TE WAIHORA/LAKE ELLESMERE

State of the Lake and Future Management

Edited by KENNETH F.D. HUGHEY and KENNETH J.W. TAYLOR

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Lincoln University Environment Canterbury

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CONTENTS

SHELLEY McMURTRIE


SHUTTERSTOCK

01 INTRODUCTION

KENNETH F.D. HUGHEY Lincoln University **KENNETH J.W. TAYLOR** Environment Canterbury

Te Waihora/Lake Ellesmere[1] is a large coastal lake, intermittently open to the sea. It is highly regarded for its conservation and related values, some of which are of international significance. Its function as a sink for nutrients from its large predominantly agriculturally based catchment, currently undergoing accelerated intensification, is also recognised, at least implicitly. It is the resulting conflict from these value sets which is mainly responsible for the ongoing debate about the future of the lake, a debate long fuelled by rhetoric and informed by a body of science which highlights the lake's complexity as a biophysical system, but has many gaps. It is a debate that now has substantial statutory implications, arising from factors which include:

- the requirements of conservation, and indigenous needs and entitlements which are growing in prominence and statutory (including property rights based) legitimacy;
- public interest in legal processes associated with further major intensification of agriculture planned for the catchment;
- a recent Environment Court decision in which serious questions about the overall biological health of the lake were raised; and
- the consequences arising from the need for Environment Canterbury to obtain resource consents for the lake operating regime.

In addition, in recent times the Waihora Ellesmere Trust (WET), a community based group advocating for improved management of the lake, has been established. It is within these diverse contexts that this State of Te Waihora/Lake Ellesmere report has been prepared—it results from the 2007 Waihora/Ellesmere Living Lake Symposium, held from 31 October-3 November 2007 at Lincoln University, Canterbury. The symposium was initiated and organised by the WET (see www.wet.org.nz).

The Living Lake Symposium had several key objectives:

- To determine the overall state of the lake, by first defining the key value sets, and indicators that could be reported against;
- To suggest future management actions that would address key issues affecting the defined values;
- To provide a forum within which lay individuals, scientists and managers could openly debate issues; and
- To provide a launching pad for integrated and focused future management of the lake and its environs.

The programme incorporated three keynote speakers: Dr Larry Hildebrand from Environment Canada, Dr Hamish Rennie from Lincoln University, and Dr Bryan Jenkins from Environment Canterbury—their addresses made a major contribution to the symposium although none are included in this report, because it is focused primarily on the science and the management options associated with the lake.

The format of this report is designed to be readily updateable. Ten of the principal presentations in the main sessions of day two of the symposium are included in this report—two Power Point presentations (both regarding water quantity and related issues) are provided as appendices to improve completeness. Over time, however, topic areas not available as full papers for this report, e.g., surface water quantity, will be written up and included in detail. Similarly, the papers herein will themselves be updated as new and significant data become available. Each subject area will be reconsidered within the same structure and context as has been provided here. One paper, 'Te Waihora/Lake Ellesmere: An integrated view of the current state and possible futures', was presented on the final formal day of the symposium and it is included as the concluding chapter of this report.

Finally, the Waihora Ellesmere Trust and many of the others attending the symposium saw merit in reconvening the event around two years after the initial symposium, to report on progress with management, indicator monitoring, scientific understanding and other matters. We support that suggestion.

In terms of report format it is important that readers note the following:

- All authors were provided with 'briefs of work' and were requested to contextualise their work with that contained within the Taylor (1996) report on the lake—this was more easily achievable for some than others. Given some lack of consistency between symposium presentations and final papers it is our intention that a revised set of agreed indicators will be considered and included in any follow-up symposium and associated reports—some considerable work will be required in some areas to achieve this objective;
- Only the wildlife and integration papers included in this report have been formally peer reviewed; and
- All other papers have been standardised and style edited-some changes have been suggested by the report editors and made by the paper authors.

Finally, an attempt has been made to present the papers in a logical sequence of 11 chapters: chapter 1 sets the scene; chapters 2-7 cover the biophysical science dimensions (groundwater, water quality, native vegetation, native fisheries, trout, wildlife); chapters 8-10 deal with the human dimensions (Ngāi Tahu, recreation, economics); and chapter 11 deals with integration of the findings from the previous chapters and setting the scene for future management.

[1] Note that the Geographic Place Names Board has defined the name as Lake Ellesmere (Te Waihora). It is not our intention to debate the nomenclature, but rather to put the focus where we consider it should lie, within the lake's initial historical and cultural context for indigenous Maori.

SHIRLEY HAYWARD

03

WATER QUALITY in the Ellesmere catchment

SHIRLEY HAYWARD Environment Canterbury **JONET C. WARD** Lincoln University

The water quality of Te Waihora/Lake Ellesmere is one of high nutrient and sediment concentrations, consequently with high phytoplankton biomass and low water clarity. However, despite its highly enriched state, Te Waihora/Lake Ellesmere does not exhibit many of the detrimental characteristics of a highly enriched lake, such as algal blooms, deoxygenation and fish kills. Furthermore, it supports abundant fish and bird communities.The quality of the lake tributaries reflect the intensive land use surrounding them, with elevated nutrients and bacteria found in many sites. Monitoring of the lake over the past 15 years shows little change in nutrient concentrations and phytoplankton biomass but it has shown a decline in water clarity. The salinity of the lake has also shown a decrease in the past 15 years. Lake level management is an important driver of many components of the lake, and particularly influences lake salinity. The varying salinity across the lake is a key factor in the lakes' diversity. Being a lowland lake, it not only receives inputs within the immediate vicinity of the lake but also from the wider catchment across the Plains up to the foothills. This has implications for the scale of management issues. Riparian protection around the lake margin and tributaries will greatly help reduce some contaminant inputs such as sediment and phosphorus, but catchment wide nutrient and water allocation management will be needed to reduce nitrates and improve freshwater inflows to the lake.

3.1 Introduction

Environment Canterbury's water quality monitoring programme for the lake and tributaries has been carried out routinely since 1993, with occasional monitoring from 1973 (Taylor 1996). This report discusses the current state and changes in lake water quality since 1993. Potential drivers for these changes are suggested along with some land use changes in the region since the 1990s. Comparisons with other Canterbury coastal lakes are illustrated.

Four lake sites and nine inflowing rivers and streams have been sampled (Figure 1). Tests for nutrients (nitrogen and phosphorus), chlorophyll a, clarity, salinity, oxygen and suspended solids have been carried out in addition to microbial analyses.

