Rangitata River Catchment Conservation Values

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1. INTRODUCTION

The Department of Conservation (DOC) recently identified 14 new “stretch goal” sites across New Zealand as priorities for freshwater conservation. The priority sites were selected at a national level based on representation and protection of the conservation values present and taking into account current levels of protection. Preferred criteria for stretch goal sites included: intact headwaters (facilitating “mountains to sea” conservation); contain lowland reaches of residual value; representative important ecosystem types; engaged communities and DOC staff; and “fixable pressures” that can be restored. In the eastern South Island management area there are two existing stretch goal sites: Ō Tū Wharekai in the Ashburton Lakes and upper Rangitata River, and Project River Recovery, in the upper Waitaki River. The two new sites in the eastern South Island are the Rangitata River catchment and the lower Waitaki River catchment.

A new role has recently been established within the DOC Operations team in Geraldine and a significant part of their focus will be on the Rangitata River catchment. They will work with relevant agencies to develop a restoration plan aimed at improving the Rangitata’s ecological integrity and resilience, with an emphasis on biodiversity restoration. To support the new role, DOC contracted Instream Consulting to undertake a preliminary information gathering exercise.

This report summarises conservation values, issues, and priorities for protection and action within the Rangitata River catchment. The report purpose is essentially to provide a quick reference guide and an overview of current work happening for DOC staff developing the catchment restoration plan. The information presented here is based on a considerable wealth of existing review reports and bibliographies, to which the reader is referred to for further details. In addition, the report author, Dr Greg Burrell, interviewed people from various agencies to obtain further information (see Section 6). The scope did not include iwi consultation, as this will be done by DOC staff.

2. CATCHMENT OVERVIEW

The headwaters of the Rangitata River arise from the eastern slopes of the Southern Alps / Kā Tiritiri o te Moana. The Havelock and Clyde rivers are the two major tributaries draining the Southern Alps that converge to form the Rangitata River (Figure 1). Other major tributaries include the Lawrence and Potts rivers, while smaller tributaries include Bush Stream and Forest Creek. These rivers all flow through mountainous country, before coalescing in a broad alluvial inter-montane basin. This basin includes the iconic Mesopotamia, Erewhon and Potts high country stations, which have historically been grazed as sheep and beef cattle farms. Further downstream, the river narrows into the Rangitata Gorge, which includes major rapids that are regularly paddled by rafters and kayakers. The gorge divides the river into distinct upper and lower reaches: the upper reach is defined by its mountainous backdrop and low intensity farming, while the lower reach traverses the flat Canterbury Plains that have become the focus of more intensive dairy farming over the last 20 years. No major tributaries join the river downstream of the gorge and the river flows into the Pacific Ocean approximately 30 km northeast of Timaru.

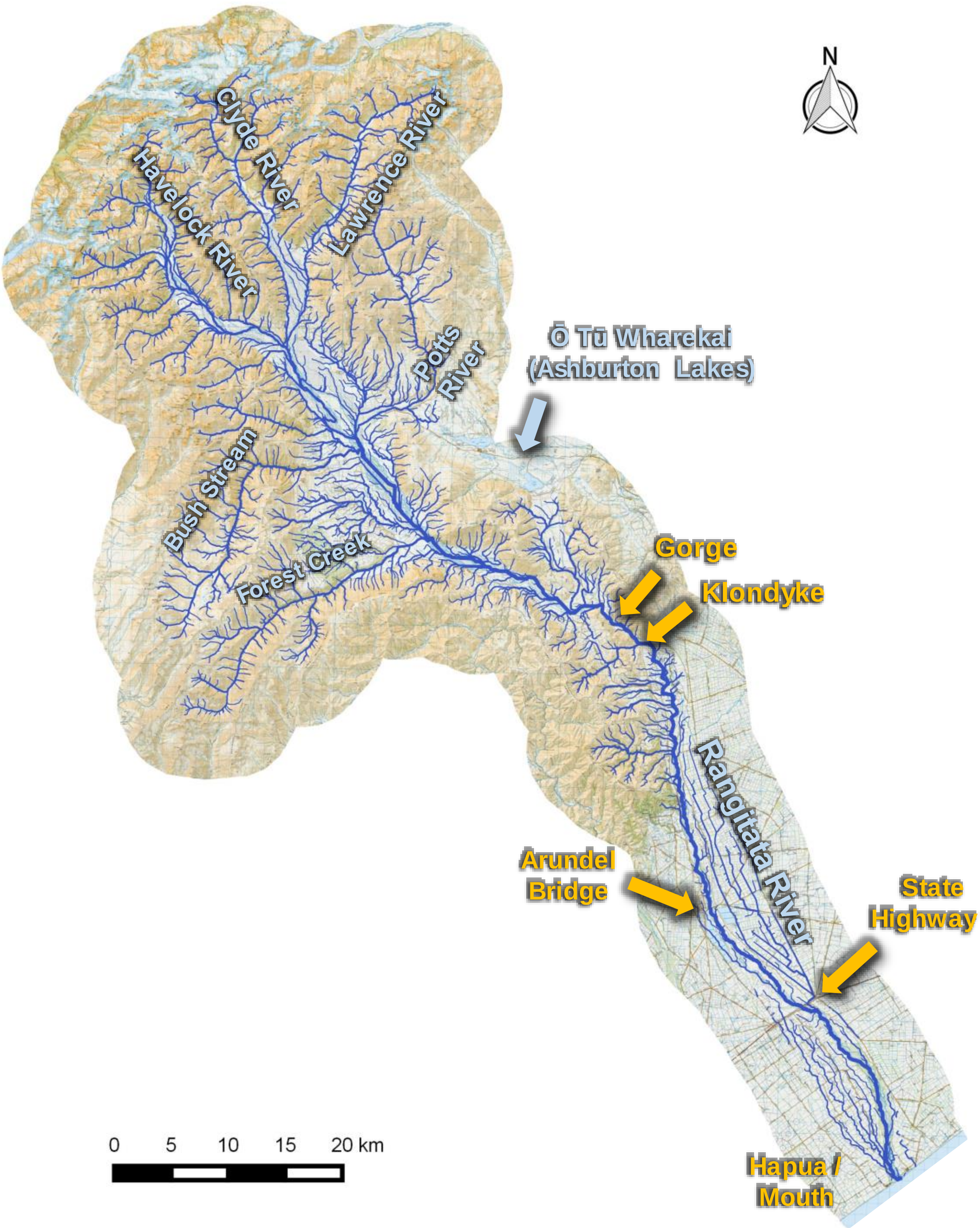

Figure 1: Rangitata River catchment. Topographical data are from the LINZ Data Service and licensed for reuse under the CC BY 4.0 licence.

A distinctive feature of the Rangitata River is its braided channel morphology. Braided rivers are *"characterised by a number of alluvial channels separated by bars and islands that look from the air to have the intertwining effect of a braid"* (Gray et al. 2016). These intertwining braided channels with unstable, shifting gravel beds carry most of the river's flow, but there are numerous other important aquatic habitats that occur throughout the river. At the head of the catchment, steep mountain streams such as the upper reaches of the Potts River are high-energy environments, characterised by frequent floods and consequently they have unstable gravel beds that support minimal vegetation. Mountain streams and the mainstem of braided rivers in the catchment typically have relatively low nutrient concentrations, due to the predominantly alpine source of flow.

At the other end of the stability spectrum are springfed streams that seldom flood and therefore have greater algal and plant growth, which supports higher overall productivity. Springs are often associated with wetland habitats and they can have either stony or fine sediment beds. There are more extensive spring and wetland habitats in the upper catchment, due to historic wetland draining for land development in the lower catchment (see Figure 2 and Figure 3). Notable springfed streams in the upper catchment include Black Mountain Stream, Deep Creek, and Deep Stream (Figure 2), while McKinnons Creek and Ealing Springs are notable springfed streams in the lower catchment (Figure 3). Numerous unnamed springs and seeps occur at the edge of the braided channels that are less frequently impacted by floods. Springfed streams are particularly susceptible to fine sediment deposition from erosion and land runoff, because they lack regular floods to flush out fine sediment. Springfed streams in the upper catchment have historically been less affected by farming-derived fine sediment deposition and nutrient enrichment than in the lower catchment, but this has been changing in recent years (see Section 3.4 below).

The river mouth, or hapua is another distinctive habitat of the river. Hapua are long, narrow and shallow river mouth lagoons at least partially enclosed by a gravel barrier beach formed by longshore drift (Hume et al. 2016). Hapua are predominantly freshwater, unlike estuaries that are more saline. Unlike many smaller rivers along the Canterbury coastline with hapua, the mouth of the Rangitata River is nearly always open, with mouth closure being rare. However, cumulative effects of water abstraction over the last 70 years and associated reduced river flows may have contributed to a more elongated hapua and a gradual migration of the mouth northwards (Rogers et al. 2018).

The Rangitata River is one of the larger braided rivers in Canterbury, with a total catchment area of 1,773 km^2. Being an alpine-fed river, flows are generally lowest in winter and highest in early summer, when snowmelt is occurring. The Klondyke flow recorder site is at the downstream end of the gorge, approximately two kilometres upstream of the Rangitata Diversion Race (RDR) water intake. Flow statistics for the recorder site include a median flow of 74 m^3/s, seven-day mean annual low flow of 39.9 m^3/s, and a mean annual flood of 1,186 m^3/s (Scouller & Veendrick 2016; Table 1).

