



CLUTHA HYDRO SCHEME

LAKE HĀWEA OPERATING RANGE

**A summary of ecological values and
potential effects on those values**

Prepared for Contact Energy Limited

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Prepared for Contact Energy Limited
by Greg Ryder Consulting

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Cover photo: Lake Hāwea from Craig Burn looking north, 27 February 2025. (photo: G. Ryder)

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1. Introduction

1.1. Background

Contact Energy Limited (Contact) owns and operates the Clutha / Mata-Au Hydro Scheme (the Scheme). Lake Hāwea (or simply the Lake) is one of three large feeder lakes to two downstream hydro-electric power stations (Clyde and Roxburgh) (Figure 1). Lake Hāwea has a control structure on its outlet (Hāwea Dam) that was constructed in the mid 1950s and commissioned in late 1958. The Hāwea Dam increased the depth of the lake by an average of 15.2 m and the area by 28.5 km².

Prior to the commissioning of the Hāwea Dam, the Lake had an uncontrolled mean lake level of 327.7 m above sea level (asl) (Figure 2). The control structure was used to control the lake level within the range 327.6 – 347.3 m asl. Between 1958 and 1980, the lake operated with a maximum level of 346.75 m and an uncontrolled minimum level of 327.7 m (an operating range of 19.05 m). In September 1980, the National Water and Soil Conservation Authority (NWASCA) fixed the maximum and minimum levels for Lake Hāwea at 346 m and 336 m asl, respectively, subject to conditions. Further detail on lake level fluctuations is presented in section 2.

1.2. New consents sought

Currently, Lake Hāwea has a consented, normal operating range of between 338 m and 346 m asl. Current consents also provide for an emergency contingency storage operating range down to 336 m asl.

Contact is seeking new consents to dam Lake Hāwea to improve New Zealand's electricity system security. The new consents sought are to permit (also see Figure 2):

- (i) Lowering the minimum of the normal operating range from 338 m to 336 m asl.
- (ii) Lowering the minimum of the emergency contingency storage operating range from 336 m to 330 m asl.

Potential triggers for the new consents are as follows:

- Normal operating range reduced to 336 m asl to apply all the time.
- Contingent storage to 333 m asl to be available at alert level (4% of the Electricity Risk Curve – or ERC) (this is the current Contingent Storage Release Boundary, or CSRB for Lake Hāwea).
- Contingent storage to 330 m asl to be available before a conservation campaign is commenced (8% ERC).

Currently, the Lake Hāwea emergency contingent storage is available once the ERC reaches a 4% chance of the national electricity system having insufficient energy (this is the Alert level). The ERCs are calculated by Transpower, and the operators of contingent storage do not have control over the triggers for access. This level has not been triggered since the current Lake Hāwea consents were granted in 2007.

Contact is also seeking a stage 2 trigger that would enable access to water down to 330 m asl when the Alert level reaches 8% of ERC (8% chance of running out of energy in modelled forecasts).

Ideally, there would never be a need to access the contingent storage as it indicates that the electricity system is very stressed. Contact would only be able to access the contingent storage if Transpower, as the system operator, state that there is a real risk of running out of electricity if the contingent storage is not accessible.

1.3. Report content

This report describes the physical environment of Lake Hāwea, key ecological issues, its current ecological values and the potential effects of the proposed activities on those ecological values in support of a Referral Application made by Contact under the Fast-track Approvals Act 2024.

1.4. Key ecological issues

Historically, several ecological issues have been raised with respect to Lake Hāwea and its management as a hydro-electric storage reservoir. The main issue has been the effects of operational factors, including the dam barrier, on the Lake's salmonid and native fisheries. Other issues include the effects of operational factors on the shoreline, lake weed (macrophytes), vegetation and birds. Fish passage into and out of the Lake via the Hāwea Dam is not considered to be affected by the proposed changes to the lake operating regime and so is not discussed further in this report. Currently, there is no upstream fish passage at the Hāwea Dam and a modified lake level regime will not materially alter flows in the Hāwea River in a way that would affect upstream passage to the base of the dam. Downstream passage out of the Lake is only possible via the dam's lake intake structure and this will continue to provide downstream passage for fish under a modified lake operating range.

1.5. Information for assessment purposes

Information on the existing ecological character of Lake Hāwea has been derived from previously commissioned studies which addressed a number of aspects of the Lake's ecology including aquatic benthic communities, fish, birds and shoreline vegetation.

The first survey (Chisholm *et al.* 2000¹) was undertaken in April 1999, when lake levels were at 344.16 m asl and had been at high levels for a prolonged period. Several aspects of that study were repeated in a subsequent survey in November 2001 (Thompson and Ryder 2002²) when the Lake was at a lower level (341.1 m asl) and had been relatively low in the months leading up to the survey (for example, 339.2 m asl in July 2001, Figure 3). This latter study also gathered additional information on lake fisheries, benthic and shoreline communities, and made a comparison with neighbouring Lake Wanaka, a similar lake to Hāwea, but with a natural lake level regime.

The results from these studies, and other relevant, more recent studies and surveys, are summarised in subsequent sections of this report.

¹ Chisholm, P., Thompson, R., and Ruth, D. 2000. *Lake Hāwea Ecosystem Study*. Prepared for Contact Energy.

² Thompson, RM. And Ryder GI. 2002. *Lake Hawea Supplementary Study – Fisheries and Low Lake Level Ecological Study*. Study Brief CLU #22. Prepared for Contact Energy.

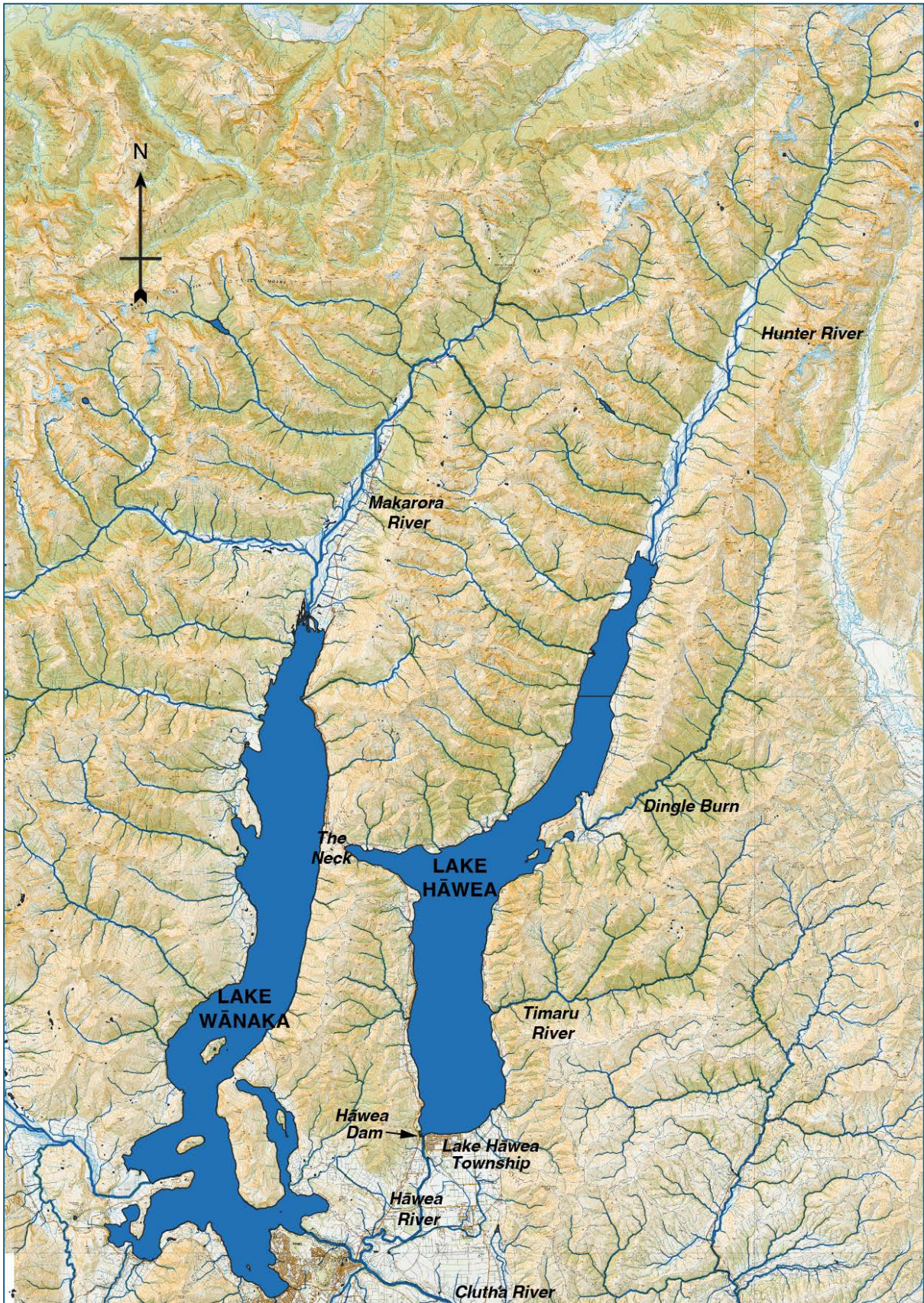


Figure 1. Map of Lake Hāwea and surrounds.

