

Lower Waitaki River Catchment Conservation and Restoration

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EXECUTIVE SUMMARY

The Lower Waitaki River catchment, downstream of Waitaki Dam, is a priority for restoration for the Department of Conservation. This report summarises aquatic conservation values and restoration priorities for the catchment, based on a desktop review of existing data and interviews.

The Lower Waitaki River extends 65 km from Waitaki Dam to the ocean, and it has a catchment area of 2,300 km². Braided river ecosystems are rare internationally and the Lower Waitaki River faces pressures from encroachment of agricultural land, water abstraction, invasive vegetation, and the Waitaki Power Scheme. Encroachment of agricultural land into the braidplain is a major issue in the Lower Waitaki River, with an estimated 31% of the contemporary braidplain now in high production pasture. Flow regulation by Waitaki Dam is associated with reduced seasonality in flows, lower summer flows, reduced magnitude and frequency of floods, and large daily and weekly variations in flow, compared with an unregulated river.

A total of 556 wetlands have been identified in the Lower Waitaki catchment, of which, only 72 have been ground-truthed with field surveys. As such, the state and condition of many of these habitats is not known. Of the wetlands that have received detailed field surveys, most are in poor condition.

The Waitaki River mouth is an Area of Significant Natural Value in the Regional Coastal Environment Plan for Canterbury. The mouth and hapua provide roosting and nesting habitat for native birds, as well as habitat for numerous native fish species. The hapua may also provide spawning habitat for At Risk – Declining munga (adult whitebait), although this requires confirmation with field surveys.

A total of 27 native plant species have been reported in aquatic environments in the Lower Waitaki River catchment, including six species with an At Risk – Declining conservation status. The primary pressures on native plant species in the catchment include agricultural encroachment and intensification, competition with exotic weeds, and herbivory by introduced pest species.

A total of 20 native and four introduced fish species have been recorded in the Lower Waitaki River catchment. The catchment has high fish conservation values, with a total of four Threatened and nine At Risk species recorded. The most acutely threatened species are Canterbury mudfish and lowland longjaw galaxias, which both have a conservation status of Threatened – Nationally Critical. Primary pressures on native fish populations in the Lower Waitaki River catchment relate to agricultural intensification, hydro-electric power generation, and native-exotic species interactions. However, without established monitoring programs, the degree of impact these pressures have on fish communities are uncertain.

Twenty-six freshwater bird species have been recorded in the Lower Waitaki River catchment, with 24 of these being native species. There are four Threatened and nine At Risk bird species present. Key pressures on freshwater bird conservation values in the Lower Waitaki River catchment relate to hydro-electric power generation, invasive weeds, predation, and human disturbance.

Restoration actions need to address the major pressures on conservation values and fill knowledge gaps. Key pressures on conservation values include: the Waitaki Power Scheme, agricultural intensification (including encroachment of the braidplain), introduced predators

and weeds, and flood and erosion protection measures. The first order priority for restoration is engaging with key stakeholders and mana whenua, including: active engagement with the Waitaki Power Scheme consenting process; working with the Waitaki Irrigators Collective; working with Environment Canterbury; and engagement with local rūnanga. The second order priority for restoration includes a variety of actions aimed at filling knowledge gaps, and various restoration actions.

Knowledge gap-filling priorities include: freshwater fish and bird monitoring; wetland surveys; Waitaki Dam fish impact studies; identification and prioritisation of fish passage barriers; fish screen survey; lowland longjaw galaxias survey; Canterbury mudfish monitoring and surveys; threatened fish spawning surveys; study of bird movements between meta-populations; a survey of terrestrial invertebrates and lizards; and a study of climate and land use change on threatened native fish.

Priority restoration actions include: fairway weed control; predator control; Waitaki Power Scheme consenting discussions; fencing and riparian planting; prevention and reversal of agricultural encroachment; berm vegetation from exotic to native species; securing land behind the hapua; wetland enhancement fund; fish barrier remediation; trout barriers to lowland longjaw galaxias sites; Canterbury mudfish management; threatened bird habitat island construction and maintenance; and reducing human disturbance of native birds.

1. INTRODUCTION

The Lower Waitaki River catchment, downstream of Waitaki Dam and including the Hakataramea River, has been identified as a priority river for restoration by the Department of Conservation (DOC). An Iwi management plan for the catchment was developed in 2019 (Kāi Tahu Ki Otago 2019). For DOC to be an effective partner to support the aspirations of mana whenua as expressed through their plan, it requires a clear understanding of the opportunities for biodiversity restoration within the catchment. To support that work, the Department contracted Instream Consulting to undertake a preliminary information gathering and restoration scoping exercise.

This report reviews existing information on the Lower Waitaki River catchment, summarising conservation values and identifying priorities for restoration. Indicative costings for restoration were prepared with input from DOC staff and were provided separately. The information presented here is based on a desktop review of reports and databases, supported by numerous interviews with people from a range of organisations (see Section 7). The scope did not include iwi consultation, as this will be done by DOC staff.

2. CATCHMENT OVERVIEW

With a mean flow of 368 m³/s at Kurow (Leong and Chesterton 2005b), the Waitaki River is the largest braided river in New Zealand. The Waitaki River sources water from the McKenzie Basin, including three major lakes positioned at the foot of the Southern Alps: Lake Tekapo, Lake Pukaki, and Lake Ohau. Collectively these lakes drain the eastern side of the alps, receiving rainfall, snowmelt, and glacial waters. Water captured by these lakes is discharged into Lake Benmore via various canals and rivers. From Lake Benmore water flows downstream to Lake Aviemore and then Lake Waitaki, via the Waitaki River. At the downstream (eastern) end of Lake Waitaki lies the Waitaki Dam, the most downstream of eight hydroelectric power stations in the catchment. The Waitaki Dam power station is owned and operated by Meridian Energy Ltd, along with five of the other stations. The other two power stations in the upper catchment are owned by Genesis Energy Ltd.

Waitaki Dam was constructed in 1935 for power generation and it has a total upstream catchment of 9,735 km² (Leong and Chesterton 2005a). Reaches of the Waitaki River above the dam are referred to as the Upper Waitaki River, and those below, the Lower Waitaki River. Below the dam, the Waitaki River flows through a c. 5 km length of gorge, before taking on a braided river form, near Kurow. The river continues east through the Waitaki Valley, bordered by a thin strip of agricultural farmland against the foothills. The valley opens to an alluvial fan near Black Point, which is used intensively for agriculture. The Waitaki River flows through this agricultural land before discharging into the Pacific Ocean via the mouth and hapua, approximately 60 km to the south of Timaru. The total length of the Lower Waitaki River, from the dam to the ocean, is approximately 65 km.

The Lower Waitaki River catchment is large, with its total area of 2,300 km² (Heslop *et al.* 2015) comparable to the entire Rakaia River catchment of 2,600 km², and considerably larger than the entire Rangitata River catchment of 1,500 km² (Morgan *et al.* 2002). Within this catchment exists diverse aquatic habitats, that can be broadly categorised as: the braided river mainstem, hill-fed tributaries, spring-fed tributaries, wetlands, and the hapua / mouth.

These habitats are described briefly in the paragraphs below, with their general extent shown in Figure 1.

The Lower Waitaki River mainstem provides a large area of braided river habitat. At the centre of this habitat are the active channels, which carry most of the flow. These channels intertwine, intermittently separated by islands and bars, creating the characteristic braided appearance from above (Gray *et al.* 2018). This habitat is typically dynamic, with channels shifting and reorganising during flood flows. In the Lower Waitaki, these flows are moderated by Waitaki Dam, with the dam impacts described below (see Section 3.2). The shifting gravels and variable flows of the active channels result in a high disturbance environment, for both instream and island habitats. However, the lateral extent of the braided river habitat continues beyond the active channels. For this report, we consider the braided river habitat to extend the width of the braidplain. While a river's braidplain may be defined in various ways, in this report we refer to 'contemporary braidplain', defined by Hoyle and Bind (2018) as "...the area that the river channels could possibly adjust within, based on elevation and topography that captures geomorphic features such as river terraces." In the Lower Waitaki catchment, by this definition, the braidplain extends into the surrounding agricultural land to the river terraces, up to c. 1.5 km from the actively flowing channels.

Between the active channels and the lateral extent of the braidplain typically more stable aquatic habitats exist. The riparian vegetation along the length of the Waitaki River is dominated by introduced willow trees (*Salix spp.*), among which there are numerous backwaters, pools, and wetland habitats. Beyond the immediate riparian zone, spring-fed streams and further wetlands rise, amongst farmlands. In comparison to the dynamic habitats of the mainstem, these spring-fed streams and wetlands are very stable, resulting in greater algal and macrophyte growth, and generally supporting higher overall productivity.

Beyond what is sourced from the Upper Waitaki catchment, the hill-fed tributaries are the other major sources of flow in the Lower Waitaki River. The most substantial of these tributaries is the Hakataramea River, which drains the Hakataramea Valley, to the north of the Waitaki River near Kurow (Figure 1). Other notable hill-fed tributaries in the catchment include the Awakino, Otekaieke, and Maerewhenua Rivers. Further wetlands exist amongst these hill-fed catchments, scattered across the valley floors. Data sourced from the Otago Regional Council (ORC) and Environment Canterbury (ECan) indicates that there are 556 aerially mapped wetlands in the Lower Waitaki catchment, although only 72 have been ground-truthed with field surveys.

The Waitaki River mouth and hapua represents another distinct aquatic habitat type in the catchment. Hapua are a form of coastal lagoon that arise due to fluvial and coastal processes, resulting in the formation of a gravel bar that runs parallel to the coast (Kirk and Lauder 2000). The resulting lagoon is elongated along the coast, and unlike estuaries, is a predominantly freshwater environment.

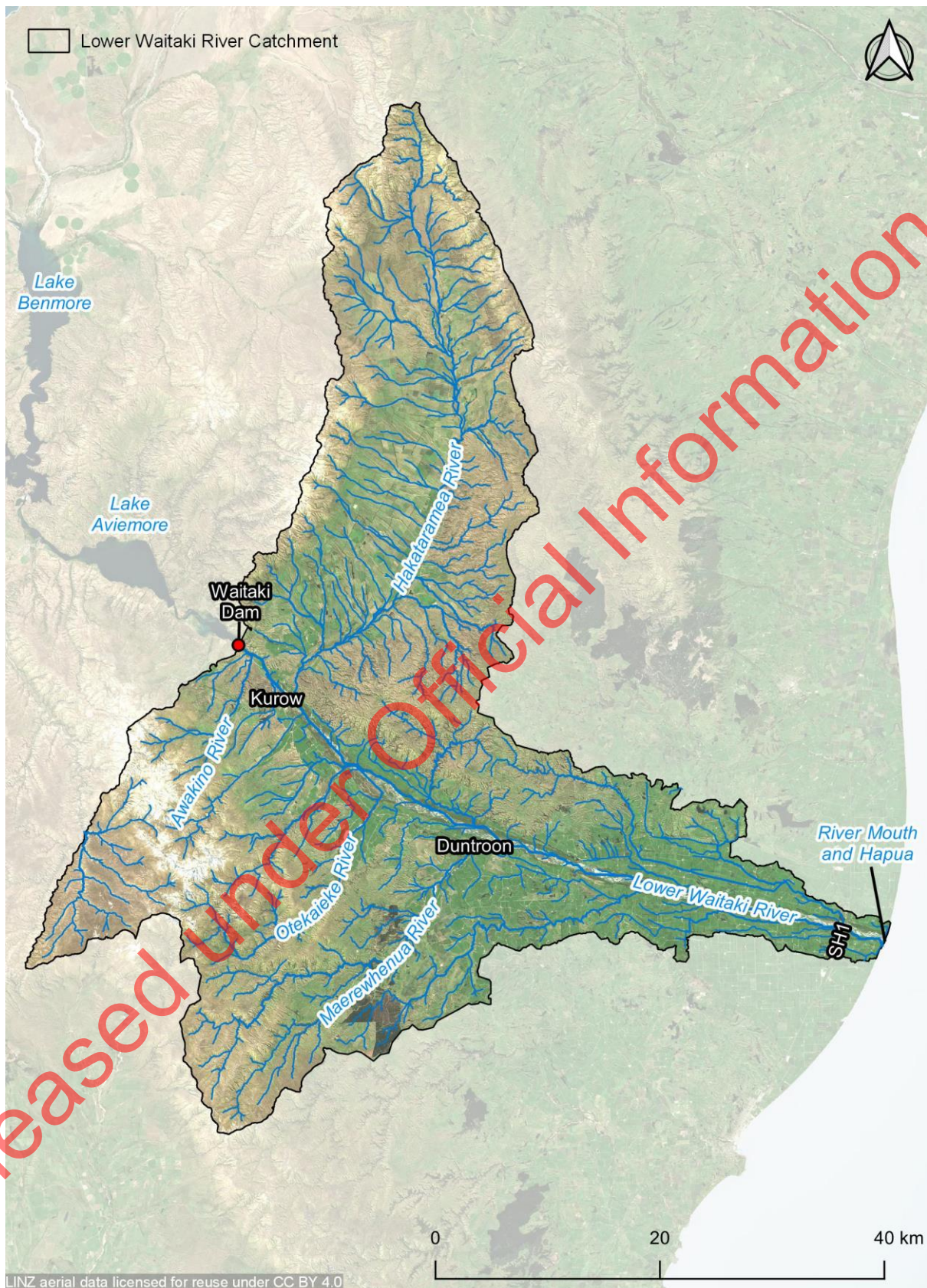


Figure 1: The Lower Waitaki Catchment.

The braided river habitat of the Lower Waitaki River is shaped largely by its underlying glacial history and hydrology. The river's hydrology is controlled by natural process, including rainfall, snow melt, and groundwater levels, but is highly modified by human activities. Long term monthly mean flows at Waitaki Dam averaged 364 m³/s from 1952–2004 (Figure 2). Flows are highest over the late spring and summer, the result of snowmelt and north-westerly rains (Hoyle and Bind 2019). Modelling by Hoyle and Bind (2019) demonstrated that the Waitaki Dam operation dampens the natural seasonal flow variation, reducing flows over the October–January period and elevating flows from January–September, creating more consistent flows over the year (Figure 2). Flow regulation by Waitaki Dam also reduces the magnitude and frequency of flood events (Figure 3), which also affects braided river habitat (see Section 3.2). High daily and weekly flow fluctuations occur downstream of Waitaki Dam, in response to demand for electricity generation. Ecological implications of these flow fluctuations are discussed in Section 3.2.