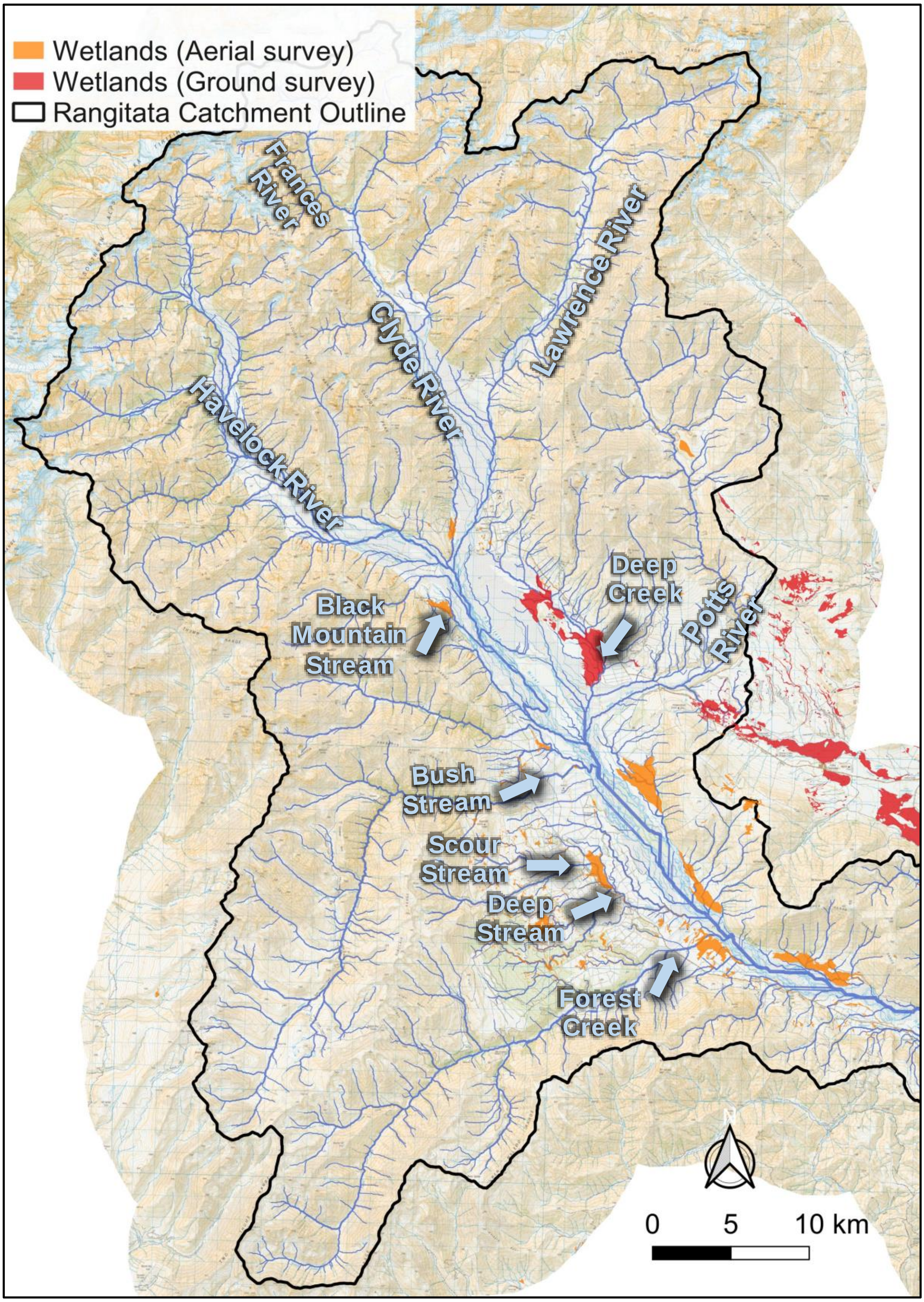

Figure 2: Upper Rangitata catchment tributaries and wetlands. ECan sampling locations are indicated by arrows. Black line indicates the catchment boundary. Data are courtesy of ECan and LINZ (CC BY 3.0 NZ).

Figure 3: Lower Rangitata catchment tributaries, wetlands, and major irrigation takes. Black line indicates the catchment boundary. Data are courtesy of ECan and LINZ (CC BY 3.0 NZ).

Large floods, in the order of mean annual floods of at least 1,186 m³/s, cover the width of the riverbed, reworking the braid pattern and removing woody vegetation. Smaller floods or "freshes" in the order of 111 to 222 m³/s (1.5 to 3 times median flow) occur more frequently and play an important role in scouring periphyton and fine sediment. As flows drop to around mean annual low flow, habitat availability reduces for some aquatic species. River mouth closure may occur at residual flows (i.e., downstream of all water takes) of less than 30 m³/s and flows in excess of 150 m³/s may be necessary to breach the mouth if it closes (Rogers et al. 2018).

A total of 54.726 m³/s of surface water and 553 L/s of surface water-depleting groundwater is currently allocated for abstraction from the Rangitata River (Rogers et al. 2018). Rangitata Diversion Race Management Limited (RDRML) is the single largest abstractor, with resource consent CRC011237 to take up to 30.7 m³/s from just downstream of the gorge. RDRML were recently granted consent to abstract an additional 10 m³/s of water at high flows for irrigation and storage in a large pond near Klondyke (Rogers et al. 2018, Figure 3), but that decision was under appeal at the time of writing. The next largest abstractor is Rangitata Water Limited (RWL), which holds consents CRC001229.1, CRC042094.1, and CRC070924.1 to take a total of 20 m³/s from their intake just upstream of the highway bridge at Arundel (Figure 3). Other substantial takes include Cumberland Dairy Farm Limited, who hold consent CRC154670 to take 1.5 m³/s from the RDRML intake, and Mesopotamia Station, who hold consent CRC092108 to take 1.5 m³/s from a tributary upstream of the gorge. Most of the water taken is used for irrigation, although the RDRML take is also used for electricity generation, mainly outside of the irrigation season.

Table 1: Flow statistics for Canterbury braided rivers. Data provided by Environment Canterbury.

River	Flow monitoring site	Monitoring period	Median flow (m³/s)	Mean flow (m³/s)
Waitaki	Kurow	1964-1970, 1977-2019	334	344
Rakaia	Gorge	1978-2019	157	210
Waimakariri	Gorge	2016-2019	85	110
Rangitata	Gorge (Klondyke)	1979-2019	74	96
Waiau	Marble Point	1967-2019	71	96
Hurunui	Mandamus	1956-2019	39	53
Ashburton	State Highway 1	1996-2019	13	20
Opihi	State Highway 1	1998-2019	8	15
Ashley	Gorge	1972-2019	7	12
Orari	Gorge	1982-2019	6	9

Fishing (whitebaiting in the lower river and angling), white-water rafting, kayaking, and jet-boating are highly-valued recreational activities on the Rangitata River. The gorge section of the river contains technical white-water that is the domain of advanced to expert paddlers, whereas downstream of the gorge the channel is broader, so it produces less challenging white-water that is mainly used by beginner to intermediate paddlers (Rogers et al. 2018). The Rangitata River is one of the top five rivers fished in New Zealand, with approximately 28,000 angler days recorded in the 2014/15 fishing season (Webb 2018). The riverbed is also used for offroad driving, particularly in the upper catchment, although data are lacking on how intense this activity is. Sightseeing has grown in popularity in recent years in the upper catchment, largely because Mt Sunday (between the Potts and Clyde rivers) featured in the Lord of the Rings movie series.

3. CONSERVATION VALUES

3.1. Introduction

The following sections summarise conservation values, pressures, and knowledge gaps in the Rangitata River catchment. Various definitions of "conservation value" exist (Capmourteres & 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 endangered ecosystems (Holdaway et al. 2012) comprised of a mosaic of habitat types that contribute to their biodiversity value. These habitats occur across a "braidplain" (Gray et al. 2016; Gray 2018), which is a term that encompasses both the young alluvial surfaces of the frequently disturbed floodplain and the more mature, less frequently disturbed surfaces towards the edge of the river (Figure 4). Major and minor braids carry most of the river's flow and they traverse a relatively young alluvial surface. While regular floods restrict productivity within the braided channels, floods also maintain gravels that are relatively free of vegetation, which is preferred habitat for rare native birds (see Section 3.7). The more mature surfaces of the braidplain are peppered with groundwater seepages and springs that provide stable, productive habitats for algae, plants, invertebrates, and fish.

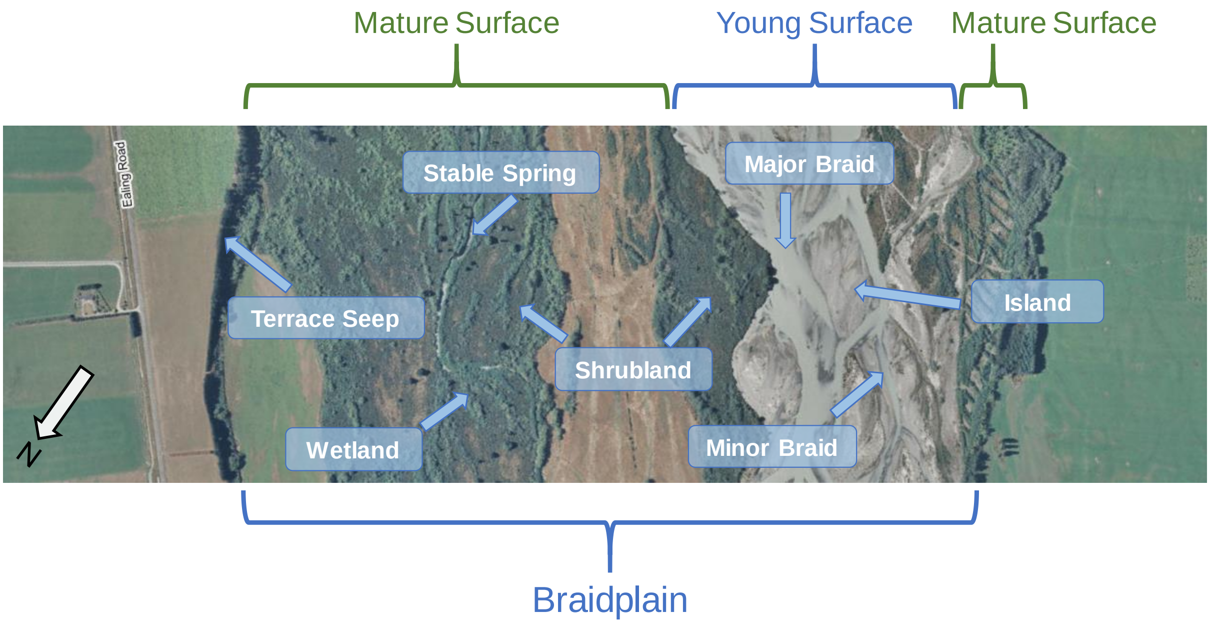

Figure 4: Aerial view of the Ealing reach of the Rangitata River, showing the braided habitat mosaic. Terminology are adapted from Gray (2018) and the aerial image is courtesy of Environment Canterbury.

The complex interplay between river flow and physical habitat can be assessed using two-dimensional (2D) hydraulic habitat models. Duncan & Hicks (2001) constructed 2D models for two reaches of the Rangitata River: a predominantly single thread reach 3 km upstream of the Arundel Bridge (and downstream of the RDR intake); and a braided reach downstream of State Highway 1 at Ealing. The model was based on field data that included a detailed topographic survey, flow gaugings, and measurements of bed material. The 2D hydrodynamic model *2de* was subsequently used to predict the relationship between river flow, depth and velocity for the modelled reaches[1]. These data were then combined with published depth and velocity preferences of fish and invertebrates to predict how aquatic habitat (as Weighted Usable Area, WUA) changes with flow. It was concluded that the response of WUA to flow varied markedly amongst species, but that maximum WUA occurred at around 30-40 m^3/s for many species (Duncan & Hicks 2001). These results were subsequently used to help inform the process of setting minimum flows, below which water abstraction must cease.

The existing 2D models for the Rangitata River were developed for assessing low flow requirements, which limits their use for modelling the full range of flow requirements of a braided river. The modelled flows ranged from 10 to 80 m^3/s, which is low compared to a mean river flow 96 m^3/s and mean annual flow of 1,186 m^3/s. This means the existing models cannot be reliably used to predict flood flow requirements for removing woody vegetation, which is important for maintaining riverbird nesting habitat. However, new hydraulic habitat models are currently being developed for the river, which may address the shortcomings of the existing models, including the relationship between flow and erosion, sedimentation, channel avulsion, and sediment scour (see Section 4.4 below).

Water quality monitoring is undertaken monthly by ECan at six sites in the Rangitata catchment, including three sites on the mainstem of the Rangitata River and three springfed tributary streams (Table 2). Water quality is excellent in Bush Stream, Deep Stream, and Rangitata River at Arundel Bridge, with very low nutrient concentrations, faecal contamination (indicated by low *E. coli* counts) and low turbidity (Table 2). Water quality data from these three sites are all within the A Band of the draft National Policy Statement for Freshwater 2019 (NPSFM)[2]. Dissolved reactive phosphorus (DRP) is the bio-available form of phosphorus and it is low at all monitoring sites. However, bio-available nitrogen shows an increasing trend with distance downstream in the Rangitata River and is very high in McKinnons Creek (Table 2). The median concentration of total organic nitrogen (TON) in McKinnons Creek is 4.6 mg/L, which puts in NPSFM Band C and could be adversely affecting growth of sensitive species such as juvenile salmon. Elevated *E. coli* counts in the two lower Rangitata sites and McKinnons Creek would be associated with an increased risk of infection to people coming into contact with the water.