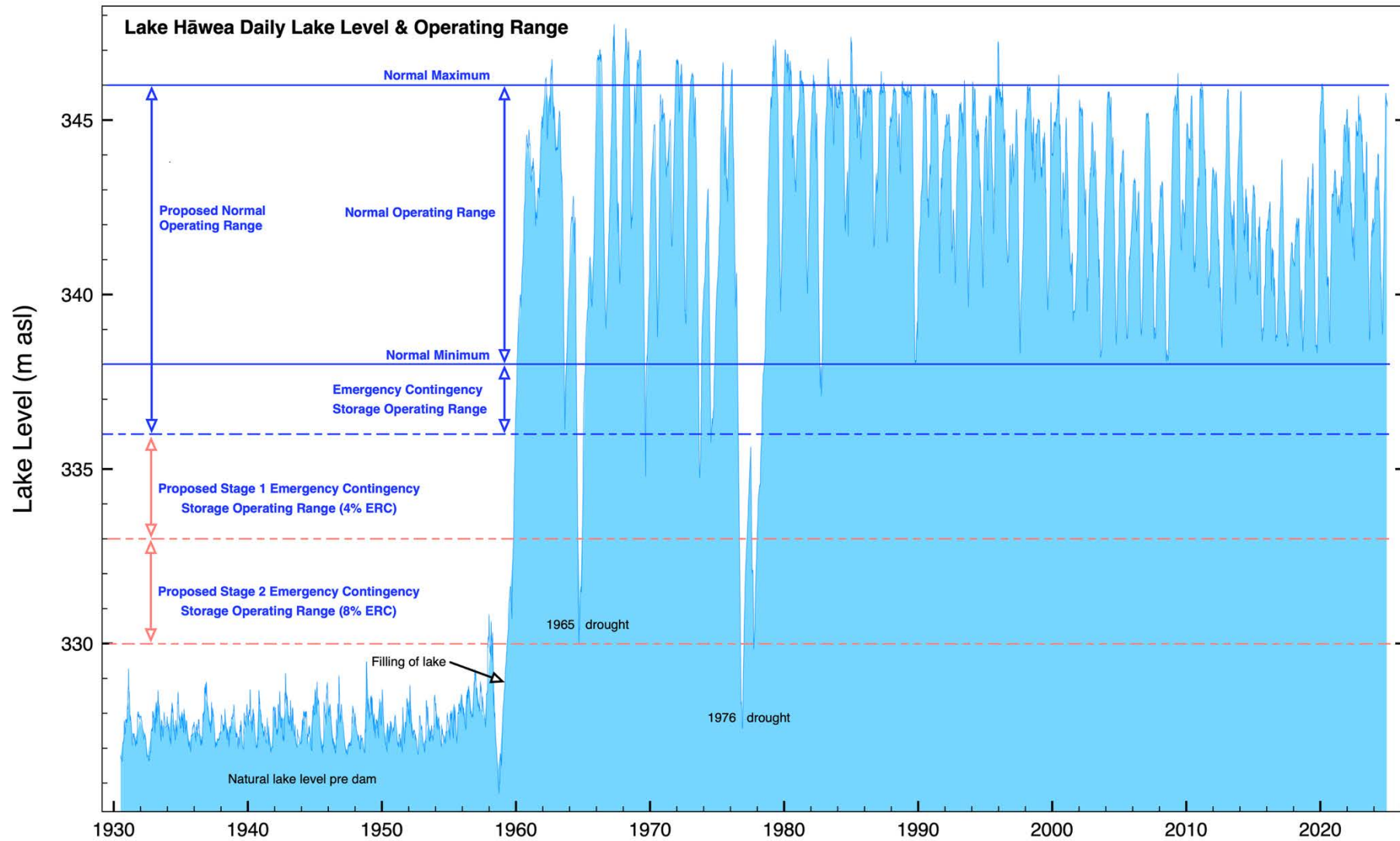


Figure 2. Plot showing daily lake levels since 1930s.

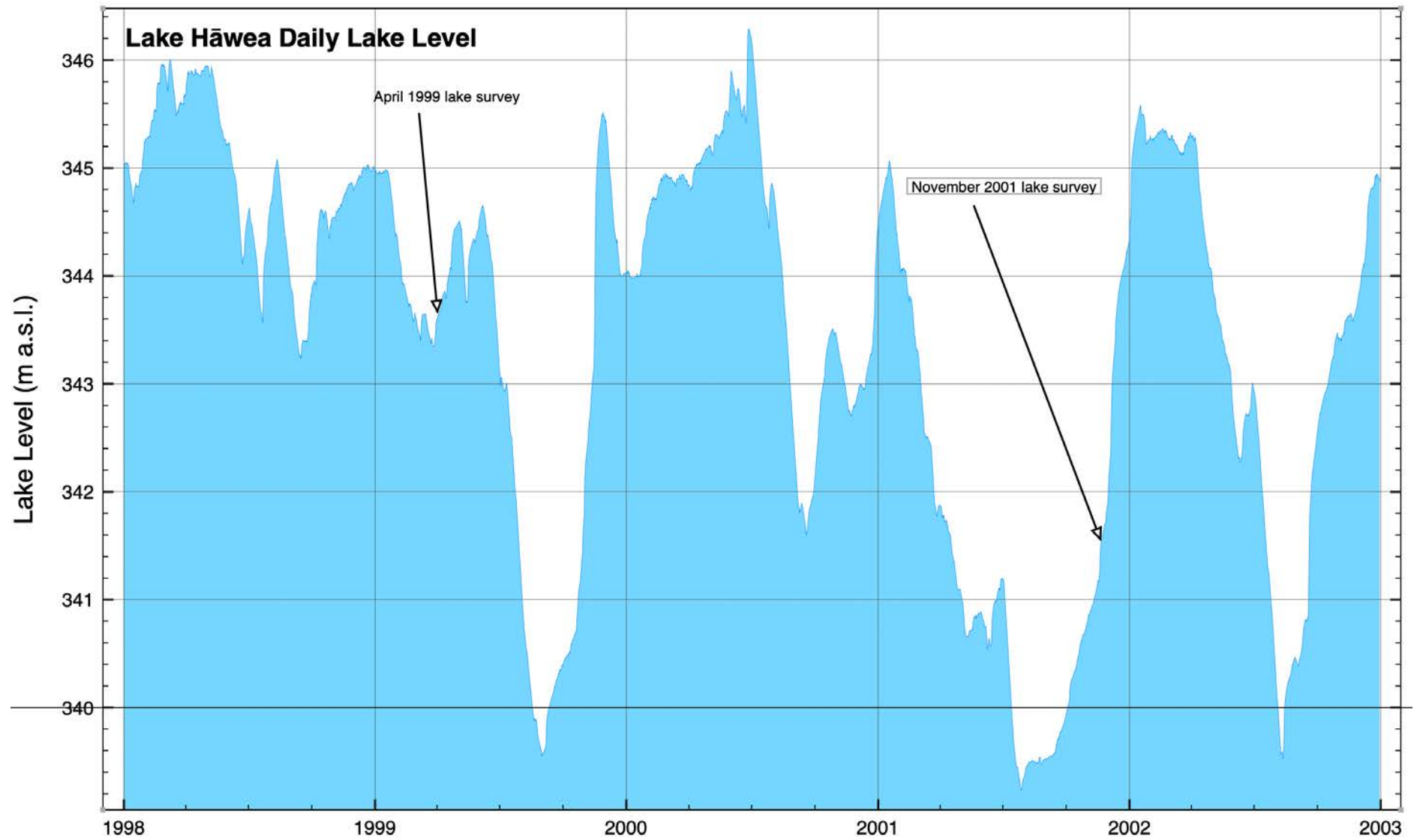


Figure 3. Plot showing close-up of daily lake levels when surveys of the lake were undertaken by Chisholm et al.(2000) and Thompson & Ryder (2002).

2. Physical environment

2.1. General

Lake Hāwea is a large (143.6 km²), deep (maximum depth 384 m) glacial lake, formed at the base of a retreating glacier behind a terminal moraine (a bar of debris deposited by glacial action). It is one of three significantly sized inland Otago lakes set within the Clutha River / Mata-Au catchment (the others are lakes Wānaka and Whakatipu). The main section of Lake Hāwea runs approximately north-south, on average 5 kilometres wide and 20 kilometres long. The Hunter Valley Arm extends a further 25 kilometres to the north east, to meet the broad, braided riverbed of the Hunter River.

Another smaller arm extends east-west approximately half way up the lake, close to a feature commonly known as the “Neck”, which is a relatively narrow area of land separating Lake Hāwea from Lake Wānaka (Figure 1).

The surface of Lake Hāwea lies at an altitude of approximately 346 m asl and is bounded on three sides by steep mountains. To the east are Breast Hill (1578 m), Corner Peak (1683 m), Dingle Peak (1835 m), Mount Jones (1683) and Mount Arnold (1978 m). To the west are Mount Maude (1315 m), Mount Burke (1417 m), Sentinel Peak (1814 m) and Terrace Peak (2027 m).

Some fifty streams discharge into Lake Hāwea, over half of which are tributaries of the Hunter River. The most notable water courses flowing into the lake are Hunter River, Dingle Burn and Timaru River.

To the south of the Lake is a terminal moraine formation which created the original lake. The town of Lake Hāwea is situated here. The Lake Hāwea Control Structure, which includes the Hāwea Dam, is situated at the south-western corner of the Lake. The Dam is 30 m high, earth-filled and includes a concrete control structure with four radial gates to control the outflow. The Dam was designed to give an effective control of the lake level over a range of 21.65 m, between 327.6 m and 346.7 m asl.

The Hāwea River to the south discharges from the Lake into an 18 m deep, incised channel. It continues south for 12 km before it reaches the Clutha River / Mata-Au below Albert Town.

Flow releases from the Hāwea Control Structure are dictated by downstream power station demand and managed in accordance with the existing consents held by Contact. The historic pattern of flow releases is that over the spring, summer and early autumn, flows are held close to minimum, except in flood conditions or when plant outages or grid problems necessitate augmented generation from the Clyde and Roxburgh Power Stations. In the late autumn and winter months, flows are increased up

to the maximum permitted discharge of 200 m³/sec (cumecs).

2.2. Lake level fluctuations

Prior to impoundment in 1958, annual fluctuations in lake levels were approximately two metres (Figure 2). Following regulation this fluctuation increased, with low levels occurring in 1965 (330 m), 1976 (327 m) and 1977 (330 m). A consequence of the low levels in the Lake in 1976 and 1977 was that the maxima during the intervening year was only 336 metres, and the lake spent a prolonged period at low levels (Table 1, Figure 2). In 1978 the Lake was operated without a draw down in order to let it refill.

Since 1980, lake levels have not experienced lows to these levels, with much reduced variation. The Lake was at a minimum during the 1980's in 1982 when it reached 337.5 m and in 1989 when it reached 338 m. In the 1990's it fell below 340 m on three occasions (October 1993, 339.6 m; August 1997, 338.3 m; August 1999, 335.6 m). Between 2000 and 2025 the lake level has regularly lowered to below 340 m (in 18 of the 25 years between 2000 and 2025), with these annual minima typically in the range of 338-339 m (Figure 2).

The maximum annual variation in depth since 1980 has been 9.6 m (1982). Lowest levels in the lake are typically associated with the winter following a drought year. Lake levels on average are low in winter and early spring, with the lake largely full for the remainder of the year. The time taken for the Lake to refill after a draw down depends on the level to which the Lake is dropped and the volume of inflow to the Lake.

Table 1. Average number of days per year over each period of years that Lake Hawea remained below various lake levels. Orange band represents bottom of normal operating range (338 m asl).

Lake Level (m asl)	Period (years)				
	1961-1979	1980-1989	1990-1999	2000-2009	2010-2024
<346	311	321	360	363	365
<345	266	156	261	312	332
<344	223	100	168	267	292
<343	190	66	105	210	237
<342	155	44	68	148	163
<341	132	30	32	97	99
<340	107	22	9	57	50
<339	81	16	2	25	22
<338	70	7	0	0	0
<337	58	0	0	0	0
<336	47	0	0	0	0
<335	39	0	0	0	0
<334	31	0	0	0	0
<333	25	0	0	0	0
<332	18	0	0	0	0
<331	11	0	0	0	0
<330	6	0	0	0	0

3. Current ecological values

3.1. Avifauna

3.1.1. General

Birds associated with Lake Hāwea were surveyed between May and September 1999 as part of the wider Lake Hāwea survey of Chisholm *et al.* (2000) (Table 2). Over this time, the lake was at a range of levels from high (344 m asl) in May to low (339 m asl) in September. Birds can be affected by fluctuating lake levels in a number of ways. Exposure of delta flats at low lake levels can make productive feeding habitat available to waders. Grass colonisation of delta shores also represents a food resource to species such as paradise shelduck. Lower lake levels can allow diving birds (or long-necked grazers such as swans) to access weed beds which are normally too deep to be reached. However, fluctuating lake levels also reduce the level to which weeds can extend up the shore, and so at high lake levels the weed beds accessible to grazers and divers are often lower than in non-fluctuating lakes.

