ASHBURTON WATER MANAGEMENT ZONE COMMITTEE AGENDA

A **Meeting** of the Ashburton Water Management Zone Committee will be held as follows:

DATE: Tuesday 26 November 2024

TIME: 1.00 pm

VENUE: Council Chamber, Te Whare Whakatere
2 Baring Square East, Ashburton

MEETING CALLED BY: Hamish Riach, Chief Executive, Ashburton District Council
Stefanie Rixecker, Chief Executive, Environment Canterbury

ATTENDEES:

Chris Allen
Adi Avnit
Clare Buchanan
Angela Cushnie
Bill Thomas
Sidinei Teixeira
TBC (Te Runanga o Arowhenua)
Arapata Reuben (Te Ngai Tuahuriri Runanga)
Jess Hobbs (Te Taumutu Runanga)
TBC (Tangata Whenua Facilitator)
Councillor Richard Wilson (Ashburton District Council)
Councillor Ian Mackenzie (Environment Canterbury)
Mayor Neil Brown (Ashburton District Council)

Zone Facilitator
Jaimee Grant
Tel: 027 220 2694
jaimee.grant@ecan.govt.nz
Environment Canterbury

Committee Advisor
Carol McAtamney
Tel: 307 9645
carol.mcatamney@adc.govt.nz
Ashburton District Council

Tangata Whenua Facilitator
TBC

Environment Canterbury

Ashburton Zone Committee Meeting

Tuesday 26 November 2024

Meeting Commences: 1.00pm

Order of Business

4 Register of Interests

Chris Allen	Farm owner of sheep, beef, lambs, crop Water resource consents to take water from tributary of Ashburton River and shallow wells Member of Ashburton River Liaison Group
Adi Avnit	Mid Canterbury Community Vehicle Trust - Treasurer
Clare Buchanan	Head of Environment & Innovation at Align Farm Align Farms holds an irrigation resource consent to take water from shallow wells hydraulically linked to the Ashburton river Align Farms holds MHV water and Fonterra Shares Align Farms suffered significant flood damage on their support block
Neil Brown	Mayor Acton Irrigation Limited - Director Irrigo Centre Limited - Director Acton Farmers Irrigation Co-operative Limited - Director Browns Farm Limited – Director and Shareholder
Angela Cushnie	Kanuka Mid Canterbury Regeneration Trust - Trustee Hinds Reserve Board Committee member Mid Canterbury Catchment Collective – Coordinator Secretary for Hekeao Hinds Lowlands Catchment Group
Jess Hobbs	
Ian MacKenzie	Environment Canterbury Councillor
Arapata Reuben	Trustee – Tuhono Trust Trustee – Mana Waitaha Charitable Trust Member - National Kiwi Recovery Group Rūnanga Rep – Christchurch – West Melton Water Zone Committee
Bill Thomas	Farm owner of Longbeach Estate Ltd (sheep, beef, lambs, arable, dairy) Member of Eiffelton Irrigation Scheme Hekeao/Hinds Water Enhancement Trust – Settler Director of Longbeach Estate & Longbeach Dairies
Sidinei Teixeira	Masters student at Lincoln University studying a Master's in Water Resource Management Former Head of Science at Mt Hutt College and Chemistry teacher at Christ's College Recipient of the Callaghan Innovation fund to conduct research on the impacts of the May/June 2021 rainfall event through MHV Water Passionate about the sustainable use of natural resources
Richard Wilson	Ashburton District Councillor Dairy Farmer at Hinds Shareholder in MHV Irrigation

5 Confirmation of Minutes

Unconfirmed Minutes

Minutes of a meeting of the **Ashburton Water Management Zone Committee** held on Tuesday 22 October 2024, commencing at 1.11pm in the Council Chamber, Te Whare Whakatere, 2 Baring Square East, Ashburton.

Present

Mayor Neil Brown, Councillor Richard Wilson, Adi Avnit, Chris Allen, Angela Cushnie, Bill Thomas (Chair) and Sidinei Teixeira (via MS Teams).

Non attendance

Arapata Reuben

In attendance

Environment Canterbury: Dave Moore (Facilitator) and Ashburton District Council: Carol McAtamney (minutes)
Department of Conservation: John Benn

0 members of the public in attendance.

1 Welcome

Dave Moore opened the meeting with a Karakia.

2 Apologies

That apologies for absence be received on behalf of Clare Buchanan, Jess Hobbs and Councillor Ian Mackenzie

Thomas/Wilson Carried

3 Extraordinary Business

Nil.

4 Register of Interests

Nil.

5 Confirmation of Minutes

That the minutes of the Ashburton Water Management Zone Committee meeting held on 24 September 2024, be taken as read and confirmed.

Thomas/Cushnie Carried

Chris Allen joined the meeting at 1.15pm

1. Matters Arising

Nil.

6 Correspondence

Inward:

Nil.

Outward:

Nil.

7 Public Contributions

Nil.

8 Zone Committee Action Plan – funding presentations and considerations

Presentations from applicants for their funding projects:

- **Ashburton Forks Catchment Group (Will Wright)**

Pest and Predator Control Programme, requested $8,480.51
Chris Allen – declared an interest and took no part in decision making process
Angela Cushnie – declared an interest as chair of Mid Canterbury Catchment Collective and took no part in the decision making process

Recommendation

That the Zone Committee supports the allocation of $8,480.51 from the Zone Committee Action Plan Budget for FY 2023/34 to the Ashburton Forks Catchment group for the purchase of 15 AT220 traps.

Wilson/Thomas Carried

- **Hakatere Rūkau Group (Ross Hawthorne – apology)**

Chalmers Avenue – Trevor's Road River Development, requested $13,045.39 (includes gst)

Recommendation

That the Zone Committee supports the allocation of $11,343.00 from the Zone Committee Action Plan Budget for FY 2023/34 to the Hakatere Rūkau group for the:

1) Purchase of plants, plant guards, bamboo sticks and fertiliser tabs
2) Engaging a contractor to poison Silver Poplars and to spray ivy.

Avnit/Allen Carried

- **Mike Prince (apology)**

Awa Awa Rata Reserve and Pudding Hill Reserve Predator Management, requested $5,589.70

Recommendation

That the Zone Committee supports the allocation of $5,589.70 from the Zone Committee Action Plan Budget for FY 2023/34 to the Awa Awa Rata Reserve and Pudding Hill Reserve Predator management for the purchase of traps, lures and accessories to expand and maintain trapping coverage.

Allen/Cushnie Carried

- **Ashburton District Biodiversity Advisory Group (Dr Christian Chukwuka and Donna Field - apologies)**

Pudding Hill Stream Weed Control (Phase 2), requested $7,370.00

Recommendation

That the Zone Committee supports the allocation of $7,370.00 from the Zone Committee Action Plan Budget for FY 2023/34 to the Ashburton District Biodiversity Advisory group for chemical purchase and contractor's hourly payment to enable the continuation of the weed work around Pudding Hill stream that stopped in March 2024 and will be undertaken around October 2024 or by March/April 2025

Thomas/Wilson Carried

- **Hekeao Hinds Water Enhancement Trust (Dr Brett Painter)**

Neil Brown - declared an interest and took no part in decision making process
HHWET Native Plant Maintenance 2024, requested $8,000.00

Recommendation
That the Zone Committee supports the allocation of $6,000 from the Zone Committee Action Plan Budget for FY 2023/34 towards maintaining up to 15,500 plants at four NRR and MAR site, the work will be undertaken by Brailsfords.
Thomas/Allen Carried

- **MHV Water Ltd & Cloud8 Dairy Ltd (Mel Brooks-apology)**

Richard Wilson – declared an interest and took no part in decision making process
Cloud8 Planting, requested $249,855

Recommendation
That the Zone Committee request the applicant to come back with a more targeted request that is realistic to the Zone Committee Action Plan budget.
Cushnie/Thomas Carried

9 Zone Committee Action Plan – funding presentations and considerations

- **Methven Lions Club – Garden of Harmony project**

At the previous meeting a request was made from the Methven Lions Club Garden of Harmony project to repurpose the funding allocation of $7,306 from plant purchasing to assist with the costs associated to the establishment of a Landscape Concept plan.

It has now been advised that the project has received a funding allocation from the Methven Community Board so will not need to repurpose the Zone Committee funding.

- **CWMS Zone Committee Review**

Chris Allen, Adi Avnit and Angela Cushnie will attend an online session on Wednesday 30 October which is to provide the CWMS Zone Committee chairs and deputy chairs with an update on the zone Committee review.

- **Actions from previous meetings/workshops**

Point 6 – Ashburton Lyndhurst Irrigation hearing noted that the Hakatere/Ashurton hapua is degraded.
A request was made from the Zone committee for an Environment Canterbury staff member to come and present to the committee on this finding.
It was be advised that staff are unable to present – what is the reasoning for this?

Point 7 – Greenstreet Creek
The Zone Committee were unhappy with the response, would like more details/facts to back up the statements made by Environment Canterbury.

- **Rangitata Revival Project**

An invite is to be extended for representatives to come and provide and update to the Zone Committee.

- **Rangitata Revival Project**

As we are now approaching the summer season it was suggested that a representative from Environment Canterbury be invited to a Zone Committee meeting to give an update on key points of contact within their organisation.

10 Other Business

Nil.

Next meeting

The next meeting of the Ashburton Water Zone Committee will be held in the Ashburton District Council Chamber Hine Paaka at 1:00pm on Tuesday 26 November 2024.

The meeting closed at 3.12pm with a Karakia by Dave Moore.

Dated this 26th day of November 2024 ________________________________ (Chair)

HUI/MEETING: Ashburton Zone Committee	
AGENDA ITEM NO: 9	**KAUPAPA/SUBJECT:** Ashburton/Hakatere hāpua
KAITUHI/AUTHOR: Jaimee Grant, Facilitator	**WĀ/MEETING DATE:** 26 November 2024

Purpose

For the Zone Committee to receive information on the Ashburton/Hakatere hāpua and its state.

Recommendation

That the Zone Committee:

1. **Receives** the presentation on the Ashburton/Hakatere hāpua.

Background

Following the Committee's July meeting, Chris Allen, Deputy Chair, put forward a request for information on the Ashburton/Hakatere hāpua noting reference had been made in a High Court hearing to the hāpua being in a degraded state. The request asked for information on how the state of the hāpua was determined.

Environment Canterbury provided a copy of three reports in August which informed the state of the hāpua which are also attached:

- NIWA Anecdotal state of river mouth users
- Science Summary - hāpua fish survey 2020-21
- NIWA report - potential drivers of the decline of hāpua fish populations

Subsequently, an additional request was received asking if there were any further reports that were used to determine the state of the hāpua.

At their October meeting, the Committee expressed its frustration with the timeframes for receiving information on several topics including this request. Subsequently, Environment Canterbury advised information on the degradation of the Ashburton/Hakatere hāpua would be presented by the Principal Freshwater Scientist at its November meeting.

Presentation

Adrian Meredith, Principal Scientist – Water Ecology Science from Environment Canterbury will provide a presentation on the Ashburton/Hakatere hāpua and its state. A copy of the presentation will be provided at the meeting.

Attachments

- Report 1: NIWA (2022) *Perceptions of change: Recording observations over decades for Canterbury hāpua*
- Report 2: Environment Canterbury (2023) *Fish community surveys of Canterbury Hāpua 2020/21*
- Report 3: NIWA (2022) *Potential drivers of the decline of hāpua fish populations*

Perceptions of change: Recording observations over decades for Canterbury hāpua

Prepared for Environment Canterbury

January 2022

Prepared by:
Don Jellyman
Melanie Mayall-Nahi

For any information regarding this report please contact:

Don Jellyman
Principal Scientist
Freshwater Ecology
+64-3-343 7889
don.jellyman@niwa.co.nz

National Institute of Water & Atmospheric Research Ltd
PO Box 8602
Riccarton
Christchurch 8011

Phone +64 3 348 8987

NIWA CLIENT REPORT No: 2021348CH
Report date: January 2022
NIWA Project: ENC21503

Revision	Description	Date
Version 1.0	Final Report	27 January 2022

Quality Assurance Statement		
	Reviewed by:	Shannan Crow
	Formatting checked by:	Rachel Wright
	Approved for release by:	Phillip Jellyman

Contents

Tables

Figures

Executive summary

In response to concerns about perceived physical and biological changes to the hāpua of three major Canterbury rivers (Rakaia, Ashburton/Hakatere, Rangitata), Environment Canterbury (ECan) commissioned a survey of experienced river users to ascertain their observations over the years they had been associated with particular hāpua. Lists of interview protocols and questions were prepared and circulated to ECan and within the National Institute of Water and Atmospheric Research (NIWA) for approval. Although potential interviewees were sought from a range of community groups, only anglers responded to this request. Twenty experienced anglers were interviewed, and this provided 12 responses for the Rakaia River, six for the Ashburton River, and seven for the Rangitata River. Interviewees had an average of 50.5 years association with the hāpua they were responding to, and spent an average of 118 days/year engaged in some activity associated with the hāpua (e.g., fishing, bird watching, generally observing and "hanging out") although fishing for salmon, sea-run brown trout, and whitebait were the main activities. Many anglers had family associations with the various hāpua that spanned generations.

The main physical issues identified for all three hāpua were insufficient flows and deteriorating water quality, followed by increased fine sediment and periphyton and more frequent migration of river mouths to the north. Most respondents considered these issues were directly attributable to an overcommitment of ground and surface water, with resultant changes to both water quality and quantity – accordingly there were frequent strong criticisms of resource managers. The main fishery issues identified for all three hāpua were reduced abundance of smelt, sea-run brown trout (*Salmo trutta*) and Chinook salmon (*Oncorhynchus tshawytscha*). There was general agreement that the decline of Stokell's smelt (S*tokellia anisodon*), a keystone species, was reasonably recent, especially over the past five years. The high feeding dependence of sea-run brown trout on smelt is thought to have resulted in a parallel decline in trout abundance, although the decline may have been over a longer period. The decline in numbers, size and condition of Chinook salmon was considered to be much longer term, perhaps going back to the late 1990's. In contrast to these three species, whitebait were considered to be maintaining their abundance. The almost complete disappearance of Stokell's smelt seems to have resulted in considerable mortality of adult and juvenile seabirds, especially black-billed gulls (*Larus bulleri*), an issue of considerable concern to many anglers. Anglers often discussed the emotional impacts that the loss of hāpua fisheries has had on their lives, and how the fishing huts at the hāpua of all three rivers were now primarily used for community activities rather than fishing.

1 Introduction

The Canterbury region has the largest number of braided rivers in Aotearoa New Zealand. The seven alpine rivers that contribute 88% of the flow within the region are all braided – i.e., the Waiau Toa/Clarence, Waiau Uwha, Hurunui, Waimakariri, Rakaia, Rangitata and Waitaki Rivers (Environment Canterbury 2019). The unique braided character is maintained by periodic large channel-forming floods, sediment supply, and room to move laterally (Ashmore 2013). Compared with other regions, Canterbury has abundant water, with more than 4700 lakes and tarns and over 78,000 km of rivers and streams. About 70% of Aotearoa New Zealand's known groundwater is in Canterbury.

Flow in braided rivers is divided among many small channels, the average depths of which are less than would be that of a single channel carrying all the flow (Mosley 1982). Provision of adequate flows to maintain sufficient depth for instream uses like fish passage (especially Chinook salmon), jet boating, kayaking and the maintenance of biodiversity is of critical importance when considering aspects of flow management like water abstraction. With climate change, "higher temperatures, less rainfall and greater evapotranspiration are likely to cause increasing pressure on water resources, particularly in North Canterbury; droughts are likely to become more frequent and more extreme" (Ministry for the Environment 2018). This scenario will put even more pressure on the use of water throughout the province.

So, although Canterbury has a lot of water it is not always in the right place at the right time, and this has resulted in both considerable abstraction of groundwater and development of large-scale irrigation schemes. There is widespread concern that over-commitment of ground and surface waters has led to the reduction and loss of many Canterbury waterways, a situation exacerbated by periodic droughts (Mitchell 2016). The intensification of land use, especially dairying, has resulted in considerable increases in nitrate levels in groundwater (e.g., Deans 2021). Increased enrichment (eutrophication) of a number of both high country lakes (e.g., Ashburton Lakes; Drinana and Robertson 2019) and lowland lakes (e.g., Te Waihora/Lake Ellesmere; Pegasus Lake) has been linked to more intensive farming and urban development (e.g., Waihora – Ellesmere Trust 2017). A number of Canterbury rivers that were renowned for their trout fishing have much reduced flows and often long periods of no surface flow (e.g., Hinds River, Selwyn River).

Prior to the granting of a National Water Conservation Order (NWCO) for the Rakaia River in 1988, there was a concerted effort to determine the fisheries resources of the catchment, including surveys of both native and introduced fish within the hāpua (Eldon and Greager 1983), mainstem (Davis et al. 1983), and flows that would facilitate fish habitat and fish passage (Glova and Duncan 1985). The survey of the hāpua (Eldon and Greager 1983), showed fish numbers were dominated by Stokell's smelt *Stokellia anisodon* (88% of all fish recorded; 96% of all fish recorded from November to January). These fish were so prolific that a small commercial fishery developed in the Ashburton River where smelt were caught and dried for sale in Southeast Asia and Fiji – an estimated 6 and 15 tonnes were harvested in 1981 and 1982 respectively, although subsequent catches were smaller (McDowall 1990). However, over recent years, anglers have reported the potential disappearance of this species (Littlewood 2020) which has consequent implications for fish and nesting birds utilising this prey species as a food resource.

Hāpua are key areas for fishers who variously attempt to catch whitebait (*Galaxias* spp.), sea-run brown trout, and Chinook salmon. Historically, such hāpua and associated wetlands were important areas for customary harvest of species like Stokell's smelt (McDowall 2011). While quantifying the extent of physical and biological changes on hāpua is challenging, many anglers and batch owners have long associations with particular hāpua, often going back decades. During such periods, they frequently notice changes to the river morphology and flows, and the abundance of target fish species. Anecdotal observations over several years can provide records of changes at both small- and large-time scales. For example, a previous postal questionnaire study of experienced trout anglers who fished lowland rivers in Aotearoa New Zealand (Jellyman et al. 2003) showed a strong consensus for a decline in angling quality (mainly fish abundance more so than fish size) over 70 years of memory; Canterbury was one of the regions where this decline was most marked with concerns over decreasing water quality (North Canterbury) and low flows (South Canterbury).

To compare the historic and present-day abundance of fish within the Rakaia hāpua, ECan recently commissioned a survey of the fish population of this area (at the time of writing the present report, this survey was ongoing, so final results were not available). In addition, ECan commissioned a series of interviews of experienced anglers, hut owners, and general public to obtain anecdotal accounts of the state of the hāpua and changes to fish stocks (this report). The present study collated information on perceived changes to fish stocks in general, but it had a particular focus on observations of Stokell's smelt, being a species that sustains both seabirds and many predatory fish species.

2 Methods

To ensure consistency of interviews, a standard series of questions were developed; these were submitted to ECan for approval, and then to NIWA's Human Ethics Committee to ensure they complied with NIWA's standard protocols for interviews. The first question ascertained which hāpua the participant was most familiar with; the next series of questions identified their length of experience and approximate effort they would spend each year pursuing those activities; this was followed by a series of questions related to changes they may have noticed to the hāpua, specifically changes in flows, sediment size and deposition, configuration of river channels and/or mouth configuration. The final series of questions were about their observations on the fish species they targeted or observed - any changes to the seasonality and overall abundance of each species, and any concerns they wished to express and suggestions they might recommend. In addition, a Verbal Consent Form and a Participants Information Sheet were developed to inform interviewees of the process of the interviews and gain their consent to participate. Copies of these forms and the question sheet are contained in Appendices A, B, C and D.

Names of experienced anglers were initially supplied by North Canterbury and Central South Island Fish and Game, and ECan. Approaches were also made to local fishing clubs, Forest and Bird, and local rūnanga (Arowhenua and Waihao) although no further names were supplied from these sources. During the initial angler interviews, several additional names were also supplied who were then approached and asked to be included in the present study. Preference was given to conducting face-to-face interviews, either by visiting interviewees at their home, or at a central location (North or South Rakaia huts). However, it was not possible to conduct face-to-face interviews of all people, often because of availability and adherence to national guidance on COVID-19 related restrictions. In such cases, interviews were conducted by phone. All participants were interviewed individually to avoid any collaboration between individuals.

In all interviews, the same set of questions was used, and responses recorded, usually by two NIWA staff, but also by electronic recording. Care was taken not to ask "leading questions" although sometimes it was necessary to ask interviewees to elaborate on answers. Information was later transcribed by one of the NIWA staff, and then checked by the other for accuracy. For each river, answers to each of the questions were then "cut and pasted" into a spreadsheet that collated relevant information about each subject (e.g., incidence of floods, sediment deposition, observations on salmon abundance, etc.). Many people took the opportunity to provide additional information, often expressing concern over management of water resources and fisheries – most of this was recorded and is given in Appendices F, G and H of this report. We also endeavoured to capture much of the emotion that accompanied responses by many interviewees when describing the physical and biological changes (usually adverse) to the rivers that have been such an important part of their lives.

In general, interviewees were able to answer all questions from their own knowledge and observations. In a few instances where individuals were not familiar with the areas in question, they mentioned the views of another person; however, such hearsay responses were not included in our analysis.

Summary comments for each river were then prepared from the spreadsheet. In addition, consistent themes across rivers were identified and are discussed in the report. Many suggestions for observed changes were given, and in general little or no attempt has been made to validate these opinions. Likewise, opinions about the reasons and impacts of changes varied between observers, and it was not always possible to find a consistent conclusion. Unless otherwise indicated, the opinions are those of the interviewees, although the authors have provided some additional context for some of the comments. Some additional information on life history aspects of the main fish species involved has been provided, together with some directions for possible ongoing studies.

Note that anglers refer to smelt as “silveries” although we have opted to use the term “smelt”. In large Canterbury rivers south of Banks Peninsula, Stokell’s smelt is the seasonally dominant species, and unless specified otherwise, “smelt” in this report refers to this species and not the common smelt (*Retropinna retropinna*). In practice, it is difficult to distinguish between the two species in the field and anglers cannot be expected to do this. Likewise, “trout” in this report refers to sea-run brown trout unless indicated otherwise, while “salmon” refers to Chinook salmon. Italicised comments in parentheses are those provided by the authors for clarity. As anglers almost invariably refer to the weight of fish in pounds (lb), we have also adopted this convention.

3 Results

Long-time anglers were the only group interviewed; this was not by design but due to the lack of other respondents. However, anglers proved an observant group of participants, as “fishing is more than catching fish”, and for many anglers, their involvement at the various hāpua was partly a lifestyle choice, and a desire to be involved with the outdoors. Successful fishing, especially salmon fishing, involves an intimate understanding of the relationships between the physical environment (flows, water clarity, depth, etc.) and the biological environment (the influence of seasonal and local conditions, the likelihood of a fish been resident in the area fished, best time of day, presentation of the lure, etc.). Over time, they build up an understanding of the complex relationships between the physical and biological ecosystems, and thus notice when something changes both within and between years. The benefit of longevity is therefore the ability to notice changes over long-time periods; many of these may be small yet incremental between years, and it can take several years until differences become obvious. While the reasons for such changes might not always be obvious, anglers are usually not short of theories and ideas!

The strength of collating anecdotal information is when the same observations are made by many different people — such occasions enhance the validity of observations, especially if they can then be cross-correlated with any quantitative data like flow, fishing diary records, or fish population surveys. We have structured the following results section for each hāpua based on these common themes and attempted to bring together the repeated concerns and observations that were independently mentioned by the participants. The present report was not required to provide reasons for consistent observations, although some likely influences are suggested and also some further research opportunities that might clarify particular assumptions.

For each river, summarised comments for each subject mentioned by interviewees are given below. The full list of all replies for each hāpua are given in Appendices F, G and H.

3.1 Interviewee profiles

Although we interviewed 20 people, a number were able to reply for two of the rivers — thus we effectively had 12 replies for the Rakaia, six for the Ashburton, and seven for the Rangitata. Because of such dual replies, it was not possible to assign the estimated years of association and the estimated days per year fished to each river. Rather, the data were combined to give overall estimates of use.

The estimated years of association with rivers ranged from 25 to 70, with an average of 50.5 years. The estimated days per year when people were actively associated with their activities on the river (usually fishing of some sort, but also birdwatching, just “hanging out”, etc.) ranged from 40 to 360 days per year, with an average of 118 days/year (note: for this, angling was recorded as occurring during “prime years” when people were still actively engaged in angling). Thus, the interviewees spent almost a third of their year engaged in some fishing activity on these three rivers. Collectively the 20 anglers surveyed had spent an estimated total of 326 years engaged in fishing on the Rakaia, Ashburton, and Rangitata Rivers. This is a significant amount of time spent observing and sometimes recording changes to river environments and adds considerable weight to the significance and validity of the outcomes of the survey.

3.2 Interviewee reasons for association to hāpua

Answers as to why an interviewee associated with a particular hāpua were many and varied. Many anglers on the Rakaia and Rangitata owned huts, and some of these had been in the family for three generations. The main motivating factor was the high quality of fishing available for both sea-run brown trout, and salmon. Whitebaiting also featured but was almost always a secondary reason compared to fishing for trout and salmon. Several Rangitata anglers spoke of the international reputation the river had enjoyed; it was variously described as **THE** salmon river, or on a par with the Rakaia. Another strong element in people's association with the rivers was the opportunity to be outdoors in an unspoiled environment "communing with earth, sea and sky". For Christchurch, Ashburton, and Timaru residents, the rivers were variously "local" and accessible, although riverside access to the Rakaia is more limited. The Ashburton River was described as "a hidden gem" and was considered "a safe" river.

With the significant declines in both trout and salmon fisheries, the huts at the hāpua mouths have changed from simply residences for anglers, to "social centres" where people interact more through competitions and other organised activities. Likewise, emphasis in the annual salmon fishing competitions has shifted from "a numbers game" (number and size of fish caught) to more of an excuse for mates to get together, go fishing and tell 'yarns'.

3.3 Rakaia Hāpua

3.3.1 Flows

Low flows

A significant issue raised by interviewees was the lack of flow of the Rakaia River relative to their historical observations. One person commented that anglers used to call the river "The mighty Rakaia" so "don't fall in or you risk death", but by late 2000's he was able to wade right across as if "the water wasn't there". Some interviewees recorded that the North Branch occasionally had no flow at all and considered this was a result of gravel extraction works and river diversion at the quarry at the head of the North Branch. Most interviewees assumed that low flows were a result of excessive water abstraction and increased intensification of farming. One interviewee stated that "anglers and farmers need to coexist, but intakes from the river must be effectively screened" (to prevent the entry of juvenile fish, especially salmon). There was some concern that lower flows lead to increased water temperatures. Some validation of lower flows came from an angler who said he used to need a two ounce lead weight above a Z spinner to get down deep, but now only needed ¼ of the weight (a half ounce weight) due to reduced flow and velocity.

Flood flows

Most people interviewed had noted faster recession rates of floods. There were also comments about the possible reduced magnitude of floods. For example, some interviewees have witnessed floods of 5800–6000 m^3/s years ago, but today would regard 1000 m^3/s as a large flood. Historically, increased flows of, say, 400 m^3/s would result in the river being too dirty to fish (for salmon) for a week, but now it clears in 2–3 days. This has impacted the angler's ability to fish for salmon as optimal turbidity occurs in a shorter window of time.[1] This was put succinctly by one angler: "[The] main thing is reduced flow. Used to be that flows 180–200 m^3/s were good for salmon fishing; now can fish at 100 m^3/s. The river now gets too clear too quick". Two others agreed with the historic optimal fishing flows (180–200 m^3/s) although there were differences in their observations of the impacts of lower flows with one stating "now at flows of less than 150 it's too dirty to fish", while the other claimed that today 150–160 m^3/s is best, and by 180 m^3/s the water is turbid.

[1] Note that conventional salmon fishing is most successful at a moderate level of turbidity. Adult salmon do not feed once in freshwater, but seemingly the passage of a spinner or fly in close proximity evokes an aggressive response. However, if the water is too clear, salmon avoid angler's lures, and if the water is too turbid, they do not see the lure.

So, there was a general consensus that two significant factors had affected the opportunity for successful salmon fishing (ignoring the issue of whether there were actually salmon available in the river). The first was that floods receded much faster than formerly, and the second was that the river clears more rapidly. The net impact of these changes is that the "window" of time for successful salmon fishing is now much reduced. Any changes to flood recession rates should be able to be detected from comparing rates of comparable -sized floods over time. However, reasons why the river is more turbid today than it was historically at similar flows also require further research – for example, this could be associated with angler's perceptions that there has been a noticeable increase in the amount of fine sediment in the river, and the amount of sediment in transport at given flows is simply greater today than formerly (and this is particularly obvious at the receding flows targeted by anglers).

3.3.2 Sediment

Fine sediment

All interviewees indicated significant changes in the fine sediment of the Rakaia River. Anglers presume that the apparent reduction in large floods has resulted in less transport of sediment and greater deposition within the river channel. Over time, interviewees have observed fewer boulders on the beach and more fine substrates, especially sand, at the mouth and bar of the hāpua. An accumulation of mud was reported from the upper hāpua, and this solidifies as it dries. Mention was also made of "fines" filling the interstitial spaces between rocks. It was suggested by one angler that with more fine sediment in the river channel, a relatively small fresh would result in resuspension of sediment and hence turbid water.

The accumulation of fine substrates has also made it harder for individuals to take their vehicles along the bar, and one boat ramp is no longer usable due to a build-up of silt. Interviewees have noted that these finer sediments in the hāpua are a result of low flows. Also, a couple of interviewees highlighted the impact of spraying on the hāpua. Impacts of spraying include "broom no longer holding the shingle together" and "large amounts of dead woody debris".

Coarse sediment

All interviewees except one explained the "hissing" and "roaring" of boulders/rocks down the river during flood flows as something of the past.[2] One interviewee however, stated they still hear this process. Another interviewee has observed these changes to be gradual over the past 20 years.

3.3.3 River fairway

Braid pattern

All interviewees stated they have noticed significant changes in the Rakaia's braid pattern. A few interviewees have noted that there are not as many braids as there used to be in the river. In the past, interviewees have observed 3–4 main braids, but today there are few or even no braids in sections of the river; this lack of "wandering braids" has resulted in fewer holes for salmon to rest in. It was claimed that the various flood protection works have reduced the natural braided character of the river, and the river is now more consolidated in fewer braids and shifts less. This has also resulted in the river channels not being as wide as they used to be. Furthermore, interviewees have concluded that spraying has changed the structure of the braids. This is considered to have

---

[2] This "hissing" and "roaring" refers to the noise made by the transport of large substrates downstream during floods. The implication is that there are less boulders moving under present-day floods, but whether this is due to the reduced availability of boulders or whether they are less mobile due to embeddedness is not clear.

significantly impacted the Rakaia, as one interviewee has stated it is a “braided river that is not allowed to be a braided river”. Importantly, one interviewee argued that “ECan don’t monitor the “special character” of the river”. This angler has a series of aerial images of the Rakaia over the past 40 years where physical changes can be seen over time.

Depth

Some interviewees made note of the decreased water levels in the river, and fewer deep holes. One interviewee stated that they have “waded across the water but could never do that in the old days.” Also, a few interviewees described the difficulty of jetboating due to the reduction in water levels and smaller braids in the river.

Lagoon

All interviewees highlighted changes in the hāpua area of the Rakaia. Significant changes include the loss of springs and small tributaries that entered the hāpua due to bulldozing and lower levels of groundwater. The lack of flow has led to a build-up of fine sediment, and several interviewees mentioned much more mud. One observer mentioned that this accumulation of fine sediment has caused a proliferation of rushes, which may be providing improved īnanga spawning and rearing habitat. There were conflicting opinions of the extent of tidal amplitude (“little tidal height”, “now very tidal”) although anglers agreed that most change in water level was due to water “piling up” during high tides, and there is little if any intrusion of saltwater (apart from occasional wave overtopping associated with big seas).

Figure 3-1: The Rakaia lagoon, 15 July 2021. The mouth is obscured by the gravel bar to the right of centre and is 3 km north of the true left bank of the river.

3.3.4 Mouth

Significant changes in the river mouth have been observed by all interviewees. These changes include the accumulation of finer sediments, movement of the river mouth from south to north, the size of the river mouth and the mouth’s ability to stay open. One interviewee noted that “the sea controls the river but historically the river controlled the sea”. For example, the same interviewee highlighted the greater historical strength and ability of the river to push through the bar and create another river mouth. However, today the river mouth is narrower and frequently migrates north and stays north for longer periods. Several interviewees considered that this process has created further difficulties for fish migration[3].

3.3.5 Algae/Periphyton

Several interviewees have noticed that low flows in the river have resulted in increased algae — previously-seen filamentous green algae is no longer there — instead, slippery brown periphyton covers rock in the river. Two interviewees also recalled invasive didymo (*Didymosphenia geminata*) in one year, although two consecutive large floods appear to have sloughed this off.

3.3.6 Water quality

The quality of water in the Rakaia is a significant issue identified by the interviewees. Most people interviewed considered that the expansion of dairying in the area has resulted in higher levels of contaminants, ammonia and nitrate [4]. All interviewees, except one, were opposed to drinking the water from the river. Increasing water temperatures were mentioned as an additional issue, especially for salmon where 18°C is usually considered as the upper limit for salmon well-being (https://www.nwf.org/Educational-Resources/Wildlife-Guide/Fish/Chinook-Salmon).

3.3.7 General comments/concerns

General comments focused on the management of water and the river itself. Many interviewees highlighted their concerns surrounding water takes from the river. Also, the lack of knowledge about where significant losses to groundwater occur (believed to be between State Highway 1 [SH1] and the hāpua). A related issue was associated with only having flows gauged at the gorge, as some interviewees claimed this is not representative of flows in the lower river. Loss of riparian vegetation and associated agricultural encroachment were of concern for interviewees. The delay in the release of the ECan "Wilco report" on flow sharing on the Rakaia and Rangitata Diversion Race (RDR) is a frustration[5]. There is also ongoing concern about the effectiveness of fish screens and the fact that some old consented takes do not require screens at all.

3.3.8 Changes to fish stocks

Smelt

Smelt are regarded by interviewees as a primary food source for many species including trout, eels, flounder, and birds (black-billed gulls and terns). Interviewees have observed a dramatic decline in smelt over the last 10 years but especially during the last five to six years. The overall decline was variously described as "substantially reduced", "massive", "dramatic", "hugely dramatic", and today the smelt are essentially gone. [6] Historically, smelt started arriving in the hāpua late September/October and continued through until February/March.

Many interviewees described migrations in the past being solid columns of fish one metre wide and running for four hours or even "days". (Note: *these migrations would have been of Stokell's smelt, but some anglers described much larger fish up to 120 mm long that would have been 2-year old common smelt*). Smelt were often a nuisance to anglers as there were so many in the hāpua there was a high chance of foul hooking one when fishing for trout or salmon. The consensus was that once

[3] Presumably because the resulting channel is longer and swifter. However, it is also possible that the outflow is more "alongshore" rather than 'offshore", and this might attract fewer juvenile fish.
[4] 4

[5] Note, this report was leaked to the media in early November 2021 (https://www.newsroom.co.nz/ecan-exposed-regulator-hides-damning-report).
[6] This observation presumably relates to Stokell's smelt, as small numbers of common smelt are present in the hāpua year-round (Eldon and Greager 1983).

smelt had entered the hāpua, they stayed there and did not come and go with tidal cycles. Anglers described how trout would drive the smelt to the surface and even into shallows, and this allowed the birds greater access to them. Sometimes the smelt would be so close inshore that they would be "dumped" on the beach by waves, and birds would then gorge on them. Apart from this, anglers had not seen significant numbers of dead (post-spawned) smelt. Smelt seemed largely confined to the hāpua, although there were reports of them traveling for up to 1 km above the hāpua. Some anglers have highlighted that due to the changes in the river (fewer cobbles and increased periphyton cover on cobbles), there is a lack of suitable spawning areas for smelt.

Brown trout

Anglers of the Rakaia River have observed a gradual but marked decline in the numbers of sea-run trout over the last 15–20 years, although the largest declines have occurred over the last 10 years. Many of the anglers recalled days when there would be 50 or so anglers at a time all catching trout. Many interviewees remembered catching a bag limit (12 trout) each evening with an average weight of 5–6 lb, but many fish ranged from 10–12 lb, even up to 18 lb. In the 1980's, one angler would catch up to 450–500 trout a season. Fishing started after dark when smelt usually ran, and often continued until 2 am. One angler noted that if Lake Ellesmere/Te Waihora was open, most sea-run fish were attracted to the lake.

Today very few sea-run trout are caught, and some anglers claimed they do not bother fishing as there are too few trout and they are in poor condition. Most anglers noticed the condition of trout is much poorer today: "pale flesh, poor condition (slabs), and …resorbing eggs due to lack of spawning condition." These anglers have concluded that the decline in trout numbers and condition is a direct result of the lack of smelt. Due to the numbers, small size, and poor condition of trout today, many anglers argue that trout are not worth fishing for or eating; as a result, some interviewees were considering not renewing their fishing license for next season.

Chinook salmon

Anglers of the Rakaia River highlighted that numbers of salmon have always fluctuated, yet in the last five to six years there has been a significant decline in the salmon population. There was a general consensus that the decline in the salmon fishery started about the mid to late 1990's – unlike the sea-run trout fishery which has crashed dramatically over recent years. The decline in salmon numbers is considered more gradual but occurring over several decades.

One interviewee reflected on the Rakaia Fishing Competition and how 25 years ago 400–500 salmon would be caught. However, today they would be "lucky if they caught 30". This interviewee noted how the Rakaia Fishing Competition is now more of a social event rather than a fishing contest. Another interviewee discussed how there would be 100 anglers at a time on either side of the river during the salmon season. Today, 25 anglers would be acknowledged as a big turnout. Early runs of the best conditioned fish, took place in November/December, followed by the main run around late January/early February to March. However, this main run did not happen this last (2020/21) season. Those who continue to fish for salmon have noticed the fish are smaller but are still in good condition. Some anglers still catch some salmon at 14–16 lb in the early run. One angler said that in 1995 the average weight of his catch was 27 lb, but now salmon would average about 5 lb. Anglers understand that there is no single issue for the state of the salmon fishery today. However, reasons suggested for the decline in salmon numbers include the closing of the salmon farm (*and Glenariffe Salmon Research Station*), releasing of fewer juveniles, lower flows, inadequate management of fish screens and an increase in dairying. Also, one angler suggested that it is possible the behaviour of fish is changing in response to climate change with clearer and warmer water resulting in fish migrating upstream more rapidly. One interviewee noted that the salmon fishery has become a very political issue, but despite this the fishery is still declining.

Figure 3-2: A day's catch of salmon, Rakaia River, 1922. Photo reproduced from Salmon Tales Café, Rakaia.

Whitebait

Whitebaiters are experiencing some of their best seasons in recent times. One fisher stated that "last season was better than the previous 10 years". Interviewees generally agreed that while the whitebait fishery can still fluctuate markedly from year-to-year, it has generally improved over the last few years. Fishers reflected on their past catches when 5–10 lb per weekend was considered a good catch. Today, fishers are catching around 60–80 lb a day, and as much as 600 lb over the season. Some interviewees have concluded that the grassier and muddier areas of the hāpua have created better spawning habitats for whitebait. Other interviewees have noted the whitebait migration is influenced by the opening of Lake Ellesmere/Te Waihora, and if the lake is open, most whitebait appear to enter it rather than the Rakaia.

Eels

One angler discussed seeing glass eels in his whitebait net, and seeing larger eels entering the river. Larger eels were also seen feeding on smelt i.e., moving downstream to the hāpua at night and then returning upstream. There was a concern that longfin eel habitat had reduced due to the loss of willow trees (as willow roots result in deeper pools and provide daytime refuges for eels).

Kahawai

Kahawai are still common offshore in the area. During the summer months, large schools of "five to six acres" are seen offshore, although some anglers consider that numbers of kahawai are declining. Anglers have concluded that this is a result of smelt migrations as anglers would observe kahawai following the smelt into the hāpua. One angler noted that schools are much closer inshore these days than they used to be, maybe because their feeding habits have changed?

Other fish and marine organisms

Yellow-eyed mullet are confined to the hāpua. Occasional adult lamprey are caught in whitebait nets, and although giant bullies were once "abundant", they are thought to be gone today [7]. Large quantities of krill sometimes get washed up on the beach.

Birds

Interviewees considered that the decline in smelt populations has had a significant effect on the birds of the hāpua. All anglers reported seeing starving and dead birds, mainly black-billed gulls, due to lack of smelt. Terns are also affected but seem more versatile feeders and can catch sprats (although these are reported to be "bigger" and "tougher" than smelt, and more difficult for chicks to swallow). One angler contacted Ministry for Primary Industries to report the die-off of birds in the area.

3.4 Ashburton/Hakatere Hāpua

3.4.1 Flows

Low flows

All interviewees mentioned concerns about the duration and magnitude of low flows. Some mentioned changes in rainfall patterns (one respondent stated that "the Ashburton relies on southerly rain, but [the] Rakaia and Rangitata rely on Norwest rain"). However, the dominant theme

[7] Note that "Recent seine, fyke and g-minnow surveys conducted in spring and summer 2020/21 found giant bullies to be present in low numbers in the hāpua". Jarred Arthur, ECan, pers. comm.

associated with low flows was the growth of intensive dairying and associated water abstraction for irrigation. One interviewee suggested that increased flows of 5–10 m^3/s would be sufficient to rectify this problem. Associated with low flows has been an increase in water temperature, although as one interviewee commented "…uncertain if water temperatures are an issue as [there is] simply not enough water" (*an indication that the lack of flow was the primary concern*- eds). Decreased depth is a consequence of low flows which is captured in the response "[It] used to be that hard to find places to cross the river, but now [I] can walk across almost anywhere".

Flood flows

Only one interviewee mentioned a decrease in the frequency of flood flows.

3.4.2 Sediment

Fine sediment

Only one interviewee mentioned a marked increase in fine sediment: "[I] used to come home and [my] socks [would be] full of sand, but now [there's] more silt than sand". Another respondent was concerned about the overall build-up of shingle as the river had less ability to transport sediment. One respondent mentioned a marked increase of fine sediment in the interstitial spaces between rocks.

Coarse sediment

One respondent mentioned that in the 1960's the bar at the mouth was composed of large cobbles ("dinnerplate" size) but was now "golf ball" size.

3.4.3 River mouth

Most interviewees mentioned that today the river closes more frequently and for longer periods than it used to, due mainly to lower flows. There was also a perception that closure was more likely when the mouth was located near the northern end of the lagoon. With mouth closure, the river is less "dynamic".

3.4.4 Algae/periphyton

There was a consensus between responses that the increase of toxic algae associated with low flows/mouth closure, was a major concern, and has restricted recreational opportunities and caused the death of dogs. At low flows, the rocks get slippery due to the growth of periphyton.

3.4.5 Water quality

There was strong agreement among interviewees that they would not drink the water straight from the river. There were also concerns that nitrate concentrations were increasing.