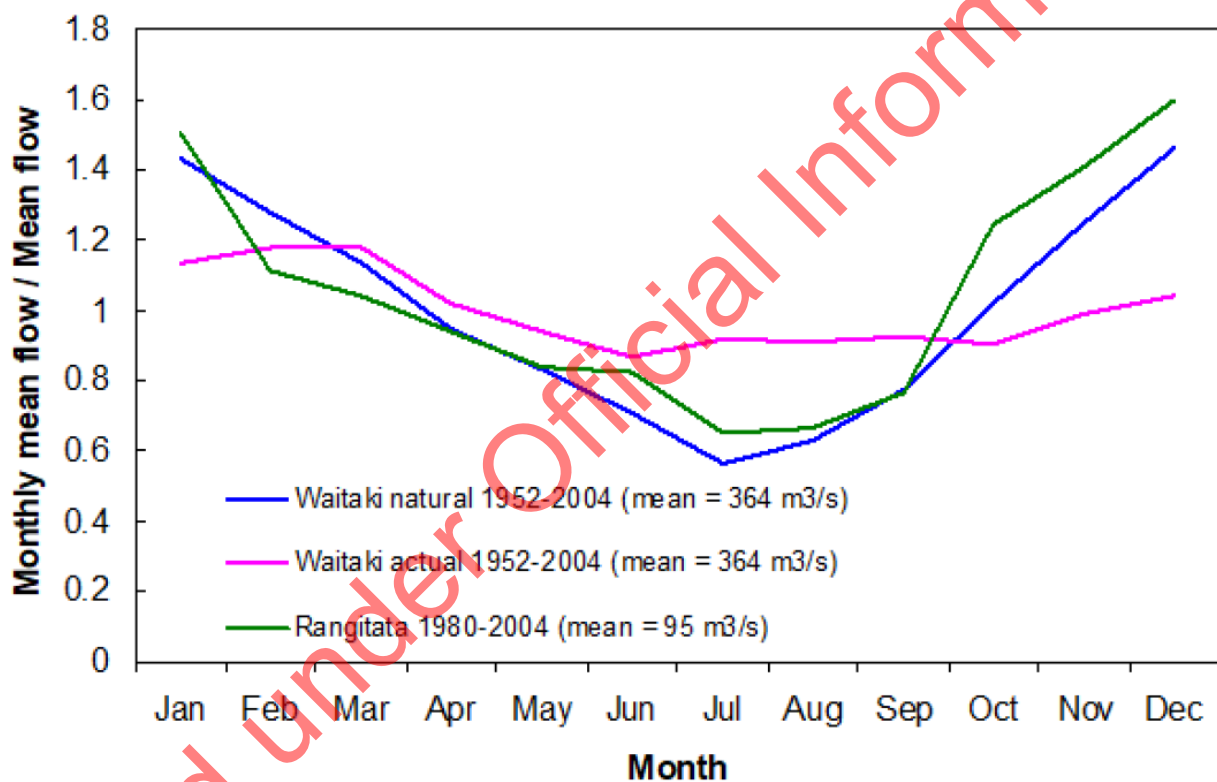


Figure 2: Monthly mean flows for the actual and simulated natural flow records at Waitaki Dam for the period 1952–2004 and for the Rangitata River at Klondyke for the period 1980–2004. This figure indicates that the natural flow regime of the Waitaki River would mirror that of the Rangitata River, which is also an alpine-fed braided river, but is unaffected by hydroelectric dams. The actual flow regime of the Waitaki River shows the dampening effect of Waitaki Dam on seasonal flow variation. Source: Hicks et al. (2006), as cited in Hoyle and Bind (2019).

The Waitaki Catchment Allocation Regional Plan (September 2005) sets minimum flows and allocation limits for water abstraction within the Waitaki River and its tributaries. Important plan limits for the Lower Waitaki River include a minimum flow (below which abstraction must cease) of 150 m³/s and a total allocation for abstraction of 79 m³/s. All the water allocated for abstraction is allocated to existing water users, with nothing further available for abstraction (ECan data). The major abstractive water use in the Lower Waitaki River is for irrigating pasture.

The Waitaki Catchment Allocation Regional Plan also includes provisions for flushing flows of 450 m³/s. These flushing flow provisions were created in response to a new hydroelectric proposal downstream of Waitaki Dam, known as the North Bank tunnel. The North Bank tunnel concept involved taking water from Waitaki Dam, carrying it along the north bank of the Waitaki River and generating power en route, before discharging water back into the river near Stonewall. Water use consents for the North Bank tunnel project were granted by the Environment Court in 2009, but the project was mothballed in 2013 in response to project costs and forecast flat electricity demand.

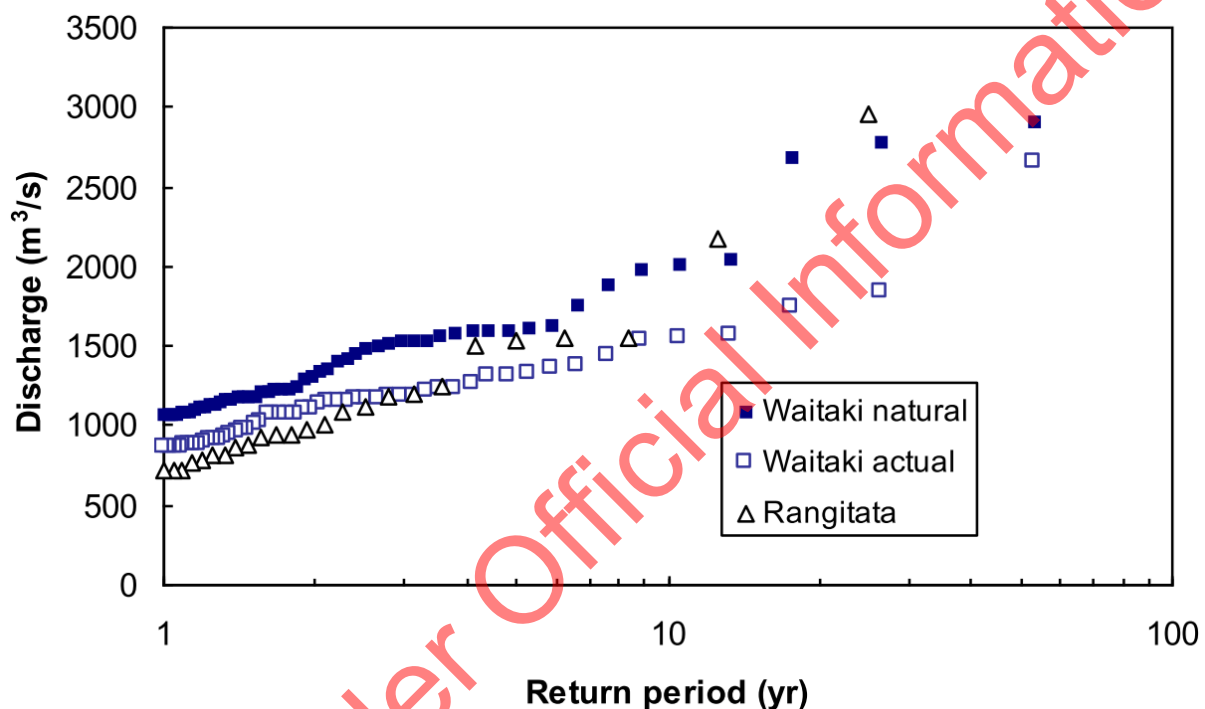


Figure 3: Flood-frequency distributions for actual and simulated natural flow records at Waitaki Dam for the period 1952-2004 and for the Rangitata River at Klondyke for the period 1980-2004. This figure illustrates the impact of Waitaki Dam on reducing the magnitude and frequency of flood events. Source: Hicks et al (2006). As cited in Hoyle and Bind (2019).

3. CONSERVATION VALUES

3.1. Introduction

The following sections summarise conservation values, including their current state, pressures, and knowledge gaps in the Lower Waitaki River catchment. Various definitions of “conservation value” exist (Capmourteres and Anand 2016), so for the sake of clarity, we broadly define conservation values as areas of high biodiversity, and rare and uncommon native species, habitats, and ecosystems.

3.2. Braided River Habitat

Braided rivers are naturally rare and endangered ecosystems, with over 80% of the world's braided rivers experiencing a severe decline in ecological functioning (Williams *et al.* 2007; Holdaway *et al.* 2012). Braided rivers comprise a mosaic of habitat types, distributed over the lateral width of the braidplain (Instream Consulting 2019). The properties of these habitats are largely shaped by their relative rates of disturbance, which forms a lateral gradient. Representing the most disturbed of these habitats are the many active flowing channels (or braids). These channels intertwine, separated by bars and islands, giving the river the characteristic braided appearance from above (Gray *et al.* 2018). Under natural circumstances, these channels are often highly mobile, reorganising during stormflows. The ability of these channels to reorganise is governed by the instance of floods to mobilise the bed, and the available supply of fresh sediments for deposition, which create new bars and islands (Gray *et al.* 2018).

Flood events, creating new islands and clearing vegetation from those existing, provides island habitats that are relatively bare of vegetation. These islands are the preferred nesting habitat of threatened braided river bird species (see Section 3.7). However, there has been a reduction in the both the quantity and quality of these island habitats in the Lower Waitaki River. The lateral extent of the river bed has reduced from a historic width of up to 2 km (pre-1940; Stecca *et al.* 2021), with current widths of generally 0.5–1 km. This represents a substantial lateral loss in riverbed habitat, the causes of which are discussed below. The quality of island habitats has also decreased, with increased vegetation cover and predator abundances.

Beyond the active channels of the Waitaki River exist more stable aquatic habitats, including backwaters, springs, and wetlands. Such habitats are situated either in the immediate riparian zone, which is dominated by stands of mature willows, or beyond, among farmland. Residual ecological values exist in these environments, including threatened plant, bird, and fish species, however, aquatic habitats are reduced in both quantity and quality. In a review of wetlands in the Waitaki Catchment, prepared for Meridian Energy, Hooson *et al.* (2020) identified 54 wetlands within the Lower Waitaki River braidplain. Of these wetlands, only eight were assessed as having 'Good' wetland condition (i.e., highly representative of the habitat type and very low levels of modification), while 29 were assessed as being in 'Poor' condition (i.e., degraded or modified), with the remaining 17 assessed as being in moderate condition.

By compiling ORC and ECan wetland GIS layers, we identified a total of 556 wetlands across the entire Lower Waitaki catchment. Of these wetlands, 72 have received detailed ground surveys, while the rest have been identified from aerial surveys. Under the recent update to the NPSFM (2020), regional councils are required to identify, map, classify, and collate existing monitoring data on all wetlands over 500 m² (and those of a type that is naturally less than 500 m²; Clause 3.23 (1); NPSFM 2020). Of the wetlands we identified, 314 exceed 500 m², of which 65 had detailed survey information attributed to them.

The mouth and hapua of the Waitaki River also contribute substantial habitat values to the catchment. The Waitaki River mouth is listed as an Area of Significant Natural Value in the Regional Coastal Environment Plan (Schedule 1; Environment Canterbury 2020), with six of the eight ecological and cultural values recognised as being present. The mouth and hapua area provides roosting and nesting bird habitat, that is well utilised by native species (Pers. Comm., Richard Maloney, DOC, November 2021). The hapua provides habitat for numerous native fish species, including Stokell's smelt (*Stokellia anisodon*; At Risk – Naturally

uncommon; Dunn *et al.* 2018). Based on models of spring high tides, the hapua may also provide inanga (*Galaxias maculatus*; At Risk – Declining) spawning habitat, however, surveys are required to confirm if that habitat is being utilised (Pers. Comm., Jarred Arthur, ECan, February 2022).

Monthly water quality monitoring is undertaken by the National Institute of Water and Atmosphere (NIWA) as part of the National River Water Quality Network in the lower Hakataramea River and in the Waitaki River at Kurow and at State Highway One. ECan also collects monthly water samples from the upper Hakataramea River and from nine other tributary sites (Figure 4). Levels of the faecal indicator bacterium *Escherichia coli* and the nutrients dissolved inorganic nitrogen (DIN) and dissolved reactive phosphorus (DRP) are generally low across the catchment, with most sites meeting their respective guidelines (Table 1). However, nutrients and *E. coli* are elevated in Waikakahi Stream, with all sites nearing or exceeding guidelines across these parameters. These elevated levels are indicative of agricultural runoff, and likely reflects the lowland spring source, the surrounding agricultural land use, and inadequate riparian buffers. Elevated nutrients, and low flushing associated with a spring source, can result in excessive macrophyte and algal growth which degrades aquatic habitats. As a result, the Waikakahi Stream sampling sites have historically failed to meet Canterbury Land and Water Regional Plan (LWRP) Freshwater Outcomes for total macrophyte cover (Clarke and Greer 2015). Given the general lack of planting around spring-fed waterways, it can be reasonably expected that habitat values are similarly degraded in spring-fed lowland waterways across the catchment.

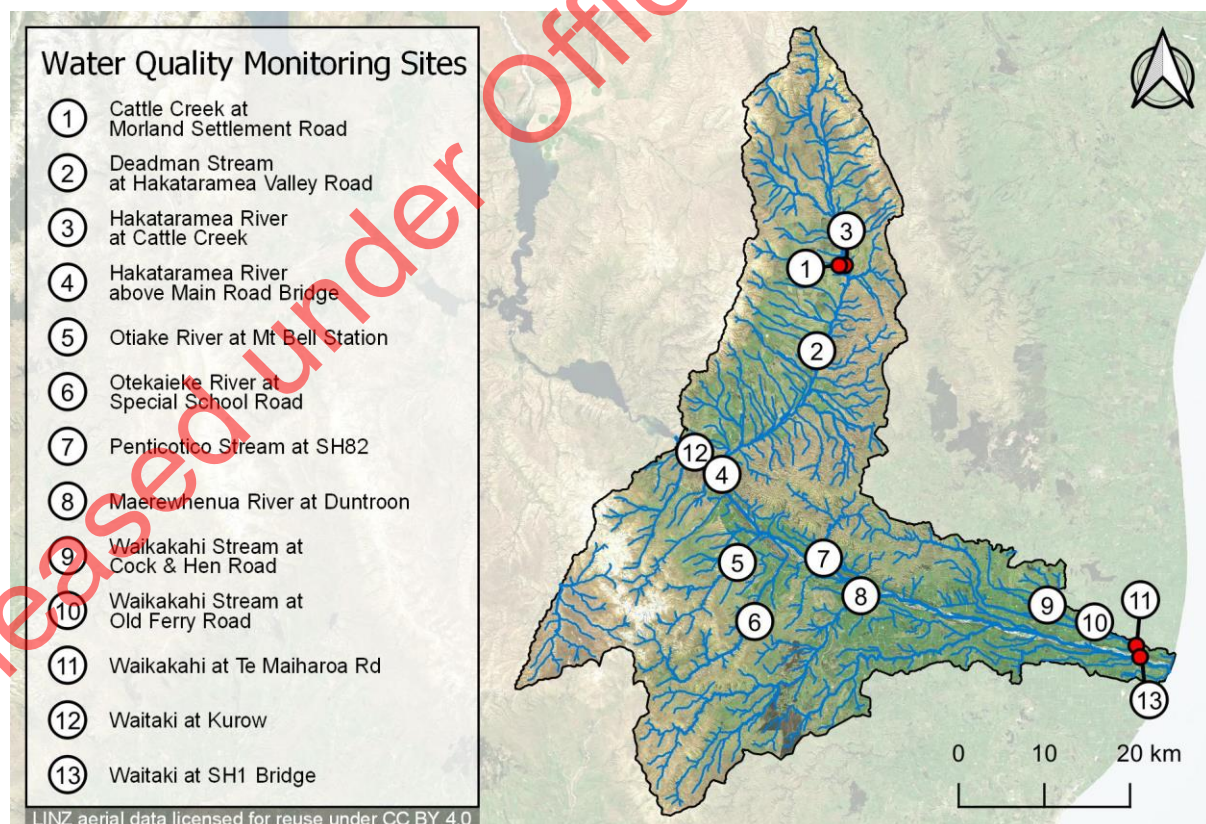


Figure 4: The locations of ECan water quality monitoring sites in the Lower Waitaki River catchment

Table 1: Five-year median values (2016–20) for selected water quality attributes, against relevant water quality standards. Site No. refers to those displayed in Figure 4. Values below each LWRP standard are indicated in red. Water quality class from LWRP Water Quality Management Units (Canterbury Maps) and Suspended fine Sediment (SS) class is from MFE's Sediment Classes for REC2.4 GIS layer. See notes for parameter descriptions.