Table 2. Relationship between the abundance of aquatic bird species and lake level (m asl) in Lake Hawea. (source: Chisholm *et al.* 2000)

Bird Common Name	Scientific Name	Major trophic niche	Average # of birds counted per transect			Total
			Lake level (m asl)			
			May	Aug	Sept	
			344.51	340.93	339.57	
			High	Med	Low	
Black fronted tern	<i>Chlidonias albostratus</i>	aquatic carnivore	0.0	0.2	0.4	0.6
White faced heron	<i>Ardea pacifica</i>	aquatic carnivore	0.7	0.5	0.1	1.3
Pied shag	<i>Phalacrorax varius</i>	aquatic carnivore	0.0	0.0	2.0	2.0
Black shag	<i>Phalacrorax carbo</i>	aquatic carnivore	1.5	0.8	2.3	4.6
South Island pied oystercatcher	<i>Haematopus finschi</i>	aquatic insectivore	0.0	5.7	0.9	6.5
Pied stilt	<i>Himantopus leucocephalus</i>	aquatic insectivore	0.0	10.8	3.1	14.0
Banded dotterel	<i>Charadricus bicintus</i>	aquatic insectivore	1.0	0.0	22.6	23.6
Scaup	<i>Aythya novaseelandiae</i>	aquatic herbivore	0.0	0.0	0.4	0.4
Grey teal	<i>Anas gibberifrons</i>	aquatic herbivore	1.0	0.0	0.0	1.0
Black swan	<i>Cygnus atratus</i>	aquatic herbivore	0.3	3.7	11.6	15.6
Paradise shelduck	<i>Tadorna variegata</i>	aquatic herbivore	18.0	7.5	21.3	46.8
Mallard	<i>Anas platyrhynchos</i>	aquatic herbivore	42.7	2.3	46.3	91.3
Canada goose	<i>Branta canadensis</i>	aquatic herbivore	0.0	35.8	57.7	93.5
Southern black backed gull	<i>Larus dominicanus</i>	semi aquatic omnivore	0.7	1.3	5.4	7.4
Spur winged plover	<i>Lobibyx novaehollandiae</i>	semi aquatic insectivore	9.2	0.2	0.7	10.0
Black billed gull	<i>Larus bulleri</i>	semi aquatic omnivore	0.0	15.2	2.3	17.5
Totals			75.0	84.0	177.1	336.1

The bird life of the lake found by Chisholm *et al.* was largely typical of inland lakes, being dominated by mallard ducks, paradise shelducks, black-backed gulls, Canada geese and black swans (Table 2). Over the survey period in 1999, birds numbers were reported as steadily increasing, with the greatest numbers occurring when lake levels were lowest. Increases in black swans and Canada geese were particularly noticeable and this reflects the fact that lower lake levels allow these birds access to macrophyte beds. There was no apparent change in wading bird numbers which could be accounted for by lake level change. Mallard numbers were extremely variable, but were also unrelated to lake levels. There have been no known formal bird surveys of Lake Hāwea since the survey completed by Chisholm *et al.*

3.1.2. Banded dotterel

Banded dotterel or Tūturiwhatu (*Charadrius bicinctus*) are classified as ‘Threatened - Nationally Vulnerable’. They prefer exposed gravel beaches for breeding, and some nest at the delta of the Craig Burn, on the western shore of Lake Hāwea. They are small birds that are very vulnerable to introduced predators, vehicles, people and dogs.

3.1.3. Grebes

No grebes were recorded in the surveys by Chisholm *et al.*, however the Southern Crested Grebe or pūteketeke/kāmana (*Podiceps cristatus*), a species classified as ‘Threatened - Nationally vulnerable’, has gained a foot-hold in the lake following initiatives that first began in nearby Lake Wānaka, based around efforts to create man-made nesting platforms adapted for Lake Hāwea³. Platforms have been established in at the ANZAC inlet, which sits adjacent to the dam at the south-west corner of the Lake (Plate 1), and others have been established at the Neck and near Silver Island. Platforms are pulled onto dry land at the end of the breeding and rearing season.



Plate 1. Grebes having a dispute at the ANZAC inlet, Lake Hāwea, 26 January 2025. (Photo: G. Ryder)

³ In particular, Dr John Darby and the Guardians of Lake Hāwea.

In recent years, grebes have been sighted in the southern section of Lake Hāwea between the Neck/Dingle Burn and the Hāwea Township (Figure 4).

Following the 2023-24 breeding season, the Guardians of Lake Hāwea reported a 700% increase in the grebe population on Lake Hāwea relative to a census conducted ten years earlier⁴.

Grebe resurgence in Lake Hāwea has not been all good news. Several dead birds were discovered in recent times and their deaths were thought to be due to starvation. Possible causes of these deaths are competition for food and a lack of suitable habitat.

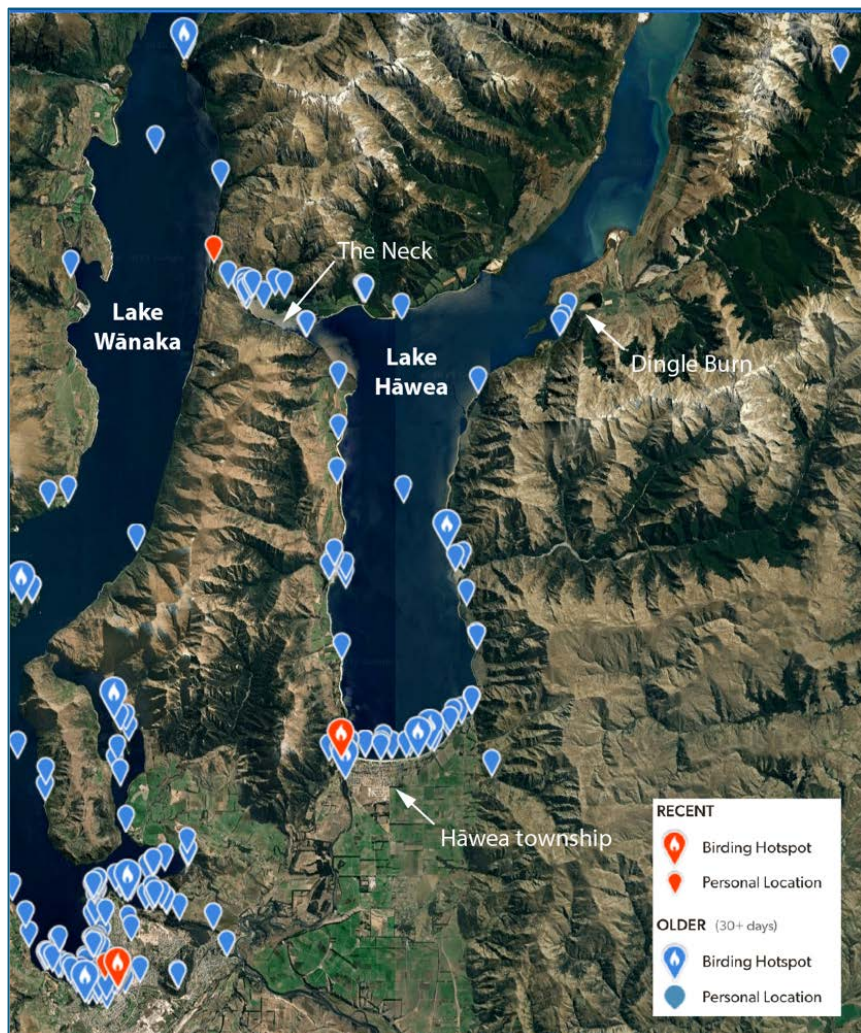


Figure 4. Reported grebe sightings in and around Lake Hāwea⁵. (data source: eBird)

⁴ <https://www.facebook.com/people/The-Guardians-of-Lake-Hāwea/100076507140611/>.

⁵ Data source: eBird <https://ebird.org/>.

3.2. Shoreline vegetation

Studies of Lake Hāwea's shoreline in 1999 and 2001 found that vegetation patterns around the lake's shoreline were largely dictated by land use. Dominant species on the higher shore at most sites were agricultural grasses with grazing impacts clearly evident at some sites. Lower down on the shore, rocky sites are typified by sparse growth of adventive native and exotic species (terrestrial weeds) while shallow sloping muddy deltas show varying degrees of development of a largely native low mound community, grading into semi-aquatic macrophyte communities. The studies found no rare or threatened plant species.

The studies compared the lakeshore vegetation patterns in April 1999 (higher lake level – 344.4 m asl) and November 2002 (lower lake level – 341.1 m asl⁶) and concluded that there was evidence of a temporary decline in semi-aquatic species around the margins and an increase in colonising exotics (typically grass and herb species). No evidence was found of any downshore shift of plant communities at the top of the beaches and deltas. Recently re-immersed areas showed strong evidence for recovery of marginal semi-aquatic plant species. Parallel surveys of Lake Wānaka, that were included in the Thompson and Ryder (2002) study, revealed many of the same vegetation patterns as Lake Hāwea, however the degree of turf development was considerably greater at the Lake Wānaka shallow gradient area surveyed, and was distinguished from those at Lake Hāwea by an extensive moss under storey and the dominance of native sedges (*Carex* sp.). Lake level fluctuations associated with Lake Hāwea are considered likely to be the cause of a higher proportion of exotic adventive grasses (i.e., 'weeds') along the shoreline relative to Lake Wānaka.

In general, lakeshore plant diversity around Hāwea can be described as being low relative to lakes such as Manapouri and Te Anau, however this is as much to do with the absence of forest and shrubland vegetation around the edge of most of Lake Hāwea. Lakes Te Anau and Manapouri have foreshores which are largely unmodified by human activity and maintain predominantly native vegetation. In stark contrast, the majority of the foreshore of Lake Hāwea has been modified by farming practices. As a result, only some very small sections of the Lake Hāwea shore have intact native vegetation (e.g. Kidd's Bush). These land uses are the dominant factor in determining Lake Hāwea's shoreline vegetation.

3.3. Water quality and phytoplankton

3.3.1. General

The Otago Regional Council (ORC) monitors the water quality of Lake Hāwea at

⁶ Prior to the November 2002 survey, in the winter of 2001, low rainfall led to the lake level steadily dropping to a low of 339.2, its lowest level since 1997.

regular intervals and results are graded based on attributes and associated attribute state bands defined by the National Objectives Framework (NOF) of the National Policy Statement for Freshwater Management 2020 (NPS-FM). Water quality parameters include Ammoniacal nitrogen, Total nitrogen, Total phosphorus, Chlorophyll-*a* and *E. coli*. Monitoring is typically undertaken at two sites and at two depths at each site. Results from sampling undertaken between July 1, 2017, and June 30, 2022, as reported by the ORC⁷, are summarised in Table 3 and discussed below.