Elevated TON concentrations in the lower Rangitata River and McKinnons Creek reflect the impact of intensive landuse on waterways draining the lower Canterbury Plains. Faecal contamination of the lower Rangitata River and McKinnons Creek could reflect impacts of runoff from livestock and or bird colonies, with the latter more likely in the Rangitata River.

[1] It is acknowledged here that there are a variety of alternative flow-setting tools now available. However, at the time, a 2D hydraulic habitat modelling approach was agreed by key stakeholders as an appropriate tool for setting minimum flows for the 2006 Rangitata River Water Conservation Order.

[2] The NPSFM 2019 is supported by an independent science advisory group of nationally recognised water quality experts. Therefore, even though the NPSFM 2019 is in draft form, the attribute bands shown here represent the best available science at the time of writing.

Monitoring data from Mountain Stream and Deep Creek in the upper catchment from 2013 to 2017 collected by ECan showed similar patterns to that for Bush Stream and Deep Stream, with median data well within A Bands of the NPSFM (Gray 2018).

Table 2: Median water quality data from 2014 to 2018 at ECan monitoring sites compared to NPSFM bands.

Site	E. coli (No./100 mL)	TON (mg/L)	DRP (mg/L)	Turbidity (FNU)
Rangitata River at Arundel Bridge	40	0.06	0.002	3.1
Rangitata River at State Highway 1	135	0.09	0.002	6.4
Rangitata River Mouth	139	0.29	0.002	2.4
Bush Stream	1	0.01	0.002	0.6
Deep Stream	29	0.07	0.004	0.9
McKinnons Creek	212	4.60	0.005	0.7
Draft NPSFM 2019 Bands				
A	≤130	≤0.24	≤0.006	<6.2 / <2.4
B	≤130	0.24 - 0.50	0.006 - 0.010	<7.9 / <2.7
C	≤130	0.5 - 1.0	0.010 - 0.018	<10.5 / <3.1
D	130 - 260	>1.0	>0.018	>10.5 / >3.1

Notes: TON = total oxidised nitrogen (nitrate + nitrite N); DRP = dissolved reactive phosphorus. The TON bands are based on nutrient enrichment; toxicity occurs at higher concentrations. Draft NPSFM bands are subject to change. Turbidity bands vary according to climate, source of flow, and geology, with McKinnons Creek being in Suspended Sediment Class 2 (River Environment Classification CD/L/AI) and Bush Stream within Class 12 (CW/M/HS). Turbidity bands are not provided for rivers affected by glacial runoff such as the Rangitata River. No turbidity band is currently available for the Deep Stream waterway type (CW/H/AI).

Threats and Knowledge Gaps

Gray & Harding (2007) listed a number of human-induced pressures on braided river ecosystems, including impoundment with dams, water abstraction, flood controls (e.g., stopbanks) gravel extraction, commercial and recreational fisheries, and pollution. Gray et al. (2016) considered key threats to braided river ecosystems in New Zealand to be encroachment of agriculture into the braidplain and impoundment by dams. More recently, Lewis & Maloney (2019) listed the following key threats to Canterbury braided river habitats: habitat loss caused by landuse change; nutrient enrichment from agriculture; trampling and sedimentation caused by stock; climate change impacts on extreme weather; gravel extraction; weeds; and water abstraction. The Rangitata River is not impounded and the Water Conservation (Rangitata River) Order 2006 prevents any dams being established on the mainstem in the future. While data is lacking for many of the other potential threats listed above, encroachment is a known, quantified, and pervasive issue for Canterbury rivers. A recent study on river encroachment found that the Rangitata River was one of the most severely affected rivers in Canterbury, with 2,258 hectares of former braidplain converted to agriculture from 1990 to 2012 (Grove et al. 2015, Figure 5).

Figure 6 shows an example of agricultural encroachment in the Rangitata River's South Branch. Between Arundel and State Highway 1, the Rangitata River was historically split into two channels known as the North Branch and the South Branch, separated by Rangitata Island. While most of the river's flow has been carried by the northern branch for nearly 100 years, floods have regularly passed down the South Branch (ECan 2017). Flood protection works maintained by ECan and funded by targeted rates include low stopbanks that are designed to prevent flows down the South Branch in floods less than 1,500 m ³/s, which have a 5 year return period (ECan 2017). However, over the last 20 years, the region's dairy boom has seen significant development on flood-prone land in South Branch and Rangitata Island (Figure 6). This has resulted in increased land values for farming and hence created a greater desire to keep flood flows out of the South Branch. This has put greater pressure on ECan to provide a greater level of flood protection for land in the South Branch and it has greatly reduced the natural values of the braidplain.

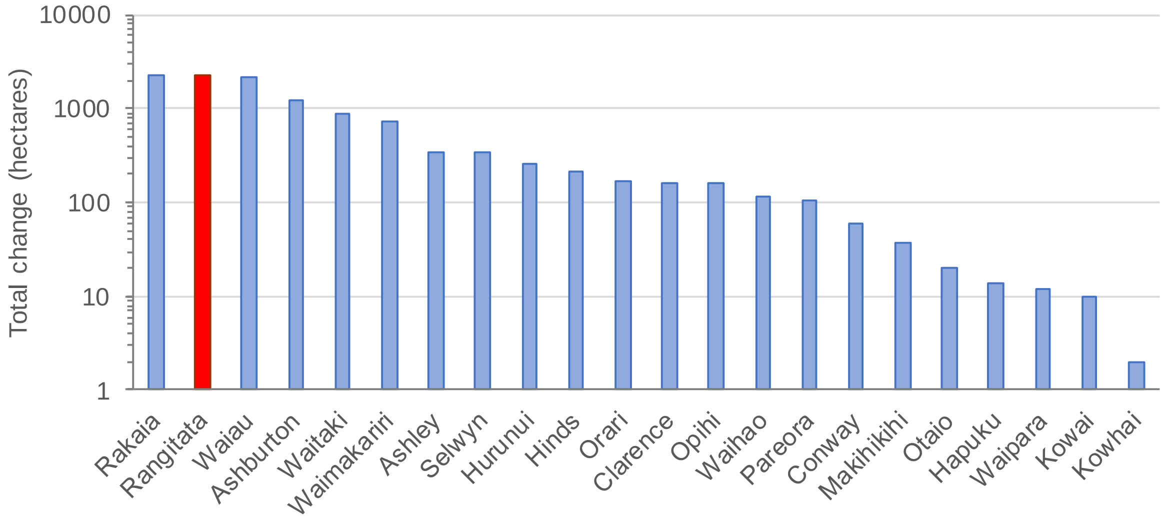

Figure 5: Total area of Rangitata River margins (red bar) developed for agriculture compared with other rivers in the lower Canterbury Plains from 1990 to 2012. Data are from Grove et al. (2012). Note the logarithmic scale.

The rapid increase in river encroachment in recent years has largely been associated with landuse intensification for dairy farming, coupled with weak legal protection of river margins. Environment Canterbury therefore sought to improve formal protection of river margins via a proposed change to the Land and Water Regional Plan (LWRP). The proposed plan change was supported by reports that described braided river values and provided methods for assessing the natural character of braided rivers (Gray 2018; Gray et al. 2018). However, this aspect of the plan change was put on hold, following the outcome of a High Court case in December 2018. The Dewhirst case involved ECan prosecuting the Dewhirst Land Company for undertaking unauthorised works in the bed of the Selwyn River. While there was no dispute by the courts that the works were carried out illegally, the High Court held that the riverbed is the area between the "reasonably observable banks" of a river, which was essentially defined as the open riverbed. This narrow definition of a riverbed provides a lower level of legal protection to the mature surfaces of the braidplain. In early October 2019, the Court of Appeal upheld the High Court decision in favour of Dewhirst. A change to the LWRP will therefore likely be required, to prevent further encroachment into braided river habitats.

During the recent consent hearing for the proposed Klondyke storage ponds and additional 10 m³/s water take, salmon anglers were particularly concerned about effects of existing takes on fine sediment build up in the lower river, and how the new take would affect that (Rogers et al. 2018). Excessive fine sediment (<2 mm diameter) can smother invertebrate communities and fish habitat, detract from natural character, and make it difficult for anglers to catch fish. Based on expert evidence presented at the hearing, the commissioners concluded that it is likely existing takes have contributed to fine sediment build up in the lower river, but that the proposed additional take would not have an adverse effect (Rogers et al. 2018). However, the commissioners endorsed a fine sediment monitoring programme proposed by the applicant, to address uncertainties. As already noted, the hearing decision is currently under appeal, so there is currently no requirement for fine sediment monitoring to occur, and there is no existing monitoring programme in the catchment. Fine sediment monitoring, coupled with proposed new hydraulic modelling, could help address this area of uncertainty regarding effects of high flow water takes on sedimentation.

Figure 6: Landuse intensification on Rangitata Island in recent years has been facilitated by stopbanks that protect land from flooding. Aerial images are at the same scale and are courtesy of Environment Canterbury.

In summary, river encroachment is the single largest known and quantified threat to braided rivers in Canterbury, including the Rangitata River. This matter is in need of urgent attention. The relationship between water abstraction and fine sediment deposition is not as well understood in the Rangitata River, and is also deserving of further monitoring and modelling (see Section 4.4 below).

Current climate change predictions for Canterbury to 2040 and 2090 include increased air temperatures, increased drought severity on the Canterbury Plains, increased rainfall along the main divide, increased flood intensity, and stronger and more extreme winds (MfE 2018). Climate change modelling for the Rangitata River up to 2040 predicted the following (Woods et al. 2008):

- Annual average temperatures approximately 1 °C warmer than the average for 1980-1999.
- Increased precipitation in the headwaters (up to 400 mm/year increase), with the greatest increases in winter and spring; little change in precipitation on the Canterbury Plains.

- Increased evaporation on the Canterbury Plains, with the greatest increase in spring and summer; little change in evaporation in the headwaters.
- Mean river flow increased by about 8 m^3/s, or 8%, compared to current.
- Monthly mean flow is:
    - Reduced by 1-2 m^3/s in December and January.
    - Increased by 18 m^3/s in August to October (although there is considerable uncertainty in this prediction).

The impacts of climate change on freshwater ecosystems are very uncertain, particularly where ecosystems are already stressed by other human-induced impacts (Robertson et al. 2016). Although climate change impacts on braided river ecosystems are uncertain, there are some specific habitat types and processes that are particularly at risk of climate-induced changes (Lewis & Maloney 2019), including:

- Interacting impacts of sea level rise and altered river flows on hapua shape, salinity, and opening frequency.
- Increased flood disturbance impacting both young and mature surfaces of the braidplain, leading to reduced productivity in those areas.
- Increased thermal stress, particularly in smaller tributaries with no shade.
- Reduced flows of springfed streams and reduced total area of wetlands and ponds.

Given the potential ecological risks and considerable uncertainty posed by climate change, there is an increased need to better protect and buffer braided river ecosystems. In practice, this means reducing existing pressures, such as river encroachment, water quality degradation, and exotic plants and animals, to “provide space” for the new pressures associated with climate change on native species. On the ground, this might involve such activities as evaluating the placement of stopbanks, to provide more space for braidplain development, or removal of introduced salmonids from selected high-value native fish habitats.