State and trends in lake water quality

The current state of water quality in Te Waihora/Lake Ellesmere and tributaries is based on the five years of monthly data (July 2002-June 2007) for the four monitoring sites. Comparison to other Canterbury coastal lakes helps put a context around interpretation of the data.

Trend analyses is based on monthly data for the four lake sites over the past 14 years (1993 to 2007). Table 1 summarises trends detected for the main water quality determinands.

Microbial quality

Microbial quality is both a human and stock health issue and affects the suitability of water for domestic and stock drinking water supply and for contact recreation. Concentrations of faccal indicator bacteria collected from the four lake sites indicate that waters were generally within the acceptable limits for contact recreation (Figure 2).

Drivers of microbial quality include inputs of faecal material from birdlife, grazing stock along the lake edge and stream inputs

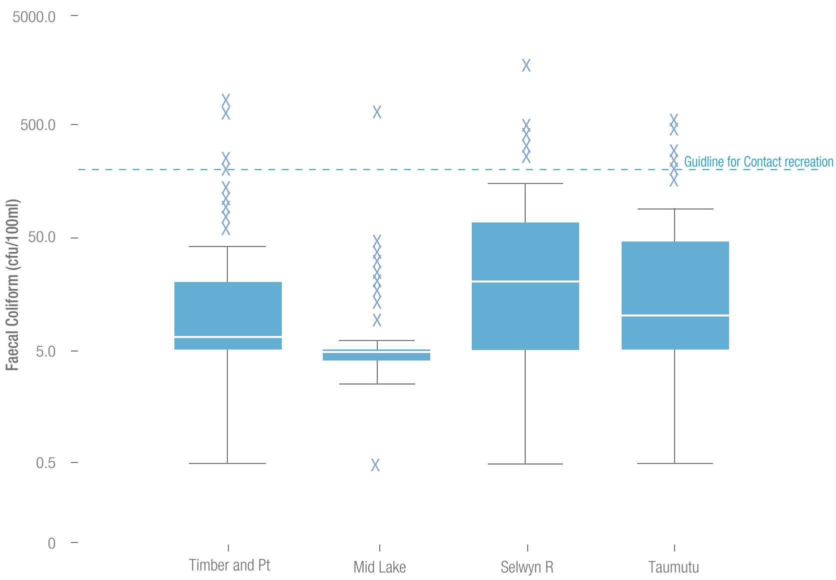

FIGURE 2. Faecal coliform concentrations in four sites on Te Waihora/Lake Ellesmere (2002-2007).

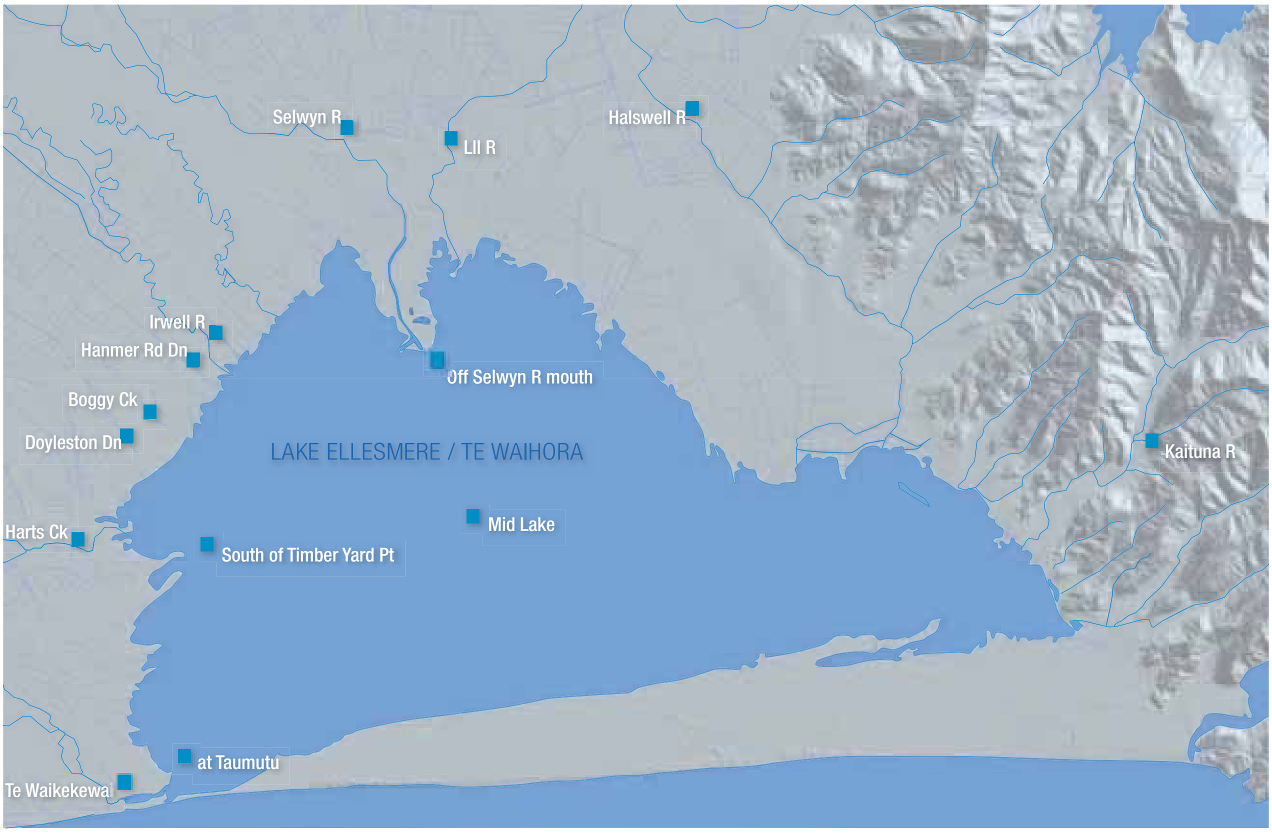

FIGURE 1. Location of water quality sampling sites on Te Waihora/Lake Ellesmere and the main tributaries. Base Map sourced from ECan.

from grazing stock, domestic animals and effluent disposal (to land).

3.2 Nutrients

Dissolved inorganic nitrogen (DIN) concentations at all four sites in Te Waihora/Lake Ellesmere showed a decrease in concentration over the last 14 years but dissolved reactive phosphorus (DRP) had increased at all sites (Table 1). The decrease in nitrogen concentrations could be explained by the decrease in DIN loading from tributaries (see below), but the increase in soluble phosphorus is in contrast to a decrease in phosphorus loadings from tributaries (Table 2).

