present	-43.28 (-47.57)	-66.33 (-72.91)	-65.62 (-72.13)	-41.07 (-45.14)	-46.79 (-51.43)

Source: Beville SB & Kerr G (in prep) Site-specific Preference Heterogeneity and Recreational Angler Site Choice: A Case Study; Stephen Beville, pers. comm.

Table 11 Fishing values for benefit transfer

Value	Value (Range)	Unit
Fishing Visits	$27 ($18-$41)	Per visit
Visibility for Fishing	$10 ($10-$20)	Per 1m improvement per visit
Trout Catch	$20 ($19-$40)	Per trout caught per visit
Size of Trout Caught	$32 ($28-$62)	Per lb of trout per trout caught

3.3.3 Aesthetics and Amenity

Aesthetic value is an expression of what people value about the environment in terms of its appeal to their senses; this might include the look, sound, smell, taste or feel of a location, and in this case, a water body. Amenity values are the characteristics of an area that contribute to the appreciation of its pleasantness. It is difficult to isolate amenity values, as they commonly modify the value of more direct uses. For example, the benefit a swimmer derives from a water body depends on amenity attributes such as clarity, odour, and pollution levels. We assume that amenity is taken into account in the factors considered under recreation (above) and existence value (below).

3.3.4 Existence and Option Values

Studies of existence and option values commonly consider changes in water quality and therefore measure include aesthetic, amenity, option, and existence values. Existence values identified in Sharp & Kerr (2005) are presented in Table 12.

As there is no clear way to distinguish Southland households into users and non-users, we consider an average of the all category for the Waimakariri and Rakaia rivers to be a transferable existence value. This is equal to $53 per household per year to avoid a development occurring that would harm the river, with low and high values of $47 and $56 respectively.

Table 12 Existence Values ($/household/year) (December 2012 values)

Value		Waimakariri	Rakaia	Waikato	Ashburton
Preserve or stop development	All	47-53	54-56	118	89
	Users	57-65	97		
	Non-users	15-19	32		
Improve water quality (eliminate health risk to recreational users)	All	43			
	Users	51			
	Non-users	18			

Source: Original (December 2003) values taken from Sharp B and Kerr G (2005) Option and Existence Values for the Waitaki Catchment. Report prepared for Ministry for the Environment.

We do not have values expressed by people in other parts of New Zealand for the existence value of these Canterbury (or any other) rivers. However, it is likely that people elsewhere do obtain an existence value for Southland water bodies. This has been most clearly expressed historically in the protests over the development of the Manapouri Hydro Scheme, and in the decisions to introduce national Water Conservation Orders for:

- the Oreti river, recognising its habitat for brown trout, angling amenity, habitat for black-billed gulls and significance in accordance with tikanga Māori; and
- Mataura river, for its outstanding fisheries and angling amenity features.

Table 13 Existence values for benefit transfer

Value	Value (Range)	Unit
Change in water quality from non-swimmable to swimmable	$43 ($18-$51)	Per household per river improved
To preserve or stop development	$53 ($47-$56)	Per household per river

3.4 Values for Transfer

In Table 14 we summarise the potential values identified for benefit transfer. Section 4 of this report uses these values in a scenario analysis of changes in water quality for Southland.

In Section 4.5 we estimate the value of five scenarios for changes in water quality. Due to the range of values identified, we construct Low, Medium and High ranges using the upper and lower values in the literature discussed above and in Annex 3. Values for domestic fishing are reversed (the low scenario uses the largest value) as improvements in water quality result in less fishing days – reducing value for fishing while other activities are increasing in values. We do not use values for additional trout catch or additional trout weight as data on these variables could not be obtained. The value of water clarity for recreation was ignored as changes in water visibility were less than 1m. Changes in water quality from non-swimmable to swimmable were valued in terms of per-visit benefits for recreational users, and not as an existence value at a per-household level, as this would have resulted in counting this value twice.

Table 14 Possible Values for Benefit Transfer

Value	Value (Range)	Unit
Fishing Visits	$27 ($18-$41)	Per visit
Visibility for Fishing	$10 ($10-$20)	Per 1m improvement per visit
Trout Catch	$20 ($19-$40)	Per trout caught per visit
Size of Trout Caught	$32 ($28-$62)	Per lb of trout per trout caught
Recreational visit	$56 ($31-$122)	Per visit
Visibility for recreation	$82	Per 4m change in clarity ($0 for less than 4m)
Change in water quality from non-swimmable to swimmable	$43	Per household
Canoeing/Kayaking	$129 ($109-$148)	Per visit
Change in water quality from non-swimmable to swimmable	$43 ($18-$51)	Per household per river improved
To preserve or stop development	$53 ($47-$56)	Per household per river

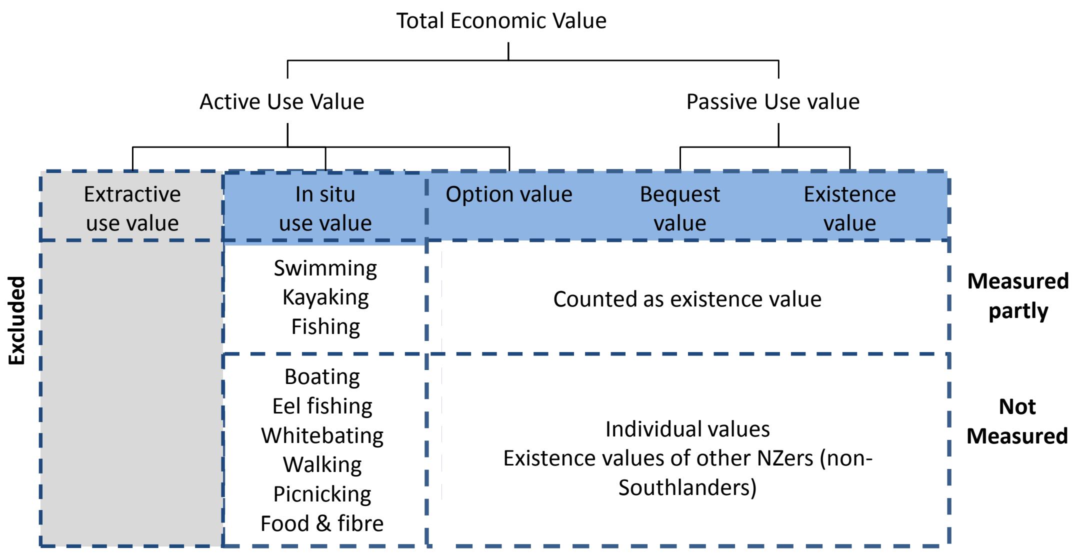
Table 15 Range of Values Used in Analysis

Input	Low	Med	High
Value of Water Clarity ($/1m visibility improvement/angler visit)	$10	$10	$20
Value of Domestic Fishing ($/angler-day)	$41	$27	$18
Value of Swimming Visit ($/visit)	$31	$56	$122
Value of Kayaking Visit ($/visit)	$109	$129	$148
Existence value ($/regional household for prevented development)	$47	$53	$56

3.5 Limitations and Missing Data

Looking back to the TEV diagram (Figure 2), there are a number of components that are not measured or only partially measured because of missing data (Figure 7).

Figure 7 Components of TEV that are measured



Extractive use values are included in other studies, and specifically the NZIER analysis of impacts on agricultural production. We have estimated values for some recreational uses of water bodies, and specifically fishing, kayaking and swimming, but have not provided values for others including whitebating (although these might be similar to those for fishing), boating (including water-skiing, jet-skiing etc) or walking, picnicking and other activities beside water bodies.

Option values are not included, but following on from Sharp and Kerr, we have not attempted to differentiate between option and existence value, or between existence values and bequeath values.

Existence values are counted for Southlanders based on values expressed by Canterbury households for preventing development of rivers in Canterbury. We do not have estimates of values expressed by people in other regions.

We have not identified separate values for Māori. Some of these may be included already in proportion to Māori's contribution to the total population in the original studies that were based on public surveys, but we do not have separate values for Māori, eg. for existence value.[45] To fully understand Māori values and their contributions to Māori value of water, further research with Tangata Whenua is required.

There are a number of limitations that result from the benefit transfer process. In particular, the rivers are not the same as those at the study sites from which the values have been obtained, and the communities are different also. The results are based largely on values obtained from stated preference studies that often suffer from hypothetical bias in which people over-state their willingness to pay compared with what they would actually pay.

We have also not analysed any impact on New Zealand's reputation for its pristine environment as a result of these impacts.

[45] We note that some studies would suggest that Māori would have higher values, despite lower incomes. See: Awatere S (2005) Can non-market valuation measure indigenous knowledge. Presented to Australian Agricultural and Resource Economics Society 2005 Conference (49th), February 9-11, Coff's Harbour, Australia

4 Case Study Analysis: Southland

4.1 Overview

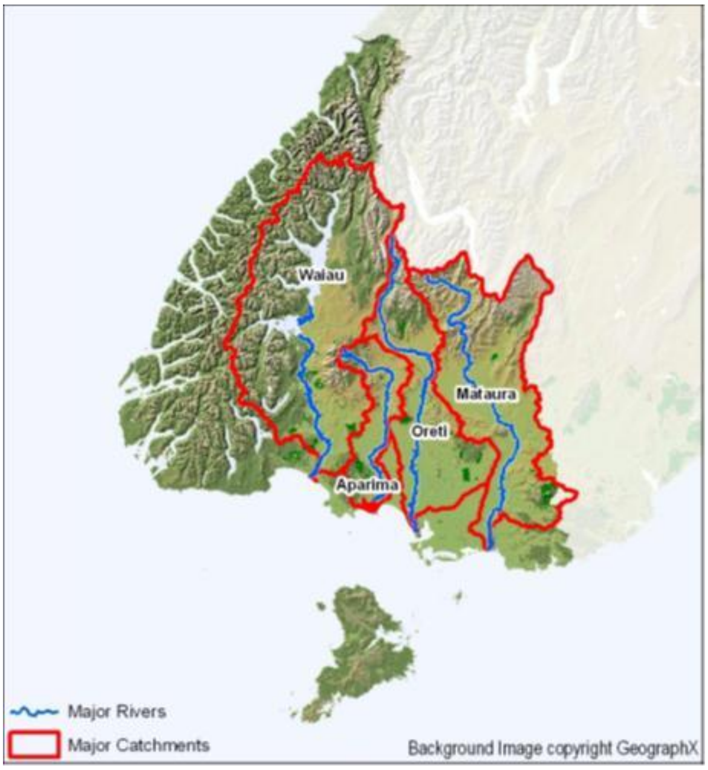
Southland is being used as a case study region in this and other related reports. We use the generic valuation data discussed above and, taking account of local information about water bodies and their current uses, we apply the data to a regional analysis of effects. The different components discussed below are:

- A summary of local information on Southland water bodies and their uses;
- scenarios of changes in water quality that we have taken from analysis by other researchers;
- analysis of the impacts of changes in water quality on attributes of water bodies that enable the values to be realised;
- compilation of these three sets of data with the values summarised in Section 3, to estimate changes to total (non-market) value.

4.2 Uses of Southland Water Bodies

In this section we summarise the baseline data on water bodies in Southland and their uses. Southland is drained by four major river catchments – the Waiau, Aparima, Oreti and Mataura catchments (Figure 8); they are described further in Annex 4.

Figure 8 Southland Catchments



Source: www.southlanddc.govt.nz/assets/2011/District-Plan-Review/Water-Quality-Full-Paper.pdf

4.2.1 Cultural Use

Cultural use is a term used to describe the wide range of ways in which Māori interact with, and as part of, water bodies. [46] However, we include the importance discussion of the importance of water and water bodies to the wider community below.

Water and water quality issues are increasingly important to Southlanders, and a recent survey of quality of life issues in Southland found that the three environmental issues of most importance were "dairy farming/effluent/polluting rivers" (45% of respondents), water quality (13%) and river waterway pollution (8%).[47] Southlanders were also asked to rank issues in terms of their importance on a scale of 1 (least important) to 5 (most important). Quality of water was 5th placed with a ranking of 4.7 out of 5, whereas the environment in general (an environment we care for) had a rank of 4.5. Ability to go hunting and fishing had a rank of 3.5, relatively high given that these activities are dominated by one half of the population – males.[48]

Water is particularly important to Ngai Tahu as tangata whanua of Southland and relationships to it provide cultural identity. As Tipa notes, "*Physically and culturally waterways have defined the lives of whānau and hapū in the Southland region*."[49] Harvests of resources such as kanakana (lamprey) and titi (muttonbirds) are traditions that have been handed down through the generations from first settlement.[50]

Ngai Tahu maintain a strong sense of community, and continue to identify themselves with a specific location; water bodies are an important part of that. These associations can remain even after an entire family has moved away from its whānau lands and community. Mahinga kai (traditional food) has been the primary food and basis of the economy of Ngai Tahu for many years. Food collection provides healthy food, exercise and is an integral part of daily life, and kai holds great cultural and social meaning. Traditions of management and gathering were and continue to be part of a knowledge base that is was passed down to future generations. Mahinga kai activities are at the heart of Ngai Tahu culture. Consistent with this, losses of mahinga kai result in a loss of cultural identity.[51]

4.2.2 Recreational Use

There is no comprehensive database of recreational use or activity in Southland, but we discuss identified sources in Annex 4. Using these sources we provide estimates in Table 16 of the number of visits (recreational days) to the largest categories of activity and a selection of other categories of water-related use, including fishing, swimming and kayaking. The data are not broken down by location within Southland, although we can assume that the scenic boat cruises are very largely at Milford Sound and Doubtful

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[46] Research First (2010) Our Way Southland. Quality of Life Research Report.
[47] Research First (2010) Our Way Southland. Quality of Life Research Report.
[48] NIWA assumes that 90% of anglers are male (Unwin M (2009) Angler usage of lake and river fisheries managed by Fish & Game New Zealand: results from the 2007/08 National Angling Survey. NIWA Client Report: CHC2009-046 Prepared for Fish & Game NZ Ltd. NIWA.)
[49] Tipa G (2011). Our Uses: Cultural Use in Murihiku. Report prepared for Environment Southland. p4
[50] Environment Southland (2010) Our Uses. Southland Water 2010: Part 3
[51] Tipa G (2011). Our Uses: Cultural Use in Murihiku. Report prepared for Environment Southland

Sound (these data do not include cruise ships that enter Milford Sound from the sea). We note that MfE has identified the following water bodies in Southland as potentially of national importance with respect to recreation: Lake Manapouri, Lake Te Anau, Hollyford River, Mataura River, Waituna Creek and wetlands, and the Titiroa River.[52]

Table 16 Average annual visits (days) to and within Southland by activity and origin of visitor

	Southland	Other NZ	Overseas	Total
Fishing Lake	57,152	6,153	6,022	69,326
Fishing River	56,588	17,449	11,066	85,104
Kayaking River	10,825	10,877	1,533	23,235
Other Water Activities	35,797	1,360	5,284	42,441
Swimming	62,245	12,576	7,394	82,215
Waterfalls	1,652	8,653	48,390	58,694
Wildlife	31,324	17,590	90,178	139,093
Walking, tramping	191,147	127,803	582,101	901,051
Sightseeing	223,299	217,752	475,778	916,830
Scenic Boat Cruises	8,530	52,429	402,101	463,060

Source: Domestic Travel Survey & International Visitor Survey, Ministry of Business, Innovation and Employment, plus Covec adjustments (see Annex 4).[53]

By visit numbers, the largest recreational activities in total are sightseeing and walking/tramping, but the data do not isolate those that are related to water. Many are likely to be in Fiordland National Park, away from the areas in which there is most conflict over water use. Amongst water uses, lake and river fishing dominates, with a total of over 150,000 days, chiefly by Southlanders. Swimming is also popular; the data do not isolate whether this includes swimming pools, but we would expect that few people would travel over 40km to go to a swimming pool. Other water uses include kayaking and a category of “other water activities”.

Specific data that are missing that we know to be important in Southland include whitebaiting. According to the Southland Whitebaiters Association there are probably 600-700 whitebaiting stands in Southland,[54] which will be used many times per year. However, although we might use these data in analysis (including estimating total days), as discussed below, we do not currently have data that relate changes in water quality to changes in whitebait numbers. The Association is not aware of any noticeable impact to date.

Fishing

Estimates of angler days are provided from a national angling survey that was undertaken most recently in 2008 (Table 17), compared with the average annual numbers shown in Table 16.

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[52] MfE (2004) Water Programme of Action Potential Water Bodies of National Importance. Technical Working Paper.

[53] The data are largely taken from the Domestic Travel Survey (DTS) which only records visits for which people have travelled 40km or more in one direction. We have scaled up these data to estimate visits by Southlanders using the ratio between the estimates of angler trips in the DTS and in the national angler survey (we have assumed this ratio is the same across all recreational activities).

[54] Brett Pearce, personal communication

Table 17 Number and Origin of Anglers in Southland (2008 data)

Location	Number ('000)	%
Southland	113,740	74%
Other South Island	20,770	14%
North Island	1,570	1%
Overseas	17,460	11%
Total	153,540	100%

Source: Unwin M (2009) Angler usage of lake and river fisheries managed by Fish & Game New Zealand: results from the 2007/08 National Angling Survey. NIWA Client Report: CHC2009-046 Prepared for Fish & Game NZ Ltd. NIWA.

4.2.3 Ecosystem (Existence) Values

The natural attributes of rivers and their ecosystems are valued by people in and outside of Southland; they include those that visit and those that do not. The ecological values that are threatened by changes in water quality are:

- Aesthetic values of the rivers that affect visitor numbers and values of visits for recreational use;
- Ecosystem health and thus the existence value of these ecosystems as natural systems;
- Specific species and habitats which are valued. This includes fish species, in particular, although Southland is not unique in its list of threatened species.

The existence values that we have identified (Section 3.4) are based on values of regional households for specific rivers. We might assume that these apply to the existence value of the major catchments in Southland; we discuss this further below (Section 4.5.2).

4.3 Physical Impacts

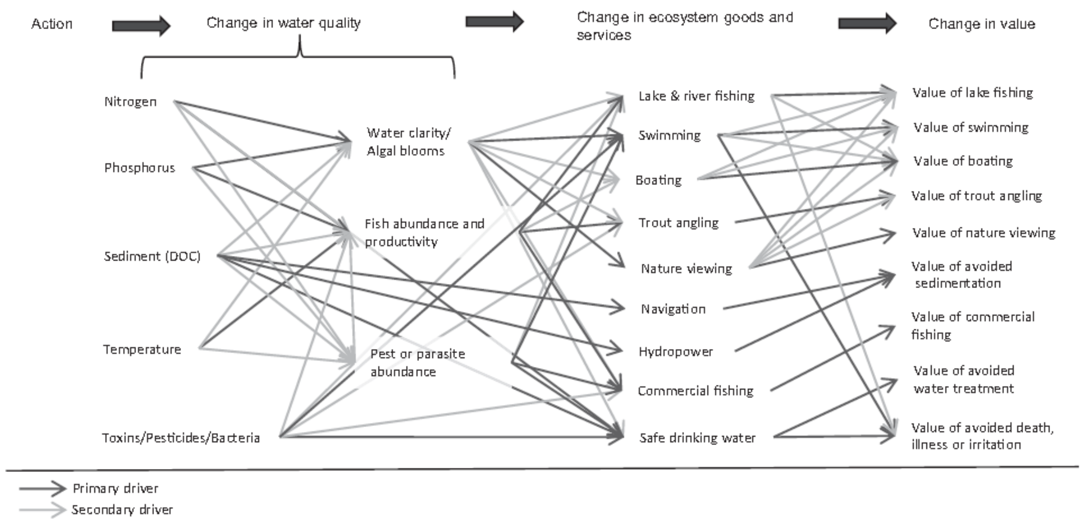
Before the changes in water quality can be converted into changes in the values associated with water, there is a need to estimate a number of additional physical impacts. This reflects the series of relationships that determine the impacts of water quality changes on changes in values, as depicted in an example in Figure 9

Analysis of these physical changes has been undertaken by Ian Jowett (Jowett Consulting) and is included in Annex 5.

In Section 4.4 we include scenarios of water quality changes for 73 separate reaches and/or water bodies. These scenarios are expressed in terms of predictions for total phosphorus (TP), total nitrogen (TN), and *E. coli* for the set of rivers in response to a number of policy scenarios (limits on N and P). In Annex 5, Ian Jowett has developed quantitative relationships that can be used to predict the effects of changes in those factors on:

- water clarity;
- adult trout numbers; and
- benthic invertebrates.

Figure 9 Relationship between changes in water quality and change in values



Source: Keelera BL, Polaskya S, Braumana KA, Johnsond KA, Finlayc JC, O'Neille A, Kovacsf K and Dalzellg B ()Linking water quality and well-being for improved assessment and valuation of ecosystem services. PNAS, 109(45): 18619–18624.

These predictions cannot be precise in absolute terms because data on the many factors controlling these variables are either lacking or are estimated from other parameters that are known. However, when averaged over all sites, they will enable the relative changes between development scenarios to be evaluated.

Below we set out a number of factors analysed in developing these physical relationships and then list a set of equations that capture these.

4.3.1 Periphyton

Periphyton is a necessary component of the food chain in rivers. Benthic macro-invertebrates feed on periphyton and native fish and trout feed on macro-invertebrates. An increase in periphyton is beneficial to the fish and trout because it increases benthic invertebrate biomass. However, dense growths of filamentous algae can change the composition of the benthic invertebrate community and is an annoyance to river users because they consider it unsightly and slippery and it can become entangled in anglers' lures.

Periphyton accumulation is controlled primarily by the frequency and magnitude of floods and freshes. Both nitrogen and phosphorus are necessary for the growth of periphyton and the rate of growth increases as the concentration of these nutrients increase. Thus nutrients will increase the rate of accrual and will reduce the time taken to reach nuisance levels after a flood or fresh. Periphyton growth rates also depend on water temperature with low growth rates during the winter and high growth rates during the summer.

4.3.2 Macroinvertebrate Community Index (MCI)

Benthic invertebrate community composition is influenced by water depth and velocity, flow regime, algal biomass, sediment deposition and water quality.

Stark[55] developed an index of benthic community composition, the MCI macroinvertebrate community index. This index is used as a measure of stream "health" and is calculated as the sum of scores for invertebrate taxa. Invertebrates common in unpolluted streams are given high scores and invertebrates common in polluted streams are given low scores. Scores of more than 100 are considered indicative of a healthy stream.

4.3.3 Benthic Invertebrates

Benthic invertebrate biomass is affected by flow, instream habitat, algal biomass, substrate size and sediment movement. Benthic invertebrates feed on periphyton and organic detritus on the stream bed. Total benthic invertebrate biomass is probably the most important factor influencing brown trout density. Predictions of the effect of water quality changes on total benthic invertebrate biomass could be used to predict changes in trout density.

4.3.4 Brown trout

The main factors affecting trout density are habitat suitability, food supply, cover, water temperature, and river and catchment characteristics. An important outcome is that increased nutrient discharges to rivers will increase river productivity, the quantity of food and fish (trout) numbers.

This combined with analysis that shows a link between fish numbers and fishing days means that reductions in nutrient discharges to water will tend to reduce fish numbers and the number of fishing days and hence the value of fishing. This result has led to some questions amongst researchers about the extent to which this relationship continues across a broad range of outcomes or if there is some kind of threshold above which fish numbers deteriorate with nutrients. We discuss this below.

Thresholds

Jonsson et al. note that "it is generally accepted that nutrient enrichment increases fish production".[56] However, anecdotal evidence from anglers is that increasing levels and intensities of dairy farming have been detrimental to fish availability and angling quality; this was one result of a survey undertaken by NIWA for Fish & Game New Zealand (FGNZ) between December 2000 and June 2001.[57] FGNZ was concerned that many fisheries were becoming increasingly degraded. The survey reported angler comments regarding the likely causes of this degradation, but the authors note that

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[55] Stark JD (1985). A Macroinvertebrate Community Index of water quality for stony streams. Water and soil miscellaneous publication No. 87, National Water and Soil Conservation Authority, Wellington. 53p.

[56] Jonsson B, Jonsson N and Ugedal O (2011) Production of juvenile salmonids in small Norwegian streams is affected by agricultural land use. Freshwater Biology, 56: 2529-2542.

[57] Jellyman DJ, Unwin MJ and James GD (2003) Anglers' perceptions of the status of New Zealand lowland rivers and their trout fisheries. NIWA Technical Report

attempts to corroborate the survey findings using more quantitative data were generally unsuccessful.

Tony Hawker of North Canterbury Fish and Game comments on the impacts of land development on fish numbers in a number of rivers in Canterbury.[58] He notes deteriorating trout numbers relating to increased intensity of land use, but his comments suggest that the major impacts relate to sediment discharge and siltation. For example, he notes with respect to the Cam, a tributary of the Kaiapoi River that it has seen a significant downturn in angler use and that the "*reason for the downturn is obvious for anyone who visits the river. The Cam is now severely degraded from stock access and intensified landuse. The substrate is clogged with silt and the water clarity is seldomly clear enough for site fishing*." These are different impacts from the changes modelled here.

A New Zealand study that examined the impact of catchment development levels on benthic invertebrate numbers[59] suggested that catchment development, measured as the percentage of the catchment developed to improved pasture, resulted in an increase in invertebrate biomass without changing the community type. This result occurred up to approximately 30% of catchment development, but above this level there appeared to be a reduction in overall species diversity and a switch in the species that dominated. The authors examined the likely impact on trout and suggested that total trout biomass was lower in the rivers in more highly developed catchments (>30% development and with a median in their sample of 70%), although they also suggested that the significance of the results was limited by the small number of rivers in these categories.

A study in Finland similarly found that increasing the intensity of agriculture (measured as the percentage of a catchment used for agriculture) was correlated with reducing numbers of some fish species and increases of others.[60] They note that brown trout did not respond strongly to the intensity of agriculture, although they comment that stocking of brown trout may have influenced the results. They suggest that reduced oxygen saturation of river water and increased sedimentation of the spawning gravels are the key mechanisms transmitting the effect of agriculture on trout populations.

A Norwegian study of 12 streams sought to identify some of the individual factors that might be responsible for effects on fish (trout) production.[61] Some of the results are shown in Figure 10, including the fitted curves. The authors suggest that brown trout production reflected a dome-shaped relationship between the percentage of agricultural land and the concentration of nitrogen and calcium in the water: there was an optimal level of agricultural production (approximately 20% of the catchment in agriculture) and

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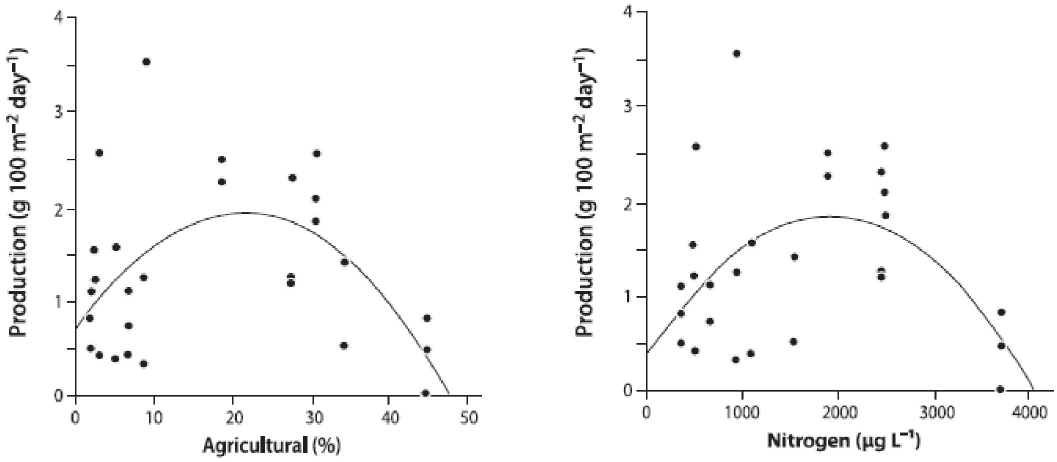
[58] Evidence in Chief of Tony Hawker on Behalf of Nelson/Marlborough, North Canterbury and Central South Island Fish and Game Councils Before the Independent Commissioners in the Matter of the Resource Management Act 1991 and in the Matter of the Proposed Canterbury Land and Water Regional Plan. 8 April 2013.
[59] Quinn JM and Hickey CW (1990) Magnitude of effects of substrate particle size, recent flooding, and catchment development on benthic invertebrates in 88 New Zealand rivers. New Zealand Journal of Marine and Freshwater Research, 24:411-427.
[60] Sutela T and Vehanen T (2010) Responses of fluvial fish assemblages to agriculture within the boreal zone. Fisheries Management and Ecology, 17: 141-145.
[61] Jonsson B, Jonsson N and Ugedal O (2011) Production of juvenile salmonids in small Norwegian streams is affected by agricultural land use. Freshwater Biology, 56: 2529-2542.

of nitrogen in the water (2.4mg/litre), above which trout production fell. However, the shape of the assumed relationship appears to be highly uncertain and is significantly influenced by three data points that are from a single stream. A visual scan of the data would suggest that removing the data from this one stream would significantly affect the results and the assumed shape of the curve.

Figure 10 Factors affecting Trout production – agricultural intensity and N concentration



Source: Jonsson B, Jonsson N and Ugedal O (2011) Production of juvenile salmonids in small Norwegian streams is affected by agricultural land use. Freshwater Biology, 56: 2529-2542.

However, even if the result is correct and the relationship does follow this inverted-U, then the impacts of reducing nutrient inputs are still uncertain: reducing nutrient inputs is beneficial for rivers with high current levels of nutrients, but beyond a certain level it is detrimental.

Hay et al[62]expressed an opinion that the four key parameters for the protection of adult trout are water temperature, dissolved oxygen, water clarity and food (represented by the MCI). They note that, although higher densities of invertebrates (potential trout food) may be associated with high algal biomass, there is evidence that these invertebrates may not be as readily available to drift feeding trout. But they also note that trout are visual predators and that drift feeding is the predominant foraging behaviour in most rivers. Because of this, increased turbidity would be expected to have an adverse effect on trout because it reduces their foraging radius and efficiency. Increased turbidity did not reduce daily food consumption levels, but more energy was expended in finding the food so growth rates are reduced.

The literature suggests that there is evidence of a relationship between agricultural intensity and fish abundance, but that the mechanisms that affect this are not certain. We use the relationship developed by Jowett as our base case for analysis, but in sensitivity analysis we ignore the impacts on fish numbers, as discussed in Section 4.5.1 below.

[62] Hay J, Hayes J and Young R (2006) Water Quality Guidelines to Protect Trout Fishery Values. Report Prepared for Horizons Regional Council. Cawthron Report No.25.

4.3.5 Equations

Ian Jowett's work suggests that:

- an increase of nutrients will cause an increase in the rate of growth of periphyton (dependent on the concentrations of N and P);

- an increase in periphyton will
  - increase benthic invertebrate biomass and trout densities;
  - will decrease MCI and stream "value" for recreational users, primarily through a reduction in water clarity.

The analysis enabled the definition of three equations (Box 2) that we use to predict:

- water clarity;
- benthic invertebrates as a measure of ecosystem health; and
- adult trout numbers.

Box 2 Equations Used to Predict Physical Effects

Water Clarity

$Log_{10}(\text{Water clarity}) = -0.596 \times Log_{10}(\text{Particulate phosphorus}) -0.990$

Benthic Invertebrates

$MCI = -284.66 \times \text{Total phosphorus} - 9.21 \times \text{Total nitrogen} - 0.078 \times Chla + 127.10$

Trout Numbers

$\text{Number of large and medium trout per km} = 7.982 \times \text{Mean flow}^{0.466} \times (\exp(0.774 \times MALF^{0.313} + 3.891 \times TKN + 0.525) -1)$

Where:

Water clarity =	black disc visibility (the sighting distance in metres of a black disk placed underwater)
Particulate phosphorus =	total phosphorus minus dissolved reactive phosphorus (both as concentrations in mg/l)
Total phosphorus =	concentration in mg/l
Total nitrogen =	concentration in mg/l
Chla =	a measure of periphyton concentration as chlorophyll a in mg/m^2
Mean flow =	measured in m^3/second
MALF =	Mean Annual Low Flow in m^3/sec
TKN =	Total Kjeldahl Nitrogen = total nitrogen (TN) minus Nitrate-N and Nitrite-N.

4.4 Scenarios of Water Quality Changes

To assess the impacts of limits on water quality and quantity we analyse a number of scenarios for 73 separate freshwater sites in Southland. These are the results of modelling by NIWA and Aqualinc. This is an important limitation to the study, particularly as nutrients will tend to accumulate in estuaries.

Table 18 below shows:

- the N and P limits assumed in the modelling under the different scenarios;
- the expected land use responses; and
- the water quality outcomes for a number of parameters that correspond to the factors we include in the equations discussed above (and summarised in Box 2).

The results are shown for current (modelled) levels, and for five scenarios of outcomes in 2037: a baseline scenario (A) and scenarios that result in different responses that include on-farm mitigation (B, C and D) and land use change away from dairy farming (E). The modelled water quality outcomes represent an average of the levels at 73 separate stretches of river and other water bodies in Southland.

Table 18 Scenarios of Average Water Quality Parameters for Southland Water Bodies

			2037 Scenarios				
Parameter	**Unit**	**Current**	**A**	**B**	**C**	**D**	**E**
Limits and on-farm response							
N limit	(kg/ha)		60	45 - 60	45 - 60	30	15
P limit	(kg/ha)		1.5 - 2	1 - 2	0.5	0.5 - 2	0.5 - 2
Response			Baseline - no change	64% of farms mitigate	100% of farms mitigate	Stronger mitigation	No dairy
Modelled Water Quality Outcomes							
Total Phosphorus	TP(mg/l)	0.04	0.04	0.03	0.03	0.03	0.02
Dissolved Reactive Phosphorus	DRP (mg/l)	0.01	0.02	0.01	0.01	0.01	0.01
Particulate Phosphorus	PP (mg/l) = TP - DRP	0.02	0.02	0.02	0.02	0.02	0.01
Ammonium-Nitrogen	NH_4N (mg/l)	0.02	0.03	0.02	0.02	0.02	0.01
Nitrate-Nitrite Nitrogen	NNN (mg/l)	1.05	1.22	1.17	0.95	0.89	0.58
Total Nitrogen	TN (mg/l)	1.19	1.38	1.33	1.08	1.01	0.68
Nitrate Nitrogen	NO_3N (mg/l)	0.76	0.90	0.86	0.70	0.65	0.43
Total Kjeldahl Nitrogen (TKN)	TKN (g/m^3) = TN – NO_3N	0.43	0.48	0.47	0.38	0.36	0.25
Algal Biomass (chla)		55	56	54	50	50	47
E Coli	(Median/ 100ml)	317	287	241	259	268	264
Other input data							
MALF	m^3/s	9	9	9	9	9	9
Mean Flow	m^3/s	31	31	31	31	31	31

Source: limits – MfE; Modelled outcomes and other input data – Ton Snelder, Aqualinc (personal communication)

The modelling has been limited to river sites rather than other water bodies, such as lakes and estuaries.