3.3. Plants

At least 184 plant species have been identified from stream channels, wetlands, riverbeds and riparian margins in the Rangitata catchment (Benn 2010). Of these, 138 are native species and 46 species are introduced, and most of the introduced species are considered weeds. Benn (2010) cites fourteen native plant species from the catchment as being At Risk or threatened, but the threat status of native plants has changed in recent years. As a result, the threat status of the two most acutely threatened species (*Cassula multicaulis* and *Mysostis brevis*) has decreased (i.e., has become less acutely threatened), although they remain threatened (Table 3). However, of greater concern is that the conservation status of three At Risk plant species has been elevated from At Risk to Threatened: *Craspedia* sp. “Havelock” has changed from Naturally Uncommon to Nationally Endangered, while both *Muehlenbeckia ephedroides* and *Raoulia monroi* have changed from Declining to Nationally Vulnerable (Table 3). There have likely been further changes to the threat status of plants previously recorded from the Rangitata River catchment, but they were not reviewed for this report.

Table 3: Native plant species Benn (2010) noted as being present in the Rangitata catchment. The previous threat status was from de Lange et al (2009), while the current threat status is from de Lange et al. (2018).

Taxon	Common name	Localities	Previous Threat status	Current Threat Status
Crassula multicaulis	-	Butler Downs (tarn margins)	Nationally critical	**Nationally endangered**
Myosotis brevis (prev. known as M. pygmaea* var. *minutiflora)	Pygmy forget-me-not	Sinclair Range (tarn margins)	Nationally endangered	**Nationally vulnerable**
Myosotis uniflora	Cushion forget-me-not	Rangitata River (Havelock confluence to gorge); Rangitata river valley	Naturally uncommon	Naturally uncommon
Montia angustifolia (Neopaxia leariifloia)	-	Butler Downs (tarn margins)	Naturally uncommon	Naturally uncommon
Ranunculus maculatus	-	Butler Downs (tarn margins)	Naturally uncommon	Naturally uncommon
Craspedia* sp. *"Havelock"	Woollyhead	Havelock River & Clyde River	Naturally uncommon	**Nationally endangered**
Leptinella serrulata	Dryland button daisy	Mesopotamia Stream (stream margins & dry riverbed sections)	Naturally uncommon	Declining
Carmichaelia appressa	Native broom	upper Rangitata riverbed, downstream from the lower Clyde River	Naturally uncommon	Naturally uncommon
Aciphylla subflabellata	Spaniard	Forest Creek; Raules Gully; Mt Sunday (wetlands)	Declining	Declining
Muehlenbeckia ephedroides	Leafless pohuehue/muehlenbeckia	Rangitata (dry channels & fringes, esp, south branch Canterbury Plains)	Declining	**Nationally vulnerable**
Raoulia monroi	Fan leaved mat daisy	Rangitata (dry channels & fringes)	Declining	**Nationally vulnerable**
Luzula celata	Dwarf woodrush	Rangitata River (Havelock confluence to gorge); Mt Potts bridge: at least 12 sites in upper Rangitata	Declining	Declining

The current status of riverine native plants in the catchment is overall poorly understood. In contrast, there has been substantial research into the distribution and management of plant weeds in the upper catchment. The most recent publication is an upper Rangitata catchment ten year weed plan commissioned by ECan (Boffa Miskell 2019). The weed plan includes detailed maps and descriptions of the extent and status of various weed species, along with recommendations for managing the weeds. The following quote is taken from the executive summary of the Boffa Miskell (2019) report:

"Weed control within the upper Rangitata catchment has been consistent and coordinated, involving landholders, Department of Conservation, Environment Canterbury, Land Information New Zealand and Fish and Game. This management has enabled the control of weeds within significant areas of riverbed and has limited the spread of weed species considerably. Gorse, broom and Russell lupin have been controlled regularly throughout

much of the Rangitata riverbed. The upper extent of these species has not changed significantly within the last 16 years, and areas of dense infestations have been removed and/or reduced. Conversely, the abundance and distribution of wind-dispersed species such as grey willow and false tamarisk have increased markedly within the catchment. These species can disperse more readily in an upstream direction and are less conspicuous when flowering compared to gorse, broom and lupins. This creates difficulties in surveillance activities aimed at recording weed presence. Ongoing monitoring and control of these species is required to further prevent an increase in range and abundance."

Threats and Knowledge Gaps

Key threats to native plants in braided river ecosystems include competition with introduced weed species, habitat and ecosystem loss from agricultural encroachment, potential climate change impacts, and lack of space to retreat to from environmental changes (Lewis & Maloney 2019). The status of weeds is well known in the upper Rangitata catchment, but poorly understood in the lower catchment. The status of native plants associated with riverine environments is poorly understood throughout the Rangitata River catchment. Long term monitoring of native plants is lacking and there is considerable uncertainty as to the impacts of climate change on native plants in the Rangitata River and braided rivers in general (Lewis & Maloney 2019).

3.4. Invertebrates

Over 150 aquatic and terrestrial riverbed invertebrate species have been identified from the Rangitata catchment (Benn 2010). In a detailed survey of 11 braided rivers throughout the country, Gray & Harding (2010) recorded a total of 67 freshwater invertebrate taxa from the Rangitata River catchment, which was towards the lower end of the range of 56 to 99 taxa recorded from each of the 11 rivers. Based on recent studies in the Waitaki River catchment, the Rangitata invertebrate species count is likely a gross underestimate of the actual number of invertebrate taxa present. Thus, a total of 919 Recognisable Taxonomic Units were collected over several months of sampling in the braided Tasman River, and total taxa richness was estimated at approximately 1,200 taxa (Murray 2019). In addition to the summary of Benn (2010), ECan undertakes annual monitoring of freshwater invertebrates at four springfed streams in the Rangitata catchment (Bush Stream, Scour Stream, Forest Creek, and McKinnons Creek), and ECan recently undertook a survey of upper catchment springs (Gray 2018).

Benn (2010) reported that caddisflies (Trichoptera) are by far the most diverse invertebrate group recorded in the catchment. Invertebrate taxa associated with waterways and riverbeds with an At Risk or Threatened conservation status include red katipo (*Latrodectus katipo*), which has an At Risk – Declining conservation status (Sirvid et al. 2012) and they are found at the Rangitata River mouth (Benn 2010). The robber fly *Neoitamus smithii* has been recorded from the Rangitata riverbed near Mount Sunday (Benn 2010) and the grasshopper *Brachaspis* “Lowland” has been found on terraces of the Potts River (Chinn 2009) and in the lower Bush Stream area (Benn 2010); both species have an At Risk – Naturally Uncommon conservation status (Andrew et al. 2012; Trewick et al. 2016). Gray (2009) described a new stonefly species, *Zelandobius edensis*, from a springfed tributary of the Frances River, a tributary of the Clyde River, and this species has a Data Deficient conservation status (Grainger et al. 2018) due to its very restricted known distribution. Lastly, Gray & Harding

(2010) recorded the mollusc *Austropeplea tomentosa* (Data Deficient, Grainger et al. 2018) from the Rangitata River catchment; no specific site records were provided, but this species is typically associated with springs and wetlands.

There are no records of kēkēwai, also known as kōura or freshwater crayfish (*Paranephrops zealandicus*) from the Rangitata River catchment, either in the literature or in the Freshwater Fish Database (Crow 2018). Similarly, the only records for kākahi, or freshwater mussels (*Echyridella menziesi*), in the catchment are from stockwater races just downstream of the RWL irrigation ponds near Arundel (pers. comm. Duncan Gray, Senior Scientist – Water Quality and Ecology, ECan). However, kākahi are present at several locations in the Ashburton Lakes area (Te Rūnanga o Arowhenua 2010). It is possible that both kēkēwai and kākahi are more widespread in the Rangitata catchment, but they have not been detected due to a lack of sampling effort. This is particularly likely for kākahi, because they are not usually detected using standard sampling techniques for invertebrates or fish, whereas kēkēwai are readily caught using electric fishing methods. Both kēkēwai and kākahi are of conservation interest, as they have an At Risk – Declining status (Grainger et al. 2018).

The most comprehensive published survey of aquatic invertebrates (and fish) in the Rangitata River catchment was completed in 1984 (Bonnett (1986). That survey included bi-monthly sampling of invertebrates and fish over 1983 and 1984 at four locations in the river: above the gorge; Arundel Bridge, State Highway 1, and near the river mouth. NIWA repeated that survey over 2018 and 2019, but at the time of writing the data had not been analysed or written up, and there was no budget to do so (pers. comm. Phil Jellyman, Assistant Regional Manager, NIWA Christchurch). The key invertebrate findings from Bonnett (1986) were that the greatest invertebrate diversity occurred upstream of the gorge, and that the fauna was typical of other Canterbury braided rivers, with caddisflies the most diverse invertebrate group and *Deleatidium* mayflies dominating invertebrate abundance.

ECan invertebrate monitoring data from four springfed streams in the catchment include macroinvertebrate community index (MCI) scores in the range of 101 to 122 (Table 4), which are indicative of good to excellent water and/or habitat quality (Stark & Maxted 2007). However, under the draft NPSFM 2019[2] the overall rankings are lower, with only one site (Scour Stream) falling in the B Band for MCI scores and the other three sites falling within the C Band (Table 4). Taxa richness is moderate and typical for Canterbury springfed streams. The fauna at the ECan monitoring sites is dominated by relatively pollution-sensitive EPT taxa (Ephemeroptera, Plecoptera, and Trichoptera). Dominance of EPT taxa is unusual for Canterbury springfed streams, as many drain agricultural and urban catchments and have degraded invertebrate communities with few sensitive taxa remaining.

Recently, Gray (2018) sampled water quality, aquatic habitat, periphyton, and invertebrate communities in numerous high country springfed streams, including Black Mountain Stream, Deep Creek, and Deep Steam in the upper Rangitata catchment (Figure 2). Key findings of the survey were that springfed high country streams are highly sensitive to low levels of catchment development, resulting in reduced invertebrate biodiversity and reducing their value as fish habitat. To protect high country springfed streams Gray (2018) suggested mapping springfed stream catchments and establishment of conservative planning rules to regulate further development.

Table 4: Median invertebrate metrics from 2015 to 2019 at ECan monitoring sites compared to NPSFM bands[3].

Site	MCI	Taxa Richness	%EPT Taxa Richness
Bush Stream	**101**	16	43
Scour Stream	**122**	19	55
Forest Creek	**107**	19	47
McKinnons Creek	**103**	19	47
Draft NPSFM 2019 Bands			
A	**≥130**		
B	**≥110 and <130**		
C	**≥90 and <110**		
D	**<90**		

Notes: MCI = Macroinvertebrate Community Index; %EPT Taxa Richness = the percentage of total taxa recorded that are comprised of pollution-sensitive Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). Sampling is typically undertaken in January, so median invertebrate data from 2015 to 2019 are comparable to median water quality data from 2014 to 2018. There are no NPSFM bands for taxa richness or %EPT taxa richness.

Threats and Knowledge Gaps

With the exception of monitoring in some springfed streams by ECan, the current status of aquatic and terrestrial riverbed invertebrates is poorly understood in the Rangitata River catchment, due to a general lack of recent monitoring data. However, recent research indicates that springfed stream communities in the upper catchment are particularly sensitive to landuse intensification and that greater protection is necessary.

Weeds are the key threats to terrestrial invertebrates found on dry areas of braided river beds (Lewis & Maloney 2019). Landuse change and loss of host plants, predation and competition are other threats.