Site No.	Site Name	Water Quality & (SS) Class	E. coli (No./100ml)	DIN (mg/L)	DRP (mg/L)	Clarity (m)
1	Cattle Creek at Morland Settlement Road	Spring-fed lower basin (3)	47.5	0.031	0.0025	3.64
2	Deadman Stream at Hakataramea Valley Road	Spring-fed lower basin (3)	162	0.056	0.0138	1.39
3	Hakataramea River at Cattle Creek	Hill-fed lower (3)	39	0.00725	0.0065	3.97
4	Hakataramea above Main Road Bridge	Hill-fed lower (3)	25	0.015*2	0.0032	6.85
5	Otiake River at Mt Bell Station	Hill-fed lower (3)	13	0.0095	0.0005	6.60
6	Otekaieke River Special School Road	Hill-fed lower (3)	29	0.065	0.001105	3.66
7	Penticotico Stream at SH82	Hill-fed lower (3)	106	1.64	0.0033	3.9
8	Maerewhenua River at Duntroon	Hill-fed lower (3)	84	0.1625	0.0019	5.53
9	Waikakahi Stream at Cock & Hen Road	Spring-fed plains (2)	230	3.4615	0.062	1.84
10	Waikakahi Stream at Old Ferry Road	Spring-fed plains (1)	784.5	4.205	0.067	1.4
11	Waikakahi at Te Maiharoa Rd	Spring-fed plains (1)	249	3.855	0.062	1.73
12	Waitaki at Kurow	Lake-fed (N/A*1)	3.1	0.002*2	0.0005	4.58
13	Waitaki at SH1 Bridge	Lake-fed (N/A*1)	70.3	0.028*2	0.0005	1.51
	LWRP Freshwater Outcome		<260	-	-	-
	LWRP Receiving Standards	Spring-fed lower basin	-	0.47	0.01	-
		Hill-fed lower	-	0.47	0.006	-
		Spring-fed plains	-	1.5	0.016	-
		Lake-fed	-	0.21	0.0003	-

Notes: DIN = Dissolved Inorganic Nitrogen (nitrate + nitrite + ammonia); DRP = Dissolved Reactive Phosphorus.

Bottom of the A, B, C, and D bands for clarity (NPSFM 2020) are: SS Class 1 (1.78, 1.55, 1.34, <1.34), SS Class 2 (0.93, 0.76, 0.61, <0.61), SS Class 3 (2.95, 2.57, 2.22, <2.22). *1These bands do not apply to the Waitaki River, as the glacial flour inputs are a 'naturally occurring process' affecting turbidity (NPSFM, 2020).

*²DIN values were not available for these sites, so Total Oxidised Nitrogen (nitrate + nitrite) values were substituted. As the ammoniacal nitrogen values are near detection limits at each of these sites (5-year median mg/l: Site 4 = 0.004, Site 12 = 0.003, Site 13 = 0.002), this has little effect on the interpretation of DIN results.

Pressures and knowledge gaps

The braided river habitats of the Lower Waitaki River are subject to numerous pressures, the greatest of which relate to encroachment of intensive agriculture into the braidplain, hydroelectric flow regulation and sediment supply modification, water abstraction, and invasive plant species. These pressures are not unique to Lower Waitaki River catchment, and they have been identified as key threats by various authors across a range of braided river catchments (Gray and Harding 2007; O'Donnell *et al.* 2016; Lewis and Maloney 2019).

In a recent study of agricultural encroachment on Canterbury's lowland braided rivers since 1990, the Lower Waitaki River catchment was identified as having the third highest rate of agricultural development on the braided river margin, by area (130 ha; Greenep and Parker 2021). However, as this number does not include developments prior to 1990, the extent of the encroachment is likely much more severe. We delineated the extent of the contemporary braidplain of the Lower Waitaki River by digitising the edge of ECan's Braided River Cover Classes GIS layer. While this layer was not intended to delineate the braidplain for any sort of legislative purpose, it closely followed the river terraces, consistent with the contemporary braidplain definition of Hoyle and Bind (2018). We then overlaid the polygon representing the contemporary braidplain with the New Zealand Land Cover Database (LCDB V5.0), to estimate how much of the braidplain is in agricultural production. We found that, as of 2018, 31% (3,440 ha) of the contemporary braidplain is now in high production pasture (Figure 5), up from 27% (3,013 ha) in 1998.

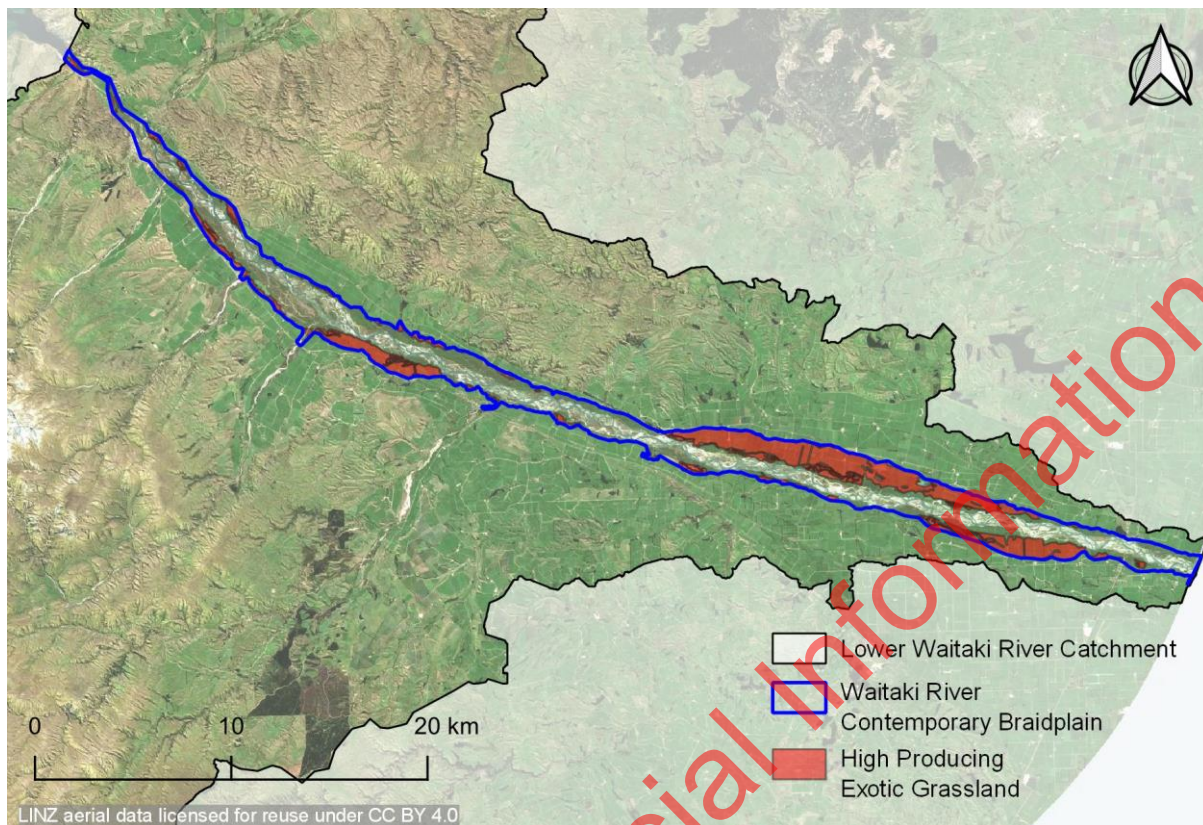


Figure 5: The area of high producing exotic grassland inside the contemporary braidplain of the Waitaki River, as of 2018. Data sourced from the New Zealand Land Cover Database. Contemporary braidplain digitised following the extent of ECan's Braided River Cover Classes GIS layer.

The matter of land ownership and the legality of this agricultural encroachment is a national issue, beyond the scope of this report. However, a draft report by Environment Canterbury (2019) has identified a number of areas where recent agricultural development has occurred on public conservation land, with no known license agreement (see for example Figure 6), totalling 149 ha in the Lower Waitaki River. Development of this land directly destroys riparian habitat for native species, greatly limits any future opportunities for ecological enhancement, and removes riparian buffers from around springs and wetlands. Furthermore, as agriculture encroaches closer to the river, there is greater public pressure to protect agricultural land and assets from erosion. Following high flows over the summer of 2019-20, ECan proposed a \$1 million work package for erosion protection, in addition to the existing \$500,000 per annum routine works program (Environment Canterbury 2020a). Routine erosion protection in the Lower Waitaki River generally includes: channel re-alignment and braid direction control, spraying of fairway vegetation, berm vegetation layering, anchored tree protection, new vegetation planting, and rock groynes maintenance and renewal (Environment Canterbury 2020a). Such works prevent the natural lateral movement of the river, as well impacting native species through the physical destruction gravel habitats, associated with braid modifications.

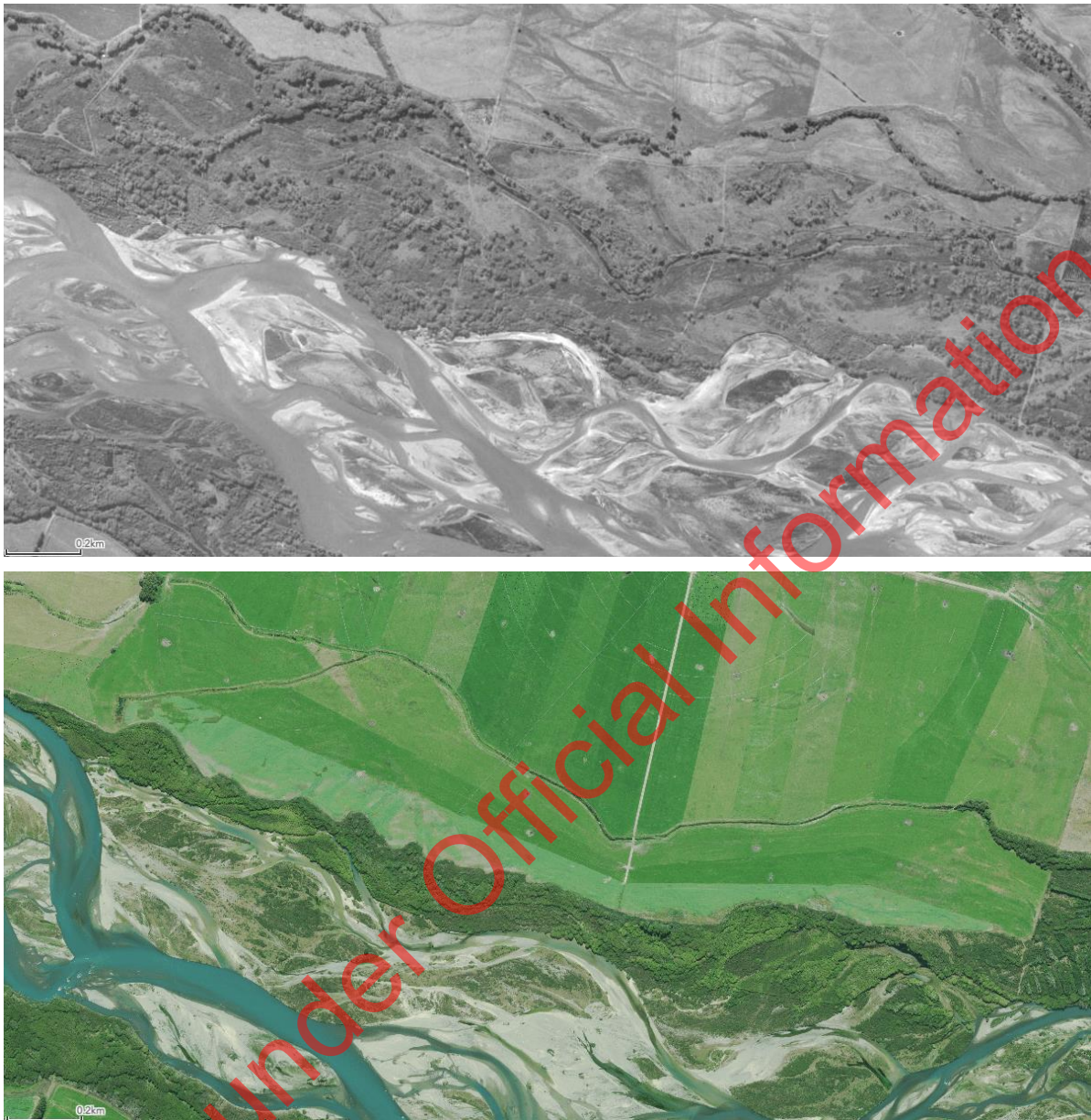


Figure 6: Agricultural encroachment between the year 2000 (top) and 2018 (bottom). Developed land is public conservation land with no known licence agreement (Environment Canterbury 2019), north bank of the Lower Waitaki River, west of Bells Pond. Aerials from Canterbury Maps.

Operation of the Waitaki Dam has substantial impacts on braided river habitats, primarily through reduced baseflow, and alterations to the sediment supply and flow regime. Consents for the operation of the Waitaki Power Scheme (WPS), including Waitaki Dam and the upstream power stations, expire on 30 April 2025. Meridian Energy is therefore preparing numerous reports that will assess impacts of the scheme and we anticipate considerable amounts of new information soon. Related reports available at the time of writing were focussed on assessing current state, rather than specifically addressing impacts of operating the WPS. However, reduced flood frequency downstream of Waitaki Dam, coupled with the armouring effect of invasive woody weeds, is associated with less braid movement, bed disturbance, and reworking of islands (Hoyle and Bind 2019). Reduced braid movement

exacerbates the proliferation of woody weeds in the lower river, although the degree of this effect attributable to the dam is uncertain. Reduced flushing flows also likely exacerbate blooms of the nuisance alga *Didymosphenia geminata*, or didymo (Kilroy *et al.* 2021). In contrast, high daily and weekly flow fluctuations downstream of Waitaki Dam result in a regularly dried and re-wetted “varial zone” along channel edges that is characterised by low algal and invertebrate productivity (Jowett 2006).