3.4.6 General comments

Comments mostly related to water management concerns — lack of consent monitoring, over-allocation of groundwater, low flows, farmers grazing in high risk areas of the river berm. Also, the perception that river management has favoured out-of-stream users, and more education is needed so that urban-based river users are more involved in decision making. One respondent summarised his feelings as "a bloody sad situation. Mother Nature, we need help!".

3.4.7 Changes to fish stocks

Smelt

Anglers agreed that historically there were huge runs of smelt into the Ashburton River hāpua; shoals could last for hours. Migrations commenced between late September and early November; movement into the hāpua mainly started in the early evening but smelt tended to go in and out of the hāpua with the tide. Trout followed the smelt, and the smelt were also predated upon by terns. One interviewee noticed declines in smelt abundance between 1997 and 2000, while another noted a decline in the last 5–6 years.

Brown trout

One angler described the former fishery for sea-run brown trout as "magnificent". Most anglers would catch at least 2–3 trout an evening, and fish were large (generally 4–6 lb, but could be >10 lb). One interviewee considered the decline in trout started as far back as the mid 1980's and has been ongoing since then. A few sea-run trout are still caught but they are much fewer and smaller (2–3 lb). Several anglers commented that without the runs of smelt to provide food for the trout and "fatten them up", the trout are both fewer in number and markedly smaller.

Chinook salmon

Relative to its size, the Ashburton River used to sustain a large salmon fishery. One angler recorded seeing up to 100 salmon in one hole, and 60–70 dead salmon from one large hole when someone detonated gelignite in it. Salmon were considered relatively easy to catch in the Ashburton River, and one angler said he would catch 50–60 each season but could have caught more. There would often be 50–60 anglers at the mouth, and sometimes up to 100 on either side. Apparently, it was not uncommon for 50–60 salmon to be caught over a single weekend, and one morning an angler claimed there were 200 caught at the mouth when a "run" happened. Another angler estimated he once saw 200 salmon enter the hāpua in 20 minutes. When "runs" like that happened, anglers could "chase" the salmon upstream as they would hole up in deeper pools.

Opinions about when the decline in salmon numbers started varied, with one angler stating declines started in the mid 1970's, and another noticing a gradual decline over the past 20 years, but especially the last 10 years. One angler stated that it would be "lucky if there was a dozen caught throughout [the] whole year". Several anglers said that salmon fishing was now a waste of time, and one had not fished for the past nine seasons as it is "not worth the effort".

One angler was quite specific about the best conditions for salmon fishing – he considered that fishing was best at flows ~ 12 m^3/s ; higher flows (~ 18 m^3/s) were required to encourage salmon to enter the hāpua, and best fishing was for next 8–10 days as flows receded, but after that the river would get too low and clear.

The size of salmon used to be in mid-20 to 30 lb range but they are much smaller today. The largest one angler could record seeing was 32 lb. Anglers suggested several reasons for the decline in the salmon fishery. The smaller size of salmon was considered to point to something happening with food availability at sea. Lack of flow and warmer water temperatures were considered factors working against attracting salmon to the river mouth. One angler suggested that perhaps the Ashburton fishery was partly maintained by the discharges of Rangitata River water (via RDR) that used to occur, especially from the 1930's–1960's, as this would also have transferred many salmon smolts to the Ashburton River.

Whitebait

One fisher claimed that "last season was one of the best ever for Ashburton, Rakaia, Opihi and Rangitata Rivers".

Kahawai

Two anglers recalled there was a great fishery for kahawai at the mouth of the hāpua, and salmon anglers would frequently catch kahawai as they entered the mouth chasing smelt upstream. Shoals offshore could be seen as 'a black mass', but not today. It is assumed that such reductions are due to commercial fishing, but also increased recreational fishing.

Other fish species

It used to be possible to catch red cod by handline off the beach at Hakatere, but they are gone these days. Likewise, it was possible to catch groper (*Polyprion oxygeneios*) off the beach, but the angler who reported this has not seen one caught for maybe 40 years.

Birds

One angler mentioned he used to see a lot of black cormorants (*Phalacrocorax carbo novaehollandiae*) feeding on smelt, but not now.

3.5 Rangitata hāpua

3.5.1 Flows

Flood flows

Interviewees have observed how the decline in flood flows has affected levels of sediment in the river: "Floods don't seem large enough to transport sediment out to sea and much of it is deposited in the lower river but becomes resuspended by small freshes." One interviewee noted that the floods are receding faster and that this has further affected the ability to fish for salmon as the river today "is either too dirty or clears too quickly".

Low flows

All interviewees highlighted the significant impact of the RDR on decreased flows in the river [8]. One person noted the river has experienced subtle changes over the 70 years of his experience, while another considered that changes have been more noticeable over the last 20 years. Many interviewees considered that having the river at persistent low levels has changed not only the pattern and structure of the river, but also its whole aquatic ecology. Anglers have had to change their fishing technology to adjust to the changes in river flow. Furthermore, the continued low flows are thought to have led to fewer deep holes throughout the river (so less holding areas for adult salmon), and even when the river is turbid, flows are insufficient to attract salmon. It was commented that at low flows these days, it is possible to walk across the river mouth, something that was not possible historically.

[8] although the RDR was officially opened in 1945, it wasn't in its present form until 1982 when the Montalto Power station was built. It is still New Zealand's largest irrigation scheme

3.5.2 Sediment

Fine sediment

Changes in sediment types and deposition are also a key concern for anglers. All interviewees observed that increased fine sediment in the river is one of the greatest changes they have noticed, and the persistent low flows have made it difficult for sediment to be transported. One interviewee considered that “silt and sand from the RDR sand trap doesn’t get flushed out of the system - the past 3–4 years has been a period of relatively low flows so there has been much deposition of silt in [the] river.” The accumulation of fine sediments has also impacted the structure of the river mouth, bar, and river margins.

Coarse sediment

Some interviewees noted that during flood flows, rocks can be heard tumbling down the river. There were some concerns about gravel starvation[9], especially consequent lack of protection for the huts on either bank.

3.5.3 River fairway

Braid pattern

Concern was expressed at changes to the braiding pattern of the river, considered to be associated with operation of the RDR. One interviewee highlighted how changes to the hāpua and mouth (maintained north for longer) have increased the vulnerability of the huts due to shoreline erosion. Another interviewee wished that the “river should be allowed to do its natural thing”.

Depth

A few interviewees considered that changes in river braid patterns has led to changes in the structure of pools in the river; consolidation of banks by the extensive planting of willows is considered a major cause of this. Some anglers have observed deeper holes that have largely filled in over time and this can result in salmon becoming stranded or isolated.

3.5.4 Lagoon

A few interviewees commented on the state of the bar at the river mouth and changes it has experienced over time. One interviewee noted that “cobbles building up on the bar now makes it easy to cross the river”. However, another interviewee thought that there has not been much change to the bar (except that shingle is now larger on the north side than the south side), but access is now easier by quad bike than by four-wheel-drive vehicle.

3.5.5 Mouth

All interviewees observed significant changes to the mouth over time. A common theme was that the mouth is in the northern lagoon more often than it has been in the past. As one interviewee said the “river was dynamic and dominated the sea (at the mouth), but with depowering of the river, the mouth stays north for longer and the river is now strangulated.” The interviewees consider that these changes to the mouth are a result of the low flows caused by the water abstraction. Some interviewees also mentioned the need for the mouth to be mechanically opened at times, causing further impacts to the hāpua ecosystem. Mouth closure has been noted but this seems to be rare and only for a single tide. Tidal effects are small and depend where the mouth is located — “if the

---

[9] Whether this was considered a natural or human-induced process was not determined

mouth is north then the area affected by the tide extends only a little way into the hāpua, but if the mouth is straight out then the tide effect can cause a backup for 400 m".

One angler summarised his observations as "during prolonged low flows and with predominant southerly offshore currents, the mouth gets pushed further north. During the 1950's, there were lots of northeast winds and the river mouth went south of the huts. The coastline has receded at least 100 m over the past 50 or 60 years. Once the Waitaki Dam was built, this trapped much alluvial sediment moving along the coast and now Timaru Harbour traps a lot of shingle".

3.5.6 Algae/periphyton

Most interviewees have noticed an increase in algae through their time at the river. More specifically, the formation of algal (periphyton) mats that trap sediment and cause discolouration when resuspended during small floods. Stones are slipperier than previously. Didymo was reported to have been scoured out by a large flood (norwest conditions) but is coming back. One person noted that increased sediment and algae have led to reductions in invertebrate life.

3.5.7 Water quality

All interviewees were certain that they would not drink water from the Rangitata River. This is due to increased levels of contaminants from dairy farming. Several anglers expressed concern about increased water temperatures, especially on cloudless days and during low flow periods when the greater areas of exposed riverbed absorb more heat. One angler claimed to have recorded water temperatures of 24–26^{o}C (*note – the preferred upper limit for Chinook salmon is typically quoted as 18^{o}C*).

There were also concerns about water clarity with claims that the river contains less glacial flour these days and is generally much clearer than it used to be and/or it clears much quicker after a flood. It was suggested that historically the river was still fishable for salmon at 130 m^3/s but nowadays it is still too dirty to fish at 80–90 m^3/s, (one angler suggested the river could still be too dirty at flows as low as 20 m^3/s), and hence the "window" of time for successful salmon fishing is much reduced). Assuming the consensus of more fine sediment in the river these days is correct, then it is possible that such sediment is resuspended at relatively small floods/freshes, causing the river to be turbid at lower flows than formerly.

3.5.8 General comments/concerns

Interviewees expressed many concerns about the current state of the river, and these often included comments about how this has affected them personally. A number of anglers used emotive phrases like: "…Part of the river has died. It was a living river, it was interesting. When you fish a river, you notice everything."; "The future of the river is probably past the point of no return"; "I'm depressed at the state of the river. Intensification of dairying is affecting the river. I have feeling for the river in my blood and body. It's all gone and lost. How do you feel when your back yard is polluted?"; "Fishing is more than just catching fish".

Many anglers expressed anger at the ineffectiveness of the NWCO for the river – they had anticipated an overall "cap" on irrigation, but this did not eventuate, and now creative ways seem to have been found for trading unused water between irrigators (although some interviewees indicated that details of such arrangements are deemed to be commercially sensitive and unavailable for scrutiny). In addition, there were concerns that the Canterbury Water Management Strategy "…hasn't met the needs, hasn't done anything for our rivers at all. Environment was to have first priority. We've gone backwards". There was also recognition that many farmers are in an economic trap, having invested in expensive plant and equipment and having to maintain or increase production to be economically viable.

ECan were widely criticised, not only for water management issues, but also for their “indiscriminate” aerial spraying, allowing intensive farming on unsuitable soils, and lack of enforcement on fish screening. Also, nobody seems to be monitoring the “special character” of the river (as identified in the NCO). One person mentioned concerns about a “duty of care” to forthcoming generations, and another suggested that anglers have been customary users of the river for decades and this should translate into some rights.

3.5.9 Changes to fish stocks

Smelt

All anglers noticed a decline in smelt over the last 10 years, and especially in the last five years. One angler reported a total collapse in smelt last season, while another saw only one small shoal all season; a further angler estimated smelt numbers today were only 5% of what they used to be. Historically, the smelt season started in late October and continued through until the end of January, although runs could occur as late as April. Shoals of smelt, about a metre wide, were reported as running for hours and at times all day and night. At one stage a shoal the width of the river was seen at the Rangitata mouth.

Smelt were confined to the hāpua and were reported as moving in and out of the hāpua with tides. One angler reported seeing dead smelt in the hāpua (*presumably post-spawned Stokell’s smelt*), while smelt would often get dumped on the beach by wave action. Smelt were a primary food source for many fish species and anglers reported that they were eaten by trout, red cod, kahawai, flounders, eels - birds could access smelt when trout “pushed shoals to the surface”. One angler thought smelt spawned at night in shallow (<2 cm deep) sandy areas, and clean cobbles provided places for their eggs to adhere to, but accumulated sediment and algae had reduced the quality of cobbles as spawning sites.

Brown trout

Anglers have observed a huge decline in numbers of sea-run brown trout in the hāpua. Opinions of when the decline first started were varied, but there was a general consensus that it was noticeable as far back as 15 years, and perhaps 20. The decline has been especially marked over the past 5–6 years, probably associated with the “crash” in smelt numbers. Smelt were the primary food source for sea-run trout, and trout would often be caught with 20–30 smelt in their stomachs.

Sea-run trout would arrive in “runs”, starting in early October – these early fish were “skinnier” as the smelt had not arrived yet. The largest fish were recorded in November–December, and it was suggested that post-spawned trout feeding on smelt could improve their condition within a few weeks. Fortuitously, the arrival of smelt generally coincides with the need for trout to regain condition after spawning (McDowall 1994b). The arrival of trout at the Rangitata was apparently affected by Lake Ellesmere/Te Waihora, because if the lake was open, trout would arrive at the Rangitata about three weeks later compared to when it was closed. One angler suggested there was “a pool” of sea-run brown trout offshore and they followed the available food.

Anglers considered that the Rangitata trout fishery might not have been as extensive and widely recognised as the Rakaia fishery, “but when it was on, it was on!”. One angler reported catching 300 trout per year, and up to 40 per day; others caught less, but numbers varied from “a few dozen” to 80–90 for the season. Fishing would start after sunset and continue until after midnight. As salmon numbers began to decline, more anglers targeted sea-run trout. A few riverine trout (*distinguishable by colour, size, condition, and whether scales were easily dislodged or not*) were caught on occasions, especially after a large flood; rainbow trout were rare. Most trout were in the 3–4 lb category, but often 6–8 lb, with some >10 lb. The largest one angler knew of was 18.75 lb. The sex ratio was reported as being more females than males.

Today, many anglers have concluded the "fishery is a shadow of what it used to be" and even that "there is no sea-run trout fishery today". Reasons suggested for the decline in the trout population include intensified irrigation and pollution of rearing areas, but mainly the lack of smelt.

Chinook salmon

The Rangitata River once had an international reputation for salmon fishing and attracted overseas anglers. Unfortunately, over time there has been a progressive decline in the salmon population. Significant declines were identified in the late 1980s and early to mid-1990's — by the late 1990's, numbers had dropped. Reportedly, salmon numbers made a comeback in the early 2000's but numbers have declined since then, especially from 2015 onwards. One angler described that during peak times in a season there could be up to 400 anglers "shoulder to shoulder" along the river, and catches of 50 salmon per morning were normal, whereas today it would be more like 1–2 per morning. Total seasonal catches would be about 2000–3000 fish, but numbers are very low these days with 108 caught in the past season (Fish and Game 2021a). Catches would fluctuate with seasons — for instance, 1978 was described as a "fantastic fishing year in the Rangitata", but there would also be the "odd bad season". Catches could also vary markedly between days and one angler recalled one day in the 1990's when about 150 anglers caught 180 salmon, yet the following day, the same number of anglers caught only three salmon. One angler suggested about 5% of anglers would catch up to 100 salmon for the season; the largest number one interviewee caught was 68 for the season.

The size and condition of salmon has also decreased substantially over time. In the 1970s, one angler described the average weight of salmon being around 25 lb, with occasional fish up to 35 lb — the largest on record was 44 lb. Today most fish are 10–12 lb, and a 15 lb salmon would be regarded as a big fish. A frequent comment amongst salmon anglers today is that there are so few salmon, they are not worth fishing for, and several very experienced anglers have stopped fishing altogether. One angler stated that "In hindsight, we might've caught too many salmon. We didn't bring them home because we didn't want anyone to know we caught fish".

Anglers presume there are many reasons for the decline in salmon populations. Suggested reasons were lower average flows, higher water temperatures, differences in behaviour between wild fish and hatchery fish, impacts of large floods, loss of fry and smolts in irrigation schemes, lack of deep holes as refuge and cover for adult fish moving upstream, bycatch at sea and less food available at sea. The anglers also have many concerns about the management of salmon populations and irrigation schemes. Several anglers emphasised the need to better maintain key spawning streams.

Whitebait

Although there were comments that the whitebait fishery had shown some decline over the period of people's experience, most whitebaiters agreed that that recent seasons have been some of the best for many years, and that whitebait "have held up better than other species". In the past, one whitebaiter reported catching 20–30 lb of whitebait a season, although today catches of 8–10 lb per year are more common, but one person said they could catch more if they wished. While the vast majority of whitebait will be īnanga, mention was made of climbing bait (kōaro) and big golden bait, late in season (possibly banded kōkopu).

The north side is regarded as the better side for whitebaiting, although this partly depends where the mouth is. One person considered that the best whitebaiting places were in the north arm of the hāpua when the mouth was south, and vice versa. Several people drew attention to the importance of spring fed streams as important spawning and rearing habitats.

Other fish species

Anglers reported fewer yellow-eyed mullet, flounder, and kahawai these days. Red cod were described as "completely gone". While one angler considered elephant fish and rig were almost gone, another thought they were coming back.

Birds

Interviewees have observed significant changes in the birdlife of the Rangitata River. Many interviewees mentioned seeing 100's to 1000's of dead birds this past year, due to the failure of the smelt arrival. One angler picked up 200–300 dead adults and chicks, mainly black-billed gulls, from the hāpua this last year, while other anglers reported seeing many dead birds. Some interviewees noticed that terns were not as badly affected as gulls due to their ability to catch sprats, but black-billed gulls seem reliant upon smelt and were starving.

4 River summaries

Summaries of issues related to physical aspects of the river and fish stocks are provided in Table 4-1 and 2 respectively. From Table 4-1, insufficient low flows and “wouldn’t drink” the water were dominant themes for all three hāpua, followed by issues like increased fine sediment and periphyton and more frequent migration of river mouths to the north. Of the fish species (Table 4-2), decreased abundance of smelt, sea-run trout, and salmon were all identified for all three rivers as key concerns; there was also a strong consensus about salmon being smaller and in poorer condition than previously. In contrast, whitebait were considered to be maintaining their abundance. Starving and dead birds were major issues for the Rakaia and Rangitata River. There was general agreement across all three rivers that the decline of smelt was reasonably recent, especially over the past five years. For trout, the decline was more prolonged, and the fact that no anglers considered that declines in the Rakaia and Ashburton Rivers were observed over the past five years was presumably because trout were noticeably reduced in number from these rivers by then. For salmon, declines were noticeably recorded over all three time periods listed, indicating a long-term trend in decreased abundance of this species. Note that Fish and Game estimates for the number of salmon caught by anglers in the three rivers for the 2020/21 season were 434 for the Rakaia, 108 for the Rangitata, and none for the Ashburton (despite 55 anglers fishing for salmon): see https://fishandgame.org.nz/dmsdocument/1905.

Table 4-1: Summary of issues related to physical aspects of the river.

● = mentioned; ●● = mentioned by some; ●●● = mentioned by most

Issue	Aspect	Rakaia River	Ashburton River	Rangitata River
Flow	Insufficient low flow	●●●	●●●	●●●
	Decreased flood frequency	●●	●	●●
	More rapid flood recession	●●●		●
Sediment	Increased fine sediment	●●●	●	●●●
	Decreased coarse sediment	●●●	●	●
Braid pattern	Fewer braids	●●●		●●
Depth	Fewer deep pools	●●	●	●●
Mouth	More frequent closure		●●●	
	More frequent migration north	●●●	●	●●●
Algae	Toxic algae problems		●●	
	Increased periphyton	●●	●●	●●●
Water quality	Increased water temperature	●●	●	●●
	Would not drink	●●●	●●●	●●●
	Increased nitrate levels		●	●

Table 4-2: Summary of issues related to fish stocks.

● = mentioned; ●● = mentioned by some; ●●● = mentioned by most

Species	Aspect	Rakaia River	Ashburton River	Rangitata River
Smelt	Decreased abundance	●●●	●●●	●●●
	Declines: 0–5 y	●●●	●	●●●
	6–10 y	●●		●●●
	>10 y		●	
Sea-run trout	Decreased abundance	●●●	●●●	●●●
	Decreased size and condition	●●	●	●
	Declines: 0–5 y			●●
	6–10 y	●●●		●●
	>10 y	●●	●	●●
Salmon	Decreased abundance	●●●	●●●	●●●
	Decreased size and condition	●●●	●●	●●●
	Declines: 0–5 y	●●	●●	●●
	6–10 y	●●	●●	●●
	>10 y	●●	●	●●
Whitebait	Maintaining abundance	●●●	●	●●●
Other fish species	Generally fewer	●●	●●	●●
Birds	Starving or dead	●●●	●	●●●
	Changes in diet	●		●●

5 Discussion

5.1 Biology of key fish species

Stokell's smelt

The most comprehensive seasonal records of this species are from the Rakaia hāpua (Eldon and Greager 1983). Table 5-1**.** shows the seasonality of both species of smelt they recorded, with the main period for Stokell's smelt being November to January. McMillan (1961) recorded that the spawning season of this species extended from September to April, and "large migrations began in November and continued sporadically throughout December, January and February". He observed that spawning began immediately as the shoals reached the stretches of river entering the lagoon, with favoured sites being "silt-bottomed reaches of subsidiary streams where current is light". McDowall (1990) stated that Stokell's smelt spawned in areas of little river current and over sandy bottoms. He also noted that large numbers of spent or partly spent fish could be netted in the spawning reaches. Because of the long spawning season and "the enormous size of the shoals", McMillan (1961) stated that this species "plays a most important part in the ecology of the river mouth region of the Rangitata River", and observed smelt being preyed upon by black-billed gulls, black-backed gulls, white fronted terns, and schools of kahawai which followed the smelt into the river mouth.

Table 5-1: The monthly catches (%/month) of Stokell's and common smelt recorded from the Rakaia hāpua, July 1980–July 1981 by Eldon and Greager (1983).

Month	Stokell's smelt	Common smelt
Jul	>0.1	1.2
Aug	>0.1	1.5
Sep	>0.1	2.8
Oct	1.0	12.8
Nov	5.1	10.3
Dec	83.7	2.1
Jan	7.5	6.8
Feb	0.7	3.1
Mar	2.0	35.6
Apr	>0.1	14.5
May	>0.1	5.5
Jun	>0.1	3.8
Jul	>0.1	1.2
Aug	>0.1	1.5
Total number	69336	818

In a study of the distribution and freshwater residence of Stokell's smelt, Bonnett (1992) considered migrations mostly occurred from October to March, and ripe and spent fish could be found throughout this period. The presence of some females with relatively small eggs lead him to conclude that some smelt may remain in fresh water for weeks or even months. Although smelt were found from the Waiau River (north Canterbury) to the Waitaki River (**Error! Reference source not found.**), Bonnett (1992) only recorded large shoals from the major rivers which included the Rakaia, Ashburton and Rangitata. Smelt were almost always confined to estuarine and lagoon areas, although small numbers penetrated up to 6 km upstream of these reaches in the Rakaia River (Davis et al. 1983). From the length distributions of smelt, both McMillan (1961) and Eldon and Greager (1983) concluded that Stokell's smelt are an annual species, spawning once at the end of their first year of life. Common smelt (*Retropinna retropinna*) are also found in the lower reaches of Canterbury rivers, although not in such vast numbers as Stokell's smelt. The life history is similar to that of Stokell's smelt, with mature adults entering rivers to spawn in spring and summer, laying eggs on sandy substrates in the lower river and estuarine reaches. Adults die after spawning and the newly hatched larvae get swept out to sea where they spend most of their lives. Although most common smelt have a one-year life span, occasional larger individuals encountered indicate a small proportion of the population can live for an additional year or two.

Table 5-2: The proportion of Stokell's smelt in samples (where sample number >100) of smelt from east coast rivers and lakes from the South Island. From Bonnett (1992).

River	Sample size	% Stokell's smelt
Waiau (Canterbury)	122	1
Ashley	106	9
Waimakariri	1709	30
Lake Ellesmere (Te Waihora)	1964	0
Rakaia*	70154	99
Rakaia	130	100
Ashburton	157	100
Rangitata	169	100
Waitaki	229	7
Taieri	204	0
Clutha	119	0
Waiau (Southland)	110	0

*From Eldon and Greager (1983).

Brown trout

Brown trout are not obligatory diadromous species (i.e., they do not have to go to sea to complete their lifecycle), but often leave fresh water and spend a considerable part of their life at sea, returning to fresh water to feed and spawn. For example, brown trout tagged in the upper reaches of the Rakaia River have been recaptured in the Ashburton and Waitaki Rivers (Davis et al. 1983), and trout tagged in the Waitaki lagoon have been recaptured at the mouth of the Ashburton River (Deverall 1986). Such "sea-run" brown trout fisheries are well known at the mouths of many South Island rivers, and the occurrence of this life history increases with increasing latitude (McDowall 1984). High country brown trout stocks are dominated by males, but after spawning, females frequently migrate downstream to hāpua to regain condition by feeding in these food-rich areas (Jellyman and Graynoth 1994).

Sea-run brown trout are invariably in good condition, and larger than riverine trout; these qualities together with their pink flesh, good flavour, and fighting capabilities, make them a prized target for anglers (McDowall 1984). In the hāpua investigated in the present survey, sea-run brown trout were described by many anglers as coming into the hāpua in "waves", chasing the shoals of smelt. These migrations of trout usually started after sunset, and as smelt would migrate close to the banks at night, trout could be caught in shallow water. During daylight hours, trout would attack the shoals of smelt from below, forcing the shoals close to the surface where they would come under attack from gulls and terns.

Chinook salmon

Since their introduction to Aotearoa New Zealand in the early 1900's (McDowall 1994a), Chinook salmon have become widespread in Canterbury rivers. Chinook salmon are a diadromous species so they migrate from fresh water to the sea to feed and return to fresh water to spawn 2 or 3 years later. In its native North America, this species frequently spends a year or more in fresh water before entering the sea as a juvenile (smolt); estuaries are very important areas for the rearing of juvenile salmon and also provide an area of varying salinities, allowing a gradual transition from fresh to saltwater. However, because east coast Aotearoa New Zealand rivers have short hāpua, often with no significant saltwater zone, most salmon enter the sea as fry (35–80 mm in length, a few weeks or months old) and survival of this life stage is significantly less than that of the larger smolts (Unwin and Glova 1997). Numerically however, fry dominate riverine populations of juvenile salmon, and still make a major contribution to numbers of returning adults.

Salmon exhibit a high degree of homing to their natal river, and this characteristic has enabled hatcheries to develop, with returning adults being a source of ova for ongoing operations (e.g., McKinnons Creek hatchery, lower Rangitata River). Unlike sea-run brown trout, adult salmon do not feed in fresh water, and their catchability is due to their "aggressive response" to a lure that passes close to them. This response appears partially triggered by sight but also by the hydraulic disturbance created by a lure, and in clear water salmon apparently see any lure and ignore it – thus successful fishing within rivers is dependent upon a degree of 'milkiness' in the water (as a rule of thumb, anglers often say that good fishing conditions are when in knee-deep water, a person can just see their feet). Many salmon are caught when they are resting in the deeper and often cooler water associated with 'holes' in the river channel. Salmon fishing in the surf is less dependent upon impaired water clarity but as such salmon are usually actively migrating into a hāpua, the time available to catch them is shorter. Salmon migrations into rivers and also upstream within rivers, are triggered by increased flows (McDowall 1990) – thus for river mouth fishing, increased flows are probably of more importance than impaired water clarity (although in practice, decreased water clarity is normally associated with increased flow).

5.2 Validity of subjective information

From the results of their postal assessment of perceptions of changes in trout fishing in lowland Aotearoa New Zealand rivers, Jellyman et al. (2003) concluded that the survey methodology of assessing changes over decadal time periods from anglers' recall, was indeed a valid technique. The survey provided "compelling evidence" of an overall decline in angling quality, mainly in fish abundance more than size of fish. Of the three rivers being considered in the present report, only the Ashburton was included in the Jellyman et al. (2003) survey. Of the five Central South Island catchments assessed where there were >10 responses, (Ashburton, Opihi, Orari, Pareora, Waitaki), the Ashburton received the overall lowest score (i.e., was assessed as the most impacted). Of the 13 comments provided by anglers for this river in Jellyman et al. (2003), 10 mentioned lack of lows/too much abstraction, three mentioned poor water quality, and one angler mentioned the river was totally devoid of fish.

The information gathered from anglers in the present report reflects the depth of knowledge that is gathered through personal experiences with the environment (Tengö et. al. 2014). The present report shows the importance of 'expert' local knowledge as a source of recording environmental changes over time and space. Further research would need to include other knowledge sources, specifically Māori perspectives of the environment. Diverse understandings of hāpua need to be included to inform future decision-making processes associated with Canterbury river management.

5.3 Emotional attachment to hāpua

In this section, we attempt to capture some of the deep feelings and emotions that many people expressed when looking back over changes they had observed during their lifetimes.

Almost all anglers interviewed expressed considerable concern at the extent to which the various fishery resources of the three rivers had become seriously degraded or lost. This was borne out by the comparisons they often made to numbers of salmon and sea-run trout caught in former years compared with present day catches. We found their responses to be sad commentaries on the degradation and loss of treasured resources, and for us as recorders, it was reminiscent of writing a eulogy about the loss of a loved one. Interviewees frequently wanted to express that fishing is a lot more than catching fish, they identified it's about connection with friends and the environment, observing the changes that occur with tides, weather, seasons, and cycles, about lifestyles and personal values.

Many anglers have been making observations, making submissions, presenting evidence at hearings for most of their lives. Guardianship of cherished waterways has become an intrinsic part of their lives, "gut issues" as some described it. To many, the state of these rivers is indicative of human values – rivers that were once large, dynamic, and challenging to fish but productive, have become small, "tame", and unproductive. Several anglers used phrases to describe the mouths of the hāpua like "the river used to control the sea, but now the sea controls the river". To many, the very heart of these rivers has been "ripped out" by over-abstraction of surface and ground water.

While there was recognition that fresh water is a community resource, there was frequently a deep-seated frustration and anger that water allocation favoured abstraction rather than instream values - many spoke of the tragedy of loss of smaller lowland rivers like the Ashburton, Hinds and Selwyn, where once prolific trout fisheries have been lost, and body contact recreation is unwise or not permitted — a Tragedy of the Commons. There was also a mistrust of the fairness of decision makers and a perception that emphasis has been put on facilitating irrigation at the expense of the environment.

5.4 Overview of responses

A number of anglers lamented the loss of what were formerly large and powerful rivers (Rakaia and Rangitata). Some used expressions like "The mighty Rakaia" to indicate what the river had been prior to widespread abstraction and water storage. Such feelings were also reflected in comments about being able to occasionally wade right across the river and seeing the river mouths being closed off for short periods of time. One angler mentioned the loss of the mauri of the Rangitata, while another stated while the river used to control the Rakaia hāpua, now the sea does.

Lack of flow was a common theme across all three rivers. Impacts of this were issues like increased water temperatures, insufficient flow to flush fine sediment from hāpua, increased algae on rocks, insufficient flow to attract salmon into the river and enable them to migrate upstream. Increased fine sediment was commonly observed, especially in the Rakaia and Rangitata, where sand and silt had accumulated in the interstitial spaces between cobbles and rocks. The increased fine sediment was accompanied by deceased coarse sediment and no longer hearing boulders crashing against other substrate during floods.

Floods were acknowledged as being of particular physical and biological importance. Large floods were observed to reform the braiding pattern in the main fairway, remove vegetation from islands, resuspend and transport fine sediment, "punch out" the river mouth opposite the main fairway, and provide an incentive for migratory fish to enter the river and migrate upstream. There were some concerns that the incidence of large floods had decreased over time, although this was suggested as a response to longer-term climatic changes. A number of anglers on the Rakaia and Rangitata Rivers had observed more rapid recession rates of small and medium sized floods; the result of this was the river both drops and clears more rapidly after floods, and this gives a much shorter optimal window of time for successful salmon fishing (assuming there are still salmon to catch). Interviewees were uncertain of the reasons for this although it was suggested it could be partly due to irrigation companies harvesting water at higher flows than previously (especially for filling of large settling ponds), and also increased losses to groundwater as the water table is already depleted due to extensive abstraction. Such assumptions could be worth researching to clarify reasons for changes to flood recession rates, although it is recognized that there may be practical limitations to this due to flow being only gauged at the gorges of both rivers which will not take into account downstream losses to groundwater; this issue would be further complicated by the apparent lack of longitudinal studies of these waterways that document where significant groundwater recharge areas are located.

In addition to the quantity of water available, the quality of water was also a significant concern. Anglers across all three rivers stated they would no longer drink the river water, and there were particular concerns for the Ashburton about the presence of toxic cyanobacterial blooms. Associated with lower flows were observations of increased water temperatures, and especially the impact of this on salmon – several anglers commented that salmon are a "cool water fish", and warm water temperatures will inhibit their migration into fresh water, but also effect their rate of upstream passage, and sometimes their well-being within rivers. One angler suggested that 18°C was the upper limit for Chinook salmon, and this figure is substantiated by the scientific literature (e.g., Carter 2005, states that temperatures of 18–22°C create thermal blocks for migrating adult Chinook salmon, while temperatures of holding water should not exceed 16–17°C). Some temperature modelling could be informative to see whether significant temperature increases can be expected at reduced flows associated with various scenarios of anthropogenic changes and climate change.

The four "species" of fish most important to anglers on these rivers are salmon, sea-run brown trout, smelt and whitebait. Of these species, smelt are not harvested but are recognised as the primary food source for sea-run trout (plus also predated on by eels, flounder, kahawai, birds, etc). Over all three rivers, anglers have observed a dramatic decline in smelt over the last 10 years but especially during the last five to six years, to the point that smelt are virtually gone. From records of Eldon and Greager (1983), and Bonnett (1992), almost all these smelt will have been Stokell's smelt; a recently commissioned survey by ECan has indicted that this species is only present in small numbers in the Rakaia hāpua (Jarred Arthur, ECan, pers. comm.). Many anglers also commented about the numbers of starving and dead seabirds and chicks they had seen during their visits to the hāpua (e.g., Littlewood 2021).

Formerly, massive quantities of smelt arrived during late spring and summer to spawn in the hāpua of these rivers. It is not possible to reliably quantify numbers but McDowall (1990) recorded a harvest of 15 t from the Ashburton River during 1982. Using a mean length of 80 mm (the mean of Bonnett's 1982 samples) and the length/weight relationship from Jellyman et al. (2013), then the mean weight of an individual smelt would have been ~ 30 g. Thus 15 t would have been comprised of ~ 0.5 million smelt. Anglers who knew of this harvest were unconcerned about the overall impact of it on numbers of smelt in the Ashburton hāpua because of the enormous abundance of this species. For example, anglers on these three rivers had observed shoals of smelt passing for several hours and sometimes days – shoals were usually described as ~ 1 m wide and maybe 0.5 m deep with fish closely packed. Using *conservative* estimates of each smelt being 5 cm from its neighbour, and two fish lengths (~ 15 cm) from those in front or behind, and travelling at a speed of 0.2 m/s (given by Mitchell 1989 as the sustained swimming speed for common smelt), then a shoal that passed a fixed pint for 3 hours could have contained ~2.9 million smelt. If smelt were 'nose-to-tail", this would have doubled the estimated number.

Such estimates reinforce the observations of anglers that millions of smelt annually migrated into the hāpua of the three rivers, and provided an abundance of food for trout and a range of other fish and bird species. Why such a formerly abundant species should "crash" so dramatically is unknown, but this parallels the disappearance of the native grayling (*Prototroctes oxyrhynchus*) which was both widespread and abundant around Aotearoa New Zealand (McDowall 2011). Reasons suggested for the loss of the grayling, also a diadromous species, include overharvesting, loss of habitat, and predation by trout– but such practices do not explain its disappearance from remote catchments. A recent evaluation of possible reasons for its extinction (Lee and Perry 2019) strongly suggested that source-sink dynamics played a major role i.e., "sources" would represent those habitats where grayling were successful, while "sinks" represent those catchments where grayling have been unable to sustain their population. The balance of these criteria can determine whether populations thrive or decline, often quite rapidly as was the case with grayling.

Further investigations of the freshwater life history of Stokell's smelt could be informative and help clarify/elucidate probable reasons for its rapid decline – for instance, what are the smelt's preferred spawning substrates? are these susceptible to "smothering" by algae? are smelt particularly sensitive to changes in water temperature? are smelt arriving off shore of hāpua deterred by lack of flow/ possible mouth closure? what are Stokell's smelt temperature preferences? with increasing sea and river temperatures, is the distribution of Stokell's smelt shifting to more southerly rivers?

Of course, it is also possible that something has changed in the marine environment where smelt spend most of their lives, with the prevalence of warmer than average water along the Canterbury Bight being a possibility (Pinkerton et al. 2018). Having a one-year life cycle, similar to most īnanga, means that responses of smelt to changes in environmental variables can also be expected to be rapid, and the potential loss of a single cohort could have significant impacts. Fish invariably have some life history "bet-hedging" (aspects of their biology that provide some buffer against such adverse effects as high predation or significant environmental change e.g., widespread distribution, multiple spawning events, nonspecialised diets) and Stokell's smelt must have had some resilience to have withstood the uncertainties of previous droughts, floods, and temperature anomalies – for example, a protracted spawning season. However, Stokell's smelt are particularly vulnerable as although they existed in vast numbers, their geographic range is limited to the major rivers of the central South Island east coast. They could also be vulnerable to Allee effects, whereby an overall reduction in successful spawning can be due to social and behavioural impacts associated with a reduced number of spawning fish. Should there be some widespread environmental calamity in these rivers that might extirpate Stokell's smelt from them, there are no outlying populations that could reinvade the main rivers. Given the magnitude of the suggested reductions in Stokell's smelt abundance, it may already be on a pathway to extinction.

Common smelt coexist with Stokell's smelt in Canterbury rivers, although their numbers have historically been much fewer than Stokell's smelt (Bonnett 1992; Eldon and Greger 1983). Common smelt are a reasonably adaptable species and can form lacustrine (non-migratory) populations within lakes. Indeed, the successful transfer of common smelt to Lake Taupo from 1934–1940 resuscitated the failing rainbow and brown trout fishery of the lake after trout had virtually eliminated the resident koaro (McDowall 1994b). Large shoals of common smelt are known from many North Island rivers (McDowall 2011) but whether numbers will increase in the large Canterbury rivers in the virtual absence of Stokell's smelt is unknown. Given the similarity on their key life-history characteristics (spawning seasons and habitats, fecundity, longevity, etc), this possibility cannot be discounted but neither should it be assumed as a likely consequence.

Anglers generally noted a close relationship between the abundance of smelt and sea-run brown trout. Thus, although trout abundance was often considered to have shown a gradual decline over the past 15–20 years, this has been most marked over the past 10 years and especially the last 5–6 years. Given the importance of smelt in the diet of sea-run trout (e.g., Rutledge 1991), this parallel decline between trout and smelt would be expected as there is no other forage species to fill the niche previously occupied by smelt. The incidence of sea-run trout increases with distance south, but stocks further south than the Waitaki River will not be dependent upon Stokell's smelt as this is the present southern limit of the distribution of this species. Because of such variability in diet and the general adaptability that typifies brown trout, the species is obviously not at risk although without a seasonally concentrated source of food like smelt, there is little incentive for trout to congregate at the mouth of the hāpua, and this traditional fishery will increasingly become a thing of the past. Riverine trout will likely continue their post-spawning downstream migrations to the hāpua, as the opportunity to feed on other species like bullies, īnanga and mullet, will still be an attraction.

The gradual decline in salmon abundance is something that anglers have been aware of for decades, and there was general agreement from interviewees that this had commenced in the early 1990's, but has been more pronounced over the past 10 years, and especially the last 5–6 years. These are similar time scales to those of sea-run brown trout, and the emphasised 10 years and especially 5–6 years is similar across all three species. While a close association between smelt and trout abundance is expected, this would not necessarily be the case for salmon as adults do not feed upon entering fresh water – thus their decline is for other reasons, and the reduced numbers, size and condition are strong indicators that events at sea play a major role. As stated by Dr Andrew Simpson (chair, Central South Island Fish and Game Council) "The decline in spawning runs might be caused by a host of factors, including habitat and water quality, hydropower development and irrigation practices, and even ocean temperatures. Most of these factors are outside of Fish and Games control" (Fish and

Game 2021b). In the absence of controls in the marine environment (apart from bycatch of salmon at sea by trawlers targeting red cod and silver warehou), fishery managers concentrate their efforts on the freshwater phase by minimising fry and smolt losses, maintaining water quality and quantity, ensuring unimpeded upstream passage of adults, protection of spawning streams, and monitoring harvest rates. Experiences in ocean ranching of salmon (whereby millions of fry were reared and released with the anticipation that resulting adults would return to the "farm gate") demonstrated that hatchery-reared fish were maladapted to life in the wild, or the ocean's ability to rear salmon was finite and lower than required for financial viability, perhaps indicating that salmon are more vulnerable to events at sea than would be anticipated.

In future, to maintain some semblance of a wild salmon fishery, managers will no doubt continue and probably escalate their concerns for provision of improved water quality and quantity. In addition to their considerable importance as a game fish, maintaining sufficient depth and flow for salmon passage and angling have been advanced as major arguments when setting flow parameters on many South Island east coast rivers.

Perhaps unexpectedly, there were consistent comments about how well the whitebait fishery was doing, with many fishers stating that last season was one of the best for many years. While some whitebaiters thought there had been an overall decline in whitebait abundance over their decades of experience, this needs to be considered in light of the fact that there are probably more people engaged in whitebaiting these days, so individual catches may have decreased but perhaps not the overall abundance. Some fishers believed that spawning habitat has benefited by the accumulation of finer sediments in the hāpua as this has resulted in more marginal grasses and rushes, potential spawning habitats. Of particular interest is the fact that whitebait catches are being maintained or even improved over recent years, in sharp contrast to the massive decline in smelt abundance; yet both species have a mainly annual life cycle, approximately equal fecundity (Stokell's smelt ~5000 – 8000 eggs, Bonnett 1992; īnanga "few hundred" - 13 500 McDowall 1990), but smelt are predated as pre- and post-spawning adults and whitebait as pre-spawning juveniles. Īnanga spawning is usually closely associated with the incidence of spring tides (McDowall 1990), but recent research has highlighted the spawning success of īnanga in hāpua that have very little tidal amplitude (Orchard and Schiel 2021).

As a final comment, the convergence of opinions from a diverse but experienced group of anglers about physical and biological changes they have noticed during their decades of involvement with one of the three hāpua, provide compelling evidence of change. Unfortunately, almost all such changes have been negative.

6 Acknowledgements

Thanks to the people who participated in this study – for making time to be interviewed, and for the frank and informative replies to our questions. Particular thanks go to Bill Southward for his encouragement and for making his home available as a place to meet several anglers from the North Rakaia huts. Thanks also to Roddy McDowell, for the similar availability and use of his home at the South Rakaia huts, and Julian Sykes, NIWA, for assisting with several interviews.

7 References

Ashmore, P. (2013) Morphology and Dynamics of Braided Rivers Chapter 17: In: Treatise on Geomorphology pp 289-312.

Bonnett, M.L. (1992) Distribution and freshwater residence of Stokell's smelt, *Stokellia anisodon* (Stokell), in the South Island, New Zealand. *New Zealand Journal of Marine and Freshwater Research, 26*: 213-218.

Carter, K. (2005) The Effects of Temperature on Steelhead Trout, Coho Salmon, and Chinook Salmon Biology and Function by Life Stage. Report for California Regional Water Quality Control Board. 27 p.