3.5. Fish

A total of 22 freshwater fish species have been recorded from the Rangitata catchment (Table 5). Twenty of these species are recorded in the New Zealand Freshwater Fish Database (Crow, 2018), while an additional two estuarine species are reported by Bonnett (1986). Benn (2010) indicates two additional freshwater species were noted from historic references as potentially present: Crans bully (*Gobiomorphus basalis*) and redfin bully (*G. huttoni*). However, neither species have been recorded from the catchment since, plus Crans bully is only known from the North Island (McDowall 1990), so neither are expected to be present in the Rangitata catchment.

[3] There are no guidelines, limits or Freshwater Outcomes for these invertebrate indices in the LWRP.

Table 5: Freshwater fish species recorded from the Rangitata River. Data are from the Freshwater Fish Database and Bonnett (1986).

Common name	Scientific name	Conservation status	Migratory?	River Distribution
Native Species				
Shortfin eel	*Anguilla australis*	Not threatened	Yes	Lower
Longfin eel	*Anguilla dieffenbachii*	Declining	Yes	Widespread
Torrentfish	*Cheimarrichthys fosteri*	Declining	Yes	Lower
Koaro	*Galaxias brevipinnis*	Declining	Yes	Upper
Inanga	*Galaxias maculatus*	Declining	Yes	Estuarine
Alpine galaxias	*Galaxias paucispondylus*	Naturally uncommon	No	Upper
Upland longjaw galaxias	*Galaxias prognathus*	Nationally vulnerable	No	Upper
Canterbury galaxias	*Galaxias vulgaris*	Declining	No	Upper
Lamprey	*Geotria australis*	Nationally vulnerable	Yes	Lower
Upland bully	*Gobiomorphus breviceps*	Not threatened	No	Upper
Common bully	*Gobiomorphus cotidianus*	Not threatened	Yes	Lower
Giant bully	*Gobiomorphus gobioides*	Naturally uncommon	Yes	Estuarine
Bluegill bully	*Gobiomorphus hubbsi*	Declining	Yes	Lower
Black flounder	*Rhombosolea retiaria*	Not threatened	Yes	Estuarine
Stokells smelt	*Stokellia anisodon*	Naturally uncommon	Yes	Estuarine
Common smelt	*Retropinna retropinna*	Not threatened	Yes	Estuarine
Yelloweye mullet	*Aldrichetta forsteri*	Not threatened	Yes	Estuarine
Introduced species				
Chinook salmon	*Oncorhynchus tshawytscha*		Yes	Widespread
Rainbow trout	*Oncorhynchus mykiss*		No*	Upper
Brown trout	*Salmo trutta*		No*	Widespread
Brook char	*Salvelinus fontinalis*		No	Upper
Perch	*Perca fluviatilis*		No	Upper

Notes: Conservation status of native fish is from Dunn et al. (2018). River distribution is based on Bonnett (1986) and the Freshwater Fish Database: Upper = upstream of gorge; Lower = downstream of gorge; Widespread = found throughout the catchment; Estuarine = near river mouth. *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.

Seventeen of the 22 recorded fish species are native, including 11 species with a Threatened or At Risk conservation status (Dunn et al. 2018; Table 5). Upland longjaw galaxias (*Galaxias prognathus*) and lamprey (*Geotria australis*) are the most acutely threatened fish species in the catchment, and they share a Nationally Vulnerable status. Fourteen (64%) of the fish species recorded undertake migrations between the sea and freshwater to complete their life cycle. The remaining eight species are either non-migratory or undertake localised spawning migrations within freshwater (Table 5).

The fish fauna can be broadly split into groups that are found predominantly near the estuary, in the lower river (downstream of the gorge), in the upper river (above the gorge), or widespread throughout the catchment (Table 5). Fish species with an At Risk or Threatened conservation status occur in all of these spatial groupings (Table 6). This means that any measures aimed at protecting native fish species will need to target the whole river, rather than focussing on a particular habitat or part of the river.

Table 6: Distribution of At Risk (AR) and Threatened (T) native fish in the Rangitata River.

Common name	Scientific name	Conservation status	River distribution			
			Upper	Lower	Estuarine	Widespread
Koaro	*Galaxias brevipinnis*	AR - Declining	✓			
Alpine galaxias	*Galaxias paucispondylus*	AR - Naturally uncommon	✓			
Upland longjaw galaxias	*Galaxias prognathus*	T - Nationally vulnerable	✓			
Canterbury galaxias	*Galaxias vulgaris*	AR - Declining	✓			
Torrentfish	*Cheimarrichthys fosteri*	AR - Declining		✓		
Lamprey	*Geotria australis*	T - Nationally vulnerable		✓		
Bluegill bully	*Gobiomorphus hubbsi*	AR - Declining		✓		
Inanga	*Galaxias maculatus*	AR - Declining			✓	
Giant bully	*Gobiomorphus gobioides*	AR - Naturally uncommon			✓	
Stokells smelt	*Stokellia anisodon*	AR - Naturally uncommon			✓	
Longfin eel	*Anguilla dieffenbachii*	AR - Declining				✓

Note: Conservation status of native fish is from Dunn et al. (2018). River distribution is based on Bonnett (1986) and the Freshwater Fish Database: Upper = upstream of gorge; Lower = downstream of gorge; Widespread = found throughout the catchment; Estuarine = near river mouth.

Threats and Knowledge Gaps

The current status of most freshwater fish populations is poorly understood in the Rangitata River. Within the last decade, there have been several surveys in the upper catchment for upland longjaw galaxias (Clucas 2011; Dunn 2016), which is the most intensively studied native fish in the catchment. Aquatic ecology surveys have also been undertaken in the Mt Potts (Bowie 2002) and Erewhon (Bowie 2010, 2014) pastoral leases in the upper catchment. These investigations highlight concerns for the extent and security of upland longjaw galaxias, including a fragmented population and low numbers.

The most recent comprehensive published survey of fish communities in the Rangitata River was completed in 1984 (Bonnett 1986). As noted in Section 3.4, the Bonnett (1986) survey included bi-monthly sampling of invertebrates and fish over 1983 and 1984 at four locations in the river: above the gorge; Arundel Bridge, State Highway 1, and near the river mouth. In addition to commenting on the general distribution of fish species along the river (per Table 5), Bonnett (1986) noted that the density of fish was generally highest in small side channels and in riffles. It was also noted that the Rangitata River is unique compared to other Canterbury braided rivers, with migratory fish rarely found above the gorge (except for climbing species such as koaro and eels), and non-migratory species rarely found below the gorge.

NIWA repeated the Bonnett (1986) survey over 2018 and 2019, but the data has not yet been analysed or written up (pers. comm. Phil Jellyman, Assistant Regional Manager, NIWA Christchurch). Environment Canterbury is also proposing to undertake monitoring of fish populations around the river mouth soon (pers. comm. Adrian Meredith, Principal Scientist – Water Quality and Ecology, Environment Canterbury).

Numerous potential threats to native freshwater values have been identified for the upper catchment (Bowie 2016), and these threats range from impacts of invasive species on non-migratory galaxiids to gravel extraction and stock grazing. Key potential threats in the lower catchment include water abstraction, habitat modification (especially encroachment), and introduced fish species. However, the relative importance of these various pressures is not well understood, largely due to a lack of ecological monitoring in the catchment. Other possible threats include impeded connectivity for migratory species, loss of fish into water intakes, climate change, habitat loss and changing land use practices.

In summary, we suggest the following are key uncertainties regarding the status of native freshwater fish in the Rangitata River catchment:

- Lack of data on the status of most fish populations, due to a lack of recent survey data.
- Poor understanding of ecological requirements and threats facing some species such as upland longjaw galaxias and lamprey, and knowledge of what is required to improve and better protect these key habitats. Status of fish populations in the lower river are generally less known.
- Degree of impacts of introduced sports fish, especially on non-migratory species in the upper river.

3.6. Lizards

This section of the report has been deliberately removed.

3.7. Birds

Eighty-eight bird species have been recorded for the Rangitata catchment, including 41 riverbed/water species and 47 species associated with forest or open-country (Benn 2010). The bed of the Rangitata River provides nationally significant habitat for breeding riverbird species (O'Donnell & Schmechel 2001). Several Threatened and At Risk bird species are present on the Rangitata River, including black-billed gull (Nationally Critical); black-fronted tern (Nationally Endangered); wrybill, banded dotterel and Caspian tern (Nationally Vulnerable), and pied oystercatcher (Declining) (Sanders 2018). Most birds are found on the wider, more braided reaches of the river, above the gorge and below the Arundel Bridge (Sanders 2018). The upper Rangitata River includes outstanding habitat for wrybill, as it contains up to 60% of the New Zealand-wide breeding population of the species (O'Donnell & Schmechel 2001). Kakī (black stilt, Nationally Critical) have nested in the upper Rangitata during both the 2017 and 2018 breeding seasons. Three chicks fledged in the 2017 season and there are multiple reports of kakī annually in the area between Forest Creek and Dr Sinclairs Grave (pers. comm. Brad Edwards, DOC).

Threats and Knowledge Gaps

Two key threats to braided river birds are predation by introduced mammals and weed encroachment into breeding habitat that can lead to habitat loss and exacerbate natural variability in breeding success (Lewis & Maloney 2019). Major predator and weed control programmes are already in place in the upper catchment, largely funded by DOC and ECan, but there is less known regarding the status of weeds and predators in the lower catchment. Trials of controlling predators and weeds on braided river islands in the Waitaki and Clarence rivers could potentially be undertaken in the Rangitata River. In addition, Southern black-backed gulls have become very abundant in the Rangitata catchment, to the point of excluding black-fronted tern colonies from below State Highway 1 for the last three years (pers. comm. Brad Edwards, DOC). The Upper Rangitata Gorge Landcare Group and DOC have provided control over Southern Black-Backed Gull nesting colonies in the bed of the upper Rangitata River for the last five years (pers. comm. Brad Edwards, DOC).

4. RIVER MANAGEMENT, LEGISLATION, AND STAKEHOLDERS

4.1. Legislation

Ngai Tahu Claims Settlement Act 1988

The Rangitata River is listed as a Statutory Acknowledgement Area under the Ngai Tahu Claims Settlement Act 1988. This formally recognises the cultural, spiritual, historic and traditional association of Te Rūnanga o Ngāi Tahu with the river. The Rangitata River falls within the takiwā (district) of Te Rūnanga o Arowhenua and their marae is in Temuka. The Rangitata catchment is dotted with the traditional trails (ara tawhito), mahinga kai (food and food gathering places), and other taonga (treasures) that collectively form the cultural landscape that is part of the identity of Te Rūnanga o Arowhenua.

Important cultural concepts include maintaining the river's mauri, or life force (comprised of biophysical and spiritual aspects), through maintenance of flows, water quality, and protection of its full range of habitats (Waaka-Homes 2018). Also important is the concept of ki uta ki tai, which means caring for the river from its mountain source to the sea (Tipa 2015). Historically important mahinga kai activities for Te Rūnanga o Arowhenua in the Rangitata catchment included: catching eels and whitebait (juvenile inanga) during their annual migration; harvesting birds and their eggs; and use of various plant resources for use as food, medicines, and making clothes (Waaka-Homes 2018).

National Policy Statement for Freshwater Management 2014 (amended 2017)

The National Policy Statement for Freshwater Management (NPSFM) is a statutory document with objectives and policies that direct local government on how to manage water in an integrated and sustainable way, within water quantity and quality limits. The NPSFM includes a National Objectives Framework that requires regional councils to assign all freshwater bodies in their region to identified freshwater management units, and to formulate freshwater objectives to maintain or improve freshwater outcomes within those management units. Appendix 2 of the NPSFM lists freshwater parameters (referred to as "attributes" in the NPSFM) and associated water quality bands (referred to as "attribute states") that are to be applied to Freshwater Management Units. The attributes include "national bottom lines" that state the minimum level at which a freshwater objective may be set in a regional plan.