The ORC reports that all the above parameters monitored in Lake Hāwea are within the NOF 'A' band representing the highest quality water⁸. Phosphorus concentrations are very low and the report also indicates that nitrate-nitrite-nitrogen concentrations are decreasing over time at the Lake Hāwea outflow at the Dam, based on a 10-year dataset. The narrative description for the NOF 'A' band is:

*Water quality generally good, communities are healthy and resilient, similar to natural reference conditions. High conservation value systems. 99% species protection level.*⁹

Table 3. Lakes - Summary results for Total N (TN), Total P (TP) and phytoplankton concentrations (measured as chlorophyll-*a*). TN and TP units are mg/L, chlorophyll-*a* units are mg/m³.

Site name ¹⁰	# TN/TP samples	TN median	TN Ann Max.	TP median	TP max	# Chl-a	Chl-a median	Chl-a max
Lake Hawea North Open Water 10m	20	0.036	0.075	0.001	0.006	20	0.535	1.4
Lake Hawea North Open Water HYP	20	0.042	0.189	0.001	0.003	n/a	n/a	n/a
Lake Hawea South Open Water 10m	56	0.036	0.063	0.001	0.004	56	0.56	1.3
Lake Hawea South Open Water HYP	55	0.041	0.192	0.001	0.005	n/a	n/a	n/a

In general, Lake Hāwea typically has very good water quality. Water clarity is very high, and conversely suspended sediment concentrations are very low, however, shallow shoreline water can become turbid under windy conditions. Seechi disc measurements of the water show Lake Hāwea to be in the 'A' band for water clarity (Figure 5).

⁷ Ozanne, R., Levy, A., and Borges, H. 2023. *State and Trends of Rivers, Lakes, and Groundwater in Otago 2017 – 2022*. Prepared by the Otago Regional Council.

⁸ ORC. 2021. *Upper Lakes Rohe (Clutha/Mata-Au FMU) River & Lake Water Quality State and Trends*. Prepared by the Otago Regional Council.

⁹ Dengg, M. 2024. *Water Quality & Ecosystem Health Otago 2018-2023*. ORC publication (<https://www.orc.govt.nz/media/selhmd2a/water-quality-soe-2018-2023-npsfm.pdf>)

¹⁰ Lakes are monitored at different depths, '10m' denotes sample was taken at 10 m depth and 'HYP' means that the sample was taken 5 m off the bed of the lake.

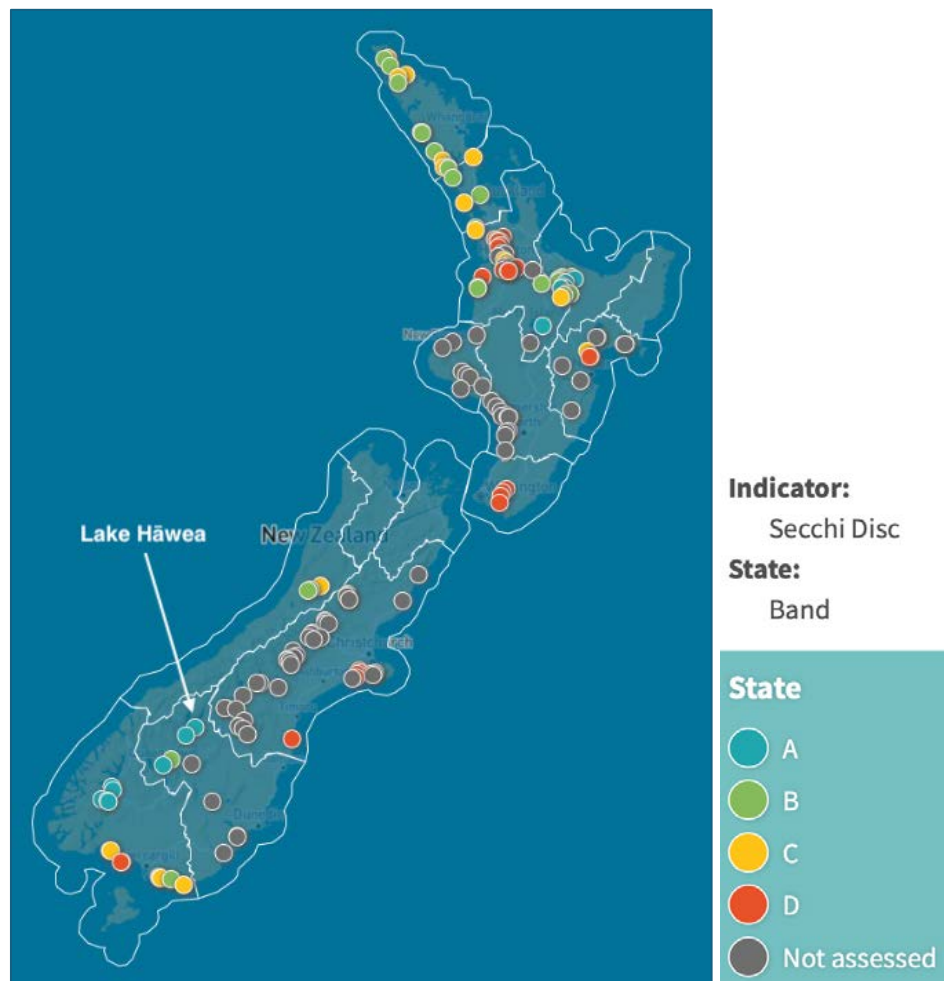


Figure 5. Nation-wide comparison of lake water clarity based on Secchi disc¹¹ readings. (source: LAWA website).

3.3.2. Trophic level Index (TLI)

The Trophic level index (TLI) is used as an indication of the overall ecological condition of a lake (or an arm of a lake) based on the amount of nutrients and algae growing in it. The concentrations of nitrogen and phosphorus (totals) and algae biomass (assessed as the concentration of chlorophyll-*a*) are combined in a set of equations to derive a single TLI score. The lower the score the better the condition of the lake.

The LAWA website presents an extended TLI history for Lake Hāwea for the period 2007 to 2023 (Figure 6). It shows that the lake has remained within the microtrophic states over this period (TLI scores between 0 and ≤ 3), indicating very good water

¹¹ Lake clarity is measured using a Secchi disc attached to a tape measure. The disc is lowered into the water until it disappears; this depth is noted from the tape measure. The disc is lowered a little further and then slowly raised until it reappears, this depth is noted. The average of the two readings is the final Secchi depth visibility depth. (source: <https://www.lawa.org.nz/>)

quality. Lake Hāwea TLI scores are better than those for lakes Wānaka and Whakatipu.

The survey data presented above indicates that Lake Hāwea is in very good health and there is no evidence of increasing nutrient enrichment over time. If anything, water quality in these parts of the lake has improved in recent years.

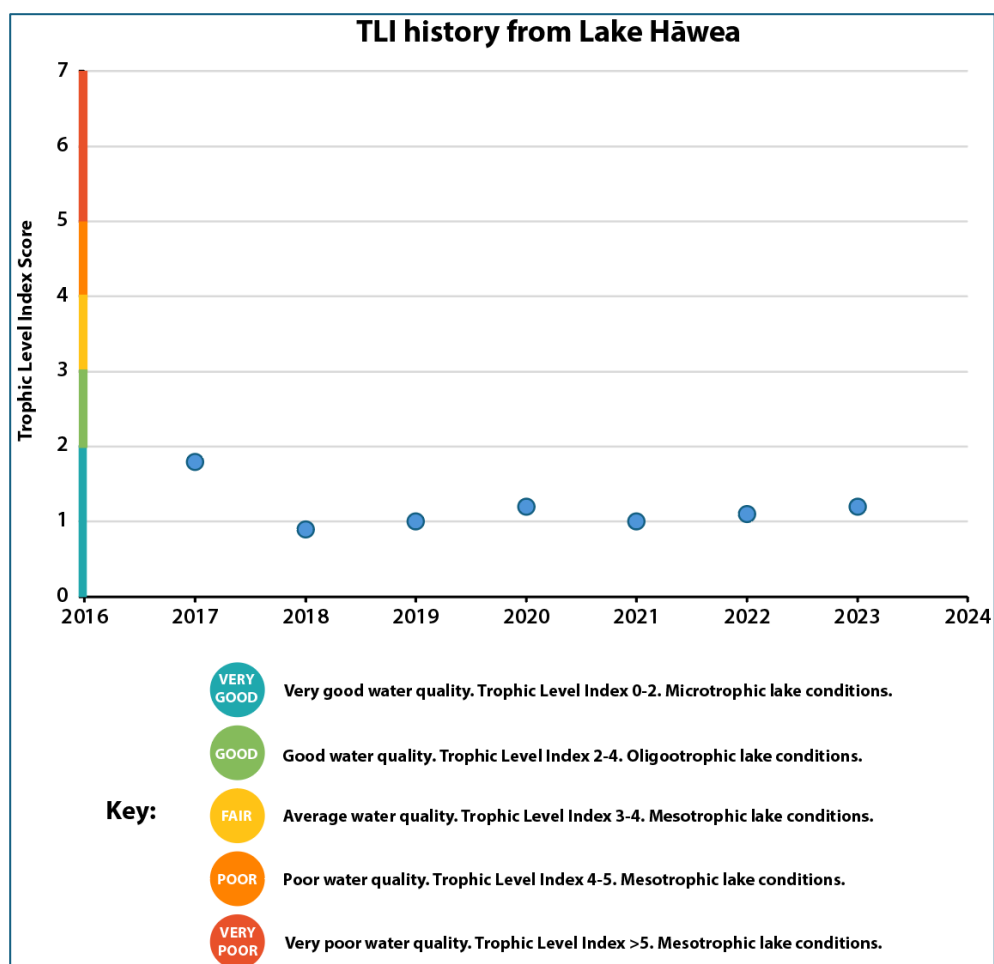


Figure 6. Top: Lake Hāwea TLI annual scores since 2016. Bottom: Explanation of the coloured data points and vertical axis on the chart. (Source: LAWA website).

3.3.3. Lindavia

The invasive diatom *Lindavia intermedia*, more commonly known as ‘lake snow’ (or ‘lake snot’), was discovered in Lake Hāwea around 2015-2017. It produces mucilaginous strands in the water column that can foul fishing lines and clog water intake filters. This diatom has been found in a number of (mainly) South Island lakes¹² and there is a strong circumstantial case that the *L. intermedia* strain found in New Zealand originated

¹² Ryder, G.I. 2017. *Lake Snow Technical Workshop, 20 December 2016: Report on workshop discussions and outcomes*. Prepared for the Otago Regional Council.

from the Northern Hemisphere, particularly North America¹³. New Zealand lakes that are subject to lake snow occurrence tend to be oligotrophic (poor in nutrients and abundant in dissolved oxygen: that is, good water quality features), and Lake Hāwea is no exception. The ORC reports that, since winter 2021, Lake Hāwea has lower abundance of lake snow than lakes Wānaka and Whakatipu, and the most recent sampling recorded the lowest levels of lake snow in the Lake since 2021 (Borges 2024¹⁴).