Davis, S. F., Eldon, G. A., Glova, G. J., Sagar, P. M. (1983) Fish populations of the lower Rakaia River. New Zealand Ministry of Agriculture and Fisheries, Fisheries Environmental Report 33. 109 p.

Deans, Z. (2021) *Testing shows Ashburton is “loaded with nitrate contamination”.* Greenpeace. https://www.greenpeace.org/aotearoa/press-release/testing-shows-ashburton-is-loaded-with-nitrate-contamination/

Deverall, K.R. (1986) Fishes of the Waitaki lagoon. New Zealand Ministry of Agriculture and Fisheries, Fisheries Environmental Report 64. 35 p.

Drinan, T., Robertson, H. (2019) Water quality monitoring of Ō Tū Wharekai/Ashburton lakes and streams. Summary of findings. Presentation to the Ashburton Zone Water Management Committee file:///C:/Users/ADMIN/AppData/Local/Temp/AgendaandMeetingPapersAshburtonZoneWaterManagementCommittee26March2019.PresentationatmeetingbyDOConWaterQualitymonitoringofOTuWharekaiAshburtonlakesandstreams.PDF

Environment Canterbury. (2019) *Braided rivers – what’s the story?* https://www.ecan.govt.nz/get-involved/news-and-events/2019/braided-rivers-whats-the-story/

Eldon, G. A., Greager, A. J. (1983) Fishes of the Rakaia Lagoon. New Zealand Ministry of Agriculture and Fisheries, Fisheries Environmental Report 30. 65 p.

Fish and Game (2021a) Report to Respondents of the 2020/21 Salmon Harvest Survey: August 2021. Unpaged. https://fishandgame.org.nz/dmsdocument/1905

Fish and Game (2021b) Licence changes to sea-run salmon. *Fish and Game New Zealand. Special issue 53.* 14-15.

Glova, G. J., Duncan, M.J. (1985) Potential effects of reduced flows on fish habitats in a large braided river, New Zealand. *Transactions of the American Fisheries Society 114*: 165-181.

Jellyman, D.J., Graynoth, E. (1994) Headwater trout fisheries in New Zealand. New Zealand Freshwater Research Report 12. 87 p.

Jellyman, D.J., Unwin, M.L., James, G.D. (2003) Anglers’ perceptions of the status of New Zealand lowland rivers and their trout fisheries. NIWA Technical Report 122. 61 p.

Jellyman, P.G., Booker, D.J., Crow, S.K., Bonnett, M.L., Jellyman, D.J. (2013) Does one size fit all? An evaluation of length–weight relationships for New Zealand's freshwater fish species. *New Zealand Journal of Marine and Freshwater Research 47*: 450-468.

Lee, F., Perry, G.L.W. (2019) Assessing the role of off-take and source–sink dynamics in the extinction of the amphidromous New Zealand grayling (*Prototroctes oxyrhynchus*). *Freshwater Biology 64*: 1747 – 1754.

Littlewood, M. (2020) *Conservation groups hunt rare 'at risk' Stokell's smelt.* Timaru Herald. https://www.stuff.co.nz/timaru-herald/news/123572151/conservation-groups-hunt-rare-at-risk-stokells-smelt

Littlewood, M. (2021) *Reports of gull chicks dying near the Rangitata River.* Timaru Herald. https://www.stuff.co.nz/timaru-herald/news/123912231/reports-of-gull-chicks-dying-near-the-rangitata-river

McDowall, R.M. (1984) Trout in New Zealand waters. The biology and management of trout in New Zealand's lakes and rivers. The Wetland Press. 120 p.

McDowall, R.M. (1990) New Zealand freshwater fishes—a natural history and guide. Auckland, Heinemann Reed. 553 p.

McDowall, R.M. (1994a) The origins of New Zealand's chinook salmon, *Oncorhynchus tshawytscha*. *Marine Fisheries Review 56*:1–7.

McDowall, R.M. (1994b) Gamekeepers for the nation. Canterbury University Press. 494 p.

McDowall, R.M. (2011) Ikawai: Freshwater fishes in Maori culture and economy. Canterbury University Press. 832 p.

McMillan, H.M. (1961) An addition to the knowledge of the fish, *Retropinna anisodon* Stokell (Retropinnidae). *Transactions of the Royal Society of New Zealand Zoology 1*: 139-144.

Ministry for the Environment. (2018) *Climate change projections for the Canterbury region*. https://environment.govt.nz/facts-and-science/climate-change/impacts-of-climate-change-per-region/projections-canterbury-region/

Mitchell, C. (2016) *Christchurch's vanishing streams worry residents*. Stuff. https://www.stuff.co.nz/environment/77605645/christchurchs-vanishing-streams-worry-residents

Mitchell, C.P. (1989) Swimming performances of some native freshwater fishes. *New Zealand Journal of Marine and Freshwater Research 23*: 181-187.

Mosley, M.P. (1982) Critical depths for passage in braided rivers, Canterbury, New Zealand. *New Zealand Journal of Marine and Freshwater Research 16*: 351-357.

Orchard, S., Schiel, D. R. (2021) Whitebait conservation and protected areas at non-tidal rivermouths: integrating biogeography and environmental controls on īnanga (*Galaxias maculatus*) spawning grounds. *Pacific Conservation Biology* https://doi.org/10.1071/PC21004

Pinkerton, M., Sutton, P., Woods, P. (2018) Satellite indicators of phytoplankton and ocean surface temperature for New Zealand. NIWA Client Report No: 2018180WN. 87 p.

Rutledge, M.J. (1991) Adult trout diet in the lower Waitaki River and tributaries, 1983 – 1986. New Zealand Freshwater Fisheries Report 126. 18 p.

Tengö, M., Brondizio, E. S., Elmqvist, T., Malmer, P., Spierenburg, M. (2014) Connecting diverse knowledge systems for enhanced ecosystem governance: The multiple evidence base approach. *Ambio, 43*(5), 579-591.

Unwin, M.J., Glova, G.J. (1997) Changes in life history parameters in a naturally spawning population of chinook salmon (*Oncorhynchus tshawytscha*) associated with releases of hatchery-reared fish. *Canadian Journal of Fisheries and Aquatic Sciences 54*: 1235-1245.

Waihora Ellesmere Trust (2017) Te Waihora/Lake Ellesmere State of the Lake 2017. Ford, D.E., Hughey, K.F.D., Taylor, K.J.W. (eds). 48 p. www.wet.org.nz/wp-contents/upload/2017/11/State-of-the-lake-report-final.pdf (wet.org.nz)

Appendix A Human Research Ethics Application

Application for Human Research Ethics Approval

Project title: Hāpua Fishery Anecdotal Study

Principal Investigator
Name: Phillip LittlewoodOrchard
Organisation: National Institute of Water and Atmospheric Research
Email: Phillip.Jellyman@niwa.co.nz
Phone: +63 3-343 8052

Research Investigator
Name: Don Jellyman
Organisation: National Institute of Water and Atmospheric Research
Email: Don.Jellyman@niwa.co.nz
Phone: +64 3-343 7846

Research Investigator
Name: Melanie Mayall-Nahi (Ngāti Whātua, Te Rarawa)
Organisation: National Institute of Water and Atmospheric Research
Email: Melanie.Mayall-Nahi@niwa.co.nz
Phone: +64 4-382 1615

Aims/objectives of the project

There is increasing recognition that the state and health of fish communities in Aotearoa-New Zealand (A-NZ) is experiencing significant environmental impact/s. Fishers interacting with their local hāpua are observing changes in these ecosystems. Many locals within the Rakaia, Ashburton and Rangitata hāpua fishing community have requested for their experiences and interactions with these hāpua to be recorded. Local fishers in these areas have observed declines in fish species, which have cumulatively affected other marine and terrestrial species that interact with the hāpua. It is not only important to recognise the history and experiences of these local fishers but also to acknowledge the depth and breadth of these knowledge holders.

The work proposed here seeks to contribute to these goals by actively collecting anecdotal fisheries (and habitat) observations from fishers who interact the hāpua of the Rakaia, Ashburton and Rangitata. The findings from these interviews will be used to inform ECan's Water Quality and Ecology Group of any consistent themes and observations from the interviewees that might reinforce results from a recent fish survey of the Rakaia hāpua commissioned by ECan.

Date application submitted

1/5/2021

Proposed project start date
1/5/2021

Proposed project finish date
31/8/2021

Funding sources
This project will be funded by Environment Canterbury.

Any financial conflicts of interest?
The above funding sources do not constitute a financial conflict of interest.

Any other conflicts of interest?
No.

Study Design - Methodology - Methods
Semi-structured interviews with key participants in the Rakaia, Ashburton and Rangitata hāpua will be undertaken by members of the project team. It is anticipated that the interview target will be a minimum of five interviews per hāpua. It is also understood that there may be need to broaden the scope of interviewees from anglers to include individuals who interact with these hāpua, but for different reasons – e.g., birdwatchers, foragers and fishing guides. The intended length of interviews with individuals will be 60 minutes. These interviews will include fishers of the Rakaia, Ashburton and Rangitata hāpua. Names of possible interviewees will mainly be supplied by North Canterbury and Central South Island Fish and Game staff, ECan, angler clubs, and individuals known to the NIWA staff involved.

Preference will be given to face-to-face interviews, but it is likely that a few interviews may need to be conducted by phone. A "meeting" format will be avoided.

Draft interview questions will be sent to ECan to ensure they encapsulate ECans' requirements. Results from the interviews will be analysed using a thematic approach, although relevant specific comments may also be included.

Is any deception involved? If so, please justify
No deception will be involved in this project.

Are ethical/cultural approvals from internal or external groups required?
The interviews will be conducted or facilitated by members of the research team. To the best of our knowledge no further approvals are required.

Will the project team need to be aware of, and use, culturally safe practices?
Due to the nature of interviewing local fishers, the project team will need to ensure their research methods are non-ambiguous, and not leading (e.g., not directed at apportioning blame for river or fishery management issues).

This research project includes scientists related to the research topic including freshwater scientists and a Māori social scientist with community knowledge and/or organisational knowledge. Our collective skill will allow us to employ robust techniques to establish respect for and validity of the evidence. This may include following the tikanga and kawa of the rohe we visit, and also the homes that we may visit.

Participants
Interview participants are expected to be dominated by anglers that may hold the historical knowledge of Rakaia, Ashburton and Rangitata hāpua. The project team anticipate interviewing approximately 15 fishers, five per hāpua. No children will be interviewed in this project.

Participant recruitment
Fishers of the Rakaia, Ashburton and Rangitata hāpua will be recruited by one of the project team members. Interviewees will be selected based on their interactions with the hāpua. Due to the research seeking changes over time, participants will need to exhibit knowledge and experience interacting with the hāpua over time. Possible participants who are known to researchers already, or whose contact details are publicly available, will be approached directly via phone contact or email. Other possible participants who are identified by previous contacts (snowballing) will first be approached by the common contact wherever possible. Participation in this research will be voluntary. Interviewees are free to withdraw participation at any time without giving a reason.

How much time will participants have to give to the project?
Each interview is anticipated to take no more than 60 minutes. A mutually agreeable time will be set through phone contact or email and a clear indication of time demands will be outlined. There may be a requirement for a brief follow-up conversation to confirm the integrity of information shared, but no further time requirements are expected. We will also confirm in advance of all interviews whether participants have other time commitments to minimise cutting interviews short and/or interrupting the plans.

Potential harm
This study is unlikely to cause any harm. If uneasiness or distress is experienced by a member as a result of participation in this study, we will immediately ask if they need to stop the interview or have a break from the interview. We will confirm at the beginning of each interview that participants are comfortable in the place where the interviews are being held.

For example, they may want to conduct the interviews in their marae, home or outside overlooking the landscape that they are discussing. Participants may have other individuals/whānau present during the interview for support. We are also mindful that participants may share information that they did not intend to, or that others may not happy with them sharing with us. Participants can let us know at any time (e.g., during or after the interview) if they want us to exclude anything they have said in the interview. We will omit any information from our records and reports that the participants do not want to share.

Potential benefits
We are hopeful the study will enrich and empower ECan in making more informed decisions about future river management and entrainment. Also, results may highlight the well-being of particular fish species and associated fisheries, and implications of these for flow-on effects like bird nesting and rearing success - such information would be of value to agencies like Ngai Tahu, Fish and Game, Department of Conservation, as well as the general public.

The potential benefits for those involved in this study include the collaborative recounting and documentation of perceived physical changes to the hāpua and fish stocks, and the detection of short- and long-term changes in the coastal environment, Notwithstanding these potential benefits, we acknowledge that participants will decide for themselves the benefits of becoming involved.

Informed consent
We will gain verbal consent only from each participating member in this project. This will involve paraphrasing the 'Participant Information Sheet', providing opportunity to clarify questions, reiterating that the information shared is private and confidential, and that this can be withdrawn without providing a reason at any point throughout this research project.

Confidentiality and anonymity
Throughout the research period, all information provided by interview participants will be treated as private, confidential and will only be used for the purposes of the outlined research. Anonymity will be ensured throughout this process unless the interviewee requests to be named. No identifying information will be displayed.

Intellectual Property protection
Intellectual property protection is not required for this study. All stories, memories and events shared through the course of this project will only be used for the purposes of the outlined research.

Further, interview participants will have the option of excluding contributions if they wish for those to be removed.

Data protection
The Principal Investigator will store all materials collected during the study on NIWA's secure data system. During the duration of the study, NIWA will hold onto the raw material (any auditory records and interview notes). Once the final report is completed, and after an appropriate period and in consultation with ECan, the data collected from the interviews will be disposed of. Decisions made about any future use of the raw data would only be made with the further consent from individuals whose data was collected. The future use of this data should only be used in projects related to individual's perception of change to the three hāpua being investigated.

What is the anticipated use of the data?
With respect to the reporting of results from this study, a report will be prepared for ECan and a copy of the report will be provided to all participating members who wish to receive a copy. This report may be used by ECan to make decisions about any suggested or required changes to their management of the hāpua. Results may also provide useful information to those agencies with responsibility for fish and bird management and interests (e.g., Ngai Tahu, Fish and Game councils, Department of Conservation).

Anything else?
There is nothing further to declare.

Applicant declaration
The information supplied is accurate, to the best of our knowledges.

Appendix B Participant Information Sheet

Participant Information Sheet

Project title: Hāpua Fishery Anecdotal Study

1. **What is the study about?**

The work proposed here seeks to actively record anecdotal observations from those who frequent the Rakaia, Ashburton and Rangitata hāpua. The project encourages those who have observed changes over time in these hāpua to recount stories, memories and events meaningful to them through interviews.

2. **Who is conducting this research?**

Principal Investigator
Name: Phillip Jellyman
Organisation: National Institute of Water and Atmospheric Research
Email: Phillip.Jellyman@niwa.co.nz
Phone: +63 3-343 8052

Research Investigator
Name: Don Jellyman
Organisation: National Institute of Water and Atmospheric Research
Email: Don.Jellyman@niwa.co.nz
Phone: +64 3-343 7846

Research Investigator
Name: Melanie Mayall-Nahi (Ngāti Whātua, Te Rarawa)
Organisation: National Institute of Water and Atmospheric Research
Email: Melanie.Mayall-Nahi@niwa.co.nz
Phone: +64 4-382 1615

Research Funder:
This project is funded by Environment Canterbury.

3. **Do I have to take part in this research study?**

Participation in this research study is voluntary. If you do not want to take part, you do not have to. If you decide to take part and later change your mind, you are free to withdraw from the study at any stage.

If you decide you want to take part in the research study, please:

- Verbally confirm you have read the information provided and your decision to participate.
- Take a copy of this form with you to keep.

4. **What does participation in this research require, and are there any risks involved?**
Participants in this research study will be interviewed individually, at a location of your choosing. We anticipate the interviews being 60 minutes. The interview questions will be related to your observations of the hāpua/estuary that you have frequented over time. There are no risks involved in this research study, however, if uneasiness is experienced during the interview process, you are free to take a break and/or ask that information be excluded from the interview.

5. **What are the possible benefits to participation?**
We are hopeful the study will enrich and empower those who take part. The potential benefits from participating in this study include the recounting and documentation of environmental history from of hāpua of interest, the detection of short and long term changes in hāpua, and the opportunity for local and community knowledge to inform and contribute to future environmental management options. We also acknowledge that participants will decide for themselves the benefits of becoming involved.

6. **What will happen to information about me?**
By agreeing to participate, you consent to the research team collecting and using the information you provide for this study. You will not be directly identified unless you choose to be. During the period of research, all study materials will be stored within the National Institute of Water and Atmospheric Research (NIWA) secure data system. Audio files will be returned to interview participants if requested at the conclusion of the research study.

7. **How and when will I find out what the results of the research study are?**
All stories, memories and events shared through the course of this project will only be used for the purposes of the outlined research. The final results of the research study will be collated into a report that will be returned to you at the conclusion of the project if you wish to receive a copy.

8. **What if I want to withdraw from the research study?**
If you do consent to participate, you may withdraw at any time. You can do so by ringing or emailing the research team and telling them you no longer want to participate. Your decision not to participate or to withdraw from the study will not affect your relationship with the National Institute of Water and Atmospheric Research (NIWA). If you decide to leave the research study, the researchers will destroy any information about you that was collected during your participation in the study.

9. **What should I do if I have further questions about my involvement in the research study?**
Please call or e-mail the research team if you have any further questions about your involvement this study.

Name ………………………………………………………

Signature………………………………………………… Date…………………………………………………………

Appendix C Verbal Consent Script

Verbal Consent Script

Project title: Hāpua Fishery Anecdotal Study

Principal Investigator
Name: Phillip Jellyman
Organisation: National Institute of Water and Atmospheric Research
Email: Phillip.Jellyman@niwa.co.nz
Phone: +63 3-343 8052

Research Investigator
Name: Don Jellyman
Organisation: National Institute of Water and Atmospheric Research
Email: Don.Jellyman@niwa.co.nz
Phone: +64 3-343 7846

Research Investigator
Name: Melanie Mayall-Nahi (Ngāti Whātua, Te Rarawa)
Organisation: National Institute of Water and Atmospheric Research
Email: Melanie.Mayall-Nahi@niwa.co.nz
Phone: +64 4-382 1615

Verbal Declaration by the participant:

Following review of the Participation Information Sheet the following declarations will be verbally confirmed with interview participant.

- ☐ Have you read the Participant Information Sheet?
- ☐ Do you understand the purposes, study tasks and risks of the research described in the study?
- ☐ Do you agree to participate in this research study as described and understand that you are free to withdraw at any time during the study?
- ☐ Do you agree to be audio-recorded for this project?
- ☐ Do you provide your consent for the information collected about yourself to be used for the purpose of this research study only?
- ☐ Would you like to receive a copy of the final report and/or an audio file of your interview, and have you provided your contact below so that they be used for this purpose only?

Appendix D Interview Questions

Interview Questions

Project title: Hāpua Fishery Anecdotal Study

PRE-INTERVIEW MATTERS

1. Review the 'Participant Information Sheet'
2. Review the 'Verbal Consent Script'

    Note: Confirm the interview participant is comfortable with the location for the interview, and the expected duration of the interview.

INTRODUCTORY QUESTION

1. Can you tell us about yourself, what hāpua you're reporting on and your connection to this place?

KEY QUESTIONS – PART 1: Hāpua

1. What is your main activity/involvement with the hāpua?
2. How many years have you been associated with this hāpua?
3. Approximately how many days each year would you spend at this hāpua?
4. Why do you choose to come to this place?
5. Have you noticed any long-term changes to the hāpua? How has this affected you?
    a. What locations do the changes relate to? (barrier/lagoon/outlet/channel/rivers etc.)
    b. If this includes changes to sediment, do the changes relate to gravel, sand or silt/mud?
    c. Do the changes relate to specific river flow conditions or times of year?
    d. Do the changes relate to specific outlet channel configurations?

KEY QUESTIONS – PART 2: Fish and their habitats

1. Which fish species are you most familiar with?
2. Have you noticed any significant changes in the numbers/abundance of this species over time?
3. Have you noticed any changes to the seasons this species is present in the hāpua over time?
4. If you have noticed any changes to the abundance and/or the seasons, how long do you think this has been happening for?
5. If you have noticed long-term changes to the hāpua, how do you think these changes might have affected this species? How have such changes affected you?
6. Do you think there are actions that could be taken that would improve the hāpua for this species?

7. Are there any other changes that you would like to see happen to the hāpua and catchment?

END QUESTION

1. Is there anything else about the hāpua that you would like to talk about or that we may have missed?

Appendix E Table of respondents

Rakaia River	Ashburton River	Rangitata River
Johnny Richards	Matthew Hall	Trevor Isitt
Paul Watts	Alex Wood	Peter McLaughlin
Brian Rooney	Ian Watson	Alan Brooks
Rodney McDowell	Murray Beach	Paul Hodgson
Danny Fisher	Peter Trolove	Phil de Joux
Bill Southward	Martin Baker	Matthew Hall
Ken Hemingway		Ian Watson
Noel Muckle		
Mike Pritchard		
Martin Baker		
Peter Trolove		
Paul Hodgson		

Appendix F Rakaia River comments

Changes to hāpua

- Noticed changes in Rakaia hāpua in mid-1990's – fewer mayfly hatches, fewer wrybills, quality of fishing declined.

Flows

Median flows

- Used to call river "The mighty Rakaia" so don't fall in, but by late 2000's he was able to wade right across, as "the water wasn't there".

Flood flows

- Floods have faster recession curves and don't scour hāpua properly anymore.
- The river clears quicker after a flood - was 8- 10 days, now 4-5.
- Reduced large floods – recorded 5800 m^3/s flow years ago, but today 1000 m^3/s regarded as big. Used to hear rocks rumbling during floods but not these days – smaller floods and more silt than rocks transported.
- Flow recession much faster these days, especially over past 10 years e.g., 3 days vs a week.
- Used to have floods up to 6000 m^3/s but now 1000 m^3/s is a big flood.
- Used to be that 400 m^3/s flood would take a week to clear but now two days. After 800 – 900 m^3/s flood these days can be fishing within few days

Low flows

- Concerned about water intakes and inadequate screens- thinks there are about 400 takes. On the north side, the old boarder dyke system resulted in thousands of fry on paddocks = gull tucker.
- Less flow – springtime flows seem OK though. Occasionally can walk across mouth but could never do this in old days (probably > 20 years ago). Ultimately need to reduce dairying and associated water abstraction.
- Need higher flows back.
- Less flow volume and water velocity.
- Water level reduction associated with less flow in river, water takes blamed for this.
- Noticeable recent reduction in flow recession times e.g., much less than the 10-day recession in the past, before fishing could resume "used to wait a week for river to clear, now just a few days". River fishable these days at 100-120 m^3/s, but used to be more like 200m^3/s
- North branch generally not flowing.
- Lower flows. Shallower water results in warmer water.

- Noticed a drop in water level by 10cm.
- Abstraction rule seems to be “Minimum for the river, maximum for the economy”.
- Generally reduced flows -thinks this is due to excessive take of groundwater for irrigation
- Flows are generally lower and don’t flush out the silt, the frequency of large flood events is also much less.
- Flows a lot lower and less velocity – e.g., Used to need a 2 oz lead weight above Z spinner to get down deep, but now only need 0.5 oz weight
- Main problem is reduced flow. Concerns with North Branch low/no flows
- Has noticed reduced flows, faster flow recession and river clears quicker.
- Main thing is reduced flow. Used to be that flows 180-200 m^3/s were good for salmon; now can fish at 100 m^3/s. River now gets too clear too quick.
- Used to be that in 1970’s could fish at 180 – 190 m^3/s, but now at flows of < 150 its too dirty to fish.
- The amount of water taken from rivers and groundwater is too much but unlikely to change. So, anglers and farmers need to coexist, but intakes from the river must be effectively screened, especially as smolts tend to migrate along river margins and hence get entrained into intakes. Whatever happens at sea is beyond our control.
- During old days, could salmon fish at 180 – 200 m^3/s but now 150-160 m^3/s is best, and by 180 m^3/s water is turbid (fishing best when slightly turbid e.g., knee deep and just see feet). A friend walked across the mouth at 80 m^3/s and water only knee deep – have only been able to do that over past 20 years.
- Lost faith in Fish & Game who say things like “Rivers will be fine and fishable this week so get out and go fishing “ = just revenue generating talk. Gave an example of accessing the river by vehicle at the Rakaia golf course (there is an “Angler Access” sign there) - they heard a bulldozer working upstream and when they drove back the water was over the front of his 4WD and the other vehicle was washed away but they manage to retrieve it. ECan eventually replied that the consent holder was complying with conditions but in future anglers were advised to use another road to access the river.
- Thinks that if managed correctly there should be enough water for everyone -irrigation is a fact of life and generates jobs and $
- Dec – March, flows can be so low that saltwater flows in = river flows backwards rather than just slows down.

Sediment

Fine sediment (silt, sand, fine gravel)

- Recalls going out to the Rakaia and come home with socks and boots full of sand.
- Rakaia – after 5500 m^3/s flood, he saw a large pile of gravel ~ 0.5 – 1 km offshore = indicative of extent of bedload movement that occurs.
- Old boat ramp near huts no longer used as it's silted up and not enough water now to launch boats.
- Many fines between rocks now.
- Less big boulders along the beach, and beach now has finer substrate but still a hard (compacted) surface that vehicles can use but need to drive faster to avoid getting stuck.
- Much more sand at river mouth and bar where get strips 50 – 100 m wide. Used to be gritty sand but now "softer and finer".
- More fine substrates – could ride BMX along barrier as compact and hard, but not now as soft and sandy.
- Mud a big problem as it settles and solidifies, especially at top of lagoon. Now many fewer large rocks (wasn't sure if they're gone or just buried).
- Helicopter spraying of main channel = broom used to hold shingle together.
- Noticed there was generally much more silt in the Hāpua than in previous times.
- More weed in the lagoon, and much more silt and sand.
- Marked change to a generally smaller substrates – much more sand.
- Much more sand/silt in hāpua than formerly. Size of rocks is smaller (thinks with reduced flow, river less able to transport large substrate)
- Noticed much more mud in silt in the Hāpua during the last 10-15 years and doesn't flush as well.
- The gravel bars in the lower river and hāpua are filled with silt and no longer clean gravel like in the past, there is a noticeable lack of large rocks. Large amounts of dead woody debris from spraying up-river, collects on beach – used to get trees/branches on beach and was good firewood, now just dead broom, gorse etc, probably from spraying.
- Much silt/mud now covering rocks.
- Not aware that sediment composition of mainstem has changed much, but bar has changed a bit with less gravel and more sand – has to pull stuck vehicles out, but not often.
- Suspects like Rangitata that with more fines in river, a relatively small fresh will result in resuspension and turbid water.

Coarse sediment (rocks, boulders)

- Still hear rocks rumbling in floods, but mainly when NW conditions when noise travels to South Side of river.
  No longer big boulders along the shoreline – these came from further south (maybe Waitaki?). Used to hear the river "roaring" during floods but not now.
- Used to hear river 'hissing" during flood – not now.
- Used to hear hissing and fizzing noise of stones continuously moving in flow.
- Hasn't heard the crashing of rocks down the river in a large flood event for years.
- Can still hear the river when it's in a big flood (tumbling rocks).
- The bar used to have a lot of big rocks, but now it's much softer and vehicles get stuck. Changes have been gradual over the last 20 years.
- Not many big rocks left but has been an accumulation of silt and sand.

River fairway

Braid pattern

- River changes – the main channel shifts from north to south but has been mainly on south side for past 4-5 years.
- Not as many braids – used to be 3 or 4 main ones. Almost all gone and have much softer substrates – much mud. Interstitial spaces filled with mud.
- River channels not as wide e.g., Can fish in boat close to mouth of river, but not in past when river bigger and more violent.
- Need wandering braids to create good holes but fewer braids today.
- Spraying has altered river channels.
- Flood protection works have pushed main braids around and reduced natural bed changes.
- Spraying → structure of braided rivers gone. Defoliated with herbicide. No vegetation in braids now.
- North Branch was important trout nursery stream (lots of mayflies) but now largely silted up. Used to be braided, now confined to singe channel.
- Braided river not allowed to be a braided river.
- Used to 3 main braids above hāpua, but now only one.
- When started fishing the river, the bed was open, but now more weed. Bed became more consolidated and shifted about less – sometimes bed is "like concrete" and biology has deteriorated.
- Went back to Rakaia hāpua a few years ago, and whereas water used to "charge through the lagoon, now it is just "falling in", and quad bikes could drive across it.

- ECan don't monitor the "special character" of the river, although have a series of aerial pictures over 40 years
- Concerns that water takes are too large to maintain the braided nature of the river

Depth

- Harder to jet boat as shallower.
- North Branch has dried up several times in past years – probably due to gravel extraction works and diversion, but also less recharge from springs (fish get attracted to cool water but then stranded when flow ceases).
- No deep holes in lower river anymore as main flow has reduced.
- River still Ok for jet boating though.
- The river is much more difficult for jet boats to negotiate.
- Depth a lot less – has waded across the river but could never do that in old days. Used to have a jetboat but not now – jetboating more difficult these days with reduced depth and smaller braids.

Lagoon

- Lagoon has a little tidal height variation as water slows and "piles up" over high tide events. No real saltwater intrusion though except wave overtopping.
- Now very tidal.
- Fewer springs but some still going.
- Fewer small tributaries in hāpua – Cold Stream still flows though.
- Build-up of mud and silt in Hāpua that is not being flushed out to sea. Gravel bars associated with Hāpua and lower river are infilled with fine sediments. Lagoon now "a mudhole" (used to be gravelly, now muddy).
- Hāpua has changed with intensification of dairying on Rakaia Island.
- Doesn't think there's any greater tidal amplitude in the lagoon than previously = virtually no tidal signature except some water backing up.
- Margins of lagoon now muddier and colonised by rushes etc (used to be all shingle edges), so better whitebait spawning and rearing habitat.
- Lack of springs in hāpua (thought much flow re-emergence was due to springs). Cold water. When river flooded, lagoon didn't get dirty as enough outflow to prevent entry of floodwater, but not these days.
- Physical changes to hāpua = unsure but not major. Maybe shallower but substrate composition has changed to much more sand and silt.
- Loss of small streams entering hāpua – some lower terraces have been bulldozed etc and streams lost; others may be due to lowered groundwater?

- The springs around the top of the (north of boat ramp) Hāpua have disappeared - the upwellings were 150mm above the Hāpua water level.

Mouth (width, migration etc)

- Mouth moves a lot easier.
- More shingle noticed around river mouth area, no rumble of substrate/boulders in outlet channel.
- Mouth used to be much wider.
- Having the North Branch flowing would be an improvement.
- The bar is softer and more fine substrates, so cars get stuck more often.
- The mouth migrates “faster” now than previously.
- River mouth stuffed. Rakaia island is now farmland.
- Mouth has virtually closed off on several occasions = possible to walk across. Never happened in older times
- “Today the sea controls the river but historically the river controlled the sea” i.e., the river punched out through barrier and mouth was usually opposite main channel, but today the mouth migrates north frequently.
- Need to form river mouth groups at main hāpua to collate and collect data and report back to ECan.
- The river mouth is at the end of a long canal heading North (1-1.5 km north). It was never like this in the past, most of the time it punched directly out to sea from the lower river. Mouth much shallower.
- Access to the main Hāpua and lower braids has become more difficult for migrating fish, as access from the sea is mostly along the extended canal from the North. When the river mouth was located closer to lower river, access was much easier for most migrating fish species
- The mouth is narrower and migrates north more rapidly. Used to be that spring floods also flooded huts before river punched out – not now though.
- River mouth – with lower flows and southerly swells, mouth goes north quicker than it used to, and stays north for longer. Doesn’t go straight out as often as it used to.

Algae/periphyton

- Many rocks in main stem get coating of crusty algae. One season had a lot of Didymo, then got a 700 m^3/s flood and it got sloughed off. Then came a 1200 m^3/s flood and that finished off Didymo, and now sediment and algae cover rocks. This brown stuff is slippery.
- No aquatic plants in hāpua, just slime and discoloured water.

- Used to see filamentous green algae on rocks = don't see that now but changed to furry brown coating – used to be that current was main problem when wading, but now its slippery rocks.
- Sustained low flows, algae blankets stones.
- Marked increase in the infilling by sediment of spaces between rocks. Rocks also coated with algae which is not a good substrate for smelt egg deposition.
- Don't get filamentous green algae on rocks now but rather slippery silty brown covering. Likely that interstitial spaces are filled with sediment but unsure.
- Rock very slippery these days = "crusty stuff" – aware that not as adventurous as used to be due to getting older, so tends not to wade across braids so much – partly due to slippery surface but also due to his age.
- Has been told that on south side (depending on winds etc) there are more "toxic" algal blooms along shoreline – thinks this is due to nutrients not flows – usually green blooms but can be red also and can smell (acrid) and waves cause long lanes to form (reports of few kahawai and mullet). Reports that in low flow conditions, hāpua often now gets green hue = algal bloom, not periphyton.

Water quality (including temperature)

- Reduce nitrate use/infiltration
- Impacts of dairying are bad and lead to contaminants, especially in groundwater
- Increase stream planting and fencing.
- Ultimately if continue to infringe then control contamination by restricting water take.
- Wouldn't drink river water anymore.
- Local dirty water conditions more frequent even though river running clean at SH1.
- Noted ECan bulldozers more often and consequent dirty water is more frequent.
- Wouldn't drink the water these days!
- Can smell ammonia in water at river mouth. Would still swim in the water but prefer not to drink it.
- Willow Island – nitrate levels are increasing (ECan are monitoring nitrate). Mathias Creek = 6.9 mg/l; 9.8 mg/l at Coes Ford (Netherlands limit is 0.87 mg/l, but New Zealand = 11.3). Selwyn River (flowing water) is 9.5 – 9.8 mg/l!! Lag effect = can be 20-30 years, but depends on which aquifer tapped into.
- River much less dynamic than used to be, and increased water temperatures. At night, river very different than during the day.
- Would drink water from main river. Bugger all nitrate. Not from North Branch – seen fish kills there since 2015. Not smelt cow urine smell in water, but generally get dairy shed smells and baleage smells.

- Dairying expansion occurred unchecked and now reduced flows, higher nitrate levels etc.
- The lower river water has been observed to turn "green" occasionally during the summer months. Wouldn't drink it
- Today, river stays dirtier for longer.
- 20-30 years ago, would happily swim and drink water, but not now.
- So, because of lower flows, river warms much quicker. Not good for salmon.
- Would still drink the water.
- Started recording water temperatures and noted that 18°C was upper limit for salmon catchability but noticed more days at higher temperatures. Pre-didymo, hooked much algae (but not in Rangitata). 2000 was year of big drought and fishing in Rakaia was poor, but better in Rangitata.
- Noticed that in spring especially, Rakaia has good number of days when water quality improves = don't get "frothing" or smell of cows (frothing mainly seen in small backwaters). Frothing more pronounced in summer and water appears "oily" – maybe runoff contaminants? Road to South Rakaia huts sometimes a "poo-pass" with cow dung (splatters cars).

General comments/concerns

- Rakaia – believes big losses to groundwater between SH1 bridge and the sea – nowadays as aquifer is so depleted, even more loss to groundwater in this reach, so floods recede faster
- Enforce consented takes and effective fish screens.
- Beach debris used to be trees and branches, now just dead gorse, and broom from spraying – spraying started ~ 18 years ago and dairy proliferation started about same time.
- removing the cows from Rakaia Island, and ceasing to spray the lower reaches of the river as all the dead vegetation is deposited in the Hāpua and around the river mouth, this makes fishing difficult.
- Note that 200 ha of swampy ground in lower North Branch were bulldozed and burnt – probably good īnanga habitat?
- Concerns about instream gravel abstraction and resulting fines and turbid water.
- Riparian margins lost by agricultural encroachment (springs, creeks). Whole Rakaia Island leased to dairy/farm to pay for river restoration – now has 5, 800 milking cows.
- Canterbury Plains → Braided streams that are all connected. Plume of nitrates – coming down country with flow because it's connected.
- 2001 Rakaia Island – environmental change (couldn't walk through riverbed). Calici virus released in 2001 to control rabbits and resulted in vegetation increase.

- Still don't think there's one fish screen that works. Thinks there are ~ 700 fish screens in Canterbury, and has an estimate of 2 million smolts on paddocks as result of RDR (boarder dyke days)

- Remove cows from Rakaia Island.
  There's much less vegetation now because of spraying - the big holes used to be associated with willows, but the trees are now gone. There used to be more islands but now there are more lupins!

- Farmers have the power now and Fish and Game should have fought the conditions for irrigation more.
  WILCO report discusses flow sharing on the Rakaia and RDR (the way rules are currently operated means it is possible to take flows to less than the NCO limits). Report "under final review" within ECan. We need to see it!

Changes to fish stocks

Smelt

Overall status

- Harvesting 15 tonne would have made no difference (*comment relates to small fishery that developed in Ashburton River*). Seen clouds of smelt - dark band amongst shingle. Migrations started in October and through to Feb/March.

- Massive decline

- Years of decline

- Yes, massive decline noticed, especially in last 7 or 8 years.
  Migrations of silveries (smelt) have declined dramatically in past 10 years.

- Since 2010 the smelt migration has substantially reduced, especially over past 5-6 years. Didn't see dead/spent ones.

- Noticed reduction in 7-8 years. Hugely dramatic.

- See the old smelt dead but not a massive die off, and not seen spawning. Decline reasonably recent, maybe over past 5 years.

- Not really any change to the season because the smelt virtually gone.

- Smelt declines over past 10 years, especially last 4-5 years.

- This year didn't see any shoals and no foul hooking of smelt either.
  Loss of smelt mainly over last 8-9 years

Observations on shoals (size, duration etc)

- Used to see shoals 1 m wide that went for hours. Saw a few during last whitebait season, one was 20 cm long. Would see them washed up on the beach =pre-spawning fish that were swimming along wave zone and got picked up and dumped by waves – often piles 0.5 m deep and hundreds of metres long. Stunk!

- Migrations were a metre wide, high density, constant streams of fish coming in from the sea along the margins of the outlet channel, this went on for days. The migration season duration was September/October to January/February. Fishing was generally from 9 pm onwards, often for 4 hours or more. Sometimes large numbers of smelt were washed up by big seas and buried under gravel or dumped in piles amongst the shingle.
- Were prolific and migrations were so extensive as to be a nuisance as was difficult to cast a spinner without foul-hooking smelt. Use to catch them by the sack full and dig into the garden. Season was mainly late November to early January.
- Haven't seen columns of smelt for the past eight years.
- The smelt migration was a solid one-metre wide column of fish (1 m wide, 0.5 m deep) that migrated up the margins of the river day and night.
- In the last 10 – 12 years the migrations are significantly smaller and due to this the different size classes of fish have been more easily observed (small 60 – 70 mm, large 120 mm).
- Shoals 1 m wide and sometimes continue for days; several occasions like that per season also. This year didn't see any shoals and no foul hooking of smelt either.
- Once saw a shoal that was running in morning, still going by evening and still going next morning! Has not seen anything like that over past 7 years. Still a few about though. Old timers claimed smelt would go upstream as far as Ferry Road. Shoals were "on a mission", so moving upstream at a slow walking pace; positive they didn't go in and out of river with tides – unsure himself where they all went though. "When they came in they stayed in". Shoals were about 2 feet away from the bank – trout would drive them closer to the surface, and then they were more accessible to terns.
- Saw smelt dead outside river in 2010/11, with banks of dead smelt 3 m wide and 1 foot thick. Couldn't say whether this was associated with algal bloom = unsure, but not just a result of stranding by wave action. Smelt haven't recovered since. Thinks loss is result of intensification of agriculture and dairying.

Importance in food chain

- 3-4 years ago, black-billed gull chicks were starving. Smelt drive the food chains in hāpua.
- Smelt are an important food source for gulls. - waves would often dump smelt on the beach and birds would gorge on them, sometimes birds would be so full they couldn't fly. Birds mainly terns and gulls, few blue herons. Terns would dive effectively but gulls would "blind bomb" and less efficient.
- So many that when lure fishing for trout, often foul-hooked smelt. Trout spewed smelt. At night would see eels feeding on smelt, and flounders also ate them.

Other comments

- Unsure about different species but certainly two distinct size groups. The PDL report will show virtual lack of smelt.
- Lack of suitable spawning substrates may be an issue?
- Usually after a fresh when water was still dirty, smelt would travel upstream for 0.5 – 1 km above lagoon to the lower braids.
- Used to get washed up on the beach when caught by waves

Brown trout

Overall status

- A lot less!

Years of decline

- Decline in sea-run trout fishery started 15-20 years ago.
- Decline started ~ 18 years ago, coinciding with aerial spraying and dairy conversions.
- Not worth fishing these days
- There has also been a decline in sea-run brown trout caught in the river mouth or lower braids, these fish were very silvery in colour and had scales that came off easily when handled.
- A slow decline starting about 10 years ago.
- Sea-run trout numbers crashed, in conjunction with smelt.
- Sea-run brown trout populations have declined significantly in the last 8-10 years, a gradual but steep decline in numbers.
- Decline probably over past 15 years.
- Big decline, especially in last 3 or 4 years.

Catch rates

- Has diaries but only recorded trout > 2 kg – none this past year. Regularly caught 5-6 trout an evening, all > 4 kg.
- Often 50 anglers fishing, 10 pm – 2 am, and all would catch trout. Fishing depended on runs of smelt - when smelt started arriving, so did trout. Would also see sprats at river mouth but these don’t enter freshwater like smelt do, so trout chased smelt into river.
- Not worth fishing for sea-run trout as no food (silveries) means no trout
- Fishery has collapsed – don’t bother fishing now as too few fish and in poor condition. Used to regularly catch 20-40 trout per evening – there were also tidal runs of trout = incoming tide during the day, but mainly an evening fishery.
- Easy to catch 12 fish per day, the largest fish weighing 15 lb.

- Often 20-30 people fishing, but not now. Only caught 12 trout for whole season.
- Always caught limit bag every time fishing. Once from 11pm-1am caught 30 trout, with some fish ~10-12 pound. Could catch trout in water that was too dirty for salmon fishing.
- Fish on both lures sometimes.
- Overall, the fishing pressure has reduced in the past few years. Used to be that you had to get to mouth early to get a good possie and could be 60-70 anglers there. Rainbows are rare.
- Trout decline a recent decline. Expect 4 trout every time I'd go out.
- In 1980 he would catch 450 – 500 trout per season.
- Usually catch 12-15 trout/evening. Several hundred for the season. This season caught 12 sea-runs.
- Was a high chance of catching fish when smelt were running. Would expect to get 3 or 4 /evening.
- When smelt arrived "everyone" got hook-ups (although he avoided shoulder-to-shoulder fishing and would go elsewhere). Would catch 40+ per season but keep very few (3 or 4 for whole season). North side was better for sea-runs than south side, and often south side anglers would take boat across. Weren't always a great fight as seemed to be too gorged on smelt.