Table 19 summarises the percentage changes in key parameters. For Scenario A this shows the change in the baseline between 2012 and 2037; for the other Scenarios the change is relative to Scenario A (in 2037).

Table 19 Percentage Changes in Key Parameters

Scenario	Total Phosphorus	Total Nitrogen	Algal Biomass (chla)	E Coli
A (compared with 2012)	-7%	-15%	-3%	10%
B (compared with A)	14%	4%	5%	16%
C (compared with A)	31%	22%	11%	10%
D (compared with A)	30%	26%	11%	7%
E (compared with A)	43%	51%	17%	8%

The deterioration from 2012 to 2037 is greatest for nitrogen, and E Coli levels are projected to improve on average. In contrast, the limits will have the largest impact on phosphorus levels.

4.5 Impacts on Values

In this section we estimate the impact on non-market water values of the changes in water quality, as described via the different scenarios. The results shown compare the different policy scenarios with a baseline of water quality in 2037. The results shown are annual values in 2037 using current (2012) dollar values.

In general, reduced nutrients in waterways will reduce food supply for fish, fish numbers will fall, and fishing days are expected to fall as there are fewer fish to catch. However, the value of each fishing day is expected to increase as a result of increased water clarity. Swimming and kayaking activity is expected to increase as water quality improves with respect to clarity and *E Coli* levels. Because people value the existence of water bodies, and value them more when they are in a more pristine state, improvements in water quality will increase existence values also.

4.5.1 Recreation

Swimming

In 2011 there were 74,821 annual domestic swimming days in Southland, with a total value of $4,190,000 where each recreational visit was valued at $56 under our Medium scenario.

To analyse changes in swimming values, we considered a river to be swimmable if it was below a median level of 540 *E.Coli*/ml, categorised as 'poor' due to the risk of infection being over 5%. We assume changes in median values (which is how the modelling results have been provided) represent a reasonable proxy for the change in the number of rivers classified as swimmable and or that are actually used for swimming. We also assume that the impact is seen in terms of total increase in swimming visits (or an avoided reduction compared with water quality continuing at current levels), although in practice there may be some shift in where people swim rather than an absolute increase; this means there may be some over-statement of value.

However, in the other direction, increasing the number of swimmable rivers may mean that people do not have to travel so far to swim; this would reduce travel costs and increase the "surplus" from a swimming trip.

Of the 73 Southland rivers/streams surveyed, 63 were forecast to be considered swimmable in 2037 (compared with 62 currently). We have not assessed individual sites to assess if each is swimmable but used changes in median qualities across all river sites as a proxy for changes in medians at swimmable sites. Our interest is not in the absolute number of swimmable rivers but the change in number. Table 20 assesses marginal changes in the value and number of recreational visits for changes in E.Coli levels.

Table 20 Marginal changes in swimming values for changes in E.Coli under different scenarios

% Change in E.Coli	2037 Scenarios				
	A (Baseline)	B	C	D	E
Number of Swimmable Rivers	63	66	63	64	65
Number of Swimming Visits	76,028	79,648	76,028	77,235	78,441
Change in Swimming Visits		+3,620	0	+1,207	+2,414
Value of Change in Swimming Visits from Baseline ($000)					
Low		**$112**	**$0**	**$37**	**$75**
Medium		**$203**	**$0**	**$68**	**$135**
High		**$442**	**$0**	**$147**	**$294**

Note: All dollar values are in 2012 dollars

The most significant increase in swimming visits occurs under Scenario B, where three more sites become suitable for swimming.

Kayaking

We performed a similar analysis on Southland's 21,702 domestic kayaking days in 2011. At $129 per visitor per day for canoeing/kayaking, this activity generates a total value of $2,788,707. For secondary contact including boating and kayaking, levels of above 1000 *E.Coli*/ml will be unsafe.

Again, we looked at the number of additional streams/rivers that support kayaking under changes in E.Coli levels. As with swimming, we assume that there is an absolute increase in kayaking as a result (or an avoided reduction as above).

Under the baseline scenario, 70 rivers will be suitable for kayaking in 2037, compared to 68 currently. Again, the estimate of number of rivers that are suitable will be different from the reality because this is a modelled result only and is being used as a proxy for relative changes in numbers of suitable kayaking sites. The outcomes under the baseline scenario are better than under scenarios C and D. As a result, the number of kayaking visits decreases under these scenarios.

Table 21 Marginal changes in kayaking values for changes in E.Coli

% Change in E.Coli	2037 Scenarios				
	A (Baseline)	B	C	D	E
Number of Boatable Rivers	70	72	69	69	71
Number of Kayaking Visits	22,340	22,979	22,021	22,021	22,659
Change in Kayaking Visits		+638	-319	-319	+319
Value of Change in Kayaking Visits ($000)					
Low		**$70**	**-$35**	**-$35**	**$35**
Medium		**$82**	**-$41**	**-$41**	**$41**
High		**$94**	**-$47**	**-$47**	**$47**

Note: All dollar values are in 2012 dollars

Fishing

To identify the value of changes in angler visits we use different approaches for New Zealanders and overseas visitors. For New Zealanders we use a change in the number of fishing days (and the expressed value of a fishing day) and the value of improved water clarity.[63] For the international visitors we estimate reductions in total visits to New Zealand and the reduction in value added that is retained in New Zealand as a result of their expenditures.

Between 2007 and 2011 there was an average of 136,702 domestic angler-days across the Southland region, to a value of $3,691,000 (at $27/angler-day).[64] Similarly, there was an average of 17,008 international angler-days, 50% of which we assume would not visit NZ if Southland had no fishing.[65] Each international angler-day contributes $119 of value-added to NZ – a total value of $1,014,000 at risk if there was no fishing in Southland.[66]

By constructing relationships between measurable attributes (such as particulate phosphorus and total nitrogen), components (such as water clarity and trout numbers) and value, we can estimate marginal values for changes in river quality.

Water Clarity

Work by Jowett Consulting indicated the relationship between water clarity (metres of visibility) and particulate phosphorous (total phosphorus less dissolved reactive phosphorus) as shown in Box 2 on page 38.

Average particulate phosphorus (PP) across Southland sites surveyed by ES was 0.22mg/l, which corresponds to an average visibility of 1m. At $10 per metre improvement in visibility per angler visit, the value of water clarity improvements under each scenario are presented in Table 22.

[63] These are all estimates of consumer surplus
[64] MBIE Domestic Travel Survey. Data averaged across 2007 to 2011.
[65] This is estimated following discussions with companies that provide fishing trips for tourists. Southland rivers, particularly the Mataura are internationally known trout rivers and reductions in “fishability” would be expected to result in some overall reduction in numbers of visits.
[66] Tourism Satellite Account (2012), International Visitor Survey (2012)

Table 22: Marginal changes in fishing values for changes in Phosphorus.

% Change in Water Clarity	2037 Scenarios				
	A (Baseline)	B	C	D	E
Particulate Phosphorus (PP)	0.023	0.020	0.016	0.016	0.013
Visibility (m)	0.97	1.05	1.21	1.20	1.36
Change in Visibility (m)		+0.09	+0.25	+0.24	+0.40
Value of Change in Water Clarity ($000):					
Low		**$114**	**$317**	**$302**	**$511**
Medium		**$119**	**$330**	**$314**	**$532**
High		**$250**	**$691**	**$659**	**$1,115**

Note: All dollar values are in 2012 dollars

Sources: Data from MBIE, NIWA, Jowett Consulting and Beville & Kerr (in prep).

These values are only calculated for domestic anglers, as the change in spend by overseas visitors for different water clarities could not be quantified.

Trout Numbers

Jowett Consulting identified the relationship between nitrogen levels, water flows and trout numbers (Box 2 on page 38). This relationship means that a reduction in nutrient levels causes a reduction in trout numbers.

We also tested the inverted-U shaped relationship as noted in Figure 10 on page 37. Using Jonsson et al's[67] estimated threshold of 2.4mg/l as the optimal level of total nitrogen, we estimated the impacts of the different scenarios. Only Scenario B results in rivers, on average, with nutrient levels closer to the optimal; the others result in average nutrient levels that are further away from the optimum and thus fewer fish. However, the optimal level will differ by location,[68] reflecting other contributing factors to food production and feeding. This relationship appears to be somewhat uncertain, so we include Jowett's equation as our base analysis but in sensitivity analysis we remove any impacts on trout numbers reflecting the uncertainty over this underlying relationship.

To relate Trout/Km to the number of angler-days, we performed a regression analysis on values from a 1990 survey (see Annex 3). This relationship was treated as the Medium scenario, with the 95% confidence interval treated as the Low and High scenarios. Details of this analysis are presented in Annex 3.

We hold Mean Flow and MALF constant, and calculate changes in angler-days for marginal changes in TKN under each scenario in the following table.[69]

[67] Jonsson B, Jonsson N and Ugedal O (2011) Production of juvenile salmonids in small Norwegian streams is affected by agricultural land use. Freshwater Biology, 56: 2529-2542

[68] The 2.4mg/l is for Norwegian stream

[69] Average Mean Flow across rivers surveyed was 31.0m^3/s, average MALF was 8.7m^3/s, and average TKN was forecast for Baseline 2037 at 0.48g/m^3. Using the above relationships, the average Trout/Km was 1,986, which corresponds to an average of 13,207 angler-days per 'typical river' in the Medium scenario. Since we know there were 155,151 actual angler-days in 2008 (89% domestic, 11% overseas), the Southland region can be considered to comprise 13.2 'typical rivers'.

We note that as the water quality improves (ie. less nitrogen), the number of trout/km decreases, resulting in fewer angler-days. This is because the immediate effect of increased nitrogen is increased stream productivity and thus increased food for fish. This works in the opposite direction to the effect of visibility calculated above, but is consistent with the findings of similar studies under the EU Water Framework Directive (see Section 3.2.1). Thus our prediction is that improvements in water quality result in fewer angler days because of the reduction in the number of fish but increased value of a fishing day because of the increase in water clarity.

All of the scenarios analysed result in a reduction in fishing value compared with the 2037 baseline (Table 23).

Table 23 Marginal changes in fishing values for changes in TKN

% Change in TKN	2037 Scenarios				
	A (Baseline)	B	C	D	E
TKN	0.480	0.471	0.383	0.363	0.253
Trout/Km	1,944	1,917	1,359	1,259	819
Change in Domestic Angler-Days					
Low		-866	-20,679	-24,687	-44,873
Medium		-3,466	-34,833	-40,870	-69,589
High		-5,040	-48,774	-56,777	-92,775
Value of Change in Domestic Angler-Days ($000)					
Low		-$35	-$848	-$1,012	-$1,840
Medium		-$94	-$940	-$1,103	-$1,879
High		-$91	-$878	-$1,022	-$1,670
Change in International Angler-Days					
Low		-54	-1,286	-1,536	-2,791
Medium		-216	-2,167	-2,542	-4,329
High		-314	-3,034	-3,532	-5,771
Value of Change in Overseas Angler Visits ($000)					
Low		-$6	-$153	-$183	-$333
Medium		-$26	-$258	-$303	-$516
High		-$37	-$362	-$421	-$688
Value of Change in Fish Numbers ($000)					
Low		**-$42**	**-$1,001**	**-$1,195**	**-$2,173**
Medium		**-$119**	**-$1,199**	**-$1,407**	**-$2,395**
High		**-$128**	**-$1,240**	**-$1,443**	**-$2,358**

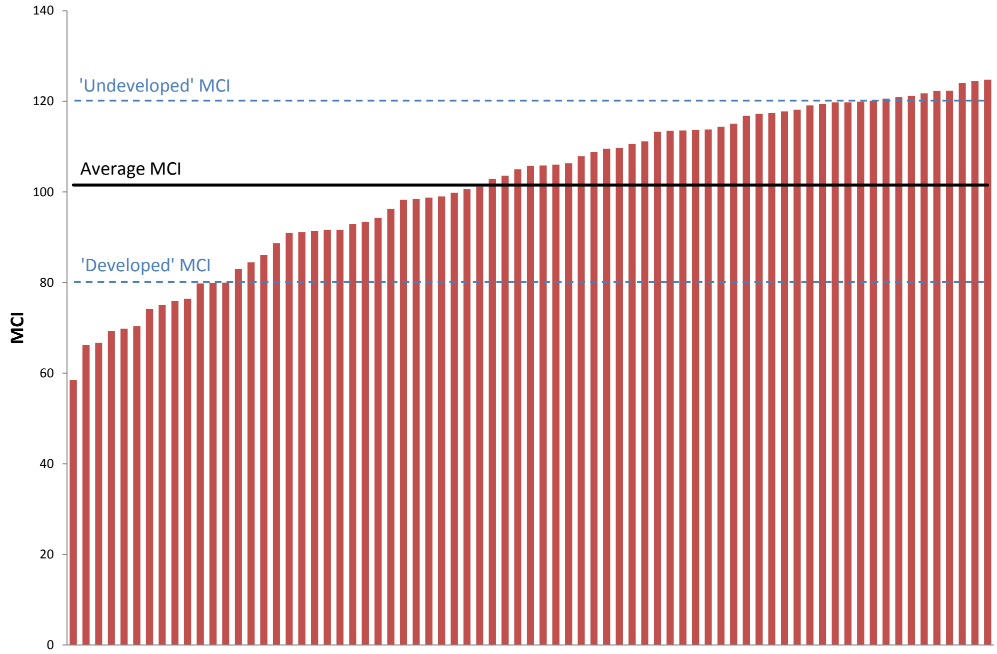
Note: All dollar values are in 2012 dollars

4.5.2 Existence Value

To estimate changes in existence values for Southland households, we use the MCI score, which is a measure of ecosystem health. Although there are other attributes that may be valued, we have monetary values relating to the change in level of development that may change ecosystem health. We use the MCI score for each of the 73 rivers/streams surveyed based on the formula in Box 2. MCI values across Southland are presented in Figure 11.

The average estimated MCI is 102, where scores of more than 100 are considered a healthy stream. There was no clear clustering of MCI values in order to distinguish water which had been "harmed" by a development. As such, we aligned our consideration of a "developed" and "undeveloped" river MCI to the water quality categories for macroinvertebrates used by MfE, presented in Table 24.

Figure 11: MCI for 73 surveyed rivers and streams in Southland



Source: Data provided by Aqualinc Research Ltd.

Table 24 Water quality category based on MCI scores

MCI Score	Water Quality Category
>119	Excellent
100-119	Good
80-99	Fair
<80	Poor

Source: Ministry for the Environment (2013) Macroinvertebrates: Water quality category of national monitoring network sites based on average MCI scores, 2005-2007.

We use an MCI of 120 to represent an "undeveloped" river, and an MCI of 80 corresponds to a "developed" river. Households are willing to pay $53 each per year to prevent an undeveloped river from being developed (Table 15). We assume this corresponds to a linear relationship where a 1 unit increase in MCI is associated with a $1.31 per household per year per river (for the 4 main rivers considered in this analysis) increase in existence values. We repeated this process for low and high scenarios of household WTP, corresponding to values of $1.18 to $1.40 per household per year per river.

Table 25 presents the changes in existence values associated with scenarios for changes in Total Nitrogen (TN), Total Phosphorus (TP) and chlorophyll (Chla) for Southland households.

Table 25: Marginal changes in existence values for Southland households

% Change in TP, TN, Chla Levels	2037 Scenarios				
	A (Baseline)	B	C	D	E
Average MCI	99	101	106	106	111
Average Change in MCI		2	7	7	12
Change in Value per Household per River					
Low		$2.56	$7.78	$8.34	$13.92
Medium		$2.86	$8.69	$9.31	$15.55
High		$3.05	$9.27	$9.93	$16.59
Total Change in Value per River[1]					
Low		$79,186	$240,505	$257,588	$430,145
Medium		$112,540	$341,807	$366,086	$611,326
High		$147,485	$447,942	$479,760	$801,150
Total Change in Existence Value ($000)					
Low		**$317**	**$962**	**$1,030**	**$1,721**
Medium		**$450**	**$1,367**	**$1,464**	**$2,445**
High		**$590**	**$1,792**	**$1,919**	**$3,205**

[1] Based on 2037 estimates of the number of households, see below.

Note: All dollar values are in 2012 dollars

Our estimates of the number of households in Southland in 2037 are based off the low, medium and high Stats NZ population projections series. We grow the 2031 projections at a rate matching the growth trend (between 2006 and 2031). Using this method we estimated 30,899 households in the low scenario, a medium of 39,314, and a high scenario of 48,301.

Existence values will also be held by people outside of Southland, eg. by households in Otago or further afield. However, we do not have values from existing studies that enable us to take these values into account. It does mean the values here are under-estimates.

4.5.3 Summary of Values

To estimate the results we have used different approaches to averaging:

- For recreational impacts (swimming and kayaking) we have estimated the number of river sites that are swimmable or suitable for contact recreation based on the E Coli levels. The percentage change in number of suitable sites is used to estimate a percentage change in swimming and kayaking activity (and hence in values) (note this ignores the fact that people may shift where they undertake these activities rather than total activity levels changing);

- For fishing we have estimated the change in average phosphorus and nitrogen concentrations across all river sites to estimate the change in the number of fish and in average water clarity. We have used percentage changes in these averages to estimate percentage change in the value of fishing days (water clarity related) and the number of fishing days (related to the number of fish);

- For existence value we have estimated the change in average ecological health (measured using a Macroinvertebrate Community Index, MCI) across all river sites.

The overall results are shown in Table 26.

Table 26 Summary of scenarios for Change in Parameter Values Relative to Baseline in 2037 ($000)

Valued Parameter	Scenario B	Scenario C	Scenario D	Scenario E
Low				
Water Clarity for fishing	$114	$317	$302	$511
Fishing Days	-$42	-$1,001	-$1,195	-$2,173
Swimming	$112	$0	$37	$75
Kayaking	$70	-$35	-$35	$35
Existence Value	$317	$962	$1,030	$1,721
Total	**$571**	**$242**	**$139**	**$168**
Total (ignoring fish numbers)	**$613**	**$1,244**	**$1,335**	**$2,341**
Medium				
Water Clarity for fishing	$119	$330	$314	$532
Fishing Days	-$119	-$1,199	-$1,407	-$2,395
Swimming	$203	$0	$68	$135
Kayaking	$82	-$41	-$41	$41
Existence Value	$450	$1,367	$1,464	$2,445
Total	**$735**	**$457**	**$398**	**$758**
Total (ignoring fish numbers)	**$854**	**$1,656**	**$1,805**	**$3,154**
High				
Water Clarity for fishing	$250	$691	$659	$1,115
Fishing Days	-$128	-$1,240	-$1,443	-$2,358
Swimming	$442	$0	$147	$294
Kayaking	$94	-$47	-$47	$47
Existence Value	$590	$1,792	$1,919	$3,205
Total	**$1,248**	**$1,196**	**$1,234**	**$2,303**
Total (ignoring fish numbers)	**$1,376**	**$2,436**	**$2,678**	**$4,661**

Note: All dollar values are in 2012 dollars

The values that we have analysed here aggregate to a total annual value of the policy interventions in 2037 (in 2012 dollars) ranging from $0.1 - $2.3 million, with central estimates of $0.4 - $0.8 million per annum. The most significant contributor to value is the existence value that accrues largely to Southland households; this ranges from $0.3 - $3.2 million per annum. The impacts on fishing are in the opposite direction to the other values because more nutrients are estimated to result in an increase in fish numbers and fishing days. If we ignore the fishing values the range of measured non-market values is $0.6 - $4.7 million per annum.

4.5.4 Southland Regional Values

To assess the wider context of these results, we estimated the portion of values which accrue explicitly to Southland Region rather than to NZ as a whole. The impacts are based on the following calculations using the recreational visit data:

- 83% of swimming visits in Southland by domestic residents involve Southland residents;
- 50% of kayaking visits in Southland by domestic residents involve Southland residents;
- 83% of angler-days in Southland by domestic residents involve Southland residents; and
- 18% of all nights in NZ were spent in Southland by overseas visitors who fished in Southland.

Existence values have only been calculated for Southland households.

The overall results are shown in Table 27. Apart from Scenario B, the size of the impact is greater for Southland than for New Zealand as a whole. This is because our estimates of existence value are measured only for Southlanders, so these do not change and the impacts of the scenarios are positive on existence value. In contrast, some of the other impacts are negative, particularly on fishing values, and when we count only the impacts falling on Southlanders there is a smaller negative effect. Summed together the net measured effects on Southlanders are greater than for other New Zealanders. If we ignore the negative impact on fishing days, then the impact on Southlanders is slightly smaller than for NZ as a whole.

Table 27 Summary of value to Southland region of scenarios for Change in Parameter Values Relative to Baseline in 2037 ($000)

Valued Parameter	Scenario B	Scenario C	Scenario D	Scenario E
Low				
Water Clarity for fishing	$95	$262	$250	$423
Fishing Days	-$31	-$730	-$871	-$1,584
Swimming	$93	$0	$31	$62
Kayaking	$35	-$17	-$17	$17
Existence Value	$317	$962	$1,030	$1,721
Total	**$509**	**$477**	**$423**	**$639**
Total (ignoring fish numbers)	**$540**	**$1,207**	**$1,294**	**$2,223**
Medium				
Water Clarity for fishing	$99	$273	$260	$441
Fishing Days	-$82	-$825	-$969	-$1,649
Swimming	$169	$0	$56	$112
Kayaking	$41	-$21	-$21	$21
Existence Value	$450	$1,367	$1,464	$2,445
Total	**$676**	**$794**	**$792**	**$1,370**
Total (ignoring fish numbers)	**$759**	**$1,620**	**$1,760**	**$3,019**
High				
Water Clarity for fishing	$207	$572	$545	$923
Fishing Days	-$82	-$792	-$922	-$1,507

Valued Parameter	Scenario B	Scenario C	Scenario D	Scenario E
Swimming	$367	$0	$122	$245
Kayaking	$47	-$24	-$24	$24
Existence Value	$590	$1,792	$1,919	$3,205
Total	**$1,130**	**$1,548**	**$1,641**	**$2,889**
Total (ignoring fish numbers)	**$1,211**	**$2,341**	**$2,563**	**$4,396**

These results have quantified the value of water quality limits, measured as the change in certain non-market values, as ranging from approximately $10-$112 per household per annum in Southland.

4.5.5 Baseline Changes in Value, 2012-2037

To consider what would occur under the baseline scenario, we calculate the change in values between 2012 and 2037 if none of the proposed policies were adopted. These values are presented in Table 28.

With water quality worsening between 2012 and 2037, existence values and the value of water clarity for fishing will decline in the absence of intervention. E Coli levels are forecast to fall on average, making a few more rivers swimmable/boatable, increasing the value of these activities. Because of an increase in nitrogen levels, fish numbers are expected to increase and the number and value of fishing days will also increase. Overall, in the absence of policy interventions, non-market water values in Southland are estimated to increase by $116,000 to $208,000 per year. Ignoring changes in the number of fishing days we estimate a decrease in non-market values of -$308,000 to -$548,000.

Table 28 Baseline change in values, 2012 to 2037 ($'000)

Valued Parameter	Low	Medium	High
Water Clarity for fishing	-$50	-$52	-$110
Fishing Days	$485	$629	$664
Swimming	$37	$68	$147
Kayaking	$70	$82	$94
Existence Value	-$365	-$518	-$679
Total	**$177**	**$208**	**$116**
Total (ignoring fish numbers)	**-$308**	**-$421**	**-$548**

The results are different from the comparison of 2037 scenarios: in the 2012-2037 analysis the absolute change in values associated with the change in fishing days is higher than the change in existence values, whereas the relative values are around the other way for the 2037 analysis. This reflects the different percentage changes in different factors as set out in Table 19.

5 Summary and Conclusions

5.1 Summary of Results

The analysis in this report has been used to estimate the impacts of a number of scenarios of water quantity and quality limits on non-market values of water. The analysis is limited in its scope because there are large gaps in data. This includes the following:

- values of water are missing for a significant number of categories of TEV. This includes several recreational uses, option values applied to other use categories (including extractive use), and existence values for southland rivers for people outside of Southland;
- relationships between changes in water quality and changes in factors that are valued. For example, we do not know how the water quality changes will affect whitebating or eel fishing;
- the limitation of the analysis to the rivers and streams included in the modelling by NIWA and Aqualinc. This ignores the impacts on estuaries and other wetlands where nutrients and other contaminants may accumulate;
- distinct values expressed by Māori – although we have identified some differences, we were unable to quantify them.

Nevertheless, we have identified changes in values for a number of significant uses of water bodies in Southland, including swimming, kayaking and fishing. We have also provided some changes in existence values of rivers, although this is limited to the values of Southlanders. The values that we have analysed here aggregate to a total annual benefit in 2037 of the water quality limits ranging from \$0.1 - \$2.3 million (in 2012 dollars), with central estimates of \$0.4 – \$0.8 million per annum. The impacts on fishing are in the opposite direction to the other values because more nutrients are estimated to result in an increase in fish numbers and fishing days. If we ignore the fishing values the range of measured non-market values is \$0.6 - \$4.7 million per annum.

5.2 Discussion

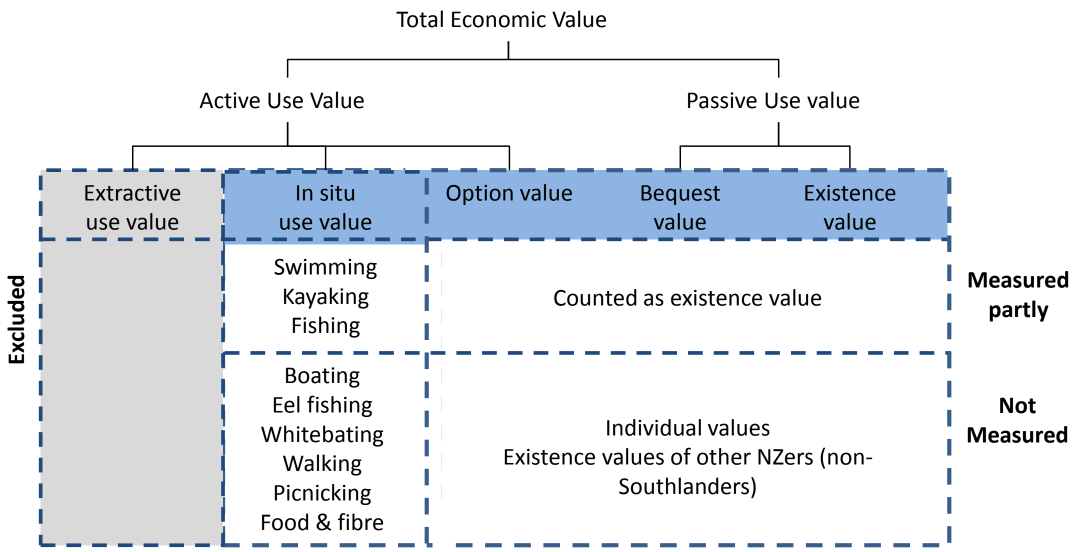
The results from this study suggest that the measurable values attributable to the environmental, recreational and other non-market benefits of water quality improvements are lower than the costs of limiting the activities that cause reduced water quality. This raises the questions of whether missing values are extensive, whether people really do not value the environment very highly, or whether the analytical approach is inappropriate.

5.2.1 Missing Benefits

One reason for the low relative level of environmental benefits is because of missing values. Specifically, we have values for some of the elements of TEV but not for others. Figure 12 shows the extent of coverage:

- extractive use values are outside of the scope of this study but are included elsewhere;
- in-situ use values are partially covered. We have collated data on a number of recreational activities (swimming, kayaking and fishing) but many other activities are not included, eg. boating, whitebaiting and recreational activities beside water bodies; and
- option values and passive use values are all assumed to be included under the heading of existence value. This assumption reflects findings that survey participants are largely unable to differentiate between these different sources of value.

Figure 12 Coverage of TEV categories



Thus the study has partial coverage of total economic value, however both the extent of missing values and their size is uncertain.

5.2.2 Relative Value of the Environment

The underlying assumption used in the analysis here is that we have a water resource that is to be shared between different potential users who are effectively bidding for its use. Those wishing to bid to use it for recreational reasons and/or because they value its pristine state are not willing to pay as much as those that wish to use it as a sink for pollutants. This would suggest that using the resource to support polluting activities is allocating it to its highest value use.

In Section 2.5 we noted that there are income constraints to stated expressions of value, but that this is simply a reflection of relative preferences for the environment and other things that changes with income. This does not invalidate the method.

The values are relatively small because of the relatively small population of Southland, and reflecting the human value-centred approach. Alternative decision approaches that take account of other issues may be appropriate in some circumstances, and the legal obligations towards Māori values may suggest that greater weight is given to environmental improvements to reflect Māori preferences.

5.2.3 Limitations

There are a number of limitations that result from the benefit transfer process. In particular, the rivers are not the same as those at the study sites from which the values have been obtained, and the communities are different also. The results are based largely on values obtained from stated preference studies that often suffer from hypothetical bias in which people over-state their willingness to pay compared with what they would actually pay.

We have also noted the limitations in the study resulting from the hydrological modelling work that has produced results for rivers only and does not include other water bodies, such as lakes and estuaries. This affects the results in the context of the averaging approach that we have used (see Section 4.5.3). The water quality impacts if averaged across all sites (including estuaries) would be different from the averages across river sites only, as used here.

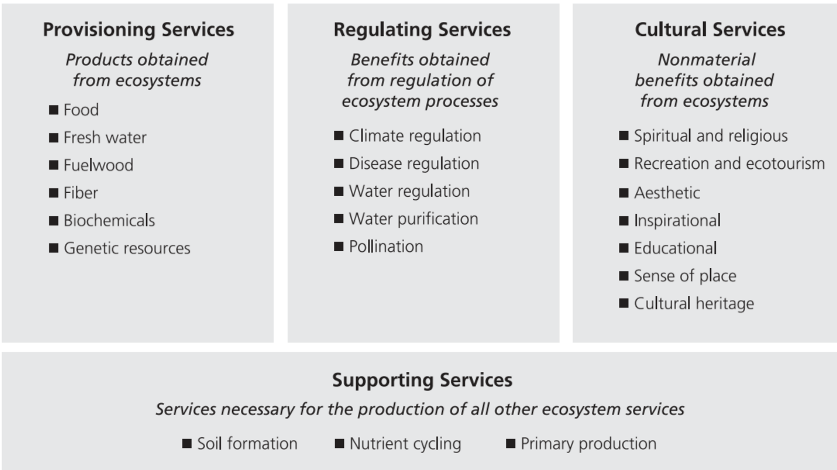
Annex 1: Ecosystem Services and TEV

In the past few decades there has been a growing awareness of the adverse impact that human activities have on the environment. Ecologists and environmental researchers have made an effort to emphasise the point that much of human well-being depends on the environment. The concept of ecosystem services was born out of these efforts; it is a concept that entails the various goods and services that humans derive from their natural surroundings. Landmark studies like Costanza et al's[70] 1997 valuation of US$16–$54 trillion per year of global natural capital popularised the concept. The authors defined ecosystem services as follows:

> *Ecosystem goods (such as food) and services (such as waste assimilation) represent the benefits human populations derive, directly or indirectly, from ecosystem functions.*

Later the Millennium Ecosystem Assessment (MEA)[71] embedded ecosystem services in the language of environmental management by categorising the services into four groups (see Figure 13 below). The MEA simplified the definition of ecosystem services to be "the benefits that people obtain from ecosystems."

Figure 13 Ecosystem Services



The ecosystem services concept can be used to identify the services/benefits that freshwater bodies produce. The provisioning, regulating and cultural services are equivalent to 'final' products in the language of economists, whereas the supporting services do not affect wellbeing directly; they are similar to 'intermediate' products that enable the production of the final products.

MfE has initiated the mapping of the relationship between ecosystem services and the TEV framework, including Table 29 and Figure 14 below.

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[70] Costanza R, d'Arge R, de Groot R, Farberk S, Grasso M, Hannon B, Limburg K, Naeem S, O'Neill RV, Paruelo J, Raskin RG, Suttonkk P and van den Belt M (1997) The value of the world's ecosystem services and natural capital, *Nature*, 387: 253-260.

[71] Millenium Ecosystem Assessment, (2005) Eocsystems and human well-being: A framework for assessment, Island Press, Washington.

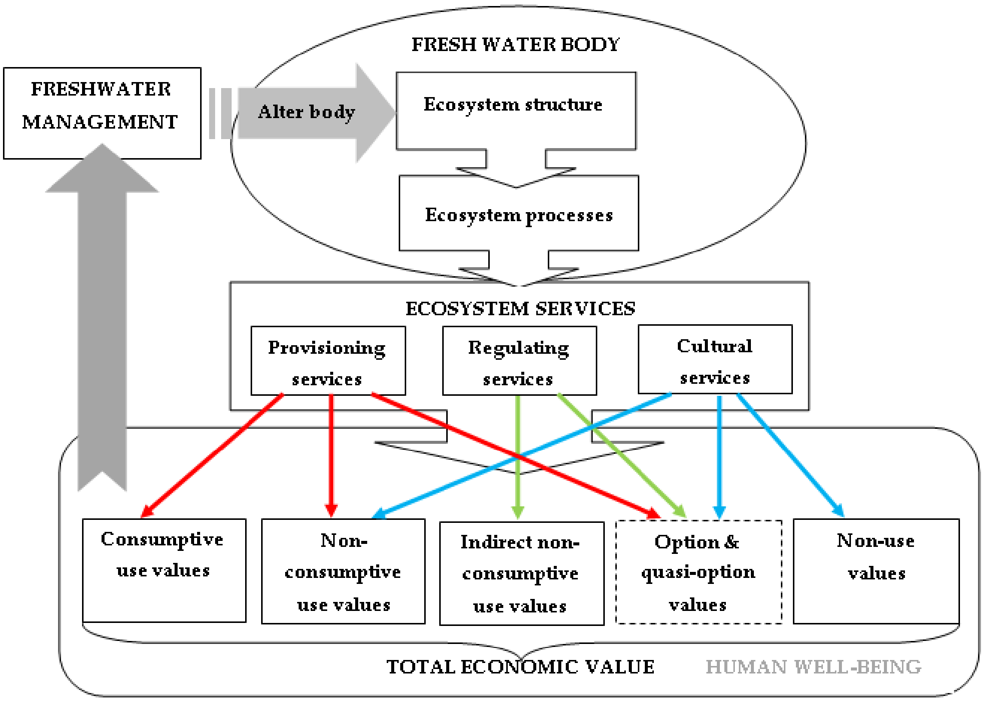
Table 29 Aligning Ecosystem Services with the TEV Framework

	Ecosystem Service	Activity of Value	TEV Class
Provisioning	Food	Aquaculture Sport fish Mahinga kai	Direct consumptive use
	Fibre	Flax Driftwood Fibre for decorative handicraft	Direct consumptive use
	Fresh Water Supply	Irrigation Municipal water Industrial water	Direct consumptive use
		Hydroelectricity Commercial transport	Direct non-consumptive use
	Abiotic Products	Gravel extraction for concrete Stones for decorative handicraft	Direct consumptive use
	Genetic and Medicinal Resources	Pharmaceuticals	Direct consumptive use
Regulating	Disease Regulation	Parasite and toxic algae regulation	Indirect use
	Fresh Water Regulation	River flow regulation	Indirect use
	Fresh Water Purification	Removal of pollutants	Indirect use
	Pest Regulation	Mitigation of invasive non-native species	Indirect use
	Erosion Control	Stabilization of river/lake banks	Indirect use
	Natural Hazard Regulation	Flood and drought protection	Indirect use
Cultural	Education	Historical interest Scientific knowledge systems	Direct non-consumptive use
		Archaeological interest	Direct consumptive use
	Conservation	Charismatic endangered species & wild landscapes	Direct non-consumptive use
		Existence of endangered species & biodiversity	Non-use
	Aesthetic	Perceived beauty	Direct non-consumptive use
	Spiritual & cultural	Inspiration Tranquillity Māori site of significance Taonga species	Direct non-consumptive use
		Wahi tapu	Non-use
	Recreation	Ecotourism, fishing, hunting, kayaking, swimming	Direct non-consumptive use

Source: MfE

MfE's conceptual model was adapted from Hein et al's[72] ecosystem valuation framework which illustrates the role of the MEA's ecosystem services classifications in such valuations. MfE's adaptations made it more specific to water and included management of water bodies and their inputs and outputs. The latter addition describes how feedback on changes in the TEV can be used as a stimulus for policy tools to manage the quantity and quality of the water, thereby altering the ecosystem and the services it provides.