Invasive woody vegetation in the Lower Waitaki River increases island stability, reducing braid reorganisation, and it negatively affects bird habitat (see Section 3.7). A recent history of vegetation encroachment of the lower Waitaki River fairway found that prior to 1940, the riverbed was 2 km wide (Stecca *et al.* 2021b). By 1950, increasing congestion from crack willow and broom was observed, with gorse and other weeds also established on the bed and margin. Vegetation control for flood protection started during the 1950s, and a 500 m fairway was cleared in the middle of the river. Other maintenance has included “scarifying and loosening-up gravel bars and islands with earth moving machinery to encourage river flow within the cleared corridor, cutting temporary pilot channels, and protection of banks with willow trees, pied rail retards, shingle stopbanks and planting to reinforce the margins of the corridor” (Stecca *et al.* 2021b). The fairway corridor has been reduced to 400 m since the 1970s and willow growth is currently controlled by ECan on a 3–5 year rotation.

3.3. Plants

A total of 27 native plant species have been reported in aquatic environments in the Lower Waitaki catchment (Williams 1982; Hooson *et al.* 2020; Hoyle *et al.* 2021). This includes six species with an At Risk – Declining conservation status. One such species, a native bidi bidi (*Acaena buechananii* var. *picta*), was reported by Williams (1982), but has not been identified during any survey since (Hoyle *et al.* 2021), and may no longer be in the system.

Much of the contemporary braidplain of the Lower Waitaki River is now under high production pasture (see Section 3.2). Some residual native plant values remain in these areas, however, these are generally restricted to various wetlands. Several native plant species have been recorded in wetland habitats, including various sedges, rushes, and herbs (Table 2); however, exotic species such as crack willow (*Salix fragilis*) are also common. Flax wetlands are also present amongst the agricultural land, but these are rare (Hooson *et al.* 2020).

The immediate riparian areas on both banks of the Lower Waitaki River are dominated by crack willow. Among the willows, further wetlands exist, however, margins are often dominated by exotic gorse, blackberry, or broom, with native sedges and ferns occasionally present (Hooson *et al.* 2020). Crack willow extends from the riparian zones onto the fairway, also colonising many of the river’s islands. Among the more stable areas of the riverbed, shrubland communities exist, dominated by gorse and broom, with exotic grass species in areas of open canopy (Hoyle *et al.* 2021).

In less stable areas of the Waitaki River, herbaceous species dominate. This includes several native species, however, these are sparsely distributed on relatively bare islands (Table 3; Hoyle *et al.* 2021). Numerous exotic herbaceous species are also present such habitats, including Californian poppy (*Eschscholzia californica*), sheep’s sorrel (*Rumex acetosella*), St John’s wort (*Hypericum perforatum*), and Californian poppy (*Eschscholzia californica*), among others. False tamarisk has been present in the upper Waitaki catchment since 2016, and may now also be present in the lower catchment (Hoyle *et al.* 2021).

There is little information available on aquatic macrophytes in the Lower Waitaki River catchment. Williams (1982) noted the presence of two native species in the slow flowing backwaters and ponds of the Waitaki River, *Potamogeton cheesemanii* and *Myriophyllum elatinoides* (Table 2), along with numerous exotic species. Monkey musk (*Erythranthe guttata*) has been reported across a number of tributaries, with associated negative impacts on fish habitat (Ravenscroft et al. 2010).

Pressures and knowledge gaps

The primary pressures on native plant species in the catchment include agricultural encroachment and intensification, competition with exotic weeds, and herbivory by introduced pest species. Agricultural landuse in the catchment has direct effects on riparian plant species via the conversion of habitats to pasture (See Section 3.2). Stock grazing and trampling may also impact plant communities in reaches lacking adequate fencing. Exotic weeds may compete with native plant species for space and resources. This pressure may be heightened by the presence of Waitaki Dam, regulating flows, preventing plant community turnover and allowing dominant exotics to establish. Introduced herbivores, such as rabbits, hares, and wallabies may graze upon native plants. Wallabies are of particular concern, with their numbers increasing in the catchment, and their ability to access island habitats across flowing channels. Wallabies have been recently reported on several islands in the Waitaki River (Pers. Comm., Brent Glentworth, ECan, February 2022).

Table 2: Native plants recorded in the Lower Waitaki catchment with aquatic associations. Data from Williams (1982), Hooson et al. (2020), and Hoyle et al. (2021). Table ordered by threat status and vegetation classification. Vegetation classifications modified from Hoyle et al. (2021).

Common name	Scientific name	Threat Status	Vegetation Classification
Small-leaved tree daisy*	<i>Olearia lineata</i>	At Risk - Declining	Grey scrub
Native bidi bidi	<i>Acaena buechananii</i> var. <i>picta</i>	At Risk - Declining	Herbaceous vegetation
Native scabweed	<i>Raoulia australis</i>	At Risk - Declining	Herbaceous vegetation
Carex	<i>Carex buechananii</i>	At Risk - Declining	Wetland (and stream margin) vegetation
Swamp nettle	<i>Urtica perconfusa</i>	At Risk - Declining	Wetland vegetation
Native scabweed	<i>Raoulia monroi</i>	At Risk - Declining	Herbaceous vegetation
<i>Myriophyllum elatinoides</i>	<i>Myriophyllum elatinoides</i>	Not Threatened	Aquatic macrophyte
<i>Potamogeton cheesemanii</i>	<i>Potamogeton cheesemanii</i>	Not Threatened	Aquatic macrophyte
Creeping pohuehue	<i>Muehlenbeckia axillaris</i>	Not Threatened	Herbaceous vegetation
Montia fontana	<i>Montia fontana</i>	Not Threatened	Herbaceous vegetation

Common name	Scientific name	Threat Status	Vegetation Classification
Native scabweed	<i>Raoulia haastii</i>	Not Threatened	Herbaceous vegetation
Native scabweed	<i>Raoulia subsericea</i>	Not Threatened	Herbaceous vegetation
Native scabweed	<i>Raoulia tenuicaulis</i>	Not Threatened	Herbaceous vegetation
Willow herbs	<i>Epilobium billardierianum</i>	Not Threatened	Herbaceous vegetation
Willow herbs	<i>Epilobium brunnescens</i>	Not Threatened	Herbaceous vegetation
Willow herbs	<i>Epilobium microphyllum</i>	Not Threatened	Herbaceous vegetation
Willow herbs	<i>Epilobium rostratum</i>	Not Threatened	Herbaceous vegetation
Carex	<i>Carex sinclairii</i>	Not Threatened	Wetland (and stream margin) vegetation
Carex	<i>Carex coriacea</i>	Not Threatened	Wetland (and stream margin) vegetation
Carex	<i>Carex secta</i>	Not Threatened	Wetland (and stream margin) vegetation
<i>Eleocharis acuta</i>	<i>Eleocharis acuta</i>	Not Threatened	Wetland (and stream margin) vegetation
Flax	<i>Phormium tenax</i>	Not Threatened	Wetland vegetation
<i>Gunnera dentata</i>	<i>Gunnera dentata</i>	Not Threatened	Wetland vegetation
Jointed rush	<i>Leptocarpus similis</i>	Not Threatened	Wetland vegetation
Mud buttercup	<i>Ranunculus limosella</i>	Not Threatened	Wetland vegetation
Raupo	<i>Typha orientalis</i>	Not Threatened	Wetland vegetation
Toe toe	<i>Cortaderia richardii</i>	Not Threatened	Wetland vegetation

*Note: This species is generally not associated with aquatic environments, however, it was reported at a single wetland by Hooson et al. (2020).

3.4. Invertebrates

Annual freshwater invertebrate monitoring is undertaken by NIWA in the Waitaki River at Kurow and at State Highway One. ECan also undertakes annual invertebrate monitoring at an additional eight tributary sites (Figure 7). At the time of writing, Meridian Energy was preparing a summary report on the current state of aquatic invertebrates in the Waitaki River catchment. The most recent summary of invertebrate communities in the Lower Waitaki River catchment

found Quantitative Macroinvertebrate Community Index (QMCI) scores from lake and hill fed rivers regularly failed to meet Canterbury LWRP Freshwater Objectives, with the exception of the Hakataramea River (Clarke and Greer 2015). In our review of data collected from 2015-2020, we found that all the monitored sites fell within Attribute Bands C and D of the National Policy Statement for Freshwater Management 2020, indicating a dominance of pollution-tolerant taxa (Table 3).

Low invertebrate community index values at the Waitaki River monitoring sites is likely because invertebrate sampling occurs in a large braid of the main stem of the river, and low invertebrate diversity in this habitat type is typical (Clarke and Greer 2015). This is supported by invertebrate studies in the Lower Waitaki River and other braided rivers, which found that stable habitats supported twice the density of invertebrates as unstable areas, and they also had significantly higher taxonomic richness and numbers of sensitive mayfly, stonefly and caddisfly taxa than unstable habitats (Skelton *et al.* 2008). As noted in Section 3.2 above, large daily and weekly flow fluctuations that occur downstream of Waitaki Dam create an unproductive “varial zone” along the channel margin that is largely devoid of invertebrates. One of the advantages provided in support of the North Bank tunnel proposal was that it would reduce these daily and weekly flow fluctuations, resulting in a narrower varial zone and increased productivity along the river margin (Skelton *et al.* 2008). However, the North Bank tunnel project did not go ahead, so flow variability still presumably impacts invertebrate communities of the Lower Waitaki River.

Low QMCI and MCI¹ scores in spring-fed tributaries have been associated with fine sediment deposition and high macrophyte cover (Clarke and Greer 2015). Fine sediment deposition in spring-fed agricultural streams is typically associated with sediment runoff and stock access, while excessive macrophyte growth occurs in stable streams dominated by fine sediments, where nutrients are elevated and shade is lacking.

There are no records of kākahi, or freshwater mussels (*Echyridella menziesii*) from the Lower Waitaki River catchment in the New Zealand Freshwater Fish Database (NZFFD; Richardson 2005)². However, kākahi are not typically captured using standard invertebrate or fish sampling techniques, so it is possible that kākahi are present within the catchment, but they have simply not been searched for. There are three records of kōura, or freshwater crayfish (*Paranephrops zealandicus*) within the Lower Waitaki River catchment. However, the kōura records are all from 1966-1978, so it is unclear what their status is within the catchment. Both kākahi and kōura have an At Risk conservation ranking (Grainger *et al.* 2018) and they are valued mahinga kai.

Compared with aquatic invertebrates, relatively little is known of the terrestrial invertebrates likely to occur alongside waterways in the Lower Waitaki River catchment. Warren Chinn, a DOC entomologist, commented that indigenous terrestrial invertebrate values would likely be associated with shrublands along waterways (Pers. Comm., Warren Chinn, DOC, February 2022). Mr Chinn also said likely species to occur in these habitats would include: “Pyronota festiva beetles, Costelytra zealandica (grass grub), possibly geometrid moths, certainly Orocrambid and pyrelid moths, a handful of diptera (syrphids, march flies and the like), ground

¹ The Macroinvertebrate Community Index (MCI) and the QMCI are based on the same pollution tolerance scores for invertebrates, but the MCI uses presence-absence invertebrate data, while the QMCI uses abundance data.

² As its name suggests, the NZFFD primarily records the presence of freshwater fish. However, it also includes records for mega-invertebrates, including freshwater mussels and freshwater crayfish.

beetles (*Oregus spp.*, *Mecodema*, maybe *Holcaspis spp.*). Spiders could be interesting - *Dolomedes aquaticus*, *Uliodon spp.* and perhaps *Porrthele antipodiana* if lucky.”

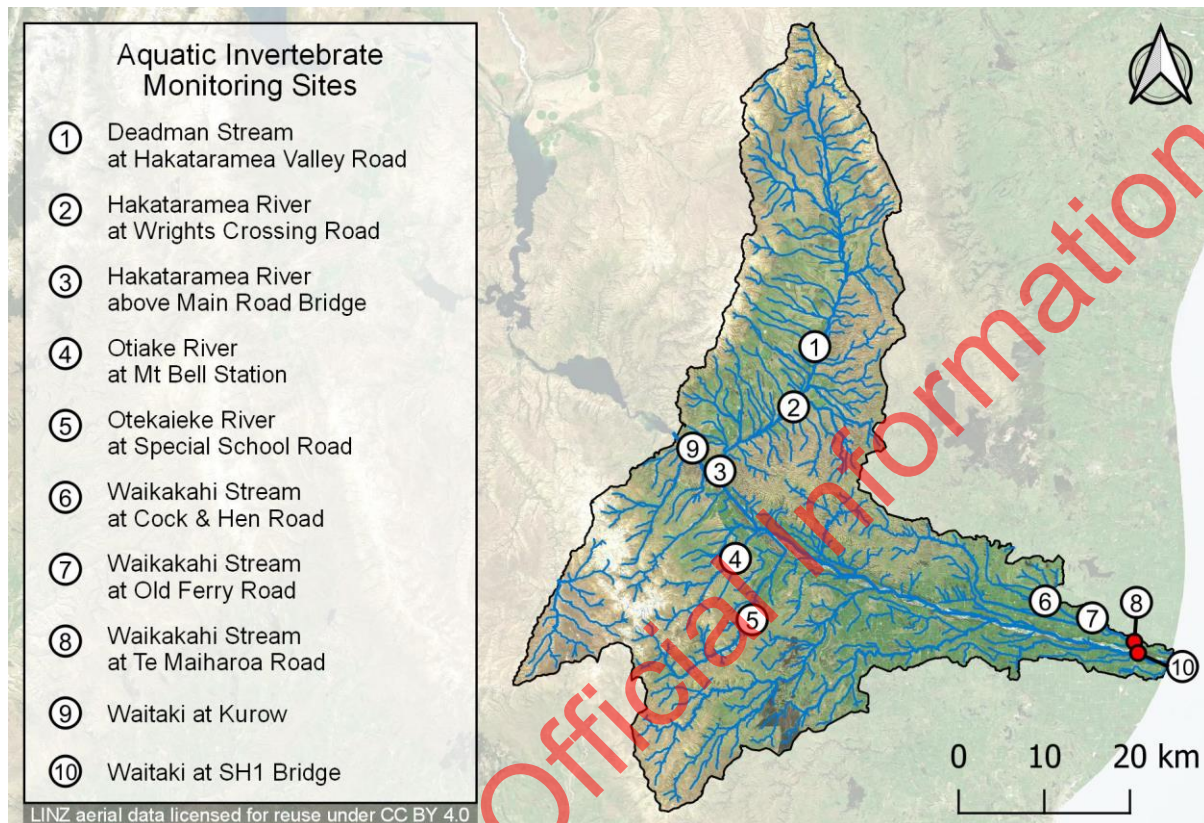


Figure 7: Selected ECan and NIWA annual aquatic invertebrate monitoring sites with data since 2016.

Table 3: Selected aquatic invertebrate metrics from ECan and NIWA monitoring sites. Site No. refers to that displayed in Figure 7. All values are a five-year median for annual sampling over the years 2015–2020, except for Otiake River at Mt Bell Station, for which only three years of data was available. Note that % EPT refers to abundance, unless indicated otherwise.