Size and condition of fish

- Sex ratio about 50:50.
- Always caught fish, including fish in 8 – 10 lb class regularly. Now a 3-4 lb fish is a "winner".
- Condition a lot poorer.
- Trout are not here. Big ones would only come with smelt. Go from C+ to A after feeding. He stopped trout fishing in 2015.
- Trout today are skinny and not worth eating – pale flesh, poor condition (slabs), and thinks has seen resorbing eggs due to lack of spawning condition. Trout are all small – last year's fish?
- The average weight was 5-6 lb, and the largest fish 14 lb. Ten lb fish were common and not really regarded as trophy fish. Last year seven fish were caught averaging 3.5-4 lb. Trout in recent years have generally been in much poorer condition.
- Were some 10-12 lb fish
- Size usually 4-7 lb, biggest he caught was 13 lb.
- Fish smaller and poorer condition – mostly slabby fish today but are definitely sea-run fish, not river fish

- Rakaia had much better runs than Rangitata. In Rakaia could catch 10 per evening. Largest he caught was 17.75 lb

Riverine trout

- since 2010, Hāpua dwelling brown trout in Spring/Summer comprised mostly river resident fish, instead of being dominated by sea-run fish as in the past. The condition factor of Hāpua brown trout has also noticeably declined since 2015.

Possible reasons for decline

- The reduction in sea-run trout numbers coincided with the decline in smelt that has occurred since 2010.
- North Branch was important trout nursery stream (lots of mayflies) but now largely silted up. Used to be braided, now confined to singe channel.
- North Rakaia was a trout nursery
- "Do I buy a license for next year?" (neighbours).
- It was also noted that fish used to be full of smelt when caught. ("spew out smelt when landed").
- Shoal of trout would follow smelt in and then there'd be many hookups
- Sea-runs linked to Lake Ellesmere – if lake open, then trout mainly went there
- Fishery died as trout had nothing to feed on – coincided with reduction in smelt over a 12-13-year period.

Salmon

Overall status

- Fishery decimated.

Years of decline

- By mid 2000's, stopped seeing a lot of salmon smolts around river edge and close to surface
- Rakaia Fishing competition. 25 years ago, Friday - Sunday. 400 to 500 salmon. Lucky if they caught 30 today.
- Used to be salmon farms that would release many young salmon – now shut down so may have affected adult run. Optimal flow used to be 200 m^3/s, but now 100 m^3/s. Salmon run started Nov/Dec (fishing best below SH1 bridge) but after Xmas fishing better above SH1 bridge. Experienced fishers would easily get 1 fish/week.
- Numbers always fluctuated have a gradual decline, especially in the last 5 to 6 years.
- Abundance a lot less.
- Salmon fishing catches have slowly reduced over time.
- Salmon numbers have reduced gradually over time, but no sudden drop off like trout

- Today, a big day would have 25 anglers but used to have up to 100 anglers on either side. Southbridge pub has record of biggest salmon going back many years.
- Used to have early run fish in Nov/Dec, then main runs Feb-April. Early season fish were best conditioned. Decline noted from late 1990's.
- Longer term decline over several decades.
- Longer term decline in numbers – probably since late 1980's.
- There has been a significant decline in salmon numbers since mid-1980's.
- A marked decline from mid to late 1990's.
- 2000/2001, the Rakaia crashed – with other anglers, started to explore the river to the gorge and realised fewer birds, fewer salmon and trout, so changes were incremental. By 2000, most of these anglers had changed to fishing the Rangitata.

Catch rates

- Main salmon run used to be late January/early February to March, but didn't happen this year. Might be as many as 50% of fish were Montrose reared fish as were adipose fin clipped.
- Caught first salmon at age 12. Dad once caught 30 salmon in one day. Would fish every day as long as it was safe. Last season, his neighbours fished almost every day all season and caught 1 and 4 salmon respectively.
- Used to catch > 20 per season. Enjoyed fishing in the surf.
- Once saw 150-200 salmon migrate past him at Dobbey's Ford, lower Rakaia. Did spawning counts at Lake Heron (Lake Stream) for many years – most was 700 dead fish, but 200-300 was typical. Never saw an adipose-removed fish.
- Numbers of people fishing have reduced dramatically, there are now 25 people fishing on a busy day at the mouth instead of hundreds in the past.

Size and condition of fish

- Fish smaller now but in good condition. Still get some 14 to 16-pound fish, usually in early run.
- In 1995 was a season of large fish where the average weight of a catch was 27 lb. His catches higher than most as knows how and where to fish.
- Size now smaller e.g., In 1995, average weight of 13 salmon he caught was 27 lb: now ~ 5 lb. A lot of interannual variability in numbers though.
- Fewer salmon and smaller.
- Warmer sea might affect condition?
- Fish much smaller.
- The average size of fish has also decreased – today a big fish is 14-15 lb, but used to get fish to 35 lb.

- Size much smaller today.
- The 1994/95 season was one of big fish in Rakaia and one of 41 lb was caught.

Possible reasons for decline

- Pity so few juveniles released these days – thinks only costs 50 c to raise fry to 50 g so should be more releases.
- Clearer and warmer water results in salmon swimming upstream faster. Clearer water gives more time for anglers to catch fish, and there are more anglers using high tech gear and result is more pressure on the salmon numbers.
- No single issue for decline in salmon, but likely a combination of low flows, irrigation, dairy conversions, climate change.
- Change in temperature, salmon would die if they swam in the area (25 degrees).
- Concerns (management issues, intake screens etc)
- Become very political and subject of much discussion etc. Fishery poor compared with what it used to be. Father caught a 40 lb salmon that took him 2 km downstream before he landed it. A fresh run salmon hooked in fast water is the ultimate fishing experience.
- Salmon fishing contest is now less about catching fish and more a social event.
- The need to monitor fish screens, and any unscreened intakes, especially as water takes are from the edge where most juvenile fish swim
- Note that "scratchers" can fish in dirty water *("scratchers" use rapid retrieves and jerks to often foul-hook salmon*)
- Sad commentary – Fish and Game useless. Inadequate fish screens and many juvenile salmon end up in ponds (knows one farmer who buys fish feed and feeds salmon in his pond – takes them as needed for food). Thinks Fish and Game should net ponds and release fish back into rivers – would also provide evidence that screens aren't working. Whisky Creek and Montrose hatcheries closed now.
- Regards himself as a good salmon angler but can't be bothered these days (i.e., for past 2 seasons). When water gets too warm, salmon just sit and wait for a fresh. In smaller rivers like Rangitata, this has always happened and yet the fishery has survived-maybe the Rakaia will also?

Whitebait

Overall status

- Fishery is best it's ever been by a long way. Still varies a lot from year to year.
- Whitebait migrations are relatively unchanged "they come and go", there are still some large runs like last season.
- Still doing OK. There are still good and bad years but overall the species seem to be holding their own. They love the springhead areas.

- Has improved over last few years.
  Rakaia was very good. Last season better than previous 10 seasons.

Catch rates

- Used to think 5-10 lb per weekend was a good catch, but now 60 – 80 lb is a good day. Might catch 600 lb over the season.
- Last year could catch up to 60 lb, then stop but still whitebait coming in.
- Last year was an exceptional year, catches of 10 pounds on an average day.

Species composition

- Sometimes catch greenish bait – smaller and climb sides of bucket (*these would be koaro whitebait)*

General comments/concerns

- Seems to be lots of grassy edges in hāpua that whitebait like, plus increased tidal amplitude probably gives them access to more habitat
- Fishery highly influenced by opening of Lake Ellesmere. People use scoop nets = like a set net with handle, in the surf.
- Don't see adult īnanga on South side. Considers the fishery is very similar to what it was historically.
- Margins of lagoon now muddier and colonised by rushes etc (used to be all shingle edges), so better whitebait spawning and rearing habitat.
- Whitebait benefitted from changing habitat. Whereas smelt have not. Lagoon used to just be shingle.
- Some concerns are about loss of small streams and wetlands.
- There were some large migrations of whitebait season last year (2020) and was very good season overall. As late as January, whitebait was observed washed up on the beach. Catches vary with Lake Ellesmere opening = if lake open in early season, all whitebait go there.
- North side is better. South side can be dangerous, and people have drowned – almost all wear life jackers these days.

Eels

- See a few glass eels in whitebait net but go through the mesh. Also see larger eels coming into river. Bigger eels seen to move downstream at night to feed on smelt and go back upstream later.
- Used to see lots of shortfins ("streams of them") about 75 cm feeding on smelt. But not now.
- Sees lots of shortfin eels but longfin habitat suffered from loss of willows and groundwater.

Kahawai

- Used to be that needed a very long cast to reach kahawai schools, but these days the school close to the shoreline and are very accessible. Maybe they've changed their feeding habits?
- Kahawai are still very common, and present in large schools (5-6 acres) offshore during the summer months. Numbers dropped off after purse seiners arrived. Kahawai chased smelt.
- Used to see 4-5 acres offshore but less now. Kahawai would chase smelt alongshore, now chase sprats. Pretty sure kahawai spawn at river mouth.

Other fish species and general comments

- Mullet - generally only go 200-300m upstream
- Krill - occasionally gets washed up on beach – maybe 100 m long deposit. See more out at sea as red patches. Sometimes find big quantities washed up on the beach.
- Giant bullies: Used to be abundant – up to 25 cm. Would take a dry fly. Just caught for fun and then released. Probably gone now. Fewer cockabullies today also – a few in hāpua and only get any numbers when Lake Ellesmere is open.
- Occasionally adult lamprey has been observed or caught in whitebait net.

Birds

- Terns and black-billed gulls – would see flying at dusk with fish in mouths. Colony was on N Bank
- Terns and gulls have nothing to feed on – blackback gulls and shags seem to be OK
- Used to see black-billed gulls sitting and eating smelt (successful breeding). Feed was there all the time for them, not now. But have continue to nest in same area.
- Terns seem to be OK but black-billed gulls are not doing well as chicks are starving. Thinks gulls having to catch sprats as no smelt and sprats bigger and tougher, so more difficult for chicks to eat. Gulls changed nesting site over last 3 or 4 years - not on braids but on barrier berm.
- More big black shags about, but 2 years ago, shags were very hungry.
  In November 2010, he rang MPI as big die-off of birds, especially terns. This was followed by a "massive die-off of smelt) in December.

Appendix G Ashburton River comments

Changes to hāpua

Flows

Flood flows

- River doesn't flush as often, and increased temperatures affect fisheries

Low flows

- ECan need to have a better minimum flow. It's not enough now. Need at least another 5 m^3/s for Ashburton but 10 m^3/s would be better
- need more water from southern alps to fill rivers. We just need more water!
- Flows decreased significantly: Taking water out for irrigation (7 m^3/s from Ashburton); climatic changes cause lower flows warmer waters
- We wouldn't be in this state if there was no irrigation. Haven't got depth of water. No food source for fish
- Farming community have a business to run. No water mans a drop in income. Not getting rainfall we used to. River is suffering now.
- Irrigation throughout summer via centre pivots. On Norwest days, maybe 20% of water is lost to evaporation but need weight of water in the pipes to stop systems from blowing over.
- Biggest concern for past 30 years has been lack of flow.
- Flows – could fix the problem in 5 minutes! = increase minimum flows in all rivers i.e., 10 m^3/s more for Ashburton, and 15 m^3/s more for Rakaia and Rangitata.
- Uncertain if water temperatures are an issue as simply not enough water
- Message to ECan. Increase minimum flows i.e., 10 m^3/s more for Ashburton, and 15 m^3/s more for Rakaia and Rangitata. ECan has a lot to answer for – council has been stacked with Federated Farmer reps. Mid Canterbury used to be 100% sheep, now 80% dairying, and nitrate a huge issue.
- Ashburton – river destroyed by mid 1980's. Fishing became unreliable due to low flows and warmer water.
- Can walk across wherever you like now but in 1960's had to find somewhere to cross it.
- Used to be that had to find places to cross the river, but now can walk across almost anywhere

Sediment

Fine sediment (silt, sand, fine gavel)

- More fine sediment these days – used to come home and socks full of sand, but now more silt than sand.
- Build-up of shingle as flow is not enough to transport sediment.
- Sediment and sand in paddocks after flood. The Canterbury plains formed on that.

Coarse sediment (rocks, boulders)

- In 60's and 70's the bar was mainly large cobbles ("dinnerplate" size), but now "golf ball" size. Can still drive along bar though.

Mouth (width, migration etc)

- River mouth closes more frequently these days.
- River mouths are not as big as they used to be 70s and 80s when there was an abundance of water. Irrigation has a place but there is too much draw off.
- mouth is closed more often than it used to be due to persistent low flows.
- after a flood the mouth would turn south. Have seen it closed many times, more regular occurrence due to low flow
- Note: Ashburton relies on southerly rain, but Rakaia and Rangitata rely on Norwest rain
- In early 1900's, apparently there was the odd summer when mouth would close briefly but would then quickly reopen.
- Mouth migrates north, but after a fresh can head south. About 80% of time heads north though. In 1960's and 70's, the odd mouth closure, but now more frequent and for longer periods. If river flowing at < 8 m^3/s and mouth is 1-2 km north, then very likely that seas will close mouth
- The position of mouth affects the whitebait catch
- When the river is closed to the sea, "river life is less dynamic" – closure happens frequently these days

Algae/periphyton

- Increased algae (periphyton) Temperature gets warm, flow too low.
- Notices in the papers over the last few years - do not take your dog there. More toxins and algae in the river - dogs have died in the area.
- Build-up of algae and weeds.
- Freshes kept river alive and flushed sediment.
- If mouth closes or low flows, then stones get covered in green slime – rocks slippery and spaces between rocks now filled with fine sediment.

Water quality (including temperature)

- Would not drink out of any mid-Canterbury river. Even on a hot day. 1963 would cup hands and have a drink. Today would end up with diarrhoea if you drink it.
- Some days you would walk in and it would be so cold you'd want to hop out.
- Used to see kids swimming in the Ashburton. Not recently though due to poor water quality. People are not swimming in the rivers (*South Canterbury*) like we used to. Because of water quality.
- Definitely wouldn't drink Ashburton River water today!
- Wouldn't drink Ashburton River water these days
- Nitrates building up in groundwater as not enough water to dilute them.

General comments/concerns

- Irrigation: shouldn't happen on hot days. Groundwater used to end up in rivers but not now. Extraction of water causes increased water temperatures and salmon don't like warm water.
- Water consents: Once they expire, leases shouldn't be renewed. Will have to find other sources of water. Can't ring farms and say no more water extracted.
- A lot more intensive farming because they can get water. Can't say flow changes are all due to climate. Water use needs to be closely monitored.
- RDR water shouldn't be allowed to go to Rakaia but should be returned to Rangitata i.e., if Barhill/Churtsey scheme can pump tailrace water from Highbank back up the terrace, then should have done so before and returned Rangitata water to Rangitata!
- Hinds River. One angler remembered standing on Black Bridge and seeing about 100 trout. Was one of the best fly-fishing rivers in the country "a wee cracker in the early 1960s". Not a very good river for white baiting though. Thinks over-allocation of groundwater has stuffed this river – no flow at SH1 bridge.
- Ashburton District Council has shut down many stock waters races, but why wasn't that water returned to the river?
- Many farmers have extended grazing onto" high risk" flood-prone berms, and now want compensation for flood damage!
- Overall, "a bloody sad situation. Mother Nature, we need help!".
- ECan: need more emphasis on educating people about water issues, especially urban people as issues are not just rural ones. Many conflicts of interest among decision makers. "No swimming" signs around Ashburton River - is that going to be the way of the future? So, we won't be able to swim or even go near our rivers? Need better river planning and management e.g., Only spray where it's needed; keep Ashburton mouth open.
- "I stopped fishing in 1984 as it was too depressing seeing the death of a river".

Changes to fish stocks

Smelt

Overall status

- Numbers greatly diminished these days.

Years of decline

- dropped in last 5-6 years.
- In 1960's used to dry silveries and sell them (export).
- Were huge shoals. Brief commercial netting and dried smelt sent to Fiji. Migrations usually started at end Sept/early Nov. Declines started between 1997-2000

Observations on shoals (size, duration etc)

- Mainly migrated in evenings and often went back to sea with the tide as no sea-run trout could be caught, but some would stay upstream (as trout could be caught then)
- Silveries weren't around last year.
- In 1970s, 80s and 90s would see shoals and shoals, lasting for several hours. Don't see the numbers now. Tended to go in and out of the river mouth with the tide. Didn't see any dead (*post-spawned*) ones.

Importance in food chain

- Sea-run trout gorged on them
- Black shags not there now. No silveries to target.
- Used to see terns diving in water for silveries. Not today.

Brown trout

Overall status

- Sea-run trout virtually disappeared

Years of decline

- Decline started in mid-1980's and has been ongoing since then.

Catch rates

- On the right evening, most anglers would catch 2 or 3 at least. Still a few sea-runs about.
- Regulars still getting a few sea-run trout but not like former days. Thinks there is significant movement of sea-run trout all along the Canterbury coast – an "interlinked" fishery.

Size and condition of fish

- 40 years ago caught a 10 pound trout (when gutted). Two to three-pound mark more common today as the food source is not there to fatten them up. Last September caught half a dozen but none of them were sea-run trout. Today fishes more at Lake Alexandrina as Ashburton "is stuffed".

- The Ashburton fishery for sea-run browns was 'magnificent"– fish were usually in 4-6 lb range

Possible reasons for decline

- Salmon and Trout not coming in (*immigrating into the river*) the same, maybe as water too warm. Smaller size indicates something going on in the food chain.

Salmon

Overall status

- Salmon are gone

Years of decline

- Started from about 1975
- Bycatch at sea. In 1994-96 when trawlers were banned from coming inshore, anglers saw an immediate increase in the numbers of large salmon.
- Decline started ~ mid 1970's and has been gradual since then. He hasn't fished for past 9 seasons as not worth the effort.
- Last 20 years been a gradual decline. Last 10 years have been worse - you don't ask if someone has caught a salmon because they wouldn't.

Catch rates

- Not worth going to the Ashburton for salmon fishing today. It's a waste of time. Early 1970s, usually 50-60 caught per weekend. Not uncommon to see people walking out with a salmon.
- Always see people catch salmon. Used to catch about one a week "back in the day" but could go out 40 times now and not get anything.
- Salmon were easy to catch in Ashburton – "could take as many as you liked". Would often catch 6 before work, then another 6 after work! One morning there were 200 salmon caught at the mouth. He would catch 50-60/season but could have caught more.
- Would often be 50 – 60 anglers at the mouth
- Could be up to 100 fishermen either side of the mouth (Fish and Game figures). Today - would be lucky if there was a dozen caught throughout whole year. The salmon fishery is in the worst condition of his lifetime.
- In early 1970s could go to a hole in the South Branch and see up to 100 salmon. People used to dynamite them. In 1968 he recalled going to Hoods Crossing (about 5 km upstream of Ashburton) and hearing a loud boom as someone detonated gelignite -the result was 60 to 70 dead salmon. These were often sold or raffled off in local pubs.

- Best fishing flow was ~ 12 m^3/s. At flows ~ 18 m^3/s, salmon would enter the river as flow receded, and best fishing was for next 8-10 days as flows receded. After that, river would get too low and clear. Anglers would “chase” schools of salmon upstream, and fish would hole up in deep pools under willows. One year he estimated he saw 200 salmon enter in 20 minutes.
- The proposed limit of 2 salmon per season won't help as the salmon aren’t there.

Size and condition of fish

- Fish were usually in mid-20 to 30 lb. largest he saw was 32 lb. Much smaller today.

Possible reasons for decline

- Salmon and Trout not coming in (*immigrating into the river*) the same, maybe as water too warm. Smaller size indicates something going on in the food chain.
- The big runs of salmon in the Ashburton in the 1980’s and 1990’s coincided with Rangitata water being dumped into Ashburton and this transferred a lot of salmon smolts and may have contributed to bigger runs in the 1990’s?
- In 1930’s-1960’s, thinks that many Rangitata smolts ended up in Ashburton River via RDR, and maybe 50% of adult salmon caught in Ashburton were of Rangitata origin.
- Maybe not enough stable nursery streams/ environment.
- Concerns about lack of effective fish screens, and screen efficiency not tested
- Ashburton - lack of flow is main problem and river mouth closure.

Whitebait

Overall status

- Last season was one of the best ever for Ashburton, Rakaia, Opihi and Rangitata.

Kahawai

- Used to be a great fishery at Ashburton mouth and fish would come upstream maybe 200 m chasing smelt. Commercial fishery has led to reduced numbers.

Other species (rig, elephant fish, bullies…) / other concerns

- Red cod: Gone. Used to catch on a handline off beach at Hakatere, but gone now.
- Birds: used to be a lot of black shags (fed on smelt), but not now.
- Used to be able to catch groper off the beach but haven't seen one caught in 40 odd years - that hasn't recovered.

Appendix H Rangitata River comments

Changes to Hāpua

Flows

Flood flows

- Floods don't seem large enough to transport sediment out to sea and much of it is deposited in the lower river but becomes resuspended by small freshes.
- Still hear boulders moving during a flood.
- recede faster and seem smaller – maybe due to lack of glaciation in upper catchment (snow base), and changes in land use.
- Thinks big chunk of flood flows that provided sediment transport, now harvested so less carrying capacity for sediment.

Low flows

- Fishing "technology" changed. Flow is unacceptable for fishing.
- Total flow pattern changed. Changed whole structure of river.
- River drops too quick and sudden (i.e., flood recession rate shorter, so shorter fishing window); it's depositing too much sediment.
- Reduction in flow → more northward drift of river mouth. Reduce water flow = reduce river moving sediment.
- Minimum flows too low for too long. Not good for ecology of river. Lost mauri of river - lost food source.
- Over the past 20 years especially has noticed a lower average flow and increased temperature of the water.
- Possible to walk across the river mouth now at low flows!
- The NCO says 110 m^3/s min flow but additional takes re not quantified (?)
- Greatest change = when hydro power was added to RDR as then year-round abstraction. Half the time, RDR takes a third of the flow. 70 years of depowering of Rangitata, it's not the river it was. 70 years of subtle change.
- Recently, unusual season – May/June floods rather than in spring. Changes in weather patterns? Usual pattern in freeze-up in winter months, then spring floods. With low flows, groundwater springs contribute relatively more base flow.
- Low flow (June, July, August, September) – RDR taking half of water out, and now only 15-18 m^3/s left in river. (NCO = 15 Sept – 14 May, min flow is 20 m^3/s; 15 May – 14 Sept, min flow is 15 m^3/s).
- Getting productivity or water. 200-300 dead-end ponds not ending back in river. RDR asses to liability. Productivity not even there in the start.

- Rivers spent too much time at low flow - ecologically not viable.
- A lot fewer deep holes now – salmon used to rest up in these and provide greater fishing spots if you knew where to go. Thinks that under present low flow conditions, a relatively small fresh will induce salmon to run. Flows so low now the river is like what the Ashburton used to be. Even when it's turbid, not enough flow to attract salmon.
- Lower flows. Flow for catching salmon was optimal after a flood, but today river is either too dirty or too clear too quickly.
- NCO – had expected a cap for irrigation but didn't happen. At NCO, some compelling evidence was on value of recreation and difference between a dry and productive riverbed.
- RDR now building big ponds on north side (was to take extra 10 m^3/s but they withdrew from that application).
- South Rangitata ponds – large banks on south bank of river, and now much water coming out of banks, so presume ponds are not well sealed and leaking.

Sediment

Fine sediment (silt, sand, fine gavel)

- Huge depositions of sediment in floods. Fewer stones in lagoon now, mainly slit and sand. Unsure of source but much (?) could be from RDR sand trap flushing.
- Sediment being deposited in lower river
- People wanting shingle out of river. Especially Ashburton River.
- Rangitata huts not getting shingle it needs. Shingle bank not as strong as it used to be.
- Main change is much more fine sediment associated with less transport ability of river due to lower flows. So, silt and sand from RDR sand trap doesn't get flushed out of system. For past 3 -4 years has been a period of relatively low flows so there has been much deposition of silt in river.
- So, river was dynamic and dominated the sea (at the mouth), but with depowering of river, mouth stays north for longer and the river is now 'strangulated". With reduced "power' of the river, less sediment transport, and more deposition – slippery rocks (periphyton) that captures fine sediment = results in less invertebrate biota and spaces between rocks clogged.
- Altered sediment, issue at river mouth not getting shingle build up. Not providing protection.
- Cobble size much larger when kids. Sediment is sand and fines now.
- Gravel starvation on beach – starved of cobbles. Only shingle coming from erosion of bank. A lot of clay not stone.
- Depowering affected river bar. Stone always going down river.

- More fines in river, especially on beach/bar. Doesn't believe it's because of the sand trap. Couldn't fish on days when it would be flushed (30 years ago). Note that RDR doesn't create "new" sediment but is just depositing natural sediment.
- Taken water and energy from depowering the river. Not enough energy in water to move sediment, so gets dropped (much clay now).
- Low flows and more fines in river.
- More fine silt – this is monitored at Arundel Bridge but further downstream would be better.
- sediment is building up downstream of gorge. River mouth – sediment stirs up when you walk but there are also more armoured areas (but some soft patched where you can sink up to your waste in silt = potentially dangerous). Vehicles get stuck more often – never used to happen.
- Adult salmon avoid fine sediment in holes, so will be where water is cooler, usually in reaches of coarse gravel with groundwater intrusion. From helicopter flight, was staggered at the stability of islands – some had pine trees growing on them
- "Fines" have increased in river, and now a relatively small fresh will result in resuspension and turbid water.
- Much muddier and siltier. Silt is deep enough to be dangerous in some places.
- More sediment in hāpua and lack of velocity in the river. When first started fishing, could only cross minor braids – today could cross the river in gumboots at times. Rangitata had bigger boulders than either Rakaia or Waimakariri. Today it is "bony" and a minefield for jetboats.
- Hāpua has much more sediment – water abstraction takes peak flows and the resulting lower velocity means much more sediment is dumped in the hāpua
- Coarse sediment (rocks, boulders)
- when RDR were excavating recently, they uncovered huge boulders, 1-2 m across. Can still hear the sound of bedload transport during floods.
- Hear rocks tumbling in floods.

River fairway

Braid pattern

- Has noticed changes to river pattern since abstraction (especially RDR).
  A feature of Rangitata is it's very accessible, up and down the river.
- In 1960's, river moved and carved off chunk of bank, 30-40m taken. Sea now hard up against banks, and shoreline recession now occurring at ~ 1m/year.
- ECan pushing river north (wanting to protect the south). Various tensions. DOC want to protect hāpua. Rangitata huts = no shingle to protect hut front. Stop pushing it North. South lagoon was good whitebait spawning habitat but ECan wants the mouth to be

north and so bulldoze it this way. From 1957-61, the mouth was mainly below South huts.

- River should be allowed to do its natural thing.
- Significant changes = willows. Were few willows but then they were widely planted for river protection – resulted in changing dynamics of streams, and willows taking water.
- Spraying of fairway occurs about every 2 years to control willow encroachment and other weed species.
- Huts vulnerable to coastal environment.

Depth

- Fewer pools in main river. Some deep wells near coast have dried up as groundwater had dropped – some saltwater contamination now.
- Structure of pools change. Fish don't get far and get stranded/isolated.
- After the big 1986 flood, the catchment board bulldozed the upper river from Fairlie to Dobson into one stream and that effectively filled in all the good holding pools for salmon and trout.

Lagoon

- Structure of the bars dramatically changed. Cobbles building up on bar making it easy to cross river.
- Times where lagoon not attached to river. Can be shut off completely from shingle build up.
- South lagoon largely lost as beachhead is much closer than it used to be.
- Not much change in composition of the bar but access now only by quad bike not 4WD. Shingle is larger on the north side than south side.

Mouth (width, migration etc)

- Rangitata river a shadow of itself now. River mouth spends a lot more time north than it used to. Ecan "opens" every now and then by bulldozer (often 1 or 2 x/year).
- Mouth is the area that has changed most dramatically.
- During prolonged low flows and with predominant southerly offshore currents, the mouth gets pushed further north. During the 1950s, there were lots of northeast winds and the river mouth went south of the huts. The coastline has receded at least 100 m over the past 50 or 60 years. Once the Waitaki dam was built, this trapped much alluvial sediment moving along the coast and now Timaru Harbour traps a lot of shingle.
- The shingle at the mouth has got finer.
- Approximately 3 years ago, ECan sprayed South lagoon.
- Riverbed built up at North Branch – classic example of taking depowering to the extreme.

- River bar visible now. Rangitata mouth migration accentuated by depowering of the river.
- Issue with hāpua – if closed, only for a tide long period.
- Heavy southerly you get overtopping. Rising of sea levels likely to happen more often. There is some tidal influence in hāpua but depends on the shape and location of the mouth
- Rangitata mouth open, makes it easier for fish species to migrate.
- Only saw mouth close once (during 1994-2000) but only over one tide
- Mouth migrates a long way north and stays north for longer these days. Used to be more "central" more often.
- The mouth is much smaller these days, but some saltwater does still come in.
- Has only seen the mouth close for one tide, although could sometimes (these days) could walk across the mouth at low tide. In old days, islands used to form at the mouth – these were good fishing spots.
- The effect of tides depends where the mouth is - if the mouth is north then the area affected by the tide extends only a little way into the hāpua, but if the mouth is straight out then the tide effect can cause a backup for 400 m.
- Used to get day after day of clear surf at river mouth, but today sea gets stirred up (and discoloured) – wonders if due to silt from Opuha Dam collapse?

Algae/periphyton

- More algae than there used to be. Didymo arrived but a big NW storm scoured it out.
- Get algae growing on rocks in winter, but as rocks are dirty (accumulated sediment) the algae is easily sloughed off and discolours the water ("oily").
- Slippery rocks. Substrates changed completely. Didymo and algal (periphyton) blooms. Don't get the invertebrate life like you would, vegetative and it clogs.
- Less algae than Rakaia.
- At mouth, water on north side can be green with algae yet clear on south side.
- More algae on rocks and rocks slipperier, some Didymo coming back.
- Rocks have much periphyton (brown algae), especially when low flows and warm temperatures, and get very slippery.

Water quality (including temperature)

- Wouldn't drink the river water these days.
- With lower flows and more exposed gravel, the shingle heats up more, both in the mainstem and in small tributary streams. Below SH1 bridge there used to be springs but a lot fewer today.
- Wouldn't drink the water today.

- Seems to be less glacial flour as the river is much clearer than it used to be.
- Future of the river probably past the point of no return – farmers have invested in land and can't afford to reduce nitrate use.
- Doesn't contain glacial flow/colouration which comes from snow melt. i.e., was clear enough to fish at 130 m^3/s, but now at 90 m^3/s doesn't clear like it used to, so the "window" for salmon fishing is smaller as the river clears quicker.
- Likely that increasing water temperatures is an issue but needs researching.
- If less groundwater abstraction, springs would be better.
- Recorded water temperatures of 24-26^oC in mainstem = too high for salmon to enter the river.
- River can be 130-140 m^3/s at Klondyke, but yet no change to flows in lower river!
- River generally too low and warm, and don't get flow variability at median flows like used to get. Especially bad on cloudless days (gets too warm for salmon). Presume NCO conditions still apply. Reported that on 31 August 2020 at Arundel bridge, river flow was low and clear, but one hour later the river was completely de-watered, presumably as irrigation storage ponds were being filled – he rang ECan but no action was taken.
- Reported that in 1990's, saw an old raceway 3.6 km upstream of mouth (has bars to prevent salmon entering) with so much foam that it was blowing across the road = dairy shed effluent.
- Water was a deep green, especially in deeper holes. Now more discoloured whereas at high flows it never used to be as muddy. Today even at 20m^3/s river is still dirty.
- Wouldn't drink the water. High nitres even in McKinnon's Creek (8.5 – 8.7 mg/l)
- Water temperatures have increased substantially.
- Wouldn't drink the water because of dairy farms – effluent often drains into spring fed streams.
- Doesn't think the river clears any quicker than it used to, but when it drops to a flow where it should be clear (based on what it was like previously), it should be clear but is still too discoloured to fish. For example, 80 m^3/s at Klondyke used to be optimal for salmon fishing, but today the river is still dirty at that flow.

General comments/concerns

- Biggest physical change: Size of Rangitata. RDR always taking water. Previously was always frightened to cross river but not now
- Part of the river has died. It was a living river, it was interesting. When you fish a river, you notice everything. Fishing rod a part of you and it talks to you. To understand the fishery, you can't be a casual fisher.
- Depressed at state of the river. Intensification of dairying affecting the river. Feeling of river in blood and body. It's all gone and lost. How do you feel when your backyard is polluted? Grandchildren all have river in their blood. Would only bother fishing now if he took his grandson. Fishing is more than just catching fish!
- RDR + South Rangitata allowed to trade water (mirror agreement). South Rangitata Water has 20 m^3/s consent – not always used though and can be added back to river causing access problems (e.g., river by quad bike Ok at minimum flows but suddenly further 20 m^3/s added and can't get back!). Tenure review opened up more high country, but farmers responded by intensifying farming. People getting gagged (politically).
- RDR releases surplus water to Rakaia, but now farmers downstream of Highbank take the water out again!
- NCO was bit of Claytons order as allowed for additional 20 m^3/s take. 2009 = start of reforms. Hearings etc. Canterbury Water Management Strategy sets out community goals and aspirations, but things haven't improved much, even though the environment is supposed to have priority.
- Conflict since 1980's. Battle after battle in hearings for water. Canterbury Water Management Strategy: Goals and Aspirations for community in Canterbury. Hasn't met the needs, hasn't done anything for our rivers at all. Environment was to have first priority. We've gone backwards. Values placed on rivers gone.
- RDR screens are 70 years too late. RDR withdrew application for additional 10 m^3/s after opposition from Ngai tahu. Were concerned about losing some of existing current allocation if taken to Environment Court. Rather trade take then not take at all.
- Helicopter spraying takes place "but they don't clean up their rubbish".
- Widespread concerns among farmers, caught in economic trap – many are depressed.
- River is dynamic and changes with every fresh – Believes process hasn't changed whole time.
- Glaciation/snow melt – Loss of snow base – has this affected flow? Climatic change affecting river.
- ECan a disaster – helicopter spraying is indiscriminant - "spray the lot". Lack of knowledge in contractors. Spraying mainly to kill willows in middle of river. Keeping fairways clear. Leadership not there.

- Extra water application by RDR was stymied by Ngai Tahu and treaty claim/ownership of water. RDR caught out (politically RDR saw the light in keeping on side with Ngai Tahu).

- South Rangitata Irrigation - fish screens don't work; fish move at night.

- River management things: RDR appealed after loss of 10 m^3/s to Rangitata Water Ltd. Irrigators appealed NCO on Rangitata. At RDR hearings, anglers didn’t get a good hearing – Fish and Game and salmon Anglers presented anecdotal evidence but no numbers. No research underway but realised the history of what was happening to Rangitata was 10-15 years behind what had happened to Rakaia. Realised the importance of social history – anglers have initiated an oral history of Rangitata. Waterways Centre for Freshwater Management (University of Canterbury), did a LIDAR survey of Rangitata. RDR takes 30 m^3/s all year round, and farmers can transfer unused allocation back. Since 2000, has been big proliferation of dairying. ECan have been spraying the flood plain (Rangitata?) since 2014 to prevent the weed build-up.

- Well diggers now digging deeper wells to get groundwater – with abstraction there comes a point where there is a disconnect between groundwater and surface water, and this reduces the river’s ability to cool.

- Must put into place a monitoring plan for special character of the rivers. Key features should be the build-up of weeds on islands and sediment. Suggests a holistic scorecard to track health of river from source to sea (a “traffic light” system of red, amber, green). Present time is the best for environmental action with a sympathetic Government, widespread concerns about dairying impacts, and availability of good science. We have a “duty of care’ for future generations – as kids we swam at Coes Ford in Selwyn River, but today algae gives kids itchy skin and rashes on arms and legs. Must collect evidence to counter arguments.
  Fish screens – BAFF system failed and rock bunds don’t work.

- Rangitata – worst situation was when irrigators won consents to take more water and promised screens etc. but little compliance and smolt entrainment a big concern.

- Barhill - Churtsey scheme takes 40 m^3/s and proposed double fish screens to get consents but didn’t happen.

- Helicopter spraying is indiscriminant – certain that a big die off of smelt coincided with spraying. Better to use jet boat access and spot spray. Used to sit outside batch in evenings and during NW winds could smell lupins, but now only cow shit smell.

- At time of Rangitata NCO hearings, anglers formed an Instream Users group = understood flow sharing regime for RDR etc. But at hearing for additional 10 m^3/s take from Rangitata (was won but not actioned as storage reservoir was shelved, maybe due to economics but also Ngai Tahu objections), the group learned of an additional cross-consent (= mirror consent) between RDR and South Rangitata Irrigation Co. Group asked ECan three times for info but no reply so asked under Official Information Act and Ecan replied info is commercially sensitive so can’t divulge.

- ECan spraying appears rather indiscriminate. Now a lot of willow planting underway to stabilise banks, ~ 3 km upstream on south side.

- Customary use – note that anglers have been customary users for decades so should have some rights.
- Farmers are blaming ECan for not taking enough gravel and river aggrading and causing more flooding – also lack of big floods. Too much water allocated, and intensive farming allowed on unsuitable soils i.e., in free draining soils, nutrients are past root zone quickly and not taken up by plants. In Canterbury, many rivers gone (Selwyn, Hinds) are badly degraded. With global warming, unlikely we'll get more water back in rivers.
- Fish screens = consents too lose and not complied with – ECan should reduce water takes as a penalty.
- Waitaki River was the last frontier for salmon fishing. River was so big could only fish between 10 am and 3 pm, due to Waitaki dam generation cycle. Flows went to 400-500 m^3/s daily and would "smother" pools = could only fish as water receded and pools reappeared.

Changes to fish stocks

- River had international reputation and visitors.
- Used to get up to 400 anglers at a time at Rangitata mouth.

Smelt

Overall status

- Major decline
- Years of decline
- Silveries not prolific - decline in last 10 years.
- Overall decline noticed over past 10 years, but especially over past 5.
- Now 5% of what they used to be.
- Noticed change reasonably sudden over last 5-6 years. Coincided with huge shoals of kahawai.
- Major decline relatively recent, past 2-3 years; this year has been a total collapse.

Observations on shoals (size, duration etc)

- Shoals run all day and night 1m width. Trout drove fish upwards.
- Used to get dumped on the beach by wave action. Shoals could be 18" wide and run for 3 hours or more. This year only saw 1 small shoal all season.
- Distribution is lower hāpua as none seen in McKinnon's Creek (~ 2 km upstream of hāpua); hasn't seen any spent fish (although has heard stories of lots of dead/spent ones). Not aware of any association of migrations with floods and tides.
- He often netted for smelt for bait (around the silt/sand edge of springs in south lagoon) , and noticed the odd huge one.

- Only difference is their numbers. Would come in their millions in autumn, usually in afternoon than morning. Season was last week in October until end of January, but occasionally could get runs as late as April. In Ashburton, seemed to start earlier, in September. If NW wind (water warmed up) then migration could last for hours. Smelt would move in and out of river with tides. Has seen dead smelt next morning (assumed they were Stokell's smelt). Has seen whole width of river mouth covered in silveries ("black" with smelt).
- by mid-2000's stopped seeing smelt shoals that used to be 2-3 m wide and run for days. Knows that smelt numbers in both Rakaia and Ashburton have dropped off over past 10 years.
- Smelt would come in each tide and run to top of the tidal area. Strings of smelt but would go out on outgoing tide. This year locals saw a few.

Importance in food chain

- Smelt accumulate at the river mouth and are primary food source of trout and birds, also kahawai
- Catch red cod, kahawai, trout, eels, flounder full of silveries.
- Spasmodic runs. Black strip 800m long with birds feeding. Trout pushed shoals to surface and birds then had access.

Other comments/observations

- White posts put in to confine "scratching" (*foul hooking of salmon*) may also coincide with upstream limit of smelt spawning.
- Spawning habitat for silveries hasn't changed, but maybe quality of habitat has declined. Thinks smelt spawn in sandy areas and there are still some clean cobbles at edges of runs but many cobbles have "mucous" on them now. Smelt spawn at night in very shallow water, often < 2 cm deep. River is "nocturnally active". Shine a light and see smelt/trout.
- Thinks sedimentation of stones a major issue for successful spawning

Brown trout

Overall status

- "Fishery a shadow of what it used to be".

Years of decline

- Would fish for them all night as a kid.
- Trout fishery in big decline. Something to do with nursey of fishery? Early trout bred in smaller waterways like Hinds River. With intensified irrigation, fish have disappeared.
- About 3 weeks after Lake Ellesmere opened, would get sea-run trout in Rangitata. Limit was 12/day and he caught that several times. Fish were up to 14 lb.
- Started to notice a decline in number 10-15 years ago; size also declined.

- Trout fishery > 50% reduced.
- Trout come in several waves. Would see 20-30 come past the bar around the 1950's - 60s.
- Noticed major change/decline from mid 90s onwards, but mainly last 15-20 years, and especially last 5-6 years as smelt have declined hugely (now not enough smelt to draw in trout to river mouth)
- Didn't target but did catch some. As salmon declined, more anglers turned to trout.
- Decline started ~ 6-8 years ago
- Decline started ~ 15 years ago. Now hopeless – last Xmas he caught none.
- Decline since mid-1990's. During the 1980's to 1990's, would get the odd "bad" season, but would still be able to catch trout. Stopped fishing both Rakaia and Rangitata for trout as not worth the effort
- Shoals of trout would follow smelt shoals into river after dark. Milky water always better for catching trout in day.
- Trout came in waves after smelt in hundreds. Attitude back in the day – catch fish to feed family. Now – catch and release -a social change.

Catch rates

- Rangitata wasn't a legendary trout fishery, but when it was on it was on! Trout would typically have 20-30 smelt in stomachs. Alan would usually catch several dozen per year- last year caught 2.
- 1985-1987 caught up to 40 trout a day.
- 300 trout a year (in heyday). Caught 84 in one week once (Between Xmas and New Year).
- No sea-run trout fishery today really. He might catch 1-2 trout per night, and almost all are sea-run, with occasional river resident fish. Used to only get ~ 1 rainbow per season
- Fished from sunset till after midnight. Often catch 10, release almost all - catch rates like that were consistent.
- Would catch 80 -90 for the season (could catch more). Never caught a rainbow but saw someone else catch one once.
- Were lots, now virtually none. He doesn't take trout from lower Rangitata any more as size and condition has dropped, but fish seem Ok above gorge. Anglers used to get fish 15-18 lb, but now 2-3 lb. His best seasons catch was 37 trout, many in 6-8 lb class, and great condition. Didn't have to pick times to go fishing, although some times were better than others.

Size and condition of fish

- Size also dropped. 'Swirl" area between river and where river hits the sea was prime area. Trout would sometimes beach themselves eating silveries. Trout will follow silveries all the way into the mouth
- Smelt help trout regain condition within a few weeks; size was often 6-8 lb, with many in 3-4 lb category.
- Some 3-4 pound, some 1 pound (maiden fish at Xmas time), 2-3 10 pound a year (Nov/Dec). Seem to come in runs. Start beginning Oct, best taste but skinnier (as smelt haven't arrived yet). Largest fish in Nov/Dec. Silveries taint taste but bigger because of feeding. Condition very good. Flesh varies yellow, pink, white (ex-spawners had white flesh).
- Less prolific than Rakaia. Largest he heard of was 18.75 lb.
- Size – range up to 10 lb, with 5-6 lb common; largest he caught was 14 lb. Sex ratio = more females than males. They ate smelt.