There are less consistent trends in total nutrient concentrations (Table 1). Total nitrogen concentrations decreased at two sites, but no trends in total phosphorus concentrations were found. Total nitrogen and phosphorus concentrations are generally considered more relevant indicators of lake trophic status and include the dissolved and bioavailability nutrients plus nutrients attached to particles and contained within phytoplankton cells.

Total nitrogen concentrations from the four sites on Te Waihora/Lake Ellesmere were greater than those of other coastal lakes in Canterbury and generally fall into the hypertrophic classification (Figure 3). Total phosphorus concentrations were also generally higher (median) than the other coastal lakes, although Lake Forsyth/Wairewa and Wainono Lagoon also fall into the hypertrophic classification for TP (Figure 4). Drivers of the trophic state of the lake as a whole include nutrient inputs from tributary streams, groundwater and wildlife, and light availability-limited by suspended sediment and seasonal temperature. Current estimates of nutrient inputs of total phosphorus load to the lake are: 90% from tributaries, 6% from rainfall and 4% from birdlife. Total nitrogen loading estimated to arise from tributaries is 98%, rainfall 1% and direct ground water inputs 1%.

TABLE 1. **Summary of statistically significant trends in water quality data collected from 1993 to 2007 for four sites on Te Waihora/Lake Ellesmere.**

	Timberyard	Mid lake	Off Selwyn	Taumutu
Dissolved oxygen (% saturation)	0	0	0	0
Suspended solids concentrations	0	0	0	+
Clarity (Secchi depth)	-	-	-	-
Salinity	-	-	-	-
Dissolved inorganic nitrogen (nitrate+nitrite+ammonia) (DIN)	-	-	-	-
Total nitrogen concentrations (TN)	-	0	-	0
Dissolved reactive phosphorus (DRP)	+	+	+	+
Total phosphorus concentrations (TP)	0	0	0	0
TN:TP ratio	-	-	-	-
Phytoplankton biomass (Chlorophyll a)	0	0	0	0
Faecal coliform bacteria	0	0	0	0

0 no statistically significant trend
- statistically significant trend of decreasing value
+ statistically significant trend of increasing value

3.3 Phytoplankton biomass

Despite the decrease in nitrogen inputs, there has been no change in chlorophyll a in Te Waihora/Lake Ellesmere from 1993 to 2007 (Table 1). This suggests (as others have suggested) that nitrogen availability is not generally limiting to phytoplankton growth. However, there are indications it could be

TABLE 2. **Summary of statistically significant trends in tributary water quality data (concentration (Conc.) and load) collected from 1996 to 2007.**

		Kaituna R	Halswell R	LII R	Off Selwyn	Irwell R	Hanmer Rd Dn	Doyleston Dn	Harts Ck
Flow		0	-	-	-	-	-	-	-
Dissolved Inorganic Nitrogen	Conc.	0	-	-	+	-	+	-	+
	Load	0	-	-	-	-	0	-	-
Total Nitrogen	Conc.	-	-	-	+	-	+	-	+
	Load	0	-	-	-	-	0	-	-
Dissolved Reactive Phosphorus	Conc	0	+	-	+	0	+	+	+
	Load	0	0	-	-	-	-	0	0
Total Phosphorus	Conc.	0	0	-	0	0	0	0	-
	Load	0	-	-	-	-	-	-	-

0 no statistically significant trend
- statistically significant trend of decreasing value
+ statistically significant trend of increasing value

limiting at times during periods of calm, warm weather and high lake levels. During this time low levels of suspended sediment may result in increased light penetration and therefore greater opportunity of phytoplankton growth (Hawes and Ward 1996, Hamilton 2008).

Phytoplankton biomass (measured as chlorophyll a) was overall higher in Te Waihora/Lake Ellesmere than in the other three coastal lakes from 1993 to 2007 (Figure 5). However, the annual maximum chlorophyll a was lower in Te Waihora/Lake Ellesmere than in Lake Forsyth/Wairewa where toxic algal blooms are more frequent (Figure 6).

There is some debate over the definition of the trophic status of the lake. Although Te Waihora/Lake Ellesmere has high nutrient and phytoplankton values that place it in the category of hypertrophic (extremely enriched), the lake does not exhibit many of the characteristics of such a classification, i.e., it does not regularly undergo severe oxygen depletion, nor does it produce unsightly or toxic algae blooms (unlike its neighbour, Lake Forsyth/Wairewa, which fits into the same trophic status and does routinely have toxic algae blooms, deoxygenation problems and occasional fish kills).

An important driver in phytoplankton growth is light availability which is driven by suspended sediments. While there does not appear to be any major changes in suspended solid concentrations, clarity (Secchi depth) has shown a consistent decreasing trend (Table 1). Lake level and climate are also significant factors in controlling phytoplankton production. The highest overall chlorophyll *a* values occurred during the 1998-99 drought, when lake levels were maintained at low levels because of high evaporation rates and low freshwater inputs. High water temperatures would have also been important in phytoplankton production.

3.4 Clarity

Visual clarity of the lake water, as measured by Secchi disk, is important for recreation and amenity values and ecologically for visual feeding of insects, fish and birds and for plant and algal growth. Figure 7 indicates that clarity is low and shows little variation throughout the lake although clarity has shown a consistent decreasing trend at all sites (Table 1).

Drivers of visual clarity, and its inverse turbidity, include phytoplankton biomass (driven by nutrients, light, temperature), suspended sediment (wind driven re-suspension of bed sediments) and sediment inputs (stream inflows, lakeshore erosion).

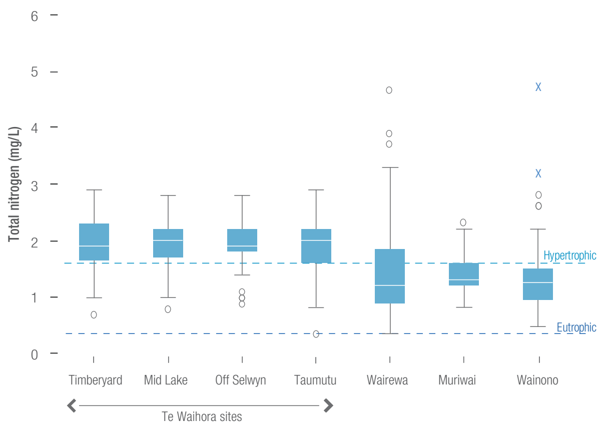

FIGURE 3. Total nitrogen concentrations in four sites on Te Waihora/Lake Ellesmere compared to other coastal lakes (2002–2007).