Figure 14 A conceptual model of MEA ecosystem services and the TEV framework

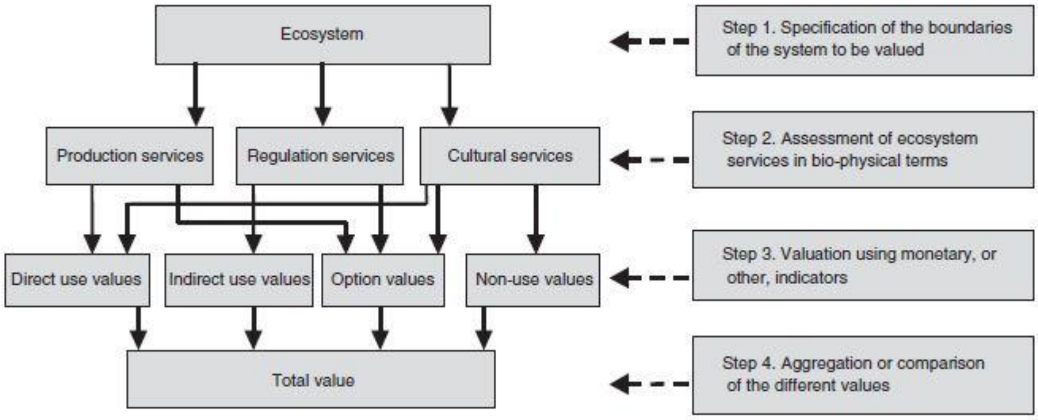


Source: MfE

MfE's adapted model excludes a key feature of Hein et al's original model (Figure 15): the principal steps in the valuation of an ecosystem. Here, in Step 2, the authors outline that the MEA's classifications are valuable in the "assessment of ecosystem services," and that the use of these classifications does not extend further into the valuation process – the TEV framework takes over at the next step. The implication is that the relationship between the ecosystem services framework and the TEV framework is simple: the ecosystem services framework aids in identifying the services the ecosystem provides, while TEV outlines the type and (ideally) the amount of value these services have.

[72] Hein L, van Koppen K, de Groot RS, van Ierland EC (2006) Spatial scales, stakeholders and the valuation of ecosystem services Ecological Economics (57):209-228.

Figure 15 Hein et al.'s ecosystem valuation framework.



Note: The solid arrows represent the most important links between the elements of the framework. The dashed arrows indicate the four principal steps in the valuation of ecosystem services
Source: Hein et al. (2006)

Annex 2: Māori Values Relating To Water

Rationale and Legislative Requirement to Consider Māori Values

Understanding Māori perspectives on values pertaining to water is an important element of this work. Not only can tangata whenua perspectives be different, the requirement to address these values in decision-making is legislated.

Resource Management Act

In Section 6 of the Resource Management Act 1991 (RMA) "*the relationship of Māori and their cultures and traditions with their ancestral lands, water, sites, wāhi tapu and other taonga*" is noted as a matter of national importance that should be recognised and provided for "*by all persons exercising functions and powers under the Act, in relation to managing the use, development, and protection of natural and physical resources*". The wording of this section also provides for the inclusion of tangible and intangible aspects of the Māori values of water. As Roberts observes:

> *The inclusion of the wording "the relationship of Māori..." is significant. For the first time New Zealand's environmental laws requires consent authorities to consider not only the tangible aspects of Māori culture, for example an unidentified pa, maunga (mountain) or river, but also the local whānau, hapū or iwi relationship with sites* (p217).[73]

Section 7 of the RMA also requires decision-makers to have particular regard to kaitiakitanga. The Act defines kaitiakitanga as:

> *The exercise of guardianship by the tangata whenua of an area in accordance with tikanga Māori in relation to natural and physical resources; and includes the ethic of stewardship based on the nature of the resource itself.*

The reference to "tikanga Māori" reinforces the need to consider Māori worldviews.[74] One of the responsibilities of Tangata tiaki is to protect the integrity of resources so that they are passed down in a healthy condition to future generations, thus ensuring the continuity of cultural practice. This requires Māori to focus on long term environmental results which are likely to include healthy ecosystems with robust mauri that are able to sustain cultural uses.

The current proposed RMA reform would elevate this requirement for decision-makers, who would need to "recognise and provide for" kaitiakitanga.[75]

The application of Mātauranga Māori within resource management is one practical way of having regard to kaitiakitanga:

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[73] Roberts N (2002). Planning and Tangata Whenua Issues: A Proactive Approach. In: Kawharu, M. Whenua: managing our resources, Reed Publishing.
[74] Roberts (op cit)
[75] Ministry for the Environment. 2013. Improving our resource management system. A discussion document. Wellington: Ministry for the Environment

Iwi and hapū envision the environment through indigenous knowledge – mātauranga Māori. This way of seeing and experiencing the environment has given rise to the concept of kaitiakitanga, an emerging approach to environmental management arising from traditional principles, perspectives and worldviews. The concept has captured attention in a variety of quarters, including the Resource Management Act 1991, which makes provision for kaitiakitanga, which it defines as 'the exercise of guardianship'. It is the combination of Māori communities and kaitiakitanga protection and enhancement that makes this 'space' distinctive.[76]

Local Government Act

The Local Government Act also recognises the Crown's responsibility to take appropriate account of the principles of the Treaty of Waitangi and to maintain and improve opportunities for Māori to contribute to local government decision-making processes. Local authorities must, in the course of the decision making process "…*take into account the relationship of Māori and their culture and traditions with their ancestral land, water, sites, wāhi tapu, valued flora and fauna, and other taonga*."

Conservation Act

Management of water on public conservation lands via the Department of Conservation for the purpose of the Conservation Act 1987 needs to "… *be interpreted and administered as to give effect to the principles of the Treaty of Waitangi."*

Land and Water Forum

Iwi rights and interests in fresh water are being addressed through direct engagement between iwi and the Crown. Although iwi rights and interest were not on the table for discussion by the Land and Water Forum[77], the forum recognised the need for this to be addressed. In its first report the Forum said (p vii):

Iwi see economic development as vital for New Zealand, but subject to the constraints of reducing environmental footprints, including through smart technologies and innovation. They look to formal participation in setting strategic priorities at the national level, and involvement at the local level which allows them to ensure that their values and objectives are taken into account in practice. Iwi seek outcomes from water that sustain the physical and metaphysical health and well-being of waterways as a matter of first principle; ensure the continuation of customary in-stream values and uses; and satisfy iwi development aspirations.[78]

The Land and Water Forum second report also recognised (p31) that:

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[76] Ministry of Research Science and Technology (2007) New Zealand research agenda discussion document. Wellington, N.Z.: Ministry of Research, Science and Technology.
[77] a group comprising of over 60 members - drawn from the primary sector (including farming, horticulture, and forestry) from industry (including power generators) from the services sector (including tourism) and from civil society (including Green NGOs) and five river iwi.
[78] Land and Water Forum. (2010). A Fresh Start for Fresh Water. Report of the Land and Water Forum.

For iwi, the contemporary discussion of fresh water evokes legacies marked by their exclusion from decision making, by delegated authorities that have not included them, and by painful ecological and cultural losses. Iwi consider that these legacies are a fundamental part of their conversations with the Crown and create obligations such as the recognition of iwi rights and interests, clean-up of degraded waterways, and 'future-forward' attention to effective governance participation.[79]

The Mana Atua Mana Tangata model (see Box 3) was developed by the iwi members of the Land and Water Forum to enable understanding of iwi values for fresh water to support their effective consideration in practice and allow iwi to engage more fruitfully in the process of objectives setting.

Ngāi Tahu Whānui

Given this study focuses on Southland, context needs to be given on the Ngāi Tahu Claims Settlement Act 1998 that applies to the Ngāi Tahu takiwā/tribal area, which includes over 80% of the South Island, including all the lands, islands and coasts of the South Island south of White Bluffs on the east coast and Kahurangi Point on the west coast.[80]

The Ngāi Tahu Claims Settlement Act 1998 gives effect to the provisions of the Deed of Settlement, entered into between Ngāi Tahu and the Crown in 1997. A significant component of the Ngāi Tahu Settlement is the cultural redress elements, which seek to restore the ability of Ngāi Tahu to give practical effect to its kaitiaki responsibilities. However this Settlement did not address the full rights and interests of freshwater within the Ngāi Tahu whānui takiwā.

Te Rūnanga o Ngāi Tahu is made up of 18 rūnanga, four of which are in Southland/Murihiku: Oraka/Aparima, Waihōpai, Awarua and Hokonui. These rūnanga have recognised status as kaitiaki and manawhenua within their respective takiwā (area).

Whakapapa (genealogy) is about relationships of all life forms to each other, people and atua (deities). It also describes bonds, relationships and connections and is central in describing cultural activities, including kai gathering. This study focuses on values and constructs from a Ngāi Tahu ki Murihiku (Southland Ngāi Tahu) perspective, and cannot be generalised for all iwi, hapū or whānau.

Here we focus on the values of water in Murihiku and look at how these perspectives could fit within the definitions/headings of total economic value. We also present examples of how changes in water quality can change a wide range of Ngāi Tahu values/uses. This should not be taken as a full assessment of Māori economic values of water. Such assessments would require participatory research methodologies and the use of interdisciplinary methodologies, including Mātauranga Māori.

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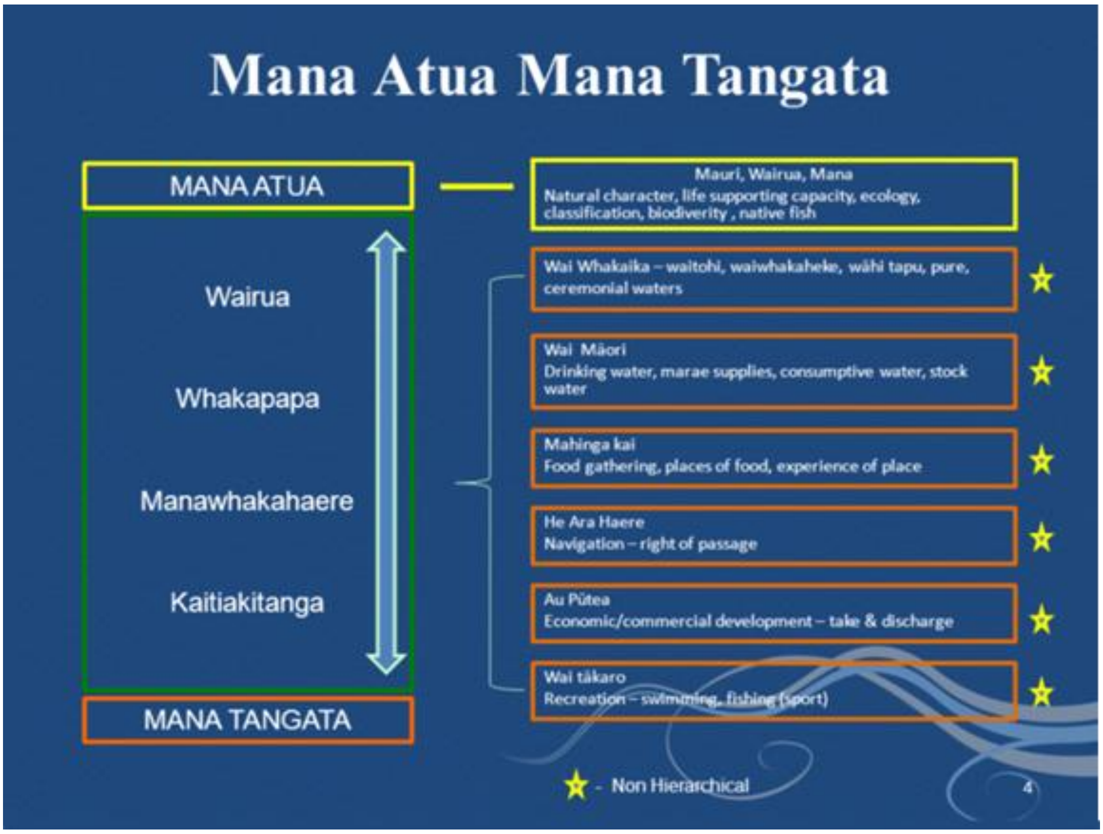
[79] Land and Water Forum. (2012). Second Report of the Land and Water Forum: Setting Limits for Water Quality and Quantity, and Freshwater Policy- and Plan-Making Through Collaboration
[80] Section 5 of Te Rūnanga o Ngāi Tahu Act 1996 describes the takiwā.

Box 3 Mana Atua Mana Tangata Framework

Mana Atua represents the water resource in a holistic sense, including the life cycle of water as it circulates between the realms of Ranginui and Papatuanuku. Mana Tangata represents the human interaction with that system, and the impacts of our interaction on the resource within the cycle.

The Mana Atua Mana Tangata model aligns an iwi world view of tangata whenua relationships and responsibilities in respect to freshwater. This model distinguishes Mana Atua values (which includes Mauri, Wairua and Mana), that are similar yet distinct from intrinsic values, from six classes of use values.. The use values include: Wai Whakaika (ceremonial waters), Wai Māori (drinking and other consumptive water), Mahinga kai (food gathering), He Ara Haere (navigation or right of passage), Au Pūtea (economic use), and Wai takaro (recreation).

Figure: Mana Atua Mana Tangata model illustrating Tangata whenua Values and Relationship with Fresh Water



Source: Land and Water Forum. April 2012. Second Report of the Land and Water Forum: Setting Limits for Water Quality and Quantity Freshwater Policy and Plan Making Through Collaboration.

Ngāi Tahu whānui Perspective

> *Water is a taonga, or treasure of the people. It is the kaitiaki responsibility of tangata whenua to ensure that this taonga is available for future generations in as good as, if not better quality.*[81]

The identification of values for natural resources and the environment need to be understood within the wider framework of community organisation and the relationships between indigenous people and their environment to meet material,

[81] Ngāi Tahu ki Murihiku. 2008. Te Tangi a Tauira: Ngāi Tahu ki Murihiku Natural Resource and Environmental Iwi Management Plan. Te Ao Marama Incorporated. Invercargill.

biological, social, cultural and spiritual needs.[82] These relationships, or indigenous economic systems, are defined in this report by the main principles of:[83]

- Reciprocity—the requirement for reciprocal actions such that anything taken (food or other resources) is balanced by giving, ie. restoration to ensure the on-going functioning and wholeness of the environment;

- Social responsibility in which the wellbeing of the group is emphasised rather than just the individual; and

- Sustainable use of resources recognising the responsibility towards future generations.

World views (of all people – indigenous and otherwise) affect the way that people relate to the environment and participate in the economy.[84] For Ngāi Tahu whānui values relating to water reflect core cultural principles such as Whakapapa, Mauri, Kaitiakitanga, Mātauranga, Manaakitanga, Whanaungatanga (See **Error! Reference source not found.** for descriptions of these and other core Māori values relating to freshwater).

Water is particularly important to Ngai Tahu in Southland and relationships to it provide cultural identity. As Tipa notes, "*Physically and culturally waterways have defined the lives of whānau and hapū in the Southland region*."[85] For example, whānau and hapū can be identified by the specific waterways that they relate to and the species that they collect there for food.

This overall perspective has implications for the expressions of value and the classifications of value in the TEV diagram (Figure 2):

- there is no sense in which some of the values listed are less tangible to "users" – all are tangible;

- there is an inter-play between values. For example, the way in which a resource is managed or used for some use, including extractive uses, is passed on as knowledge to future generations, and requires management to be balanced to enable other values.

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[82] Shimray GA (2008). Indigenous Political Economy. A concept note presented for discussion at the fourth ID Conference on "Economic Sufficiency and Environmental Sustainability", Kota Kinabalu, Sabah, Malaysia, 23-26 September, 2008

[83] Lasimbang J (2008). Indigenous Peoples and Local Economic Development, @local.glo(5), 42–45; Shimray GA (op cit).

[84] Phillips VJ (2008). Indigenous (Ecological) Economics Remastered. Washburn Law Journal,, 89(2006), 781–804.; Anderson, R. B., Dana, L. P., & Dana, T. E. (2006). Indigenous land rights, entrepreneurship, and economic development in Canada: "Opting-in" to the global economy. Journal of World Business, 41(1), 45–55. doi:10.1016/j.jwb.2005.10.005

[85] Tipa G (2011). Our Uses: Cultural Use in Murihiku. Report prepared for Environment Southland. pg 4

How does changing water quality affect Māori values?

> *Water has the spiritual qualities of mauri and wairua. The continued well-being of these qualities is dependent on the physical health of the water. Water is the lifeblood of Papatūānuku, and must be protected. We need to understand that we cannot live without water and that the effects on water quality have a cumulative effect on mahinga kai and other resources.*[86]

Mahinga kai has been the primary food and the basis for economy of Ngāi Tahu for generations. It is integral to the Ngāi Tahu way of life; cultural identity and wellbeing. Loss or deterioration of mahinga kai via impacts on water quality can affect all other of the core values listed in **Error! Reference source not found.** as well as contribute to further cultural disruption.

Full assessment and quantification of the effects of marginal changes of water quality on cultural values and indicators require development of participatory approaches similar to that of the Cultural Flow Preference Model.[87] This model assesses the river flows necessary to protect cultural interests and calculates cultural flow preferences. However, in the absence of such participatory approaches we can draw out a number of possible conclusions on the ways in which Māori values relating to water would change as a result of marginal changes in water quality. Distinct from other people, there appear to be three key differences:

1. The concept of reciprocity in which in which anything taken (food or other resources) is balanced by giving. This means that there is a requirement for restoration to ensure the on-going functioning and wholeness of the environment. Mana is in part maintained by the concept of reciprocity, and the failure to look after the local environment is a source of loss of mana, regardless of the extent to which the local environment is modified as a result of human activity, including by non-Māori. Any deterioration in quality means an additional responsibility and additional loss of mana. This loss of mana is also expressed with reference to any failure to produce traditional food or other resources from the local environment for others, eg. for visitors or gifts taken when a tribe member is a visitor to some other region;

2. The importance of knowledge (mātauranga). Management and use of water, and the relationship with the water body, provides resources for the group but also builds knowledge and provides educational experiences that can be passed on to future generations. Thus there is a marginal increase in knowledge with an increase in water quality because there is an increase in the opportunities for use

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[86] Ngāi Tahu ki Murihiku. 2008. Te Tangi a Tauira: Ngāi Tahu ki Murihiku Natural Resource and Environmental Iwi Management Plan. Te Ao Marama Incorporated. Invercargill. pg 147

[87] Tipa, G. (2010) "Cultural Opportunity Assessments: Introducing a Framework for Assessing the Suitability of Stream Flow from a Cultural Perspective" in Mulholland, M. Maori and the Environment
Tipa, G. Nelson, K. (2012a) Identifying Cultural Flow Preferences: The Kakaunui River Case Study where Manawhenua identified their flow preferences. Journal of Water Resources Planning and Management, 138(6), 660-670.
Tipa, G. Nelson, K. (2012b) Cultural Flow Preferences for the Orari Catchment – A report prepared for Environment Canterbury

of a resource that yields opportunities for education . Generation and application of mātauranga comes from being able to interact safely with waters and resources as tūpuna (ancestors) did;

3. The importance of specific environment and its use to the cultural identity of the group. Whānau and hapū are defined with respect to the environment and resources that they relate to, whereby the loss of ability to use a resource reduces their identity as a group. Substitution is not a valid management response for environmental degradation. Identity is place-specific, and cultural practice / use specific. Cultural identity is a fundamental component that underpins wellbeing.

All of these factors could add to loss of value associated with deterioration of water quality and mean that there is greater value for quality improvements while at the same time maintaining sustainable use of water..

Annex 3: Monetary Values in the Literature

In this section we report on the approaches and data used to value the uses of non-market values of water. Specific values identified for New Zealand are included. Before we discuss individual values, we first describe the different approaches to valuation.[88]

Non-Market Valuation

For a number of uses of water there are no readily available market data with which to estimate either the benefits or the costs of supply. The solution taken by economists to the absence of market problem is to construct markets using well designed surveys or infer preferences and values through individuals' choices. Over time a number of different methods have been developed and feature in the New Zealand valuation literature. The four primary types are referred to as contingent valuation, travel cost, hedonic, and choice modelling which can be broadly classified as stated preference and revealed preference methods. In this next section these four methods are briefly described to provide a basic, non-technical understanding of how the values in each of the reported studies were derived. Many other reports discuss these techniques in detail and we do not repeat this detail here.

Valuation Approaches

Contingent Valuation

The most direct means of valuing an environmental good or change in its quality is to present scenarios to individuals asking them whether or not they would be willing to pay or accept a specified amount to maintain a resource at a determined level of quality. Examples include returning water quality to the 1960s level,[89] improving water quality so that it is safe to swim,[90] or reducing agricultural runoff in lakes which cause the appearance of algal blooms.[91] The method of directly asking individuals to state their value(s) is referred to as the contingent valuation method (CVM). Gluck, in an angling study,[92] was the first to apply CVM in New Zealand. Early forms of contingent valuation often employed open-ended questions asking respondents the amount they would have to be compensated to allow the pollution of river X or alternatively, how much they would be willing to pay to preserve or restore river Y. The open ended approach is susceptible to a number of biases such as strategic behaviour whereby individuals over or understate their WTP. Following the famous Exxon Valdez oil spill, largely in response to the open-ended format problems, a panel of economists (the so-called "blue ribbon" or NOAA "panel") including two Nobel laureates (professors

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[88] This is taken from Denne T, Scarpa R and Beville S (2011) Gap Analysis of Freshwater Economic Valuation Information. Report to Ministry for the Environment

[89] Harris BS (1984) Contingent valuation of water pollution control. Journal of Environmental Management 19: 199-208

[90] Kerr GN, Sharp BMH and Leathers KL (2004). In-stream Water Values: Canterbury's Rakaia and Waimakariri Rivers. Research Report No. 272, Agribusiness and Economics Research Unit, Lincoln University

[91] Bell B and Yap M (2004). The Rotorua Lakes: evaluation of less tangible values. Report prepared for Environment Bay of Plenty

[92] Gluck RJ (1974) An economic evaluation of the Rakaia fishery as a recreational resource. MAgSci thesis, University of Canterbury (Lincoln College)

Arrow and Solow), set specific guidelines for CVM for the purpose of using the result of this valuation method for court litigation.[93] These were:

- surveys to be conducted in person rather than over the phone;
- collecting willingness to pay (WTP) responses according to a "yes" or "no" referendum format;
- asking ancillary questions to ensure that the respondent sufficiently understood the task at hand, with a possibility to revise their selected response;
- using reminders of budget constraints.

Very few studies in the NZ literature fully conform to the set of stringent requirements set by their report.

However, the protocol was designed for the specific needs of litigation for public liability of environmental damage in the USA. Lower standards are expected and indeed used routinely in many studies conducted for other purposes. From the theoretical perspective though, if one endorses the notion that only referendum type responses are to be collected in CVM studies, and with in-person surveys, then the method remains extremely expensive because of the size of the sample necessary to achieve any degree of accuracy in value estimation with these types of data. Each response, in fact, only produces a "No" or "Yes" vote in response to a given dollar amount proposed in exchange of a given provision of the good. Other options have been proposed to obtain more information from each respondent. [94]

Regardless of the response type that is collected, the CVM does not allow the components of value to be derived. This is because, by definition, the CVM is a stated preference direct method in which the entire value of what is the subject of valuation is directly asked to the respondent. It is a whole-or-nothing valuation method.

So, CVM is ideally used for valuing policies in which the end scenario is set and it is not of interest to evaluate the different dimensions (attributes) of the policy. But it is expensive to run with quality data. Choice modelling (see below), instead, is ideally used to inform policies that have higher degrees of freedom. For example, earlier on in the policy formulation stage when some dimensions of the policy outcomes are not yet set in stone. At this stage the marginal values and the trade-offs across competing policy outcomes are most useful.

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[93] Arrow K, Solow R Portney PR, Leamer EE, Radner R and Schuman H (993) Report of the NOAA Panel on Contingent Valuation *Federal Register*, January 15, vol 58(10): 4601-4614.

[94] For example, the use of uncertainty scales whereby respondents are to provide a certainty scale to each of the elements in a ladder of values. For example, say we have 3 values: $100, $250 and $500, for each of these the respondent would provide a "Certainly Yes", "Certainly No", or a "Perhaps" (or some other intermediate certainty scale). However, the certainty scales have been used to separate out the "Yes" responses in "true" Yes (those with higher certainty) and "somewhat unreliable" Yes, those with low certainty. This approach was motivated by an effort to reconcile hypothetical with real payment results. In other words, these scales have been introduced to reduce "hypothetical bias" which translates itself into upward bias in estimates of value.

Travel Cost Method

The oldest indirect method of assessing the value of a non-market resource is the individual travel cost method (ITCM). The ITCM is based on the insight that individuals' valuation of a water resource is related to how far and how much they are willing to pay to travel to a site with a given environmental quality, typically for water recreation such as angling, or other outdoor activities (hunting, skiing, rock-climbing, snow-boarding etc). By incorporating information on the number of trips that individuals take to a particular site and a large sample of individuals with different travel costs it is possible to value a resource by estimating willingness to pay (the demand curve) for visitations over a given period. The ITCM is well established both in the New Zealand and international valuation literature. However, the ITCM has a number of limitations. ITCM cannot:

1. take into consideration individuals who purposefully locate their residence closer to a particular resource that they highly value;
2. be used to value marginal changes in the quality of a site;
3. be used to understand how change, for example reduction in water quality at one site, affects use of that site and use of all other substitute sites; and finally,
4. allow the total value of a resource to be decomposed into its constituent attributes. For example, the values individuals attach to water quality, fish stock, riparian margin vegetation, and overall ecological health.

To overcome the above problems, choice-based travel cost methods (CB-TCM) were developed. These models have soon grown in popularity and have come to dominate the literature. The difference with ITCM is that with CB-TCM what is modelled is the probability of visiting alternative destination sites for the specific outdoor activity on the basis of the attributes that the sites provide. Because the probability of visit depends on the quality of the sites and the implied travel cost to reach them, it is possible for analysts to compute the trade-off between marginal travel cost changes and marginal changes in any of the site attributes (eg. catch rate, water quality etc). These models can be combined with a total visitation model and can also be extended to simultaneously model number of visit and site selection.

Hedonic Pricing

The hedonic pricing method like the TCM infers preferences through purchase behaviour; however it is typically based on choice of residential location or of property investment. Commonly used in real estate valuation the method rests on the assumption that benefits that environmental goods provide are reflected in property values. For example, agricultural land with abundant water resources will be more highly valued than land where water availability is scarce. Provided sufficient variation in the levels of water abundance and property values exist in a given area statistical analysis can be used to estimate the impact of water abundance on property value. The objective is to control for as many other factors that dictate property values. That way the value of water can be established. Searches through the literature suggest that only one New Zealand water-related study has used the hedonic pricing method.[95] This

[95] White PA, Sharp BMH and Kerr GN (2001) Economic Valuation of the Waimea Plains Groundwater System. Journal of Hydrology (NZ) 40(1): 59-76

particular study estimated the maximal marginal value of an additional cubic meter of water per day to the 260 irrigators on the Waimea plains at $240-$300.

Choice Modelling

Another commonly used indirect nonmarket valuation technique used today is known as choice modelling (CM), sometime called choice experiments. Unlike the CVM in which the dollar value is directly elicited, in choice modelling the value is elicited *in*directly. It is derived on the basis of the observed choices and some assumptions about choice behaviour using random utility theory. Choice models allow the value of a water resource to be decomposed into its constituent attribute components, simultaneously allowing valuation of changes in the quality, for example of, improving water quality to a swimmable level, improving ecological health, or water clarity.[96] Data are generated through what are known as choice experiments where individuals are simultaneously shown two or more alternatives or policy options which are described by an array of attributes.[97] Typically one of the options is specified as a status quo alternative or, in the case of angling, an option to not go fishing. An underlying experimental design varies the attribute levels across alternatives and choice scenarios to impose trade-offs to respondents which reveal their preferences (eg. Ferrini and Scarpa 2007).[98] These preferences are quantified in a choice model using statistical techniques. By including a cost variable in the experiment, the researcher is able to use the preference parameters estimated from the observations to derive the monetary value of a marginal change in an attribute level or quality. In recent years developments in the field have increased the level of sophistication in statistical analysis of choice models greatly. This has opened new insights into individual differences in valuation. For example, preference parameters are now routinely estimated to account for differences in preference across the population. Further, models can now be estimated which more closely identify individuals' substitution patterns, eg. where lowland stream anglers are likely to go fishing if lowland streams become degraded.[99]

There is little research work done on the separation of value components, such as use and various non-use values, by using choice modelling. It is normally not a relevant question in the policy arena, which is usually concerned with either estimates of use value, or estimates of total value of a resource, and hence of both use and non-use value. However, the method can accommodate the valuation of these components, for example by hypothesising the existence of options on use and the presence of markets for the purchase of such options.

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[96] Marsh D (2009).Comparing welfare estimates from fixed status quo attributes vs. people's perceived attributes of water quality? Paper presented at the New Zealand Agricultural and Resource Economics Society Conference. Nelson, 28 August, 2009

[97] Beville SB (2009) Modelling differences in anglers choice behaviour with advanced discrete choice models. PhD thesis, Lincoln University

[98] Ferrini S and Scarpa R (2007) Designs with a priori information for nonmarket valuation with choice experiments: A Monte Carlo study. Journal of Environmental Economics and Management, 53(3): 342-363

[99] Beville SB (2009) Modelling differences in anglers choice behaviour with advanced discrete choice models. PhD thesis, Lincoln University

Benefit Transfer

Many of the non-market valuation studies apply to individual water bodies and the values reflect the specific local circumstances. The policy study may be concerned with a water body for which there are no directly applicable studies or it may be focussed on more general questions that relate to the value of water bodies in general. For example, what is the total value of a national policy that establishes environmental "bottom lines"?

Values may need to be taken from site-specific studies and used to value other water bodies or water in general. This process is termed benefit transfer, although the principles can apply equally to the transfer of cost data. These studies that rely on transfers of value estimates strongly rely on the validity of the study from which they source the original estimates.

In general terms, the more similarities between two sites, the greater the confidence in the transferred values,[100] but not to make use of studies from elsewhere is a very inefficient use of information. In the context of biodiversity valuation, Nimmo-Bell suggest that factors to be considered in looking for similarities between sites include those relating to the physical characteristics of the site, the population that use it (eg. national versus local) and the methodology used, characterised as farming issues (eg. the way in which data were elicited, the payment methods chosen when people expressed their preferences). They suggest that two methods can be used for transfers:

- Direct transfers when the sites are very similar and the values can be used directly; and
- Function transfer when statistical relationships are used as the basis for transfer, eg. statistical analysis is used to relate values to site characteristics and other explanatory variables.

The latter approach is similar to methods used elsewhere. For example, regulated prices for monopoly industries have used benchmarking approaches in which an efficient price for a company is derived from the market prices of firms that are different but have some characteristics in common.[101]

Relative Values

Further to our discussion in Section 3.2, Brander et al conducted a meta-analysis of 190 wetland valuation studies found the following mean and median values for components of wetland value.[102]

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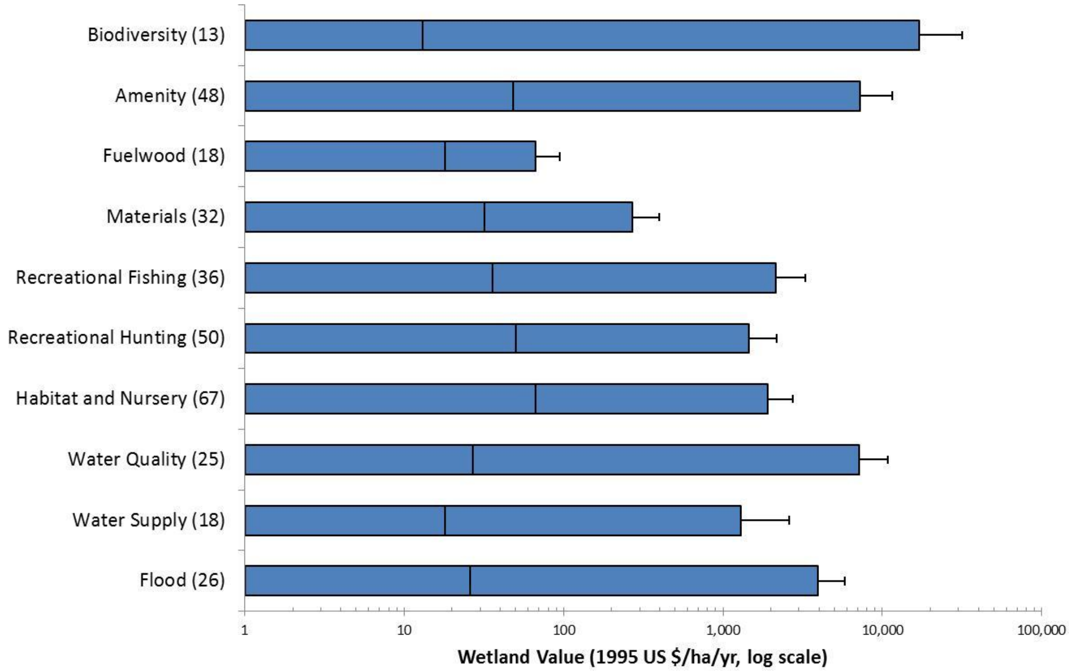
[100] Nimmo-Bell & Company (2009) Bidoversity Vauation Manual. A technical manual for MAF BNZ.
[101] Shleifer A (1985) A theory of yardstick competition. Rand Journal of Economics 16(3):319-327
[102] Brander, L. M., Florax, R. J. G. M. & Vermaat, J. E. (2006) The Empirics of Wetland Valuation: A Comprehensive Summary and a Meta-Analysis of the Literature.