Action for Healthy Waterways – Ministry for the Environment Proposals

The Ministry for the Environment (MfE) has recently launched the "Action for Healthy Waterways" initiative, which is aimed at stopping further degradation in water quality, improving water quality over time to an acceptable state, and providing fair allocation of water. There are numerous aspects to the initiative, including speeding up the planning process by amending the Resource Management Act; amending the NPSFM, and introducing a new National Environmental Standard for Freshwater (NESF). Relevant components of the proposed changes to the NPSFM and new NESF include: special protections for wetlands; limitations on infilling of river beds; fish passage provisions; various restrictions relating to farming and stock access to waterways; and identification and protection of threatened species. Numerous new attributes have also been proposed for the National Objectives Framework, including: nitrogen, phosphorus, fine sediment, invertebrates, fish, submerged aquatic plants, and ecosystem metabolism. At the time of writing all of these proposals carried little statutory weight as they were in draft form and public submissions were still open.

Water Conservation (Rangitata River) Order 2006

The Rangitata Water Conservation Order (WCO) recognises the following outstanding characteristics, features, and values: amenity and intrinsic values; habitats; fishery values; wild and scenic characteristics; scientific and ecological values; recreational, historical, spiritual, and cultural values. Key aspects of the WCO include retaining the Clyde and Havelock rivers in their natural state, prohibiting damming of the mainstem of the river and its major tributaries, and restrictions on alterations to river flow and water quality. The water quality restrictions relate to activities that alter water temperature, pH, impacts on biological growths and periphyton, suitability for contact recreation, *E. coli*, and dissolved oxygen. No mention is made of nutrients.

A key component of the WCO is its restrictions relating to water abstraction. The WCO includes minimum flows below which abstraction must cease and also an upper limit or cap on the total amount of water allocated for abstraction that is taken when flows are below 110 m^3/s. The WCO does not include an allocation cap for abstraction when the river exceeds 110 m^3/s, provided the takes cease when flows fall below 110 m^3/s. In their final report on the proposed WCO, the commissioners concluded that *"How the additional flows above 110 m^3/s may be allocated can be dealt with in a Regional Plan…".* However, the Canterbury Land and Water Regional Plan does not include an upper cap to allocation for the Rangitata River. It was stated in the recent Klondyke hearing that the addition of an allocation cap is not currently a priority for ECan (Rogers et al. 2018).

Canterbury Land & Water Regional Plan

The Canterbury Land and Water Regional Plan (LWRP) includes rules that stipulate minimum flows and allocation limits for rivers throughout the region. In the case of the Rangitata River, the LWRP defers to the WCO for minimum flows and allocation limits, as well as listing the Havelock and Clyde rivers as being areas of high natural value (as per the WCO). The LWRP has also affords special protection to mapped salmon spawning habitats, including numerous locations in the upper Rangitata catchment, and inanga spawning habitat, including around the mouth of the Rangitata River. The LWRP also includes region-wide water quality limits for discharges to land and water, as well as "Freshwater Outcomes" that are to be met for different waterbody types in the region (Table 8).

Plan Change 7 of the LWRP[4] proposes an increase to the number of native freshwater fish species protected by planning rules (Gray & Allibone 2019). The associated planning maps include numerous locations in the upper Rangitata River catchment. While the planning maps simply refer to "indigenous freshwater species habitat", we understand that they are based on the known distribution of upland longjaw galaxias in the upper catchment (pers. comm. Sjaan Bowie, Freshwater Technical Advisor, DOC).

[4] Submissions on Proposed Plan Change 7 closed on 13 September 2019. No date for a public hearing had been announced at the time of writing.

Proposed Plan Change 7 also requires that Farm Environment Plans identify all springs on a farm, and that the plans describe actions taken to minimise effects of farming activities on water quality.

Table 8: Freshwater Outcomes for different management units in the LWRP.

<table>
<tr><th>Attribute</th><th colspan="5">Management Unit</th></tr>
<tr><td></td><td>Alpine – Upland</td><td>Alpine – Lower</td><td>Hill-fed – Upland</td><td>Spring-fed – Upland</td><td>Spring-fed – Plains</td></tr>
<tr><td>QMCI (min)</td><td colspan="4">6</td><td>5</td></tr>
<tr><td>Dissolved oxygen % (min)</td><td colspan="4">90</td><td>70</td></tr>
<tr><td>Temperature °C (max)</td><td colspan="5">20</td></tr>
<tr><td>Emerg. Macrophytes % cover (max)</td><td colspan="3">No value set</td><td>20</td><td>30</td></tr>
<tr><td>Total Macrophytes % cover (max)</td><td colspan="3">No value set</td><td>30</td><td>50</td></tr>
<tr><td>Periphyton attributes</td><td colspan="5"></td></tr>
<tr><td>Chlorophyll a biomass mg/m² (max)</td><td>50</td><td>120</td><td>50</td><td>50</td><td>200</td></tr>
<tr><td>Filamentous algae >2 cm long % cover (max)</td><td>10</td><td>20</td><td>10</td><td>10</td><td>30</td></tr>
<tr><td>Cyanobacteria mats % cover (max)</td><td>20</td><td>30</td><td>20</td><td>20</td><td>50</td></tr>
<tr><td>Fine sediment <2mm % cover (max)</td><td>10</td><td>10</td><td>15</td><td>10</td><td>20</td></tr>
<tr><td>Suitability for contact recreation grade</td><td>Good</td><td>Good to fair</td><td>Good</td><td>Good</td><td>No value set</td></tr>
<tr><td>E. coli count per 100 mL (median)</td><td colspan="5">130</td></tr>
<tr><td>E. coli count per 100 mL (95th %ile)</td><td>540</td><td>1,000</td><td>540</td><td>540</td><td>1,200</td></tr>
<tr><td>Cultural attribute</td><td colspan="5">Freshwater mahinga kai species sufficiently abundant for customary gathering, water quality is suitable for their safe harvesting, and they are safe to eat.</td></tr>
</table>

Notes: Rangitata catchment waterway classification by LWRP maps: **Alpine – Upland** = Rangitata River upstream of Arundel Bridge, Deep Creek, Black Mountain Stream, Bush Stream, Forest Creek; **Alpine – Lowland** = Rangitata River downstream of Arundel Bridge; **Hill-fed – Upland** = Scour Stream, Deep Stream; **Spring-fed – Upland** = tributaries of Deep Stream, Deep Creek, Black Mountain Stream; **Spring-fed – Plains** = Ealing Springs, McKinnons Creek.

4.2. River Management

Canterbury Water Management Strategy

ECan recently committed to completing nine new braided river plains over the next 10 years, with the first river plan due in June 2020. The objective of the new river plans is to “deliver a step change in biodiversity in braided river catchments”, with a focus on mahinga kai and recreation (pers. comm. David Owen, Principal Biodiversity Advisor, Braided Rivers, ECan). At the time of writing, ECan was in the concept stage of plan development and no decision had been made as to what river plans would be developed first. However, earlier indications are that there is an interest in managing braided rivers collectively, rather than as stand-alone river plans, as currently occurs.

Ō Tū Wharekai

The Ō Tū Wharekai wetland restoration project is centred on the Ashburton Lakes area, but also includes the upper Rangitata River. Ō Tū Wharekai is part of the Arawai Kākāriki Wetland Restoration Programme lead by DOC and it has the aim of increasing knowledge, awareness and protection of wetlands (Sullivan et al. 2011). The programme has a strong focus on wetlands, birds, and weed control, but has also included species inventories of plants, invertebrates, and lizards. The existing management framework and stakeholder relationships associated with Ō Tū Wharekai will greatly assist the development of a restoration plan for the Rangitata River.

4.3. Past and Present Restoration Programmes

Upper Catchment Weed and Predator Control

As noted in Section 3.3, there is a major and ongoing weed control effort in the upper Rangitata catchment that involves numerous parties (including DOC, ECan, LINZ, the Upper Rangitata Gorge Landcare Group, and local landowners). Weed control work in the upper Rangitata River covered nearly 2,000 hectares in December 2017 and January 2018. Predator trapping is also ongoing in the upper catchment and is coordinated across a similar multi-agency group. Predator trapping focusses on protecting wrybill and black-fronted terns, and there has been considerable recent effort in the vicinity of Mount Sunday to White Rock. Control of black-back gulls has also been undertaken in the upper catchment by the multi-agency group over at least the last six years.

Deep Stream Riparian Enhancement & Protection

A major stream and wetland restoration project has been undertaken along Deep Stream on Forest Creek and Mesopotamia Stations (Stevens 2015). The work was instigated by Fish & Game in response to concerns regarding landuse impacts on important salmon spawning habitat. The project was funded by ECan's Immediate Steps biodiversity fund. Works undertaken in 2014/15 included: willow removal from 2.5 km of stream bank; willow regrowth control along 6 km of stream bank; aerial willow control over 24.4 hectares; riparian fencing along 1.64 km of stream bank; and planting of over 1,000 native plants along the fenced off stream bank (Stevens 2015). Additional willow control work was undertaken by the Upper Rangitata Landcare Group and additional fencing and planting was subsequently undertaken too.

Deep Creek Culverting, Fencing & Flood Protection

A stock-crossing culvert was installed over Deep Creek in 2004/5 following concerns by Fish & Game regarding stock damage to significant spawning habitat (pers. comm. Mark Webb, Fish & Game). The project was funded by Mt Potts Station and Fish & Game. In addition, Fish & Game instigated the instalment of a stopbank to prevent floodwaters from the Clyde River washing out Deep Creek, with the works completed in 2004/5 (pers. comm. Mark Webb, Fish & Game). Mt Potts Station also fenced stock out of Deep Creek in approximately 2006, in exchange for Fish & Game obtaining consents and installing a fish screen on the station's stockwater intake (pers. comm. Mark Webb, Fish & Game). Additional stockexclusion fencing was completed in the Mt Sunday wetland area in 2013, with funding from ECan's Immediate Steps biodiversity fund.

Whiterock Station Wetland Fencing

Approximately 1 km of fencing was installed to exclude stock from a red tussock wetland and unnamed springfed stream on Whiterock Station, immediately upstream of Rangitata Gorge (Figure 2). The project was funded by ECan's Immediate Steps biodiversity fund and was completed in 2017.

Ealing Springs Fine Sediment Removal

In 2011 Fish & Game were granted consent CRC110841 from ECan to remove fine sediment and install sediment retention ponds in Ealing Springs. Following granting of the consent some trials were undertaken and Fish & Game are looking to do further work in Ealing Springs within the next two years (pers. comm. Mark Webb, Fish & Game).

Thornton Wetland Planting and Weed Control

This project involved weed control and native planting in a small wetland on the true left (north) bank of the Rangitata River, immediately downstream of State Highway 1 (Figure 3). The project was funded by ECan's Immediate Steps biodiversity fund and was undertaken in 2017/2018.

McKinnons Creek Riparian Planting

In April 2019 volunteers from the McKinnons Creek salmon hatchery supplied native plants and labour to plant-up the spring headwaters of McKinnons Creek on the farm of Henry Bolt.

Proposed Klondyke Ecological Refuge

An "ecological refuge" is proposed by RDRML on a low river terrace near the proposed Klondyke storage facility. The ecological refuge is proposed to include: creation and enhancement of three hectares of wetland habitat; two hectares of native planting; and one hectare of lizard habitat enhancement (Rogers et al. 2018). The related resource consents were subject to appeal at the time of writing.