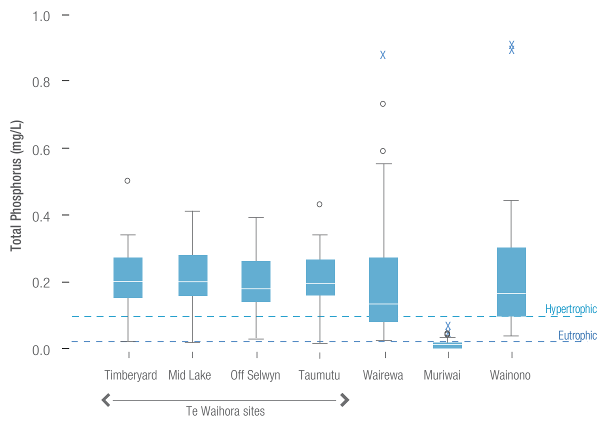

FIGURE 4. Total phosphorus concentrations in four sites on Te Waihora/Lake Ellesmere compared to other coastal lakes (2002–2007).

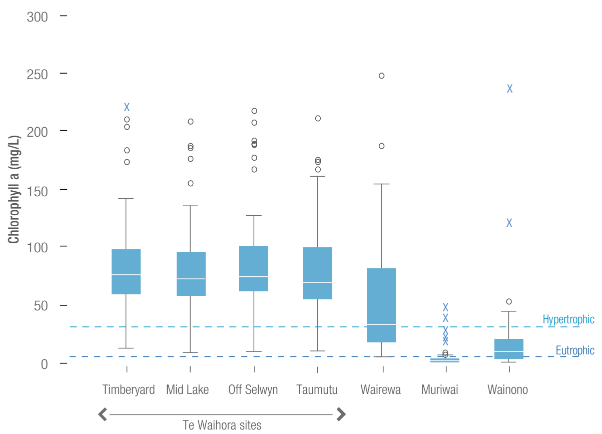

FIGURE 5. Chlorophyll a concentrations in four sites on Te Waihora/Lake Ellesmere compared to other coastal lakes (2002–2007).

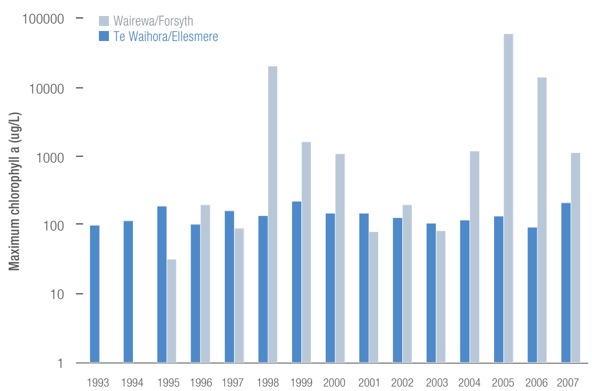

FIGURE 6. Annual maximum chlorophyll a in Te Waihora/Lake Ellesmere (mid lake site) and Lake Forsyth/Wairewa (January 1993–2007).

3.5 Salinity

The brackish nature of Te Waihora/Lake Ellesmere is a result of the mixing of sea water and fresh water inflows. Sea water inflows occur during lake openings and from waves overtopping the gravel bar. The salinity of the lake varies spatially and temporally throughout the lake and contributes to habitat diversity and therefore biotic diversity such as salt marshes and freshwater raupo beds.

There has been a significant decrease in salinity at all sites within Te Waihora/Lake Ellesmere which appears to be related to decrease in frequency of openings, overall lake levels (linked to decrease in freshwater inflows-both base flows and floods) and rates of evaporation (Figure 8). The highest annual average salinity occurred during the 1998/99 drought, when the frequency and duration of lake openings were low and the lake level remained unusually low because of high summer temperature and reduced freshwater inflows (Figure 8). Between 2002 and 2007 salinity in Te Waihora/Lake Ellesmere was generally higher than in Wairewa although the range was not as great (Figure 9).

Tributaries to the lake

Tributaries are valued in their own right for recreational, ecological and amenity values but they also have a major influence on the lake itself. Inflows come from about 40 rivers and streams, dominated by groundwater fed streams. Most streams are small and vulnerable to adjacent land use impacts as they flow across intensively farmed land. Trends (Table 2) in water quality include an overall reduction in nutrient loadings to the lake. This is driven primarily by reduction in flows over the past 10 years (Hayward 2007) rather than a reduction in instream nutrient concentrations. The exception is inputs from the Kaituna River, which has not shown any significant decrease in flows or nutrient loadings.

Most tributaries exceeded the contact recreation guideline for faecal coliforms (Figure 10). Faecal coliform concentrations in Boggy Creek and Doyleston Drain frequently exceeded the stock-drinking water guideline value.

Dissolved reactive phosphorus concentrations were typically above instream guideline values and were particularly high in the Irwell River, Hanmer Drain, Boggy Creek and Doyleston Drain (Figure 11). Nitrate/nitrite nitrogen concentrations were similarly high at most sites except for the Kaituna River (Figure 12). Suspended solids showed a wide range among sites (Figure 13). Dissolved nutrient concentrations

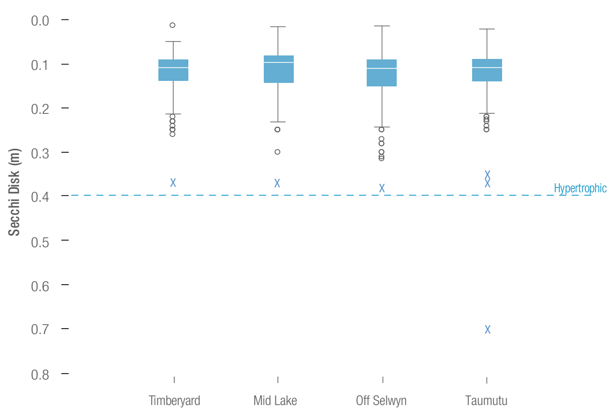

FIGURE 7. Secchi disk depth for four sites on Te Waihora/Lake Ellesmere (2002–2007). Note the reverse order of the y-axis.