Site No.	Site Name	MCI	Taxi Richness	% EPT
1	Deadman Stream at Hakataramea Valley Road	71	18	3
2	Hakataramea River at Wrights Crossing Road	94	22	64
3	Hakataramea above Main Road Bridge	98	30	43*
4	Otiake River at Mt Bell Station	97	15	81
5	Otekaieke River at Special School Road	105	24	72
6	Waikakahi Stream at Cock & Hen Road	88	21	12
7	Waikakahi Stream at Old Ferry Road	86	22	14
8	Waikakahi Stream at Te Maiharoa Road	91	26	30
9	Waitaki at Kurow	89	20	41*
10	Waitaki at SH1 Bridge	88	24	38*
	NPSFM 2020 Attribute Bands			
	A	≥130		
	B	≥110 and <130		
	C	≥90 and <110		
	D	<90		

Note: *These sites are reported as % EPT taxa richness.

3.5. Fish

A total of 24 fish species have been recorded in the NZFFD for the Lower Waitaki River catchment (Table 4). Of the 1,504 fish records in the Lower Waitaki River catchment, 68% were from the year 2000 onwards, and all species presented in Table 4 have been recorded since this date. Thus, we expect that this species list is representative of the current fish community in the Lower Waitaki River catchment. The following paragraphs summarise freshwater fish values in the catchment. Detailed species-wise information on the distribution, habitats, ecology, and taxonomy of these species can be found in Bonnett *et al.* (2013a) and Jellyman *et al.* (2019).

The recorded fish community consists of 20 native and four introduced species. Fifteen of these are obligate migratory species, requiring passage to and from the ocean to complete their life cycle. The catchment has high conservation fish values, including four Threatened and nine At Risk species (Table 4; Dunn *et al.* 2018). The most acutely threatened species are Canterbury mudfish and lowland longjaw galaxias, which both have a conservation status

of Threatened – Nationally Critical. Both species are well documented in the catchment, with ongoing management of their populations (see Section 4.1 for details of their management). The other threatened fish species in the catchment are bignose galaxias and lamprey (kanakana), however, there are few records of these species. This likely reflects a very sparse population of bignose galaxias, however, as lamprey are not easily sampled by standard electric fishing methods (the dominant survey method in the catchment), their prevalence in the catchment is uncertain.

Of the Threatened and At Risk fish species present, seven have more than 10 records in the catchment, allowing some understanding of their distributions. These distributions are presented in Figure 8. The most abundant and widespread of these species are the Canterbury galaxias (At Risk; 9.6% of all records; Table 4) and the longfin eel (At Risk; 7.2% of all records). Canterbury galaxias have been recorded across many of the smaller hill-fed tributaries in the catchment, whereas longfin eel appear abundant through the Lower Waitaki River and Hakataramea River mainstems. The remaining Threatened and At Risk species are, by comparison, much less abundant in the catchment, with no individual species accounting for more than 3% of the total fish records.

Records of torrentfish and bluegill bully (both At Risk) are generally restricted to the Waitaki River Mainstem and are more prevalent closer to the ocean. Conversely, records of kōaro (At Risk) are most often found in the Waitaki River mainstem near the confluence with the Hakataramea River, although sparse records of this species exist in the hill-fed tributaries of the catchment. Distributions of both Canterbury mudfish and lowland longjaw galaxias (both Threatened) in the catchment are generally more restricted than the above species. Canterbury mudfish are found only among the riparian ponds on the south bank of the Waitaki River, and in some ponds, wetlands, and water races on the northern side of the Waitaki River mainstem. In the Lower Waitaki River catchment, lowland longjaw galaxias records only occur in the Hakataramea River and, more commonly, its associated hill-fed tributaries.

Introduced salmonids also have a strong presence in the catchment, and the Lower Waitaki River mainstem is regarded as a sports fishery of 'national significance' (O'Neill and Pfluger 2004). The sport fishery consists largely of brown trout, chinook salmon, rainbow trout, and to a lesser extent brook char. These salmonids are both widespread, being found across most habitats in the catchment (Figure 9), and highly abundant, collectively accounting for a total of 32% of all freshwater fish records in the catchment (Table 4).

Table 4: Freshwater fish species recorded in the Lower Waitaki River catchment. General distribution of fish species recorded in the Lower Waitaki catchment, as per the NZFFD (downloaded November 2021). Table ordered by threat status, as defined by Dunn et al. (2018).

Common Name	Scientific name	Threat Status	No. (% of records)	Diadromous	Distribution
Canterbury mudfish	<i>Neochanna burrowsius</i>	Threatened - Nationally Critical	39 (2.59%)	No	Spring-fed and riparian wetlands/ ponds
Lowland longjaw galaxias	<i>Galaxias cobitinis</i>	Threatened - Nationally Critical	19 (1.26%)	No	Hill-fed Tributaries of the Hakataramea
Bignose galaxias	<i>Galaxias macronasus</i>	Threatened - Nationally Vulnerable	2 (0.13%)	No	Hill-fed Tributaries of the Hakataramea

Common Name	Scientific name	Threat Status	No. (% of records)	Diadromous	Distribution
Lamprey	<i>Geotria australis</i>	Threatened - Nationally Vulnerable	4 (0.27%)	Yes	Spring-fed tributaries
Bluegill bully	<i>Gobiomorphus hubbsi</i>	At Risk – Declining	27 (1.8%)	Yes	Waitaki mainstem
Canterbury galaxias	<i>Galaxias vulgaris</i>	At Risk – Declining	144 (9.57%)	No	Upper Waitaki tributaries (incl. Hakataramea)
Inanga	<i>Galaxias maculatus</i>	At Risk – Declining	7 (0.47%)	Yes	Waitaki River mouth
Koaro	<i>Galaxias brevipinnis</i>	At Risk – Declining	24 (1.6%)	Yes	Channelised mainstem downstream of Waitaki Dam and hill-fed streams
Longfin eel	<i>Anguilla dieffenbachii</i>	At Risk – Declining	108 (7.18%)	Yes	Waitaki River mainstem, lowland spring tributaries, and the throughout the Hakataramea catchment
Torrentfish	<i>Cheimarrichthys fosteri</i>	At Risk – Declining	22 (1.46%)	Yes	Waitaki River mainstem
Alpine galaxias	<i>Galaxias paucispondylus</i>	At Risk - Naturally Uncommon	1 (0.07%)	No	Waitaki River Mainstem
Giant bully	<i>Gobiomorphus gobioides</i>	At Risk - Naturally Uncommon	3 (0.2%)	Yes	From Sh1 to mouth
Stokell's smelt	<i>Stokellia anisodon</i>	At Risk - Naturally Uncommon	7 (0.47%)	Yes	Mouth and hapua
Black flounder	<i>Rhombosolea retiaria</i>	Not Threatened	20 (1.33%)	Yes	Mouth and hapua
Common bully	<i>Gobiomorphus cotidianus</i>	Not Threatened	187 (12.43%)	Yes	Throughout
Common smelt	<i>Retropinna retropinna</i>	Not Threatened	25 (1.66%)	Yes	Mouth and hapua
Redfin bully	<i>Gobiomorphus huttoni</i>	Not Threatened	1 (0.07%)	Yes	Lower Waitaki mainstem
Shortfin eel	<i>Anguilla australis</i>	Not Threatened	122 (8.11%)	Yes	Waitaki River mainstem (notably excluded from Hakataramea catchment)
Upland bully	<i>Gobiomorphus breviceps</i>	Not Threatened	255 (16.95%)	No	Throughout
Yelloweye mullet	<i>Aldrichetta forsteri</i>	Not Threatened	7 (0.47%)	Yes	Mouth and hapua
Brook char	<i>Salvelinus fontinalis</i>	Introduced and Naturalised	19 (1.26%)	No	Hill-fed headwaters of Hakataramea
Brown trout	<i>Salmo trutta</i>	Introduced and Naturalised	259 (17.22%)	No*	Throughout
Chinook salmon	<i>Oncorhynchus tshawytscha</i>	Introduced and Naturalised	77 (5.12%)	Yes	Waitaki mainstem
Rainbow trout	<i>Oncorhynchus mykiss</i>	Introduced and Naturalised	125 (8.31%)	No*	Throughout

Notes: Conservation status of native fish is from Dunn et al. (2018). Distribution is based on mapping of the New Zealand Freshwater Fish Database records. *Rainbow trout and brown trout undergo spawning migrations, but do not undertake obligatory sea migrations to complete their life history, unlike the other migratory species listed.

Pressures and knowledge gaps

The spatial distribution of fish in the Lower Waitaki River catchment is generally well understood, through the collective records of the NZFFD, and through the reviews of Bonnett *et al.* (2013a) and Jellyman *et al.* (2019). However, there is little temporal population monitoring in the catchment, and surveys have historically been erratic or qualitative. Establishment of temporal monitoring programs, with robust designs, is essential to identifying, quantifying, and mitigating pressures on freshwater fish values in the catchment. The following paragraphs discuss the key pressures which require remediation actions, or further study. However, without established monitoring programs, the degree of impact these pressures have on fish communities are speculative. The primary pressures in the catchment relate to agricultural intensification, hydro-electric power generation, and native-exotic species interactions.

Agricultural intensification and associated riverbed encroachment has been discussed above in Section 3.2. In addition to habitat encroachment, agricultural land use also places pressure on instream values through various other mechanisms. Inadequate riparian fencing and lack of riparian vegetation cover may increase nutrient and sediment inputs, reduce fish cover via grazing of overhanging vegetation, and reduce shade, resulting in increased water temperatures. Under such conditions, nuisance macrophyte growth is also common. In combination, these effects modify fish habitat, food supply, and community dynamics, ultimately reducing fish abundance and diversity (Hanchet 1990). In the Lower Waitaki River catchment the lowland spring tributaries are likely to be most susceptible to these pressures, owing to the intensity of the surrounding agricultural landuse, low sediment flushing, and low nutrient dilution. These effects are evident in Waikakahi Stream, as discussed above (see Section 3.2).

Water abstraction for irrigation may also reduce the quality and quantity of native fish habitat in the catchment. Lowered baseflows associated with abstraction reduce water depths, limiting habitat (especially for larger individuals), increasing water temperatures, and creating potential for fish passage issues. Abstraction may also place pressure on fish populations directly through fish entrainment into pumps or impingement on ineffective fish screens, as well as indirectly, through the loss of fish from natural systems into intake channels. There are c. 120 surface water takes in the catchment, and to our knowledge, only six have received field validation of their fish screens (Pers. Comm, Dylan Marriot, ECan, February 2022). Therefore, the level of risk for fish entrainment and impingement in the catchment is relatively unknown.

Agricultural intensification is also associated with the installation of instream structures, including weirs and culverts, which may reduce or prevent fish passage and habitat access. By intersecting the road and track lines with river centrelines (Topo50, LINZ data, 2021), we identified approximately 1,500 waterway crossings. Of these crossings, approximately 1,000 involve roads (i.e., mostly public structures) and 500 involve tracks (i.e., mostly private). There have been no recent fish passage assessments of these structures, to our knowledge (NIWA, Fish Passage Assessment Tool data, 2022). Remediation of potential barriers is complicated by the high number of migratory species that may benefit from passage enhancement (Table 4), and the presence of non-migratory native fish species that may be sensitive to predation

and/ or competition, including lowland longjaw galaxias and Canterbury mudfish (O'Brien and Dunn 2008; Ravenscroft *et al.* 2010). Therefore, an understanding of the surrounding fish community must be applied when considering fish passage enhancements in the catchment.

By far the greatest impact on fish passage in the Waitaki catchment is the presence of hydroelectric dams. Waitaki Dam is the most downstream man-made barrier in the Waitaki River mainstem, which separates the 2,300 km² Lower Waitaki catchment from the 9,735 km² Upper Waitaki catchment. An eel trap and transfer program was established by Meridian Energy Ltd in 1998 to reduce the impact of Waitaki Dam on migrating eels. As part of this program, juvenile eels are relocated from below Waitaki Dam, to a variety of locations upstream, averaging c. 4,100 eels per year (Jellyman *et al.* 2019). The transfer program also shifts much smaller number of adult migrants downstream of the dam, with just 1,173 transferred between 2003–14 (Jellyman *et al.* 2019). The level of mortality of downstream migrants at the dam is currently not known, however, NIWA is currently drafting a report on eel mortality at such structures. Quantifying the impact of Waitaki Dam on eel populations is essential to ensuring mitigation and offsetting measures are of an appropriate scale.

Fish habitat availability is reduced by Waitaki Dam, not only through physical obstruction to upstream habitat, but also via modification to the downstream flow regime. Reduced summer baseflow and variable discharges from the dam reduce habitat area, create uninhabitable zones due to lack of water permanence (i.e., varial zone), and may affect fish spawning habitat availability. Inanga, which spawn among riparian vegetation on a spring tide, have been observed to have their eggs washed following large hydro-electric discharges (Richardson and Taylor 2002). Rapid variation in discharges from the dam also create a risk for fish stranding. Overseas studies have found that stranding risk is greatest when hydro-discharges are reduced rapidly (i.e., rapid down-ramping; Nagrodski *et al.* 2012). Under the current Waitaki Dam consent, there is no set ramping rate, allowing rapid reductions in flow. Investigation into impacts of flow ramping at various rates, and salvages of stranded fish, has been integrated into fish management plans for overseas hydro operations (Golder Associates 2020). In the absence of similarly detailed studies in the Lower Waitaki catchment, the effect of fluctuating flow rates on fish stranding is not known.

The final major pressure on native fish values in the catchment is the presence of introduced species. Primarily, this includes the four introduced salmonid species, which are abundant and widely distributed, as discussed above. These species predate on native fish, and also compete for habitat and food resources. The ecological damage caused by these species is conflicted by their recreational value in the catchment, where they are highly valued by sports fishers. A salmon hatchery operates out of Welcome Creek, a tributary of the Waitaki River near State Highway One, run by the Riparian Enhancement Society Inc. The society aims to increase the number of salmon returning to the catchment.

The threat of exotic fish species on lowland longjaw galaxias is well documented (Ravenscroft *et al.* 2010). Three fish barriers have therefore been installed in tributaries of the Hakataramea River to protect lowland longjaw galaxias populations. Exotic macrophytes and algae, such as monkey musk (*Erythranthe guttata*) and didymo (*Didymosphenia geminata*), may also place pressure on lowland longjaw galaxias populations by preventing substrate access, clogging interstitial spaces, and modifying invertebrate food supplies (Ravenscroft *et al.* 2010). Increasing wallaby numbers in the catchment have the potential to reduce habitat quality for lowland longjaw galaxias and other fish species, through increased sediment inputs and reductions to water quality, however, the extent of this threat is likely low in comparison to agricultural pressures.