Riverine trout

- Previous Xmas after a big flood (which broke the banks!) did well in upper hāpua, but thinks they were river resident fish that probably got washed downstream by flood and not true sea-run fish. These fish soon disappeared.

Possible reasons for decline

- Food train affected, possibly nitrate. Smelt very sensitive. Whitebait not as affected.
- Many small creeks and drains that used to be great trout rearing areas, are now polluted and/or the fish are gone.
- In 1950's to 70's, noticed some decline probably associated with landuse changes. Presumes there is a "pool" of sea-run brown trout offshore and they follow the available food.

Salmon

Overall status

- "a disaster"

Years of decline

- Rangitata salmon in decline in 1990's. Then fish came back early 2000's (2005). Big decline 2015 (stopped fishing). After the first month of fishing you understand how the season will be. In 2015 fished a whole week (caught 6 or 7), but few fish about. In hindsight, we might've caught too many salmon. Didn't bring them home because we didn't want anyone to know we caught fish.
- Heyday was up to 400 anglers (shoulder to shoulder).
- Huge changes since the late 1960s.
- Major declines started in the late 1980's, especially 1987 and 1988 into the early 1990's.

- By ~ 2010, salmon fishing in Rangitata started to decline. Optimal fishing window was 70-100 m^3/s, but < 70 river was too clear
- 1978 = fantastic fishing year in Rangitata – also 1994, 95/96, and in 1997 many fish but small. Note that 1990 and 1991 were both years of very cold winters. By late 1990's, salmon numbers had dropped a lot – not just associated with decreased flows. From 1999/2000, would get few decent freshes in early season, and water was gin clear and low so no good for salmon fishing.
- In 1990's has a photo of ~150 anglers fishing hāpua, and 180 fish caught in one day – following day though, same 150 anglers but only 3 salmon caught.

Catch rates

- Seasons catch from Rangitata was 2000-3000, now 20 and 17 in past 2 seasons.
- Not allowed to fish in April anymore.
- Total catch of salmon was 2000 -3,000
- In a good year, he would catch ~ 20 salmon (only fishing 1 day/week).
- Doesn't bother to fish these days as too few salmon about.
- Don't come into river during a flood; was possible to chase a run upstream as water cleared and fish migrated upstream. Probably < 10% of historic catches today, and he hasn't caught a salmon for past 4 years despite being a very good salmon angler (lost 2 though but they were hooked very close to the edge of river and he thinks their behaviour may have changed). South side is best for salmon but north side better for trout
- 5% of anglers used to catch 100 or so a year. Now going to be allowed 2 per season – Fish and Game can't manage the fishery. Salmon/Trout numbers went down together over same time span
- One year caught 20 salmon before Xmas, most around 30 pounds (1970s).
- Last 10 years 1 or 2, where it used to be 2 every time you go out 20 years ago.
- Numbers declined in Rangitata since 2000. He used to take 8-10 salmon each season (a mix from Rakaia and Rangitata) but hardly bothers to fish these days as too few fish.
- Salmon numbers dropped markedly – used to see 50 caught per morning, now more like 1-2. He would catch 8-10/year, now hasn't caught any for past 3 years.
- Mid 1960's were great years. His best catch was 68 for the season.
- One day, with brother, each caught their 4-bag limit. Used to fish scour trenches a lot.

Size and condition of fish

- Fish are smaller and fewer.
- 1970's = 25 pounds and occasional one at 35 lb. November 12 to 13 pounds. Today for Rangitata, a 15-pound fish regarded as a big fish.
- Number and size of salmon decreased dramatically over his experience.
- Used to have "Tucker's fish of the season" (trying to catch biggest fish). Salmon over 40 pounds then. Biggest was 44 lb
- Numbers/size has dropped. Salmon have to be big and strong to migrate through the gorge. Big floods allow salmon to adjust to saltwater (freshwater plume).
- Big fish around during 1978-79, and some fish were 36-40 lb. At this time there was a lot of krill seen up the coast which may have led to big fish.
- Fish are smaller, but condition is good/average but not premium.
- Today, salmon would average 10-12-pound
- Gradually become smaller e.g., 25 years ago would average 22 lb, now 10-12 lb.
- ~ 1993 (or a nearby year) was a year of big fish – largest was 36 lb.
- Salmon definitely smaller and in poorer condition these days – use to catch many fish in 20-30 lb class, but not today. A gradual decline since early 1990's and downhill since then.
- Possible reasons for decline
- Not enough water and water goes out quickly, river drops faster. Doesn't have gradual flow. Window for salmon fishing is very narrow.
- Water temperature critical for migration. Water gets too warm in January - need to get the cool nights so cooler water every morning. If salmon in river, as temperatures increases, fish would hunker down in deeper (and cooler?) pools. Noticed that if river water got too warm (say > 18^{o}C) salmon would sometimes drop back to the sea.
- Hatchery fish that get to McKinnon's Creek have to wait 2-3 months to spawn. Seen them in big shoals, can't catch them because river too warm (17 degrees maximum for fishing). Would assume temperatures are higher now in the summer.
- Noticed change in migration when hatchery fish released. Wild fish weren't migrating in same waters as hatchery fish. Wild fish aggressive towards hatchery fish in same pool.
- Hatchery fish caught more at mouth then sea. Put him off how he used to fish the river. You have to read the water to know how to make presentation of your lure aggressive enough for a bite.
- For one or two years, salmon had many stomach worms, and this affected their condition, but this problem was gone by 1963. Thinks there is a relationship between salmon abundances and the disappearance of red cod - there used to be heaps of red cod and they were a staple food for salmon [trawlers used to target schools of red cod

as they knew they could also catch salmon). Salmon are still caught with hoki in Cook Strait.

- There was a major flood in 1986 that may have initiated the decline – salmon numbers certainly decreased after that time. Since then the situation has got "worse and worse".
- Presumes there are combined impacts of abstraction and bycatch at sea that caused major changes in salmon numbers.
- Have lost the premium salmon fishing window as much reduced transition period. Used to take > 5 days for river to become fishable after a flood, now 3-4 (Rakaia used to take 10 days). Not fishable at 100 m^3/s.
- McKinnon's Creek hatchery manned by volunteers but aims at 60- 100 000 smolts per year. Believes that lack of fry and smolts is single biggest issue for salmon decline.
- Decline in numbers over the past 20 years but accelerated since Rangitata Water Ltd got their additional 20 m^3/s.
- Water temperature has always been an issue. Salmon won't run if it's too hot.
- Salmon competing with other species (no krill). There is the odd good fish but generally smaller.
- Used to catch two dozen juvenile salmon when trying for silveries. Not now.
- Flows of 66-67 m^3/s at Klondyke produce poor fishing conditions at mouth – salmon might enter river and move up to top of lagoon but "get nervous" as no wate depth and cover, and then drop back down river and re-enter the sea.

Concerns (management issues, intake screens etc)

- Haven't fished for a few years because of the state of the fishery. Gave up fishing for the sake of salmon fishery. Have to get more fish to spawning streams. Fishers having effect on numbers.
- Don't know if we're going to lose salmon. Need to be careful with interacting with nature
- Look after key spawning streams of Deep Creek, Mesopotamia, Erewhon. Have always lost smolts to floods but these days to irrigation schemes – he has been involved in smolt salvage and used to get a bucket of smolts from each drop (were ~ 75 drops for border dyke irrigation). If canals had been operated better they could have been major rearing areas for smolts, provided there were returns back to main rivers.
- First noticed changes ~ 2004/05 – salmon anglers became so concerned they formed a group and purchased some eggs and looked for suitable small stream for incubation. In 2005 found a disused ex-commercial hatchery in McKinnons Creek. Got eggs from Montrose hatchery for 3 years – in year 4, got about 300 adults back to hatchery; year 5 got 500, year 6 got 900. After that were self-sufficient for eggs. Numbers subsequently dropped off – year before last ~ 100, this year 5. Will release 50 000 smolts this year.

- Used to see 80-100 anglers at the mouth.
- Salmon fishing competitions generate good $ and opportunities to lobby for salmon and rivers – few fish caught though.
- Salmon fishery is sad reflection on river changes i.e., decline in water quality and quantity, nitrate infiltration, changing ocean environment, plus losing juveniles to irrigation intakes. Salmon are a cool water fish.
- Less abstraction! Think salmon decline largely coincides with Rangitata South Irrigation taking additional 20 m3/s. Screening of RDR should make a big difference (due Sept 2022, cost $17 m).
- Joined Fish & Game Council because believed fishery was worth saving.

Whitebait

Overall status

- "Seem to be doing OK"

Catch rates

- Went whitebaiting five times in Rangitata last year but wasn't there at peak - got a pound. As a kid would get two kerosene tins full of whitebait (20 to 30 pound) per year. Thinks whitebait declining as well.
- Whitebait runs over recent years some of the best he's seen.
- Can be big runs in January and February when the whitebait are bigger than īnanga bait. Last season was the best year in the Rangitata for many years.
- Seem to have held up better than other species, but Rangitata not known as a whitebait fishery (north side is best).
- He catches 8-10-pound whitebait a year = enough, but could catch more. Could be 20 pound back in the day. Not seeing the decline of whitebait. Whitebait season finishes at end of November, but sees heaps in December, through to Feb/March.

Species composition

- One time when the season was extended, he saw big golden whitebait. Often sees climbing whitebait (*koaro*].

General comments/concerns

- Success depends where the mouth is. North Lagoon is big nursery area but can get almost cut-off from main river when mouth straight out.
- Note importance of spring- fed streams like McKinnon's Creek, Eeling Springs, Withell's Island – important whitebait spawning, rearing areas – some are prone to impacts of floods, but flood-free ones are especially important as habitat for whitebait and other juvenile fish.
- Note that best whitebait habitat in North lagoon is when river mouth is south, and vice versa. So potentially both lagoons are good, but depends on location of mouth.

- Rangitata “weeps” are important habitat for īnanga, also eels and bullies. Predator free habitat. Seen a lot of whitebait and eels in weeps. Greatest predator is sea birds
- Whitebait habitat needs to be careful management.

Flounder

- Fewer yellow eyed mullet and flounders these days.

Yellow eyed mullet

- Fewer yellow eyed mullet and flounders these days.

Kahawai

- Chased smelt into hāpua.
- Many less and used to enter the river chasing smelt.
- Recall 20 years ago at Rangitata, stand on bank and see black mass offshore = Kahawai at sea waiting to come into river mouth chasing silveries. More often than not would catch a kahawai. Don’t see such large shoals today

Other fish species

- Red cod
- Red cod - as kids, used to catch many but not now. Hasn’t seen one in years
- Red cod completely gone.
- Used to catch with surfcasting from the beach but cod now completely gone. Once could fishing the surf with salmon gear, would catch one after the other, but not now.
- Rig and elephant fish coming back though.
- Elephant fish never been dominant.
- Elephant fish and rig = almost gone also – he uses a drone to get line well out!

Birds

- Birds this year around Rangitata died by 100s/1000s. They were starving.
- Birds are starving! Less black-backed and red-billed gulls over past few years.
- Last year was exceptional as a large flock of black-billed gulls, 400-500, (plus some red-billed and terns) nested on a high bank. He picked up 200-300 dead birds from hāpua, a mix of adults and chicks – very few birds were going out to sea but mostly going up the lagoon looking for food, and flying north. Terns usually feed more at sea, maybe on sprats(?) as few smelt
- Birds – could go up and touch a tern (comatose). Counted 60 dead birds. Birds scavenging around huts. No smelt run.
- River could not provide. Birds walking 600m along riverbank looking for food. Tide came in/out leaving dead birds along beach.

- Terns switched to sprats and seemed to survive. Birds often sitting on his fishing trailer desperate to get his bait
- Last year was the first time he's seen it like that (*dead and dying birds*). Spoilt his Christmas.
- Black fronted terns seemed to disappear. White fronted feed mainly out at sea. Impacted by smelt population but will feed on sprats. Black-billed gulls' main diet was silveries, and seen seabirds starving in Rangitata hāpua due to lack of smelt.
- Tern colony is starving. Has seen dead terns and gulls floating down river and out of mouth (this year).

Environment Canterbury Regional Council
Kaunihera Taiao ki Waitaha

Fish community surveys of Canterbury Hāpua 2020/21

Environment Canterbury Science Summary:
R23/03

Fish community surveys of Canterbury Hāpua 2020/21

Environment Canterbury Science Summary: R23/03

Jarred Arthur

April 2023

Reviewed by: *Duncan Gray, Senior Scientist – Water Quality and Ecology*
Shirley Hayward, Team Leader – Water Quality and Ecology
Dr Elaine Moriarty, Surface Water Science Manager

200 Tuam Street
PO Box 345
Christchurch 8140
Phone (03) 365 3828
Fax (03) 365 3194

75 Church Street
Timaru 7940
Phone (03) 687 7800
Fax (03) 687 7808

Website: www.ecan.govt.nz
Customer Services Phone 0800 324 636

Key messages

- Braided river hāpua (freshwater lagoons) are high value coastal ecosystems that are important habitat for birds and fish. In Canterbury, they support a regionally endemic species of smelt (Stokell's smelt) that is an important component of the aquatic food chain.

- Despite the ecological, cultural and recreational importance of hāpua, their fish communities and habitat have been rarely surveyed. The most notable surveys were conducted 40 years ago on the Rakaia Hāpua (Eldon and Greager, 1983). Consequently, we have little understanding of the health of hāpua ecosystems.

- In November 2020 and February 2021, Environment Canterbury worked primarily with the Department of Conservation (DOC), North Canterbury Fish and Game (NCFG), and Central South Island Fish and Game (CSIFG) to survey the fish communities of the Rakaia, Rangitata and Hakatere/Ashburton hāpua. Surveys were designed to as best as possible replicate the methods employed by the historical Rakaia surveys of the 1980s.

- Surveys found a similar diversity of fish species across the three hāpua, but fish numbers varied between waterbodies and the dates sampled. In particular, the Hakatere/Ashburton Hāpua had a very low overall abundance of fish in February 2021 which coincided with low river flows and poor fish passage at the river mouth.

- Long-term change in hāpua fish community structure is difficult to ascertain due to the limited historical data available, and ever changeable fish numbers and habitat structure in the hāpua over the spring-to-summer fish migration season. The 2020/21 surveys indicate a potential decrease in the populations of several fish species (i.e., black flounder, longfin eel, Chinook salmon, brown trout and smelt). However, increased sample replication is required to better compare results to that of historic surveys (e.g., Eldon and Greager, 1983).

- Our recommendations for further investigation include increasing the research focus on hāpua with good historical datasets (e.g., Rakaia Hāpua), increasing the sampling effort during the key migration season, targeting methods towards species of interest (e.g., Stokell's smelt), filling information gaps with mātauranga and community accounts of habitat and fish population change over time, and examining the environmental drivers (riverine and oceanic) of fish community structure in hāpua.

Table of contents

List of Figures

List of Tables

1 Introduction

Many New Zealand river and lake fish species spend parts of their lifecycles in both freshwater and the sea (McDowall, 2000). These migratory fish use river mouths for passage and associated habitats, such as hāpua, serve as breeding, rearing and feeding grounds. Hāpua are highly dynamic, freshwater lagoons that form near the coast of large alluvial braided rivers (Hart, 2015; Measures *et al.,* 2020). Despite their importance as fish habitat, particularly in the context of large alpine and hill-fed rivers in Canterbury, hāpua fish communities have been rarely surveyed.

The most thorough investigation of fish communities in Canterbury hāpua was undertaken in the Rakaia Hāpua approximately 40 years ago (Eldon and Greager, 1983). Some studies on braided river lagoon systems have been undertaken since, but most of these pre-dated the 1990s, targeted estuarine habitats, and/or posed very targeted research questions and therefore used limited sampling methods (e.g., Eldon and Kelly, 1985; Bonnett, 1986; Deverall, 1986). This means that there is a significant gap in our understanding of lower river fish communities in Canterbury as well as the overall ecological wellbeing of hāpua.

Hāpua are the receiving environments of large, braided river catchments and are impacted by the cumulative effect of land and water use across large areas of land. Over the last decade, there have been frequent comments from rūnanga and members of the public that the state of fish populations and physical habitat in hāpua are changing. Specifically, mana whenua mātauranga and angler observations have noticed a reduction in the quality of the trout and salmon fishery, increased fine silt on the riverbed, and more recently a disappearance of smelt (Jellyman and Mayall-Nahi, 2022). Long-term climatic shifts occurring in both marine and freshwater environments (e.g., changing water temperatures and river flows) may also be influencing migratory fish populations.

Stokell's smelt (*Stokellia anisodon*) seasonally migrate from sea into the lower reaches of some Canterbury braided rivers (e.g., Rakaia, Rangitata and Hakatere/Ashburton) in large numbers (Eldon and Greager, 1983; Bonnett, 1992; McDowall, 2000). Stokell's smelt are restricted to Canterbury whereas their easily confused counterpart, the common smelt (*Retropinna retropinna*), is more widely found throughout New Zealand. Smelt (commonly referred to as a "silvery") are a small fish that serve as an abundant food resource for predatory fish and riverine birds in hāpua (McDowall, 1978; McMillan, 1961; Rutledge, 1991). Known to Māori as paraki (or other names depending on fish size and life-stage), they were traditionally sun-dried and an important source of mahinga kai (McDowall, 2011). There was also a commercial harvesting operation present in the lower Hakatere/Ashburton River between the 1980s and early 1990s (Jellyman and Mayall-Nahi, 2022; McDowall, 2000, 2011). For these reasons, smelt are important for their ecosystem, cultural, recreational, and commercial value.

In November 2020 and February 2021, Environment Canterbury led multi-agency fish surveys to improve our knowledge about the state of hāpua fish communities in the lower Rakaia, Rangitata and Hakatere/Ashburton rivers. The Department of Conservation (DOC), North Canterbury Fish and Game (NCFG), and Central South Island Fish and Game (CSIFG) were key partners in the research. The work also had input and involvement from other organisations (e.g., Pattle Delamore Partners), rūnanga (notably Te Rūnanga o Arowhenua) and the community. Surveys were designed to test the fish survey methodologies used by Eldon and Greager (1983) in the Rakaia Hāpua during the early 1980s and to as best as practicable compare survey findings to their data.

Bonnett (2021) details the initial findings of this research with a report on data collected during November 2020 surveys. The following report updates these data and adds information obtained from subsequent surveys undertaken in February 2021. It compares November-February 2020/21 results with findings from 1980/81 Rakaia Hāpua surveys undertaken during a similar time in the migration season (Eldon and Greager, 1983). It also has recommendations for further research.

2 Methodology

2.1 Site information

The hāpua fish communities of the Rakaia, Rangitata and Hakatere/Ashburton rivers were each surveyed on two occasions: the first between 16-25 November 2020 and second between 1-10 February 2021. Fifteen seine net sites were surveyed in the Rakaia and Rangitata hāpua, and 14 sites in the Hakatere/Ashburton (Figure 2-1 – Figure 2-3). The site locations for other fishing methods (fyke netting, gee-minnow trapping, electric fishing and eDNA) were variable depending on the habitat characteristics observed at each waterbody and date. For example, the number of backwater "arm" or spring-fed creek inflow habitats in each hāpua varied and were targeted by fyke netting and gee-minnow traps. Seine netting was conducted at a variety of habitat types ranging from sandy or muddy bottomed bays, to gravel bottomed river backwaters and beaches.

River flow and weather conditions varied on sampling dates, but near base flow conditions were generally observed (Figure 2-4) with moderate or high river water clarity. The one exception was the Rangitata River on 18 November 2020 when high inland rainfall on the days prior to surveying resulted in a higher flow (max 179 m^3/s at Klondyke recorder) and turbid, brown water. The location of each hāpua mouth relative to the inflow of the main river braids varied between each waterbody and sampling date with the northward migration of the mouth observed over time in each (Figure 2-1 – Figure 2-3).

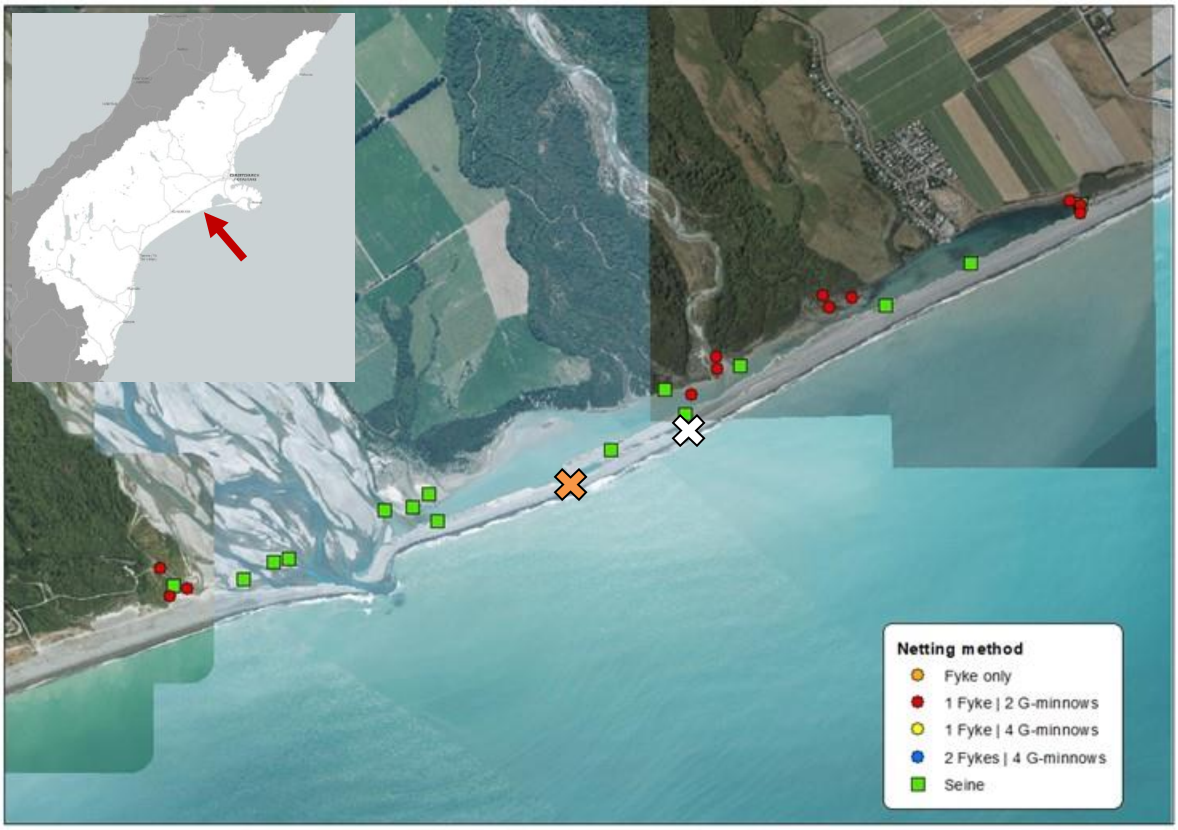

Figure 2-1: Approximate sampling locations on the Rakaia Hāpua (inset: red arrow). Orange and white 'X' is approximate location of mouth on 24-25 November 2020 and 1-2 February 2021 respectively

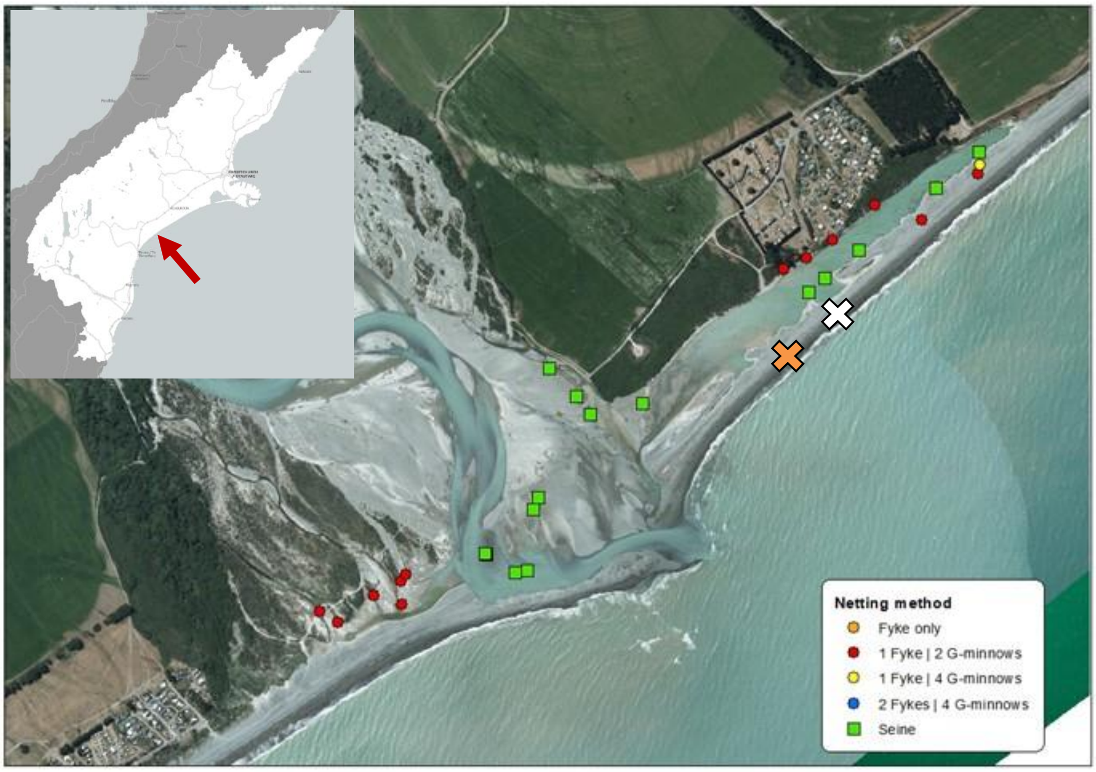

Figure 2-2: Approximate sampling locations on the Rangitata Hāpua (inset: red arrow). Orange and white 'X' is approximate location of mouth on 18-20 November 2020 and 9-10 February 2021 respectively

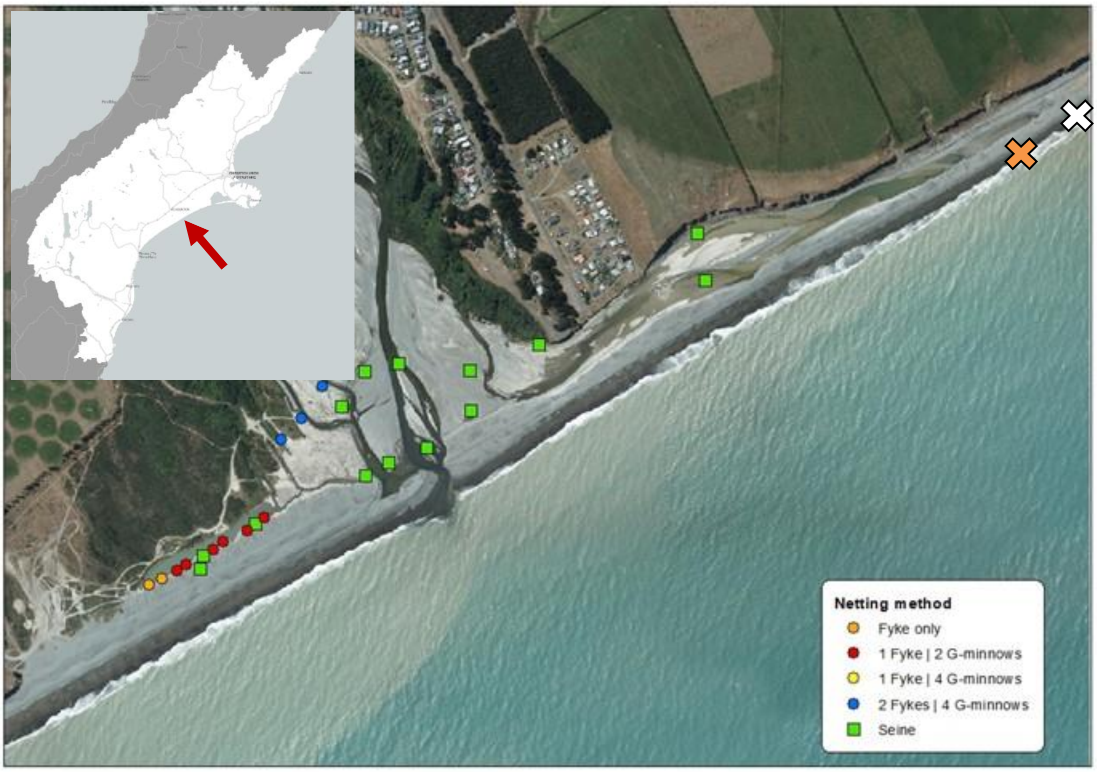

Figure 2-3: Approximate sampling locations on the Hakatere/Ashburton Hāpua (inset: red arrow). Orange and white 'X' is approximate location of mouth on 16-17 November 2020 and 4-5 February 2021 respectively

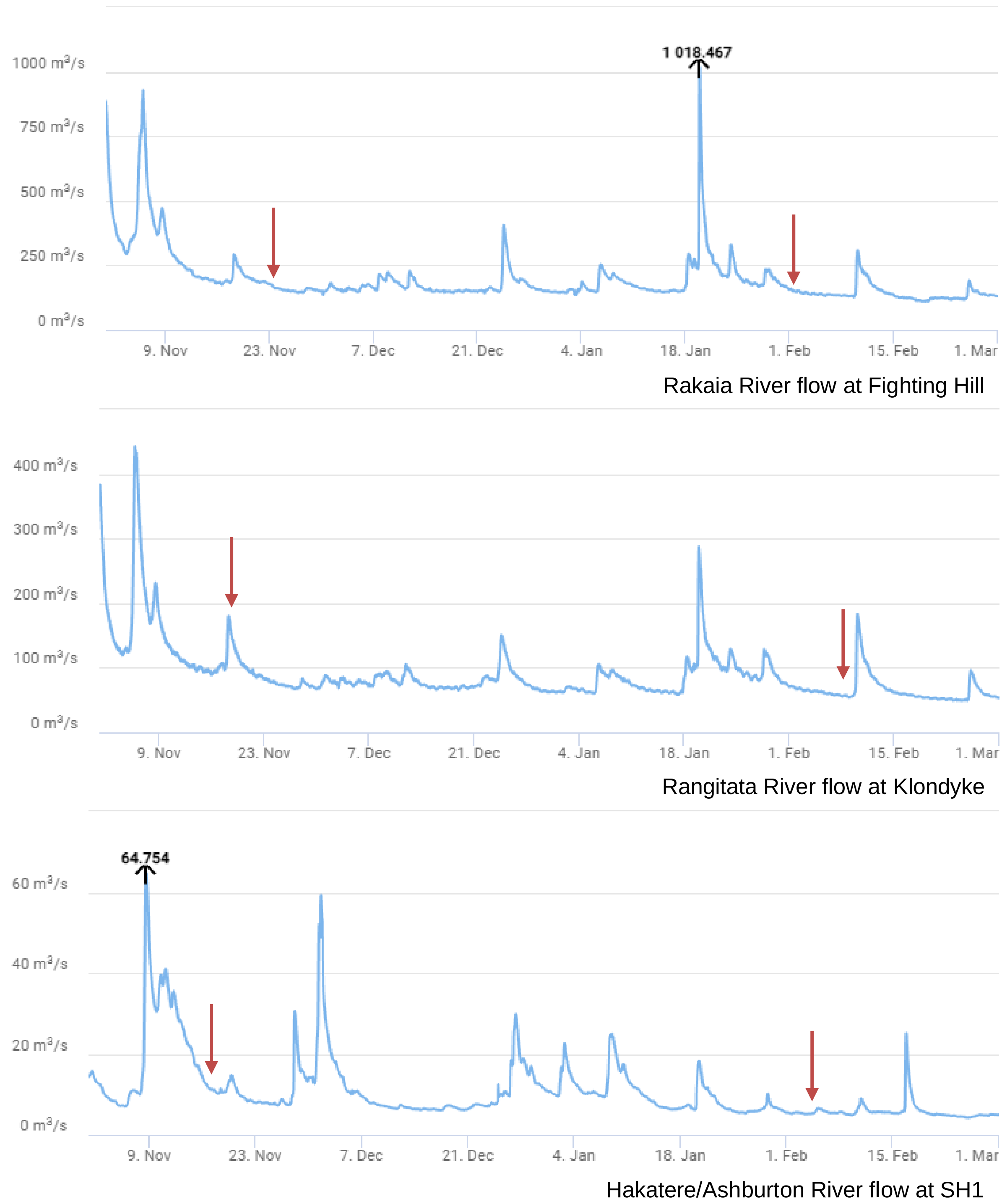

Figure 2-4: River flow between 1 November 2020 and 1 March 2021 at the flow recorder sites; Rakaia River at Fighting Hill (top), Rangitata River at Klondyke (centre), and Hakatere/Ashburton River at State Highway 1 (bottom). Red arrows indicate the dates that fish communities were sampled in each hāpua

2.2 Fishing methods

A suite of fishing methods was used with netting types (seine and fyke) and site locations approximating those used by Eldon and Greager (1983) in the Rakaia Hāpua during 1980/81 surveys. The following describes the 2020/21 fish survey methods as adapted from Bonnett (2021) (which documented the interim results of November 2020 surveys).

Note that gill nets of various mesh sizes were used during the 1980/81 surveys of Eldon and Greager (1983). This method was not employed during the 2020/21 hāpua surveys due to the high risk of mortality to fish captured by gill nets.

2.2.1 Beach seine netting

Daytime beach seine netting was carried out in all three hāpua surveyed in November 2020 and February 2021 (Figure 2-5). The nets used were of similar specification to those used in the surveys of the Rakaia Lagoon in 1980-81 (Eldon and Greager 1983) and Waimakariri Estuary in 1983-84 (Eldon and Kelly 1985). Seine net specifications were as follows:

- 20 m or 30 m long with 3 m bridles and 30 m haul ropes attached at each end;
- 2.5 m high with lead weighting on the bottom rope and buoys on the top rope; and
- 12 mm (stretch) knotless mesh, which provided an equivalent aperture of roughly 5-6 mm side-of-square so that relatively small fish, including some whitebait, were collected.

Beach seine netting was typically carried out using a boat to assist the deployment of the net parallel to the shore and up to the extremity of the haul ropes and bridle (i.e., up to 30 m offshore). The nets were then hauled gradually to shore while ensuring the weighted bottom rope maintained contact with the riverbed as much as possible (Figure 2-5). The area of riverbed sampled from each seine net haul was estimated and noted. Captured fish were identified and counted, and a subsample of specimens were measured. Some smelt were euthanised and preserved for laboratory and genetic identification (see Section 2.2.5).

The beach seining technique worked best where the beach shelved gradually and where there was little or no water flow. Some variations of the technique were required where netting took place in embayment’s along the shoreline, or when snags, aggregations of sediment, or flow interfered with the haul. The deployment and hauling of seine nets was difficult and often unsatisfactory where river flow was moderate because the bottom rope of the net would “roll” and not fish effectively.

Figure 2-5: Beach seine netting at a site in the northern arm of the Hakatere/Ashburton Hāpua, 16 November 2020

2.2.2 Fyke netting

Two types of fyke net were used in the 2020/21 hāpua surveys:

- Single ended “green” fine mesh nets (6 mm stretch), 3 m long x 0.6 m high with a 3 m long leader; and
- Single ended “black” coarse mesh nets (18 mm stretch), 2.5 m long x 0.5 m deep with a 3 m long leader.

These nets were different to the fyke nets used during studies undertaken during the 1980s (e.g., Eldon and Greager, 1983) when a mixture of “commercial” eel fyke nets and “mini -fyke” nets were used. “Commercial” eel fyke nets were much larger than the “green” fykes used in 2020/21 and used much coarser netting. “Mini-fykes” were roughly half the size of the “green” fykes and used a 15 mm stretch mesh.

Fyke nets were set, without bait, overnight at backwater locations within each hāpua or near the inflow of spring-fed tributaries (Figure 2-1 – Figure 2-3). Nets were set to ensure they were not stranded on the outgoing low tide cycle when water levels in the hāpua dropped. Generally, sets were deployed with the leader of the net staked close to the shoreline and the cod-end (i.e., the trap end) of the net almost perpendicular to the shoreline (Figure 2-6). The cod-end was weighted with river stones placed inside the net before it’s end was tied, and then the net was “cast” out into deeper water. In flowing areas (e.g., small tributary stream inflows) fyke net leaders were staked upstream (or tied to a log) with the cod-end orientated in a more downstream direction. Fyke nets were recovered the following morning and the fish removed, identified, and counted. The length of a sub-sample of fish were measured.

Figure 2-6: Fyke net in a spring-fed tributary of the Rakaia Hāpua, 24 November 2020

2.2.3 Gee-minnow trapping

Two-piece stainless steel gee-minnow traps (2 mm mesh) were set at backwater and spring-fed inflow locations similar to the fyke nets (Figure 2-1 – Figure 2-3). Each trap was attached to a light rope line and secured to the shore or a set fyke net. Similar to fyke nets, care was taken to ensure the gee-minnow traps were not left dry on the falling low tide. They were set overnight without bait and recovered the following morning. Caught fish were removed, identified, counted and subsamples measured for length.

2.2.4 Electric fishing

Areas of braided river and spring-fed stream habitat upstream of each hāpua were spot fished using an electric fishing machine (EFM, Kainga EFM300 portable) (Figure 2-7). Electric fishing was limited to shallow (< 1 m deep) and moderately flowing areas of stream channels. Stunned fish were collected either by the EFM operator's dip net (6 mm mesh) or an assistant's pole seine net (1.5 m wide, 1 m high, 6 mm mesh) placed downstream. Fish caught during electric fishing were identified, counted and subsamples measured for length.

Figure 2-7: Spot electric fishing the lower braided river margins of the Hakatere/Ashburton River just upstream of the hāpua, 17 November 2020

2.2.5 Fin clipping for DNA analysis

In most cases, fish species were easily identified in the field using the eye of experienced freshwater ecologists. However, differentiating species of smelt (i.e., Stokell's and common smelt species) was difficult given their similarities in morphology and colour, and the lack of consistent diagnostic features within each species.

Sub-samples of up to 100 smelt specimens less than 90 mm long (because they were the most likely size-class to be Stokell's smelt) were collected across the three hāpua on each sampling occasion to aid in species identification, and to quantify the relative abundance of each smelt species caught. Specimens were euthanised in the field using fish anaesthetic (Aqui-S) and preserved in 90% ethanol solution. Specimen features were examined under microscope in the Environment Canterbury ecology laboratory before fin clips were extracted using sterilised equipment. Fin clips were sent to the Zoology Department at University of Otago for genetic identification. The results of genetic analyses were then compared with in-field and laboratory diagnostic observations.

2.2.6 eDNA water sampling

Environmental DNA (eDNA) water samples were collected from the lowest riffle of each river during February 2021 surveys only. This formed part of a nation-wide regional council survey (coordinated by

WilderLab Ltd) to develop eDNA techniques for surveying freshwater fish. It also served as a useful method for detecting the presence-absence of fish species in the lower reaches of each river.

Water samples were collected using eDNA syringe sampling kits supplied by WilderLab and using the WilderLab sampling protocols[1]. Twenty-four 1 L replicate water samples were collected at each river site near the time of low tide and under base flow river conditions (i.e., clear water). Using sterile nitrile gloves, syringes were used to collect and filter (via an attached filter housing) 50 mL of river water at a time. After 1 L of water was collected, each replicate filter housing was flooded with a preservative solution, capped, and packaged for transport to the WilderLab laboratory for DNA analysis.

3 Results

The following section reports the results of fish catches obtained using each sampling method during the 2020/21 hāpua surveys. Appendix 1 contains catch data for each hāpua and each sampling date per net and trap method. Appendix 2 contains a selection of photographs from the surveys.

3.1 Seine and fyke netting

Total fish caught by seine net was greatest in the Rangitata Hāpua followed by the Rakaia then Hakatere/Ashburton (Figure 3-1). Fish numbers on 18-19 November 2020 in the Rangitata Hāpua were at least double that for any other sampling occasion and for any river. Only 14 fish were caught across 14 seine sites in the Hakatere/Ashburton Hāpua on 4 February 2021. This could have in-part been because of the prolonged low flows in the river leading up to the survey which resulted in very poor fish passage at the river mouth (Figure 2-4 and Figure 3-2).

Smelt (both common and Stokell's) were the most dominant taxa caught in the Rakaia and Rangitata hāpua on both survey dates (Figure 3-1). The next most abundant fish species was yellow-eye mullet (*Aldrichetta* forsteri) or common bully (*Gobiomorphus cotidianus*) followed by inanga (*Galaxias macronasus*). Seine catches in the Hakatere/Ashburton Hāpua were dominated by common bully. The number of salmonids caught in seine nets were low with no more than six brown trout (*Salmo trutta*) or three Chinook salmon (*Oncorhynchus tshawytscha*) being caught across all seine sites at any waterbody for any given sampling occasion.

Seine nets generally targeted static or slow flowing water in the main body of the hāpua or the back waters of the lower river braids, whereas fyke nets fished the margins of spring-fed inflows or the northern and southern extremes of the hāpua. For this reason, fyke net catches were dominated by species differing to that caught by seine nets. Common and giant (*Gobiomorphus goboides*) bully, smelt, inanga, and longfin (*Anguilla dieffenbachii*) and shortfin (*Anguilla australis*) eel were caught in fyke nets at all waterbodies on all dates (Appendix 1). Shortfin eel were generally much more abundant than longfin eel. Inanga, common bully, or whitebait (likely to be predominantly juvenile inanga) were generally the most abundant species caught in fyke nets depending on date and sampling location.

Table 3-1 combines the seine and fyke net data for each species caught in each of the three hāpua. It also compares Rakaia Hāpua catch data to seine, fyke and gill-net data (the latter of which was not used in 2020/21 surveys) obtained from the Rakaia Hāpua during 1980/81 at a similar time of season. The results show that a greater number of giant bully were caught in the 2020/21 surveys, while numbers of black flounder (*Rhombosolea retiarii*), longfin eel, Chinook salmon and brown trout were less than the 1980/81 survey results. The number of smelt that were caught in 2020/21 Rakaia Hāpua survey were less than the peak numbers caught in the 1980/81 surveys. There was no obvious difference in the size of common bully, inanga, shortfin eel and yellow-eye mullet populations in the Rakaia Hāpua between 1980/81 and 2020/21. Given the differences in the number of net sites used between the surveys, netting methods used, and time of year sampled, there is a high level of uncertainty about how much fish communities may have changed between the 1980/81 and 2020/21 surveys.

[1] See https://www.wilderlab.co.nz/directions#active for detailed methods.

3.2 Gee-minnow trapping

Appendix 1 contains catch data from gee-minnow traps, which was used as a fishing method to compliment fyke netting in the spring-fed inflows and northern and southern extents of the hāpua. Gee-minnow traps targeted smaller fish species and juveniles (e.g., whitebait). Catch numbers were dominated by inanga/whitebait and/or common bully across both sampling occasions at each waterbody. Both inanga/whitebait (66-87% decrease) and common bully (35-99% decrease) numbers decreased at all sites between November 2020 and February 2021 sampling. As with the changes observed in seine net catches, the biggest decrease in inanga/whitebait (>99% decrease) and common bully (87% decrease) numbers occurred in the Hakatere/Ashburton Hāpua.