Figure 16: Wetland value by service



Source: Brander et al. (2006).
Note: The horizontal scale is logged. The bars represent the means with error bars. The black lines represent the medians.

Fishing

Range of Values

There are six identified studies of the value of recreational fishing in New Zealand. Five of these studies present their results as the value of a fishing trip at a specific river per angler per day (Table 30), while another study reports estimates of the changes in value in response to a number of differing site-specific factors (catch rates, water visibility etc) (Table 31); values are converted to 2012 dollars using the latest CPI data.[103] These provide us with alternative approaches for valuing changes in river parameters; we discuss the different approaches below.

The studies in Table 30 provide comparable values of recreational fishing between rivers. To use the values requires that we have corresponding data on the number of angler days and on how these change with changes in water quality or quantity. Figure 17 shows fishing values for four rivers; the range extends from approximately $18-$141 per angler/day.

[103] Statistics New Zealand, (2012) Infoshare Database: CPI Index All Groups for New Zealand

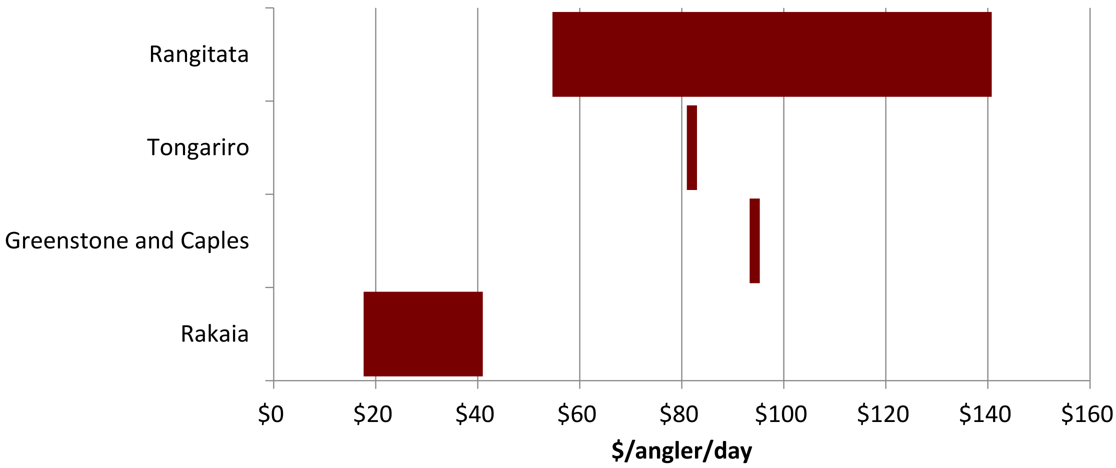
Value Per Trip

Table 30 Recreational fishing values

Study location	Measurement method	Value ($/angler/day) (2012 dollars)	Author(s)
Rakaia River, Canterbury	TCM & CVM	$27-41	Gluck (1974) in Denne et al. (2011)
Rakaia River, Canterbury	TCM	$18	Leathers, Kerr & Sharp (2004)
Greenstone & Caples Rivers, Otago	CVM	$94	Kerr (1996)
Tongariro River, Waikato	TCM & CVM	$82	McBeth (1997)
Rangitata River, Canterbury	TCM	$55-$141	Kerr & Greer (2004)

Sources: Denne T, Scarpa R and Beville S (2011) Gap Analysis of Freshwater Economic Valuation Information. Report to Ministry for the Environment; Kerr GN, Sharp BMH and Leathers KL (2004) Instream Water Values: Canterbury's Rakaia and Waimakariri Rivers. Lincoln University Research Report No272; Kerr GN (1996). Recreation values and Kai Tahu management: the Greenstone and Caples Valleys. New Zealand Economic Papers 30(1): 19-38; McBeth R (1997) The recreational value of angling on the Tongariro River. Non-market valuation using the travel cost method and contingent valuation method. MA thesis, Department of Geography, University of Auckland; Kerr GN and Greer G (2004). New Zealand River Management: Economic Values of Rangitata River Fishery Protection. Australasian Journal of Environmental Management

Figure 17 Study site value estimates for recreational fishing ($/angler/day)



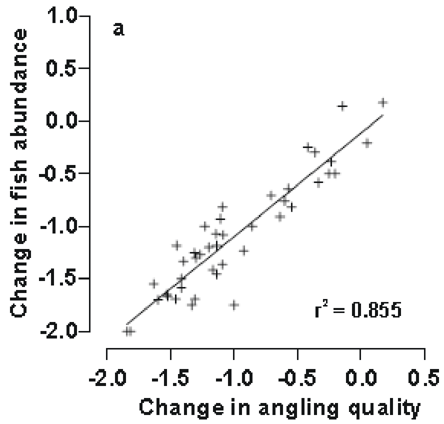
Sources: Table 30

The Rangitata and Rakaia rivers are known as two of the top New Zealand salmon fisheries in New Zealand[104] so caution is required in transferring these values to other rivers. It is not clear, for example, if relative values of fishing days will vary with the ordering of the river in some national classification of fishing quality, if relative values will vary with regional (rather than national) rankings, or if fishing values are relatively independent of such rankings. For example, does the fact that these rivers represent top salmon fishing rivers mean that the value of a fishing day is higher than it is for trout rivers in Southland? The data in Figure 17 suggest that the quality of the fishing

[104] http://www.fishingmag.co.nz/cant-salmon-map.htm

experience may not be that important; recorded values are lowest for the Rakaia, which is reportedly the best fishing river for salmon, whereas higher values for the Tongariro plus Greenstone and Caples rivers which are only known as trout fisheries.[105] In terms of which attributes result in highest angling quality, a survey of anglers suggested that there was a more significant correlation between fish abundance and angling quality than fish size (Figure 18).

Figure 18 Relationship between anglers' perceptions of changes in fish abundance and size, and in angling quality



Source: Jellyman DJ, Unwin MJ and James GD (2003) Anglers' perceptions of the status of New Zealand lowland rivers and their trout fisheries. NIWA Technical Report

The range of values is relatively large ($18 to $141/angler /day); given the absence of site-specific values for Southland rivers, values at the low end of the range might be the *most* appropriate to use for benefit transfer as we are more confident that these represent a value of fishing as opposed to any values of the location. The estimation of fishing value at the Rakaia was derived using the Travel Cost Method which uses the costs associated with travel to the site to estimate a consumer surplus—the difference between what was paid and the willingness to pay. Surpluses will be greater for a river that is closer to a centre of population and with a lower travel cost. Transferring such values to an alternative site needs to correct for distance. However, we do not have information on the origin of fishing trips for Southland angling, so we use the surpluses unmodified.

Marginal Impact of Changes in Site Parameters

The results above are relevant for marginal change sin the number of fishing trips as a result of changes in water quality or quantity; Beville and Kerr's study (Table 31) estimates the impacts on the value of a fishing day of marginal changes in factors that determine that value. It examined whether the intensity of angler preference for attributes of sites differed between sites and what were the determining factors.

The results are shown in Table 31. This shows the impacts on the value of an angling trip (in $/angler/day) of changes in the following variables:

- Increasing water visibility by 1 metre;

[105] www.nzfishing.com

- Increasing the bag limit allowing anglers to catch and keep one additional trout;
- Changing the fishing success rate such that one more trout is caught;
- An increase in the size of trout caught by 1lb; and
- Whether didymo is present at the site.

Table 31 Impact of marginal changes in site-specific factors on fishing values (mean WTP) at North Canterbury Rivers ($/angler/day) – 2008 values (Dec 2012 values in parentheses)

Parameter	Generic	Mainstem-braided	Back-country	Lowland	Lake
Improved water visibility (1m)	8.86 (9.74)	17.85 (19.62)	13.06 (14.36)	10.77 (11.84)	10.26 (11.28)
Bag limit (1 more trout)	31.64 (34.78)	36.61 (40.24)	55.81 (61.35)	30.67 (33.71)	34.84 (38.3)
Catch rate (1 more trout)	18.39 (20.21)	23.29 (25.6)	36.51 (40.13)	21.77 (23.93)	16.98 (18.66)
Trout size (per lb)	28.81 (31.67)	43.66 (47.99)	56.13 (61.7)	27.56 (30.29)	25.26 (27.77)
Didymo present	-43.28 (-47.57)	-66.33 (-72.91)	-65.62 (-72.13)	-41.07 (-45.14)	-46.79 (-51.43)

Source: Beville SB & Kerr G (in prep) Site-specific Preference Heterogeneity and Recreational Angler Site Choice: A Case Study; Stephen Beville, pers. comm.

Using these values requires information on marginal changes in these factors, eg. the way in which changes in water quality will change the catch rate or trout size.

Implications for Analysis

Both sets of values can be used as follows:

1. The values per trip can be used if combined with predictions of how changes in water parameters change the number of angler days (we explore this immediately below);

2. The second set of values (Marginal Impact of Changes in Site Parameters) can be used directly if we can make predictions of changes in these parameters (visibility, trout size etc). This we explore when we address the impacts of changes in water quality in Section 4.

Relating recreational fishing values to physical attributes

Using values per trip, we would calculate the change in recreational fishing value as follows:

$$\Delta FV = B_f \times \Delta V_a \qquad (1)$$

Where: ΔFV = the change in fishing value

B_f = the benefit value for fishing expressed in $/angler /day

ΔV_a = the change in angler visits

To estimate the effects of changes in water quality or quantity on fishing values we need to estimate the way in which changes in physical parameters would affect value; this would occur either through changes to the benefit value (B_f) or to the number of visitors (V_a). We have alternative values for the benefit value above; below we outline two approaches for estimating the number of visitors – one develops a relationship identified in the literature; the other uses empirical data on the number of fish and angler visits at a sample of New Zealand rivers.

Angling visits at the Rakaia river

The factors which determine the number of fishing days/visits (demand for fishing) have been addressed in theoretical terms. Researchers have developed demand functions for fishing, such as:[106]

$$\text{Demand} = f[Y, T, E, S(f), C(n,f), Z(n,f)]$$

Where: Y = income
T = tastes
E = experience or skill
S = site attractiveness
C = expected catch
Z = Congestion
f = River flow
n = number of fish in the river

Kerr et al[107] note that site attractiveness, expected catch and congestion are all likely to be influenced by flow, and that the number of fish in the river is also a function of river flow. They noted that the absence of scientific research identifying the functional relationships between site attractiveness, expected catch, congestion, number of fish in the river and flow means that this demand function cannot be identified. Consequently, they estimated an alternative, simplified demand relationship in which demand is a function of income, tastes, experience/skill and the number of fish in a river:

$$\text{Demand} = f[Y, T, E, n]$$

In the research they estimated changes in demand by varying only one component (the number of fish);[108] respondents were told that the change in fish abundance was due to management approaches designed to "protect, rehabilitate, and enhance" fish stocks.[109] Thus the respondents did not consider other improvements to the angling experience (eg. site attractiveness) that might coincide with an increase in fish stocks, thus isolating the issue of interest. Here we initially consider the extent to which changes in fish numbers might change the number of angler visits.

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[106] Daubert and Young 1981 in: Kerr G, Sharp B and Leathers K (2004) Instream Water Values: Canterbury's Rakaia and Waimakariri Rivers. AERU Research Report 272. Lincoln University
[107] Kerr G, Sharp B and Leathers K (2004) Instream Water Values: Canterbury's Rakaia and Waimakariri Rivers. AERU Research Report 272. Lincoln University
[108] Kerr G, Sharp B and Leathers K, op cit.
[109] Thus the analysis did not quantify the impacts of these other factors (eg. income) on demand for fishing

Based on Kerr et al's survey, we estimate the relationship between the number of fish and the number of fishing visits. Part of Kerr et al's work involved surveying active anglers on how changes in the abundance of salmon in the Rakaia river would affect their annual visitation rate. The number of respondents to this survey was low compared to the survey they used to calculate fishing benefit per angler per day. In the latter survey, anglers averaged approximately 16 trips per year, compared to 8.4 trips per year in this sample. This implies that the sample is biased towards anglers that are less active. Whether the change in value that these anglers obtain is more or less sensitive to changes in the abundance of salmon is unknown.

The authors also note that increases in the abundance of fish would be likely to bring new anglers to the fishery, and as such total use will increase by more than this analysis would suggest. The results of Kerr et al's survey are presented in the following table.

Table 32 The influence of changes in salmon abundance on mean annual fishing trips[110]

Rakaia River Salmon Abundance	Mean annual trips	Ratio to existing
4x present	15.98	1.91
2x present	13.64	1.63
Existing	8.37	-
0.5x present	7.79	0.93
0.25x present	4.57	0.55

The abundance of salmon is given not in terms of the quantity of salmon, but in terms of abundance relative to present numbers. Additionally, mean annual trips per angler is estimated instead of total annual visits. Total visits though, will change by the exact same magnitude that mean visits per angler do, provided the number of anglers remains constant, ie. they adjust the number of visits rather than some anglers not visiting at all. Therefore, mean annual visits are analogous to total annual visits.

As we are interested in the magnitude of change in mean or total annual visits, the figures for mean annual trips in Table 32 are meaningless – instead we use the "Ratio to existing" numbers in the third column.

While recognising that there are just five observations, a logarithmic trend fits the data well. A natural log transformation was applied to the variables trips (=mean annual trips relative to present) and abundance (=salmon abundance relative to present). This transforms the model into a linear function which is useful for ease of interpretation, since in "double log" models (where the dependent and explanatory variables are logged values) the coefficient on the explanatory variable represents an elasticity, ie. how a relative change (a % change) in the explanatory variable relates to a relative change in the dependent variable.

Using Ordinary Least Squares regression, the double log model (Model 1) was estimated. The results are presented in Table 33.

[110] Sharp B and Kerr G, op cit.

Model 1. $ln(Trips) = \beta_1 + \beta_2 \times ln(Abundance)$

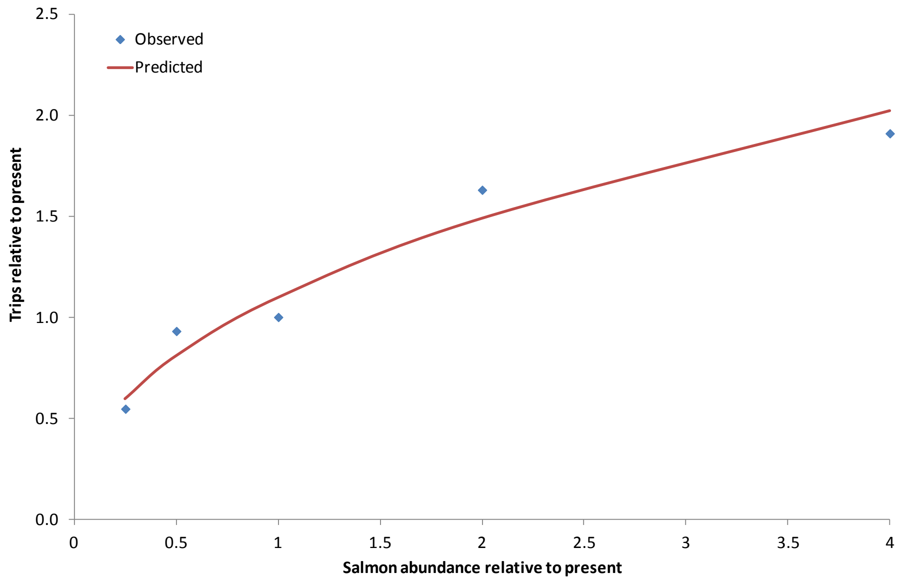
Where: β_1 = Intercept
β_2 = Coefficient on abundance (elasticity)
Trips = Trips relative to present
Abundance = Fish abundance relative to present
ln = Natural log ie. $\log_e$

Table 33 OLS estimation of Model 1.

β_1	P-value$_1$	β_2	P-value$_2$	R-square
0.092	0.202	0.442	0.003	0.95

The R^2 statistic is high, suggesting that the change in the number of fish is able to explain 95% of the variation in the mean annual fishing trips to a river. This would appear to be spuriously high. However, the p-value (the probability that the parameter is not statistically significant) is high for the abundance of fish (β_2), ie. it is not statistically significant, but is low for the number of fish (it is statistically significant at the 1% level). We use Model 1 to estimate the values and as a predictive model (see Figure 18).

Figure 19 Modelled relationship between trips relative to present and salmon abundance relative to present



The model illustrates diminishing returns to increases in the abundance of fish. That is, as fish numbers increase, the annual number of fishing trips increases at a decreasing rate. The effect of a 1% increase in abundance can be approximated by multiplying the percentage change by the coefficient on abundance (ie. 1 × 0.442). The interpretation is that a 1% increase in abundance is associated with an estimated 0.442% increase in trips.

This approximation loses accuracy as the percentage change in abundance grows larger. Therefore for changes in fish abundance larger than ~10% we must calculate the effect on trips manually.[111]

Angling visits vs fish density

Like Kerr et al's[112] survey data above, this analysis relates the annual number of angler visits to a measure of the number of fish in the river. Here there are data for a large sample of rivers (n = 85). For each river we have data on the number of angler days in the 1994/95, 2001/02 and 2007/08 seasons,[113] along with a measure of fish abundance in trout per km terms.[114]

The measurements of trout/km were taken in 1990 so there is a temporal discrepancy between the two variables. However, if we assume that variability in trout numbers over space is greater than over time, these values may be reasonable to combine in analysis. Angler days for the 1994/95 season, as opposed to the 2007/08 season for example, are much more likely to be related to fish abundance in 1990, since fish numbers will have changed over time. Hence our analysis uses the 1994/95 angler days data.

We ran regressions on a range of functional forms with the variables angler days (= angler days in the 1994/95 season) and trout/km. The observations for five rivers were deemed to be outliers, as the sites at which the trout numbers were measured were not representative of angling sites;[115] regressions were run with and without these outliers.

The results of these regressions are presented in Table 34.

In selecting the best model, we assessed the results in terms of the statistical significance of the relationship, the goodness of fit of the model (R Squared statistic), and the

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[111] The steps to achieve this are:

(1) Calculate the fish abundance relative to present: For example, if fish numbers have increased by 50%, then fish abundance relative to present would be 1.5.

(2) Substitute the fish abundance relative to present into Model 1: In the case described above, 1.5 would be substituted into Model 1 as follows:

$$\begin{aligned} \ln\text{Trips} &= 0.092 + 0.442 \times \ln(1.5) \\ &= 0.27 \end{aligned}$$

The result given in this case is 0.27 (to 2 decimal places).

(3) Undo the log transformation: Since we have log transformed our two variables, any predictive results are logged values and must be transformed back to be interpreted. To transform back, we exponentiate the logged results. In the case above, we exponentiate 0.27 to get 1.31 trips relative to present, a 31% increase in trips.

[112] Kerr G, Sharp B and Leathers K, op cit.

[113] Ian Jowett, personal communication – raw data from 100 river study

[114] Teirney LD, and Jowett IG (1990). Trout abundance in New Zealand rivers: An assessment by drift diving. MAF, Freshwater Fisheries Centre, Freshwater Fisheries Report 118, Christchurch, New Zealand.

[115] Ian Jowett, pers. comm.

Ramsey RESET test for model misspecification.[116] Note that the goodness of fit cannot be compared across models where the dependent variable is not identical, for example across Model 3 and Model 6.

Table 34 Results (p-values in parentheses)

Model[1]	**2**	**3**	**4**	**5**	**6**
Predicted Variable	Angler Days	Angler Days	Angler Days	Log Angler Days	Log Angler Days
Trout/km	22.790 (0.069)	***30.703 (0.010)	***33.770 (0.000)		
Log Trout/km				***0.554 (0.001)	***0.657 (0.000)
Constant	**2,283.611 (0.034)	478.296 (0.334)		***4.964 (0.000)	***4.399 (0.000)
Outliers	✓			✓	
n	85	80	80	85	80
R^2	0.07	0.29	-	0.14	0.23
RESET P-value	0.655	0.820	-	0.574	0.974

[1] Model 1 is in the preceding section

*** Indicates statistical significance at the 1% level.** Indicates statistical significance at the 5% level

All models pass the Ramsey RESET test – in each case there is no evidence that the functional form of the model is incorrect.

Models 2 and 5 include outliers and are presented only for comparison. They exhibit a significant change in the coefficient on trout/km and R Squared statistic compared to the equivalent models excluding outliers (3 and 6).

Considering the remaining models, we believe that Model 6 provides the best estimate of the relationship between angler days and trout/km.

For Model 6:

$$ln(AnglerDays) = \beta_1 + \beta_2 \times ln(Trout/km)$$

	β_1	β_2
Model 6	4.399	0.657

Like Model 1 above, the model illustrates diminishing returns to increases in the abundance of fish. Here, a 1% increase in trout/km is associated with an estimated 0.657% increase in angler days per season.

Again, this approximation loses accuracy with larger changes in trout/km and we must calculate the effects of such changes on angler days manually.[117]

[116] The Ramsey Regression Equation Specification Error Test (RESET) is a general test for model miss-specification. A low p-value indicates the functional form of the model has been miss-specified or important variables have been omitted.

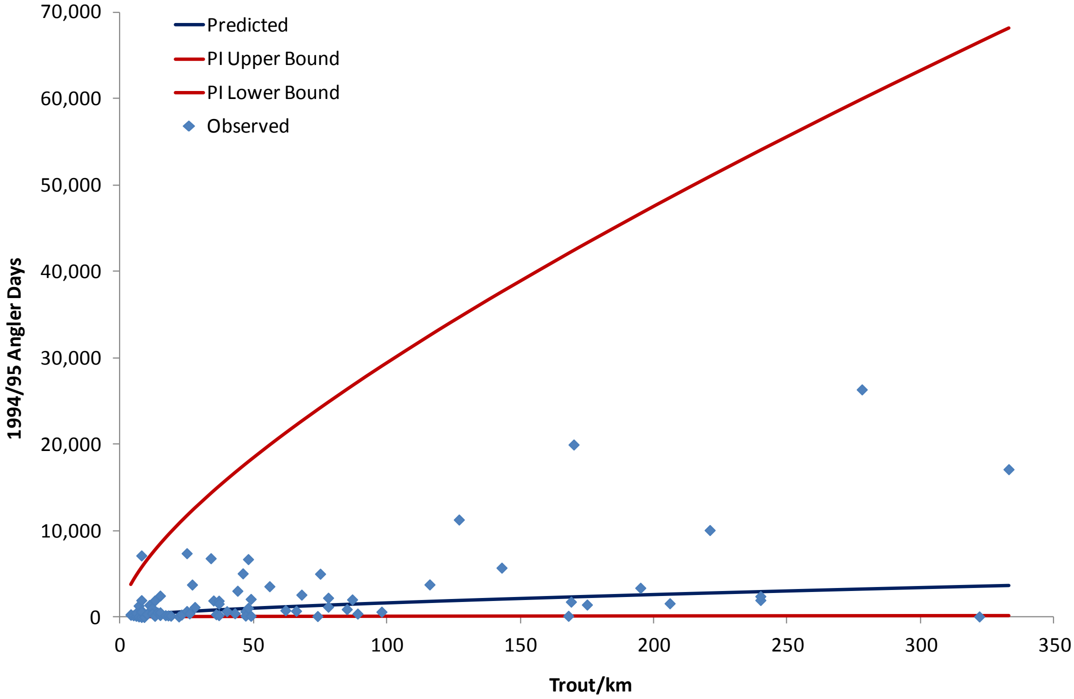
[117] For Model 6 the steps to achieve this are:

In this way Model 6 can be used to calculate the percentage change in total visits associated with a change in of any magnitude in fish abundance.

Caution must be taken when considering the output of such an exercise. The R Squared statistic for Model 6 indicates that just 23% of the variation in log angler days is explained by log trout/km. Clearly there are other factors that influence angler days (eg. income, weather) but lack of these data for each river precluded the addition of such variables to the model.

Figure 20 presents the original data along with the predicted (or fitted) values from Model 6, and a 95% prediction interval. In presenting these data, the log transformations have been undone so they can be viewed on the scale of the empirical observations.

Figure 20 Predicted values for angler days, bounded by a 95% prediction interval (PI)



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(1) Calculate the relative change in fish abundance: For example, if fish numbers have increased from 50 trout/km to 75 trout/km, the relative change is a 50% increase.
(2) Substitute the values for fish abundance into Model 6: In the case described above, we need to calculate two fitted values – one for 50 trout/km and one for 75 trout/km – as follows:
    $\ln Trips = 4.399 + 0.657 \times \ln(50) = 6.97$
    $\ln Trips = 4.399 + 0.657 \times \ln(75) = 7.24$
(3) Undo the log transformation: Since we have log transformed the variables in Model 6, any predictive results are logged values and must be transformed back to be interpreted. To transform back, we exponentiate the logged results. In the case above, we exponentiate 6.97 and 7.24 to get 1,063 angler days and 1,388 angler days respectively.
(4) Calculate the relative change in angler days: The increase in angler days from 1,063 to 1,388 is equivalent to a 31% increase.

Prediction intervals are used to measure the accuracy of predictions. A 95% prediction interval tells us there is a 95% probability that for a river with a given number of trout/km, the actual angler days per season for that river are within this interval. The width of the prediction interval follows the variance in the original data and increases along with trout/km.

However a wide prediction interval does not necessarily invalidate our model. The width of the interval is not to be unexpected – it agrees with the R Squared statistic which says Model 6 explains but a portion of the variability in angler days. Including additional explanatory variables such as income among local residents, or weather at the river, would increase the goodness of fit of the model and narrow the prediction interval. Since these variables are uncorrelated with the density of fish, they will have little to no effect on the elasticity value of 0.657.

Comparison of approaches

While both approaches outlined above estimate the relationship between the number of fish in a river and the number of angler visits per year, they differ in the nature of the data utilised.

Kerr et al's[118] study focussed on one river, the Rakaia. Their methodology was to survey a sample of anglers and present to them hypothetical scenarios regarding changes to the abundance of fish (eg. 4x present numbers). Respondents were asked how many visits to the river they would make under each scenario and the figures were compared to their existing visitation rate.

The second set of data[119] includes the number of angling trips per year for 85 rivers, along with a measurement of fish density in trout per km terms. This set of data may be more useful since it contains observed as opposed to hypothetical information (stated intentions).[120]

Table 35 Valuation approaches

	Approach 1	Approach 2
River	Rakaia River, Canterbury	85 rivers across New Zealand
Species	Salmon	Trout
Explanatory variable	Salmon abundance relative to present	Trout per km
Dependent variable	Mean annual angling visits relative to present	Total annual angling visits

Despite these differences in the nature of the data, the estimated relationship is the same ie. between the number of fish and number of angling visits. Further, for both sets of data the functional form that fits best is log transformed, therefore in each case the coefficient on the explanatory variable represents an elasticity. These elasticities mean

[118] Kerr G, Sharp B and Leathers K, op cit.

[119] Ian Jowett, pers. comm.

[120] We note that it would be more useful to have time series data for individual rivers, noting how numbers of anglers have changed over time with changes in numbers of fish. This would be a useful subject of future research.

that the results of Approaches 1 and 2 can be compared - they both describe how a 1% change in the number of fish relates to a relative change in visit numbers.

Table 36 below compares the elasticities. The elasticity from the second approach is higher than that of the first. Notably, Approach 1 is based on a survey of *active* anglers, and does not take into account the fact that an increase in fish will be likely to attract *new* anglers.[121] Therefore the estimated elasticity for Approach 1 is almost certainly understated and the results may be more alike than they appear.

Table 36 Elasticities under different approaches (% change in angler visits:% change in fish density)

	Approach 1/Model 1	Approach 2/Model 6
Elasticity	0.442	0.657

The results of Approach 2 are also likely to be more widely applicable since they refer to trout density (as opposed to salmon). Salmon are found almost exclusively in lower South Island rivers, while trout are common in rivers throughout the country. Additionally, the Approach 1 results relate to the Rakaia River and must be extrapolated to any other river, while Approach 2 uses a comprehensive sample of 85 rivers.

Considering the above, Approach 2 appears to present the most useful results. The data should be considered more valid (observed versus hypothetical), and the results are more conducive to a wider application.

Recreation

Four New Zealand studies were identified that measured the recreational benefits of fresh water bodies. A brief review of each of these studies is presented in the following table, with values converted to 2012 dollars using CPI.[122]

Table 37 Collection of study sites for recreational benefit transfer

Study location	What was valued	Method	Value (2012 dollars)	Author(s)
Wanganui & Whakapapa Rivers, Manawatu-Wanganui	Recreational canoeing benefits	CVM	\$109-\$148 per visitor/day	Sandrey (1986)
Lake Tutira, Hawke's Bay	General recreational benefits	TCM	\$31 per visitor/day	Harris & Meister (1981)
Upper Wanganui & Whakapapa Rivers, Manawatu-Wanganui	Recreational rafting, kayaking, canoeing benefits	TCM	\$190 per visitor/day	Cocklin, Fraser & Harte (1994)
Artificial Lake, Methven, Canterbury	General recreational benefits	CVM	\$56-\$122 per household/year	Meyer (1994)

The study by Cocklin et al. (1994) has been deemed unsuitable for transferability; according to Kerr (2003) a study by Meister and Weber (1989) presented evidence that illustrated major deficiencies in, and discredited, the Cocklin *et al.* study.[123]

[121] It will also persuade some to shift sites
[122] Statistics New Zealand, (2012) Infoshare Database: CPI Index All Groups for New Zealand
[123] Kerr, G. N. (2003) Extra-market values and water management in New Zealand. Presented to Australian Agricultural and Resource Economics Society.

Of the remaining three studies, two valued recreational benefits at lakes. To some extent this conflicts with the benefit transfer assumption that the study site and the policy are similar, yet lakes and rivers are both freshwater bodies and the recreational activities that take place at these sites are similar. In the absence of more suitable study sites we consider these valuation results transferable.

Drivers of recreational use

The studies did not identify drivers for recreational demand, but water variables affecting recreational use are likely to be those relating to site aesthetics, including visibility and presence of periphyton, plus health-related factors affecting the swimmability of the water. With respect to swimmability, the standards for fresh water quality are set out by MfE and are based on the presence of the bacterium *E coli*.[124] Levels of *E coli* which represent suitability for swimming might be used as a way to predict some changes in levels of recreational use, although this might be limited to swimming use (and would depend on whether the information on *E coli* levels was available).

Table 38 Microbiological standards for recreational use of fresh water[125]

Mode	Freshwater (*E coli*/100ml)
Surveillance/Green (very safe for swimming)	No single sample greater than 260
Alert/Amber (satisfactory for swimming)	One single sample between 261 and 550
Action/Red (Could be a health-risk for swimming)	One single sample greater than 550

In the past fresh water quality standards have been assessed in terms of faecal coliform count as opposed to *E Coli*, but MfE provides an indicative conversion factor.[126]

Impacts of Water Quality Changes

As there was for fishing values, there are studies that relate changes in factors relevant to recreational values to changes in water quality (Table 39). However, many are expressed in terms of the impacts per household per year; they reflect the change in values for those that visit the site and for those that do not. These are therefore not pure recreational values, but some combination of values for active recreational use and passive (existence) use. This does not make these values redundant, but means we are less able to classify values in terms of the TEV categories.

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124 MfE, (2003). Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas, pE9

125 Adapted from Otago Regional Council, n.d. Water quality and what we measure. http://www.orc.govt.nz/Information-and-Services/Water/Water-quality/Water-Quality/

126 126 E Coli per 200 faecal coliforms (MfE, http://www.mfe.govt.nz/issues/water/water-quality-faqs.html#question4)

Table 39 Impacts of Changes in Water Quality on Recreational Value

Study location	What was valued	Method	Value ($/household/year)	Author(s)
Karapiro, Waikato	Water quality improvements	CM	Risk of algal bloom **(for swimming)**: $39-$190 (2009) Ecological health: $51-$136 (2009)	Marsh (2010)
Lower Waimakariri, Canterbury	Improving water quality to **swimmable standard** (D to C)	CVM	$72-$153 (1993)	Sheppard, Kerr, Cullen & Ferguson (1993)
Orakei Basin, Auckland	Improvement in water quality	CVM	$11 (2003)	Williamson (1998)
Selwyn River, Canterbury	Attributes	CM	**Safe to swim: $68-$299** (2003) Gorse in stream bed: -$39 to -$180 Predominantly clear water: -$2 to $183 25 days no flow in summer: -$2 to -$62	Kerr & Swaffield (2007)

Source: Marsh D (2010). Water Resource Management in New Zealand: Jobs or algal blooms? Paper presented at the Conference of the New Zealand Association of Economists. Auckland, 2 July, 2010; Sheppard R, Kerr GN, Cullen R and Ferguson T (1993) Contingent valuation of improved water quality in the Lower Waimakariri River. Research Report No. 221; Williamson J (1998) An estimation of the value which Auckland residents place on an improvement in the water quality of the Orakei Basin: Summary. Report to Auckland City Council; Kerr GN and Swaffield S (2007). Amenity values of spring fed streams and rivers in Canterbury, New Zealand: A methodological exploration. AERU Research Report No. 298. Agribusiness and Economics Research Unit, Lincoln University.

Aesthetics and Amenity

Aesthetic value is an expression of what people value about the environment in terms of its appeal to their senses; this might include the look, sound, smell, taste or feel of a location, and in this case, a water body. To some extent this is a value in its own right, but generally it modifies the value of other more direct uses, particularly recreational uses or visits. People go to visit a river because of its aesthetic value and the value that they obtain from that visit changes with its aesthetic value. There is also likely to be a high correlation between the aesthetic value of a water body and the extent to which it is in a pristine state, although this is not certain and may differ between people.

Amenity value is the term used in New Zealand legislation to capture the concept of aesthetics; the Resource Management Act 1991 (Section 2) defines the concept as "*those natural or physical qualities and characteristics of an area that contribute to people's appreciation of its pleasantness, aesthetic coherence, and cultural and recreational attributes.*"

Amenity values have been included in a number of valuation studies, particularly those associated with existence. As with recreational studies, often there are difficulties with separating out aesthetics in terms of the value for active users from values for passive users. [127]

In New Zealand there a number of studies have produced values that might be classified as amenity values of water (Table 40).