3.4. Macrophytes and the Lake Submerged Plant Indicator index

Occasional surveys of the macrophyte beds of Lake Hāwea have been undertaken over a number of years with the earliest by Coffey (1974¹⁵) and Robinson (1983¹⁶). The most recent survey was undertaken in by NIWA in March 2024 (de Winton and David¹⁷). A similar survey by NIWA was undertaken by NIWA in February 2020 on behalf of the ORC (Burton 2021¹⁸).

NIWA uses the Lake Submerged Plant Indicator methodology (LakeSPI) to assess the ecological condition of New Zealand lakes. It assesses the composition of native and invasive plants growing in a lake and the depth to which they grow. Once key submerged plant indicators have been identified and recorded using the LakeSPI survey method, LakeSPI applies a simple scoring system to generate indices (or scores). The LakeSPI Index is a synthesis of components from both the native condition and invasive condition of a lake and provides an overall measure of the lake's ecological condition.

The 2020 survey recorded six native charophyte species (*Chara australis*, *Chara braunii*, *Nitella claytonii*, *Nitella tricellularis*, *Nitella pseudoflabellata* and *Nitella stuartii*) that contributed to high cover meadows (>75% cover) at all five LakeSPI sites at Lake Hāwea (Plate 2). Only a few isolated plants were observed above c. 7.5 m depth (at the time of the survey the lake level was high – 345 m asl) and the charophyte meadows were recorded to a maximum depth of 20.7 m (Burton 2021).

The LakeSPI Index scores for Lake Hāwea from 1982 to 2024 range between 82.4 and 86.5 (Figure 7, Table 4), which is interpreted as ‘Excellent Ecological Health’(reflects the

¹³ Borges, H. 2022. *Lake snow report*. Prepared for the ORC Data and Information Committee. ORC Report No. SPS2221.

¹⁴ Borges, H. 2024. *Lake Programme update*. Prepared for the ORC Environmental Science and Policy Committee. Report No. GOV2462.

¹⁵ Coffey, BT. 1974. *Report on submerged weed control in the Clutha Valley with particular reference to existing and proposed hydro-electric lakes on the Clutha River*. New Zealand Electricity report. File 21/12.

¹⁶ Robinson, P.W. 1983. *Botanical study of Lake Hawea, 13-15 December 1983*. Unpublished New Zealand Electricity report.

¹⁷ de Winton, M. And David, S. 2024. *Assessment of six lakes in the Otago Region using LakeSPI*. Prepared for Otago Regional Council. NIWA Client Report No: 2024160HN.

¹⁸ Burton, T. 2021. *Assessment of six lakes in the Otago Region using LakeSPI*. Prepared for Otago Regional Council. NIWA Client Report No: 2021193HN.

presence of an extensive native plant community with little impact from invasive weed species) and places Lake Hāwea as one of the better NZ lakes with respect to ecological condition (Figure 8).

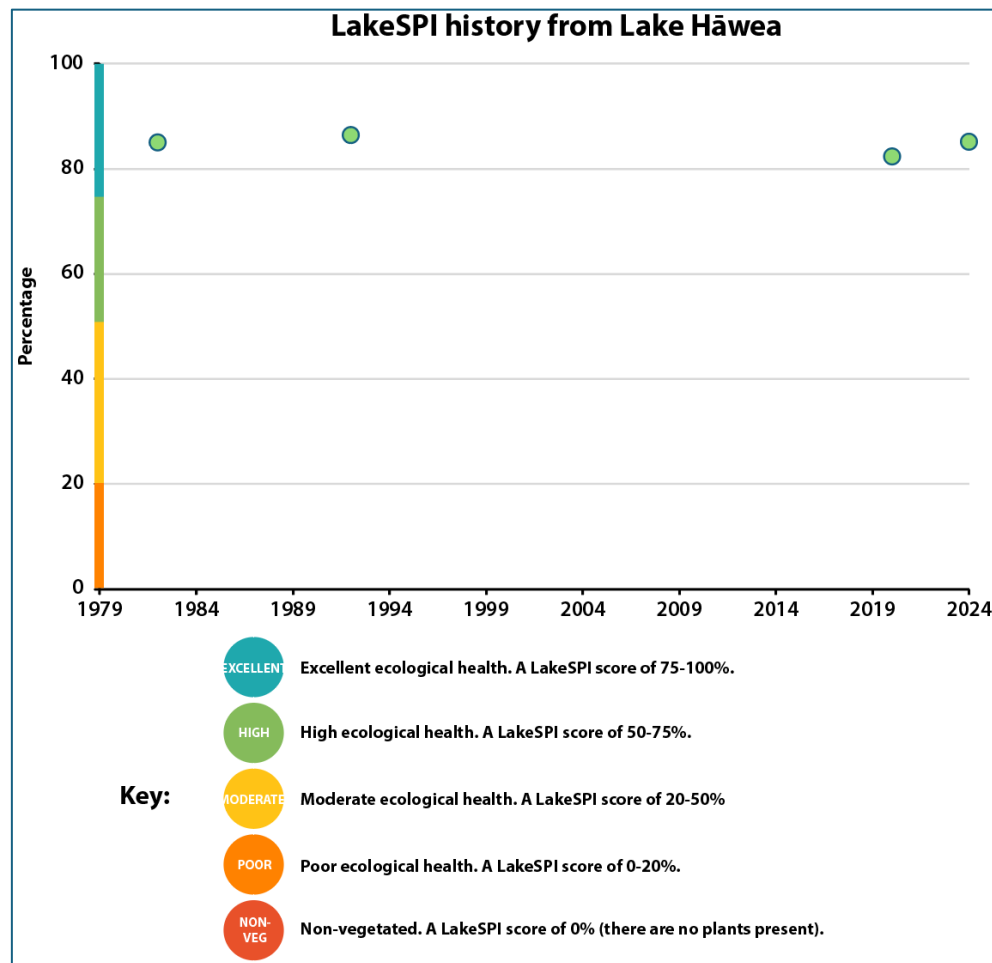


Figure 7. Top: Lake Hāwea LakeSPI scores since 1982. Bottom: Explanation of the coloured data points and vertical axis on the chart. (Source: LAWA website).

As noted in previous assessments, Burton (2021) concluded that large fluctuations in water level restricts the growth of submerged vegetation in Lake Hāwea to depths below c. 8 m, preventing the establishment and growth of shallow low mound plant communities, including turf plants and *Isoetes alpina* dominated swards. Burton considered the absence of vascular species (e.g., pondweeds and milfoils) noted during the 1982 survey and from the main body of the lake in 1992, is likely also a result lake level fluctuations as they usually occupy the 0 – 8 m depth range. Vascular and turf species recorded from historic surveys were mostly confined to seepage areas where they would be buffered somewhat from desiccation as a result of larger water level fluctuations. Similar findings were reported by de Winton and David in their 2024 survey.

The invasive Canadian pond weed (*Elodea canadensis*, see Plate 2) has been present in

Lake Wānaka since at least the 1970s and in 2020 was re-discovered in Lake Hāwea for the first time (since 1992) during the NIWA survey, but was not widespread. It was recorded from two of five survey sites, with very low covers observed at one site, and high covers (>75%) at another extending down to c. 7.7 m depth (Burton 2021). However, the majority of the lake's plant community is dominated by native forms of charophytes, milfoils, pondweeds and turf communities.

Table 4. Breakdown of LakeSPI surveys of Lake Hāwea. (source: NIWA's LakeSPI website)

Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
March 2024	Excellent	85.2%	82.0%	8.1%
February 2020	Excellent	82.4%	80.0%	12.6%
December 1992	Excellent	86.5%	77.5%	0.0%
February 1982	Excellent	85.0%	75.0%	0.0%

Deep water bryophytes (mosses and liverworts) have previously been recorded in Lake Hāwea on a mixture of rock and silt habitat at depths of between 20-35 m (Clayton *et al.* 1986¹⁹, de Winton and Beever 2004²⁰). Observations report limited distribution of bryophytes throughout the Lake, with one species of moss found at two out of thirteen survey sites located around the Lake. Deep water bryophytes have also been observed in Lake Whakatipu (to 60 m depth) and Lake Wānaka (to 50 m depth).

¹⁹ Clayton, J., Schwarz, A., and Coffey, B. 1986. *Notes on the submerged vegetation of Lake Hawea*. New Zealand Journal of Marine and Freshwater Research v20: 185-189.

²⁰ de Winton, M.D. and Beever, J.E. 2004. *Deep-water bryophyte records from New Zealand lakes*. New Zealand Journal of Marine and Freshwater Research v38: 329–340.