Other species caught in gee-minnow traps varied depending on the hāpua and date of sampling. Both juvenile shortfin eel and giant bully were caught in tributaries of the Rakaia Hāpua on both sampling occasions, and in the Hakatere/Ashburton Hāpua during February 2021 only. Upland bully (*Gobiomorphus breviceps*) were caught in the Rakaia and Rangitata hāpua in November 2020. Low numbers of freshwater shrimp (*Paratya curvirostris*) were caught in the Rakaia (November 2020 only) and Rangitata (both sampling dates) hāpua using gee-minnow traps and/or fyke nets.

3.3 Electric fishing and eDNA

Spot fishing using an EFM targeted the lower river braids and spring-fed tributaries of each hāpua, but sampling effort was variable depending on site location and date. In comparison, eDNA water sampling targeted the lowest riffle of each braided river during February 2021 surveys only. eDNA techniques are only suitable for detecting the presence or absence of flora and fauna in water (i.e., not abundance) as the magnitude of analytical signatures (represented as a number for each species for any given sample replicate) cannot be treated as like-for-like between species. For example, a large, narrow fish that is relatively inactive during the daytime (e.g., a longfin eel) is likely to emit a different DNA signature than a small, robust fish that is relatively active during the daytime (e.g., a torrentfish). For these reasons, electric fishing and eDNA results are presented as presence/absence data in Table 3-2.

The highest number of species detected by EFM and eDNA methods were found at the Rangitata Hāpua. The Rangitata Hāpua was the only site where black flounder was detected (despite black flounder being found in seine or fyke nets in the Rakaia and Hakatere/Ashburton hāpua also; Table 3-1). The Rakaia Hāpua contained 12 distinct species. It was the only waterbody where inanga or Stokell's smelt were not detected (though whitebait, likely to be inanga, were detected and Stokell's smelt presence was confirmed via fin clip analyses of seine caught specimens; see Table 3-3). Yellow-eye mullet were only found in the lower Rakaia River and Canterbury galaxias (*Galaxias vulgaris*) in the lower Hakatere/Ashburton River, both using eDNA. Fyke nets and gee-minnow traps caught giant bully in the lower Hakatere/Ashburton, despite no detection by EFM or eDNA methods.

3.4 Smelt fin clip analyses

Table 3-3 contains the genetic analysis results for fin clips obtained from a random selection of smelt specimens (less than 90 mm long) collected from seine nets in the field. A small proportion (17-26%) of smelt were identified as Stokell's smelt on both sampling occasions in the Rangitata Hāpua. No Stokell's smelt were genetically identified from fin clips collected from the Hakatere/Ashburton Hāpua during November 2020 or Rakaia Hāpua during February 2021.

The subsampling of smelt targeted individuals less than 90 mm in length. This was to intentionally bias the selection towards the fish most likely to be Stokell's smelt in the absence of good taxonomic keys (i.e., fish greater than 90 mm in length are increasingly likely to be common smelt as they are thought to be longer lived). Furthermore, only small subsamples were collected meaning the relative proportions of species represented in Table 3-3 cannot be extrapolated to estimate the total number of Stokell's or common smelt caught by seine nets (see Appendix 1). Despite this, the low proportion of positively identified Stokell's smelt from collected subsamples signifies that the entire population may have declined when compared to historic data. For example, Bonnett (1992) found total smelt populations to be greatly dominated by Stokell's smelt (i.e., greater than 99%) in the Rakaia, Rangitata and Hakatere/Ashburton hāpua.

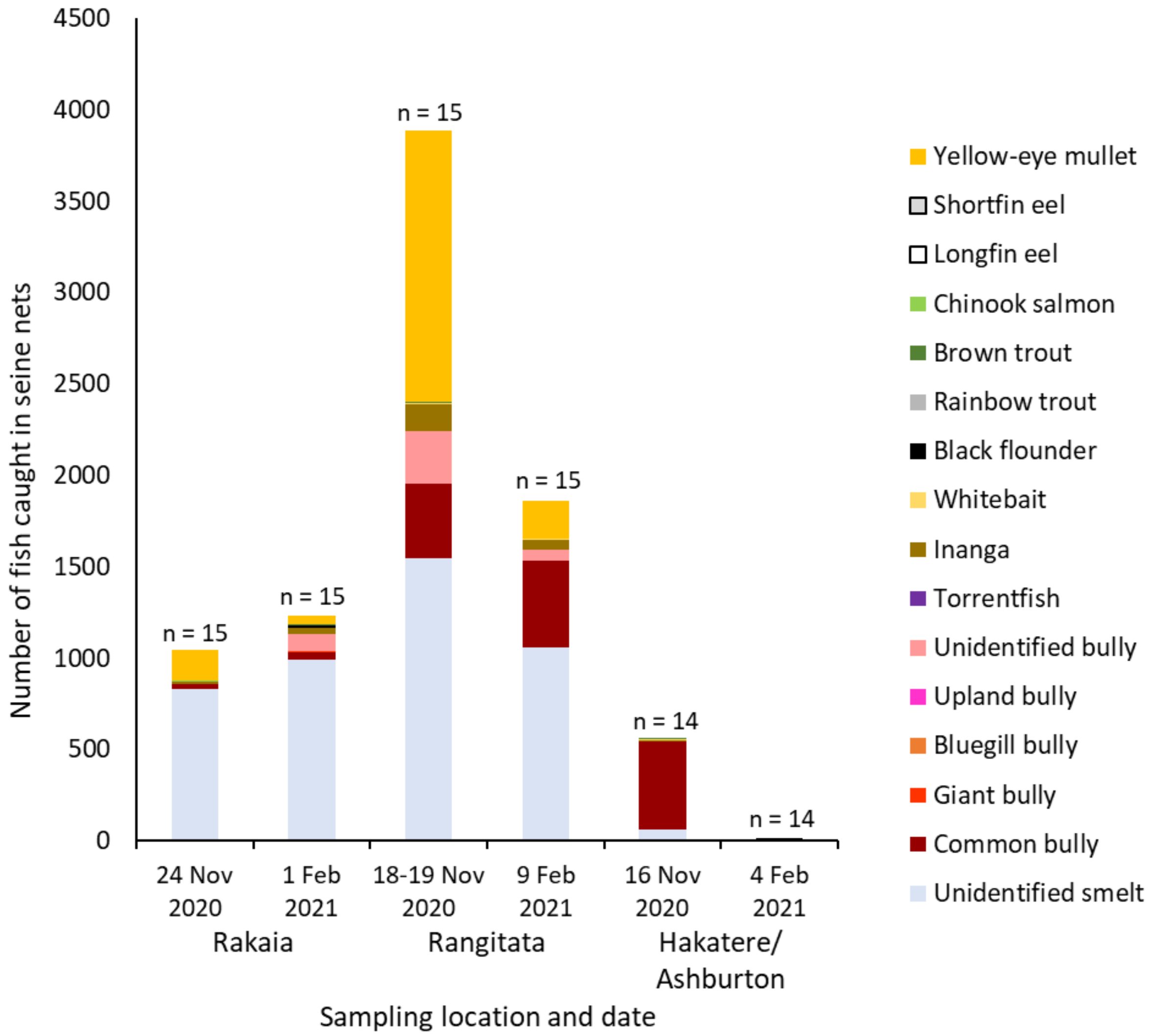

Figure 3-1: Total number of each fish species caught by seine nets in each hāpua on different sampling occasions, November 2020 – February 2021. The number of sampling sites on each sampling occasion is denoted above each bar (n)

Figure 3-2: Hakatere/Ashburton River Mouth, 4 February 2021. Fish passage was very poor owing to prolonged low river flows and a shallow, steep mouth running over beach gravels

Table 3-1: Total catch data using seine and fyke nets in the Rakaia, Rangitata and Hakatere/Ashburton hāpua, November 2020 – February 2021. Also included for comparison are data from Rakaia Hāpua surveys during November 1980, and late January and early February 1981 (Eldon and Greager, 1983). Note that November 2020 results have been updated and differ to the Bonnett (2021) data report

	No. of nets			Bully						Galaxias					Eel						
	Seine	Fyke	Gill	Giant	Common	Upland	Bluegill	Unidentified	Unidentified smelt	Inanga	Whitebait	Torrentfish	Yellow-eye mullet	Black flounder	Longfin	Shortfin	Unidentified	Rainbow trout	Brown trout	Chinook salmon	Paratya shrimp
Rakaia Lagoon																					
11-13 Nov 1980	12	7	1	0	43	0	0	0	623	88	-	0	4	34	24	26	0	0	14	39	-
25-27 Nov 1980	11	7	1	0	69	0	0	0	3164	225	-	3	17	43	12	24	0	0	21	42	-
24-25 Nov 2020	15	12	0	14	44	0	0	12	848	200	546	0	168	2	14	32	2	0	5	3	10
21-23 Jan 1981	9	7	1	0	114	0	0	0	3488	590	-	1	225	67	32	28	0	0	3	2	-
3-5 Feb 1981	7	7	1	0	20	0	0	0	384	284	-	0	81	8	23	8	0	0	6	42	-
1-2 Feb 2021	15	12	0	28	71	0	0	109	1012	1395	0	0	66	14	2	37	1	0	8	0	0
Rangitata Hapua																					
18-20 Nov 2020	15	12	0	24	586	0	0	651	1566	234	48	0	1487	0	21	74	0	0	5	2	12
9-10 Feb 2021	15	13	0	3	736	0	3	58	1173	204	4	0	228	0	15	51	2	0	0	1	15
Hakatere Hapua																					
16-17 Nov 2020	14	14	0	4	3613	0	0	1	64	145	411	1	0	0	5	31	0	0	3	0	0
4-5 Feb 2021	14	10	0	13	102	0	0	22	7	1254	0	0	0	2	2	89	0	0	0	0	0

Table 3-2: Presence (✓) or absence (-) of fish species found in spring-fed tributaries and lower river braids using spot fishing (EFM) and eDNA water sampling (lowest braid of main river only) methods. Grey boxes indicate taxa not tested for by a specific technique and/or that don't count toward final species count (except where * is denoted)

Species	Rakaia			Rangitata			Hakatere/Ashburton		
	Nov 2020	Feb 2021		Nov 2020	Feb 2021		Nov 2020	Feb 2021	
	EFM	EFM	eDNA	EFM	EFM	eDNA	EFM	EFM	eDNA
Common smelt			✓			✓			✓
Stokell's smelt						✓			✓
Unidentified smelt	✓	-		✓	-		✓	-	
Common bully	✓	✓	✓	✓	-	✓	✓	✓	✓
Giant bully	✓			✓	-		-	-	-
Bluegill bully	✓	✓	✓	✓	-	✓	✓	✓	✓
Upland bully	✓	-	✓	✓	-	✓	✓		✓
Unidentified bully	✓	-		✓	✓		-	-	
Torrentfish	✓	✓	✓	✓	-	✓	✓	-	✓
Inanga	-	-	-	✓	✓	-	✓	-	✓
Whitebait	✓*	-		✓	✓		✓	-	
Canterbury galaxias	-	-	-	-	-	-	-	-	✓
Unidentified galaxias	-	-		-	-		-	✓	
Black flounder	-	-	-	✓	-	-	-	-	-
Rainbow trout	-	-	-	-	-	-	-	-	
Brown trout	✓	-	✓	-	-	✓	-	-	✓
Chinook salmon	-	-	✓	-	-	✓	-	-	
Longfin eel	-	-	✓	-	-	✓	-	✓	✓
Shortfin eel	✓	-	✓	✓	-	✓	✓	✓	✓
Unidentified eel	✓	-		✓	✓		-	-	
Yellow-eye mullet	-	-	✓	-	-	-	-	-	-
Total taxa/species	12			13			11		

* Whitebait counts as distinct species towards 'total taxa/species' as likely inanga which was otherwise undetected using EFM or eDNA in the Rakaia Hāpua.

Table 3-3: Results of DNA fin clip analyses for smelt specimens collected in the field. Specimens less than 90 mm long (i.e., the size class most likely to be Stokell's smelt) were randomly selected from each hāpua

Hāpua	Date	No. of samples	Common smelt	Stokell's smelt	Ratio of Stokell's smelt
Rakaia	Nov 2020	30	30	0	0%
	Feb 2021	38	28	10	26%
Rangitata	Nov 2020	30	25	5	17%
	Feb 2021	55	42	13	24%
Hakatere/Ashburton	Nov 2020	30	23	7	23%
	Feb 2021	3	3	0	0%

4 Discussion

Fish diversity was similar between the three hāpua with between thirteen (Ashburton/Hakatere) and fourteen (Rakaia and Rangitata) species caught overall. Some species were only detected using a single sampling method and/or during a single sampling occasion. For example, Stokell's smelt were not found using net, trap or EFM methods in the Rakaia Hāpua during November 2020, but was later confirmed to be present in February 2021 by genetically testing specimen fin clips (specimens were collected from seine nets). Chinook salmon and yellow-eye mullet were found in the Rangitata and Rakaia rivers but not the Hakatere/Ashburton, whereas the latter was the only waterbody where the presence of Canterbury galaxias was detected (only by using eDNA water sampling).

The catch number for each fish species in each hāpua changed between November 2020 and February 2021. This was likely due to the change in migratory fish numbers coming into the hāpua from the ocean (or from the upper river) and the ever-changing arrangement of hāpua habitats and features over time (e.g., river mouth size and location). This seasonal change in community structure was highlighted during Eldon and Greager's (1983) fortnightly sampling of the Rakaia Hāpua between July 1980 and July 1981 when smelt numbers were extremely variable (ranging from tens to tens of thousands of fish caught) between sampling occasions. Our 2020/21 fish surveys showed a substantial reduction in fish community diversity and abundance in the Hakatere/Ashburton Hāpua in February 2021 compared to November 2020. This was likely owing, at least in-part, to prolonged low river flows and therefore a reduced river mouth size resulting in poor fish passage from the ocean.

Little historic survey data exists for fish populations in Canterbury hāpua making it difficult to assess long-term changes in fish community structure. Additionally, the seasonal change in fish numbers and ever-changing physical characteristics of hāpua mean that like-for-like comparisons of fish community structure between the Rakaia Hāpua in 2020/21 and 40 years ago (e.g., Eldon and Greager, 1983) is challenging. The November 2020 and February 2021 survey results suggest that some fish species numbers in the Rakaia Hāpua may have decreased long-term (i.e., black flounder, longfin eel, Chinook salmon, brown trout and smelt) but each survey can only be considered as a "snapshot" in time. The within-season sampling of hāpua fish communities needs to be frequent and representative of multiple habitat types. An increase in the temporal replication of sampling over spring/summer will allow a better comparison of results to historic data.

Based on the results of the 2020/21 fish surveys of the Rakaia, Rangitata and Hakatere/Ashburton hāpua, several recommendations were made for next steps in investigating the state of fish communities in Canterbury hāpua. These were:

- Focus research on hāpua with good historical datasets (e.g., Rakaia Hāpua).
- Increase the temporal replication of surveys to better measure the seasonal change in fish migration numbers and physical habitat, and better replicate historical survey information.
- Use sampling techniques that best target species of interest (i.e., seine nets for Stokell's smelt).

- Survey and document the mātauranga and observations of experienced river mouth users (e.g., anglers) to fill information gaps on habitat and fish community change over the last 40 years.
- Given the potential long-term change in smelt populations (particularly Stokell's smelt), improve the techniques used for identifying different species of smelt in the field.
- Examine the potential environmental drivers of fish community structure in Canterbury hāpua.

Some of these recommendations have already been implemented. Jellyman and Mayall-Nahi (2022) have surveyed and reported river user observations of change over time in the lower Rakaia, Rangitata and Hakatere/Ashburton rivers. Fortnightly seine net surveys of the Rakaia Hāpua were undertaken by Environment Canterbury, DOC, NCFG and CSIFG between October 2021 and March 2022 to compare results to Eldon and Greager (1983) (Arthur and Gray, 2022). Some smelt specimens collected during October-March 2021/22 were tested for genetics (University of Otago) and sent to a fish taxonomist (Unitech Institute of Technology, Auckland) to improve our knowledge on the morphological traits of Stokell's and common smelt. Lastly, National Institute of Water and Atmospheric Research (NIWA) has undertaken a literature review of potential environmental drivers of fish community change in Canterbury hāpua and made detailed recommendations about the further research required to understand these (Hickford, 2022).

5 References

Arthur, J.B., and Gray, D.P. (2022). *Fish Communities of the Rakaia Hāpua: A Comparison with Historical Survey Data, 1980/81 and 2021/22.* Environment Canterbury Science Report No. R22/27.

Bonnett, M. (1986). *Fish and benthic invertebrate populations of the Rangitata River*. Fisheries Environmental Report No. 62. Fisheries Research Division: NZ Ministry of Agriculture and Fisheries.

Bonnett, M. (1992). Distribution and freshwater residence of Stokell's smelt, *Stokellia anisodon* (Stokell), in the South Island, New Zealand. *New Zealand Journal of Marine and Freshwater Research 26: 213–218.*

Bonnett, M. (2021). Canterbury hāpua fish survey – pilot study. Pattle Delamore Partners Report No. C03818800 prepared for Environment Canterbury.

Deverall, K. (1986). *Fishes of the Waitaki Lagoon.* Fisheries Environmental Report No. 64. Fisheries Research Division: NZ Ministry of Agriculture and Fisheries.

Eldon, G. A., and Greager, A. (1983). *Fishes of the Rakaia Lagoon.* Fisheries Environmental Report No. 30. Fisheries Research Division: NZ Ministry of Agriculture and Fisheries.

Eldon, G. A., and Kelly, G. (1985). *Fisheries of the Waimakariri River Estuary.* Fisheries Environmental Report No. 56. Fisheries Research Division: NZ Ministry of Agriculture and Fisheries.

Hart, D. (2015). Morphodynamics of non-estuarine rivermouth lagoons on high energy coasts. *Journal of Coastal Research* 56: 1355–1359.

Hickford, M. (2022). Potential drivers of the decline of hāpua fish populations. NIWA Client Report No. 2022282CH prepared for Environment Canterbury.

Jellyman, D., and Mayall-Nahi, M. (2022). Perceptions of change: recording observations over decades for Canterbury hāpua. NIWA Client Report No. 2021348CH.

McDowall, R. (1978). *New Zealand Freshwater Fishes: A Guide and Natural History*. Heinemann Educational Books.

McDowall, R. (2000). *The Reed Field Guide to New Zealand Freshwater Fishes*. Reed.

McDowall, R. (2011). *Ikawai: Freshwater Fishes in Māori Culture and Economy*. Canterbury University Press.

McMillan, H. (1961). An addition to the knowledge of the fish *Retropinna anisodon* Stokell (Retropinnidae). *Transactions of the Royal Society of New Zealand: Zoology 1*: 138–144.

Measures, R., Hart, D., Cochrane, T., and Hicks, D. (2020). Processes controlling river-mouth lagoon dynamics on high-energy mixed sand and gravel coasts. *Marine Geology 420*: 1–15.

Rutledge, M. (1991). *Adult trout diet in the lower Waitaki River and tributaries, 1983 – 1986.* Fisheries Environmental Report No. 26. Fisheries Research Division: NZ Ministry of Agriculture and Fisheries.

Appendix 1: Number of fish species caught by each trap or netting method

The data tables below contain the number of each fish species caught using net and trap methods during November 2020 – February 2021 hāpua surveys. Not included are electric fishing machine spot fishing results which were only suitable for presence/absence of species. Note that November 2020 results have been updated and differ compared to the Bonnett (2021) data report.

Rakaia 24 - 25 Nov 2020	n	Bully					Smelt	Galaxias		Torrentfish	Yellow-eye	Black	Eel			Rainbow	Brown trout	Chinook	Paratya
		Giant	Common	Upland	Bluegill	UID	UID	Inanga	Whitebait		mullet	flounder	Longfin	Shortfin	UID	trout		salmon	shrimp
Seine net	15	0	24	0	0	0	832	14	2	0	167	0	0	0	0	0	2	3	0
Fyke net	12	14	20	0	0	12	16	186	544	0	1	2	14	32	2	0	3	0	10
Gee-minnow trap	24	4	34	1	0	32	0	585	164	0	0	0	0	2	0	0	0	0	6
RAKAIA TOTAL		18	78	1	0	44	848	785	710	0	168	2	14	34	2	0	5	3	16

Rangitata 18 - 20 Nov 2020	n	Bully					Smelt	Galaxias		Torrentfish	Yellow-eye	Black	Eel			Rainbow	Brown trout	Chinook	Paratya
		Giant	Common	Upland	Bluegill	UID	UID	Inanga	Whitebait		mullet	flounder	Longfin	Shortfin	UID	trout		salmon	shrimp
Seine net	15	0	408	0	0	289	1545	151	3	0	1486	0	0	0	0	0	5	2	0
Fyke net	12	24	178	0	0	362	21	83	45	0	1	0	21	74	0	0	0	0	12
Gee-minnow trap	27	0	241	0	0	163	3	308	8	0	0	0	0	0	0	0	0	0	0
RANGITATA TOTAL		24	827	0	0	814	1569	542	56	0	1487	0	21	74	0	0	5	2	12

Hakatere 16 - 17 Nov 2020	n	Bully					Smelt	Galaxias		Torrentfish	Yellow-eye	Black	Eel			Rainbow	Brown trout	Chinook	Paratya
		Giant	Common	Upland	Bluegill	UID	UID	Inanga	Whitebait		mullet	flounder	Longfin	Shortfin	UID	trout		salmon	shrimp
Seine net	14	0	484	0	0	0	61	3	11	1	0	0	0	0	0	0	2	0	0
Fyke net	14	4	3129	0	0	1	3	142	400	0	0	0	5	31	0	0	1	0	0
Gee-minnow trap	24	0	286	2	0	3	0	253	336	0	0	0	0	0	0	0	0	0	0
HAKATERE TOTAL		4	3899	2	0	4	64	398	747	1	0	0	5	31	0	0	3	0	0

Rakaia 1 - 2 Feb 2021	n	Bully					Smelt	Galaxias		Torrentfish	Yellow-eye	Black	Eel			Rainbow	Brown trout	Chinook	Paratya
		Giant	Common	Upland	Bluegill	UID	UID	Inanga	Whitebait		mullet	flounder	Longfin	Shortfin	UID	trout		salmon	shrimp
Seine net	15	11	41	0	0	92	990	32	0	0	46	14	0	0	0	0	6	0	0
Fyke net	12	17	30	0	0	17	22	1363	0	0	20	0	2	37	1	0	2	0	0
Gee-minnow trap	22	21	22	0	0	12	0	251	0	0	0	0	0	1	0	0	0	0	0
RAKAIA TOTAL		49	93	0	0	121	1012	1646	0	0	66	14	2	38	1	0	8	0	0

Rangitata 9 - 10 Feb 2021	n	Bully					Smelt	Galaxias		Torrentfish	Yellow-eye	Black	Eel			Rainbow	Brown trout	Chinook	Paratya
		Giant	Common	Upland	Bluegill	UID	UID	Inanga	Whitebait		mullet	flounder	Longfin	Shortfin	UID	trout		salmon	shrimp
Seine net	15	1	476	0	0	58	1060	55	2	0	209	0	0	0	0	0	0	1	4
Fyke net	13	2	260	0	3	0	113	149	2	0	19	0	15	51	2	0	0	0	11
Gee-minnow trap	26	0	96	0	0	0	0	48	0	0	0	0	0	0	0	0	0	0	7
RANGITATA TOTAL		3	832	0	3	58	1173	252	4	0	228	0	15	51	2	0	0	1	22

Hakatere 4 - 5 Feb 2021	n	Bully					Smelt	Galaxias		Torrentfish	Yellow-eye	Black	Eel			Rainbow	Brown trout	Chinook	Paratya
		Giant	Common	Upland	Bluegill	UID	UID	Inanga	Whitebait		mullet	flounder	Longfin	Shortfin	UID	trout		salmon	shrimp
Seine net	14	0	4	0	0	0	1	7	0	0	0	2	0	0	0	0	0	0	0
Fyke net	10	13	98	0	0	22	6	1247	0	0	0	0	2	89	0	0	0	0	0
Gee-minnow trap	20	9	1	0	0	1	0	79	17	0	0	0	0	1	0	0	0	0	0
HAKATERE TOTAL		22	103	0	0	23	7	1333	17	0	0	2	2	90	0	0	0	0	0

Appendix 2: Sampling photographs

A2.1 Rakaia Hāpua

24-25 November 2020 – Rakaia Hāpua south end (left), north end (centre), and middle near the inflow of the Rakaia River North Branch (right).

24-25 November 2020 – Rakaia Hāpua north end (left), fyke net setting at south end (centre), and seine netting on sandy/muddy bay opposite ocean mouth (right).

24-25 November 2020 – Seine netting Rakaia Hāpua near inflow of main river (left), gee-minnow trap in hāpua (centre), and smelt caught in seine net (right).

24-25 November 2020 – Spot fishing spring-fed tributary using electric fishing machine (left), black flounder (centre), and fyke net in spring-fed tributary (right).

1-2 February 2021 – Seine netting sandy bay in Rakaia Hāpua near inflow of main river (left), and small black flounder (right).

1-2 February 2021 – Cobble and sandy margin of hāpua downstream of main river braids (left), and seine netting onto gravel beach (right).

A2.2 Rangitata Hāpua

18-20 November 2020 – Rangitata Hāpua pictured from the south (left) and north (centre), and river mouth to ocean (right).

18-20 November 2020 – Spring-fed tributaries flowing into the southern end of the Rangitata Hāpua (left), retrieving a fyke net (centre), and a lower braid of the Rangitata River after two days of receding high flows (right).

18-20 November 2020 – Seine netting in the northern Rangitata Hāpua (left), seine catch of yellow-eye mullet (centre), and a common smelt (right).

18-20 November 2020 – Seine netting a sandy margin of the Rangitata Hāpua (left), setting a fyke net in a spring-fed inflow (centre), and inanga caught in a gee-minnow trap (right).

9-10 February 2021 – Rangitata River Mouth (left), seine netting of sandy margin of true left of lower river (centre), and laying a seine net by row boat in the northern arm of the hāpua (right).

9-10 February 2021 – Hauling a seine net in the northern arm of the Rangitata Hāpua (left), a Chinook salmon (centre), and laying a seine net by row boat in the southern hāpua (right).

A2.3 Hakatere/Ashburton Hāpua

16-17 November 2020 – Hauling a seine net in a muddy margin of lower Hakatere/Ashburton River (left) and onto the gravel beach (centre), and laying a seine net in the hāpua (right).

16-17 November 2020 – A fyke net set in a spring-fed inflow of the Hakatere/Ashburton Hāpua (left), and spot fishing (centre) and catch (torrentfish, inanga/whitebait, smelt, and common bully; right) using an electric fishing machine.

4-5 February 2021 – Hakatere/Ashburton River Mouth (left), and retrieving a seine net into a gravel backwater (centre) and onto a gravel beach opposite the main river inflow (right).

4-5 February 2021 – Hauling a seine net into a gravel beach in the southern arm of the Hakatere/Ashburton Hāpua (left), a black flounder (centre), and laying a seine net by row boat near shags roosting on the gravel beach (right).

Environment Canterbury Regional Council
Kaunihera Taiao ki Waitaha

Taking action together to shape a thriving and resilient Canterbury, now and for future generations.

Toitū te marae o Tāne, toitū te marae o Tangaroa, toitū te iwi.

www.ecan.govt.nz

Environment Canterbury offices

Christchurch
200 Tuam Street
PO Box 345
Christchurch 8140

P 0800 324 636

Timaru
75 Church Street
Timaru 7940

Kaikōura
96 West End
Kaikōura 7340

Potential drivers of the decline of hāpua fish populations

Prepared for Environment Canterbury

October 2022

Prepared by:
Mike Hickford

For any information regarding this report please contact:

Mike Hickford
Freshwater Fish Ecologist
Freshwater Ecology
+64-3-341 2841
mike.hickford@niwa.co.nz

National Institute of Water & Atmospheric Research Ltd
PO Box 8602
Riccarton
Christchurch 8011

Phone +64 3 348 8987

NIWA CLIENT REPORT No: 2022282CH
Report date: October 2022
NIWA Project: ENC22505

Revision	Description	Date
Version 2.0	Final Report	31 October 2022

Quality Assurance Statement		
	Reviewed by:	Don Jellyman
	Formatting checked by:	Rachel Wright
	Approved for release by:	Phillip Jellyman

Contents

Executive summary

In response to concerns about perceived declines in the abundance of fish communities — particularly Stokell's smelt — in Canterbury hāpua, Environment Canterbury commissioned a report reviewing information relevant to hāpua fish species (with a focus on Stokell's smelt) and the drivers that influence their physiological, behavioural and/or habitat requirements. This report examines available information on possible changes to these drivers over time and how these may have impacted fish communities (particularly Stokell's smelt). It constructs leading theories of causes of fish population decline in Canterbury hāpua, specifically that observed in Stokell's smelt, and suggests next steps for investigating potential drivers.

Stokell's smelt are a regionally endemic, migratory species with a relatively complex life cycle. These characteristics appear to make them vulnerable to population decline. Such a decline could be caused by significant changes to crucial migration pathways, critical, stage-specific habitats, chronic environmental stress, and/or changes to ecological interactions such as predation, competition, or disease.

If spawning populations of Stokell's smelt have declined across the Canterbury region, the most likely driver is a significant change in the Canterbury coastal oceanographic environment. Observed changes in sea surface temperature in the Canterbury region may have decreased larval survival rates. The simplest, and most direct, mechanism for this is a mismatch between larval production and food availability. However, potential indirect mechanisms include a disruption to advection barriers, or changes in rates of predation or competition levels.

If the Stokell's smelt metapopulation has declined because of an anthropogenic impact(s), then the first step to restoring and protecting the species is understanding its full life history and identifying bottlenecks. As such, the priorities for investigating potential drivers of the decline are:

1. identify spawning sites in hāpua and complete a threat assessment of this habitat;
2. understand dispersal pathways between hāpua populations;
3. characterise the distribution, growth, and diet of larvae during the marine phase.

1 Background

Freshwater ecosystems are under immense pressure from habitat loss, invasive species, climate change, and over-exploitation (Dudgeon et al. 2006). Globally, it is estimated that 32% of the ~12,000 assessed freshwater fishes are vulnerable to extinction (IUCN 2022). In North America alone, 57 species of freshwater fish have gone extinct in the last 120 years and the extinction rate is increasing (Miller et al. 1989; Burkhead 2012). Some freshwater fish extinctions result from obvious and direct drivers (e.g., habitat loss or over-exploitation), However, in many cases, extinction is due to more subtle factors, such as source–sink dynamics, demographic and/or environmental stochasticity, and Allee effects (Melbourne and Hastings 2008; McDowall 2010b). Frequently, a combination of drivers (Miller et al. 1989) act synergistically to expedite extinction.

Many of New Zealand's indigenous freshwater fishes are endemic; some have very localised distributions and are only found in certain catchments. In 2017, 76% of indigenous freshwater fishes were threatened with extinction or at risk of becoming extinct (Dunn et al. 2018). These declines are the result of land use changes and associated pollution, changing waterways from their natural form, reducing flows, and bringing in new species intentionally or accidentally (Ministry for the Environment & Stats NZ 2020).

In historical times, New Zealand has only had a single freshwater fish become extinct - the grayling (*Prototroctes oxyrhynchus*). This amphidromous species is closely related to the Southern Hemisphere smelts (McDowall 1990b). It was abundant across much of the country, but by 1870 it had begun to decline and became scarce in the 1900s. It was last caught in 1923 on the east coast of the North Island. The period of decline and extinction of the grayling overlapped with a period of rapid environmental change in New Zealand, as deforestation, industrial development and the introduction of non-native species occurred throughout the country, facilitated by European colonisation (Ewers et al. 2006; Townsend and Simon 2006). This overlap led some (Allen 1949; McDowall 1990b) to blame the extinction of the grayling on multiple aspects of anthropogenic environmental change (most commonly predation and/or competition from introduced trout).

More recently, source-sink dynamics have been added to the list of interacting factors that may have driven the New Zealand grayling to extinction (e.g., Lee and Perry 2019). For species that exist in metapopulations and exhibit source–sink dynamics, it is critically important to identify the proportion of total habitats that must remain as sources to allow the species to persist. In these systems, high local abundances can be misleading and are not a guarantee of population security. Once a critical threshold is passed, extinction may be rapid and inevitable. For amphidromous fishes particularly, quantitative measures of local fecundity and rates of immigration and recruitment are essential for managing metapopulations.

Delta smelt (*Hypomesus transpacificus*) is a Californian endemic, semi-anadromous species that uses estuarine areas for spawning (Hobbs et al. 2019). This species' spawning habitat in the San Francisco Bay-Delta Estuary overlaps with pumping facilities that provide fresh water to 23-million people and irrigation for a multibillion-dollar agriculture industry (Moyle et al. 2018). At times, large numbers of adult and larval Delta smelt are entrained in these pumping networks and are killed (Kimmerer 2011; Moyle et al. 2016; Reis et al. 2019). Despite numerous protections, conservation efforts, and ecological studies over the last 30 years, the Delta smelt population has continued to decline and is now less than 1% of its historic abundance (Moyle et al. 2016; Hobbs et al. 2017). The Delta smelt population is now at such low abundance that long-term monitoring surveys are struggling to find the species in the wild.

Over recent years there has been community concern that the state of fish populations and physical habitat in Canterbury hāpua are degrading (e.g., Littlewood 2020, 2021; Trolove 2021). In response, Environment Canterbury (ECan) engaged Pattle Delamore Partners (PDP) in 2020 to design and assist with undertaking pilot surveys of fish communities in three Canterbury rivers (Hakatere, Rangitata and Rakaia). The main objectives of the hāpua surveys were to develop survey methodology, to assess the current state of the fish communities relative to historic surveys from the 1980s (Rakaia Hāpua: Eldon and Greager 1983; Rangitata Hāpua: Bonnett 1986) and to provide a template for regular surveys in the future.

The initial pilot surveys were completed in November 2020 and February 2021 as a cooperative effort by ECan, the Department of Conservation (DOC), the North Canterbury and Central South Island Fish & Game Councils, and PDP. Te Rūnanga o Arowhenua, local residents and other organisations were also involved. Initial findings showed that the abundance of black flounder (*Rhombosolea retiaria*), longfin eel (*Anguilla dieffenbachii*), brown trout (*Salmo trutta*) and Chinook salmon (*Oncorhynchus tshawytscha*) in the Rakaia Hāpua was reduced compared to the surveys in 1980/81 (Bonnett 2021; Arthur 2022).

Difficulties with differentiating between Stokell's smelt (*Stokellia anisodon*) and common smelt (*Retropinna retropinna*) during the 2020/21 surveys meant that the abundance of these species was not determined (Bonnett 2021). Subsequent DNA analysis of smelt samples, and targeted surveys between October 2021 and March 2022 revealed a major reduction in the abundance of Stokell's smelt in the Rakaia, and potentially other, hāpua (Table 1-1; Arthur and Gray 2022).

Table 1-1: Summary of differences identified by Arthur and Gray (2022) between historic and present-day populations of fishes in the Rakaia Hāpua. The conservation status (Dunn et al. 2018) is shown for each of eight fishes along with a summary of changes between 1980/81 and 2021/22 in abundance (Catch Per Unit Effort) and mean length of fish captured in surveys: ↓↓ major decrease; ↓ moderate decrease; ≈ approximately the same; ↑ moderate increase; ↑↑ major increase.

Common name	Species	Conservation status	CPUE	Mean length
Stokell's smelt	*Stokellia anisodon*	Naturally uncommon	↓↓	↑
Common smelt	*Retropinna retropinna*	Not threatened	↑↑	↓
Common bully	*Gobiomorphus cotidianus*	Not threatened	↑↑	↓↓
Black Flounder	*Rhombosolea retiaria*	Not threatened	≈	↓↓
Brown trout	*Salmo trutta*	Introduced and naturalised	≈	≈
Chinook salmon	*Oncorhynchus tshawytscha*	Introduced and naturalised	↓↓	≈
Īnanga	*Galaxias maculatus*	Declining	↓↓	↓↓
Yellow-eye mullet	*Aldrichetta forsteri*	Not threatened	↑↑	↓

Arthur and Gray (2022) found that several of the fish species that recruit to the Rakaia Hāpua and lower river as juveniles showed major reductions in mean size (e.g., common bully and black flounder), or both abundance and mean size (īnanga) between 1980/81 and 2021/2022. They suggested that some change(s) in the hāpua and lower river environment may be preventing these species reaching maturity and/or causing them to move to other habitats. The observed differences in the abundance of Stokell's smelt and Chinook salmon, which migrate into rivers as adults, could be caused by riverine and/or oceanic processes.

ECan wished to better understand the potential drivers of the decline in Stokell's smelt and engaged NIWA to:

- Undertake a literature review of information relevant to hāpua fish species (with a focus on Stokell's smelt) and factors that influence their physiological, behavioural and/or habitat requirements;
- Examine available information on possible changes to above factors over time and how these may have impacted fish communities (particularly Stokell's smelt);
- Construct theories of fish population decline in Canterbury hāpua (specifically that observed in Stokell's smelt);
- Suggest next steps for investigating these drivers of fish decline in more detail.

2 Stokell's smelt

2.1 Species description

Gerald Stokell (1941) first described <u>*Retropinna*</u> *anisodon* in his revision of the Retropinnids. He identified a "*form from brackish and coastal waters, and river mouths of Canterbury*" (Stokell 1941) that is "*separated from other smelts in the family Retropinnidae by a number of rather esoteric characters, and identification is not easy*" (McDowall 1990b). Stokell's smelt has had only one specific name, *anisodon*, which relates to the lack of teeth on the maxilla. The generic allocation of this species was amended by Whitley (1955) who placed *Stokellia anisodon* as the sole species in the new genus *Stokellia* to honour Stokell's extensive work on the nomenclature and classification of native freshwater fishes of New Zealand.

The basic biology of Stokell's smelt has received very little attention. McMillan (1951, 1961) described their osteology and egg development, and others have described the distribution and fecundity of mature adults (Bonnett 1992) and the timing of spawning migrations (Davis et al. 1983; Eldon and Greager 1983). However, there is a remarkable lack of fundamental biological and ecological knowledge for this short-lived, narrow-ranged, endemic species.

2.2 Historical abundance of Stokell's smelt

There is little doubt that historically Stokell's smelt were very abundant in Canterbury. An article from The Press in December 1913 comments on the high quality of sea-run brown trout being taken by fishers "*in the Rakaia, in which at present there is a run of silveries, the shoals being about 18 inches wide, and lining both banks*" (The Press 1913). Another account states "*when the silveries* [Stokell's smelt] *were running up the* [South Canterbury] *rivers in the spring of the year, the Maoris* [sic] *would catch huge quantities of them in nets … I have known them to catch dray-loads in a day or two, for some of the shoals would keep running for weeks*" (Studholme 1940).

McMillan (1951) noted the "*enormous shoals*" of Stokell's smelt entering the mouths of many Canterbury rivers. He stated that "*despite the actions of predators (including the introduced trout) there appears to be no decline in the size or duration of the spawning runs".* Although, on a more cautionary note he concluded "*Should these fishes suffer the same fate as the graylings (Prototroctes oxyrhynchus), the numbers of the predatory birds and fishes in the vicinity of the river mouths concerned would be greatly diminished*".

In the 1980s, it was recognised that the shoals of mature Stokell's smelt entering rivers on the South Island's east coast rivers were "*one of the largest freshwater fisheries resources of the area*" (McDowall 1990b); a small fishery based on catching migrating fish at the mouth of Mid-Canterbury rivers (McDowall 1983) existed in the 1980s. Annual catches of up to c. 15,000 kg were recorded, with one fisherman catching 830 kg in 4½ hours in the Ashburton-Hakatere River in 1986 (McDowall 1990b). McDowall (1990b) stated "*there is no evidence that the present small levels of exploitation have any effect on the availability of* [Stokell's] *smelt as trout food*", but both he and Bonnet (1992) felt that the fishery would be difficult to manage because of Stokell smelt's annual and diadromous life history.

Few studies have used structured surveys to measure the abundance of Stokell's smelt. Seminal work by Eldon and Greager (1983) surveyed the abundance of Stokell's smelt in the Rakaia Hāpua. However, they noted the species was "*so numerous that it was often impractical to count the catch, and only estimates were made of numbers*". Later surveys (e.g., Davis et al. 1983; Eldon and Kelly

1985; Bonnett 1992) established the numerical dominance of Stokell's smelt in some Canterbury hāpua from late spring to early autumn. However, there is some doubt around the reliability of differentiation between the two smelt species in the field, especially when they are caught in large numbers (Bonnett 2021; Jellyman and Mayall-Nahi 2022).

In a 2021 survey of experienced anglers from three Canterbury rivers (Jellyman and Mayall-Nahi 2022), there was a perceived "*dramatic decline in* [Stokell's] *smelt over the last 10 years but especially during the last five to six years, to the point that smelt are virtually gone*." The anglers had an average of 50.5 years association with hāpua, with fishing being the main activity that brought them to the hāpua. The high feeding dependence of sea-run brown trout on Stokell's smelt was thought to have resulted in a parallel decline in trout abundance, although the decline was perceived to have been over a longer period. Many experienced river users reported considerable mortality of adult and juvenile seabirds, especially black-billed gulls (Littlewood 2021; Jellyman and Mayall-Nahi 2022). Some surveys of wetland/coastal bird nesting colonies near hāpua have been completed (A. Crossland, Christchurch City Council, pers. comm.) but the resulting data have not been analysed.

To some, the decline of a short-lived, narrow-ranged, regionally endemic species may seem of little importance. However, losses of small vertebrate species can have disproportionate and ecosystem-wide consequences. For example, small vertebrates are often important conduits for routing basal energy and biomass into food webs (Cury et al. 2011), so their loss could compromise ecosystem functioning through diminished bottom-up inputs (Ripple et al. 2017). For anadromous species like Stokell's smelt, this energy transfer role is even more important, because they are one of the few vectors transporting marine-derived carbon/energy into rivers (McDowall 2008).

3 Vulnerability to decline

Every species contributes to ecosystem function, but some species are more vulnerable to decline, or their decline has a greater impact, than others. Species that are vulnerable to decline often include:

3.1 Species at the top of food chains

Apex predators play a critical role in ecosystems, by regulating all underlying trophic levels directly and indirectly. Top predators need a large territory to get sufficient prey and their abundance is relatively low. Reproduction and growth are slower than for smaller species and so is their recovery after partial depletion. They are targeted by fisheries and prone to overfishing (Roberts and Hawkins 1999; Olden et al. 2007). Top predators are a vulnerable group of which most species have declined sharply, in some cases more than 90% (Worm et al. 2005).

3.2 Specialised endemic species

Specialised species that have small or geographically restricted populations are more susceptible to threats than those that are abundant or widespread because for each population affected by some impact such as habitat loss or overexploitation there are fewer others to offset local declines and to supply immigrants to replenish losses (WWF 2020). Specialisation also often reduces a species' ability to adapt to change. Specialised species may fulfil important functions for local ecosystems that are lost if the specialist is replaced by native or non-native generalist species that compete more efficiently on a larger scale (Clavel et al. 2011).