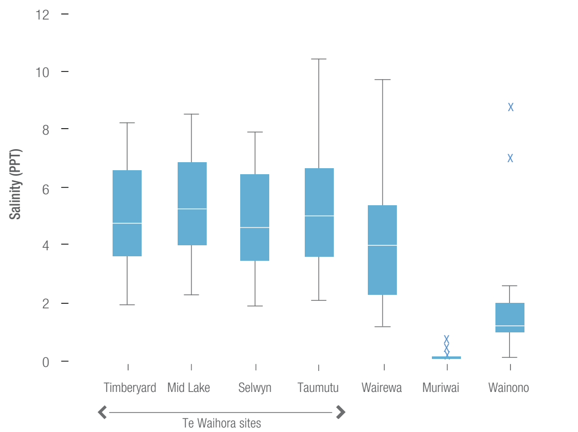

FIGURE 9. Salinity in four sites on Te Waihora/Lake Ellesmere compared to other coastal lakes (2002–2007).

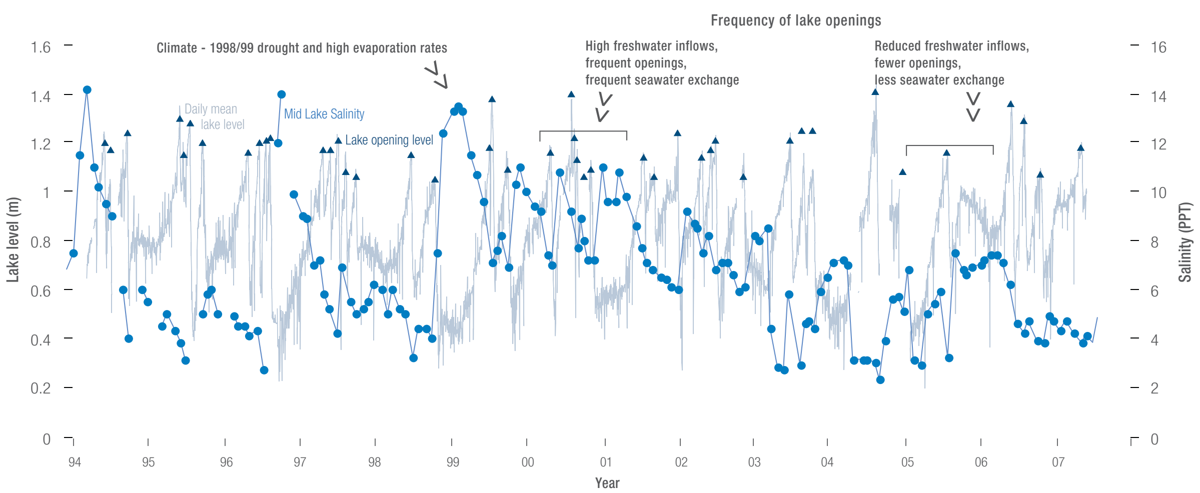

FIGURE 8. Drivers in change of salinity in Te Waihora/Lake Ellesmere (January 1994–2007).

exceeded guideline values in most streams, reflecting the vulnerability of these streams to adjacent land activities. In the case of nitrate/nitrite nitrogen, most is received via inflows of nitrate-enriched groundwater.

Different aspects of water quality are driven by different influences. Flows have a significant influence on water quality; many contaminants increase for short periods during floods. During periods of low flows, contaminants can also increase in concentrations because of lack of dilution and instream processes which release nutrients from sediments. Figure 14 illustrates this relationship in Boggy Creek, where dissolved phosphorus concentrations increase during low flow periods, particularly during the extreme low summer period of 2005-2006. During this period, dissolved oxygen decreased greatly, to well below recommended values (Figure 15).

In contrast to dissolved phosphorus, nitrate/nitrite concentrations were lowest during low flow periods (Figure 16). Furthermore, following the June 2006 snow event, nitrate/nitrite concentrations rose dramatically, exceeding the aquatic toxicity threshold. Boggy Creek is fed primarily by groundwater, which clearly has a strong influence on stream flows and nitrate concentrations.

Suspended solid concentrations have shown a considerable improvement over the past four years in Boggy Creek (Figure 17). This is not strongly related to flows, but reflects a significant improvement in riparian protection. Figure 18 shows mature vegetation that has been planted along Boggy Creek, which has resulted in reduced inputs of sediment.

Two aspects of flow have changed:

- Lower base flows of groundwater fed streams (all except Banks Peninsula streams) caused by climate (lack of winter recharge) as well as by increased groundwater abstraction
- Less frequent floods cause by climatic factors.

Invertebrate communities reflect water quality and habitat. Reduction in flows has had a major influence on the state of tributaries. For example, during the extreme low flow event of 2005/2006, the Selwyn River invertebrate community changed dramatically, with the loss of sensitive species (Figure 19).

Management issues

The loss of the macrophyte beds in the late 1960s resulted in a large increase in lake turbidity (especially at the lake margin) affecting people's perception of the lake as well as dramatically changing the primary production with cascading effects on other biota (e.g., trout, black swans). There have been frequent calls for efforts to restore the macrophyte beds. The feasibility of this is being investigated. If successful (as a long-term goal) this could have both positive and negative effects on the lake. Negative effects could include algal blooms around the lake margin because of clearer, calmer waters as well as problems with boat access.

Other perceptions of the health of the lake probably relate to recreational and fishing opportunities, and general appeal of, and access to, the lake margin rather that water quality *per se.*

The Canterbury region, as with many other regions, has undergone some major changes and intensification of agricultural

Photo ***Visual water clarity of the lake is low and has declined at long term monitoring sites from 1998 through to 2007. However perceptions of health of the lake relate more to general appeal of the lake rather than just water quality issues.*** *Photography* ***Shelley McMurtrie.***

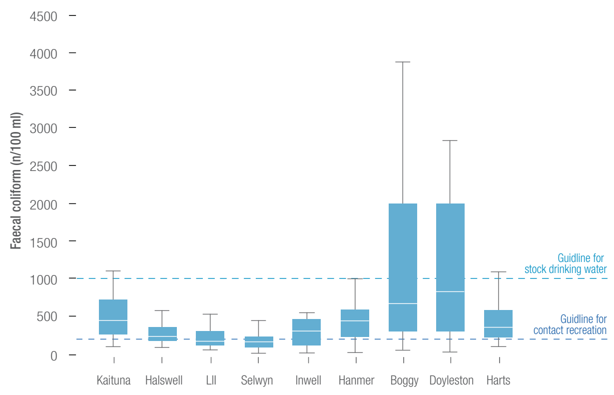

FIGURE 10. Faecal coliform concentrations in nine tributaries of Te Waihora/ Lake Ellesmere (2002–2007).