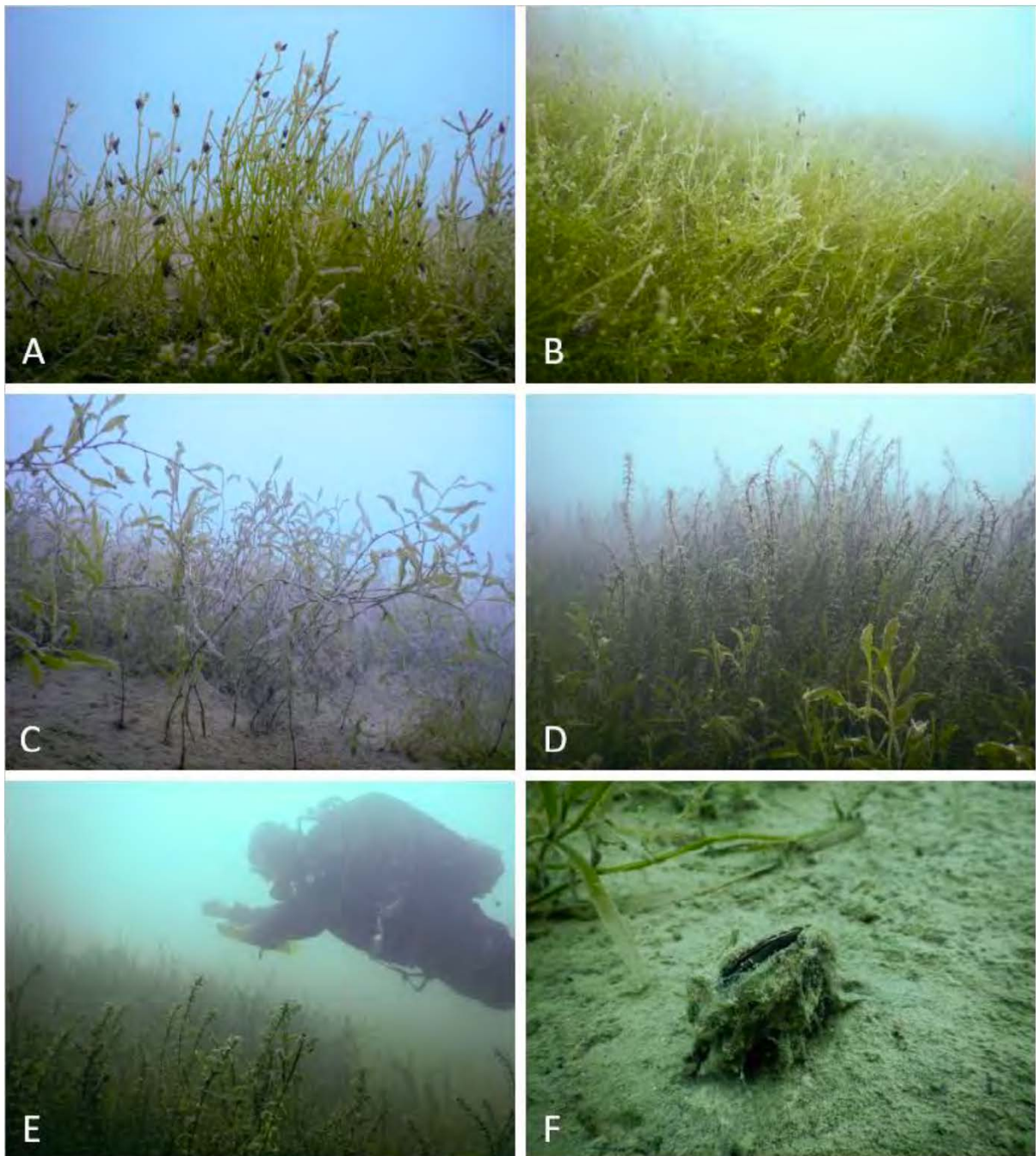


Plate 2. Lake Hāwea plant communities. A) & B) native charophytes, C) native pondweed (*Potamogeton ochreatus*), D) an invasive bed of elodea with native pondweeds in front, E) diver swimming over elodea weed bed, F) freshwater mussel. (source: Burton 2021)

Burton noted that Lake Hāwea is adjacent to Lake Wānaka, and it contains extensive areas of the invasive weed lagarosiphon (*Lagarosiphon major*). Lagarosiphon has not been recorded in Lake Hāwea and Burton and others (e.g., Thompson and Ryder) consider it unlikely that it would establish and have significant impacts given the current wide water level fluctuation range of the lake, which is a greater range (8 m) than the

depth range recorded for lagarosiphon (maximum depth of 6.5 m).

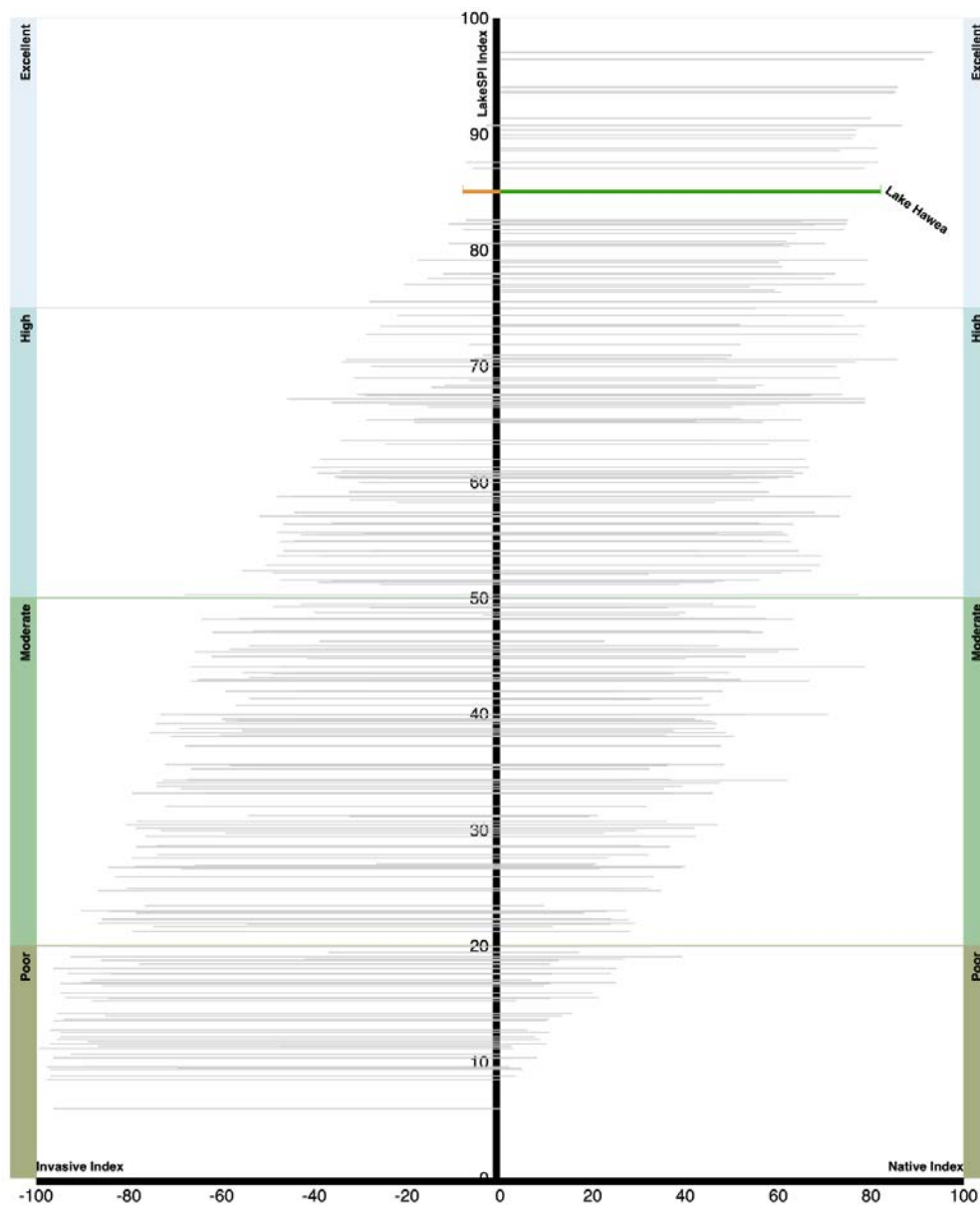


Figure 8. Chart generated from NIWA's LakeSPI website showing the status of Lake Hāwea relative to other lakes monitored throughout New Zealand.

3.5. Benthic macroinvertebrates

The invertebrate communities associated with the littoral zone²¹ of New Zealand lakes include a variety of grazing molluscs (snail), species feeding on organic detritus (midge

²¹ The littoral zone is the shallow water environment close to lake edge that is exposed to sunlight. It is typically more productive than deeper water environments.

larvae and oligochaetes) and larger species filling a variety of ecological niches (caddisflies, dragonflies). These species are the main food source of small fish (e.g., bullies), which in turn are the major food source of larger sport fish such as trout. It is known that the productivity of these littoral invertebrate and fish communities is the main factor driving trout productivity in New Zealand lakes (Mylechreest 1978²²).

Chironomid larvae, snails and bivalve molluscs dominate benthic invertebrate communities in Lake Hāwea (Chisholm *et al.* 2000; Thompson & Ryder 2002). Highest invertebrate biomass is associated with macrophyte (plant) beds, meaning that maximum invertebrate biomass occurs beyond the depth to which lake level fluctuations extend. Both biomass and diversity is low in shallow water, particularly on exposed shores which are subject to wave action.

The 2001 Thompson & Ryder study at low lake levels found a reduction in invertebrate biomass in shallow and dewatered areas was compensated for by increased biomass at depth. There was also evidence of a decline in less mobile species (e.g., snails and bivalve molluscs), which is consistent with the expected effects of lake level reductions. Less mobile species are most at risk from rapid lake level changes

The benthic invertebrate communities in Lake Hāwea and Lake Wānaka are generally similar, with the same species dominating the biomass. Similar numbers of species are found in each lake although there appear to be differences in biomass. Surveys indicate that Lake Hāwea has higher overall benthic invertebrate biomass, and this was particularly evident in shallow to intermediate depths. *Lilaeopsis* beds, which dominate the shallow to intermediate depth zone in Lake Wānaka, are typified by low invertebrate biomass in comparison to the bare substrate areas at the same depths in Lake Hāwea. It seems, therefore, that despite the low biomass of plant material in shallow and intermediate depths in Lake Hāwea, invertebrate productivity is relatively high²³.

It is also noted that Burton (2021) and de Winton and David (2024) reported that freshwater mussels (*Echyridella menziesii*) were common at all six Lake Hāwea LakeSPI monitoring sites, which is another indicator of a healthy lake environment.

3.6. Fish

3.6.1. General

Fish species known to inhabit the lake and its surrounding catchment include tuna or longfin eel (*Anguilla dieffenbachii*), non-migratory galaxiids, kōaro (*Galaxias brevipinnis*),

²² Mylechreest, PHW. 1978. *Some effects of a unique hydro-electric development on the littoral benthic community and ecology of trout in a large New Zealand lake*. Unpublished Msc thesis, University of British Columbia, Canada.

²³ Thompsom, RM. & Ryder, GI. 2008. *Effects of hydro-electrically induced water level fluctuations on benthic communities in Lake Hawea, New Zealand*. NZ J Marine and Freshwater Research, 2008, Vol. 42: 197-206.

upland bully (*Gobiomorphus beviceps*), common bully (*Gobiomorphus cotidianus*), brown trout (*Salmo trutta*), rainbow trout (*Oncorhynchus mykiss*) and chinook salmon (*Oncorhynchus tshawytscha*).

3.6.2. Eel fishery

Since the establishment of the Hāwea, Clyde and Roxburgh dams, which act as barriers to upstream migration of juvenile eels (elvers), natural tuna recruitment into Lake Hāwea has been absent. It is likely that prior to the dams, the Hāwea, Wānaka and Whakatipu lakes and their tributaries would have supported a large tuna population. Tuna can live for many decades and a remnant population of very old individuals (mostly females) still exist in these upland lakes. The longfin eel species has been classified by the Department of Conservation (DOC) as 'At Risk - Declining' (Dunn *et al.* 2018²⁴).

Population modelling by Beentjes *et al.* (1997²⁵) suggested that there was potential to re-establish a productive eel fishery in Lake Hāwea, with an estimated annual harvest of approximately 23 tonnes. In February 1998, the lake was stocked with about 9,500 juvenile longfin eels, sourced from the lower Clutha River, some of which were tagged. Following surveys of tagged eels released into the lake, Beentjes & Jellyman (2011²⁶) found that transferred eels experienced accelerated growth. Mean annual increase in body length almost doubled and growth was found to be the highest on record at the time for longfin eel, indicating they were thriving in the lake. The fast growth was attributed to low density and an abundant food source.