3.3 Migratory species

Several studies have attributed the decline of species to their migratory behaviour, although this research has focussed on specific taxonomic groups (Berger 2004) or is qualitative (Wilcove 2010). Other studies on extinction risk have found that migration was not an important predictor of extinction risk (Davidson et al. 2012). One study on birds even suggested that migration decreased the risk of extinction (Lee and Jetz 2011). It appears that migration vulnerability is dependent on complex interactions between behavioural traits, taxonomy, and the environmental system through which the species navigates (Hardesty-Moore et al. 2018). For fishes, anadromous migrants are substantially more at risk of extinction than marine migrants (Hardesty-Moore et al. 2018) because they are less able to escape habitat modifications, pollution, and water extractions during their freshwater stage (Zarfl et al. 2015; Young et al. 2016).

3.4 Species with complex life cycles

Species with complex life cycles normally need several different elements to be in place at specific times to complete their life cycles, making them vulnerable if there is disruption of any single element in the cycle (Jonsson and Ebenman 2001). The number of life stages that a species must go through, the specificity of the resources that the species relies on at a given stage and the relative vulnerability of those resources combine to determine extinction risk (Strona 2022).

3.5 Is Stokell's smelt a vulnerable species?

Stokell's smelt, an endemic, migratory species with a relatively complex life cycle and a limited geographic range appears likely to be vulnerable to decline. Ecological theory and data suggest that species like Stokell's smelt with fast life histories (Reynolds et al. 2001), i.e., short generation times and associated traits such as small body size (Reynolds et al. 2005), should be able to persist better and recover more rapidly from human activities (Dulvy et al. 2003). However, it is unclear whether the high intrinsic rate of natural increase of Stokell's smelt can offset the vulnerabilities caused by its annual life history.

4 Potential causes of decline

Major declines in population size can be caused by catastrophic changes to critical pathways (Section 4.1), habitats (Section 4.2) or chronic environmental stress, and/or changes to ecological interactions such as predation (Section 4.3), competition (Section 4.4) or disease (Section 4.5). The following sections investigate existing knowledge of the effects of each of these factors on Stokell's smelt, and the potential for each to be a driver of population decline.

4.1 Advection

Stokell's smelt are anadromous (McDowall 1976). Mature adults enter hāpua during late spring and in summer to spawn, but most of the species' life history is spent in the marine environment (McDowall 1993). Although many theories have been put forth to explain the evolution of anadromy, such a major life history character must, on balance, provide an overall advantage to individual fish. The potential advantages of anadromy include (a) a mechanism for dispersal; and (b) being able to get the 'best of two worlds'. The 'best' of the freshwater world includes reduced predation on eggs because they develop in a protected environment (but see Section 4.3). The 'best' of the marine world includes higher growth rates for maturing fish, made possible by an abundance of prey items that far exceeds the prey base of most freshwater ecosystems.

An inherent risk of an anadromous life history is advection of larvae or adults to unsuitable habitats that preclude completion of the life cycle. If Stokell's smelt eggs are demersal this may limit dispersal (Hickford and Schiel 2003) because the eggs are fixed in place during a life stage when they have no ability to swim whereas pelagic eggs drift passively with ocean currents. However, there is little doubt that a relatively long pelagic larval duration (McMillan 1951) coupled with a dynamic coastal environment throughout their geographic distribution (Stevens et al. 2021) increases the risk that Stokell's smelt are advected to unsuitable habitats during their marine phase.

4.1.1 Existing knowledge

Stokell's smelt have by far and away the narrowest distribution of all New Zealand's diadromous fishes. Their latitudinal distribution spans <2.5° of latitude (Table 4-1) when all other diadromous fishes (except *Anguilla reinhardtii*) have ranges that span >10° of latitude (McDowall 2010a). Adult Stokell's smelt have only been collected from 13 rivers in Canterbury (Table 4-1). Very limited records of the marine phase of Stokell's smelt include post-larvae that were collected using light traps in Menzies Bay, Banks Peninsula in November 1950 (McMillan 1951) and larvae (9.8–38 mm) caught in nearshore plankton tows south of the Kaikoura Peninsula from late January until March 1996 and 1997 (Dolphin 1997; Hickford 2000).

Stokell's smelt larvae hatch 8–21 days after fertilisation when incubated in water temperatures of 15–21°C (McMillan 1951, 1961). Newly hatched larvae are 4.5–4.8 mm long, transparent (McMillan 1961) and have a small yolk sac with an oil globule (McMillan 1951). Initially, larvae are positively phototaxic and poor swimmers (McMillan 1951). It is likely that soon after hatching, larvae are swept out of the hāpua and into the coastal marine environment by riverine currents if the river mouth is not blocked (McDowall 1976). McMillan (1951) suggested that larvae were initially epipelagic before becoming bathy-pelagic as post-larvae, but he provided no evidence to support this. The transition from the almost 100% freshwater of the hāpua into pure saltwater must be physiologically challenging for small larvae, and the surface brackish zone in the offshore plume from rivers may provide a transitional zone.

Stokell's smelt larvae appear to spend around twelve months in the marine environment before entering river mouths as adults to spawn. McMillan (1961) stated that the scales and otoliths of adults had no "*satisfactory evidence for the determination of age*". In his thesis (McMillan 1951), he found that sagittae did not show a winter check in growth rate but did have a "*zone of discontinuity in growth*" near the outer edge. He concluded that spawning fish were probably in their second year. However, it is possible that the growth discontinuity evident in otoliths is associated with gonad development. Many fishes show a reduction in the increment of otoliths that is associated with sexual maturation (Martin 1949; Eziuzo 1963; Cunningham 1978; Soares 1982; Agostinho 2000). Regardless, the diadromous life history of Stokell's smelt includes at least twelve months of potential dispersal in the marine environment.

Table 4-1: Current known distribution of Stokell's smelt (*Stokellia anisodon*). The river and site where smelt were collected, the date of collection and the source are listed.

Site	Site	Latitude	Most recent observation	Source
South Bay, Kaikoura	marine	42° 25'	March 1997	Dolphin (1997)
Kahutara River	mouth	42° 26'	November 2009	Ling, N. pers. comm.
Waiau River	hāpua	42° 46'	December 1987	Bonnett (1992)
Hurunui River	hāpua	42° 54'	January 1988	Bonnett (1992)
Waipara River	hāpua	43° 9'	October 1987	Bonnett (1992)
Ashley River	mouth	43° 16'	November 2009	Ling, N. pers. comm.
Waimakariri River	mouth	43° 23'	November 2009	Ling, N. pers. comm.
Avon/Heathcote Rivers	estuary	43° 33'	September 1965	Webb (1966)
Menzies Bay	marine	43° 38'	November 1950	McMillan (1951)
Rakaia River	hāpua	43° 53'	March 2022	ECan data
Ashburton-Hakatere River	hāpua	44° 3'	February 2021	ECan data
Hinds River	hāpua	44° 6'	October 1987	Bonnett (1992)
Rangitata River	hāpua	44° 11'	February 2021	ECan data
Orari River	hāpua	44° 15'	November 2009	Ling, N. pers. comm.
Waitaki River	hāpua	44° 56'	December 2022	ECan data

The known distribution of Stokell's smelt broadly resembles that of Chinook salmon, an introduced anadromous species. It has been suggested that the successful introduction of Chinook salmon into New Zealand is linked to the oceanographic configurations to the east of Canterbury that limit their dispersal (Uchihashi et al. 1979; Uchihashi et al. 1981). The similarity in the two species' distribution suggests that the distribution of Stokell's smelt may also be limited by oceanographic features (McDowall 2010a). However, this does raise the question of why similar range limitations do not apply to the many other diadromous fishes present, and often abundant, in the rivers of the eastern South Island (e.g., lamprey, eels, common smelt, inanga, kōaro, torrentfish, giant, common and bluegill bullies and black flounder).

Uchihashi et al. (1981) suggest that the Southland Current and associated Southland Front, to the east of Canterbury Bight form "*a type of fence*" that limits the dispersal of Chinook salmon and aids natal homing (Figure 4-1). The cold subantarctic Water in the Southland Current (Stevens et al. 2021) follows the 500 m depth contour (Zeldis and Hadfield 2012) and has very limited mixing with the band of relatively warmer, more salty subtropical water over the continental shelf (Sutton 2003). This produces the Southland Front which extends northwards from Otago before turning east along the crest of the Chatham Rise at c. 43°S (near the northern extent of the distribution of Stokell's smelt; Table 4-1). The salinity is generally lowest (<33.5 Practical Salinity Unit, PSU) near the coast, highest (~34.6 PSU) in the subtropical water on the outer shelf and lower again (~34.3 PSU) in the subantarctic water beyond the shelf break. It is possible that marine dispersal of Stokell's smelt is limited to the Canterbury coast by the Southland Front preventing eastward movement, the Southland Current preventing dispersal to the south, and an offshore deflection in flow, when the Southland Current interacts with the East Cape Current, preventing dispersal to the north.

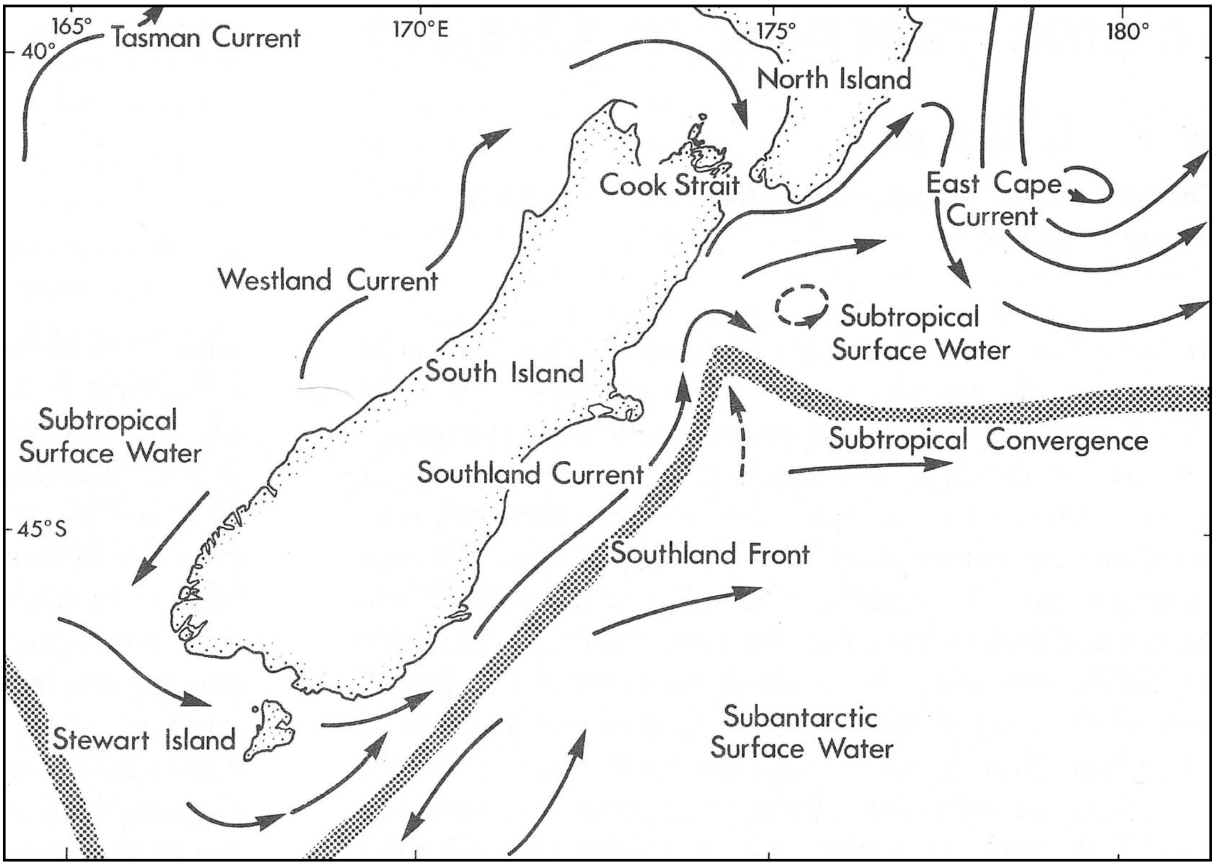

Figure 4-1: Pattern of currents and zones of convergence around the South Island. Adapted from Uchihashi et al. (1981).

4.1.2 Potential changes

There are two groups of mechanisms that could potentially disrupt the marine dispersal pathway of Stokell's smelt:

Changes in the coastal oceanographic environment

If the oceanographic configuration along the Canterbury coast limits offshore dispersal of the marine stages of Stokell's smelt, it is possible that fluctuations to this configuration may have caused, or allowed, larvae or adults to disperse away from the coast. Given that the known spawning sites for adults only include hāpua, adults must be nearshore when they are mature if they are to encounter riverine freshwater plumes that presumably lead them, like other diadromous species (McDowall and Eldon 1980), back to a river mouth. Furthermore, offshore advection could reduce growth and survival of larvae if they are dependent on specific nearshore food sources (Haywood 2004). Stokell's smelt appear to be an annual species (McMillan 1951). Therefore, a short-term change in the oceanographic configuration during a single larval period could produce marked reductions in future population sizes if it reduced larval survival or prevented the successful return of adults to a river mouth.

There are clear indications that the oceanographic configuration along the Canterbury coastline is not stable. The temperature and strength of the Southland Front are interannually variable and correlated with the El Niño-Southern Oscillation; they both decrease during El Niño and increase during La Niña events (Hopkins et al. 2010). Shaw et al. (1999) suggest that the occurrence of river plumes in the Canterbury Bight might also increase variability in the position of the Southland Front. If, as Uchihashi et al (Uchihashi et al. 1981) suggest, the Southland Front is a "*type of fence*" that limits dispersal of some diadromous fishes beyond the Canterbury Bight, it appears that the fence can move.

There is 10km wide coastal band in the Canterbury Bight in which the currents, temperature and salinity are quite variable because of freshwater input from rivers, and coastal upwelling and downwelling (Zeldis and Hadfield 2012). Newly hatched Stokell's smelt larvae emerging from river mouths will be entrained into the surface layer of this coastal band. The thin (2–5 m) surface freshwater layer (<25 PSU) drifts north-eastward but with substantial fluctuations that are largely wind driven (Zeldis and Hadfield 2012). With southerly or south-westerly winds, the coastal band narrows and can move quite quickly (within a few days) north-eastward along the coast of the Canterbury Bight and around the end of Banks Peninsula (Zeldis and Hadfield 2012). Consistent southerly winds when Stokell's smelt larvae are hatching and entering the coastal environment could produce coastal currents that transport larvae rapidly northwards (towards the point where the Southland Current deflects away from the Canterbury coast) before they develop the sensory or swimming abilities to swim against currents (Kingsford et al. 2002) or avoid them through vertical migration (Marliave 1986). Once again, even a short-term change in the oceanographic configuration during a single larval period could produce marked reductions in future population sizes if it reduced larval survival or prevented the successful return of adults to a river mouth. A short-term oceanographic change, acting synergistically with other factors, or longer-term changes could produce the reduction in the abundance of Stokell's smelt reported by Canterbury river users (Jellyman and Mayall-Nahi 2022).

Changes in river mouth characteristics

Stokell's smelt that successfully survive their marine phase and return to, or remain in, the nearshore environment are probably dependent on freshwater plumes to locate and successfully enter a hāpua. The freshwater plume at the mouth of even small rivers extends many kilometres into the coastal marine environment (Warrick et al. 2007). It is likely that Stokell's smelt, like other diadromous fishes, follow this plume of lower salinity water to locate the river mouth (McDowall and Eldon 1980). Any reduction in river flow will reduce the extent of the freshwater plume and reduce the likelihood of a Stokell's smelt encountering the plume. This could extend the marine phase of Stokell's smelt and increase the risk of predation or starvation.

Stokell's smelt rely on hāpua having an open outlet twice during their life history: as newly hatched larvae when they are carried out to sea by riverine flows and as adults when they move from the sea into a hāpua to spawn. McDowall (2010a) suggested that the absence of Stokell's smelt from smaller Canterbury rivers (e.g., Conway, Opihi, Pareora, Otaio, Makikihi, Waihao, and others) could be due partly to these smaller rivers often having blocked outlets to the sea during summer as a result of low flows – this happening at the time when Stokell's smelt are invading lowland rivers from the sea, and are present in vast numbers in the larger, lowland rivers of Canterbury (Davis et al. 1983; Eldon and Greager 1983; Bonnett 1992). Reduced flows can lead to hāpua closure if the seaward flows of freshwater are insufficient to maintain a channel through the beach berm (McSweeney et al. 2016). Hāpua closure directly impacts larval dispersal and access to the hāpua for adult Stokell's smelt. Anglers also perceived that in recent years outlets spend more time at the northern extent of hāpua (Jellyman and Mayall-Nahi 2022). This, coupled with more frequent hāpua closure, may produce a more diffuse freshwater plume as water seeps through often long beach berms. This diffuse plume may be less obvious or attractive to returning adults.

4.1.3 Next steps

The knowledge void surrounding the marine phase of Stokell's smelt makes it very difficult to quantify the potential for advection to disrupt dispersal pathways. Initially, there is a requirement for fundamental knowledge of the extent of larval dispersal away from known spawning locations. Hickford and Schiel (2003) showed that retropinnid larvae, including *Stokellia anisodon* (Dolphin 1997), are abundant between February and July in nearshore (<6 km offshore) Canterbury surface waters. These larvae can be captured using traditional plankton tows or with light traps (McMillan 1951; Hickford and Schiel 1999). A broad survey of the offshore and alongshore distribution of Stokell's smelt larvae that was centred on several major hāpua in Canterbury Bight and Pegasus Bay would generate significant knowledge around dispersal pathways. Although it is currently very difficult to visually differentiate between larvae and adults of the two retropinnid species, DNA analysis of sub-samples could be used to identify Stokell's smelt. Collections of genetically identified larvae may reveal morphometric differences between larvae of the two retropinnid species that would allow simpler, and cheaper, visual identification in the future. Collected larvae could also be used for growth and diet analysis (see below and Sections 4.2.3 & 4.4.3).

The importance of hāpua openings in the migration pathway of Stokell's smelt is obvious. Concentrations of migratory fish always attract predators. Thus, the closure or partial closure of a migratory pathway may not simply delay movement, it could result in mass mortality by stress and predation, above and beyond that which occurs naturally. Given the importance of this migratory pathway, it is essential to gather further knowledge around changes in the frequency and duration of hāpua closures and their relationship with river flow and marine and climatic parameters (*sensu* McSweeney et al. 2016). Fundamentally, this type of analysis relies on high resolution records of river mouth closures. While these data are collected at some river mouths by Fish and Game, broader surveys could be completed using citizen science. This could be achieved by issuing interested individuals with standardised diaries to record closure data in a uniform format or by providing an online portal for data entry.

Finally, an understanding of the complete life history of a species is essential for its conservation. Fundamental knowledge about age at maturity, growth variability and the influences of growth on condition and fecundity could be derived from collections of adult fish. Otolith analysis using modern microscopes and image analysis software, that were not available to McMillan (1951), will likely reveal daily increments. Analysis of daily otolith increments (*sensu* Egan et al. 2019) can be used to derive age and marine growth histories, and when coupled with morphometric measurements of mature fish can reveal legacy effects of marine development on condition and fecundity. Furthermore, microchemical analysis (*sensu* Hickford and Schiel 2016) or isotopic analysis (*sensu* Barnett-Johnson et al. 2008) of otoliths could reveal the natal origins of Stokell's smelt adults, or larvae caught at sea, which would further clarify dispersal pathways and provide data on sources/sink dynamics – it is possible that spawning from a few key rivers (e.g., Rakaia and Ashburton) sustains much of the metapopulation.

4.2 Habitat disturbance

The loss or degradation of a critical, stage-specific, habitat can cause significant declines in a population or species (Hickford and Schiel 2011). Hundreds of studies have examined the relative roles of habitat quality and connectivity in influencing the occurrence of species in fragmented landscapes (reviewed by Fahrig 1997, 2003; Prugh et al. 2008). Although commercial fishing activities disproportionately threaten large-bodied fish species, habitat degradation and loss are the main threats to smaller-bodied fishes (Olden et al. 2007; Ripple et al. 2017). Consequently, physical habitat alteration is the most frequently cited causal factor (73%) for the extinction of 40 species or subspecies of freshwater fish in North America over the last century (Miller et al. 1989).

For anadromous species such as Stokell's smelt (McDowall 1968), habitat degradation can occur during the marine phase or during freshwater spawning. For most anadromous species, the marine phase involves larger more diffuse habitats than the often-specific freshwater spawning sites. However, the restricted distribution of Stokell's smelt suggests that marine life stages are constrained in Canterbury coastal waters and thus their marine habitat is considerably smaller than that of most other diadromous fishes. In general, species with smaller geographic ranges are expected to be more vulnerable to extinction under rapid environmental change, due to limited ability to withstand stochastic environmental and demographic fluctuations (Lawton and May 1995); this has also been shown to apply to fish (Angermeier 1995).

4.2.1 Existing knowledge

Marine habitat

Water temperature sets the large-scale biogeographical distribution of most marine fishes, including the range where adults spawn. Similarly, seasonal changes in water temperatures affect the timing of reproduction in fishes such that increasing temperatures cue reproductive activity in spring-spawning species (Pankhurst and Munday 2011). Climate change will, or is already, affecting reproductive and early life history events of most fishes. This is occurring at a variety of levels and through a range of mechanisms that as our understanding develops are emerging as increasingly complex. These include the interplay of changes in physical variables with habitat, when in the reproductive cycle the thermal challenge occurs, the timing of spawning, whether events are extreme enough to initiate a physiological stress response, the energy status and reproductive age of the fish, and the thermal exposure history and adaptive capacity of the individual or the population.

Very little is known of the role Stokell's smelt's marine habitat plays in determining larval growth and survival because of the extremely limited collections of marine larvae (see Section 4.1.1). However, there is evidence of a cost to fecundity from later, or perhaps extended (the age of migrating adults is unknown), marine development. Several studies have described a decrease in the size of adults entering hāpua later in the spawning season (McMillan 1951; Eldon and Greager 1983; Eldon and Kelly 1985). Eldon and Greager (1983) noted a 10% reduction in the size of Stokell's smelt in the Rakaia Hāpua as the spawning season progressed; the mean size of females in late October was 85.6mm, but this decreased to 76.8mm by early April. Bonnett's (1992) length/fecundity relationship from the Rakaia Hāpua predicts this length decrease is associated with a 35% reduction in fecundity; 8099 eggs for a 85.6 mm female in October versus 5272 eggs for a 76.8 mm female in April. If egg survival is consistent throughout the spawning season, females that migrate and spawn earlier will have a considerably greater per capita reproductive output.

Hāpua habitat

The strong current at the mouth of most hāpua in Canterbury means even at high tide there is no saltwater intrusion (Eldon and Greager 1983). However, the water conditions within hāpua are far from stable, and it appears that there may be some association between the water conditions and the spawning migrations of Stokell's smelt. McMillan (1951) observed that when the Rangitata River was "*free of characteristic milkiness there was little or no sign of spawning fish*". However, Eldon and Greager (1983) did not observe the same association between turbidity and the abundance of Stokell's smelt in the Rakaia Hāpua; they caught high numbers when most sampling sites were "*clear*" (e.g., 21–21 January 1981) and extremely large numbers when most sampling sites were only "*moderately turbid*" (e.g., 9–11 December 1980). Interestingly, Rowe et al. (2002) found that common smelt are relatively intolerant of turbidity with survival significantly reduced at ≥2000 NTU. The Rakaia River is characterised by blue-grey turbidity throughout spring and summer (Eldon and Greager 1983) when Stokell's smelt migrate into the hāpua. Turbidity often exceeds 500 NTU, with peak turbidity of 3800 NTU measure at SH1 on 24 January 2019 (Land Air Water Aotearoa 2022).

Eldon and Greager (1983) surmised that although great numbers of Stokell's smelt enter the Rakaia Hāpua, it was doubtful whether the hāpua is important in their life history because they spawn in the river and would do so regardless of the presence of the hāpua. It is unclear how long Stokell's smelt spend in hāpua before spawning. McMillan (1961) describes spawning beginning "*immediately the shoals reach the stretches of river entering the* [Rangitata] *lagoon*". It is assumed that McMillan's findings for the Rangitata Hāpua are true of other Canterbury waterways. However, Eldon and Greager (1983) suggested that some Stokell's smelt captured in the Rakaia Hāpua "*appeared to be not fully mature and were possibly some days or weeks off spawning*". Bonnet (1992) suggested the duration of freshwater residence for Stokell's smelt in the Rakaia Hāpua "*may be variable*"; he collected many females that contained smaller eggs (0.2–0.4 mm Ø) than those in 'ripe' fish (0.6–0.7 mm Ø) implying that they had entered the hāpua "*well before they would have spawned*" (Bonnett 1992).

It is unclear if Stokell's smelt are reliant on feeding in the turbid waters of hāpua. McMillan (1951) noted that the stomachs of most of the spawning fish in the Rangitata River were empty, but some fish were found with "*amphipods, small beetles and insect larvae*" in their stomachs. Most (87%) of the 191 Stokell's smelt from the Rakaia Hāpua that were examined by Eldon and Greager (1983) had food in their stomachs. Fish had recently consumed a large variety of prey from the bottom, mid and surface of the water column. Ephemeroptera larvae were very common (15.6% by volume) in the stomachs of Stokell's smelt collected in the hāpua; these larvae may have been drifting in the water column having been displaced from further upstream.

Spawning habitat

Most current knowledge of the spawning habitat of Stokell's smelt is based on McMillan's work (1951, 1961) in the Rangitata River. McMillan (1961) describes the spawning location of Stokell's smelt as "*almost exclusively in fresh water above tidal influence*". Stokell's smelt have been collected further upstream in the Rakaia River; Davis et al (1983) captured 6500, mainly female (>94%), Stokell's smelt up to 6 km upstream of the hāpua over a 3-month period (November to January). However, these numbers are small compared to the high densities of Stokell's smelt (>100 fish m^{-2}) collected in the Rakaia Hāpua (Davis et al. 1983; Eldon and Greager 1983; Bonnett 1992).

The act of spawning for Stokell's smelt has not been observed. McMillan (1951) suspected that spawning might occur at night. Typical-sized spawning females in the Rakaia River (75–80 mm) contain between 4700 and 6300 eggs (Bonnett 1992), but it is not known whether females broadcast or brood spawn. However, unfertilised Stokell's smelt eggs have numerous oil globules throughout the yolk mass that coalesce, after fertilisation, to form one large oil globule (McMillan 1951). In freshwater fishes, oil globules within eggs provide buoyancy (Baras et al. 2018), so Stokell's smelt eggs may be, at least initially, buoyant. McMillan (1951) alludes to this by suggesting that "*a possible functional value of the larger paired fins* [of males] *in spawning is the stirring up of the bottom sediments of' the spawning bed in order that the adhesive surface of the eggs be well covered with sand grains and detritus, after which the eggs would sink more rapidly and be lightly covered, affording them good protection*". McMillan provides further evidence that the eggs are buoyant when he states, "*large numbers of developing eggs were obtained by disturbing the surface layer of silt and detritus and drawing a net through the water containing the suspended material*". Given that the act of spawning for Stokell's smelt has not been observed, and that fertilised eggs may be buoyant, developing eggs may accumulate in slower-flowing areas rather than these being the *only* spawning sites.

McMillan (1951) stated that spawning by Stokell's smelt in the Rangitata River was "*largely carried out in the slower-flowing, silt-bottomed reaches of small side streams from hightide mark to about half a mile* [800 m] *upstream. Some fish spawned in the upper parts of the lagoon which were within reach of tidal influence, but the majority of migrants spawned in parts of the streams situated from about fifty to two hundred yards* [45–183 m] *above the lagoon. The most favoured type of spawning area appeared to be the small partial backwaters situated where a piece of old stream bed angled into the new course*". However, it appears that this was based entirely on finding developing eggs and spent, or partially spent, fish in these areas rather than on direct observations of spawning. McMillan (1951) states that "*a thorough investigation of all other possible spawning sites was carried out with negative results*". However, it is possible that at least some Stokell's smelt broadcast spawn in faster-moving water in riffles and runs, with some eggs adhering to nearby cobbles and rocky substrate and others floating downstream before settling in slower-flowing areas or in the hāpua itself.

McMillan (1951) suggested that severe flooding of the Rangitata River probably caused destruction of developing eggs. He noted that after floods the "*spawning beds were covered with a thick layer of silt*" or left dry due to a change of course of the side-streams. McMillan (1961) also suggested that apart from floods, "*the greatest agent in the destruction of* [Stokell's smelt] *eggs*" was trout fishermen. He thought that while netting the spawning grounds to collect adult Stokell's smelt ("*silveries*") for bait, they probably trampled developing eggs deep into the mud, or freed them to be washed out to sea.

No studies have investigated the effects of sediment deposition on the development and survival of Stokell's smelt eggs. Coarse substrates and associated interstitial spaces are particularly important for many native species that use the streambed for nesting (McDowall 1990a), but this may not be the case for Stokell's smelt; McMillan (1961) reported that Stokell's smelt favoured silt-bottomed sites for spawning.

The effects of algal mats on the development and survival of Stokell's smelt eggs are also unknown. However, Stephens (1984) found the greatest densities of eggs of lacustrine common smelt in loose, clean sand at river mouths; he found no eggs where algal mats covered the sand.

4.2.2 Potential changes

Marine habitat

Pinkerton et al. (2019) observed an increase in coastal sea surface temperatures (SST) in Canterbury between 1981 and 2018: specifically, a period of cooling between 1990–1994 was followed by a rapid temperature rise between 1994–2000, and then more gradual warming between 2010–2018. Although this same trend occurred in most regions around New Zealand, Canterbury coastal waters are warming at a considerably faster rate (0.24°C per decade) than the country-wide average (0.20°C per decade). Unlike other regions, increasing coastal SST in Canterbury was not associated with a reduction in coastal primary productivity (Pinkerton et al. 2019). However, the consequences of these ongoing changes on higher trophic levels in the coastal marine environment are unknown.

For most fishes with a bipartite life cycle, successful completion of their marine larval phase requires a complex balance of interrelated factors including food availability, growth rate, predator avoidance and favourable advection (Blaxter 1974). Generally, survival of fish larvae is poor during the early life stages (Bisbal and Bengtson 1995; Yang 2007). Fish larvae are particularly vulnerable during the transition period from consuming endogenous reserves (yolk-sac and oil globule(s)) to exogenous energy supplies. Food availability at this critical time is crucial because starvation can lead to high larval mortality (Bisbal and Bengtson 1995; Kohno et al. 1997; Gisbert et al. 2004; Peña and Dumas 2005). Hjort (1914) was the first to suggest that cohort strength in marine fish was determined by the availability of suitable prey for larvae during a critical development stage. After yolk resorption, planktonic fish larvae, which have not yet fully developed their foraging abilities and are most vulnerable to starvation (Houde 1974; Dou et al. 2002), often depend on copepod eggs and nauplii as their first major prey item. In turn, the production of copepods is linked to the production of their major food source, diatoms. Cushing (1974, 1975) modified Hjort's critical-period concept into the Match/mismatch Hypothesis that proposes that variations in cohort strength are rooted in the constancy of the spawning time(s) of fishes in relation to temporally variable phytoplankton blooms.

The rapid increases in coastal SST in Canterbury described by Pinkerton (2019) may cause non-linear responses that unbalance established patterns of synchrony in the marine planktonic environment; this would be a consequence of different species reacting dissimilarly (Durant et al. 2007). All components of a food chain cannot be expected to shift their phenology at the same rate, and thus different trophic levels are unlikely to remain synchronous. This asynchrony could have major consequences for Stokell's smelt, an anadromous species that spends most of its life history in a very small area of marine habitat.

Hāpua habitat

Unlike most estuaries, hāpua do not experience a diurnal exchange of tidal waters because of strong riverine currents and their irregular connection to the ocean (Shulmeister and Kirk 1993). Hāpua habitats can become further isolated when freshwater flows are insufficient to maintain a channel through the beach berm (Hart 2009). The longer the duration of closure, the greater the adverse effects upon lagoon water quality, due to an increased residence time of waters (Todd 1983; Kirk 1991). Prolonged closures are more common when river flows are low (McSweeney et al. 2016).

Sustained mouth closure during low flow periods is a primary management concern as it is associated with decreased water quality, impedance of fish passage (see Section 4.1.2), and flooding (Zenkovich 1967; Kirk and Lauder 2000). Nearly all hāpua exist on rivers with hydrology that has been modified through irrigation abstraction that has led to changes in entrance morphodynamics and closure frequency. However, in many hāpua, flows are maintained above minimum thresholds to minimise the adverse effects of mouth closure on water quality.

Many hāpua on eroding coasts are unable to maintain their surface areas through parallel landward shore and barrier retreat (Hart 2009). Photographs of the Ashburton and Rangitata Hāpua show the landward shores of these hāpua have barely eroded over the last century, but barrier retreat has resulted in the loss of up to half their water surface areas (Todd 1998; Hart 1999). Similarly, the area occupied by the Opihi Hāpua has reduced by two thirds since 1866 due to barrier retreat plus landward-shore stability, and stopbank construction to truncate the length of the hāpua (Todd 1983). The potential effects of a reduction in hāpua water quality or surface area on Stokell's' smelt migration and spawning are unknown.

Spawning habitat

A thin layer of sediment attached to the strongly adhesive outer membranes of Stokell's smelt eggs (McMillan 1961) may assist with camouflage and reduce predation (see Section 4.3.1). However, McMillan (1951) identified that increased levels of sediment deposition, associated with large floods, could smother a spawning bed. Stokell's smelt appear to favour spawning in "*silt-bottomed reaches of subsidiary streams where the current is slight*". Smothering sediment could prevent adequate gas exchange for developing embryos or hatching larvae from accessing the water column. Sediment smothering could also lead to increased predation from benthic infauna.

There is little long term data on which to gauge whether suspended or deposited sediment levels have changed in the rivers where Stokell's smelt spawn. Water abstraction and climate change have modified flow volumes and patterns, but the interaction of these factors with sediment transport and deposition are complex and probably catchment specific.

Anecdotally, there is a widely held belief that fine sediment levels have increased in several Canterbury rivers with hāpua at their mouths (Jellyman and Mayall-Nahi 2022). Most respondents presumed an apparent reduction in large floods, and a concomitant increase in low flows, had resulted in less transport of sediment and greater deposition with river channels. Many survey respondents also believed that a reduction in flood events and flow, together with mouth closures, had led to increased levels of algae/periphyton.

4.2.3 Next steps

As stated in Section 4.1.3, there is a primary need to gain insight into the influences of marine habitat and larval development on the age, growth, condition, and fecundity of mature Stokell's smelt entering hāpua. This could be achieved by taking small samples of migratory fish entering hāpua throughout the spawning season. These samples could be used for simple analysis of the effects of larval growth (determined from otolith analyses) on condition and fecundity, and how each of these parameters varies with the time and duration of marine larval development.

With most diadromous species, it is difficult to correlate larval development patterns with oceanic conditions because of unknown individual marine dispersal pathways (see Egan 2017; Egan et al. 2019). However, the small geographic distribution and presumably limited marine dispersal of Stokell's smelt may enable such analysis for this species. It is likely that all Stokell's smelt larvae develop in Canterbury coastal waters. Thus, it is possible that remote sensing data (satellite imagery) detailing temporal variations in sea surface temperature and primary productivity in Canterbury coastal waters could be linked directly with individual larval growth profiles obtained by analysing the otoliths of migrating adults.

There is an immediate need to locate and characterise the spawning site(s) of Stokell's smelt in any Canterbury rivers where they spawn. This needs to be achieved through direct observations of spawning rather than being derived from the distribution of developing eggs. The influence of sediment deposition, water temperature and dissolved oxygen levels on egg development, embryo survival and larval hatching needs to be determined through *in situ* and tank-based research and experiments. Turbidity and sediment deposition is easily replicated and controlled in tank-based experiments (e.g., Rowe and Dean 1998; Rowe et al. 2002; Sear et al. 2016), and these could be used to establish critical thresholds for successful egg survival and larval hatching. It is also important to determine whether Stokell's smelt eggs are buoyant; there is the potential for many eggs to be lost to sea if fine sediments or algal mats prevent the eggs from adhering to cobble substrate.

4.3 Predation

Stokell's smelt are a short-lived, small fish; most mature adults are <100 mm long (Eldon and Greager 1983). As such, it is likely that they never become large enough to reach a size refuge from most potential predators. Their relatively long pelagic phase exposes them to many potential predators, but it is likely that predation is focussed on phases when their densities increase (i.e., when pre-spawning shoals gather near river mouths or in hāpua) or when they are sedentary as developing eggs.

4.3.1 Existing knowledge

Predation of marine life stages by fishes

There are many coastal fish species that probably consume the marine life stages of Stokell's smelt. Newly hatched larvae are positively phototactic, so it is likely that, at least initially, they are epipelagic (McMillan 1951). Likely predators of small fish in surface waters along the Canterbury coast include kahawai (*Arripis trutta*), barracouta (*Thyrsites atun*) and yellowtail jack mackerel (*Trachurus novaezelandiae*). These predatory species occupy a range of depths, but all form schools that feed on small fishes at the surface (McMillan et al. 2019).

Kahawai feed on adult Stokell's smelt near, and in, hāpua (see Section 4.3) and it seems likely that they use them as a food source throughout their marine phase. However, the specifics of the diet of kahawai in New Zealand coastal waters are not well known; the earliest information is Thompson (1892) who stated that "*small fish is the most frequently recorded food*". Graham (1956) examined many kahawai stomachs from Otago and found that "*pilchards, sprats, garfish, āhuru, mullet* [Aldrichetta forsteri]*, warehou, horse mackerel and even small ones of their own kind*" were common components of their diet. Doogue and Moreland (1960) stated that kahawai eat "*other fishes, usually yellow-eye mullet, pilchards, anchovies, smelts, and fresh-water bullies as well as its own kind*". In the most detailed study to date, Baker (1971) studied the stomach contents of kahawai (40–517 mm fork length) from Wellington Harbour (326 fish) and the Bay of Islands (20 fish). Although kahawai fed on a variety of small fishes (nine species from nine families), they appeared to take those species that were most abundant at the time: anchovy (*Engraulis australis*) in Wellington and pilchards (*Sardinops sagax*) in the Bay of Islands. Baker (1971) found no smelt in kahawai stomachs.

Small fishes (e.g., sprat, *Sprattus antipodum* and *S. muelleri*, and pilchard are an important component of the diet of barracouta in Otago coastal waters (O'Driscoll 1998), but this is especially true of fish feeding individually rather than in schools. In a large-scale Australian study (10,000 fish) anchovy (*Engraulis australis*), sprat (*Clupea bassensis*) and pilchard (*Sardinops neopilchardus*) were "*important items*" in the diet of barracouta (Blackburn 1957). Both studies mentioned that other fish species were present in stomach contents, but identification was very difficult.

Studies on yellowtail jack mackerel in Fiordland (Thompson 1892), Otago (Graham 1939, 1956) and the Hauraki Gulf (Godfriaux 1970) reported that pilchards, sprats, and conspecifics dominated the diet. Parrott (1957) and Doogue and Moreland (1960) reported a similar range of fishes in the diet, and both implied that mackerel feed more in mid-water than on the bottom.

If, as McMillan (1951) predicted, Stokell's smelt become bathy-pelagic as post-larvae, there is a range of species present on the Canterbury coast (including the species discussed above) that might include them in their diet. Rattails (*Caelorinchus* spp.), seaperch (*Helicolenus percoides*) and hapuku (*Polyprion oxygeneios*) are all abundant in Canterbury Bight and Pegasus Bay (Beentjes et al. 2002) and all are known to feed on small fishes (Francis 1988; McMillan et al. 2019).

Predation of adults near/in hāpua

There is little doubt that the enormous shoals of mature Stokell's smelt ('silveries') that enter river mouths and hāpua during their long spawning season play a "*most important part in the ecology of the river mouth region*" (McMillan 1961). As an appendix to his thesis, McMillan (1951) detailed the "*natural enemies*" of silveries at the mouth of the Rangitata River. McMillan suggested the progress of a shoal of Stokell's smelt towards the river mouth "*is largely determined by the activity of the white-fronted terns (Sterna striata striata), for they continuously circle and hover above the shoal, diving when the opportunity of a catch arises*". Then, as the shoal approaches the mouth, "*schools of kahawai may be seen feeding on the silveries*" and following them into the mouth (McMillan 1961).

White-fronted terns are the first of several bird species that prey heavily on Stokell's smelt as they enter the confines of the hāpua. The terns have large nesting areas on the landward side of the shingle barriers of hāpua and use the smelt to feed their fledglings (McMillan 1961). Nitrogen isotope values for white-fronted terns suggest a diet dominated by fish during feather growth (Rayner et al. 2021). These data are consistent with a range of studies, confirming the importance of larval and small fishes in the diet of this species taken predominantly by surface seizing and shallow dives (Higgins and Davies 1990). Higher $\delta^{13}C$ values for white-fronted terns are consistent with observed estuarine and inshore foraging habitats for this species (Higgins and Davies 1990; Bräger 1998).

As shoals of Stokell's smelt enter the confined river mouth, black-billed gulls (*Chiroicocephalus bulleri*) and black-backed gulls (*Larus dominicanus*) vie with one another for fishing sites along the banks (McMillan 1961). As the shoals of smelt swim through the narrow mouth, the gulls periodically rush in from the water edge in pursuit of fish that have strayed too close (McMillan 1951). McMillan (1951) suggested that once the shoals had moved into the deeper and quieter water of the hāpua, bird predation was minimal until they entered the shallow rapids that connect the river with the lagoon. He felt that that the greatest reduction in migrant numbers occurs in the shallows where spawning occurs (see Section 4.2.1); "*from the time the leaders enter the shallows, large flocks of black-billed gulls mill about feeding voraciously*" (McMillan 1951). McMillan (1951) also listed black-fronted terns (*Chlidonias albostriatus*) and southern skuas (*Stercorarius antarcticus*) as avian predators of Stokell's smelt in hāpua.

Despite the prevalence of avian predators, McMillan (1951) suggested that "*in the region of the river mouth, the greatest aquatic enemy of the silvery* [Stokell's smelt] *appears to be the* [brown] *trout.*" He stated, "*during the spawning season of the silvery, it is the rule that the stomach contents of captured* [brown] *trout consist wholly, or almost wholly, of silveries.*" McMillan (1951) provided evidence of the stomach of a 1.5 kg female brown trout containing 65 adult Stokell's smelt and commented that that fish was still actively feeding because it was caught on a lure that mimicked a smelt. Eldon and Greager (1983) found that fish (mainly "*smelt*") comprised 42.8% by volume of the stomach contents of 47 brown trout collected in the Rakaia Hāpua with food in their stomach. Rutledge (1991) sampled 13 sea-run brown trout (mean length 525.8 mm) from the Waitaki River mouth in 1986. He observed that their diet was composed almost entirely of smelt (mostly Stokell's smelt) during spring and summer, but that "*other forage fish (such as mullet and whitebait) feature importantly in the diet at other times of the year*". Anglers have also stated that brown trout often 'force' shoals of Stokell's smelt to the surface where the trout could more effectively capture them (Jellyman and Mayall-Nahi 2022). However, this also makes the shoals of smelt more accessible to avian predators.