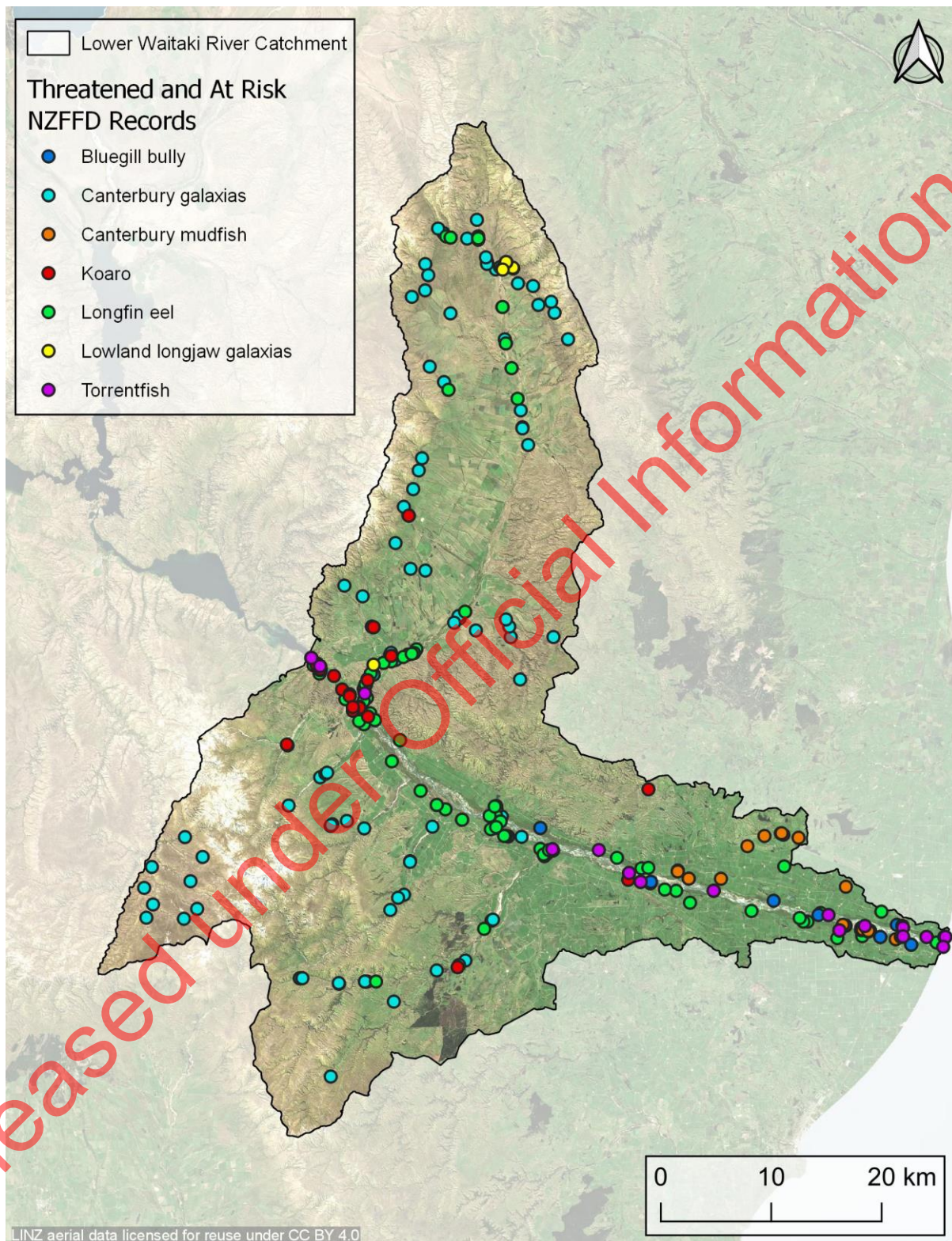


Figure 8: Distribution of Threatened and At Risk fish in the Lower Waitaki catchment (NZFFD data). Note that only species with >10 records are included.

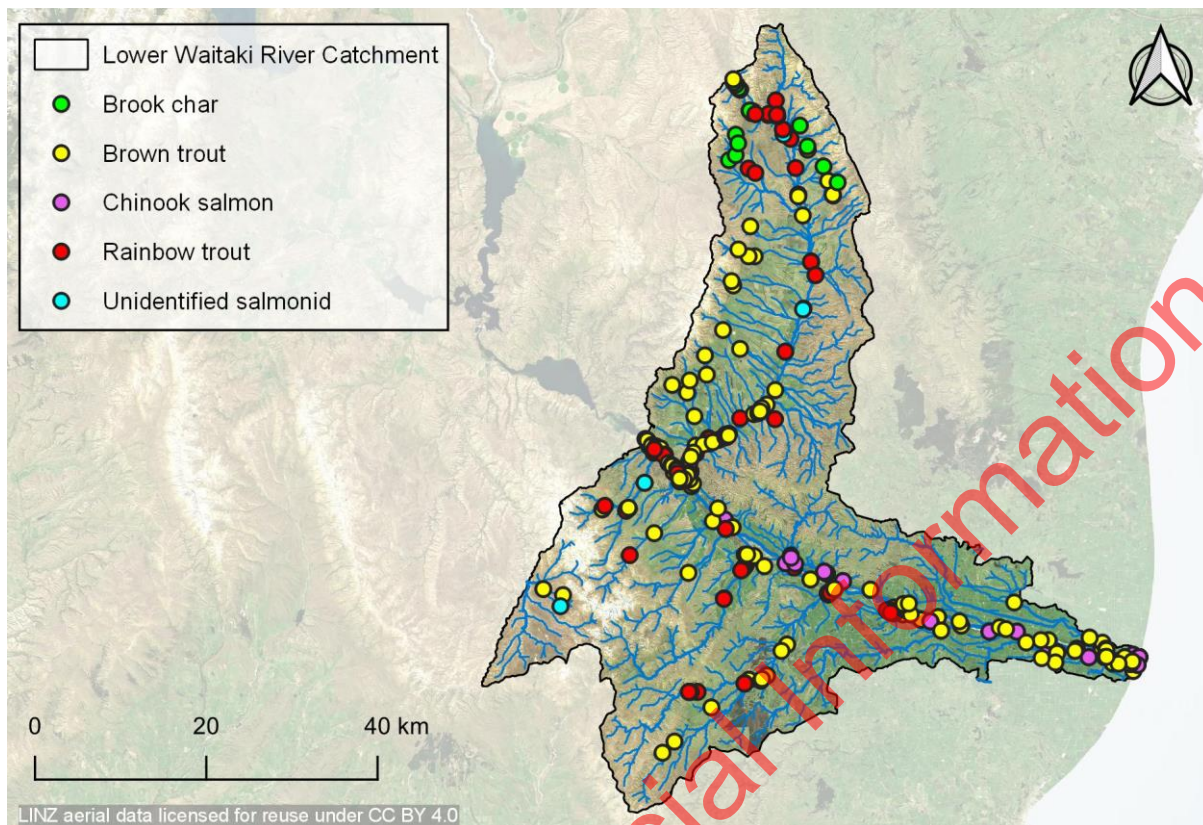


Figure 9: The distribution of introduced salmonids in the Lower Waitaki catchment (NZFFD data).

It is difficult to determine the degree to which exotic species (aquatic and terrestrial) are impacting native fish values in the catchment. However, as with many of the pressures described above, temporal monitoring of fish populations and pressures is ultimately required to identify and efficiently mitigate threats.

In summary, we have identified the following pressures and knowledge gaps as being the key areas of focus to restore and conserve freshwater fish values in the Lower Waitaki River catchment:

- Lack of temporal monitoring of native and exotic fish populations.
- Agricultural intensification and associated impacts on fish habitat availability and quality.
- Hydroelectric dam operation and associated impacts on fish passage, habitat availability, and fish stranding.
- Introduced aquatic fish species increasing predation and competition pressures on native species.
- Introduced macrophytes and algae reducing native fish habitat quality.

3.6. Lizards and Frogs

Six lizard species and two frog species have been recorded in the Lower Waitaki catchment (Table 5). All lizard species have an At Risk – Declining conservation status, except for McCann’s skink (Not Threatened; Hitchmough *et al.* (2021)). Both frog species are Introduced and Naturalised. While none of the native lizard species require aquatic habitats as part of their life cycle, they may all be found near riverbeds or in riparian areas, however, it is often not their preferred habitat (Pers. Comm., Marieke Lettink, Fauna Finders, February 2022). In addition, an abundance of skinks have been reported populating managed bird nesting islands in the Lower Waitaki River mainstem (Pers. Comm. Brad Edwards, DOC, January 2022).

Table 5: Lizard and frog species found in the Lower Waitaki catchment. Data from the Department of Conservation’s herpetofauna database. Table ordered by threat status, sourced from Burns *et al.* (2017) and Hitchmough *et al.* (2021). Records indicates the number of observations for each species, including alive and dead specimens, as well as slough (shed skin).

Common name	Scientific name	Threat Status	Records
Jewelled gecko	<i>Naultinus gemmeus</i>	At Risk - Declining	2
Korero gecko	<i>Woodworthia</i> "Otago/Southland large"	At Risk - Declining	5
Otago green skink	<i>Oligosoma</i> aff. <i>chloronoton</i> "eastern Otago"	At Risk - Declining	7
Southern Alps gecko	<i>Woodworthia</i> "Southern Alps"	At Risk - Declining	104
Southern grass skink*	<i>Oligosoma</i> aff. <i>polychroma</i> Clade 5	At Risk - Declining	24
McCann's skink	<i>Oligosoma maccanni</i>	Not Threatened	71
Brown tree frog	<i>Litoria ewingii</i>	Introduced and Naturalised	1
Southern bell frog	<i>Ranoidea raniformis</i>	Introduced and Naturalised	2

*Note: Formerly northern grass skink (*Oligosoma polychroma*).

Pressures and knowledge gaps

Few surveys of lizards have been carried out around waterways in the Lower Waitaki River catchment. Surveys in the area have generally focussed on high-country areas. There is, therefore, a lack of knowledge around the lizard communities on and around the lowland river beds. While there is little information on lizards in the Lower Waitaki catchment, key pressures on lizard communities are suggested to include introduced predators, human disturbance, habitat loss, and habitat degradation (O'Donnell *et al.* 2016; Lewis and Maloney 2019)

3.7. Birds

In a recent review of the current state of knowledge of freshwater birds in the Waitaki catchment, Hoyle *et al.* (2021) compiled data from the Department of Conservation, Boffa Miskell, two online databases (eBird and iNaturalist), and the grey literature. The review of Hoyle *et al.* (2021) identified 26 freshwater bird species that have been recorded in the Lower

Waitaki River catchment (Table 6). Native species dominate the freshwater bird community in the Lower Waitaki River catchment, accounting for 24 of the 26 recorded species. There are four Threatened species present in the catchment: Australasian bittern, black-fronted tern, Caspian-tern, and the spotted shag (Table 6). In addition, there are a further nine At Risk species.

The distribution of waterbirds in the catchment relates largely to their respective feeding guilds (Table 6). Species within guilds generally also have similar nesting and roosting habitats (O'Donnell 2000). The Australasian bittern is the only swamp specialist in the catchment, and it is also associated shallow side channels and lake margin habitats (Hoyle *et al.* 2021). Australasian bitterns have been recorded in few locations in the Lower Waitaki River catchment, however, their secretive nature makes them hard to detect (Hoyle *et al.* 2021). Their calls have been heard at the Duntroon wetlands, although no direct observations have been made (Pers. Comm., Owen King, Duntroon District Development Association, November 2021). A significant black-fronted tern population is present in the catchment, with the Waitaki River having one of the highest densities of black-fronted tern of any river catchment in the country (O'Donnell and Hoare 2010). Black-fronted terns form loose breeding colonies on the gravel islands of braided rivers, migrating to the coast over the winter (Schlesselmann *et al.* 2018). The gravel islands downstream of Kurow have been well utilised by black-fronted terns for breeding, and have been the subject of a five-year habitat enhancement project (Lewis and Maloney 2020). Both the Caspian-tern and the spotted shag are present in the Lower Waitaki River catchment, with georeferenced records restricted to the mouth of the river (Hoyle *et al.* 2021).

Table 6: Freshwater birds recorded in the Lower Waitaki catchment since 2010, compiled from App. B of Hoyle *et al.* (2021). Underlying data sourced from the Department of Conservation, Boffa Miskell, and two online databases (eBird and iNaturalist). Table ordered by threat status as per Robertson *et al.* (2021). Feeding guild classes, as per O'Donnell (2000): SS = Swamp Specialist, AGT = Aerial Gulls and Terns, OWD = Open Water Diver, SWW = Shallow Water Wader, DWW = Deep Water Wader, RWS = Riparian Wetland Specialist, and DW = Dabbling Waterfowl

Common name	Scientific Name	Threat status	Feeding Guild
Australasian bittern	<i>Botaurus poiciloptilus</i>	Threatened - Nationally Critical	SS
Black-fronted tern	<i>Chlidonias albostratus</i>	Threatened - Nationally Endangered	AGT
Caspian tern	<i>Hydroprogne caspia</i>	Threatened - Nationally Vulnerable	AGT
Spotted shag	<i>Stictocarbo punctatus</i>	Threatened - Nationally Vulnerable	OWD
Banded dotterel	<i>Charadrius bicinctus bicinctus</i>	At Risk - Declining	SWW
Black-billed gull	<i>Larus bulleri</i>	At Risk - Declining	AGT
Red-billed gull	<i>Larus novaehollandiae scopulinus</i>	At Risk - Declining	AGT
South Island pied oystercatcher	<i>Haematopus finschi</i>	At Risk - Declining	DWW

White-fronted tern	<i>Sterna striata striata</i>	At Risk - Declining	AGT
Variable oystercatcher	<i>Haematopus unicolor</i>	At Risk - Recovering	DWW
Black shag	<i>Phalacrocorax carbo novaehollandiae</i>	At Risk - Relict	OWD
Little shag	<i>Phalacrocorax melanoleucos brevirostris</i>	At Risk - Relict	OWD
Royal spoonbill	<i>Platalea regia</i>	At Risk - Naturally Uncommon	DWW
Australasian harrier	<i>Circus approximans</i>	Not Threatened	RWS
Australasian shoveler	<i>Anas rhynchotis</i>	Not Threatened	DW
Black swan	<i>Cygnus atratus</i>	Not Threatened	DW
Grey duck-mallard hybrid	<i>Anas superciliosa x platyrhynchos</i>	Not Threatened	DW
Grey teal	<i>Anas gracilis</i>	Not Threatened	DW
New Zealand scaup	<i>Aythya novaeseelandiae</i>	Not Threatened	OWD
Paradise shelduck	<i>Tadorna variegata</i>	Not Threatened	DW
Pied Stilt	<i>Himantopus himantopus leucocephalus</i>	Not Threatened	DWW
Southern black-backed gull	<i>Larus dominicanus dominicanus</i>	Not Threatened	AGT
Spur-winged plover	<i>Vanellus miles novaehollandiae</i>	Not Threatened	DWW
White-faced heron	<i>Egretta novaehollandiae</i>	Not Threatened	DWW
Canada goose	<i>Branta canadensis</i>	Introduced and Naturalised	DW
Feral greylag goose	<i>Anser anser</i>	Introduced and Naturalised	DW

Pressures and Knowledge gaps

Key pressures on freshwater bird values in the Lower Waitaki catchment relate to hydro-electric power generation, invasive weeds, predation, and human disturbance. The effects of the Waitaki Power Scheme on local bird populations have been reviewed by Whitehead (2021), in a draft report prepared for Meridian, the results of which will be discussed in the paragraphs below.