[127] Jay R. Corrigan JR, Egan KJ and Downing JA (2007) Aesthetic Values of Lakes and Rivers. RePEc:ken:wpaper:0701; Lansford NH Jr and Jones LL (1995) Recreational and Aesthetic Value of Water Using Hedonic Price Analysis. Journal of Agricultural and Resource Economics 20(2):341-355.

Table 40 Amenity Values

Site	Unit	Value ($/hh/yr)	Method	Source
Kawarau River	Use and aesthetics from preventing hydro scheme development household/ year	$197	CVM	Kerr (1985)
Waikato River	Prevent Waikato River pollution returning to 1960s quality	$93	CVM	Harris (1984)
Waimakariri River	Prevent irrigation development for 5 years Preserve in its existing state Improve Waimakariri River water quality from D to C standard	$37 $42 $34	CVM and zonal TCM	Kerr, Sharp and Leathers (2004). Sharp and Kerr (2005).
Rakaia River	Prevent irrigation development for 5 years Preserve in its existing state	$44 $43	CVM and zonal TCM	Kerr, Sharp and Leathers (2004)
Ashburton River	Preserve Ashburton River flows (Canterbury households/year) Preserve Ashburton River flows (Ashburton District non-fishing households/year)	$70 $118	CVM	Lynch and Weber (1992); Lynch (1992)
Auckland urban streams	Stream channel rehabilitation Clear, opposed to, muddy streams Streamside vegetation Loss of one native fish species	$59 $67 $21 $11	CM	Kerr and Sharp (2003a) (2003b)
Orakei Basin	Improvement in water quality	$11	CVM	Williamson (1998)
Lakes Rotorua and Rotoiti	Reduction in nutrients in the lakes (Rotorua households/year) Reduction in nutrients in the lakes (Greater Bay of Plenty households/year)	$91 $12	CVM	Bell and Yap (2004)
Karapiro Catchment	Improve water clarity to 4 metres Ecological health (50 % of readings in excellent health) Ecological health (80 % of readings in excellent health 40-70% chance of good ecological readings 40-70% chance of good ecological readings (individual specific status quo) > 70% chance of good ecological readings > 70% chance of good ecological readings (individual specific status quo) trout present trout present (individual specific status quo) Clarity (possible to see the stream bottom) Clarity (possible to see the stream bottom) (individual specific status quo)	$82 $51 $136 $17 $50 $22 $124 $44 $83 $75 $75	CM	Marsh (2010); Marsh and Baskaran (2009)
Waimea Plains	in-situ 20% reduction in extractive use to maintain stream flows and limit salt water intrusion	$183	CVM, Hedonic	White, Sharp and Kerr (2001)

Notes: CVM = contingent valuation method; CM = choice modelling; TCM = travel cost method; NS = not significant

Source: Bell B and Yap M (2004). The Rotorua Lakes: evaluation of less tangible values. Report prepared for Environment Bay of Plenty; Harris BS (1984) Contingent valuation of water pollution control. Journal of Environmental Management 19: 199-208; Kerr GN (1985). Aesthetic and use values associated with proposed Kawarau Gorge hydro-electric developments. In: Sheppard D and Rout J (eds) Kawarau hydro investigations: river recreation economic study. Wellington: Ministry of Works and Development.; Kerr GN and Sharp BMH (2003a).Transfer of choice model benefits: a case study of stream mitigation. Occasional Paper No.4, Environmental Management and Development Programme, National Centre for Development Studies, Australian National University; Kerr GN and Sharp BMH (2003b). Community Mitigation Preferences: A Choice Modelling Study of Auckland Streams. Research Report No. 256, Agribusiness and Economics Research Unit, Lincoln University; Kerr GN, Sharp BMH and Leathers KL (2004). In-stream Water Values: Canterbury's Rakaia and Waimakariri Rivers. Research Report No. 272, Agribusiness and Economics Research Unit, Lincoln University. Sharp BMH and Kerr GN (2005).Option and Existence Values for the Waitaki Catchment Research. Report commissioned by the Ministry for the Environment for consideration by the Waitaki Catchment Water Allocation Board; Lynch RJ and Weber JA (1992) Valuing water of the Ashburton River: in-stream flows versus irrigation. MAF Policy Technical paper 92/13. Wellington: MAF Policy; Lynch RJ (1992) The economic valuation of water from the Ashburton River: implications for allocation. Master of Agricultural Science thesis, Massey University.; Marsh D (2010). Water Resource Management in New Zealand: Jobs or algal blooms? Paper presented at the Conference of the New Zealand Associates for Economists. Auckland, 2 July, 2010; Marsh D and Baskaran R (2009). Valuation of water quality improvements in the Karapiro catchment: a choice modelling approach. Paper to the 53rd annual Australian Agricultural & Resource Economics Society conference. Cairns, Queensland, 10-13 February 2009; White PA, Sharp BMH and Kerr GN (2001) Economic Valuation of the Waimea Plains Groundwater System. Journal of Hydrology (NZ) 40(1): 59-76; Williamson J (1998) An estimation of the value which Auckland residents place on an improvement in the water quality of the Orakei Basin: Summary. Report to Auckland City Council.

Kerr et al[128] estimated that the present value of Rakaia angling was worth $5 million, preservation benefits were $19 million, option values $8 million. They also noted $11-30 million present value of Waimakariri preservation benefits and $4-8 million of option benefits. The authors were hesitant in recommending benefit transfer for the values estimated, but noted that “while they lack precision, the estimated values indicate that Canterbury residents placed a significant value on protection of in-stream amenities that should not be ignored in contemporary water allocation decisions.”

The studies by Marsh and by Marsh and Baskaran are highly relevant to the Southland studies. The research addresses the willingness to pay for water quality improvements in “a typical dairy catchment in the Waikato region”.[129]

The work examined the value of the following water quality attributes as shown in Table 41.

[128] Kerr GN, Sharp BMH and Leathers KL (2004). In-stream Water Values: Canterbury's Rakaia and Waimakariri Rivers. Research Report No. 272, Agribusiness and Economics Research Unit, Lincoln University

[129] Marsh D (2010). Water Resource Management in New Zealand: Jobs or algal blooms? Paper presented at the Conference of the New Zealand Associates for Economists. Auckland, 2 July, 2010. Marsh D and Baskaran R (2009). Valuation of water quality improvements in the Karapiro catchment: a choice modelling approach. Paper to the 53rd annual Australian Agricultural & Resource Economics Society conference. Cairns, Queensland, 10-13 February 2009.

Table 41 Water quality attribute levels

Attribute	Unit	'Do Nothing'	Option 1	Option 2	Option 3
Suitability for swimming and recreation	Chance of health warnings for 1-2 weeks in summer	50%	20%	10%	2%
Water clarity	Distance can usually see underwater	1 metre	1.5m	2m	4m
Ecological health	% of readings that are excellent	40%	50%	60%	>80%
Jobs in Dairying	% change	0	-5%	-10%	-20%
Cost to household ($/yr for next 10 years)	$ per year for next 10 years	About the same	$50, $100, $300, $600, $1,000		

Source: Marsh D (2010). Water Resource Management in New Zealand: Jobs or algal blooms? Paper presented at the Conference of the New Zealand Associates for Economists. Auckland, 2 July, 2010

The results of the analysis are shown in Table 42.

Table 42 Mean marginal willingness to pay for attributes - $/household/year (median in parentheses)

Attribute	Option 1	Option 2	Option 3
Suitability for swimming and recreation	$39 ($28)	$190 ($141)	$141 ($102)
Water clarity	-	-	$82 ($58)
Ecological health	$51 ($37)	-	$136 ($103)
Jobs in Dairying	-$126 (-$90)	-$67 (-$51)	-$241 (-$177)

Source Marsh (op cit)

The results show that the average WTP to improve the suitability for swimming is $39/household to reduce the chance of health warnings from 50% to 20% (the median is $28), an additional $190 to reduce this to 10% and a further $141/household/year to reduce this to 2%. Water clarity is valued, but insignificantly until visibility is increased to 4 metres. Ecological health is valued, but although there is an initial WTP for improvements (to a 50% chance of excellent readings) there is no significant increase in price to achieve a 60% chance; there is a WTP of $136 to improve this further such that there is a more than 80% chance of excellent readings.

In contrast, losses of jobs in dairying are regarded as dis-benefits. The job loss results are an interesting addition to the research, ie. they suggest that there is some wider community benefit associated with employment, ie. there are external benefits not captured in the wage rate. Understanding this WTP is not immediately clear: it might be the equivalent of a multiplier effect used in macro-economic analysis, ie. an expression of the extent to which others in the region benefit from the economic activity of employed dairy workers, or it might be an expression of a desire to live in a society with full(er) employment.

Additionally, the study by Marsh has interesting implications for policy. WTP was estimated for three policies in which all attributes achieve the desired option. For example, Policy 1 is equivalent to a 20% chance of a health warning, 1.5m underwater visibility, 50% excellent ecological readings, and assessed with and without a 5% loss in dairy jobs. Table 43 presents these estimates.

Table 43 WTP estimates for combined policy options ($/household/year)

Attribute	Policy 1	Policy 2	Policy 3
No Job Losses			
Median	$26	$51	$86
Mean	$37	$77	$126
With Job Losses	**-5%**	**-10%**	**-20%**
Median	-$4	$35	$30
Mean	-$7	$53	$46

Source: Marsh (op cit)

The figure of $26/household/year was used by the Ministry of Agriculture and Forestry in the estimation of WTP for improvements in water quality at Karapiro and Arapuni hydro lakes, where the 10 year PV across 140,000 Waikato households was $1.1million at an 8% discount rate.[130]

It is important to note that the combined policy options result in lower WTP estimates than the sum of individual attributes in Table 42. In the model used there is some cancellation between benefits, for example someone who values water quality for recreation may have a low value for ecology.[131] This highlights the problem with adding marginal WTP values where each has been estimated on a ceteris paribus assumption.

Option Values

Option values were examined by Sharp and Kerr in their study on the Waitaki catchment.[132] They make the important point that option value is likely to be small in the presence of close substitutes. Willingness to pay to retain options for using a particular site in the future will be influenced by whether alternative sites could also provide these same benefits. Thus options values depend on unique characteristics of a water body and the possibility of irreversible changes. These are important considerations for analysis.

The discussion of Māori values highlights the importance of individual rivers to individual iwi, and similar levels of attachment will apply to other members of the community with historical connections to a particular site. Also there may be individual rivers with unique characteristics, which might include their location eg. a river through an urban environment cannot be a substitute for one in a rural setting for many uses, and vice versa.

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130 Journeaux, P., Schischka, T. & Phillips, Y. (2011) Economic analysis of reducing nitrogen input into the Upper Waikato River catchment. Report prepared for Ministry of Agriculture and Forestry.
131 The author's analysis of multi-attribute improvements takes account of randomness, and therefore produces lower benefit estimates. Random parameters logit (RPL) models are commonly used to estimate willingness to pay, but when individual marginal WTP values are summed, the assumption of randomness is ignored and can overestimate WTP.
132 Sharp B and Kerr G (2005) Option and Existence Values for the Waitaki Catchment. Report prepared for Ministry for the Environment.

The irreversibility of marginal changes in water quantity and quality will be important also, or at least the extent to which quality impacts have long term effects. This will need to be considered when examining the sequence of physical effects (Section 4).

Sharp and Kerr in their analysis were able to obtain estimates of WTP to preserve rivers in their current states or to prevent irrigation development, however they were unable to differentiate between use (active use) and non-use (passive use) values. Specifically they could not differentiate option values from other active use values from existence values. People were willing to pay to preserve rivers in a natural state because they provided benefits that included the direct use of the river, knowledge that they retained options to use it and simply because they valued the preservation of the environment. Sharp and Kerr note that "in general, people place higher value on natural environments that are functioning well, are not polluted, and/or support rare or endangered species."

Given this we do not attempt to isolate these values. Below we address existence values.

Existence Values

Sharp and Kerr examined "values that citizens perceive to be embodied in the environment … independent of use of that environment".[133] Terms used to define these values include "existence", "passive use" and "non-use" values. In general existence values are greatest when the environment is least disturbed relative to its natural state and are lowest when the environment is most modified, however this is not always the case; modified environments can be valued, especially when they have qualities that enhance their aesthetic appeal. Examples from water bodies include artificial lakes and urban rivers, such as the Avon in Christchurch.

Some of these values are listed in Table 40 above. There are clear difficulties in applying these to different situations, eg. Canterbury households were willing to pay $51/year to preserve the Waimakariri River in its existing state (2003 values). However, what is not clear is what level of reduction in water quality would trigger a loss of this value. The identification of existence values is complicated by the somewhat conflicting results between studies, eg. Kerr et al[134] identify the differences in preservation values for users and non-users of two rivers. For the Rakaia River, as expected, the value placed on the river by users is more than three times the value of non-users; in contrast, for the Waimakariri River the value placed on the river by non-users is more than twice as much as users (although the differences are not statistically significant).

The information that can be gleaned from these data may be somewhat limited. We summarise the values in Table 44.

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[133] Sharp B and Kerr G (2005) Option and Existence Values for the Waitaki Catchment. Report prepared for Ministry for the Environment.

[134] Kerr GN, Sharp BMH and Leathers KL (2004). In-stream Water Values: Canterbury's Rakaia and Waimakariri Rivers. Research Report No. 272, Agribusiness and Economics Research Unit, Lincoln University.

Table 44 Existence Values ($/household/year) (December 2012 values)

Value		Waimakariri	Rakaia	Waikato	Ashburton
Preserve or stop development	All	47-53	54-56	118	89
	Users	57-65	97		
	Non-users	15-19	32		
Improve water quality (eliminate health risk to recreational users)	All	43			
	Users	51			
	Non-users	18			

Source: Original (December 2003) values taken from Sharp B and Kerr G (2005) Option and Existence Values for the Waitaki Catchment. Report prepared for Ministry for the Environment..

Preservation values for individual rivers for non-users are $15-32/household/year for two Canterbury rivers; the value for improving water quality is within the range of values for preserving existing water quality. This is based on a specified marginal jump in quality that would eliminate health risks for recreational users.[135]

Summary of Potential Values

In Table 45 we summarise a set of possible values that might be used for benefit transfer to other water bodies. For two of these, the number of fish are identified as potential drivers. For the others additional analysis is required to estimate how these might vary with changes in water quality, eg. the number of recreational visits.

Table 45 Possible Values for Benefit Transfer

Value	Value (Range)	Unit
Fishing Visits	$27 ($18-$41)	Per visit
Visibility for Fishing	$10 ($10-$20)	Per 1m improvement per visit
Trout Catch	$20 ($19-$40)	Per trout caught per visit
Size of Trout Caught	$32 ($28-$62)	Per lb of trout per trout caught
Recreational visit	$56 ($31-$122)	Per visit
Visibility for recreation	$82	Per 4m change in clarity ($0 for less than 4m)
Change in water quality from non-swimmable to swimmable	$43	Per household
Canoeing/Kayaking	$129 ($109-$148)	Per visit
Change in water quality from non-swimmable to swimmable	$43 ($18-$51)	Per household per river improved
To preserve or stop development	$53 ($47-$56)	Per household per river

[135] The question used to elicit the responses was specified as follows: What is the maximum amount in extra rates (rent) your household would pay annually to raise the water quality standard of the Waimakariri from 'class D' to 'class C'? (This level of improvement would eliminate the health risk to recreational users. The additional rates paid would go solely to water quality research and pollution control measures) (Kerr, Sharp and Leathers *op cit*)

Annex 4: Southland Data

In this Anne we present some of the background data that is used as input to the analysis.

Main Catchments

The descriptions below are taken from the Environment Southland documents[136] [137]and the District Plan Review documents.[138]

The Waiau river drains Lake Te Anau and runs through to Lake Manapouri and from there to the Foveaux Strait. The catchment area is the largest of the four catchments and the least developed. However, the Manapouri Hyrdo-Electric Power scheme diverts up to 90% of the flow (485 m^3/sec) in the catchment through to its discharge into Doubtful Sound. The Waiau used to be one of New Zealand's largest rivers (520m^3/sec), second only to the Clutha in volume terms. Currently consent conditions require at least 16m^3/sec flow through Mararoa Weir, near the outlet from Lake Manapouri.

There is considerable recreational use of the lakes (Te Anau and Manapouri), and the Waiau river itself is now regarded as one of the premier rainbow and brown trout fisheries. There is some on-going resentment in the community regarding the extent of the modification of the river as a result of the Manapouri Hydro Scheme, but it is possible that recreational opportunities have improved at the expense of its natural and wilder state.

The Aparima catchment is the smallest of the four main catchments. It has important areas of wetland, particularly the Castle Downs Swamp, the largest remaining wetland area in Southland. The catchment has a relatively low level of water abstraction, with the major uses being the abstraction of water for the Riverton reticulate community water supply in the lower reaches of the catchment, and irrigation takes from groundwater in the upper catchment. It drains into the Jacobs River estuary.

The Oreti catchment is the third largest in the region. Within the upper catchment several surface water takes supply water to community supply schemes, and recent changes in land use from sheep farming to intensive dairy farming are causing pressure on groundwater as a result of abstraction for irrigation. The upper catchment is relatively natural and is internationally known for its brown trout fishing; in August 2008 the Oreti River became subject to a National Water Conservation Order (WCO) to recognise the value of the catchment as habitat for brown trout and black-billed gulls, angling amenity and significance in accordance with tikanga Māori. The WCO prohibits the damming of any of the waters covered by the Order, requires fish passage to be maintained associated with any abstractions of water, and requires that discharges not reduce water quality beyond a zone of reasonable mixing. The Oreti is the source of drinking water for Invercargill.

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[136] Environment Southland (2010) Our Uses: Southland Water 2010: Part 3.
[137] www.es.govt.nz/media/18462/regional_water_plan_-_december_2012.pdf
[138] Southland District Council District Plan Review. Water Quantity Full Paper. www.southlanddc.govt.nz/assets/2011/District-Plan-Review/Water-Quantity-Full-Paper.pdf

The Mataura catchment is the second largest in terms of area and flow. A National WCO applies to the Mataura and Waikaia Rivers to protect the fisheries and angling amenity features of the catchment. The Mataura/Waikaia River, their tributaries upstream of Gore, and the Mimihau and Mokoreta Rivers are recognised as watercourses of outstanding natural value that provide habitat to many native species and are an internationally recognised trout fishery. The lower Mataura has been an important source of water for industrial processing and cooling, and for electricity generation; it has also been a major receiving environment for industrial and municipal effluent.[139]

The Region's large lakes are nationally significant. Lakes Te Anau, Manapouri, Monowai, North and South Mavora, Hauroko, Poteriteri, McKerrow and Gunn are highly valued for their water quality, recreational, landscape and remoteness values.

Population

The current population of Southland is estimated to be approximately 95,000.[140] At the time of the 2006 census the rural population was 27% of the total, with the urban population dominated by Invercargill (55% of the Southland population) and Gore (11%); smaller towns[141] make up the remaining 7%.[142]

Māori are approximately 12% of the population of Southland but have a long history in the region, with major settlements at Ruapuke Island (between the mainland and Stewart Island) and along the southern coast at Waikawa, Bluff and Riverton/Aparima.

There are four Ngai Tahu runanga (traditional Māori councils) that hold manawhenua (customary authority) over the resources in the region, focussed on Waihopai/Invercargill (Te Runaka o Waihopai), Awarua/Bluff (Te Runanga o Awarua), Oraka/Colac Bay (Te Runanga o Oraka/Aparima) and Gore (Te Runanga o Hokonui).

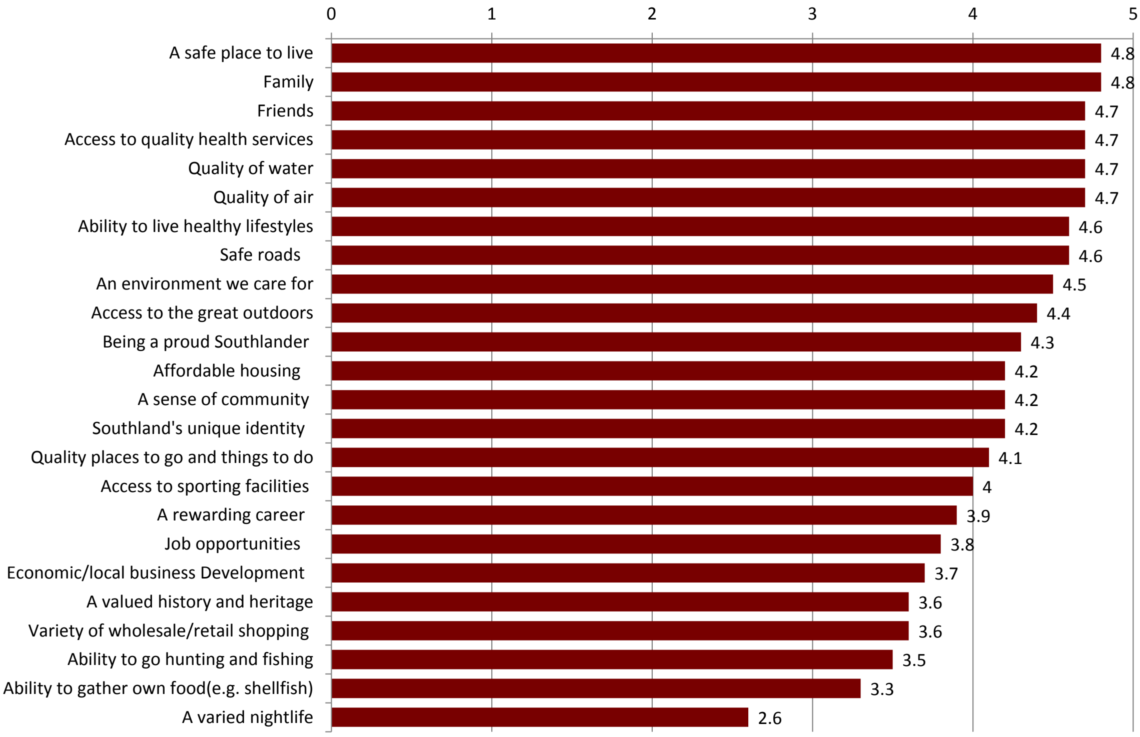
Community Values and Priorities

Water quality issues are important to Southlanders. A survey of quality of life issues in Southland found that the three environmental issues of most importance were "dairy farming/effluent/polluting rivers" (45% of respondents), water quality (13%) and river waterway pollution (8%).[143] Southlanders were also asked to rank issues in terms of their importance on a scale of 1 (least important) to 5 (most important). Quality of water was 5th placed with a ranking of 4.7 out of 5, whereas the environment in general (an environment we care for) had a rank of 4.5. Ability to go hunting and fishing had a rank

[139] Environment Southland (2010) Our Uses: Southland Water 2010: Part 3.
[140] Statistics New Zealand, Population Statistics Unit – estimate for Jun 2012 is 94,900
[141] Winton, Te Anau, Riverton/Apirama and Otautau
[142] Environment Southland (2010) Our Uses. Southland Water 2010: Part 3
[143] Research First (2010) Our Way Southland. Quality of Life Research Report.

of 3.5, relatively high given that these activities are dominated by one half of the population – males.[144]

Figure 21 Rating of Factors Important to Lifestyle



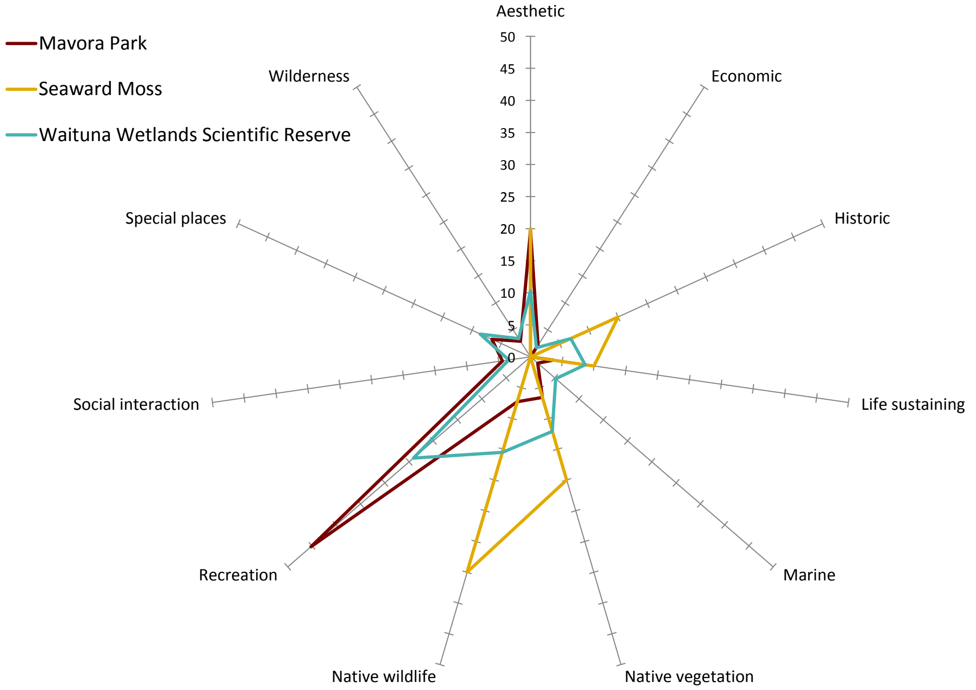
Source: Research First (2010) Our Way Southland. Quality of Life Research Report.

We can derive some idea of relative values from visits to specific sites. A DoC report on values for different conservation areas[145] provides a summary of a survey of public values, experiences and development preferences for conservation land in the Southland region. It was undertaken using a self-administered online questionnaire linked to a geographical information system (GIS), so people could link their experiences and values to specific sites. The values recorded were from answers provided by 268 people in early 2011; they were identified from a random sample of Southland residents, visitors to conservation sites and people who heard of the research. The areas identified as being associated with (non-marine) water bodies were Mavora Park and Waituna Lagoon and the nearby Seaward Moss. Recreational values were most important at two sites (Mavora Lake and Waituna), but native wildlife and vegetation were more important at the other (Seaward Moss).

[144] NIWA assumes that 90% of anglers are male (Unwin M (2009) Angler usage of lake and river fisheries managed by Fish & Game New Zealand: results from the 2007/08 National Angling Survey. NIWA Client Report: CHC2009-046 Prepared for Fish & Game NZ Ltd. NIWA.)

[145] Department of Conservation (2011) Identifying Conservation Values, Park Experiences, and Development Preferences in the Southland Region of New Zealand. A summary of a Public Participation Geographic Information System Study in the Southland region

Figure 22 Percentage of values in a conservation area



It suggests that recreational uses and the value of sites for conservation/ecological reasons will be important in estimating total value.

Māori Cultural Use

In general Māori have strong associations with the natural environment, and water bodies in particular because of their importance as sources of traditional foods (mahinga kai), eg. freshwater eels. The lakes, and rivers of Southland continue to play a major part in Māori cultural identity in the region. The rivers are culturally important to Ngāi Tahu and are recognised as mahinga kai areas (food and resource gathering areas) and traditional trails in the Ngāi Tahu Claims Settlement Act 1998.[146]

Table 46 summarises the cultural uses and associations for the four main catchments in Southland.

146 Environment Southland (2010) Our Health. Southland Water 2010: Part 1

Table 46 Cultural uses of Southland Waterbodies

Location	Cultural Uses and Associations
Ōreti	The river formed one of the main trails from inland Murihiku to the coast, with an important pounamu trade route continuing northward from the headwaters of the Ōreti and travelling, via the Mavora Lakes system, or Von River Valley, to the edge of Wakatipu and onto the Dart and Routeburn pounamu sources. There are numerous archaeological sites in the upper catchment, including sites related to stone resources that are considered to be among the oldest in New Zealand. The kai resources of the Ōreti supported numerous parties venturing into the interior, and returning by mōkihi, laden with pounamu and mahinga kai. Nohoanga along the river supported such travel by providing bases from which the travellers could obtain waterfowl, eels and inanga.
Waiau	Named during the southern voyages of Tamatea Ure Haea, and his waka Takitimu. Takitimu was wrecked near the mouth of the river (Te Waewae Bay) and the survivors who landed named the river Waiau due to the swirling nature of its waters. The river was a major travel route connected Murihiku and Te Ara a Kiwa (Foveaux Strait) to Te Tai Poutini. Summer expeditions to Manapōuri for mahinga kai, and access to pounamu, were the main motivations for movement up and down the Waiau. Numerous archaeological sites and wāhi taonga attest to the history of occupation and use of the river by Ngāi Tahu and Ngāti Māmoe. An important nohoanga site at the mouth of the river was called Te Tua a Hatu, The rangatira Te Waewae had his Kāinga nohoanga on the left bank of the river mouth. The river was a major source of mahinga kai for Ngāi Tahu, with some 200 species of plants and animals harvested in and near the river. Rauri (reserves) were applied to the mahinga kai resources so that people from one hapū or whānau never gathered kai from areas of another hapū or whānau. Wāhi ingoa associated with the Waiau are indicators of the range of resources the river provided: Waiharakeke (fl ax), Papatōtara (tōtara logs or bark), Kirirua (a type of eel found in the lagoon), Te Rua o te Kaiamio (a rock shelter that was a designated meeting place, similar to a marae) and Ka Kerehu o Tamatea (charcoal from the fi re of Tamatea).
Aparima	The mouth of the river was a permanent settlement, with associated urupā nearby. The was also an important tauranga waka located here, from which sea voyages were launched to and from Te Ara a Kiwa, Rakiura and the tītī islands. A carved tauihu (canoe prow) has been found in the estuary of the river. The river was an important source of mahinga kai, particularly shellfish, mussels, paua, tuna and inanga. An eel weir was constructed at the narrows where the Pourakino River enters the Aparima. • The relationship of the Aparima to the Takitimu Hills is an important part of the relationship of Ngāi Tahu to the river • There are numerous archaeological sites at the river mouth
Matāura	Several important Ngāti Māmoe and Ngāi Tahu tūpuna are associated with the Matāura River, including the Ngāti Māmoe rangatira Parapara Te Whenua, whose descendents traditionally used the resources of the river, and Kiritekateka, daughter of Parapara Te Whenua, who was captured by Ngāi Tahu at Te Anau. • Tuturau, once a Ngāi Tahu fi shing village, was the site of the last inter tribal Māori war, in 1836. Ngāi Tahu (under Tuhawaiki) repelled the challenge and threat from northern invaders thus the south was kept from passing into the hands of the northern tribes. • The Matāura was noted for its customary native fishery. • Te Apa Nui (Matāura Falls) were particularly associated with the taking of kanakana. Inanga remains an important resource on the river. The estuary (known as Toetoe) is a particularly important customary food gathering location. • Matāura Falls are an important feature of the cultural landscape of this river • There is a freshwater mātaitai reserve on the Matāura River (first in New Zealand), recognising the importance of the river in terms of customary food gathering

Recreational Use of Water in Southland

Enterprise Southland provides some information on activities at a selection of sites (Table 47) based on information provided by tourism providers and others, but there are large gaps, including known sites such as the Mataura river that is well used for fishing, in particular.

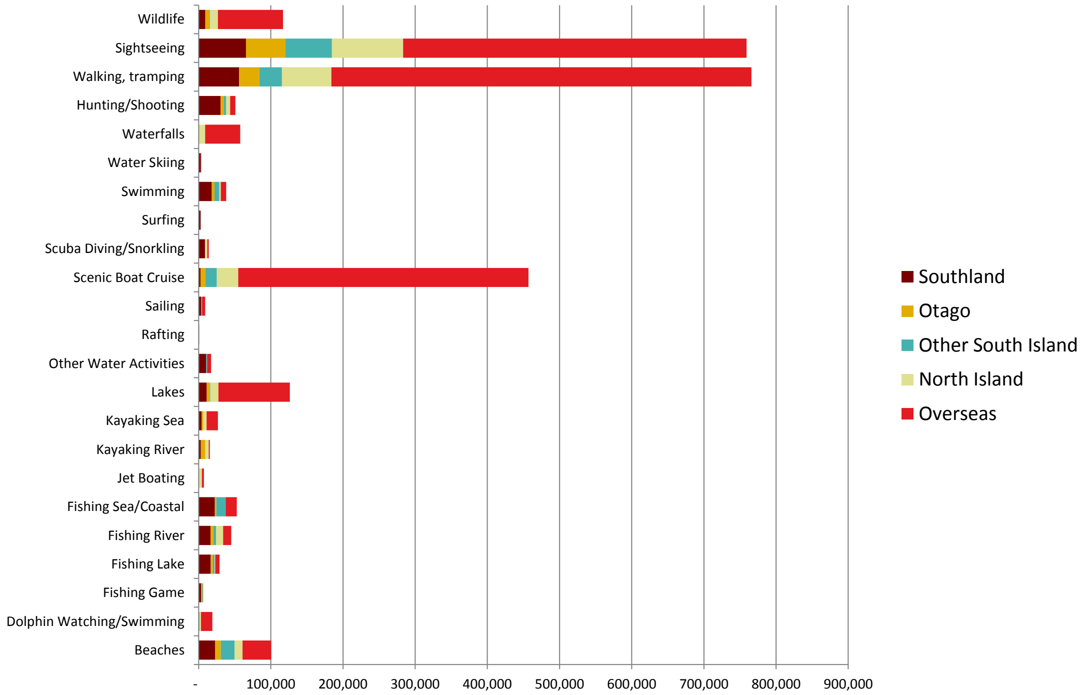
Table 47 Recreational activities at selected sites

Location	Key features and recreational uses
Waiau Catchment	
Waiau River	Trout fishing, whitebait (mouth of river), flounder fishing (mouth of river), swimming, duck shooting.
Aparima Catchment	
Riverton	Historic Port recreational and fishing port, tourist town, trout fishing, flounder fishing, shell fishing diving, surfing, swimming, boating (sailing, water skiing, rowing) *(Water quality degraded from river discharges)*
Jacobs River Estuary (mouth of the Pourakino and Aparima Rivers)	Fishing, flounder fishing, swimming, boating, duck shooting, Tourist destination (sailing, water skiing, rowing) *(Water quality degraded from river discharges)*
Oreti Catchment	
New River Estuary (including the Oreti River, Waihopai River and Omaui)	Flounder fishing, trout fishing, recent years salmon fishing, white baiting, shell fish gathering, duck shooting, swimming, boating (sailing, kayaking, water skiing, rowing) *(Water quality significantly degraded)*
Small rivers	
Waimatuku Stream	Trout fishing, flounder fishing, White baiting, swimming. *(Water quality significantly degraded)*
Coastal	
Te Waewae Bay	Tourist attraction, and located on route to Southern/West Fiordland National Park. Breeding ground for the Southern Right Whale, frequented by Dolphin, seals sea lions, Flounder fishing, crayfish, swimming, surfing
Kawakaputa	Fishing, flounder fishing, shell fish, diving, crayfish, swimming, tourist attraction *(Water quality degraded from stream discharges)*
Colac Bay	Shell fish, crayfish, flounder fishing, surfing, swimming, diving, boating, Tourist destination (local Iwi have recommended not taking shell fish and flounder from this area) *(Water quality degraded from stream discharges)*
Oreti Beach	Fishing, floundering, swimming, surfing, tourist destination
Bluff Harbour (including Awarua Bay)	Flounder fishing, trout fishing, recent years salmon fishing, shell fish, crayfish, sea fishing, shell fish farming, sailing, rowing, boating, swimming, kayaking *(Water quality degraded with rapid variations)*
Waituna Lagoon	Trout fishing some white baiting, duck shooting (*serious water quality challenges)*
Fort Rose Mataura Estuary	White baiting, flounder fishing, trout fishing, recreational boating, duck shooting, *(Water quality degraded)*
Haldane Bay	Flounder fishing
Curio Bay	Sswimming, surfing, diving, shell fishing, flounder fishing, surf casting, dolphin frequent this area major tourist area. Lack of drinking water in this area.
Waikawa Harbour	Recreational fishing, boating, sailing, dolphin, seals, sea lions (coastal area), Tourist area. (agricultural activities starting to impact on water quality)

Source: Venture Southland

Other sources of activity data include the domestic travel survey (DTS) that reports on trips made within New Zealand, including the recreational or other purpose of the trip. The DTS is a survey of 15,000 New Zealand residents and is scaled up to estimate total trips by all New Zealanders. It is limited to trips that are at least 40km (one way), but provides some idea of the types of activities undertaken in Southland. Additional data are provided in the International Visitor Survey (IVS), a survey of international visitors. In Figure 23 we use these data bases to show the estimated number of visits to (and in) Southland per year for a selection of outdoor pursuits; we ignore sporting activities and city/town-based recreation including entertainment.