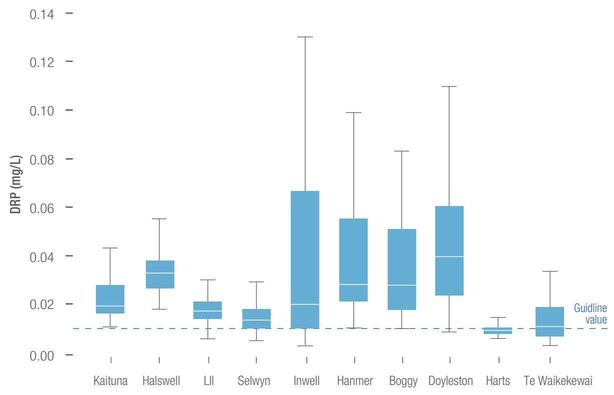

FIGURE 11. Dissolved reactive phosphorus (DRP) concentrations in ten tributaries of Te Waihora/Lake Ellesmere (2002–2007).

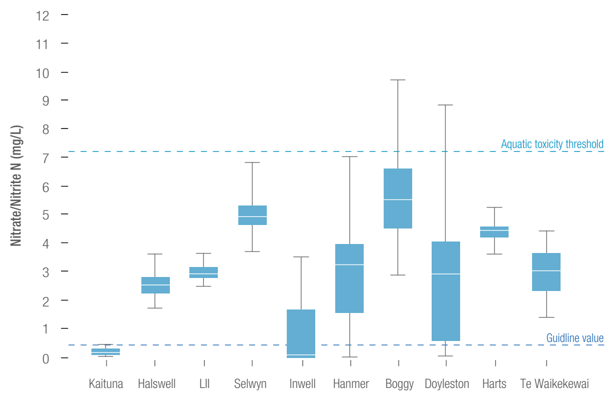

FIGURE 12. Nitrate/Nitrite Nitrogen concentrations in ten tributaries of Te Waihora/Lake Ellesmere (2002–2007).

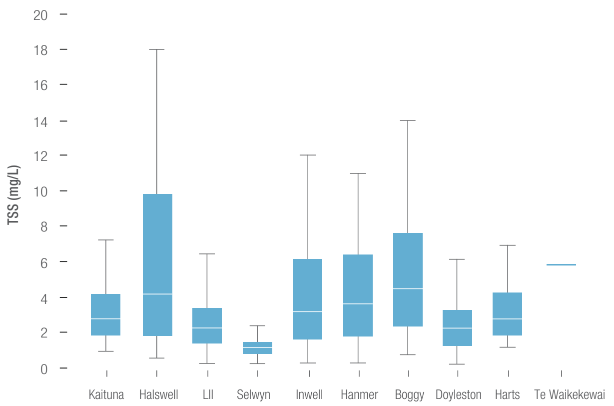

FIGURE 13. Total suspended solids (TSS) concentrations in ten tributaries of Te Waihora/Lake Ellesmere (2002–2007).

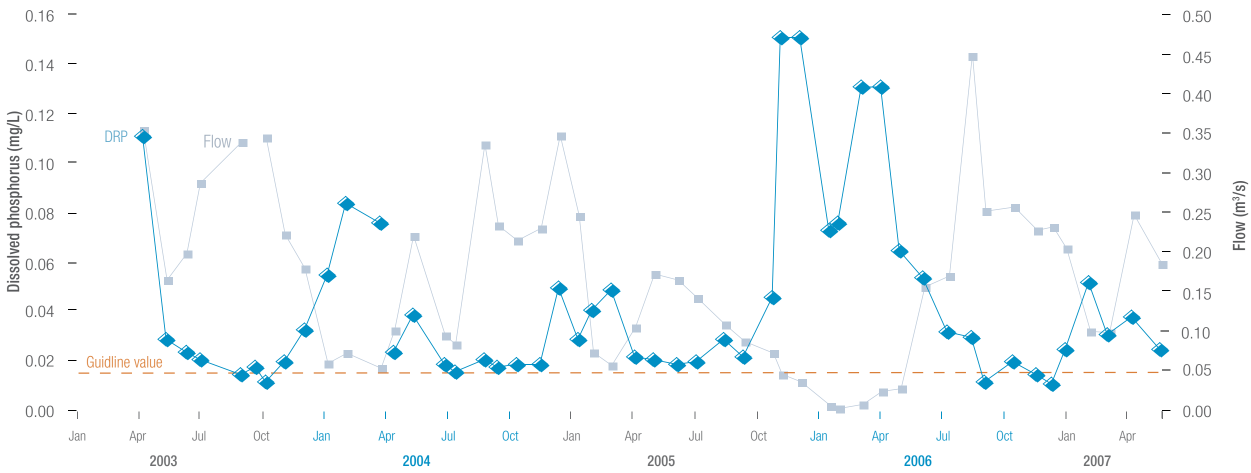

FIGURE 14. Dissolved reactive phosphorus (DRP) concentrations and gauged flows in Boggy Creek (2003–2007).

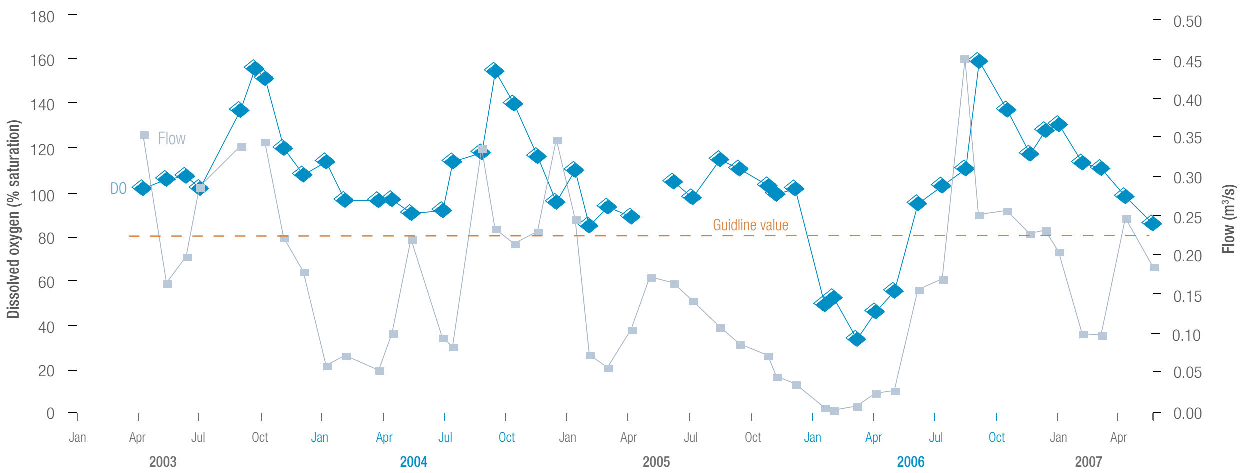

FIGURE 15. Dissolved oxygen (DO) saturation values and gauged flows in Boggy Creek (2003–2007).