In 2018, Contact funded an adult tuna survey of lakes Roxburgh, Dunstan and Hāwea (Clucas and Hishon 2018²⁷). A total of 2,151 kg (n = 1095) of longfin eels were caught (mostly in lakes Roxburgh and Dunstan). Tuna catches in Lake Hāwea were comprised mainly of relatively few, but large, longfins (159 caught with an average weight of 4.17 kg). A repeat survey between December 2020 and May 2021 netted 202 longfins with an average weight of 5 kg²⁸. Egan and Rose (2022²⁹) noted that Lake Hāwea was the most successful site for migrant eel catches in the 2020/21 survey, followed by Lake Wānaka.

²⁴ Dunn, NR., Allibone, R.M., Closs, GP., Crow, SK., David, BO., Goodman, JM., Griffiths, M., Jack, DC., Ling, N., Waters, JM. and Rolfe, JR. 2018. *Conservation status of New Zealand freshwater fishes, 2017*. New Zealand Threat Classification Series 24. Department of Conservation, Wellington, New Zealand.

²⁵ Beentjes, MP., Chisnall, BL., Boubée, JA. and Jellyman, DJ., 1997. *Enhancement of the New Zealand eel fishery by elver transfers*. New Zealand Fisheries Technical Report No. 45.

²⁶ Beentjes, MP. & Jellyman, DJ. 2011. *Evaluation of the 1998 transfer of juvenile longfin eels into Lake Hāwea from recaptures, and ageing validation based on otolith annual ring deposition*. New Zealand Fisheries Assessment Report 2011/19.

²⁷ Clucas, R., Hishon, T. 2018. *Longfin eel/tuna survey. Lakes Roxburgh, Dunstan and Hāwea 2018*. Report to Contact Energy Ltd.

²⁸ Clucas, R., Hishon, T. 2019. *Longfin eel/tuna survey. Lakes Hāwea, Whakatipu and Wānaka 2019*. Report to Contact Energy Ltd.

²⁹ Egan, E. and Rose, A. 2022. *Migrant eel trap-and-transfer in the Clutha Mata-au Catchment: Memo of data for the 2020/21 season*. Prepared for Contact Energy Limited. NIWA Client Report No: 2022052CH.

An adult eel netting survey of Lake Hāwea undertaken in early 2024 resulted in 83 adult eels being caught, with 55 of these >3.8 kg in weight released below the Roxburgh Dam.

It is also worth noting that, as a part of Contact’s elver trap and transfer programme at the Clyde and Roxburgh dams, a small proportion of elvers trapped at these dams (currently only from Roxburgh Dam) are now being transferred into Lake Hāwea³⁰.

3.6.3. Kōaro

Kōaro (*Galaxias brevipinnis*) is one of the five whitebait species. It is able to form land-locked populations (not having to go to sea to complete their life cycle). The species is ranked as ‘At Risk – Declining’ under the DOC threat classification system³¹. Its presence and abundance in Lake Hāwea is poorly understood.

Adult kōaro live in streams, where they breed in the margins and early stage young (larvae) are washed into the sea (or lake in the case of land-locked populations like Lake Hāwea) where they feed as juveniles (whitebait). Juvenile kōaro are potentially an important food fish for salmonids and tuna in Lake Hāwea. While there have been limited targeted surveys of the Lake’s kōaro population (Chisholm *et al.*’s 1999 undertook some seine netting that caught some juvenile kōaro at Kidd’s Bush), they have been observed to be present and can be abundant (Chisholm *et al.* 2000). Only juvenile (whitebait) forms of the species are likely to be present in the Lake, which migrate back into tributaries to develop into adults and spawn.

The role of kōaro in the food web is unclear, but they do tend to be more common in open water than bullies (McDowall 1990), and may be an important food resource to pelagic feeding fish (Mitchell 1996). Given their life cycle, it seems unlikely that lake level fluctuations directly impact on kōaro as a food resource to salmonids.

Juvenile kōaro are adept at climbing and are able to negotiate vertical surfaces provided they are damp (McDowall 2003³²).

3.6.4. Bully

Common bully (*Gobiomorphus cotidianus*) is a small, native, benthic dwelling fish species that is common in lakes Hāwea, Wānaka and Whakatipu (Robertson 2021³³). In

³⁰ Contact Energy. 2024. *Native Fish Management Programme: Annual Compliance Report - 2023/2024 Season*. Prepared by Contact Energy.

³¹ Dunn, NR., Allibone, RM., Closs, GP., Crow, SK., David, BO., Goodman, JM., Griffiths, M., Jack, DC., Ling, N., Waters, JM. and Rolfe, JR. 2018. *Conservation status of New Zealand freshwater fishes, 2017*. New Zealand Threat Classification Series 24. Department of Conservation, Wellington, New Zealand.

³² R. McDowall. 2003. *The key to climbing in kōaro*. Water & Atmosphere, Vol. 11, No. 1.

³³ Robertson, D. 2021. *Understanding and protecting Otago’s deepwater lakes: A Jobs For Nature Strategy for WAI Wānaka*. Prepared for WAI Wānaka.

their 2001 tuna survey of the lake, Beentjes and Jellyman (2001³⁴) noted that common bullies were present in “large numbers” and were frequently caught in fyke nets.

Comprehensive benthic environment surveys undertaken in 2001 and reported on by Thompson and Ryder (2002) found common bullies to be abundant throughout the Lake, particularly in areas where cobbles or boulders on the bed allowed them to seek refuge between stones. An unverified video of common bully over shallow stony substrate at Kidd’s Bush in January/February 2020 shows them to be relatively abundant in shallow habitat³⁵.

Thompson and Ryder (2002) concluded that high invertebrate productivity and bare cobble areas appear to provide a larger area of bully habitat in Lake Hāwea than Lake Wanaka. Comparisons of bully densities between the lakes were not conclusive, but there is some evidence of higher bully productivity at Lake Hāwea. This may provide a greater energy base to piscivorous fish (i.e., salmonids and eels) high in the food chain.

3.6.5. Salmonid fisheries

(i) Angling

Lake Hāwea is highly regarded as a sport fishery, with rainbow trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta*) and Chinook salmon (*Oncorhynchus tshawytscha*) fisheries of international standing. The Lake was ranked the fifth most popular waterbody in the Otago region for anglers in the 2021-22 fishing season (11,953 angler-days +/- 1886 standard error), the latest season to be assessed nationally by NIWA³⁶. However, the number of angler-days was significantly lower than recorded in 2001/02 (28,156 +/- 3,746) and 2007/08 (22,214 +/- 2,802) surveys.

Fish & Game Otago conducted a creel survey of Lake Hāwea during the 2022 – 2023 fishing season to gather angler and fisheries information. One hundred and ninety-six anglers were interviewed totalling 304.25 hours of angling effort for a catch of 105 fish, which equates to one fish for approximately 2.9 hours fishing (Sowry 2023³⁷). Average fish condition factor ranged between 47.9 (brown trout) and 51.9 (rainbow trout). Condition factor is a numerical value given to a trout that reflects its condition. The value is calculated using a formula that includes both the length and weight of the trout. A good conditioned trout will have a high condition factor (40+), while a trout in poor

³⁴ Beentjes, M. and Jellyman, D. 2001. *Evaluation of eel enhancement in Lake Hawea*. Final Research Report for Ministry of Fisheries Research Project EEL2000/02. Niwa Client Report.

³⁵ <https://www.youtube.com/watch?app=desktop&v=aWQXeqdutLA>.

³⁶ Stoffels, R. And Unwin, M. 2023. *Angler usage of New Zealand lake and river fisheries Results from the 2021/22 National Angler Survey*. Prepared for Fish and Game New Zealand. NIWA Client Report No. 2023189CH.

³⁷ Sowry. 2023. *Project 1122 – Creel Surveys of Lake Hāwea*.

condition will have a low factor (<30).

Fish & Game Otago repeated the creel survey of Lake Hāwea for the 2023 – 2024 fishing season (September to May) (Sowry 2024³⁸). One hundred and twenty anglers were interviewed totalling 189 hours of angling effort for a catch of 63 fish, which equates to one fish for approximately 3 hours fishing (i.e., similar to the previous year). Average condition factor ranged between 41.9 (brown trout) and 47.6 (salmon). Lake Hāwea is reported as having the highest catch rate of the three biggest lakes in Otago³⁹. Fish & Game’s fishing guide webpage for Lake Hāwea notes that “*Lake Hawea is a relatively easy lake to fish for anglers of all abilities, with many regarding it as the best freshwater sportfishery in the South Island*”⁴⁰.

Analysis of acoustic fish survey data from several surveys undertaken by NIWA and Otago Fish & Game since 2007 suggests population densities in lakes Hāwea, Wānaka and Whakatipu, Otago’s three largest lakes, are relatively stable⁴¹.

(ii) Salmonid passage into lake tributaries

Barriers to salmonid fish passage up spawning streams have the potential to reduce fish recruitment. Reducing lake levels has the potential to alter the morphology of the lower reaches of streams and rivers entering lakes and may expose barriers to fish passage. Chisholm *et al.* (2000) surveyed the deltas of two major spawning streams (Timaru River and Dingle Burn) at Lake Hāwea while the lake was at a low level (339.6 m asl, September 1999). River velocity, maximum depth and altitude profiles were constructed for the two rivers and mapped to show the physical attributes of any possible fish passage constriction sites.

For both rivers Chisholm *et al.* (2000) found evidence for barriers to fish passage associated with shallow sections on the river deltas between 340 and 341 m asl. Salmonids were observed stranded at those points and accumulating in pools downstream of the constrictions. Chisholm *et al.* (2000) concluded “*salmonid fish risk stranding during their upstream migration to spawning habitat in September when the lake level is at its annual low*”. However, it was also observed that Lake Hāwea was notable for the large numbers of small fish, suggesting that recruitment into the lake population is very successful, and that the deltas exposed by low lake levels are historical deltas which were negotiated by salmonids prior to the lake level being raised. As such, Chisholm *et al.* (2000) concluded that it seemed likely that fish were able to access spawning grounds even at the lowest lake levels.

³⁸ Sowry. 2024. *Project 1122 – Creel Surveys of Lake Hāwea*. Meeting of Otago Fish & Game Council 25/7/2024.

³⁹ <https://crux.org.nz/crux-news/good-catch-rate-recorded-in-annual-survey-of-hurricane-hawea>

⁴⁰ <https://www.fishandgame.org.nz/freshwater-fishing-in-new-zealand/where-to-fish/regional-info/otago/lake-hawea/>

⁴¹ <https://www.odt.co.nz/regions/fish-population-stable-survey>

4. Potential effects of the proposed changes to the lake operating range

4.1. Avifauna

The existing bird community of Lake Hāwea has adapted to the lake environment and lake level fluctuations over time. Exposed deltas provide foraging habitat for a number of wading birds. Lower lake levels may allow diving birds to access macrophyte beds which are normally not accessible due to water depth. Birds clearly move into the lake when lake levels are low in order to utilise that resource, and presumably move back to their previous location as lake levels rise and access to weed beds reduces. There is no evidence of loss of wetland habitat around Lake Hāwea at lower lake levels, and many bird species associated with aquatic habitats are able to adjust their feeding strategies in order to compensate for reduced lake levels.