Figure 23 Average Annual Recreational Visits to Southland - Selected Activities by origin of visitor



Note: DTS data are average over 5 years (2007-11); IVS data are averaged over 6 years
Source: Domestic Travel Survey & International Visitor Survey, Ministry of Business, Innovation and Employment.

The data suggest that outdoor recreational activities in Southland are dominated by sightseeing, walking/tramping and scenic boat cruises. Of the remaining categories, wildlife and visits to lakes, waterfalls and beaches are the next largest categories. In addition, the visits are dominated by international visitors, although this is partly because the data here ignore trips of less than 40km one-way.

To explore the implications of ignoring the shorter trips, we compare the estimates of angler days from the DTS with that from a survey of anglers that is discussed in the next Section. Table 48 shows the estimates from the different sources. The Angler Survey shows results from 2007/08, whereas the DTS is the average of 2007-11. For anglers from Southland, the difference between the angler survey and the DTS is 241% of the DTS count, whereas the differences are quite small for other origins: 5% for those from other parts of New Zealand and 2% for the overseas visitors.[147]

[147] Although we note the differences are significant when the specific regional origins of those from other parts of New Zealand are analysed.

Table 48 Comparison of angler day numbers from Angler Survey and DTS

Location	Angler survey	DTS	Difference	% difference
Southland	113,740	33,356	80,384	241%
Other parts of NZ	22,340	23,602	- 1,262	-5%
Overseas	17,460	17,088	372	2%
Total	153,540	74,045	79,495	107%

For analysis, we assume that the under-estimation of Southland anglers in the DTS applies to other recreational visits also and we scale up the estimates of Southland visit days by 241% of the value in the DTS.

In Table 49 we show data for the largest categories and a selection of other categories of water-related use, including fishing and kayaking. The data are not broken down by location within Southland, although we assume that the scenic boat cruises are very largely at Milford Sound.

Table 49 Number of visits to Southland by activity and origin of visitor

	Southland[1]	Other NZ	Overseas	Total
Fishing Lake	57,794	6,153	6,022	69,969
Fishing River	57,225	17,449	11,066	85,740
Kayaking River	10,947	10,877	1,533	23,357
Other Water Activities	36,199	1,360	5,284	42,844
Swimming	62,945	12,576	7,394	82,915
Waterfalls	1,670	8,653	48,390	58,713
Wildlife	31,677	17,590	90,178	139,445
Walking, tramping	193,297	127,803	582,101	903,201
Sightseeing	225,810	217,752	475,778	919,341
Scenic Boat Cruises	8,626	52,429	402,101	463,156

[1] Southland values in the DTS are increased by 241% to take account of short trips (less than 40km one way)
Note: DTS data are averaged over 5 years (2007-11); IVS data are averaged over 6 years .
Source: Domestic Travel Survey & International Visitor Survey, Ministry of Business, Innovation and Employment, plus Covec adjustments..

Fishing

Southland rivers have high value for fishing. Angler days in the Southland region were approximately 11% of the national total in the latest survey in 2007/08, and 16% of South Island angler days (Table 50).

The majority (74%) of angler days in Southland are by locals, ie. those with licenses registered in Southland, 10% are from Otago, 11% are overseas visitors and the remainder are from other parts of New Zealand (Table 51).[148]

[148] Unwin M (2009) Angler usage of lake and river fisheries managed by Fish & Game New Zealand: results from the 2007/08 National Angling Survey. NIWA Client Report: CHC2009-046 Prepared for Fish & Game NZ Ltd. NIWA.

Table 50 Angler days by New Zealand residents by Region (2007/08)

Region	Angler days	%
Northland	3,700	0.3%
Auckland/Waikato	29,800	2.5%
Eastern	209,500	17.4%
Taranaki	16,900	1.4%
Hawkes Bay	32,500	2.7%
Wellington	44,400	3.7%
North Island	336,800	28.0%
Nelson/Marlborough	34,400	2.9%
West Coast	43,100	3.6%
North Canterbury	195,400	16.3%
Central South Island	241,400	20.1%
Otago	215,400	17.9%
Southland	**135,900**	**11.3%**
South Island	865,600	72.0%
New Zealand	1,202,400	100.0%

Source: Unwin M (2009) Angler usage of lake and river fisheries managed by Fish & Game New Zealand: results from the 2007/08 National Angling Survey. NIWA Client Report: CHC2009-046 Prepared for Fish & Game NZ Ltd. NIWA.

Table 51 Origin of Anglers in Southland

Location	Number ('000)	%
Southland	113,740	74%
Otago	15,290	10%
Other South Island	5,480	4%
North Island	1,570	1%
Overseas	17,460	11%
Total	153,540	100%

Source: Unwin (2009)

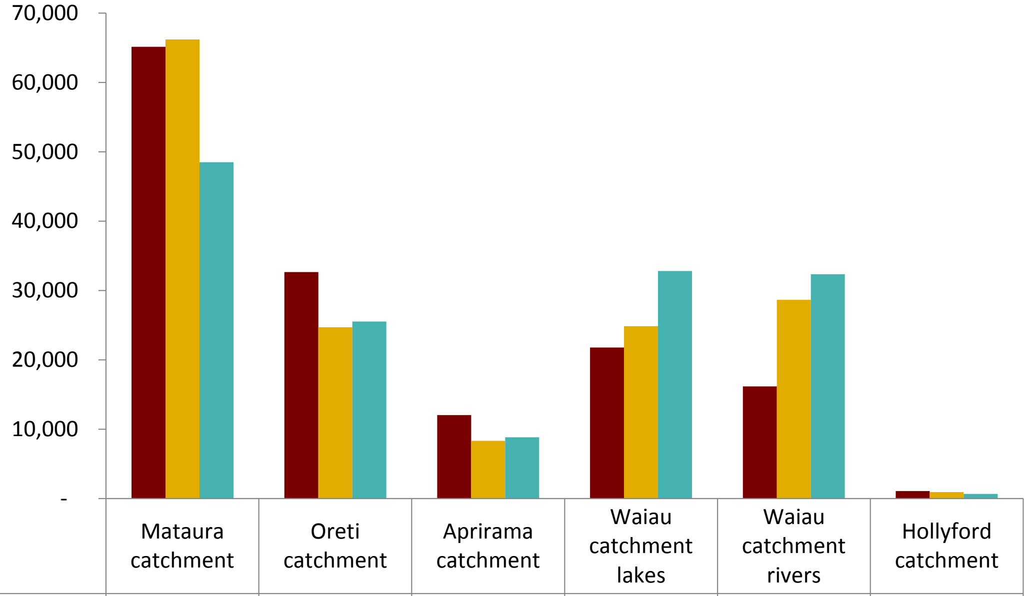
Table 52 Days per angler in Southland

	Days ('000)	Licenses	Days/licence
Adult	125.4	5825	21.5
Junior	11.4	668	17.1
Part-season	1	959	1.0
Total	137.8	7452	18.5

Source: Unwin (2009)

Angler days recorded in surveys of Southland rivers are shown in Figure 24. The Mataura river is the most important, but numbers have dropped in the latest survey. Anecdotal information suggests that this is part of a falling trend with some blame being placed on the decline in water quality reducing the angling experience.

Figure 24 Angler days in Southland catchments



	Mataura catchment	Oreti catchment	Aprirama catchment	Waiau catchment lakes	Waiau catchment rivers	Hollyford catchment
1994/1995	65,150	32,650	12,030	21,780	16,160	1,080
2001/2002	66,190	24,690	8,300	24,850	28,640	920
2007/2008	48,490	25,510	8,820	32,820	32,350	660

Numbers of anglers at different rivers are estimated for Southland in national surveys. Results for Southland are shown in Table 53.

Table 53 Number of Angler Days

Type of fishery	**1995**	**2002**	**2008**
Mainstem river	97,500	92,300	72,200
Large lake	21,700	27,800	36,200
Back country	18,400	23,100	15,400
Lowland river	8,800	5,500	6,500
Headwater	4,400	5,300	3,700
Small lake	2,000	3,100	2,800
Total	152,800	157,100	135,900

Source: NIWA (2009) Angler usage of lake and river fisheries managed by Fish & Game New Zealand: results from the 2007/08 National Angling Survey.

- Southland comprises 10.4% of Total NZ fishing licenses, with 6,669 whole-season licenses bought in the region in 2008

- The angling effort in Southland has fallen by an average of 2.4% per year since 2002, from 157,100 to 135,900 angler-days in 2002 and 2008 respectively. The most significant falls have been in back country (-6.5% p.a.) and headwater (-5.8% p.a.) fisheries, but with an average increase of 4.5% in lake fishing each year. The largest contributor to the fall in river fishing was the Mataura, most others showed little change since 2001. Usage of Lake Te Anau has more than doubled since 1995.

The reasons for the reduction in angling numbers in Southland is uncertain, although anecdotal information includes reduction in water quality as a result of increased intensity of dairy farming.[149] However, the contributing factors, ie. the link between dairy farming and water quality and thus the specific factors that reduce fishing quality, are not articulated.

Ecosystem (Existence) Values

The natural attributes of rivers and their ecosystems are valued by people in and outside of Southland; they include those that visit and those that do not. Areas of particular value include the areas in national parks (Fiordland National Park and Rakiura, Stewart Island) that together comprise over 40% of the land area of Southland. There are additional reserves and parks in the Department of Conservation (DoC) estate, such that the combined area is over 50% of the land in Southland.

Figure 25 Conservation land in Southland

149 See Appendix 4 of Jellyman DJ, Unwin MJ and James GD (2003) Anglers' perceptions of the status of New Zealand lowland rivers and their trout fisheries. NIWA Technical Report

Source: www.doc.govt.nz/getting-involved/nz-conservation-authority-and-boards/conservation-boards-by-region/southland/district/

Other areas of particular note include the Catlins Forest Park, that includes coastal and forest areas, plus the Waituna Lagoon which is a one of the best remaining examples of a natural coastal lagoon in New Zealand.[150] It is one of six sites in New Zealand recognised as wetlands of international importance[151] under the Ramsar Convention.[152]

In addition the rivers of Southland are valued in particular by the people of Southland, as expressed in the various statements of local priorities reported above.

The ecological values that are threatened by changes in water quality are:

- Aesthetic values of the rivers that affect visitor numbers and values of visits for recreational use;

- Ecosystem health and thus the existence value of these ecosystems as natural systems;

- Specific species and habitats which are valued. This includes fish species, in particular (see Table 54), although Southland is not unique in its list of threatened species and some birds, particularly the endangered black-billed gull (*Larus bulleri*), a species endemic to New Zealand, for which the majority of the population (78%) breeds in Southland, mostly on the Mataura and Waiau rivers (on the Oreti and Aparima rivers, the number of breeding birds appears to have fallen by as much as 90% in recent decades).[153]

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[150] www.es.govt.nz/environment/land/wetlands/waituna/

[151] The others are Farewell Spit, Firth of Thames, Kopuatai Peat Dome, Manawatu river mouth and estuary, and Whangamarino (www.ramsar.org/cda/en/ramsar-pubs-notes-annotated-ramsar-16101/main/ramsar/1-30-168%5E16101_4000_0__)

[152] The "Ramsar Convention is the Convention on Wetlands agreed at Ramsar, Iran, in 1971. It is an intergovernmental treaty that embodies the commitments of its member countries to maintain the ecological character of their Wetlands of International Importance and to plan for the "wise use", or sustainable use, of all of the wetlands in their territories (www.ramsar.org).

[153] www.birdlife.org/datazone/speciesfactsheet.php?id=3238

Table 54 Distribution of Threatened Fish by DOC Conservancy

	North-land	Auck-land	Waikato	East Coast Bay of Plenty	Taupo Turangi	Wang-anui	Welling-ton Hake's Bay	Nelson Marl-borough	West Coast	Canter-bury	Otago	South-land
Grayling												
Canterbury mudfish										X		
Lowland longjaw galaxias (Kakanui R)											X	
Lowland longjaw galaxias (Waitaki R)										X		
Teviot galaxias (Teviot R)											X	
Alpine galaxias (Manuherikia R)											X	
Dusky galaxias											X	
Eldon's galaxias											X	
Smeagol galaxias (Nevis R)											X	
Upland longjaw galaxias (Waitaki R)										X		
Roundhead galaxias											X	
Bignose galaxias										X		
Upland longjaw galaxias (Rangitata, Rakaia Rivers)										X		
Clutha flathead galaxias											X	
Northland mudfish	X											
Longfin eel	X	X	X	X		X	X	X	X	X	X	X
Torrentfish	X	X	X	X		X	X	X	X	X	X	X
Dwarf galaxias (Nelson, Marlborough and NI)				X		X	X	X		X	X	
Dwarf galaxias (West Coast)									X			
Giant kokopu	X	X	X	X		X	X	X	X	X	X	X
Koaro	X	X	X	X	X	X	X	X	X	X	X	X
Gollum galaxias											X	X

	North-land	Auck-land	Waikato	East Coast Bay of Plenty	Taupo Turangi	Wang-anui	Welling-ton Hake's Bay	Nelson Marl-borough	West Coast	Canter-bury	Otago	South-land
Inanga	X	X	X	X		X	X	X	X	X	X	X
Shortjaw kokopu	X	X	X	X		X	X	X	X			X
Lamprey	X	X	X	X		X	X	X	X	X	X	X
Bluegill bully	X	X	X	X		X	X	X	X	X	X	X
Redfin bully	X	X	X	X		X	X	X	X	X	X	X
Brown mudfish						X	X	X	X			
Black mudfish	X	X	X									
Northern flathead (Marlborough)								X	X	X		
Dwarf ingana (North Kaipara Head Dune Lakes)	X											
Dune lakes galaxias (Kai Iwi lakes)	X											
Tarndale bully									X			
Chatham Is mudfish							X					
Stokell's smelt										X		

Source: Allibone R, David B, Hitchmough R, Jellyman D, Ling N, Ravenscroft P and Waters J (2010) Conservation status of New Zealand freshwater fish, 2009. New Zealand Journal of Marine and Freshwater Research, 44(4): 271-87.

Annex 5 Physical Changes

This Annex is authored by Ian Jowett (Jowett Consulting).

Introduction

The Ministry of Environment has requested an economic assessment of various policy scenarios in Southland. NIWA and Aqualinc will provide data on water quality and algal biomass for the various scenarios and Covec will quantify the effects and assess relative economic outcomes.

The study sites are 65 state of the environment reporting (SOE) rivers in Southland. NIWA (Sandy Elliot) has modelled the development scenarios and provide predictions for total phosphorus (TP), total nitrogen (TN), and eColi for the set of rivers. The proportions of the various components of nitrogen and phosphorus will be taken as the average proportions that have been recorded for the respective rivers. The assumption being that the scenarios will not change the proportions, such as the proportion of dissolved reactive phosphorus in the total phosphorus prediction will be the same as measured in the river and will not vary between scenarios. Aqualinc (Ton Snelder) has calculated periphyton biomass (mean Chla) for the rivers.

The aim of this report is to develop quantitative relationships that can be used to predict the effects of total phosphorus (TP), total nitrogen (TN) and algal biomass (Chla) on water clarity, adult trout numbers, and benthic invertebrates.

Water clarity, adult trout numbers, and benthic invertebrate density and community composition are influenced by many factors, including riparian condition, flow regime, river morphology, climate, and geology and it is assumed that these factors will not change between scenarios. However water quality (nitrogen and phosphorus) and average algal biomass will vary between development scenarios, and available datasets were used to determine relationships that allow water clarity, trout and benthic invertebrates to be predicted. These predictions cannot be precise in absolute terms because data on the many factors controlling these variables are either lacking or are estimated from other parameters that are known. However, when averaged over all sites, they will enable the relative changes between development scenarios to be evaluated.

The report is not intended to be a comprehensive review of the literature.

Data

The water quality variables considered were total phosphorus (TP), total nitrogen (TN) and algal biomass (Chla), and the various soluble and insoluble components of total phosphorus and total nitrogen.

The physical variables were water clarity, measured as the distance that a black disk is visible underwater, adult trout (> 20 cm) numbers per kilometre, and benthic invertebrate community composition or Macroinvertebrate Community Index (MCI), which is a measure of the “health” of the river.

The “100 rivers” dataset contains measurements of water quality, instream habitat, benthic invertebrate biomass, periphyton cover, catchment characteristics and trout density in a large number of New Zealand rivers. This is believed to be the only data in New Zealand with invertebrate biomass and trout data to water quality. The general patterns shown by these data were presented in 1990 in issue 23 of the New Zealand Journal of Marine and Fresh Water Science (Biggs et al. 1990). However, numerical relationships derived from these data have not been published, except for brown trout (Jowett 1992).

The other datasets used were those for water quality, benthic invertebrate community composition (MCI), and periphyton in Southland collected 2000-2012 by the Southland Regional Council.

The “100 rivers” dataset was used to develop relationships predicting trout numbers and benthic invertebrate biomass. The Southland Regional Council water quality and macroinvertebrate datasets 2000-2012 were used to develop relationships to predict water clarity and MCI.

Median values of measured data were used where there were multiple measurements from a site. This avoided problems with outliers, data errors, and non-detects.

Method

Quantitative relationships between water quality and total benthic invertebrate biomass and adult trout density and numbers were derived from the 100 rivers dataset. Relationships between water quality and water clarity, macroinvertebrate community index and periphyton were derived from the Southland datasets.

Relationships were first examined graphically to select the most likely predictive variables and the form of the relationship. Stepwise non-linear generalised additive models and stepwise linear multiple regression were used to determine the best combination of predictor variables and the transforms necessary to produce predictive linear equations.

The statistics of the predictive equations are shown in the Appendix.

Water clarity (black disk visibility)

Water clarity depends on the concentration of particulate organic and inorganic material in the water column. The particulate matter comes from erosion of stream bed and banks, and catchment runoff, both of which vary with flow. However, the concentration of phosphorus in the water appeared to be a good indicator of water clarity. The Southland data (2000-2012) showed that there was a strong non-linear relationship between water clarity and total phosphorus (Fig. 1). The log-log relationship between these two variables was:

$$\textit{Water clarity} = 0.111 \times \textit{Total phosphorus}^{-0.668} \qquad (1)$$

or

$$Log_{10}(Water\ clarity) = -0.668 \times Log_{10}(Total\ phosphorus\ ) -0.953 \qquad (2)$$

This relationship explained 48% of the variation between water clarity and total phosphorus (1) and 74% of the variation in the logarithms (2). The inclusion of dissolved reactive phosphorus (DRP) (3) improved the predictive ability from 74% to 78%.

$$Log_{10}(Water\ clarity) = -0.852 \times Log_{10}(Total\ phosphorus) + 6.892 \times DRP -1.344 \qquad (3)$$

The inclusion of dissolved phosphorus as a significant variable effectively means that water clarity depends on the proportion of total phosphorus that is not dissolved (i.e., particulate matter). The log-log relationship between water clarity and particulate phosphorus (total phosphorus – DRP) (Fig. 2) explained 79% of the variance in water quality (4).

$$Log_{10}(Water\ clarity) = -0.596 \times Log_{10}(Particulate\ phosphorus) -0.990 \qquad (4)$$

Figure 1: Relationship between water clarity (black disc) and total phosphorus with the upper graph showing log-log relationship between the variables (Eqn 1) and the lower graph showing the linear relationship between logarithms of the variables(Eqn 2).

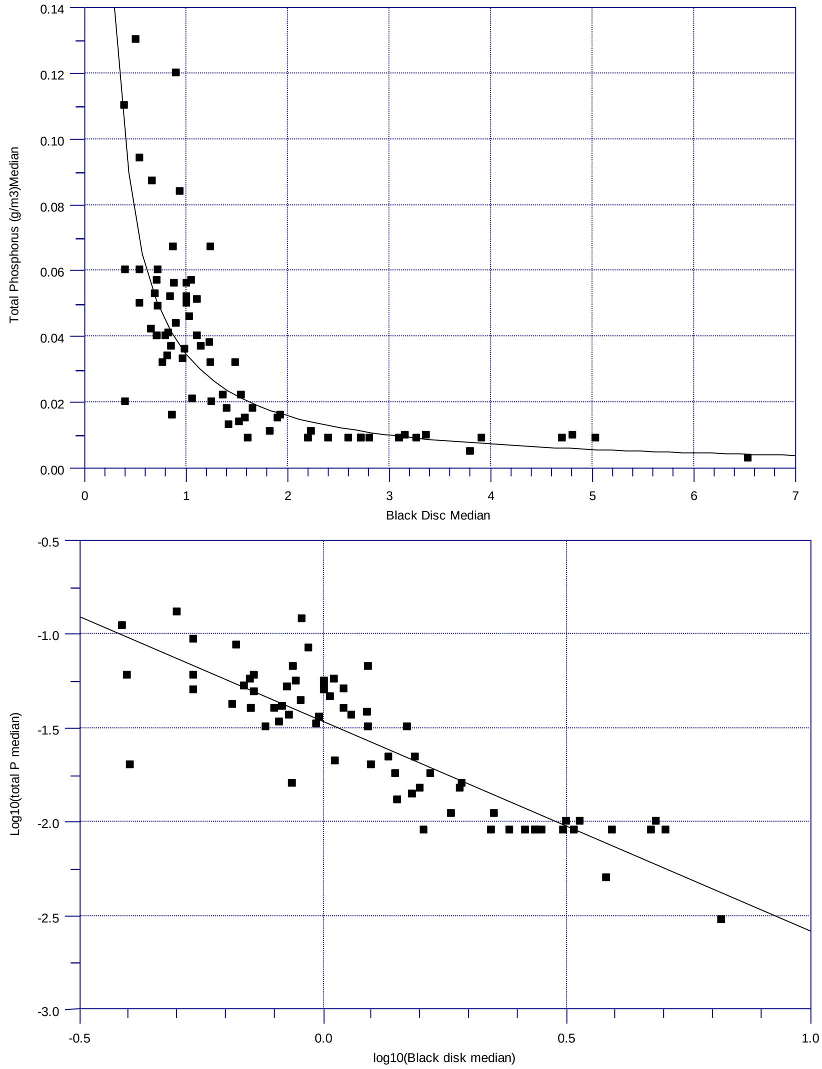
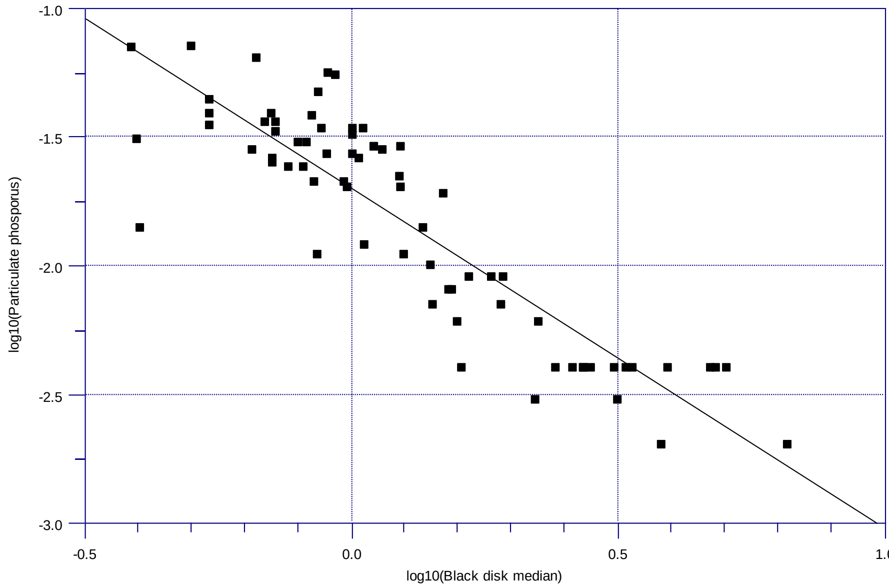


Figure 2: Relationship between logarithms of water clarity (black disc) and particulate phosphorus (Eqn 4).



Periphyton

Periphyton is a necessary component of the food chain in rivers. Benthic macroinvertebrates feed on periphyton and native fish and trout feed on macroinvertebrates. An increase in periphyton is beneficial to the fish and trout because it increases benthic invertebrate biomass. In North America, nutrients have been added to lakes to increase productivity and an experiment showed that 10 fold increase in nutrients to a stream increased the biomass of juvenile salmonids by 80% (Perrin et al. 1997). However, dense growths of filamentous algae can change the composition of the benthic invertebrate community and is an annoyance to river users because they consider it unsightly and slippery and it can become entangled in anglers' lures.

Periphyton accumulation is controlled primarily by the frequency and magnitude of floods and freshes. Both nitrogen and phosphorus are necessary for the growth of periphyton and the rate of growth increases as the concentration of these nutrients increase. Thus nutrients will increase the rate of accrual and will reduce the time taken to reach nuisance levels after a flood or fresh. Periphyton growth rates also depend on water temperature with low growth rates during the winter and high growth rates during the summer.

Biggs (2000a) developed a regression equations relating biomass to days since last flood and dissolved reactive phosphorus and soluble inorganic nitrogen. These equations indicate that doubling the nitrogen or phosphorus concentrations would increase total accrual by about 15%.

Macroinvertebrate Community Index (MCI)

Benthic invertebrate community composition is influenced by water depth and velocity (Jowett et al. 1991), flow regime (Jowett & Duncan 1990; Clausen & Biggs 1997), algal biomass (Suren & Jowett 2006), sediment deposition (Quinn et al. 1992; Suren & Jowett

2001), as well as water quality (Quinn & Hickey 1990a; Quinn & Hickey 1993).Water quality can influence benthic community composition.

Stark (1985) developed an index of benthic community composition, the MCI macroinvertebrate community index. This index is used as a measure of stream "health" and is calculated as the sum of scores for invertebrate taxa. Invertebrates common in unpolluted streams are given high scores and invertebrates common in polluted streams are given low scores. Scores of more than 100 are considered indicative of a healthy stream. This index has shown differences in invertebrate communities above and below discharges from oxidation pond discharges (Quinn & Hickey 1993). However, oxidation pond effluent contains multiple contaminants and it is not clear whether the effects are caused by particulate organic matter or other factors such as ammonia, BOD5, sBOD5, DO and high stream bed respiration.

The Southland data (2000-2012) showed that there were strong relationships between MCI and total phosphorus and total nitrogen (Fig. 3). The linear and log-log relationships with total phosphorus explained 56% and 57% of variance in MCI, respectively. The linear and log-log relationships with total nitrogen explained 53% and 41% of variance in MCI, respectively.

However, in a multiple regression analysis both variables were statistically significant ($P<0.0005$). There was no significant non-linearity of the relationship between MCI and total phosphorus and total nitrogen ($P > 0.17$), so a linear relationship between MCI and total phosphorus and total nitrogen (5) was considered appropriate and explained 67% of the variance in MCI.

$$MCI = -314.17 \times Total\ phosphorus - 8.39 \times Total\ nitrogen + 123.61 \quad (5)$$

Chlorophyll a (periphyton) was also a factor related to MCI. An increase in periphyton causes the invertebrate species composition to change and this results in a decrease in MCI. Inclusion of this variable(6) increased the variance explained to 83%.

$$MCI = -284.66 \times Total\ phosphorus - 9.21 \times Total\ nitrogen - 0.078 \times Chla + 127.10 \quad (6)$$

Figure 3: Relationship between MCI and total phosphorus and total nitrogen, showing log-log and linear relationships.

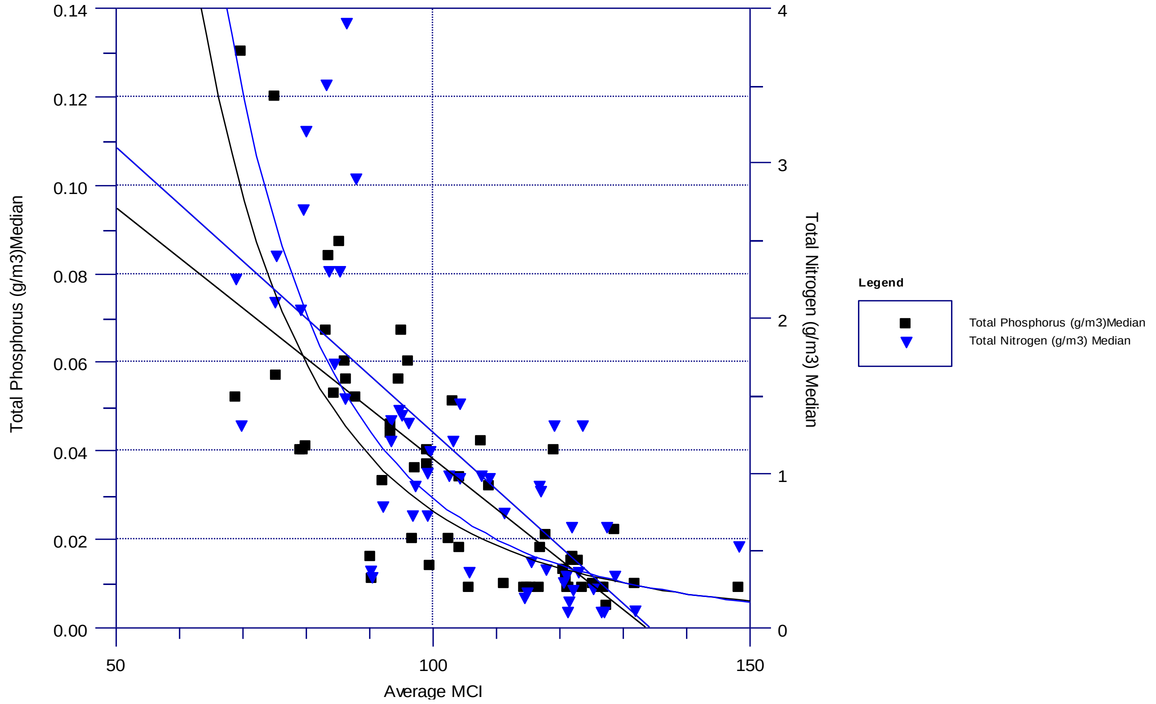
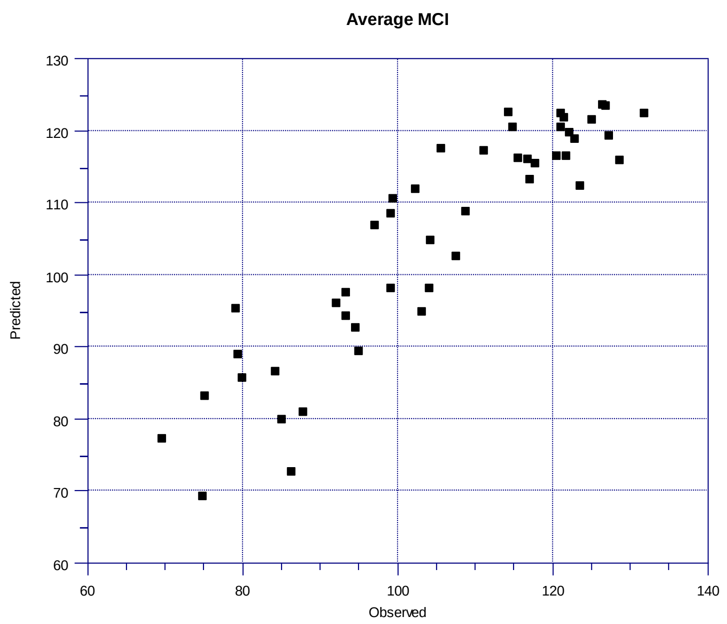


Figure 4: Relationship between observed MCI and MCI predicted from total phosphorus, total nitrogen, and Chl a (Eqn 6).