FIGURE 18. Riparian planting and fencing along Boggy Creek.

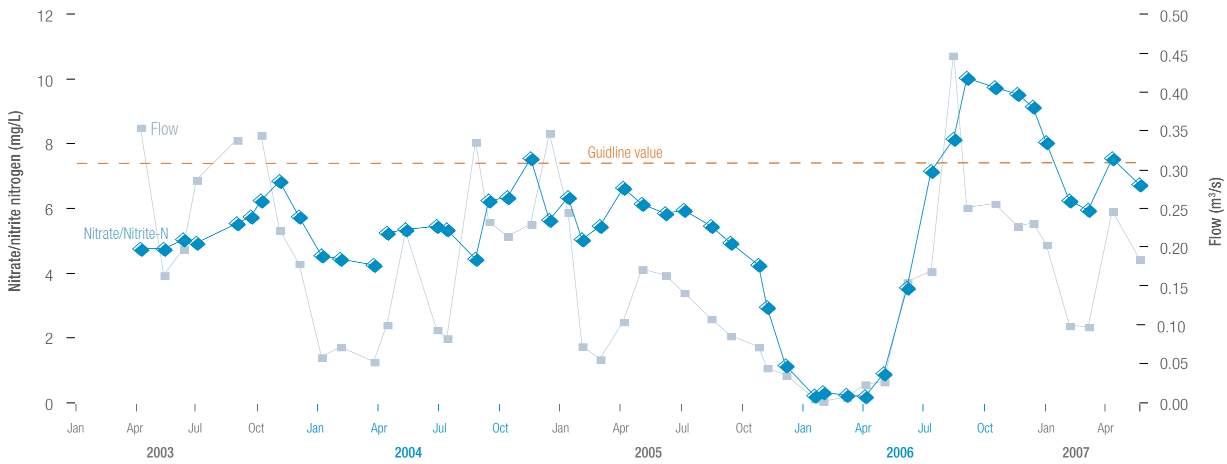

FIGURE 16. Nitrate/Nitrite Nitrogen concentrations and gauged flows in Boggy Creek (2003–2007).

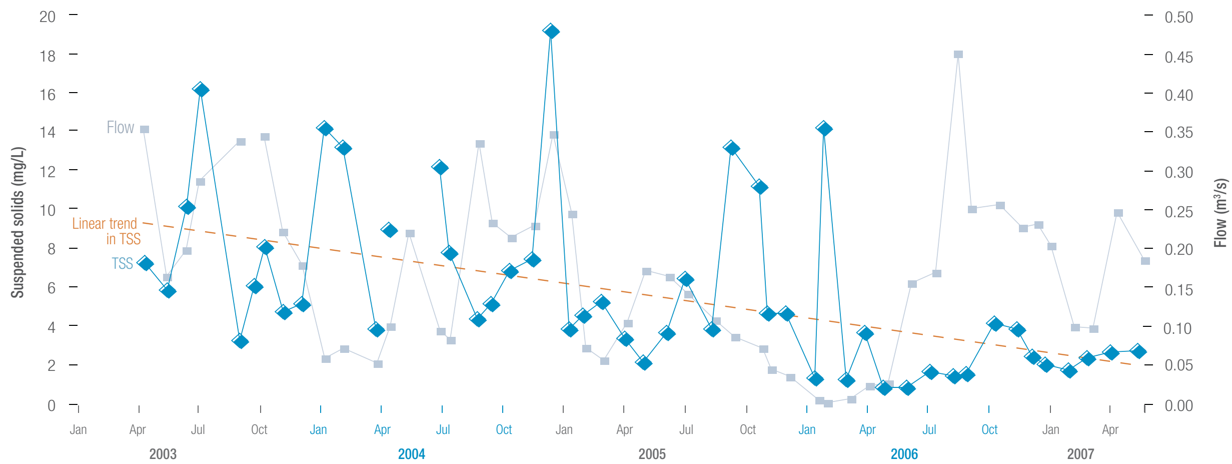

FIGURE 17. Total Suspended solids (TSS) concentrations and gauged flows in Boggy Creek (2003–2007).

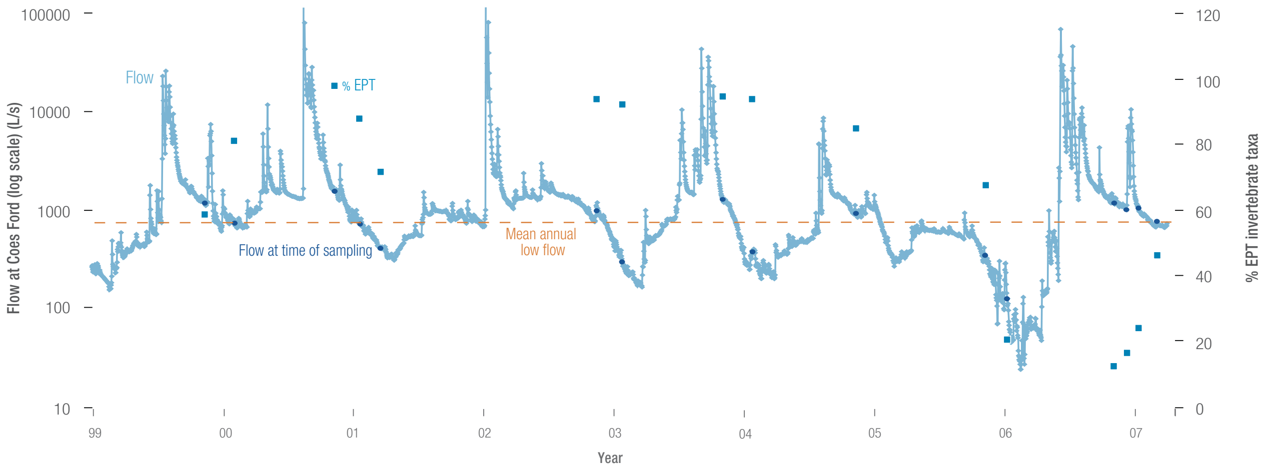

FIGURE 19. Invertebrate communities (%EPT) at Coes Ford, Selwyn River (January 1999–2007).