Hydro-electric power generation may impact downstream bird populations directly, via the destruction of nests during periods of high discharge, or indirectly, through the modification of feeding habitats, nesting habitats, and predator-prey interactions. Species particularly susceptible to these effects are braided river specialists that nest on the river gravels, such as the black-fronted tern. Over a five year study period, flooding was associated 14.5 % of nest failures on monitored black-fronted tern nesting islands (Lewis and Maloney 2020). However, nest flooding is also common in natural, unregulated systems, and similar flooding rates have been recorded in wrybill nests in the Upper Rangitata River (13% nest failure due to flooding; Edwards and Ure 2017). Whitehead (2021) suggests that Waitaki Dam in fact moderates floods, consistent with the hydrological modelling of Stecca *et al.* (2021), which would provide some protection for riverbed nesting species. Furthermore, predicted future Waitaki Dam operating conditions are suggested to have minor effects on spring flows, when nest are vulnerable to flooding (Whitehead 2021). However, physical damage to constructed island breeding habitats has previously occurred during periods of high dam discharge, outside of the nesting period (Lewis and Maloney 2020), resulting in a reduction of available nesting habitat.

Modified flow regimes associated with hydro generation may also impact bird populations through via indirect mechanisms. Artificially high daily flow variability associated with hydro-generation creates varial zones with lower aquatic invertebrate food values for birds (O'Donnell *et al.* 2016). Lowered baseflow may reduce habitat quality and quantity for wading birds, while allowing greater mammalian predator passage onto braided river islands via reduced channel widths (Whitehead 2021). Reduced flood frequency, while potentially lowering rates of nest flooding, encourages vegetation to establish on the fairway, providing greater habitat availability for mammalian predators.

In addition to mammalian predators, native avian predators such as the southern black-backed gull and Australasian harrier place pressure on threatened bird populations. In a study of black-fronted tern habitat manipulation in the Lower Waitaki, black-back gulls were identified as the primary nest predator (Schlesselmann *et al.* 2018). Black-backed gulls are increasingly abundant in the catchment, with their success likely associated with agricultural intensification, abundance of introduced mammalian prey, and anthropogenic food sources (Pers. Comm., Richard Maloney, DOC, November 2021; Whitehead 2021). DOC has previously run black-backed gull control programs around constructed nesting island habitats to reduce predation pressure on threatened bird populations.

The Lower Waitaki River is recognised for its high recreational values, and thus, human activity is common in the waters and on the river beds of the catchment. Vehicles and foot traffic on the riverbed may crush nests and eggs or disturb roosting birds, while jetboats cause flooding of nests (Pers. Comm., Brad Edwards, DOC, January 2022; Hoyle *et al.* 2021). These pressures are especially common at the mouth, where access is easy and recreational values are high. Unfortunately, this recreational activity coincides with highly utilised bird nesting and roosting habitat (Pers. Comm., Richard Maloney, DOC, November 2021).

While the above pressures are acknowledged as the greatest threats to birds in the catchment, lack of temporal monitoring of most species creates difficulties around quantifying their impacts. Furthermore, bird movements among meta-populations are also poorly understood, and thus, so are interactions between potential pressures (Pers. Comm., Richard Maloney, DOC, November 2021).

4. ORGANISATIONS, PROGRAMMES, AND STAKEHOLDERS

4.1. Organisations and Programmes

The following section outlines organisations involved with restoration programmes in the catchment. Bold font is used to indicate the first mention of an existing a programme. Organisations are ordered by their level of activity in the catchment, based on the information available. We note that limited information has been provided on the activities of rūnanga, as consultation with rūnanga was not within our scope.

Department of Conservation

DOC, in collaboration with agencies listed below, have been involved with applied and research-based restoration activities in the catchment. DOC has been heavily involved in a **Braided River Bird Habitat Research and Habitat Manipulation** project, which was initiated in 2016, as part of a doctoral dissertation by Ann Schlesselmann (Schlesselmann 2018). This study was extended by DOC, with additional funding from ECan. These studies assessed the effectiveness of clearing braided river islands to enhance the nesting success of black-fronted terns. The results of these studies indicated that island clearance may be an effective tool at creating island habitats that are use by threatened native birds for nesting, however, control of black-back gull populations is essential to enhancing nesting success (Schlesselmann *et al.* 2018; Lewis and Maloney 2020).

DOC has also been involved in the management of two threatened fish species in the catchment, **Canterbury Mudfish Populations of the South Bank**, and the lowland longjaw galaxias. DOC's involvement with the South Bank Canterbury mudfish populations has included funding a management strategy report (O'Brien and Dunn 2008), populations surveys (Department of Conservation 2014), and providing support and funding to the Lower Waitaki River Management Society Inc (LWRMS), who were in control of the management of this population from 2015–2020 (Lower Waitaki River Management Society Incorporated 2020). While under the management of the LWRMS, most of the South Bank ponds were fenced off, native plants were established, weeds were maintained, and water quality assessments were made. Funding of these actions was provided by DOC, ECan, Ministry for Business Innovation and Employment, and the Waitaki District Council. Management of this population has now been passed back to DOC.

DOC, with supporting funding from ECan, has been managing the **Lowland Longjaw Populations of the Hakataramea Headwaters**. Management of these populations has included the development of a lowland longjaw galaxias management plan (including Lower Waitaki populations and beyond; Ravenscroft *et al.* 2010), installation of three trout barriers (two in Cabbage Tree Gully and one in Nessing Stream), and removal of trout above barriers (Pers. Comm., Dean Nelson, DOC, February 2022). Mr Nelson has also been investigating the use of aquatic-friendly herbicides for macrophyte control around lowland longjaw habitats.

Environment Canterbury

ECan is highly involved with restoration in the catchment, through both direct activities, and through collaboration and funding of restoration projects. ECan currently spend \$200,000 p.a. on **Fairway Weed Control**, allowing for a 3-year rotational cycle of aerial spraying. In addition, ECan has carried out extensive **Riverbed Weed Control in the Upper Hakataramea** valley (ongoing, c. \$250,000 spent to date), as well as carrying out a programme of **Weed Control**

and Fencing at Wetlands (c. \$100,000 spent to date). In 2020, ECan received \$15.5 million in central government funding for flood protection measures under the 'shovel-ready' fund. **River Erosion Remediation** works were proposed at 13 sites by ECan in 2020, however, we are unsure what stage these works are at.

ECan collaborated with DOC on three restoration programmes (described above; Pers. Comm., Kennedy Lange, ECan, December 2021), providing funding for the management of the Canterbury Mudfish Populations of the South Bank (\$30,000 funded), Braided River Bird Habitat Research and Habitat Manipulation (\$90,000 funded), and installation of Fish Barriers at Lowland Longjaw Sites (\$13,000 funded).

In collaboration with NIWA, ECan is also working on a **Braided River Mapping and Monitoring Programme**. This project aims to monitor braided rivers in the region, both for extent (mapping) and condition (on the ground; Pers. Comm., Helen Greenep, ECan, November 2021). Their goal is to monitor two rivers per year, on a 5–10 year cycle.

ECan recently carried out a **Hapua Fish Survey**, with the support of Fish & Game, as part of a multi-river assessment of hapua fish populations. At the time of writing, the hapua survey had been completed, but the data had not been analysed and written up.

ECan has also worked closely with many of the organisations, and funded many of the projects, discussed below.

Fish & Game

The key values of Fish & Game include sports fish populations and their spawning, game bird species, and braided river natural character (Pers. Comm., Angela Christensen, Fish and Game, November 2021). While their restoration activities aim to enhance habitat for species relevant to these recreational values, their actions are also likely to improve habitat for native species. To date, their restoration programmes have included **Side Braid Enhancement for Salmon Spawning** (including willow removal), Weed Spraying, and **Waikakahi Stream Restoration** (including riparian planting, fencing, and monitoring). Central South Island Fish & Game are also running a **Study of Fish Passage and Water Depth** in the Hakataramea River. This study is modelling tributary inflows to better understand the relationships between flows, water allocation, and sport fish passage. Fish and Game also have a consistent presence in RMA matters, seeking better environmental outcomes (Pers. Comm., Angela Christensen, Fish & Game, November 2021).

Fish & Game also assisted ECan with the recent Hapua Fish Survey.

Rūnanga

As engagement with local rūnanga was beyond the scope of the current report, there is limited information on their restoration work in the catchment. We are aware that Te Rūnanga o Moeraki carrying out a **Restoration and Predator Control Programme** in the Lower Waitaki catchment, including work at the mouth and Borton Pond.

Arowhenua, Moeraki and Waihao rūnanga also work with Meridian Energy Ltd on their **Eel Trap and Transfer Programme**. This programme was established in 1998 and has been transferring juvenile eels (averaging c. 4,100 per year; Jellyman *et al.* (2019)) from below Waitaki Dam to several locations in the Upper Waitaki catchment. A small number of migrant adult eels (averaging <100 individuals per year; Jellyman *et al.* (2019)) are also transferred

from the Upper Waitaki catchment, to below the Waitaki Dam. Monitoring of this project has previously been completed by NIWA (Boubée and Boubée 2014).

Lower Waitaki River Management Society Incorporated

Management of the **Canterbury mudfish populations of the South Bank** was carried out by the Society from 2015–2020, supported by DOC (described above). Management of the mudfish habitats has now been handed back to DOC, and the Society moving towards dissolution (Pers. Comm., Ian McIlwraith, Lower Waitaki River Management Society, November 2021).

Kurow Island Restoration Group

This group lead the **Kurow Island Restoration Project**, which was previously a council landfill (decommissioned in 1996). The restoration involved the removal of exotic weeds (broom, gorse, and willows), planting of native plants, installation of a boat ramp and shelter, and a nature and history learning trail, including signs providing education about the environment. The project was supported with funding from Meridian Energy Ltd, with Waitaki and Waimate district councils each contributing yearly funding for maintenance (\$14,000 total). DOC also provided support, including native plants, and providing text and images for signage. The project drew high levels of community engagement, with much of the work completed via working bees.

Duntroon and District Development Association

This association lead the **Restoration of the Duntroon Wetland**. This project involved the removal of willows, native plantings, and the creation of paths. The Alps to Ocean cycling route also now passes through the wetland. The project has been supported with funding from Meridian Energy Ltd, ECan, and Fonterra. Adjacent farmers also allowed for the wet areas of their paddocks to be included, contributing 75% to the wetlands 40,000 km² size. The project has had strong community input, including school planting days and monthly working bees.

Meridian Energy Ltd

In addition to running the Eel Trap and Transfer Programme, Meridian has funded various projects in the catchment, including the Restoration of the Duntroon Wetlands and the Kurow Island Restoration Project.

Hakataramea Sustainability Collective

Established in 2017, the Hakataramea Sustainability Collective is a relatively young organisation in the catchment. This organisation aims to protect and enhance the Hakataramea Valley environment, and to encourage sustainable farming practices. The Collective has not yet carried out any projects that could be considered aquatic restoration, however, many of their values are well aligned with those of DOC. They wish to see the removal of riverbed weeds in the Hakataramea valley and increased predator control. Their future ambitions include a School Biodiversity Project (running a nursery with local children and teaching about planting and water quality), and an Environmental and Ecological Data Collation Project to inform plans and increase agricultural sustainability. Currently they work closely with ECan and the district council, however, they are interested in building a working relationship with DOC (Pers. Comm., Juliet Gray, Sarah Elliot, Hakataramea Sustainability Collective, December 2021).

Irrigation New Zealand

Irrigation New Zealand is currently running an national **Adoption of Good Practice Fish Screening Project**, including a site in the Awakino River. This project aims to create more effective fish screening at irrigation intakes, through the development of more efficient screens, and by providing guidance on appropriate fish screen installation.

The Lower Waitaki South Coastal Canterbury Water Zone Committee

The Committee works closely with ECan, providing recommendations for waterway management. This includes recommendations around water quality and quantity, which have been incorporated into the LWRP. The Committee also provides recommendations on environmental actions that are carried out by ECan.

The Braided Rivers Action Group and the BRIDGE project

The Braided Rivers Action Group (BRAG) was established by ECan in 2017, in response to rising public concern over land management around braided rivers. The Group consists of representatives from ECan, Te Rūnanga o Ngāi Tahu, DOC, LINZ, Federated Farmers, Forest & Bird, and territorial authorities (Instream Consulting 2019). The purpose of this group is to maintain the natural character of Canterbury's braided rivers, improve adjacent land management through identification of innovative and regulatory opportunities, and to prioritise and implement changes in a consistent manner. To our knowledge, there has not been any project run by the group focussing specifically on the Lower Waitaki River catchment.

The BRIDGE project was also initiated by ECan, with the purpose of clarifying rules around braided riverbeds, by defining the geographical extent over which riverbed rules apply. In October 2019, the Court of Appeal upheld a High Court decision on the definition of a 'riverbed' in the case of Dewhirst Land Company vs Canterbury Regional Council. This decision contradicted how ECan had previously been rules around riverbed extents. In the light of this decision, and the associated legal uncertainties, the BRIDGE project was put on hold. Since this decision, there has been no progress towards remedying these uncertainties, and thus, no improvement to the protection of braided river extents. In the Lower Waitaki River catchment, this has resulted in the ongoing encroachment of agricultural land use into the braidplain (See Section 3.2).

4.2. Stakeholders

Meridian Energy Limited

Meridian Energy is a major and influential stakeholder in the Lower Waitaki River catchment. In this report we have identified that the operation of Waitaki Dam has modified the natural character of the braided river and associated habitats, placing pressures on many native and threatened taxa. With the dam consent set to expire in 2025 (Consent CRC180721), this presents a rare and important opportunity for DOC to assess the ecological impacts the dam, and to evaluate if current mitigation measures are sufficient to offset these impacts.

River ratings group

The river ratings group includes all landowners adjacent to the Lower Waitaki River. This group incurs targeted rates, which are used to fund ECan's erosion and flood control projects. As discussed above, agricultural encroachment is one of the key pressures on the Lower Waitaki

River. Working with the river ratings ground, and ECan's flood and erosion management team, is essential to reducing and reversing encroachment on the river.

Waitaki Irrigators Collective

The Waitaki Irrigators Collective was established in 2010, and includes all five irrigation schemes in the Lower Waitaki catchment, as well a society of independent irrigators. The Collective is very enthusiastic to engage with DOC, and to foster a working relationship (Pers. Comm., Fraser McKenzie, Waitaki Irrigators Collective, Independent Chairman, December 2021). The Collective believes that they need to be accountable and responsible for any impacts caused by their operations and intend to focus on identifying protecting critical source areas from nutrient and sediment runoff. They have also acquired "Know Your Catchment" from Irrigation New Zealand, a dashboard that collates water quality information and makes it accessible to the public. They are aware that stakeholders in the catchment are frustrated with the current use of biodiversity funding, with a lack of focus on creating measurable changes to biodiversity and water quality.

Building a relationship with the Waitaki Irrigators Collective could be very beneficial to helping DOC achieve positive biodiversity outcomes in the catchment. They have strong relationships with landowners on both sides of the river and operate across district boundaries. They could be very useful in facilitating land access to carry out restoration actions, and provide a good point of contact for communication with the local agricultural community.

The Waitaki Riparian Enhancement Society

The Waitaki Riparian Enhancement Society was formed in 2010, and consists of a group of more than 240 local fisherpersons who are concerned about the declining salmon numbers in the catchment. The Society runs a volunteer salmon hatchery from which they release smolt, with the aim of increasing the number of wild salmon in the catchment. While introduced salmonids place pressure on native fish species, their recreational value in the catchment cannot be overlooked. They wish to see an improvement in the habitat and water quality of the Lower Waitaki River's spring-fed waterways (Pers. Comm. Linn Koevoet, Waitaki Riparian Enhancement Society, November 2021), creating a point of common interest between recreational and conservation values.