4.4. Treaty Partners, Major Stakeholders, and Research

Te Rūnanga o Ngāi Tahu and Te Rūnanga o Arowhenua

As treaty partners and manawhenua, Te Rūnanga o Ngāi Tahu and Te Rūnanga o Arowhenua should be integrally involved with development of any management plan in the Rangitata River. DOC will soon commence discussions with Te Rūnanga o Arowhenua.

Major Irrigators & Landowners

Major irrigation companies and farmers hold a significant vested interest in the catchment, and any restoration plan will need to take into consideration their existing needs and future plans. Rangitata Diversion Race Management Limited (RDRML) and Rangitata Water Limited (RWL) are the two largest irrigation companies and they are funded by farmer shareholders throughout the catchment and further afield. Section 4.3 includes past and present restoration activities on farms throughout the catchment.

Upper Rangitata Gorge Landcare Group

The Upper Rangitata Gorge Landcare Group is mainly comprised of landowners in the upper Rangitata catchment. Although initially formed in the early 1990s to deal with rabbit issues, the group is now involved with weed and pest management throughout the catchment. The Upper Rangitata Gorge Landcare Group controls pests and weeds on areas of riverbed adjoining their properties, particularly from Forest Creek downstream (Boffa Miskell 2019). The group works closely with agencies such as DOC, ECan, LINZ, and Fish and Game to share information on the distribution of weeds and pests, and to help coordinate pest and predator control (Boffa Miskell 2019).

Braided River Aid - BRaid

Braided River Aid (BRaid) is a community group that was formed in 2006, in response to concerns about the state of braided river species and ecosystems. While it has a broad interest, BRaid has a focus towards river birds and associated pressures, particularly weeds and introduced predators. Activities undertaken by BRaid include facilitating regular seminars on braided river science, getting involved with braided river education and advocacy, and providing input into bird, weed, and predator monitoring programmes. BRaid has particular skills in the use of marketing and social media to communicate braided river issues, which distinguishes it from many similar community-based groups and government agencies.

BRAG – the Braided Rivers Action Group – and BRIDGE

ECan convened the Braided Rivers Action Group (BRAG) in 2017, in response to public concern over land management change in braided rivers. BRAG includes representatives from ECan, Te Rūnanga o Ngāi Tahu, DOC, LINZ, Federated Farmers, Forest & Bird, and territorial authorities. BRAG's purpose is to: maintain the braided river character of Canterbury rivers; consider innovative and regulatory opportunities to improve land management; and prioritise and implement management changes consistently across the braided rivers[5].

The BRIDGE project is another ECan initiative and the aim of the project is to clarify rules defining the edge of riverbeds. The project was to culminate in new rules in Plan Change 7 to the LWRP. However, at the time of writing ECan had put the plan changes associated with the BRIDGE project on hold, due to too much legal uncertainty associated with the Dewhirst decision appeal (see discussion above).

Salmon Anglers, and Fish and Game

Both the Salmon Anglers association and Fish and Game have a significant interest in the Rangitata River, due to its popularity as a Chinook salmon fishery, and because it is also an important brown trout and rainbow trout fishery. While most salmon angling occurs in the lower river, over 90% of salmon spawning occurs in the Deep Stream and Deep Creek in the upper catchment (Webb 2018). Other known spawning sites include Ealing Springs at State Highway 1 and McKinnons Creek, approximately 4 km upstream of the river mouth (Webb 2018).

[5] Source: https://www.ecan.govt.nz/get-involved/news-and-events/2019/braided-rivers-whats-the-story. Accessed September 2019.

There are potentially competing interests between Fish and Game and DOC, due to impacts of introduced sports fish on native fish communities (especially non-diadromous species) (McIntosh et al. 2010). Fish and Game applied for the Rangitata WCO and they have been actively involved in advocating for protection of the river's natural values. Similarly, it was the salmon anglers who raised concerns around effects of water abstraction on sedimentation in the lower Rangitata River, which was one of the drivers for the new NIWA research programme in the river. Thus, salmon anglers and Fish and Game are important and influential groups in the Rangitata catchment.

NIWA Braided Rivers Research Programme

Much of NIWA's current research related to braided rivers is being conducted under the eFlows programme led by Doug Booker. The eFlows programme has a focus on understanding effects of flow regime changes on rivers and estuaries. Within that programme, a major project of relevance to the Rangitata River and run by Jo Hoyle is evaluating the implications of flow changes on the physical characteristics of rivers, in particular:

- Assessing the effects of flood harvesting on fine sediment deposition (using the DELFT3D model);
- Assessing the effects of flood harvesting on geomorphology (also using the DELFT3D model), and objective ways of quantifying changes (e.g., habitat units, braiding index, other metrics); and
- Developing remote-sensing approaches using hyper-spectral imagery to identify/monitor different nuisance exotic plant species.

Much of this work will focus on data collected from the Arundel and Ealing reaches of the Rangitata River, and will involve a mixture of new data collection and modelling. NIWA is working with Environment Canterbury and the University of Waikato to collect new high-resolution geomorphology data from the river. The University of Waikato is collecting high resolution LiDAR data (elevation data above the water line) from the river gorge to the mouth, while NIWA is collecting complementary bathymetry data (to get data below water). This has been completed in high detail for the Ealing reach and the plan is to extend this, in lesser detail, for the full length of river from Klondyke to the coast. Once field surveys are completed, the data can be used to construct physical models of the river. The physical models can then be used to run 'numerical experiments', exploring how changes in flow regimes impact fine sediment dynamics, geomorphology, and aquatic habitat (when used in combination with data on species' habitat preferences).

The short-term research goal for the braided river vegetation work is to develop a cost effective means of monitoring nuisance weeds. Assuming this is successful, the longer term goal is to use weed monitoring to improve understanding of rates of growth and thresholds of removal for nuisance weeds to both inform weed control strategies and better incorporate vegetation dynamics into morphodynamic models (e.g., building on the existing GIAM2D model used in the Waitaki River). Improving these models will enable better prediction of the impacts of flow regime change on river morphology and aquatic and terrestrial habitat.

Other related work programmes include the following:

- A current PhD research project by Richard Measures that is looking at the relationship between river flows and hapua dynamics, with a view to developing predictive models.
- Flow-temperature modelling by Doug Booker.
- Flushing flow requirements for periphyton (Cathy Kilroy).
- Flow effects on larval fish dispersal (Eleanor Gee).
- Identifying microhabitat characteristics of wrybill habitats (Amy Whitehead).
- Deposited fine sediment effects and fish (Rick Stoffels).

In addition, NIWA collected bi-monthly fish and invertebrate data from four reaches along the Rangitata River from July 2018 to June 2019. This was effectively a repeat of a similar earlier survey that was conducted in the 1980s. At the time of writing, there was no budget to analyse this data in the 2019-2020 financial year. These data would be very beneficial to DOC, as it would help address a data gap in the lower river.

A new research programme that just received funding in the 2019 MBIE Endeavour funding round is a collaboration with Lincoln Agritech that explores the relationship between surface water and ground water extent in braided rivers. This research will include data collected from the Selwyn River in Canterbury. The research goals are to deliver new knowledge and models to estimate water loss from any part of any braided river, and quantification of the environmental and economic benefits of different river management strategies. Another programme subject to funding approval is an MBIE Smart Idea proposal aimed at testing the hypothesis that restricting river braiding (e.g., by stopbanks) can decrease bedload transport. This work expands an existing Marsden Fund project and will likely focus on the Waiho River (West Coast) and Kowhai River (Kaikoura).

5. OPPORTUNITIES AND ACTIONS

There are numerous opportunities for improved understanding and protection of braided rivers that are relevant to freshwater conservation values in the Rangitata River (O'Donnell et al. 2016; Lewis & Maloney 2019). While the potential list of actions is long, for the Rangitata River these opportunities can be readily prioritised based on recurring themes noted above. Broadly, these opportunities can be split into "feet under the table" actions that involve significant collaboration between DOC and other groups, and "feet on the ground" actions that involve field-based data collection. The following suggested priorities are intended to provide a starting point for DOC, and it is assumed priorities will be further developed over time as the restoration plan is developed.

5.1. "Feet Under the Table" Actions

- **Engage with Te Rūnanga o Arowhenua.** Early engagement with manawhenua should be a high priority in the process of developing a catchment restoration plan. Partnership with Te Rūnanga o Arowhenua is an obligation of government departments, as legislated by the Ngai Tahu Claims Settlement Act 1988. Engagement should commence early in the process of restoration planning, to provide sufficient time for te rūnanga to provide a useful contribution to the process.

- **ECan & DOC braided river plan.** Work with ECan to prioritise protection of the Rangitata River as part of the new braided river planning process. Considerable time and effort could be saved if ECan and DOC work together to develop a management plan for the Rangitata River. To ensure adequate protection of the braided river habitat mosaic, the plan should encompass the entire braidplain, not just the regularly flooded gravel bed.

- **Cap on water allocation.** Work with ECan to establish a limit on the total amount of water allocated for abstraction from the river. The Rangitata River currently stands out as the only braided river in Canterbury with no total cap on allocation in place or in a proposed regional plan change. It is very difficult to manage cumulative effects of water abstraction without a clear limit in a planning document.

- **River encroachment.** Work with ECan, LINZ, and landowners to improve and halt further encroachment into the Rangitata River braidplain. Encroachment is one of the most significant threats currently facing braided river ecosystems. Discussions should first be had with ECan, as they have been most heavily involved with this matter via the Dewhirst case. Natural character, biological communities, water quality and diverse and wide planted riparian buffers in association with a more natural floodway should be promoted (Lewis & Maloney 2019).

- **Catchment springs.** Work with ECan to afford better protection to sensitive spring habitats, especially in the upper catchment. This could potentially be achieved by including springs and springfed streams as a special management unit in a new river plan. An important first step is better mapping of springfed waterways, which would entail a combination of desktop GIS work coupled with field validation.

5.2. "Feet on the Ground" Actions

- **NIWA braided river programme.** There is considerable opportunity for DOC to get involved with the new NIWA research programme that includes the Rangitata River. As the braided river programme is currently in the planning stages, this is an opportune time for DOC to assess what complementary research they could undertake to add value to the NIWA investigations. In particular, DOC could undertake targeted monitoring of plant, invertebrate, fish, lizard, and bird populations in the vicinity of physical habitat modelling reaches. This would help ensure good alignment between predictive models and conservation values in the river.

- **NIWA fish and invertebrate data.** Invertebrate and fish monitoring data collected by NIWA over 2018/19 is the most recent and comprehensive data for the catchment, but there is currently no budget for the data to be analysed. DOC could fund the analysis and reporting of this dataset, which would greatly improve current understanding of the status of fish and aquatic invertebrates in the catchment.

- **Map of conservation values.** DOC should develop GIS layers of current status and distribution of key values and habitats throughout the Rangitata including fish, plants, invertebrates, birds, lizards, and key pressures. This would then be a key resource to aid future management direction.

- **Monitoring.** It is crucial to develop a robust monitoring programme, both to establish a current baseline and to monitor changes over time in relation to management interventions. There is also an opportunity to work with ECan on their proposed monitoring of fish populations around the hapua. This could include expanding the monitoring programme to provide a better understanding of the current status of Stokells smelt populations (amongst other species) and potential factors affecting them.