A further reduction in lake levels as a result of the proposed emergency contingency storage operating range will potentially benefit some species (e.g., wading and shore birds such as dotterel, heron, stilts) as more exposed shoreline will be present. Birds that spend time on the water and feed underwater (e.g., ducks, grebes, shags) should not be too adversely affected with a reduced lake level as plenty of water habitat containing food (e.g., benthic invertebrates and benthic dwelling bullies) will remain. As lake levels recover, food availability may be more limited and be dependent on the recolonization rates of various macroinvertebrate taxa and bullies. Recovery rates are discussed in sections below, but could range between several months and a year or longer for full recovery. However, the potential changes in local habitat will be temporary only. Birds are highly mobile and will move considerable distances to find suitable habitat.

4.2. Shoreline vegetation

Land immediately surrounding the lake margin is mainly highly modified by a combination of native forest clearance, the introduction of exotic plant species and extensive sheep and cattle grazing. There is unlikely to be any ecological change to this situation if the lake level normal operating range is lowered and occasionally drops into the proposed emergency contingency storage operating range.

4.3. Water quality and phytoplankton

Water quality in Lake Hāwea is influenced by land use in the surrounding catchment and the local climate, which drives inflows. Neither of these factors are adversely affected by the proposed activities relating to the lake's lower operating range. There is no reason to suggest that water quality of the Lake will materially alter as a result of the proposed changes. Localised turbidity will occur as a result of wave action, particularly in shallow gradient areas such as river deltas, however, unless the gradient at lower lake levels is

shallower than within the normal operating range, it is unlikely that turbidity will change beyond what is currently experienced. This assessment does not consider the terrestrial effects of more dust due to a greater area of exposed lake shore under windy conditions.

4.4. Benthic environment

Aquatic plant communities most at risk from low lake levels are the low-mixed communities. Low lake levels will have both direct and indirect effects. Direct effects include desiccation and freezing of habitats, and physical disturbance through wave activity and sediment mobilisation and movement (James *et al.* 2002⁴²).

Clayton *et al.* (1986) concluded that it was unlikely that vascular hydrophytes will establish in Lake Hāwea under water level regime at the time (10 m fluctuation), and that the only significant vegetation likely to remain are charophyte species which should continue to inhabit a depth range from c. 10-35 m (336-311 m). This appears to be the situation now for the Lake. Charophytes are rapid, primary colonisers (Hopkins 2006⁴³).

The length of time for which the littoral zone is left exposed will have an influence on the degree of impact on the littoral habitat (James *et al.* 1995⁴⁴). The impacts of a low lake level appear to be short-term if the macrophyte beds are not completely destroyed. In a study of macrophyte and macroinvertebrate abundance in Lake Coleridge during and after drawdown of the lake for maintenance purposes, James *et al.* (1996⁴⁵) concluded that recovery of impacted plant communities is likely to be rapid, provided wave action is not too vigorous to limit establishment and a suitable inoculum is available.

Recovery will depend on germination and growth of oospores and seeds, or the advection and subsequent rooting of plants from other parts of the lake. Recovery of the macrophyte community due to low lake levels could take anywhere between several months to 1-2 years, depending on refilling and wave action, and is likely to vary throughout the Lake depending on lake-bed gradient, exposure to wind and wave action, the composition of lake-bed material and proximity to sources of inoculum.

The reported depth range of the bryophyte community in Lake Hāwea (326 – 311 m asl) appears well below both the bottom of the proposed normal operating range (336 m asl) and the Stage 2 emergency contingency operating (330 m asl), and, as such, unlikely to be affected by the proposed changes.

⁴² James, M., Mark, A., and Single, M. 2022. *Lake managers' handbook: Lake level management*. Prepared for the Ministry for the Environment. ISBN: 0-478-24067-8

⁴³ Hopkins, A. 2006. *The potential for Charophyte re-establishment in large, shallow, eutrophic lakes with special reference to Lake Waikare, New Zealand*. MSc thesis. University of Waikato.

⁴⁴ James, M., James, G., Hawes, I. and Hicks, M. 1995. *The effects of lake level changes on the littoral ecology of Lake Coleridge*. Report prepared by NIWA for Lake Coleridge Working Party. Consultancy report number ELE906.

⁴⁵ James, M., Weatherhead, M., and Stanger, C. 1996. *Recovery of macrophytes and macroinvertebrates in the littoral zone of Lake Coleridge following low lake levels*. Report prepared by NIWA for Lake Coleridge Working Party. Consultancy report number ELE60501.

There is no reason to suggest that the proposed changes to the Lake's operating regime will increase the presence of invasive aquatic plants. The current operating regime has been highly effective in excluding *Lagarosiphon* from becoming established in the Lake, as has occurred in nearby Lake Wānaka. There have been no reports of *Lagarosiphon* in Lake Hāwea and reports of only minor incursions of the exotic weed *Elodea*.

An exposed, dry lake bed for a few weeks or longer will result in significant mortality to most benthic invertebrate species unless they can burrow into the substrate that retains moisture. In their assessment of Lake Coleridge dewatering, James *et al.* (1996) found that shallow regions of that lake appeared to recolonise relatively quickly with chironomids (non-biting midges), some caddisfly larvae and oligochaetes (worms) appearing within weeks of the substrate being covered in water. However, other caddisfly larvae and the ubiquitous freshwater snail *Potamopyrgus antipodarum* took up to three months to start recolonising. They concluded that recovery of some macroinvertebrate taxa is on a time scale of weeks, and that it may take months for the invertebrate community to reach previous abundance and composition (consistent with the findings of previous studies). They also noted that their findings confirmed the inferences of another New Zealand study of managed lakes (Stark 1990⁴⁶) that, following a lake drawdown, there is a reduction for up to three months in macroinvertebrate abundance in shallow regions exposed for a short time, but no difference in species richness.

A similar recovery regime for the Lake Hāwea benthic invertebrate community can be expected with any lowering of the Lake's operating regime.

4.5. Fish

4.5.1. Native fish

Bullies and kōaro are likely to be important food sources for salmonids (and tuna). Bullies in particular are likely to be affected by changing lake levels as this will affect their food source (benthic invertebrates). However, they are very mobile and able to move as water levels reduce. They are also prolific breeders, and can spawn twice over the summer period, meaning they are able to re-populate quickly. Bullies generally spawn in early spring (they were observed to be spawning during the 2001 survey) when lake levels tend to be at their lowest, therefore the chance of egg strandings may be reduced.

Juvenile kōaro are adept climbers and able to move upstream on damp surfaces. Low lake levels are highly unlikely to affect their ability to migrate back into the Lake's tributaries. They spawn in the tributaries and so spawning habitat is not affected by lake

⁴⁶ Stark, J.D. 1993. *A survey of macro invertebrate communities in seventeen South Island lakes*. (229) Cawthron Report prepared for ECNZ.

level changes.

The tuna (eel) population of Lake Hāwea is in a recovery state following the development of the dams that form part of the Clutha Hydro Scheme, which have stopped natural upstream recruitment. It is not possible to accurately determine the effect of excursions into the proposed emergency operating range on the greater population, given it is depleted and only being enhanced in recent time. However, tuna are very adaptable, and a temporary lower level will not affect their ability to survive in the Lake.

4.5.2. Salmonids

The salmonid fisheries of Lake Hāwea are in good health and are some of the most productive lake sport fisheries in the South Island.

While it can be assumed that a single low lake level event will not have a lasting effect on long-lived salmonids, repeated events (i.e., annually) may reduce the productivity of the fishery (Thompson & Ryder 2002). As such, the occurrence of lake levels into the proposed emergency contingency storage operating range will potentially result in a reduction in the lake's salmonid productivity, but this may be temporary only.

Lake Hāwea is notable for the large numbers of small fish, suggesting that recruitment into the lake population is very successful. The deltas exposed by low lake levels are historical deltas which have been negotiated by salmonids prior to the lake level being raised. As such, it seems likely that fish are able to access spawning grounds even at the lowest lake levels, but this potential effect should be monitored. Barriers could potentially be reduced by deliberately cutting ramps through the constrictions using machinery or by hand.

Thompson & Ryder (2002) concluded that there appears little likelihood that juvenile and adult fish are unable to move with reducing lake levels. The relatively steep and uniform slope of most of the lake shore means that there is little opportunity for trout to become isolated in pools. Such pools do occur in places, but are generally small and comprise a negligible amount of the Lake's margin. Salmonids are highly mobile, with little site loyalty and large home ranges.

Low lake levels reduce the littoral area available to support fish productivity, and if the lake levels are low over a prolonged period (i.e., >3-6 months) could reduce the condition and number of sport fish. Thompson & Ryder (2002) reported that gut analysis showed that the salmonids in Lake Hāwea were feeding on a variety of prey, including small fish such as bullies. Bullies, in contrast to the larger fish in the Lake, tend to be loyal to a small area of the bottom, defending nesting sites beneath stones. As such the effects of lake level fluctuations may affect bully populations by stranding the fish or their eggs. However, as noted above, bullies are prolific breeders and generally spawn

when lake levels tend to be at their lowest, therefore the chance of egg strandings may be reduced.

Overall, the current lake level regime of Lake Hāwea has maintained a healthy and abundant sport fishery. This can only be achieved by a healthy physical environment, good water quality and abundant food sources (benthic invertebrates and small fish such as bullies and juvenile kōaro). Proposed changes to the Lake level operating regime are unlikely to substantially alter this situation unless incursions into lower lake levels occur on a frequent (annual) basis, in which case a drop in fish productivity benthic communities may result.

5. Conclusion

Although Lake Hāwea is subjected to large and frequent (annual) fluctuations in its lake level, all the key ecological markers suggest that it is in good to excellent ecological health, and a standout relative to most other lakes in New Zealand. Water quality is very good and the well-recognised salmonid fisheries are in good condition and valued by the angling fraternity. Native fisheries of the Lake are not diverse, and less well understood, but there is no indication that they are declining, and it is likely the tuna fishery will gradually increase as a result of the continued efforts by Contact to restock the Lake to address the adverse effects of the downstream hydro dams on upstream recruitment.

The proposed changes to the Lake's operating regime are likely to see a continuance of the current plant and benthic invertebrate communities, although potentially they may be less abundant if the new lower end of the normal operating range is exercised on a regular (annual) basis. Incursions into the new emergency operating regime may result in additional temporary reductions in benthic productivity (macroinvertebrates, macrophytes and benthic-dwelling bullies), however, this should recover after 6-12 months or so from when the lake level increases. More regular incursions (i.e., annual or near-annual) into lower lake levels, relative to the existing regime, may result in prolonged lower benthic productivity, which could have flow-on effects to the Lake's sport fishery and other aspects of the Lake's ecosystem.

More regular monitoring of the Lake's benthic environment and associated fisheries is recommended in order to gain an accurate assessment of lake level fluctuations.