TABLE 3. **Lake water quality issues and management options.**

Issue	Management options and scale
Water clarity	Re-establish macrophyte beds?
Phytoplankton – high but not blooming (yet)	Reduce nutrient inputs? Currently limited by light availability
Salinity – habitat diversity	Changing with changing hydrology

TABLE 4. **Tributary issues and management options.**

Issue	Management options and scale
Reduction in flow	Catchment management / climate
High nitrate inputs	Catchment management of groundwater nitrates
High sediment, bacteria, phosphorus inputs	Adjacent land use-riparian zone protection

land uses. Figure 20 shows changes in fertiliser usage since 1992 and Figure 21 shows changes in stock numbers from 1996. It is unknown at this stage what amount of reduction in nutrient concentrations in the lake would result in a reduction in phytoplankton biomass. Therefore, there is still an information need to better understand to role of nutrients on phytoplankton growth rates and biomass.

However, it is reasonable to assume that reduction of nutrient inputs to the lake would be beneficial. A medium term goal could be complete riparian protection of all main tributaries, and requirement of farmers to undertake nutrient budgeting. A long-term goal may be to set nutrient allocation limits for the catchment, once we have a good understanding of what nutrient targets are needed for the lake and tributaries. Also, complete or near complete riparian protection of the lake margin (and bank stabilisation through sensible planting) could be long-term goal for both nutrient management as well as a range of other benefits to the lake and lake users.

We may not be able do much about the wind but a different lake level management may help reduce re-suspension of suspended solids. Improvements in riparian protection of streams and the lake margin to reduce erosion will help reduce sediment inputs to the lake.

Hydrological and salinity models are needed to enhance understanding the influence of lake openings, lake level management, relative importance of floods and base flow of tributaries, and other climatic factors such as the effect of temperature on evaporation rates (especially important for modelling climate change impacts).

Tables 3 and 4 summarise the range of management options to address the lake and tributary issues respectively.

3.5 Conclusions

Comparison of lake water quality pre-1990s appears to show that nutrient concentrations may have been higher in the lake in the 1970s and 1980s compared to the past 10 years. This is likely to be the result cessation or improvement of direct discharges of treated sewage (e.g. Lincoln township) and piggery and dairy shed effluent to waterways. Unfortunately there is inadequate chlorophyll a biomass data to look at whether phytoplankton biomass was previously higher or not.

Tributaries flowing into the lake have suffered from low flows over the past 10 years resulting in significant adverse effects on water quality and overall health of the aquatic ecosystems. Boggy Creek has recently exceeded the nitrate toxicity threshold for freshwater ecosystems. Land use intensification is likely to be one of the key drivers of these changes.

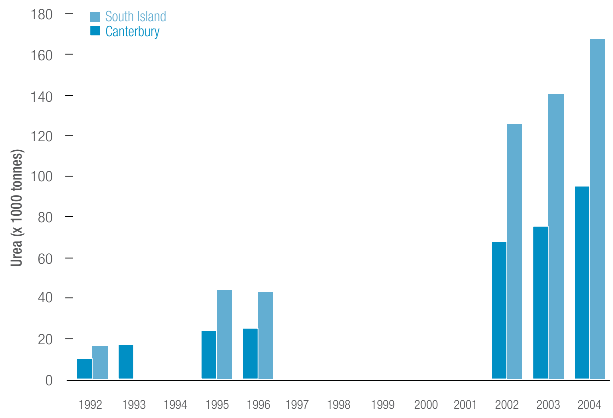

FIGURE 20. Drivers of change in fertiliser use in Canterbury and the South Island (1992–2004).

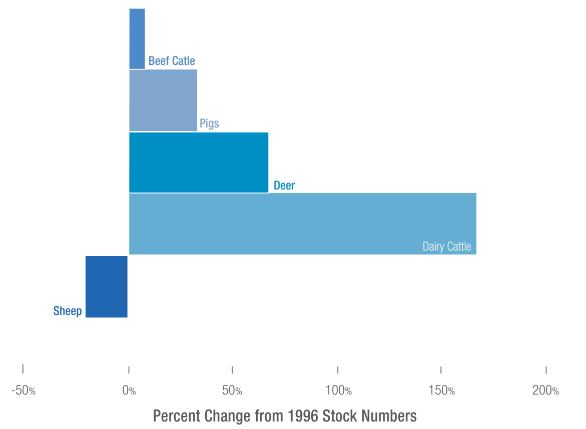

FIGURE 21. Changes in stock numbers in Canterbury (percent change from 1996).

Photo ***Despite some water quality issues, Te Waihora/Lake Ellesmere continues to support abundant and diverse wildlife and plant communities. Further benefits to water quality would require complete riparian protection in tributary waterways and the lakeshore, and reduction in nutrient losses from the catchment's agricultural areas.*** *Photography* ***Colin Hill.***

Further work on understanding the influence of water quality on the lake ecosystem as a whole is needed. Management intervention is required at a range of scales, ranging from land activities immediately adjacent to the lake and tributaries to catchment wide management of water quantity and quality (e.g., nitrates).

3.6 References

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Te Waihora/Lake Ellesmere is a large coastal lake, intermittently open to the sea. It is highly regarded for its conservation and related values, some of which are of international significance. Its function as a sink for nutrients from its large predominantly agriculturally based catchment, currently undergoing accelerated intensification, is also recognised, at least implicitly. It is the resulting conflict from these value sets which is mainly responsible for the ongoing debate about the future of the lake.

This book serves to quantify the nature of this debate by documenting changes to lake values, both over time and spatially. It provides a standardised approach to reporting these changes, set against indicators that are value-specific. Ultimately, it provides a template for thinking about future management scenarios for the lake and its environs. Given this approach the book ultimately serves as a resource for helping understand the ever-changing and current and possible future states of the lake, under a variety of management requirements and implications.