Total benthic invertebrate biomass

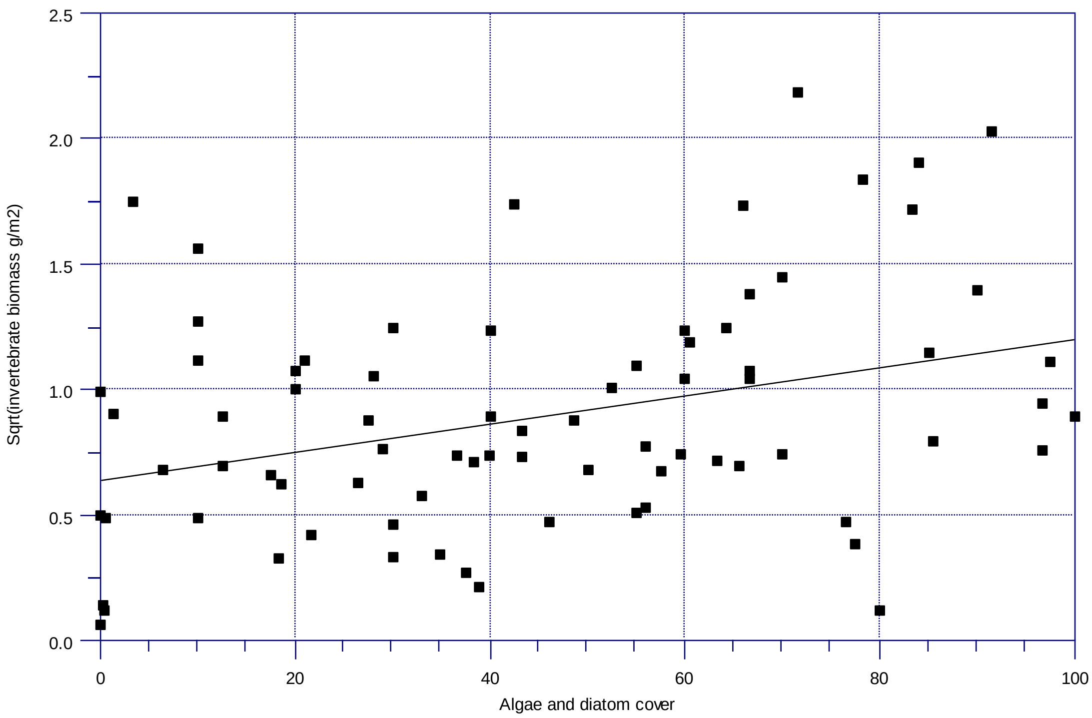
Benthic invertebrate biomass is affected by flow regime (Quinn & Hickey 1990b; Duncan & Biggs 1998), instream habitat (Jowett et al. 1991), algal biomass (Suren & Jowett 2006), substrate size (Quinn & Hickey 1990b) and sediment movement (Jowett 2003). Benthic invertebrates feed on periphyton and organic detritus on the stream bed. Jowett &

Richardson (1990) found that the density of the commonly occurring mayfly *Deleatidium* was high where periphyton formed a slippery film on the substrate and was lower where the substrate was either clean or formed a visible mat.

Quinn & Hickey (1990b) found that total invertebrate biomass, algal biomass, nitrogen and phosphorus increased with the % area of developed catchment but invertebrate community composition changed. Total benthic invertebrate biomass tends to increase with algal biomass and nutrient concentration because the algae provides a food source for the benthic invertebrates (Fig. 5), but the relationship is not strong ($r^2 = 0.12$, $N = 78$, $P = 0.002$).

Total benthic invertebrate biomass is probably the most important factor influencing brown trout density (Jowett 1992). Predictions of the effect of water quality changes on total benthic invertebrate biomass could be used to predict changes in trout density. Unlike MCI, high invertebrate biomass is not necessarily a reflection of good stream health because streams with a high coverage of periphyton and low flow can contain high numbers of benthic invertebrates (e.g., Suren & Jowett 2006).

Figure 5: Relationship between sqrt(benthic invertebrate biomass) and algae and diatom cover showing linear relationship.



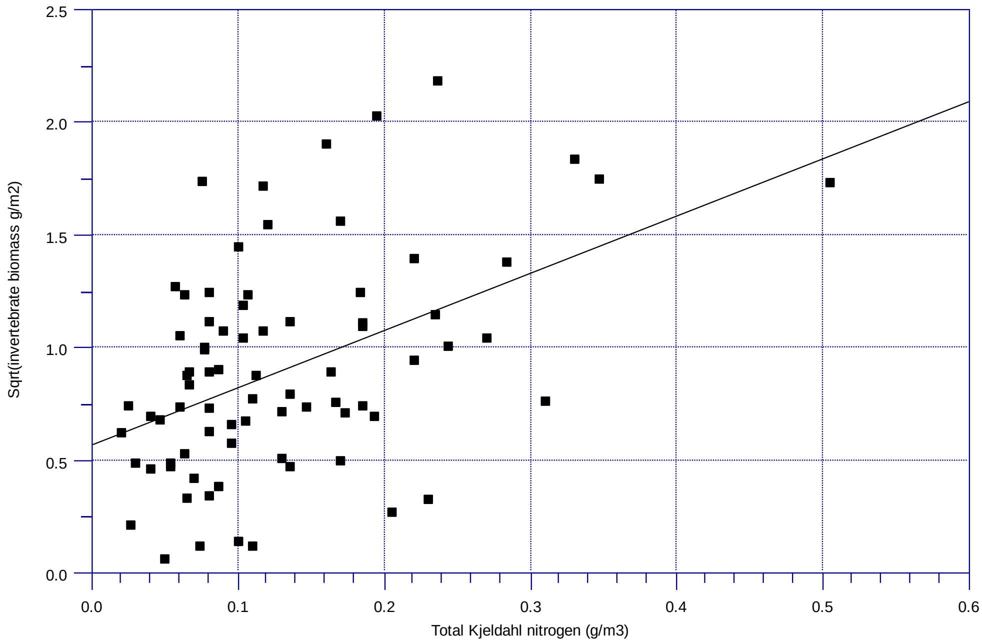
The 100 rivers dataset indicated that there was a linear relationship between the sqrt(total benthic invertebrate biomass g/m^2) and total Kjeldahl nitrogen[154] (g/m^3, TKN = total nitrogen – nitrate/nitrite nitrogen) (Fig. 6, $r^2 = 0.21$, $N = 78$, $P < 0.0005$). Further examination of the available data was only able to find one other variable that was related to benthic invertebrate biomass. This was % diatom cover and inclusion of this

[154] Total Kjeldahl nitrogen or TKN is the sum of organic nitrogen, ammonia (NH_3), and ammonium (NH_4^+). Total Nitrogen (TN) is the sum of TKN and concentrations of nitrate-N and nitrite-N.

variable increased the variance explained to 27%. However, this variable is not available for the predictive models so that the model of benthic invertebrate biomass g/m^2 and TKN (g/m^3) is:

$$sqrt(total\ benthic\ invertebrate\ biomass) = 2.527 \times TKN + 0.572 \quad (7)$$

Figure 6: Relationship between sqrt(benthic invertebrate biomass) and total Kjeldahl nitrogen, showing linear relationship (Eqn 7).



Brown trout

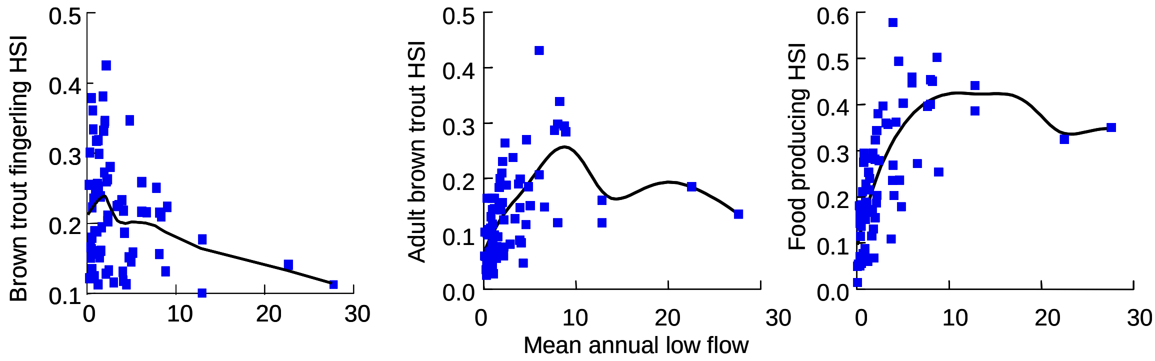
Factors affecting brown trout abundance

The main factors affecting trout density are food and habitat suitability, as described in Chapman's (1966) "food and space" paper. Jowett (1992) used the "100 rivers" dataset to identify the most significant factors influencing the density of large and medium brown trout in New Zealand rivers. He identified habitat suitability, food supply, cover, water temperature, and river and catchment characteristics as some of the factors influencing the density of brown trout.

Habitat suitability

The composition of the trout community varies with stream size. Small streams are more suited to small trout than to large trout, and vice versa. Small trout have lower swimming speeds and lower velocity and depth preferences than large trout. Adult trout usually move upstream or into tributaries to spawn and the juvenile fish rear in these areas, whereas the adults usually move back downstream to deeper waters after spawning. Because water depth and velocity increase with flow, there is usually a flow that provides the best habitat for a particular fish species and life stage. The average habitat suitability index (HSI) at mean annual low flow in 71 New Zealand rivers was calculated for a range of fish species and life stages. When HSI was plotted against flow and a smooth curve fitted for each species and life stage, the peaks of the curves give an indication of the stream sizes that provide the best quality habitat for the species and life stages (Fig. 7). Habitat quality increases with flow as streams become wider, until a threshold is reached where further increases in flow result in depths and velocities becoming too high for the species of interest. Braided rivers are an exception to this because their width is not constrained. The optimum size of a single channel river for food producing (benthic invertebrate habitat) was about 15 m^3/s, for adult brown trout 10 m^3/s, and the optimum size for trout fingerlings (< 15 cm) was about 2 m^3/s. This is in agreement with general observations of the distribution of trout, with adult trout in the larger streams and rivers, and trout rearing in small streams or headwaters.

Figure 7: Average habitat suitability index (HSI) at mean annual minimum flow (m^3/s) in 71 New Zealand rivers from Jowett et al. 2008.



Food supply

Food supply is one of the two most important factors controlling trout density. With sufficient food, a river or pond can sustain high numbers of trout and they can grow to large sizes, as shown by trout in aquaculture farms and in the Tekapo Canal.

Jowett (1992) considered that factors such as % of highly developed land and % sand influenced the food supply of trout. Percent sand substrate has a negative relationship with total benthic invertebrate biomass (Fig. 8, r^2 =0.19, N=30 , P =0.015), and there is a tendency for invertebrate biomass to increase with area of developed catchment, although the relationship is not statistically significant (Fig. 9, r^2 = 0.04, N = 79, P = 0.071).

Figure 8: Relationship between sqrt(total benthic invertebrate biomass) and the sqrt(% sand substrate

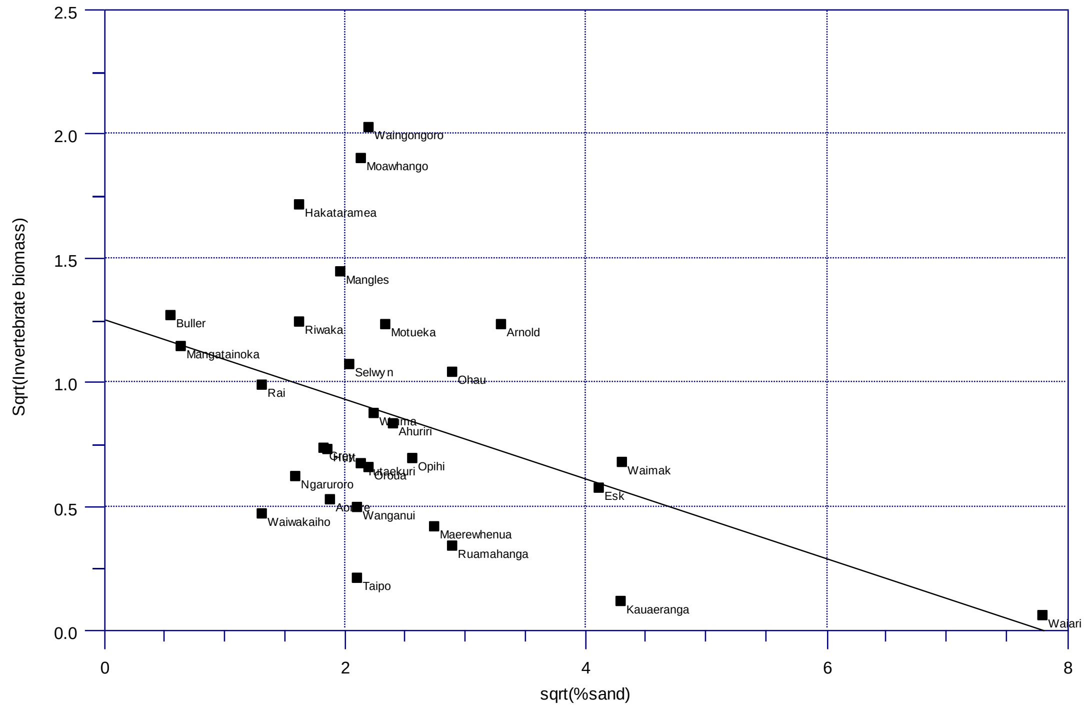
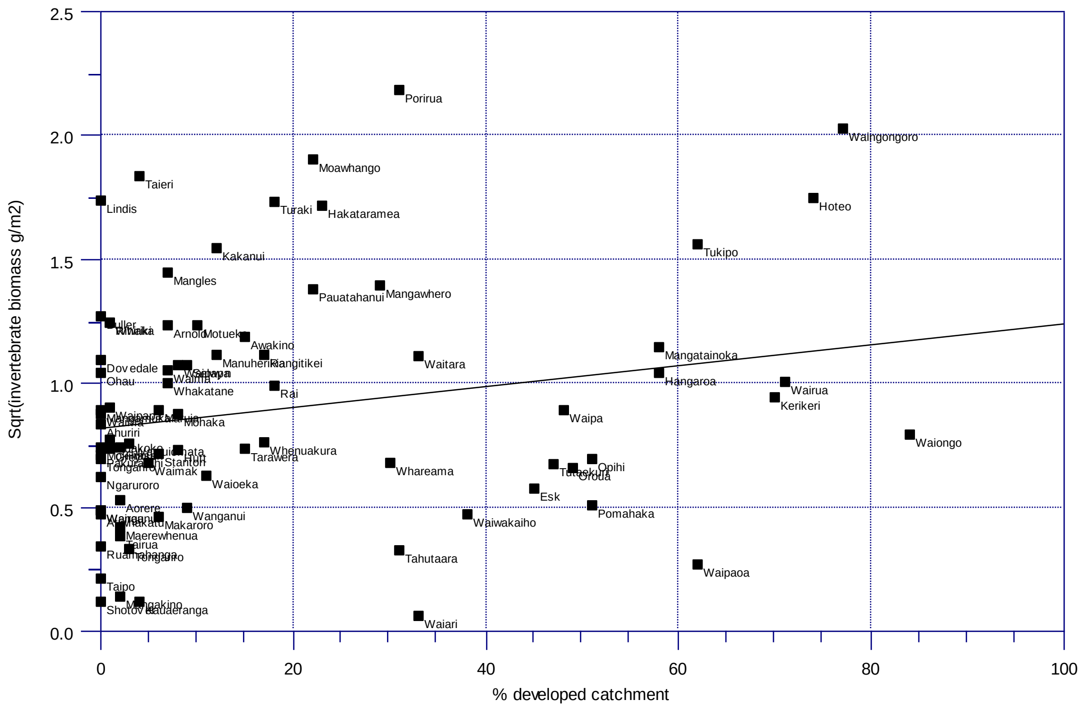


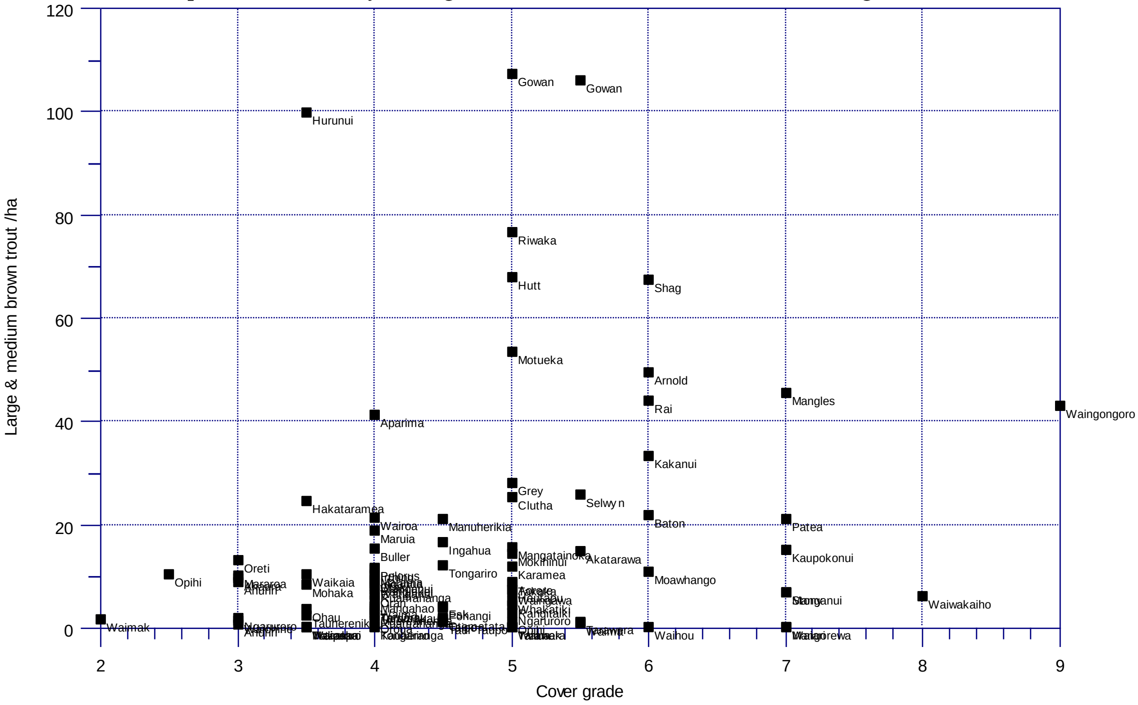
Figure 9: Relationship between sqrt(total benthic invertebrate biomass) and % developed catchment



Cover

Cover is an essential requirement for adult brown trout in rivers (Fig. 10, r^2 =0.06 , N=84, P=0.032). Cover is usually provided by river banks or boulders, but water depth can provide some cover.

Figure 10: Relationship between density of large and medium brown trout and cover grade

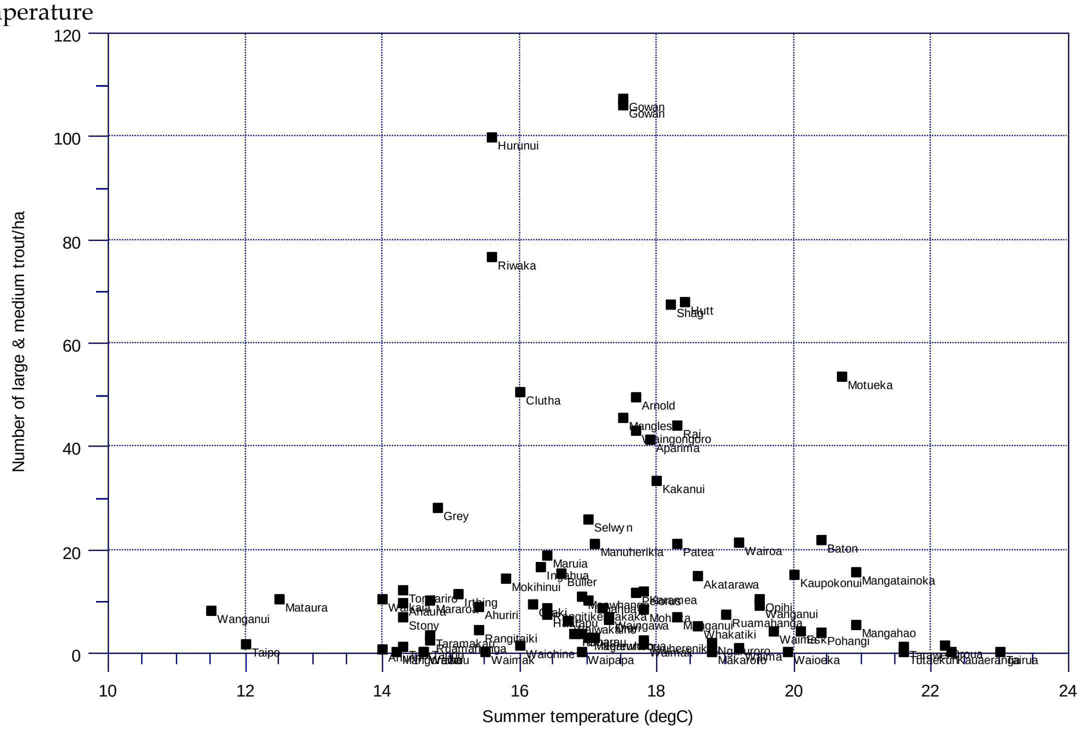


Water temperature

Water temperature limits the distribution of trout, with few or poor self sustaining brown trout populations north of the central North Island. This is thought to be caused by high winter water temperatures preventing successful incubation of eggs. Trout stop feeding at 19-20 °C (Hay et al. 2006). Usually this means that trout stop feeding during the day and feed more at night. This can affect angling, although there are rivers with summer temperatures in excess of 19 °C that are popular trout fisheries (e.g., Motueka). Lethal temperatures are in excess of 26 °C and these rarely occur in New Zealand.

In Southland, water temperature is unlikely to affect trout numbers directly but high summer water temperatures could have a slight effect on angling. Summer water temperatures of 14-19 °C tend to support the highest densities of adult brown trout (Fig. 11) and this range of temperature encompasses the optimum for maximum growth rate of about 14-17 °C.

Figure 11: Relationship between density of large and medium brown trout and summer water temperature



Dissolved oxygen

Trout are more susceptible to low levels of dissolved oxygen than native fish. Trout can avoid areas where DO is < 5 g/m^3 and cannot survive with concentrations less than 3 g/m^3. Dissolved oxygen is unlikely to be a factor affecting trout in gravel bed rivers because of the high level of re-aeration that occurs in riffles.

Suspended sediment

Suspended sediment or clarity does not appear to have a direct effect on trout, but will have a strong indirect effect through food supply and benthic invertebrate density. Suspended sediment may affect trout growth rates by increasing the feeding effort (Hay et al. 2006).

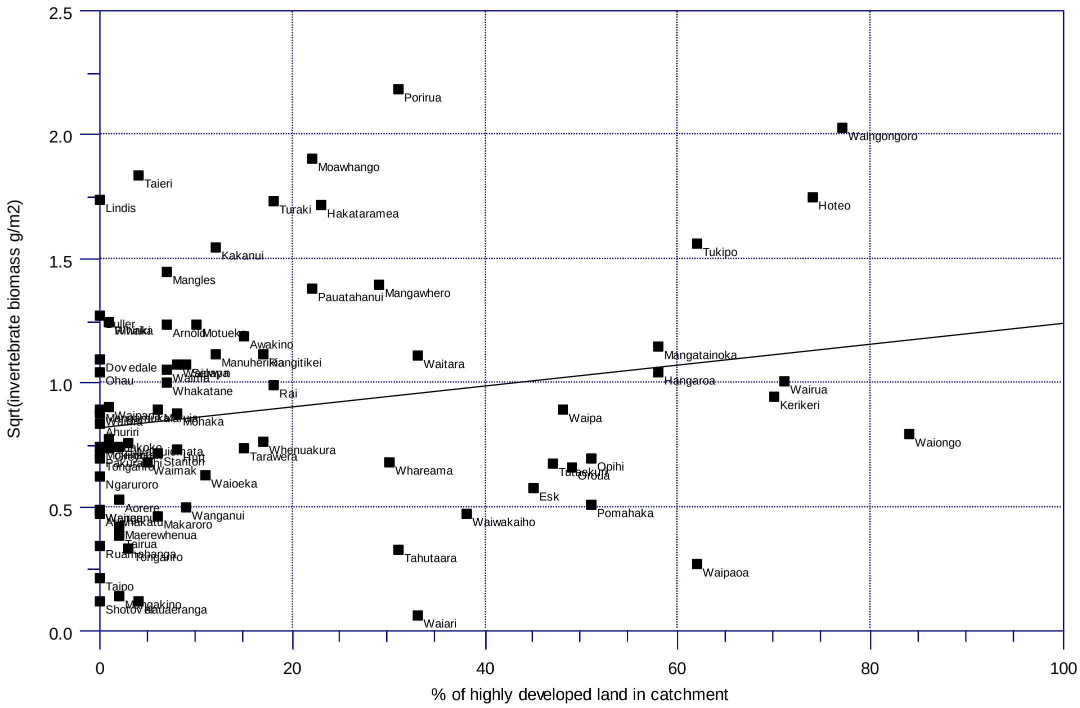
Deposition of suspended sediment on a stream bed reduces benthic invertebrate densities, either by making the substrate less suitable as habitat or by decreasing the food quality of periphyton (Suren & Jowett 2001). The effect of fine sediment deposition on benthic invertebrates is probably similar to the effect of sand deposition (Fig. 8).

Brown trout abundance model

The factors listed above are often highly inter-related. Jowett (1992) used the "100 rivers" dataset to identify the most significant factors influencing the density of large and medium brown trout in New Zealand rivers. He found that the factors related to trout density were adult brown trout habitat, cover, gradient, % sand, food producing habitat, area of lake in catchment, elevation, and % highly developed land in order of variance explained by each variable. Increased adult brown trout habitat, cover, food producing habitat and area of lake in catchment had positive influences on trout density. Increased gradient, elevation, % sand and % highly developed land had negative influences.

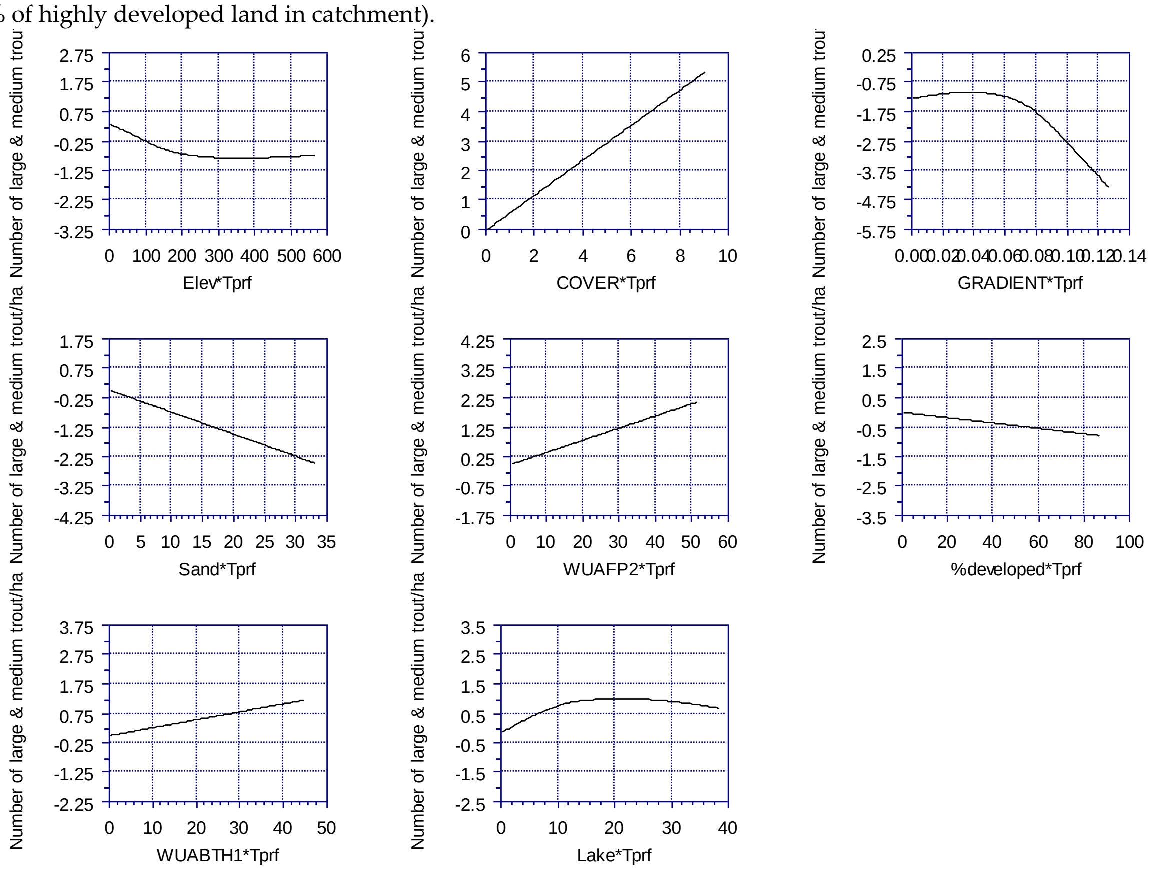
Jowett (1992) considered that factors such % of highly developed land and % sand influenced the food supply of trout. Percent sand substrate has a negative relationship with total benthic invertebrate biomass (Fig. 8), and there is a slight, but statistically insignificant, increase in invertebrate biomass with increasing area of developed catchment (Fig. 12, r^2=0.04, N=79, P=0.071).

Figure 12: Relationship between density of large and medium brown trout and % of highly developed land in catchment



Jowett (1992) used linear relationships and improved non-linear methods, such as generalised additive models (GAMs) have been developed since the early 1990s. The linear model of Jowett (1992) explained 87.7% of the variation in loge(Large and medium brown trout density+1). GAMs with a Poisson distribution and logarithmic link function were developed for the density of large and medium brown trout using the Jowett (1992) dataset to see whether there were significant non-linear relationships. This showed that linear relationships were appropriate for most variables, except sqrt(gradient) (P=0.026),elevation (P=0.036) and % area of lake in the catchment (P=0.024). Application of the non-linear GAM using only significantly non-linear variables improved the variance explained in the linear GAM model by 7% from 76% to 83%. The non-linear model shows that % highly developed land has a minor negative effect on trout density and that the optimum river gradient is about 0.0025. Elevation has a negative effect up to an elevation of about 200 m.

Figure 13: Generalised additive model (GAM) of the density of large and medium brown trout using the variables in the Jowett (1992) model (Site elevation, cover grade, sqrt(gradient), % sand in reach, food producing habitat at median flow, adult brown trout habitat at MALF, % of lake in catchment and % of highly developed land in catchment).



Water quality data were available for 39 of the 59 rivers used by Jowett (1992). The significance and effect of water quality (total Kjeldahl nitrogen TKN, total nitrogen TN[155] and dissolved reactive phosphorus DRP) was investigated by adding these parameters to the GAM. This showed that TN was the most influential of the 3 water quality variables. The simplest GAM with a water quality parameter in it, related brown trout density to cover, adult brown trout habitat, food producing habitat and total nitrogen (Fig. 14) and explained 56% of the variation in trout density. It showed that trout density increased as nitrogen increased up to about 300 mg/m^3 and then decreased trout density when it exceeded 600 mg/m^3 (lower right in Fig. 14). The GAM with total Kjeldahl nitrogen (TKN) instead of total nitrogen explained 70% of the variation in trout density (Fig 15) with trout density increasing as TKN increased.

[155] Total Kjeldahl nitrogen or TKN is the sum of organic nitrogen, ammonia (NH3), and ammonium (NH_4^+) in the chemical analysis of water or wastewater. To calculate Total Nitrogen (TN), the concentrations of nitrate-N and nitrite-N are determined and added to TKN.

Figure 14: Generalised additive model (GAM) of the density of large and medium brown trout using the variables cover grade, food producing habitat at median flow, adult brown trout habitat at MALF and total nitrogen.

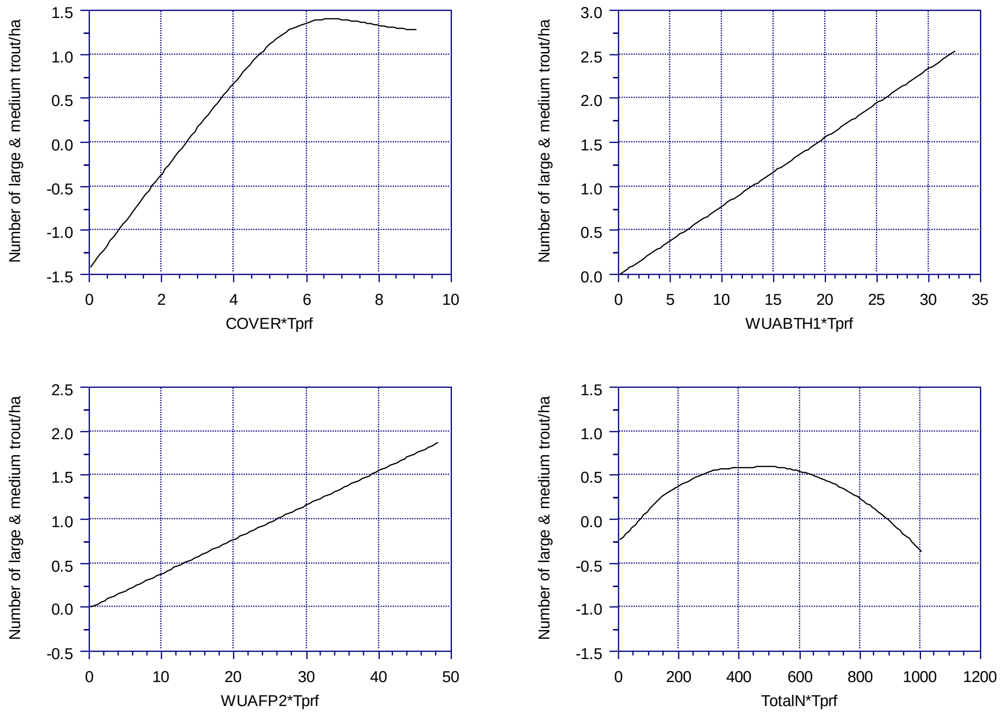
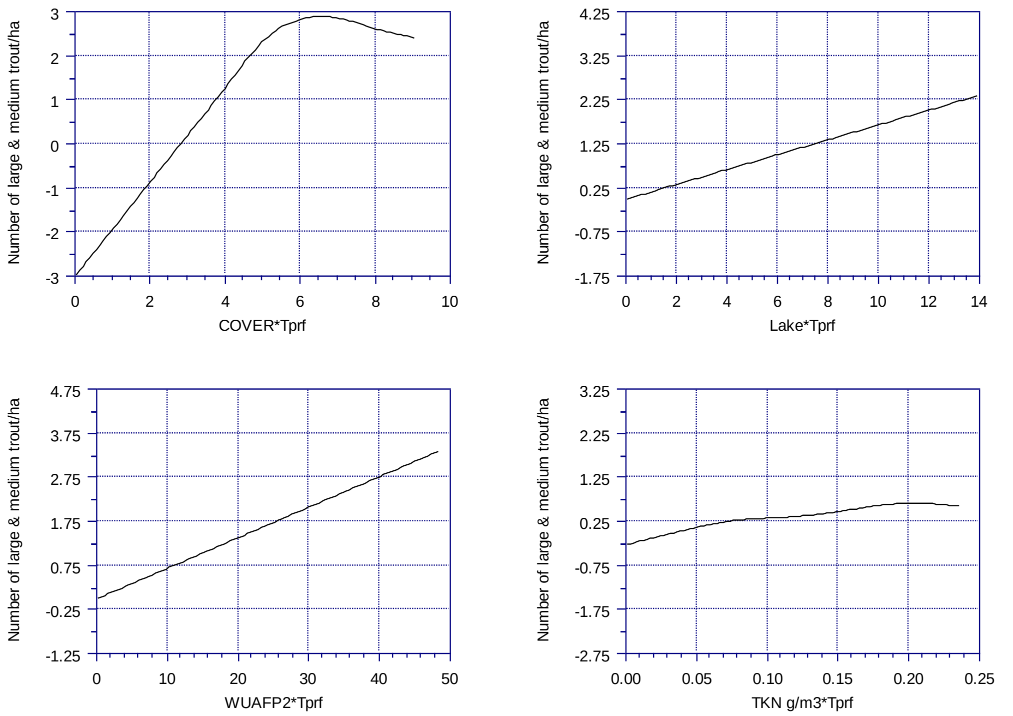


Figure 15: Generalised additive model (GAM) of the density of large and medium brown trout using the variables cover grade, food producing habitat at median flow, adult brown trout habitat at MALF and total Kjeldahl nitrogen.