5. OPPORTUNITIES AND RESTORATION PRIORITIES

5.1. Introduction

Restoration actions need to address the pressures on conservation values and fill knowledge gaps. As outlined in Section 3 above, key pressures on conservation values include:

- **Hydroelectric dams**, including impacts on flow regulation, fish passage, and river geomorphology.
- **Agricultural intensification**, including braided river encroachment, increased sediment and nutrient inputs, water abstraction, and reduced fish passage.
- **Introduced predators and weeds**, including direct impacts on native species through predation, and reductions in the quality of native bird and fish habitats.
- **Flood and erosion protection**, preventing natural geomorphological processes and thereby reducing braided river habitat extent.

- **Knowledge gaps**, the most significant of which is a general lack of temporal monitoring across all taxa.

The following sections outline what we consider to be the key opportunities and potential actions for DOC, to address these pressures, fill these knowledge gaps, and restore aquatic values in the catchment.

5.2. Opportunities

There are many potential opportunities for restoration within the Lower Waitaki River catchment, as outlined further below. However, the greatest priority should go towards working with key stakeholders and mana whenua to create a mutual understanding of values, identifying overlaps and conflicts. Through this process, a more unified approach to restoration in the catchment may be achieved, for the benefit of all. Specific opportunities for aquatic restoration in the catchment include:

- **Waitaki Power Scheme consenting**, which provides an opportunity to negotiate the terms under which Waitaki Dam operates, to minimise impacts on downstream aquatic values. It is also a time to evaluate what level of ecological offsetting is appropriate given the scale of these impacts. This might include considering an alternative whole-of-river, multi-value and inclusive approach to river management in the long term. An example of this is the Water Use Planning framework that BC Hydro power schemes operate under in the province of British Columbia in Canada (Scodanibbio 2011)
- **Working with the Waitaki Irrigators Collective**, who create a unique opportunity to liaise with the entire agricultural community across the catchment. A strong relationship with this community will be instrumental to carrying many of the restoration actions described below, and the Collective may be able to facilitate this relationship. Initial conversations indicate considerable interest of the Collective to be involved with restoration within the catchment.
- **Working with ECan**, especially with flood and erosion management programmes. There is a large amount of overlap between the agency's objectives, relating to riverbed weeds and riparian management. The recent update to the NPSFM (2020) also requires ECan to take carry out numerous actions relating to management of freshwater environments. Collaboration on these actions may allow for enhanced biodiversity outcomes and provide opportunities for cost sharing. ECan also hold consents and capabilities which may increase the efficiency of many of the restoration actions listed below.
- **Working with local rūnanga**, who are already active in the district, and have strong relationships with key stakeholders in the catchment.

5.3. Restoration Priorities

5.3.1. Filling Knowledge Gaps

- **Temporal monitoring.** There is currently very little temporal monitoring in the catchment, across both native and exotic taxa. Catchment-wide monitoring programs, with robust designs, will allow for current baselines to be established and for adaptive management restoration activities. Freshwater fish and bird species are a priority, with many threatened

species in the catchment, and many identified (but not quantified) pressures. Of lower priority are lizards and terrestrial invertebrates, as there are few known species of these taxa in the catchment that rely on aquatic habitats. Monitoring may involve yearly surveys for the first three years, with five-yearly surveys thereafter. There is an opportunity to work with ECan on establishing hapua monitoring, where they have just completed a fish survey (Pers. Comm., Duncan Gray, ECan, November 2021).

- **Wetland surveys.** While many wetlands have been mapped in the catchment via aerials, a much smaller portion have been ground-truthed. Surveys of these wetlands would identify ecological values and pressures, which may in turn be used to prioritise restoration actions. There is an opportunity to work with ECan on this, as regional councils are required to identify, map, and maintain an inventory (including collation of existing monitoring data) for all wetlands over 500 m², by 2030 (NPSFM, Ministry for the Environment (2020); Clause 3.23(1) & 3.23(5)a).
- **Waitaki Dam fish impact studies.** Many of the pressures of the Waitaki Dam operation on native fish communities are unquantified. Topics requiring research include: the mortality of downstream migrant eels through the turbines, hydro-ramping and its relationship with fish stranding, and the impact of flow modification on fish spawning.
- **Fish passage study.** Potential barriers to fish passage have not yet been identified in the catchment. A programme to prioritise potential barriers for assessment and remediation could be established to enhance native migratory fish passage. Given the widely distributed salmonids in the catchment, and the various predation sensitive native fish species, fish community surveys should be carried out around potential barriers as part of the remediation prioritisation process. There are opportunities to work with ECan on this, as regional councils are required to identify, evaluate, and prioritise instream barriers for remediation (NPSFM, Ministry for the Environment (2020); Clause 3.26(7)). The Waitaki Irrigation Collective may be able to liaise with farmers to provide access to private structures.
- **Fish screen survey.** Many of the catchments surface water takes have not been field assessed for fish screen efficiency and may be impacting native fish through impingement and entrainment. ECan holds a database of the screens that have been field and desktop assessed (Pers. Comm. Dylan Marriot, ECan, February 2022).
- **Lowland longjaw galaxias survey.** A survey of the Hakataramea catchment could be carried out (as recommended by Ravenscroft *et al.* (2010)) to identify additional strongholds for this species. A catchment-wide eDNA survey may provide an efficient way to detect populations. Follow-up electric fishing surveys would provide further information on identified populations, which could inform restoration activities.
- **Canterbury mudfish monitoring and surveys.** Better understanding of these populations may be achieved with ongoing population, water level, and water quality monitoring. Beyond the managed ponds on the south bank, the distribution of Canterbury mudfish in the catchment is poorly understood. A one-off targeted survey of the catchment may be useful to identify strongholds and potential populations for management and monitoring. This survey could extend along the south bank, across similar habitats as the known populations, as well as following-up on NZFFD records of mudfish on the northern side of the river.
- **Study of climate and landuse change on fish.** A study of the potential future threats from these pressures could be carried out, with a focus on sensitive species. Lowland longjaw and Canterbury mudfish can be considered sensitive to these pressures, as their distribution is extremely patchy, and they have a low ability to colonise new habitats in

response to changing environments. This could be suitable as a PhD thesis topic, and funding a student may be a cost effective way of acquiring a high level of information.

- **Threatened fish spawning surveys.** Both inanga and lamprey have been recorded in the catchment, however, there has been no recent investigation into their spawning habitats. Inanga spawning habitat has been modelled to be available in the hapua and a one-off survey could identify whether it is being utilised, and whether enhancements can be made. The impacts of daily flow variability associated with dam discharges, and the impacts on inanga spawning are also not known, presenting a potential area of research. A catchment wide survey for lamprey could also be carried out to identify and protect habitats. Pheromone samplers are a tool that have been used to effectively track lamprey spawning in the past (Baker *et al.* 2019), and could be implemented in the Lower Waitaki catchment.
- **Study of bird movements between meta-populations.** A study of bird movements within the catchment could be carried out to achieve a more complete, catchment wide, understanding of pressures and their management (Pers. Comm., Richard Maloney, DOC, November 2021). This study could involve using tracking tags to track the movements of key conservation and predator species. Conservation species of interest are black-fronted tern, banded dotterel, white-fronted tern, South Island pied oystercatcher, pied stilt, and black-billed gull. Predatory species of interest are black-backed gulls and Australasian harrier. Study would need to run over three years to get useful data (Pers. Comm., Richard Maloney, DOC, November 2021).
- **Terrestrial invertebrate survey.** There has not yet been a systematic survey of terrestrial invertebrates in the catchment. A one-off survey could identify if there are any significant values present and identify potential pressures. A survey of terrestrial invertebrates could involve sampling transects at 5 km intervals in the riparian areas of the Lower Waitaki River, over its length (Pers. Comm., Warren Chinn, DOC, February 2022).
- **Lizard survey.** While several At-Risk species have been recorded in the catchment, there has not been a catchment scale survey of the aquatic environments. A one-off survey could identify lizard conservation values, and identify which habitats, if any, are highly utilised by threatened species.

5.3.2. Restoration Actions

- **Fairway weed control.** Work with ECan to increase the intensity of fairway weed control. ECan currently spend \$200,000 p.a. (with contributions from the river ratings group) to control fairway vegetation via aerial spraying, which achieves a 3-year rotation. Spraying intensity could be increased to cover the entire fairway on a yearly basis. Mechanical removal and mulching in areas of dense woody vegetation, but is limited by the access requirements of the machinery (i.e., cannot cross deep channels).
- **Waitaki Power Scheme reconsenting discussions.** Discussions with Meridian could be undertaken to create a better mutual understanding of the economic and hydrologic constraints of the dam's operation, and to identify where flows may be manipulated to enhance or protect downstream ecological values.
- **Fencing and riparian planting.** Much of the catchment's spring-fed waterways and wetlands have inadequate fencing and riparian vegetation to buffer against the surrounding agricultural landuse. A yearly fencing and planting fund could be used to remedy this, starting with a study to identify priority reaches. ECan has been carrying out

a wetland fencing and planting programme, spending c. \$100,000 to date (Pers. Comm. Kennedy Lange, December, 2021). This presents an opportunity for cost sharing.

- **Prevention and reversal of agricultural encroachment.** Historic and ongoing encroachment of agricultural into the braidplain threatened riparian and aquatic ecological values. Lease modifications and land trades could be made to secure ecologically valuable land in this area. Following up on the issues and recommendations of the Environment Canterbury (2019) Authorisation Summary report is a priority. As identified by Environment Canterbury (2019), there are opportunities for cross agency support with land authorisation issues.
- **Berm vegetation transition from exotic to native.** This would require close collaboration with ECan's flood protection programs, to achieve mutual gains. Lessons may be drawn from ECan's Waimakariri River Corridor project (Environment Canterbury n.d.), to achieve greater efficiency when creating native habitats.
- **Securing land behind the hapua.** Securing the (currently private) land behind the hapua would ensure that this habitat is protected and that natural coastal processes including coastal erosion are allowed to continue. This is land of high ecological value, providing habitats for all native taxa, and also has potential for inanga spawning. On the south side of the river, the landowners have expressed interest in a land swap, which is currently at the proposal stage (Pers. Comm., Brad Edwards, DOC, January 2022).
- **Wetland enhancement fund.** A fund could be allocated to address pressures identified during wetland surveys (above) and existing known pressures. This could include a prioritisation project, to identify which wetlands and conservation actions would achieve the most efficient ecological outcomes. There are opportunities to work with ECan on this, who have already spent c. \$100,000 on wetland restoration in the catchment (Pers. Comm., Kennedy Lange, December 2021).
- **Fish barrier remediation.** Remediation of barriers identified as priority during the fish passage study (see Section 5.3.1)
- **Trout barriers at lowland longjaw galaxias sites.** Further trout barriers could be installed in priority waterways, identified during the lowland longjaw galaxias survey (See Section 5.3.1). Additional management of identified populations would likely include removal of invasive macrophytes and trout. Farm access for surveys may be facilitated by the Waitaki Irrigators Collective.
- **Canterbury mudfish management.** Ongoing maintenance of the ponds on the south bank is required to prevent the invasion of exotic weeds (Pers. Comm., Daniel Jack, DOC, February 2022). Daniel advocates for the transition of exotic vegetation to native vegetation around these areas. Willow removal and further plantings could enhance and extend this mudfish habitat.
- **Threatened bird habitat island construction and maintenance.** Lewis and Maloney (2020) demonstrated that island clearance is an effective tool for enhancing threatened aquatic bird habitats in the Lower Waitaki River. Bird populations would likely benefit from the creation of further vegetation free islands. Learning from this previous study, these island habitats may be created more efficiently, with a focus on using existing gravels, building up natural islands, and increasing channel sizes between islands and their banks (Pers. Comm., Brad Edwards, DOC, January 2022). For these islands to succeed, it is essential that nearby black-backed gull populations are controlled, and that the islands are maintained for weeds (Pers. Comm., Richard Maloney, DOC, November 2021). While Lewis and Maloney (2020) suggested this could involve helicopter and knap-sack

spraying, Brad Edwards believes knap-sack spraying is logistically inefficient due to the limited access, and that with clear instruction to contractors, helicopter spraying should be sufficient to keep islands clear.

- **Predator control.** Native taxa, including birds, lizards, and terrestrial invertebrates would likely benefit from increased predator control in the catchment. While control of exotic mammalian predators would ease pressures on all taxa, enhanced black-back gull control is a very high priority for protecting the threatened bird species that nest on the braided river islands (Pers. Comm., Richard Maloney, DOC, November 2021). There are opportunities for support from ECan, who have previously collaborated on black-back gull control programs in other catchments.
- **Reducing human disturbance of native birds.** A program of public education could be implemented to raise public awareness of activities that may be detrimental to native bird populations, and areas / seasons where birds are most sensitive to human disturbance. This may involve community engagement via meetings, educational signage, fencing around nest areas, and rangers on the ground areas with high levels of human activity. The river mouth would be a particular focus of this program, drawing a lot of human activity and with many birds roosting and nesting in this habitat (Pers. Comm., Richard Maloney, DOC, November 2021). Vehicle access at the river mouth could be restricted, as has been enacted in other districts, however, this would require a coastal plan change (Pers. Comm., Alex MacDonald, DOC, January 2022).

6. CONCLUSIONS

The Lower Waitaki River catchment includes internationally rare braided river habitat, wetlands, hill-fed tributaries, and river mouth habitat of regional significance. These freshwater habitats support numerous native species of conservation interest, including: six At Risk plant species; four Threatened and nine At Risk fish species; and four Threatened and nine At Risk bird species. Key pressures on these conservation values include hydroelectric dams, agricultural intensification and encroachment, introduced predators and weeds, and flood erosion and protection. However, numerous knowledge gaps exist regarding the distribution of Threatened and At Risk species, and there is minimal long term monitoring of their populations. Thus, there is considerable uncertainty about the degree of impact current pressures exert on conservation values, and even less is known of their long-term outlook.

Engaging with key stakeholders and mana whenua is an important first step towards protecting and restoring conservation values within the Lower Waitaki River catchment. Following engagement with stakeholders and mana whenua, restoration priorities can be broadly grouped into filling knowledge gaps and specific restoration actions. Filling knowledge gaps with a range of surveys, monitoring, and other studies would provide a better understanding of the current state and trends in conservation values within the catchment. It would also create baselines which restoration successes can be quantified against. Successful undertaking the identified priority restoration actions would see ultimately see a halt to the decline of threatened braided river habitats and species, and an increase in their extent and state.

The extent to which the Lower Waitaki River catchment is restored ecologically will depend on social, cultural, and economic considerations. However, if there is engagement and collaboration with stakeholders and mana whenua, then it is reasonable to envisage a future catchment where ecological pressures have been substantially reduced and offset. This would

be associated with enhanced ecosystems that support healthy populations of native species that are resilient to future pressures such as climate change.

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The cover photograph is by John Bisset of Stuff (www.stuff.co.nz)

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