- **Upland longjaw galaxias.** Field-based research is needed to improve understanding of the status, ecological requirements and protection of upland longjaw galaxias populations. This will likely require an improved monitoring programme that targets habitats, rather than fixed locations (due to changes in spring locations over time), and collaboration with Fish and Game regarding potential impacts of sports fish on native fish. Lamprey, eels and inanga status and extent and restoration of key habitats should also be considered.

- **Weeds, predators, and birds.** This is core work for DOC in the upper catchment and this should be continued and enhanced through closer collaboration with ECan. More work on understanding the state of weeds, predators and native birds in the lower river is required. The NIWA braided river programme provides a good opportunity to collect new data that can be used to help inform new predictive models (see first bullet point above). Targets for work goals need to be established for specific areas including eradication, containment and control.

- **Work at key habitats.** Work with landowners and key agencies to develop best practice management and restoration for improving populations and mitigating threats to threatened and at-risk species and habitats. These sites could be used as exemplar sites to show others what can be achieved.

- **Foster community interest.** Work with existing successful networks such as BRaid to further inspire, assist and develop local community interest in braided river restoration.

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7. REFERENCES

Andrew, I. G., Macfarlane, R. P., Johns, P. M., Hitchmough, R. A., and Stringer, I. A. (2012). The conservation status of New Zealand Diptera. New Zealand Entomologist 35, 99–102.

Benn, J. (2010). Instream intrinsic values of the Rangitata River catchment. Department of Conservation internal report, Document No. DOCDM-128172, August 2010.

Boffa Miskell (2019). Upper Rangitata River ten year weed plan. Weed surveillance and control plan 2019-2029. Report prepared by Boffa Miskell Limited for Environment Canterbury, May 2019.

Bonnett, M. L. (1986). Fish and benthic invertebrate populations of the Rangitata River. Ministry of Agriculture and Fisheries, Fisheries Environmental Report No. 62, January 1986.

Bowie, S. (2002). Mt Potts pastoral lease. A report on the aquatic fauna surveys. Report prepared for Department of Conservation, December 2002, Report No. OLDDM-322582.

Bowie, S. (2010). Erewhon pastoral lease. A report on the aquatic fauna surveys. Department of Conservation Report (Part 1), March 2010.

Bowie, S. (2014). Erewhon pastoral lease. A report on the aquatic fauna surveys. Department of Conservation Report (Part 2), May 2014.

Bowie, S. (2016). Draft summary of information on freshwater values and threats for the Upper Rangitata EMU (summary description of key classes and maps). Department of Conservation draft internal report, May 2016.

Capmourteres, V., and Anand, M. (2016). 'Conservation value': a review of the concept and its quantification. Ecosphere 7(10): e01476. 10.1002/ecs2.1476.

Chinn, W. (2009). A qualitative survey of invertebrate values present on O Tu Wharekai (Ashburton Lakes / Hakatere Conservation area). Department of Conservation Internal Report, August 2009.

Clucas, R. (2011). Upland longjaw galaxias (*Galaxias prognathus*) survey of the Rangitata River and catchment. Department of Conservation File Note, Raukapuka Area Office, Document No. DOCDM-1444845.

Crow, S. (2018). New Zealand Freshwater Fish Database. Version 1.6. The National Institute of Water and Atmospheric Research (NIWA). Occurrence dataset https://doi.org/10.15468/ms5iqu accessed on 4 September 2019.

Environment Canterbury (2017). Rangitata River asset management plan. Environment Canterbury internal report. Provided by David Owen, Principal Biodiversity Advisor, Braided Rivers, June 2019.

Duncan, M. J., and Hicks, M. (2001). 2D habitat modelling for the Rangitata River. NIWA Client Report CHC01/72. Prepared for Central South Island Fish and Game Council Environment Canterbury Rangitata Diversion Race Management Ltd, July 2001.

Dunn, N. (2016). Lawrence River upland longjaw galaxias (*Galaxias prognathus*) survey April 2016. Memorandum from Nicholas Dunn to Brad Edwards dated 10 May 2016, Department of Conservation Document DOC-2777479.

Dunn, N. R., Allibone, R. M., Closs, G. P., Crow, S. K., David, B. O., Goodman, J. M., Griffiths, M., Jack, D. C., Ling, N., Waters, J. M., and Rolfe, J. R. (2018). 'Conservation status of New Zealand freshwater fishes, 2017'. (Department of Conservation: Wellington.)

Grainger, N., Harding, J., Drinnan, T., Collier, K., Smith, B., Death, R., Makan, T., and Rolfe, J. (2108). Conservation status of New Zealand freshwater invertebrates, 2018. Department of Conservation New Zealand Threat Classification Series 28.

Gray, D. P. (2009). A new species of Zelandobius (Plecoptera: Gripopterygidae: Antarctoperlinae) from the upper Rangitata River, Canterbury, New Zealand. New Zealand Journal of Marine and Freshwater Research 43, 605–611.

Gray, D. (2018). Natural character assessment guidelines for braided rivers. Environment Canterbury Report R18/35, June 2018.

Gray, D. (2018). High country spring-fed streams: effects of adjacent land use. Environment Canterbury Report R18/32, August 2018.

Gray, D., and Allibone, R. (2019). Prioritisation of native aquatic species habitat for protection under the LWRP Omnibus plan change. Environment Canterbury Memorandum to Andrea Richardson, Senior Planner, 21 May 2019.

Gray, D., Grove, P., Surman, M., and Keeling, C. (2018). Braided rivers: natural characteristics, threats and approaches to more effective management. Environment Canterbury Report R17/13, August 2018.

Gray, D., and Harding, J. (2007). Braided river ecology. A literature review of physical habitats and aquatic invertebrate communities. Department of Conservation, Science for Conservation 279, November 2007.

Gray, D., and Harding, J. (2010). Spatial variation in invertebrate communities in New Zealand braided rivers. Department of Conservation Science for Conservation 302, April 2010.

Gray, D. P., Hicks, D. M., and Greenwood, M. J. (2016). Advances in geomorphology and aquatic ecology of braided rivers. In 'Advances in New Zealand freshwater science'. (Eds P. G. Jellyman, T. J. Davie, C. P. Pearson, and J. S. Harding.) pp. 357–378. (New Zealand Freshwater Sciences Society and New Zealand Hydrological Society.)

Grove, P., Parker, M., Gray, D., and Behrens, F. (2015). Land use change on the margins of lowland Canterbury braided rivers, 1990-2012. Environment Canterbury Report R15/49, April 2015.

Hitchmough, R., Barr, B., Lettink, M., Monks, J., Reardon, J., Tocher, M., van Winkel, D., and Rolfe, J. (2016). 'Conservation status of New Zealand reptiles, 2015'. (Department of Conservation: Wellington.)

Holdaway, R. J., Wiser, S. K., and Williams, P. A. (2012). Status assessment of New Zealand's naturally uncommon ecosystems. Conservation Biology 26, 619–629.

Hume, T., Gerbeaux, P., Hart, D., Kettles, H., and Neale, D. (2016). A classification of New Zealand's coastal hydrosystems. Report prepared by NIWA for Ministry for the Environment, NIWA Client Report HAM2016-062, October 2016.

Lettink, M., and Monks, J. M. (2019). Ecology of scree skinks (Oligosoma waimatense) in O Tu Wharekai Wetland, mid-Canterbury high country, New Zealand. New Zealand Journal of Ecology 43, 3354.

Lewis, D., and Maloney, R. (2019). Braided river research and management priorities: terrestrial invertebrates, lizards, terrestrial native plants, terrestrial weed invasions, and geomorphology, wetlands, river mouths and estuaries. Report prepared by Department of Conservation for Environment Canterbury.

McDowall, R. M. (1990). 'New Zealand freshwater fishes: a natural history and guide'. (Heinemann Reed: Wellington.)

McIntosh, A. R., McHugh, P. A., Dunn, N. R., Goodman, J. M., Howard, S. W., Jellyman, P. G., O'Brien, L. K., Nystrom, P., and Woodford, D. J. (2010). The impact of trout on galaxiid fishes in New Zealand. New Zealand Journal of Ecology 64, 195–206.

Ministry for the Environment (2018). 'Climate change projections for New Zealand: atmosphere projections based on simulations from the IPCC Fifth Assessment' 2nd ed. (Ministry for the Environment: Wellington.)

Murray, T. (2019). Invertebrate biodiversity and management on braided rivers. Braided River Aid, Braided Rivers Seminar, Lincoln University, 26 June 2019.

O'Donnell, C. F. G., Sanders, M., Woolmore, C., and Maloney, R. F. (2016). 'Management and research priorities for conserving biodiversity on New Zealand's braided rivers'. (Department of Conservation: Wellington, New Zealand.)

O'Donnell, C., and Schmechel, F. (2001). Rangitata River - still outstanding for wrybills. Southern Bird 8, 3.

Robertson, H., Bowie, S., Death, R., and Collins, D. (Eds.) (2016). 'Freshwater conservation under a changing climate. Proceedings of a workshop hosted by the Department of Conservation, 10-11 December 2013'. (Department of Conservation: Christchurch.)

Rogers, P., Couch-Lewis, Y., and Burrell, G. (2018). Report and decision of the hearing commissioners on the Klondyke pond, 10 cumec water take and associated resource consent applications. Hearing commissioners report to Environment Canterbury and Ashburton District Council, July 2018.

Sanders, M. D. (2018). Statement of evidence in relation to resource consent applications by Rangitata Diversion Race Management Limited (RDRML) to the Canterbury Regional Council and Ashburton District Council for resource consents for the construction, operation and maintenan. Statement of evidence of Mark David Sanders, March 2018.

Scouller, J., and Veendrick, B. (2016). Klondyke storage proposal - hydrology assessment. Report prepared by Pattle Delamore Partners for HOBEC on behalf of Rangitata Diversion Race Limited, July 2016.

Sirvid, P. J., Vink, C. J., Wakelin, M. D., Fitzgerald, B. M., Hitchmough, R. A., and Stringer, I. A. N. (2012). The conservation status of New Zealand Araneae. New Zealand Entomologist 35, 85–90.

Stark, J. D., and Maxted, J. R. (2007). A user guide for the Macroinvertebrate Community Index. Report prepared for the Ministry of the Environment. Cawthron Report No. 1166.

Stevens, H. (2015). Deep Stream/Wetland restoration. Environment Canterbury Immediate Steps Biodiversity Protection and Restoration Programme, Final Report, 31 July 2015.

Sullivan, W., Robertson, H., Clucas, R., Cook, L., and Lange, K. (2012). 'Arawai Kākāriki Wetland Restoration Programme. Ō Tū Wharekai outcomes report 2007-2011'. (Department of Conservation: Christchurch.)

Te Rūnanga o Arowhenua (2010). Cultural health assessment of Ō Tū Wharekai / the Ashburton Lakes. Report prepared by Te Rūnanga o Arowhenua, June 2010.

Tipa & Associates (2015). Cultural values for the Rangitata catchment. Report prepared by Tipa & Associates, November 2015.

Trewick, S., Johns, P., Hitchmough, R., Rolfe, J., and Stringer, I. (2016). Conservation status of New Zealand Orthoptera. Department of Conservation New Zealand Threat Classification Series 16, Wellington.

Webb, M. Statement of evidence for the Rangitata Diversion Race Consents (the Klondyke proposal). Statement of evidence for Central South Island Fish and Game Council, April 2018.

Woods, R., Tait, A., Mullan, B., Hendrikx, J., and Diettrich, J. (2008). Projected climate and river flow for the Rangitata catchment for 2040. NIWA Client Report CHC2008-097, July 2008.