The density of trout in a river will depend on the quality of the habitat (suitable water depth, water velocity, and cover) and the amount of food (usually benthic invertebrates) available to the trout. Changes in water quality will affect trout density indirectly by affecting the amount of food available. The number of trout per km is the trout density multiplied by the river width.

The logarithm of trout density (Log_e(number of large and medium trout per hectare+1)) was related to % adult brown trout habitat and the sqrt(total invertebrate biomass), $r^2 = 0.64$, N= 27, P < 0.007.

$$Log_e(\text{number of large and medium trout}+1) = 0.082 \times \%\ \text{adult trout habitat} + 1.54 \times \text{sqrt(total invertebrate biomass)} - 0.047 \quad (8)$$

The % adult trout habitat can be estimated from the mean annual low flow (MALF) in the river (Fig. 16), with this log-log relationship explaining 32% of the variance in % adult trout habitat.

$$\%\ \text{adult trout habitat} = 9.44 \times MALF^{0.313} \quad (9)$$

Rearranging equations 7, 8 and 9 gives:

$$Log_e(\text{number of large and medium trout}+1) = 0.774 \times MALF^{0.313} + 3.891 \times TKN + 0.525 \quad (10)$$

Alternatively, we could use a relationship between trout density, habitat and TKN ($r^2 = 0.53$, N=31, P < 0.018)

$$Log_e(\text{number of large and medium trout}+1) = 0.100 \times \%\ \text{adult trout habitat} + 8.512 \times TKN + 0.160 \quad (11)$$

Rearranging equations (9) and (11) gives:

$$Log_e(\text{number of large and medium trout}+1) = 0.944 \times MALF^{0.313} + 8.512 \times TKN + 0.160 \quad (12)$$

The relationship between TKN and invertebrate biomass in equation 10 is based on a larger sample size (78) than the sample size (31) in the relationship between TKN and trout density and equation 12. Thus equation 10 is probably the better equation to use to predict the effects of nitrogen on trout density.

Equation 10 becomes:

$$\text{No. of large and medium trout per Ha} = \exp(0.774 \times MALF^{0.313} + 3.891 \times TKN + 0.525) - 1 \quad (13)$$

The river width can be estimated from the mean river flow (Fig. 17) ($r^2 = 0.90$, N= 114):

$$Width = 7.982 \times \text{Mean flow}^{0.466} \quad (14)$$

Multiplying equation 13 by equation 14 gives the number of large and medium trout per km of river:

$$\textit{No. of large and medium trout per km} = 7.982 \times \textit{Mean flow}^{0.466} \times (\exp(0.774 \times \textit{MALF}^{0.313} + 3.891 \times \textit{TKN} + 0.525) - 1) \quad (15)$$

Figure 16: Relationship between % adult brown trout habitat and mean annual low flow (m³/s) showing log-log relationship (Eqn 9).

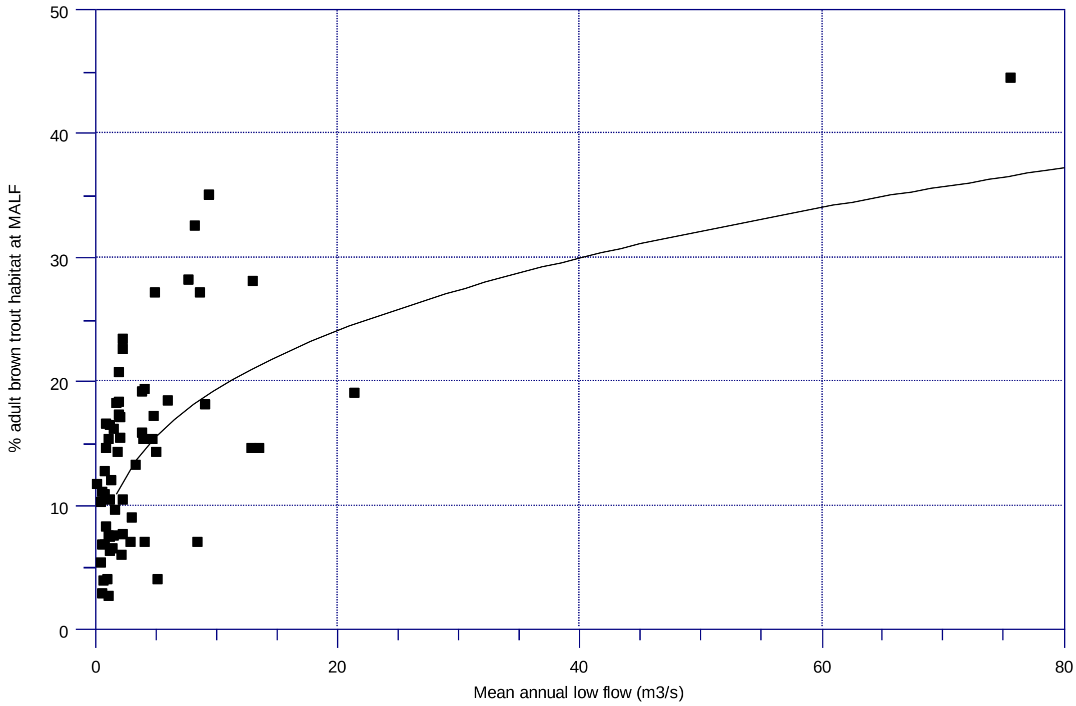
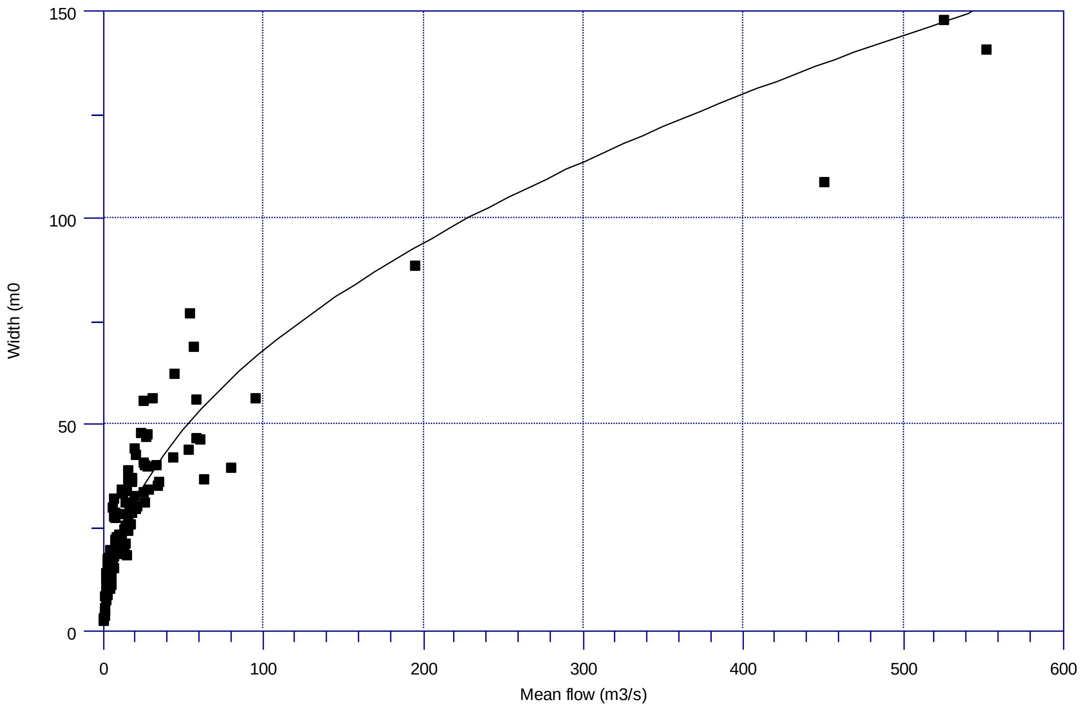


Figure 17: Relationship between river width and mean flow, showing log-log relationship (Eqn 14).



Summary

An increase of nutrients will cause an increase in the rate of growth of periphyton (dependent on the concentrations of N and P). An increase in periphyton will increase benthic invertebrate biomass and trout densities (Eqn 15) but will decrease MCI (Eqn 6) and stream "value" for recreational users, primarily through a reduction in water clarity (Eqn 4).

$$\text{Number of large and medium trout per km} = 7.982 \times \text{Mean flow}^{0.466} \times (\exp(0.774 \times \text{MALF}^{0.313} + 3.891 \times \text{TKN} + 0.525) - 1) \quad (15)$$

$$\text{MCI} = -284.66 \times \text{Total phosphorus} - 9.21 \times \text{Total nitrogen} - 0.078 \times \text{Chla} + 127.10 \quad (6)$$

$$\text{Log}_{10}(\text{Water clarity}) = -0.596 \times \text{Log}_{10}(\text{Particulate phosphorus}) - 0.990 \quad (4)$$

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Appendix to Annex 5: Statistics of regression and generalised additive models

$$Log_{10}(Water\ clarity) = -0.668 \times Log_{10}(Total\ phosphorus) - 0.953 \qquad (2)$$

Dependent variable: log_{10}(Black disk median) N: 71 R square: 0.744 Adjusted R square: 0.740

Variable	Coefficient	Std Error	t-value	P(2 Tail)
Constant	-0.953	0.077	-12.437	0.000
log_{10}(Total phosphorus)	-0.668	0.047	-14.162	0.000

$$Log_{10}(Water\ clarity) = -0.852 \times Log_{10}(Total\ phosphorus) + 6.892 \times DRP - 1.344 \qquad (3)$$

Dependent variable: log_{10}(Black disk median) N: 71 R square: 0.778 Adjusted R square: 0.771

Variable	Coefficient	Std Error	t-value	P(2 Tail)
Constant	-1.344	0.142	-9.490	0.000
log_{10}(Total phosphorus)	-0.852	0.073	-11.749	0.000
Dissolved Reactive Phosphorus (mg/l-P) Median	6.892	2.150	3.206	0.002

$$Log_{10}(Water\ clarity) = -0.596 \times Log_{10}(Particulate\ phosphorus) - 0.990 \qquad (4)$$

Dependent variable: log_{10}(Black disk median) N: 71 R square: 0.786 Adjusted R square: 0.783

Variable	Coefficient	Std Error	t-value	P(2 Tail)
Constant	-0.990	0.071	-14.045	0.000
log_{10}(Particulate phosphorus)	-0.596	0.037	-15.928	0.000

$$MCI = -314.17 \times Total\ phosphorus - 8.39 \times Total\ nitrogen + 123.61 \qquad (5)$$

Dependent variable: Average MCI N: 57 R square: 0.665 Adjusted R square: 0.653

Variable	Coefficient	Std Error	t-value	P(2 Tail)
Constant	123.608	2.401	51.476	0.000
Total Nitrogen (g/m^3) Median	-8.386	2.064	-4.062	0.000
Total Phosphorus (g/m^3) Median	-314.165	68.525	-4.585	0.000

$$MCI = -284.66 \times Total\ phosphorus - 9.21 \times Total\ nitrogen - 0.078 \times Chla + 127.10 \qquad (6)$$

Dependent variable: Average MCI N: 47 R square: 0.833 Adjusted R square: 0.821

Variable	Coefficient	Std Error	t-value	P(2 Tail)
Constant	127.104	1.873	67.879	0.000
Total Nitrogen (g/m^3) Median	-9.210	1.502	-6.132	0.000
Total Phosphorus (g/m^3) Median	-284.664	49.427	-5.759	0.000
Chla mg/m^2 Median	-0.078	0.027	-2.845	0.007

$$sqrt(total\ benthic\ invertebrate\ biomass) = 2.527 \times TKN + 0.572 \qquad (7)$$

Dependent variable: Sqrt(invertebrate biomass g/m2) N: 78 R square: 0.211 Adjusted R square: 0.200

Variable	Coefficient	Std Error	t-value	P(2 Tail)
Constant	0.572	0.087	6.560	0.000
Total Kjeldahl nitrogen (g/m^3)	2.527	0.561	4.504	0.000

Brown trout GAM

Summary of Input Data Set	
Number of Observations	59
Dependent variable	Number of large + medium trout/ha
Distribution	Poisson
Link function	Logarithmic

Analysis of Deviance

Source of variation	Sum of squares	df	Mean square
Residual	278.249	43.75	6.36
Model	1381.262	14.25	96.95
Total	1659.511	58.00	

Fit Statistics

Statistic	Value	df	P
F ratio	15.245	14.25, 43.75	0.000
r^2	0.832		
Akaike information criterion (AIC)	308.743		

Regression Model Analysis (linear component)

Parameter	Coefficient	Standard error	t-value	P
Constant	0.353	0.218	1.622	0.112
Elev*Tprf	-0.002	0.000	-7.455	0.000
COVER*Tprf	0.595	0.031	19.157	0.000
GRADIENT*Tprf	-24.110	2.194	-10.989	0.000
Sand*Tprf	-0.075	0.010	-7.877	0.000
WUAFP2*Tprf	0.041	0.004	11.239	0.000
%developed*Tprf	-0.009	0.002	-5.190	0.000
WUABTH1*Tprf	0.027	0.004	6.097	0.000
Lake*Tprf	0.023	0.003	6.869	0.000

Smoothed Model Analysis (cubic spline). This tests whether a function estimate is non-linear by comparing the full non-linear model (i.e. parameter df>1) with a model developed with the parameter linear (df=1).

Parameter	Deviance gain	df	MS	F	P(F)
Elev*Tprf	46.087	2.03	22.727	3.574	0.036
GRADIENT*Tprf	52.522	2.15	24.447	3.844	0.026
Lake*Tprf	48.726	1.80	27.018	4.248	0.024

Brown trout GAM with total nitrogen

Summary of Input Data Set	
Number of Observations	31
Dependent variable	Number of large + medium trout/ha
Distribution	Poisson
Link function	Logarithmic

Analysis of Deviance

Source of variation	Sum of squares	df	Mean square
Residual	401.595	23.01	17.45
Model	506.128	6.99	72.42
Total	907.723	30.00	

Fit Statistics

Statistic	Value	df	P
F ratio	4.150	6.99, 23.01	0.004
r^2	0.558		
Akaike information criterion (AIC)	417.572		

Regression Model Analysis (linear component)

Parameter	Coefficient	Standard error	t-value	P
Constant	-0.580	1.401	-0.414	0.683
COVER*Tprf	0.193	0.140	1.377	0.182
WUABTH1*Tprf	0.078	0.029	2.688	0.013
WUAFP2*Tprf	0.039	0.026	1.506	0.146
TN*Tprf	0.001	0.001	0.559	0.582

Smoothed Model Analysis (cubic spline). This tests whether a function estimate is non-linear by comparing the full non-linear model (i.e. parameter df>1) with a model developed with the parameter linear (df=1).

Parameter	Deviance gain	df	MS	F	P(F)
COVER*Tprf	57.308	1.02	56.296	3.226	0.085
TN*Tprf	38.647	1.95	19.839	1.137	0.337

Brown trout GAM with total Kjeldahl nitrogen

Summary of Input Data Set	
Number of Observations	31
Dependent variable	Number of large + medium trout/ha
Distribution	Poisson
Link function	Logarithmic

Analysis of Deviance

Source of variation	Sum of squares	df	Mean square
Residual	265.378	22.90	11.59
Model	642.345	7.10	90.46
Total	907.723	30.00	

Fit Statistics

Statistic	Value	df	P
F ratio	7.805	7.10, 22.90	0.000
r^2	0.708		
Akaike information criterion (AIC)	281.581		

Regression Model Analysis (linear component)

Parameter	Coefficient	Standard error	t-value	P
Constant	-2.036	1.023	-1.991	0.059
COVER*Tprf	0.391	0.115	3.399	0.002
Lake*Tprf	0.169	0.029	5.877	0.000
WUAFP2*Tprf	0.069	0.015	4.556	0.000
TKN g/m^3*Tprf	3.126	2.889	1.082	0.290

Smoothed Model Analysis (cubic spline). This tests whether a function estimate is non-linear by comparing the full non-linear model (i.e. parameter df>1) with a model developed with the parameter linear (df=1).

Parameter	Deviance gain	df	MS	F	P(F)
COVER*Tprf	165.322	1.85	89.369	7.711	0.003
TKN g/m^3*Tprf	16.377	1.25	13.090	1.129	0.314

Log_e(number of large and medium trout+1) = 0.082 × % adult trout habitat + 1.54 × sqrt(total invertebrate biomass) – 0.047 ***(8)***

Dependent variable: Log_e(Large & medium trout) N: 27 R square: 0.644 Adjusted R square: 0.615

Variable	Coefficient	Std Error	t-value	P(2 Tail)
Constant	-0.047	0.371	-0.126	0.901
Sqrt(Invertebrate biomass)*TRPF	1.504	0.378	3.980	0.001
WUABTH1*Tprf	0.082	0.027	3.002	0.006

% adult trout habitat = 9.44 × $MALF^{0.313}$ ***(9)***

Dependent variable: Log_{10}(WUABTH1) N: 64 R square: 0.318 Adjusted R square: 0.307

Variable	Coefficient	Std Error	t-value	P(2 Tail)
Constant	0.975	0.035	27.638	0.000
Log_{10}(MALF)	0.313	0.058	5.375	0.000

Log_e(number of large and medium trout+1) = 0.100 × % adult trout habitat +8.512 × TKN + 0.160 ….(11)

Dependent variable: Log_e(Large & medium trout) N: 31 R square: 0.526 Adjusted R square: 0.492

Variable	Coefficient	Std Error	t-value	P(2 Tail)
Constant	0.160	0.418	0.383	0.705
TKN g/m^3*Tprf	8.512	3.341	2.548	0.017
WUABTH1*Tprf	0.100	0.023	4.371	0.000

$$Width = 7.982 \times Mean\ flow^{0.466} \quad (13)$$

Data filter applied Width < 200 (excludes braided rivers)

Dependent variable: Log_{10}(width m) N: 114 R square: 0.904 Adjusted R square: 0.903

Variable	Coefficient	Std Error	t-value	P(2 Tail)
Constant	0.902	0.017	53.573	0.000
log_{10}(mean flow m^3/s)	0.466	0.014	32.531	0.000

Annex 6 Baseline Data

Table 55 River reaches used in Scenario Analysis

	SiteName	segX centroid	segY centroid	NZReach
1	Mararoa River at South Mavora Lake	2132279	5532143	15016464
2	Upukerora River at Te Anau-Milford Road	2098529	5519663	15020897
3	Mataura River at Garston	2172479	5518388	15021648
4	Oreti River at Three Kings	2129594	5517848	15021776
5	Waikaia River u/s Piano Flat	2200244	5510018	15024871
6	NA	2163359	5507588	15025929
7	Whitestone River d/s Manapouri-Hillside	2100494	5506853	15026001
8	Mararoa River at The Key	2110724	5505788	15026590
9	Cromel Stream at Selbie Road	2148959	5503868	15027427
10	Mararoa River at Weir Road	2097059	5498453	15029370
11	Waiau River at Duncraigen Road	2095844	5496848	15030310
12	Irthing Stream at Ellis Road	2153999	5493278	15031719
13	Waikaia River at Waikaia	2186519	5489993	15032882
14	Oreti River at Lumsden Bridge	2154344	5489153	15033324
15	Waimea Tributary at McCale Road	2158814	5486468	15034414
16	Aparima River at Dunrobin	2130074	5485658	15034889
17	Waimea Stream at Old Balfour Road	2159489	5484083	15035323
18	Waiau River at Sunnyside	2093084	5476748	15038276
19	Waimea Stream at Murphy Road	2164469	5475893	15038432
20	Waikaia River at Waipounamu Bridge Road	2182814	5475968	15038511
21	NA	2085239	5475023	15038952
22	Longridge Stream at Sandstone	2168879	5471348	15040542
23	Waimea Stream at Pahiwi - Balfour Road	2164859	5469578	15041058
24	Sandstone Stream at Kingston Crossing Rd	2178239	5466788	15041998
25	Waimea Stream at Nine Mile Road	2173649	5464553	15043125
26	North Peak Stream at Waimea Valley Road	2170694	5464508	15043151
27	Winton Stream d/s Winton Dam	2151239	5461508	15044331
28	Waimea Stream at Mandeville	2184914	5460548	15044764
29	Otamita Stream at Mandeville	2186099	5459738	15045155
30	Mataura River at Otamita Bridge	2188949	5458583	15045551
31	Otapiri Stream at Otapiri Gorge	2157959	5458073	15045776
32	Oreti River at Centre Bush	2147639	5451848	15047958
33	Makarewa River at Lora Gorge Road	2160464	5450648	15048673
34	Bog Burn d/s Hundred Line Road	2141684	5449703	15048787
35	Mataura River at Gore	2196734	5448968	15049205
36	Waikaka Stream at Gore	2197469	5448413	15049464
37	Orauea River at Orawia Pukemaori Road	2107139	5446103	15050335
38	Otautau Stream at Waikouro	2120549	5444588	15050990
39	Dunsdale Stream at Dunsdale Reserve	2169929	5443973	15051163
40	Aparima River at Otautau	2123954	5440763	15051903

	SiteName	segX centroid	segY centroid	NZReach
41	Otautau Stream at Otautau-Tuatapere Road	2121584	5441543	15051985
42	Waiau River at Tuatapere	2099504	5439773	15052505
43	Waimatuku Stream d/s Bayswater Bog	2131049	5438363	15053059
44	Mataura River 200m d/s Mataura Bridge	2190779	5437358	15053378
45	Winton Stream at Lochiel	2147489	5434853	15054215
46	Tussock Creek at Cooper Road	2156474	5430188	15055845
47	Pourakino River at Ermedale Road	2121284	5428868	15056201
48	Cascade Stream at Pourakino Valley Road	2119634	5427878	15056487
49	Mimihau Stream Tributary at Venlaw Forest	2208329	5425748	15056983
50	Opouriki Stream at Tweedie Road	2123174	5424278	15057319
51	Aparima River at Thornbury	2131484	5424548	15057386
52	Mimihau Stream at Wyndham	2190539	5423828	15057618
53	Pourakino River at Traill Road	2121584	5423048	15057663
54	Waimatuku Stream at Lorneville Riverton Hwy	2138189	5423003	15057733
55	Makarewa River at Wallacetown	2147849	5420738	15058243
56	Mokoreta River at Wyndham River Road	2189894	5419763	15058499
57	Oreti River at Wallacetown	2145269	5419733	15058642
58	Waikiwi Stream at North Road	2151884	5417138	15058921
59	Oteramika Stream at Seaward Downs	2183564	5416793	15058925
60	NA	2186159	5416163	15059190
61	Mataura River at Mataura Island Bridge	2184989	5415848	15059279
62	Waihopai River u/s Queens Drive	2153534	5414213	15059564
63	Otepuni Creek at Nith Street	2152829	5412098	15060150
64	NA	2170874	5409443	15060421
65	Mataura River at Gorge Road	2183069	5401553	15061485
66	Waituna Creek at Marshall Road	2168069	5400353	15061707
67	Carran Creek at Waituna Lagoon Road	2176364	5398058	15061958
68	Moffat Creek at Moffat Road	2170019	5398208	15062000
69	Carran Creek Trib at Waituna Lagoon Rd	2177369	5398328	15062040
70	NA	2159699	5397623	15062054
71	Waikawa River at Progress Valley	2214134	5396723	15062197
72	Waikopikopiko Stream at Haldane CurioBay	2205344	5390363	15062800
73	Tokanui River at Fortrose Otara Road	2193329	5390558	15062815

Table 56 Base Values for Nitrogen, Phosphorus and Flow

Site	DRP (mg/l)	NH_4N (mg/l)	NNN (mg/l)	NO_3N (mg/l)	TN (mg/l)	TP (mg/l)	MALF m^3/s	MeanFlow m^3/s
1	0.0025	0.0050	0.0010	0.0050	0.0550	0.0050	6.46	18.03
2	0.0050	0.0050	0.1395	0.1250	0.2250	0.0060	3.27	9.97
3	0.0070	0.0050	0.1830	0.1600	0.2200	0.0100	1.67	4.77
4	0.0025	0.0050	0.0340	0.0300	0.0640	0.0050	3.47	10.13
5	0.0060	0.0050	0.0090	0.0100	0.1100	0.0100	3.21	10.49
6	0.0053	0.0066	NA	0.2296	0.3027	0.0110	2.78	8.46
7	0.0025	0.0050	0.4275	0.3570	0.5100	0.0050	2.43	9.04
8	0.0025	0.0050	0.1230	0.0930	0.1900	0.0050	9.57	27.61
9	0.0025	0.0050	0.0050	0.0050	0.0610	0.0050	0.53	1.85
10	0.0040	0.0050	0.3800	0.2505	0.4200	0.0050	11.07	39.24
11	0.0025	0.0050	0.3700	0.2600	0.3600	0.0050	127.67	471.43
12	0.0060	0.0050	1.5100	1.0000	1.3500	0.0086	4.73	18.36
13	0.0060	0.0090	0.1720	0.1300	0.2500	0.0160	3.38	12.28
14	0.0026	0.0050	NA	0.4000	0.5116	0.0053	4.79	18.82
15	0.0080	0.0170	0.8100	0.5080	1.1000	0.0320	0.00	0.03
16	0.0050	0.0050	0.0130	0.0230	0.1100	0.0050	1.79	5.52
17	0.0080	0.0105	0.6900	0.4315	0.8450	0.0220	0.03	0.17
18	0.0025	0.0050	0.1485	0.1100	0.2200	0.0050	148.30	518.94
19	0.0130	0.0150	2.3000	1.4330	2.0000	0.0315	0.01	0.02
20	0.0080	0.0050	0.5100	0.4400	0.6300	0.0160	3.87	14.92
21	0.0006	0.0030	NA	0.0066	0.0800	0.0030	4.75	18.43
22	0.0370	0.0170	3.2000	2.7000	3.5000	0.0660	0.09	0.51
23	0.0160	0.0180	4.0500	3.0160	3.9500	0.0380	0.27	1.34
24	0.0280	0.0230	2.1000	1.2000	2.3000	0.0840	0.07	0.17
25	0.0170	0.0210	3.2000	2.4000	3.4000	0.0470	0.49	2.66
26	0.0150	0.0400	0.6400	0.5700	1.0000	0.0500	0.01	0.09
27	0.0160	0.0170	0.4400	0.2650	0.6350	0.0470	0.07	0.31
28	0.0180	0.0210	3.1000	2.1000	2.9000	0.0510	0.64	3.24
29	0.0120	0.0140	0.9900	0.5900	0.9500	0.0310	0.36	2.29
30	0.0100	0.0110	0.8400	0.5700	0.8600	0.0200	9.43	35.37
31	0.0150	0.0120	0.6050	0.3900	0.7200	0.0360	0.23	1.49
32	0.0050	0.0050	0.8800	0.7200	0.9200	0.0080	5.39	22.45
33	0.0150	0.0140	0.7895	0.5065	0.9050	0.0350	0.26	1.27
34	0.0200	0.0200	1.3700	0.6775	1.1800	0.0490	0.05	0.27
35	0.0090	0.0110	0.8800	0.7420	0.9900	0.0190	9.95	37.86
36	0.0220	0.0585	1.1700	0.6750	1.3000	0.0640	0.78	4.90
37	0.0120	0.0160	0.5300	0.4300	0.7900	0.0325	0.60	5.97
38	0.0230	0.0585	0.8200	0.8000	1.3450	0.0600	0.25	1.45
39	0.0140	0.0050	0.1940	0.1835	0.3300	0.0220	0.23	1.23
40	0.0060	0.0050	0.7150	0.5300	0.7400	0.0100	2.53	10.67
41	0.0220	0.0340	1.0100	0.8250	1.3300	0.0550	0.42	3.03
42	0.0019	0.0050	NA	0.1650	0.2924	0.0100	175.53	566.23

Site	DRP (mg/l)	NH_4N (mg/l)	NNN (mg/l)	NO_3N (mg/l)	TN (mg/l)	TP (mg/l)	MALF m^3/s	MeanFlow m^3/s
43	0.0520	0.0320	1.6600	1.3260	2.0000	0.0910	0.06	0.25
44	0.0220	0.0500	0.8700	0.6800	1.1800	0.0485	12.36	46.49
45	0.0490	0.0630	1.5050	1.4000	2.1000	0.1190	0.23	1.35
46	0.0210	0.0565	1.7890	1.7000	2.4000	0.0560	0.07	0.44
47	0.0060	0.0050	0.1230	0.0965	0.2900	0.0140	0.35	1.75
48	0.0025	0.0050	0.0160	0.0170	0.1700	0.0070	0.19	0.92
49	0.0130	0.0050	0.2395	0.0930	0.3800	0.0200	0.04	0.13
50	0.0100	0.0435	1.8100	1.5000	2.0000	0.0370	0.05	0.34
51	0.0090	0.0140	0.7110	0.6050	0.9250	0.0170	3.19	14.70
52	0.0130	0.0170	0.8960	0.7400	1.0000	0.0380	0.92	4.40
53	0.0046	0.0160	0.1590	0.1400	0.3600	0.0150	0.59	3.08
54	0.0280	0.0160	4.0520	3.2000	4.0000	0.0550	0.40	1.57
55	0.0175	0.0895	1.1650	0.9600	1.6900	0.0540	2.19	15.50
56	0.0100	0.0200	1.2310	1.0820	1.4200	0.0330	1.98	9.10
57	0.0060	0.0090	NA	0.7449	0.9200	0.0138	6.77	24.94
58	0.0130	0.0460	2.8700	2.4000	3.2000	0.0410	0.32	1.52
59	0.0270	0.0495	1.4900	1.6000	2.5000	0.0980	0.15	0.63
60	0.0147	0.0320	NA	0.9543	1.2520	0.0400	17.22	66.63
61	0.0145	0.0325	1.1480	0.9440	1.2650	0.0401	17.43	67.21
62	0.0110	0.0460	2.4500	1.9000	2.7000	0.0400	0.44	2.36
63	0.0150	0.0660	1.5000	1.3500	2.2000	0.0520	0.10	0.45
64	0.0087	0.0570	2.1535	1.8000	2.5000	0.0345	0.09	0.45
65	0.0170	0.0340	1.0400	0.8800	1.2000	0.0390	17.50	68.38
66	0.0200	0.0660	2.1000	1.2000	2.4000	0.0635	0.27	1.32
67	0.0425	0.0840	0.9750	0.2800	1.4000	0.1300	0.12	0.54
68	0.0640	0.0430	0.8200	0.2000	1.5500	0.1600	0.05	0.21
69	0.0635	0.0250	0.0210	0.0200	0.7100	0.0875	0.03	0.11
70	0.0050	0.0210	0.0110	0.0165	0.7200	0.0190	0.02	0.07
71	0.0140	0.0240	0.7500	0.6540	0.9650	0.0415	1.11	4.77
72	0.0090	0.0110	0.1790	0.1900	0.3700	0.0210	0.31	1.33
73	0.0160	0.0255	1.1000	0.9520	1.4900	0.0590	0.26	1.32

Table 57 Base Values for Chla, E Coli and NO_3 Toxicity

Site	Mean Summary Chl_a (mg/m^2)	ECOLI (Median/ 100ml)	*E. Coli* Class	NO_3N Toxicity Class	Peri Class
1	36.47	1.00	A	A	A
2	43.45	39.50	A	A	A
3	31.45	64.00	A	A	A
4	4.08	14.00	A	A	A
5	29.93	20.00	A	A	A
6	26.41	68.30	A	A	A
7	10.77	38.00	A	A	A
8	35.11	48.00	A	A	A
9	8.25	14.00	A	A	A
10	56.24	58.00	A	A	B
11	33.12	41.00	A	A	A
12	34.44	120.00	A	B	A
13	31.65	140.00	A	A	A
14	18.93	50.80	A	A	A
15	19.45	275.00	B	A	A
16	30.55	63.50	A	A	A
17	31.57	265.00	B	A	A
18	39.12	27.00	A	A	A
19	69.76	290.00	B	B	B
20	41.42	160.00	A	A	A
21	19.41	2.00	A	A	A
22	86.72	300.00	B	C	B
23	73.41	310.00	B	C	B
24	89.43	525.00	B	B	B
25	76.24	340.00	B	C	B
26	49.21	270.00	B	A	B
27	54.72	390.00	B	A	B
28	77.76	275.00	B	B	B
29	44.79	270.00	B	A	A
30	60.01	200.00	A	A	B
31	55.92	455.00	B	A	B
32	35.52	130.00	A	A	A
33	48.75	400.00	B	A	B
34	45.34	770.00	C	A	B
35	60.22	380.00	B	A	B
36	70.89	370.00	B	A	B
37	61.93	345.00	B	A	B
38	76.66	1550.00	D	A	B
39	51.29	80.00	A	A	B
40	39.35	120.00	A	A	A
41	80.89	730.00	C	A	B

Site	Mean Summary Chl_a (mg/m^2)	ECOLI (Median/ 100ml)	*E. Coli* Class	NO_3N Toxicity Class	Peri Class
42	43.27	71.70	A	A	A
43	88.18	310.00	B	B	B
44	79.19	1000.00	D	A	B
45	97.76	1100.00	D	B	C
46	77.94	1100.00	D	B	B
47	41.38	140.00	A	A	A
48	22.47	65.00	A	A	A
49	54.05	13.00	A	A	B
50	60.73	850.00	C	B	B
51	51.84	290.00	B	A	B
52	53.81	340.00	B	A	B
53	34.81	280.00	B	A	A
54	100.88	600.00	C	C	C
55	66.82	410.00	B	A	B
56	51.79	300.00	B	B	B
57	45.05	56.50	A	A	B
58	77.69	550.00	C	C	B
59	74.76	460.00	B	B	B
60	73.84	283.20	B	A	B
61	73.66	340.00	B	A	B
62	81.78	375.00	B	B	B
63	76.80	1300.00	D	B	B
64	71.33	345.00	B	B	B
65	75.79	330.00	B	A	B
66	88.65	410.00	B	B	B
67	94.27	410.00	B	A	C
68	112.60	300.00	B	A	C
69	51.43	40.00	A	A	B
70	0.00	9.00	A	A	A
71	66.69	650.00	C	A	B
72	57.08	120.00	A	A	B
73	70.18	310.00	B	A	B