Once past the river mouth, McMillan (1951) suggested that eels prey heavily on Stokell's smelt "*in the region of the spawning beds particularly, as revealed by examination of the stomach contents of the eels captured at night by torch-light*". He also suggested that "*yellow-eye mullet and even the river flounders and large gobies, capture silveries at times*" in the Rangitata River (McMillan 1951). However, a study in a nearby estuary, where Stokell's smelt are uncommon but where there are many other small fishes, showed that fish comprised <1% of the diet of yellow-eye mullet (Webb 1966, 1973). Eldon and Greager (1983) found that fish comprised 1.6% by volume of the stomach contents of only one yellow-eye mullet out of 84 fish collected in the Rakaia Hāpua with food in their stomach; Mollusca comprised the largest volume (56.0%) in most yellow-eye mullet stomachs (59.4%).

Predation of eggs

McMillan (1951) suggested that the large, paired fins of male Stokell's smelt are used to stir up deposited sediments during spawning so that the adhesive surface of eggs are covered with sand grains and detritus to help them sink and afford them some camouflage. However, given their abundance and lack of defences, it is likely that eggs are at some risk of predation during their 8–21 day development (McMillan 1951, 1961).

The eggs of land-locked common smelt are preyed on heavily by bullies around lake margins (Stephens 1984). The spawning sites of land-locked common smelt are sand bars at the mouth of tributary streams; they are analogous to the hāpua sites used by Stokell's smelt.

McMillan (1951) observed that "*although gobies, and occasionally torrent fish (Cheimarrichthys fosteri) were netted in the spawning grounds there was no evidence to show that these fishes ate the eggs*". It is likely that the "*gobies*" that McMillan caught near the spawning grounds in the Rangitata Hāpua were common bully (*Gobiomorphus cotidianus*) because these are the most widespread and abundant bully species in and near hāpua in the Canterbury Bight (Eldon and Greager 1983; Sagar and Eldon 1983). Sagar and Eldon (1983) found that fish eggs (unidentified) comprised 9.6% of the diet of common bully near the Rakaia Hāpua in spring; fish eggs were <0.1% of the diet of torrentfish in the same area. There was also evidence that common bully actively sought fish eggs because they ate proportionally more eggs than occurred in the benthos (Sagar and Eldon 1983). It seems very likely that common bully consume large numbers of Stokell's smelt eggs in hāpua during spring.

4.3.2 Potential changes

McMillan (1951) stated "*it is apparent that only a small proportion of each shoal of migrants (Stokell's smelt) actually survive to spawn*". Clearly, even as early as 1951, predation has a strong influence during some stages of the life history of Stokell's smelt. Unfortunately, the only knowledge of predators and predation levels is near/within hāpua, and this knowledge is rudimentary at best.

The relatively long marine phase of Stokell's smelt exposes this species to considerable risk of predation. It is entirely feasible that even a short-term change in marine predation levels could significantly reduce the abundance of reproductive adults and future cohort sizes. However, the black box that surrounds the marine phase of this species coupled with a lack of fundamental knowledge of the population dynamics of this species precludes any suggestion that increased marine predation may have reduced the abundance of Stokell's smelt.

In eastern Australia, the diet of kahawai has undergone a dramatic shift from one dominated by euphausiids (i.e., *Nyctiphanes australis*) historically to baitfish today (Hughes et al. 2013). Consequently, *A. trutta* have a top-down influence on the pelagic ecosystem of coastal south-eastern Australia via consumption of ~15% of the spawning biomasses of its major prey species (i.e., small pelagic fishes; Hughes et al. 2014). No data are available to determine whether kahawai in New Zealand coastal waters have had a similar switch in diet such that they are now consuming more Stokell's smelt.

4.3.3 Next steps

There is a clear need for data on predation of Stokell's smelt during marine life stages, during hāpua entry, during spawning and during egg development. Basic data could be gathered by simple gut content analysis of likely predators (e.g., kahawai, barracouta, yellowtail jack mackerel, sea-run brown trout, common bully and torrentfish). This, coupled with DNA analysis of fish remains or eggs in stomachs would provide fundamental knowledge of predators and consumption rates. The diet of adult birds and chicks in nearby nesting colonies could also be investigated using gastric lavage to obtain stomach samples (Barrett et al. 2007). This information would establish and quantify the flow of marine-derived energy from adult Stokell's smelt to the freshwater and terrestrial systems. It would also highlight the vulnerabilities associated with the loss of Stokell's smelt and these marine subsidies.

Quantifying survival rates of Stokell's smelt during mobile life stages is logistically very difficult. However, surveys of developing eggs using marked quadrats and repeated counts could be used to determine egg survival rates. These repeat surveys would need to be limited to short intervening periods to minimise losses from hatching, or gains from ongoing spawning. *In situ* or tank-based experiments could be used to investigate predation by fishes. These experiments could use cages to protect developing eggs from potential predators. Completing these experiments in tanks would minimise the risk of hatching and spawning confounding the results.

4.4 Competition

Competitive interactions and resource partitioning facilitate species' coexistence in complex ecosystems. Exploitative competition is a form of interspecific competition in which one species consumes and reduces or uses a shared limiting resource more efficiently, and therefore depletes the availability of the resource for the other species. Individuals within the same species have very similar resource requirements, so the intensity of intraspecific competition is strongly related to population density. Intraspecific competition can result in reduced resource acquisition and diminished individual growth and development rates, which in turn may lead to increased mortality.

4.4.1 Existing knowledge

Inter- and intra-specific competition could affect cohorts of Stokell's smelt during their marine life stages or once they re-enter a hāpua to spawn.

Competition during marine life stages

Newly hatched Stokell's smelt larvae have a small yolk sac with a single oil globule (McMillan 1961). The larvae of lacustrine populations of common smelt are slightly smaller than Stokell's smelt larvae (Ward et al. 1989) and they exhaust their yolk sacs 1–2 days post-hatching (Jolly 1967); diadromous common smelt larvae are similar in size to Stokell's smelt larvae and exhaust their yolk sacs after 8–10 days (Ward et al. 1989). It is not known how long the limited endogenous energy reserve of Stokell's smelt lasts but once it is exhausted, larvae must commence feeding. At that time, they may face intraspecific and/or interspecific competition for exogenous food sources.

The prolonged reproductive period of Stokell's smelt (Bonnett 1992) has been described as a "bet-hedging" (Lambert and Ware 1984) or "ubiquitous" (Sherman et al. 1984) strategy. It is likely to be adaptive in localities where prey supply is erratic (Sherman et al. 1984). The only South Island study of the temporal distribution of marine fish larvae found retropinnid larvae (probably both *Stokellia anisodon* and *Retropinna retropinna*) in Kaikoura coastal waters from mid-summer to mid-winter (Hickford 2000; Hickford and Schiel 2003). Across two years, small retropinnid larvae (6.5 mm) appeared in January and the mean size of larvae increased through until June. Very small retropinnid larvae were still being captured further offshore in June, suggesting some spawning was still occurring in late May. Most other common taxa (e.g., sprats, scorpaenids, yellow-eye mullet, triplefins and flounders) had larval abundance peaks in spring or summer or both; these species have a 'synchronous' strategy where peak larval production coincides with spring and autumn phytoplankton and zooplankton blooms (Grieve 1966). Retropinnids (and galaxiids) appear to use an "early" strategy (Haldorson et al. 1993) whereby larvae are produced throughout and after the autumn plankton blooms but prior to the spring bloom. Although risky in terms of securing adequate food supplies over winter, this strategy may offset their marine phase from many other species and thus reduce interspecific competition for food.

For food competition to influence early life survivorship, larval fish would need to exert a significant grazing pressure on the abundance of their prey (Pepin and Penney 2000). Larval fish are generally considered to be part of the heterotrophic marine food chain, whereby phytoplankton are consumed by herbivorous zooplankton, which in turn are eaten by larval fish, which are preyed upon by carnivorous plankton or larger fish. Diet analysis across many species shows that naupliar and copepodite stages of herbivorous copepods are the predominant prey for most fish larvae (Last 1978a, b; Pepin and Penney 1997; Pepin and Penney 2000). However, the diet of many larval fishes with straight guts (e.g., herring, capelin, flounder anchovy, and sardines) includes significant components of phytoplankton and heterotrophic protists from the microbial loop (Pepin and Dower 2007). After hatching, Stokell's smelt have a small gape and a very long, straight, alimentary canal (McMillan 1961). In many fishes the relative intestine lengths of herbivores are larger and more variable than those of omnivores, which in turn are larger and more variable than those of carnivores (Kramer and Bryant 1995). It is possible that the diet of Stokell's smelt larvae includes a significant phytoplankton component. If that is the case, their relatively unusual diet would reduce competition with other ichthyoplankton for zooplankton as a food source.

Competition in hāpua

The uncertainty surrounding the length of time that Stokell's smelt spend in hāpua prior to spawning (e.g., McMillan 1951; Bonnett 1992) makes it difficult to gauge whether competition for resources (e.g., food) could occur during this phase. McMillan (1961) described spawning commencing immediately after shoals of migrating fish cross the hāpua and encounter the river. Bonnett (1992) suggested that the duration of freshwater residence may be variable, but that "*some smelt remain in freshwater for weeks, or even months*" before being ready to spawn.

Regardless of the duration of freshwater residence, it appears that some Stokell's smelt may feed while in hāpua. McMillan (1951) noted that the stomachs of most Stokell's smelt in the Rangitata Hāpua were empty, but some fish had been feeding on amphipods, beetles, and insect larvae. Eldon and Greager (1983) recorded those same components in the stomach contents of fish from the Rakaia Hāpua, but also noted that "*vegetation debris*" was the most common item (36.3% proportion by volume) in most (77%) of the 166 specimens. Eldon and Greager (1983) noted that stable areas of the Rakaia Hāpua supported a rich invertebrate fauna among the macrophytes and in the water column, but unstable areas with a shifting bed were extremely sparse in food organisms. It is possible that the very high densities of Stokell's smelt (>100 fish m^{-2}) recorded in some areas of hāpua (Davis et al. 1983; Eldon and Greager 1983; Bonnett 1992) could reduce food resources at a local scale. However, it seems likely that the mobility of shoals, coupled with strong currents and a ready supply of drift from the river would quickly replenish food supplies.

The exact mode and location of spawning of Stokell's smelt is unknown. It is likely that the great abundances of Stokell's smelt in spawning aggregations together with the high proportion of males (Eldon and Greager (1983) found that males outnumbered females by 2:1 across many samples) causes intraspecific sperm competition. Common smelt are also present in hāpua during the Stokell's smelt reproductive period but are usually much less abundant (Eldon and Greager 1983; Bonnett 1992). The breeding biology of common smelt is very similar to that of Stokell's smelt (McMillan 1961; Jolly 1967; Stephens 1984; Ward et al. 1989), so the possibility of hybridisation and interspecific sperm competition does exist. However, when McMillan (1961) cross-fertilised Stokell's smelt eggs with milt from common smelt, abnormal cell division preceded the death of all embryos.

4.4.2 Potential changes

Any significant changes to the planktonic communities in the coastal marine zone occupied by Stokell's smelt larvae could alter ecological interactions such as intra- or inter-specific competition. As outlined in Section 4.2.2, Pinkerton et al (2019) described a rapid increase in coastal SST in Canterbury between 1981 and 2018. Unlike other regions, increasing coastal SST in Canterbury was not associated with a reduction in the concentration of coastal chlorophyll-a (Pinkerton et al. 2019). However, although chlorophyll-a is ubiquitous in phytoplankton, and is useful as a proxy for phytoplankton biomass (Gordon et al. 1988; Hooker et al. 1992; O'Reilly et al. 1998), it is not indicative of sub-surface phytoplankton biomass (Aiken et al. 1992; Campbell et al. 2002) nor is it likely to detect changes in community composition. If Stokell's smelt larvae do not occupy surface waters during/throughout their marine phase, or if they are dependent on a particular component of the planktonic community as a food resource, remote sensing of chlorophyll-a may not detect important changes. Additionally, even subtle changes in the timing of seasonal phytoplankton blooms could dramatically alter food resources availability and ecological interactions.

It appears that some Stokell's smelt adults may have an extended freshwater residence in hāpua presumably while their gonads develop (Bonnett 1992). During this time, they must feed to supply and replenish energy resources that being diverted to gonadal development. It is possible that if food resources within the hāpua were diminished that inter- and intra-specific competition could intensify. This may result in fewer early arriving fish surviving sufficiently long to mature and spawn.

If a decrease in the abundance of Stokell's smelt in hāpua is accompanied by an increase in the abundance of common smelt, it is possible that sperm competition dynamics could change to favour fertilisation of Stokell's smelt eggs by common smelt males. The subsequent increase in unviable hybrid embryos (McMillan 1961) could severely reduce reproductive output.

4.4.3 Next steps

Genetically identified Stokell's smelt larvae collected during the sampling program suggested in Section 4.1.3 could also be used for an investigation of their diet during the marine phase. When coupled with plankton samples and dietary analysis of other ichthyoplankton caught concurrently, this would provide fundamental knowledge of prey preferences, availability, and the potential for competition during the marine phase.

Collections of adult Stokell's smelt within hāpua could provide otoliths for microchemical analysis to ascertain the duration of freshwater residence and associated growth profiles. Parallel analyses of stomach contents and stable isotope values in muscle tissue could be used to determine the prevalence of feeding during freshwater residence and prey preferences. A more comprehensive analysis of the structure of the hāpua food web would be needed to determine the potential for competition for food resources.

As suggested in Section 4.2.3, there is an immediate need to locate key spawning sites for Stokell's smelt and to observe the spawning process. Sampling and species identification of spawning fish would reveal the risk of hybrid fertilisation and potential threats to reproductive output.

4.5 Disease

Parasites occur naturally and frequently in the aquatic environment. There are 10 billion viruses per litre of seawater (Fuhrman 1999), although not all of them can cause disease. Parasites are the most abundant organisms in the marine environment and parasitism is the most common lifestyle (Lafferty and Harvell 2014). Parasites impact individuals, by affecting fitness components such as growth and reproductive success (Howell 1967), and populations, by lowering the abundance or density of host species (Cranfield et al. 2005).

Marine disease has received little attention in New Zealand (Lane et al. 2022) or globally (Lafferty and Hofmann 2016). In fact, a 2018 survey of researchers and decision-makers across the New Zealand marine science community did not consider marine diseases to be a research priority (Jarvis and Young 2019)

Disease and parasites mostly go unnoticed in the aquatic environment until a large disease outbreak draws attention from scientists and media alike. A herpes virus that emerged in Australian and New Zealand 'pilchards' (*Sardinops sagax*) in 1995 killed 70% of the pilchard population (Jones et al. 1997). Rafts of floating dead fish up to 10 km long and piles of fish washing ashore occurred along 500 km of the New Zealand coastline (Jones et al. 1997). Affected fish died with clinical signs of respiratory distress and were diagnosed to be infected with a novel herpesvirus, later named pilchard herpesvirus (PHV) (Hyatt et al. 1997).

Disease is caused by parasites, but the presence of a parasite does not necessarily equate to disease. At any one time an animal is likely to be affected by one or many parasites but still be perfectly healthy. Disease is largely governed by the interaction of three factors: the host, the parasite, and the environment (Snieszko 1974). A disease outbreak occurs when one of these factors shifts. A shift may come in the form of pathogenicity or virulence of the parasite. Alternatively, the host may become more susceptible (e.g., immunocompromised), or the environment becomes more stressful for an organism, moving it beyond the bounds of its ability to adjust. Stress may negatively impact the host and/or parasite, but when it negatively impacts the host, the host may become more susceptible to infection.

4.5.1 Existing knowledge

McMillan (1951) found most Stokell's smelt migrating into the Rangitata Hāpua were "*relatively free of parasites*". However, he noted that the occasional poorly conditioned adult fish carried large numbers of parasites "*in the gut and body cavity*" (McMillan 1951). Although admitting that his collections amounted to an "*incomplete record*", McMillan (1951) found that ovaries of late season migrants were smaller, "*possibly due to much heavier infestation of parasites in the body cavity and alimentary canal*" (McMillan 1951). However, no detail was provided as to the type or diversity of parasites that were present.

The nematode *Hedruris spinigera* is a common parasite of New Zealand (Baylis 1931; Brunsdon 1953; Hewitt and Hine 1972; Hine 1980; Jellyman 1989) and Australian (Johnston and Mawson 1940) teleost fishes in marine, brackish and freshwater environments. Stokell (1936) found that common smelt and yellow-eye mullet in Lake Ellesmere were heavily infested with *Hedruris*. He suggested that brown trout "*become infested with Hedruris only when in the same water as* [common] *smelt*" and the parasite is merely transferred to trout when smelt are taken as food. It is very likely that *Hedruris* also parasitises Stokell's smelt.

Phyllobothriid tapeworms have been found in the stomachs of anadromous brown trout and common smelt collected at the mouth of the Rakaia River (Dix 1968). The same tapeworm species, four species of flatworm and a nematode species were found in the gastrointestinal tract of pre-spawning Chinook salmon collected in the Rakaia River (Margolis and Boyce 1990). Dix (1968) suggested that plerocercoids (the infective larval form of tapeworms) "*may be of common occurrence in local teleosts*" at the mouth of the Rakaia River; this is likely to include Stokell's smelt.

4.5.2 Potential changes

Baseline data for aquatic disease is virtually non-existent, which makes it difficult to forecast, track and mitigate disease emergence. Parasites and disease are natural parts of the ecosystems that Stokell's smelt traverses during its life history. However, climate change, invasive species and pollution can alter host and parasite ecology and the co-evolved interactions between them, changing disease dynamics, that can lead to ecosystem changes (Marcogliese 2008). New Zealand's borders are busy through commerce (MPI 2019), providing a constant supply of adventive species, and the marine environment continues to change (Law et al. 2018). Each of these could alter disease dynamics with ecological consequences for native species (Harvell and Lamb 2020), especially those with a restricted geographic range such as Stokell's smelt.

4.5.3 Next steps

McMillan's (1951) basic observations are the only data available on the frequency and consequences of parasites and disease in Stokell's smelt. Longitudinal collections of migratory fish suggested elsewhere in this report (Sections 4.1.3 and 4.2.3) should be used to investigate the frequency and diversity of parasite infestations and consequential disease, and how this varies across the spawning season and among rivers. McMillan (1951) alluded to a negative association between parasite load and fecundity in female Stokell's smelt. Collections of adult fish could be used to refine the fecundity/length relationship developed by Bonnett (1992) such that it can be used to investigate the effects of parasite infestation on egg production.

5 Conclusions

The restricted geographic range, and short, diadromous life history of Stokell's smelt increase their exposure to, and risk from, significant drivers of population decline. Advection, habitat disturbance, predation, competition, and disease could each have significant impacts on marine and/or freshwater life phases. Furthermore, the annual, semelparous life history of Stokell's smelt provides little spatial or temporal buffering against major changes to population dynamics; apart from the overlap between early-hatching larvae and late-spawning adults, there is only ever one cohort present in the metapopulation.

It is not possible to pin-point exactly when Stokell's smelt populations began to decline; the baseline abundances of Stokell's smelt in the Rakaia Hāpua were completed 40 years (and 40 cohorts) ago (Eldon and Greager 1983), and there has been little work on the species in the intervening years. However, anecdotal reports suggest the most drastic decline has occurred quite recently (Jellyman and Mayall-Nahi 2022). This knowledge gap makes it very difficult to correlate environmental change with Stokell's smelt abundance data; this means there are many potential drivers of the decline, but some seem more likely than others.

Recent surveys suggest a substantial reduction in the abundance of Stokell's smelt in the Rakaia, Ashburton-Hakatere and Rangitata hāpua (Arthur and Gray 2022). These three catchments share stressors from the widespread land-use intensification and water abstraction that has occurred across much of Canterbury in the last 20 years. The likely spawning sites of Stokell's smelt in hāpua appear to be vulnerable to changes in riverine flow and associated sediment deposition, as well as predation. It is possible that the metapopulation of Stokell's smelt along the Canterbury coastline is dependent on these three stronghold populations as 'sources' of larvae. If this were the case, a concurrent deterioration in spawning habitat in these three catchments would have widespread consequences. However, a gradual deterioration in habitat quality in multiple hāpua is more likely to produce a gradual decline in Stokell's smelt abundance rather than the "*massive*", "*hugely dramatic*" reduction described by interviewees in Jellyman and Mayall-Nahi (2022). A more parsimonious explanation for a sudden, widespread reduction in Stokell's smelt abundance is a catastrophic change during the marine dispersal phase.

A major disruption to the survival of a single cohort of Stokell's smelt during their marine phase could have long-term and far-reaching effects. It appears that the majority of Stokell's smelt spawn when they are about one year old and there is no evidence of iteroparity. A significant reduction in a single year class during their marine phase would remove most of the biomass of the species because there are no other year classes present. Even if some larvae survived, it could take many years for the metapopulation to recover to pre-perturbation abundances.

The unidirectional flow of currents along much of the Canterbury coastline (except for the eddy within Pegasus Bay) means that the consequences of a local disturbance during the marine phase of Stokell's smelt would be very different depending on *where* and *when* it occurred. It is likely that younger Stokell's smelt larvae are more passively dispersed by marine currents than older larvae (and adults). Consequently, there is probably a considerable subsidy of younger larvae from the Canterbury Bight into the coastal environment north of Banks Peninsula. It is highly unlikely that many younger larvae move southwards around Banks Peninsula. Thus, although a marine disturbance affecting the survival of young larvae in Canterbury Bight could affect the number of larvae exported into Pegasus Bay, the reverse is unlikely.

The persistence of spawning populations of Stokell's smelt at the southern range limit (i.e., Waitaki River) must rely on maturing/mature adults migrating southwards unless developing larvae can avoid being advected northwards out of the Canterbury Bight by the Southland current. If this is the case, any disturbance during the marine phase that affects the survival of larvae or adults in the Canterbury Bight would have disproportionate consequences in southern rivers.

If a major disruption during the marine phase is responsible for the reduction in abundance of Stokell's smelt in hāpua, then the most likely cause of the disruption is an alteration to planktonic production because of climate change. If a shift in the timing of planktonic production in Canterbury coastal waters caused a large proportion of the Stokell's smelt larval pool to starve, it would have consequences across the entire geographic range of Stokell's smelt; there is no long-range larval dispersal from elsewhere in New Zealand to subsidise or replace local production.

If the Stokell's smelt metapopulation has declined because of an anthropogenic impact(s), then the first step to restoring and protecting the species is understanding its full life history and identifying bottlenecks. Until that is done, Stokell's smelt will remain vulnerable to population decline and possible extinction.

6 Research priorities

Unless the fundamental knowledge gaps surrounding Stokell's smelt are filled by the research suggested in Sections 4.1.3, 4.2.3, 4.3.3, 4.4.3, 4.5.3, and the resulting data are coupled with ongoing surveys to determine the abundance of adults in spawning migrations, the future of this endemic species is uncertain.

A major disturbance during the marine phase is the most parsimonious explanation for the widespread decline in the abundance of Stokell's smelt. However, future research should prioritise confirming an ongoing decline in Stokell's smelt abundance (Table 6-1), and then addressing the life stages and associated habitats (e.g., spawning sites or hāpua openings) where local management changes or interventions are feasible. The high priority research suggestions will, at worst, eliminate these areas as being involved in the decline of Stokell's smelt. At best, they will identify key management strategies to restore and protect Stokell's smelt populations and the ecosystems they support.

Table 6-1: Research priorities to address the decline of Stokell's smelt. High priority options target life stages and habitats where interventions are feasible. Medium and low priority options primarily address knowledge gaps during the marine phase or that are influenced by the marine phase.

High priority	Medium priority	Low priority
Measure abundances of adult Stokell's smelt entering multiple Canterbury hāpua over multiple years	Identify marine distribution of larval Stokell's smelt (Section 4.1.3)	Measure effects of parasites/disease on Stokell's smelt fecundity (Section 4.5.3)
Identify Stokell's smelt spawning sites (Section 4.2.3)	Identify spawning behaviour of Stokell's smelt (Section 4.4.3)	Identify diet of larval Stokell's smelt (Section 4.4.3)
Test effects of sedimentation on Stokell's smelt egg deposition and survival (Section 4.2.3)	Measure age of adult Stokell's smelt (Section 4.1.3)	Measure hāpua residence time of adult Stokell's smelt (Section 4.4.3)
Identify natal origins of adult Stokell's smelt (Section 4.1.3)	Test effects of predation on Stokell's smelt egg survival (Section 4.3.3)	Identify diet of predatory birds near hāpua (Section 4.4.3)
Measure frequency/duration of hāpua openings (Section 4.1.3)	Measure fecundity of adult Stokell's smelt (Section 4.2.3)	Identify diet of predatory fishes near hāpua (Section 4.4.3)
	Measure growth of adult Stokell's smelt (Section 4.1.3)	

7 References

Agostinho, C.S. (2000) Use of otoliths to estimate size at sexual maturity in fish. *Brazilian Archives of Biology and Technology*, 43(4): 437-440.

Aiken, J., Moore, G.F., Hotligan, P.M. (1992) Remote sensing of oceanic biology in relation to global climate change. *Journal of Phycology*, 28(5): 579-590.

Allen, K.R. (1949) The New Zealand grayling: a vanishing species. *Tuatara*, 2(1): 22-26.

Angermeier, P.L. (1995) Ecological attributes of extinction-prone species: loss of freshwater fishes of Virginia. *Conservation Biology*, 9(1): 143-158.

Arthur, J. (2022) Fish community surveys of Canterbury Hāpua. *Environment Canterbury Science Summary Report (in draft)*: 26p.

Arthur, J., Gray, D. (2022) Fish communities of the Rakaia Hāpua: a comparison to historical survey data, 1980/81 - 2021/22. *Environment Canterbury Science Technical Report (in draft)*: 31p.

Baker, A.N. (1971) Food and feeding of kahawai (Teleostei: Arripididae). *New Zealand Journal of Marine and Freshwater Research*, 5(2): 291-299.

Baras, E., Arifin, O.Z., Slembrouck, J., Subagja, J., Kristanto, A.H., Legendre, M. (2018) Oil globule size in fish eggs: a matter of biome and reproductive strategy. *Fish and Fisheries*, 19(6): 996-1002.

Barnett-Johnson, R., Pearson, T.E., Ramos, F.C., Grimes, C.B., Bruce MacFarlane, R. (2008) Tracking natal origins of salmon using isotopes, otoliths, and landscape geology. *Limnology and Oceanography*, 53(4): 1633-1642.

Barrett, R.T., Camphuysen, K., Anker-Nilssen, T., Chardine, J.W., Furness, R.W., Garthe, S., Hüppop, O., Leopold, M.F., Montevecchi, W.A., Veit, R.R. (2007) Diet studies of seabirds: a review and recommendations. *ICES Journal of Marine Science*, 64(9): 1675-1691.

Baylis, H.A. (1931) VIII.—A species of the Nematode genus *Hedruris* occurring in the trout in New Zealand. *Annals and Magazine of Natural History*, 7(37): 105-114.

Beentjes, M.P., Bull, B., Hurst, R.J., Bagley, N.W. (2002) Demersal fish assemblages along the continental shelf and upper slope of the east coast of the South Island, New Zealand. *New Zealand Journal of Marine and Freshwater Research*, 36(1): 197-223.

Berger, J. (2004) The last mile: how to sustain long-distance migration in mammals. *Conservation Biology*, 18(2): 320-331.

Bisbal, G.A., Bengtson, D.A. (1995) Effects of delayed feeding on survival and growth of summer flounder *Paralichthys dentatus* larvae. *Marine Ecology Progress Series*, 121: 301-306.

Blackburn, M. (1957) The relation between the food of the Australian barracouta, *Thyrsites atun* (Euphrasen), and recent fluctuations in the fisheries. *Marine and Freshwater Research*, 8(1): 29-54.

Blaxter, J.H.S. (1974) *The early life history of fish: the proceedings of an international symposium held at the Dunstaffnage Marine Research Laboratory of the Scottish Marine Biological Association at Oban, Scotland, from May 17-23, 1973*. Springer-Verlag, New York: 765p.

Bonnett, M.L. (1986) Fish and benthic invertebrate populations of the Rangitata River. *Fisheries environmental report*, Fisheries Research Division, NZ Ministry of Agriculture and Fisheries: 72p.

Bonnett, M.L. (1992) Distribution and freshwater residence of Stokell's smelt, *Stokellia anisodon* (Stokell), in the South Island, New Zealand. *New Zealand Journal of Marine and Freshwater Research*, 26(2): 213-218.

Bonnett, M.L. (2021) Canterbury hapua fish survey - pilot study. *Pattle Delamore Partners Limited C03818800*, Prepared for Environment Canterbury: 28p.

Bräger, S. (1998) Feeding associations between white-fronted terns and Hector's dolphins in New Zealand. *The Condor*, 100(3): 560-562.

Brunsdon, R.V. (1953) *Studies on the nematode parasites of New Zealand fishes*. M.Sc. thesis. Victoria University. Wellington: 157p.

Burkhead, N.M. (2012) Extinction rates in North American freshwater fishes, 1900–2010. *Bioscience*, 62(9): 798-808.

Campbell, J., Antoine, D., Armstrong, R., Arrigo, K., Balch, W., Barber, R., Behrenfeld, M., Bidigare, R., Bishop, J., Carr, M.E., Esaias, W.E., Falkowski, P., Hoepffner, N., Iverson, R., Kiefer, D., Lohrenz, S., Marra, J., Morel, A., Ryan, J., Vedernikov, V., Waters, K., Yentsch, C., J., Y. (2002) Comparison of algorithms for estimating ocean primary production from surface chlorophyll, temperature, and irradiance. *Global Biogeochemical Cycles*, 16(3): 9.1-9.15.

Clavel, J., Julliard, R., Devictor, V. (2011) Worldwide decline of specialist species: toward a global functional homogenization? *Frontiers in Ecology and the Environment*, 9(4): 222-228.

Cranfield, H., Dunn, A., Doonan, I., Michael, K. (2005) *Bonamia exitiosa* epizootic in *Ostrea chilensis* from Foveaux Strait, southern New Zealand between 1986 and 1992. *ICES Journal of Marine Science*, 62(1): 3-13.

Cunningham, P.T.M. (1978) *Bionomia e ciclo de vida de Ctenosciaena gracilicirhus (Metzelaar, 1919) na plataforma continental brasileira entre as latitudes de 22°10'S e 30°S.* Dissertação de Mestrado thesis. Universidade de São Paulo: 106p.

Cury, P.M., Boyd, I.L., Bonhommeau, S., Anker-Nilssen, T., Crawford, R.J., Furness, R.W., Mills, J.A., Murphy, E.J., Österblom, H., Paleczny, M. (2011) Global seabird response to forage fish depletion—one-third for the birds. *Science*, 334(6063): 1703-1706.

Cushing, D.H. (1974) The natural regulation of populations. In: F.R. Harden Jones (Ed). *Sea fisheries research*. Elek Science, London: 399-412.

Cushing, D.H. (1975) *Marine ecology and fisheries*. Cambridge University Press, Cambridge: 278p.

Davidson, A.D., Boyer, A.G., Kim, H., Pompa-Mansilla, S., Hamilton, M.J., Costa, D.P., Ceballos, G., Brown, J.H. (2012) Drivers and hotspots of extinction risk in marine mammals. *Proceedings of the National Academy of Sciences*, 109(9): 3395-3400.

Davis, S.F., Eldon, G.A., Glova, G.J., Sagar, P.M. (1983) Fish populations of the lower Rakaia River. *Fisheries environmental report*, NZ Ministry of Agriculture and Fisheries: 109p.

Dix, T.G. (1968) Helminth parasites of brown trout (*Salmo trutta* L.) in Canterbury, New Zealand. *New Zealand Journal of Marine and Freshwater Research*, 2(2): 363-374.

Dolphin, C.H. (1997) *Larval characteristics of some fishes from the east coast of southern New Zealand*. M.Sc. thesis. University of Canterbury. Christchurch: 208p.

Doogue, R., Moreland, J. (1960) *New Zealand seas anglers guide*. A.H. & A.W. Reed, Wellington: 289p.

Dou, S., Masuda, R., Tanaka, M., Tsukamoto, K. (2002) Feeding resumption, morphological changes and mortality during starvation in Japanese flounder larvae. *Journal of Fish Biology*, 60(6): 1363-1380.

Dudgeon, D., Arthington, A.H., Gessner, M.O., Kawabata, Z.-I., Knowler, D.J., Lévêque, C., Naiman, R.J., Prieur-Richard, A.-H., Soto, D., Stiassny, M.L. (2006) Freshwater biodiversity: importance, threats, status and conservation challenges. *Biological Reviews*, 81(2): 163-182.

Dulvy, N.K., Sadovy, Y., Reynolds, J.D. (2003) Extinction vulnerability in marine populations. *Fish and Fisheries*, 4(1): 25-64.

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., Rolfe, J.R. (2018) Conservation status of New Zealand freshwater fishes, 2017. *New Zealand Threat Classification Series*, 24: 1-15.

Durant, J.M., Hjermann, D.Ø., Ottersen, G., Stenseth, N.C. (2007) Climate and the match or mismatch between predator requirements and resource availability. *Climate Research*, 33(3): 271-283.

Egan, E.M.C. (2017) *Early life history of the amphidromous galaxiid īnanga: disentangling the consequences for their migratory dynamics, population stucture and adult growth*. Ph.D. thesis. University of Canterbury. Christchurch: 209p.

Egan, E.M.C., Hickford, M.J.H., Schiel, D.R. (2019) Understanding the life histories of amphidromous fish by integrating otolith-derived growth reconstructions, post-larval migrations and reproductive traits. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 29(9): 1391-1402.

Eldon, G.A., Greager, A.J. (1983) Fishes of the Rakaia Lagoon. *Fisheries environmental report*, NZ Ministry of Agriculture and Fisheries: 65p.

Eldon, G.A., Kelly, G.R. (1985) Fishes of the Waimakariri River estuary. *Fisheries environmental report*, NZ Ministry of Agriculture and Fisheries: 59p.

Ewers, R.M., Kliskey, A.D., Walker, S., Rutledge, D., Harding, J.S., Didham, R.K. (2006) Past and future trajectories of forest loss in New Zealand. *Biological Conservation*, 133(3): 312-325.

Eziuzo, E.N.C. (1963) The identification of otoliths from West African demersal fish. *Bulletin de l'Institut français d'Afrique noire. Série A, Sciences naturelles*, 25(2): 488-512.

Fahrig, L. (1997) Relative effects of habitat loss and fragmentation on population extinction. *The Journal of Wildlife Management*: 603-610.

Fahrig, L. (2003) Effects of habitat fragmentation on biodiversity. *Annual review of ecology, evolution, and systematics*: 487-515.

Francis, M.P. (1988) *Coastal fishes of New Zealand: a diver's identification guide*. Heinemann Reed, Auckland: 63p.

Fuhrman, J.A. (1999) Marine viruses and their biogeochemical and ecological effects. *Nature*, 399(6736): 541-548.

Gisbert, E., Conklin, D., Piedrahita, R. (2004) Effects of delayed first feeding on the nutritional condition and mortality of California halibut larvae. *Journal of Fish Biology*, 64(1): 116-132.

Godfriaux, B.L. (1970) Food of predatory demersal fish in Hauraki Gulf: 2: Five fish species associated with snapper. *New Zealand Journal of Marine and Freshwater Research*, 4(3): 248-266.

Gordon, H.R., Brown, O.B., Evans, R.H., Brown, J.W., Smith, R.C., Baker, K.S., Clark, D.K. (1988) A semianalytic radiance model of ocean color. *Journal of Geophysical Research: Atmospheres*, 93(D9): 10909-10924.

Graham, D.H. (1939) Food of the fishes of Otago Harbour and adjacent sea. *Transactions & Proceedings Royal Society of New Zealand*, 68(4): 421-436.

Graham, D.H. (1956) *A treasury of New Zealand fishes*. Reed, Wellington: 424p.

Grieve, J.M. (1966) *The annual cycle of plankton off Kaikoura*. Ph.D. thesis. University of Canterbury. Christchurch: 96p.

Haldorson, L., Pritchett, M., Sterritt, D., Watts, J. (1993) Abundance patterns of marine fish larvae during spring in a southeastern Alaskan bay. *Fishery Bulletin*, 91: 36-44.

Hardesty-Moore, M., Deinet, S., Freeman, R., Titcomb, G.C., Dillon, E.M., Stears, K., Klope, M., Bui, A., Orr, D., Young, H.S. (2018) Migration in the Anthropocene: how collective navigation, environmental system and taxonomy shape the vulnerability of migratory species. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 373(1746): 20170017.

Hart, D.E. (1999) *Dynamics of mixed sand and gravel river mouth lagoons, hapua*. M.Sc. thesis. University of Canterbury. Christchurch: 221p.

Hart, D.E. (2009) Morphodynamics of non-estuarine rivermouth lagoons on high-energy coasts. *Journal of Coastal Research*, 56(2): 1355-1359.

Harvell, C.D., Lamb, J.B. (2020) Disease outbreaks can threaten marine biodiversity. *Marine Disease Ecology; Oxford University Press: Oxford, UK*: 141-158.

Haywood, G.J. (2004) Some effects of river discharges and currents on phytoplankton in the sea off Otago, New Zealand. *New Zealand Journal of Marine and Freshwater Research*, 38(1): 103-114.

Hewitt, G.C., Hine, P.M. (1972) Checklist of parasites of New Zealand fishes and of their hosts. *New Zealand Journal of Marine and Freshwater Research*, 6(1-2): 69-114.

Hickford, M.J.H. (2000) *Patterns of distribution and abundance of larval fish in a southern temperate region*. Ph.D. thesis. University of Canterbury. Christchurch: 142p.

Hickford, M.J.H., Schiel, D.R. (1999) Evaluation of the performance of light traps for sampling fish larvae in inshore temperate waters. *Marine Ecology Progress Series*, 186: 293-302.

Hickford, M.J.H., Schiel, D.R. (2003) Comparative dispersal of larvae from demersal versus pelagic spawning fishes. *Marine Ecology Progress Series*, 252: 255-271.

Hickford, M.J.H., Schiel, D.R. (2011) Population sinks resulting from degraded habitats of an obligate life-history pathway. *Oecologia*, 166(1): 131-140.

Hickford, M.J.H., Schiel, D.R. (2016) Otolith microchemistry of the amphidromous *Galaxias maculatus* shows recruitment to coastal rivers from unstructured larval pools. *Marine Ecology Progress Series*, 548: 197-207.

Higgins, P.J., Davies, S.J.J.F. (1990) *Handbook of Australian, New Zealand and Antarctic birds. Volume 3: snipe to pigeons.* Oxford University Press, Melbourne: 1028p.

Hine, P.M. (1980) Distribution of helminths in the digestive tracts of New Zealand freshwater eels 1. Distribution of digeneans. *New Zealand Journal of Marine and Freshwater Research*, 14(4): 329-338.

Hjort, J. (1914) Fluctuations in the great fisheries of northern Europe viewed in the light of biological research. *Rapports et Procès-Verbaux des Réunions. Conseil International pour l'Exploration de la Mer*, 20: 1-228.

Hobbs, J.A., Lewis, L.S., Willmes, M., Denney, C., Bush, E. (2019) Complex life histories discovered in a critically endangered fish. *Scientific Reports*, 9(1): 1-12.

Hobbs, J.A., Moyle, P.B., Fangue, N., Connon, R.E. (2017) Is extinction inevitable for Delta Smelt and Longfin Smelt? An opinion and recommendations for recovery. *San Francisco Estuary and Watershed Science*, 15(2): 1-19.

Hooker, S.B., Esaias, W.E., Feldman, G.C., Gregg, W.W., McClain, C.R. (1992) *An overview of SeaWiFS and ocean color*. NASA Goddard Space Flight Center, Maryland , USA: 24p.

Hopkins, J., Shaw, A., Challenor, P. (2010) The Southland front, New Zealand: variability and ENSO correlations. *Continental Shelf Research*, 30(14): 1535-1548.

Houde, E.D. (1974) Effects of temperature and delayed feeding on growth and survival of larvae of three species of subtropical marine fishes. *Marine Biology*, 26(3): 271-285.

Howell, M. (1967) The trematode, *Bucephalus longicornutus* (Manter, 1954) in the New Zealand mud-oyster, *Ostrea lutaria*. *Transactions of the Royal Society of New Zealand (Zoology)*, 8(22): 221-237.

Hughes, J.M., Stewart, J., Lyle, J.M., McAllister, J., Stocks, J.R., Suthers, I.M. (2013) Latitudinal, ontogenetic, and historical shifts in the diet of a carnivorous teleost, *Arripis trutta*, in a coastal pelagic ecosystem altered by climate change. *Canadian Journal of Fisheries and Aquatic Sciences*, 70(8): 1209-1230.

Hughes, J.M., Stewart, J., Lyle, J.M., Suthers, I.M. (2014) Top-down pressure on small pelagic fish by eastern Australian salmon *Arripis trutta*; estimation of daily ration and annual prey consumption using multiple techniques. *Journal of Experimental Marine Biology and Ecology*, 459: 190-198.

Hyatt, A.D., Hine, P.M., Jones, J.B., Whittington, R.J., Kearns, C., Wise, T.G., Crane, M.S., Williams, L.M. (1997) Epizootic mortality in the pilchard *Sardinops sagax neopilchardus* in Australia and New Zealand in 1995. II. Identification of a herpesvirus within the gill epithelium. *Diseases of Aquatic Organisms*, 28(1): 17-29.

IUCN (2022) *The IUCN Red List of Threatened Species*. Available at http://www.iucnredlist.org. Accessed: Sept 2022

Jarvis, R.M., Young, T. (2019) Key research priorities for the future of marine science in New Zealand. *Marine Policy*, 106: 103539.

Jellyman, D., Mayall-Nahi, M. (2022) Perceptions of change: recording observations over decades for Canterbury hāpua. *NIWA Client Report 2021348CH*, Prepared for Environment Canterbury: 90p.

Jellyman, D.J. (1989) Occurrence of the nematode *Hedruris spinigera* in the stomachs of freshwater eels. *New Zealand Journal of Zoology*, 16(2): 185-189.

Johnston, T.H., Mawson, P.M. (1940) Some nematodes parasitic in Australian freshwater fish. *Transactions of the Royal Society of South Australia*, 64(2): 340-352.

Jolly, V.H. (1967) Observations on the smelt *Retropinna lacustris* Stokell. *New Zealand Journal of Science*, 10: 330-355.

Jones, J.B., Hyatt, A.D., Hine, P.M., Whittington, R.J., Griffin, D.A., Bax, N.J. (1997) Australasian pilchard mortalities. *World Journal of Microbiology and Biotechnology*, 13(4): 383-392.

Jonsson, A., Ebenman, B. (2001) Are certain life histories particularly prone to local extinction? *Journal of Theoretical Biology*, 209(4): 455-463.

Kimmerer, W.J. (2011) Modeling Delta Smelt losses at the south Delta export facilities. *San Francisco Estuary and Watershed Science*, 9(1): 1-9.

Kingsford, M.J., Leis, J.M., Shanks, A., Lindeman, K.C., Morgan, S.G., Pineda, J. (2002) Sensory environments, larval abilities and local self-recruitment. *Bulletin of Marine Science*, 70(1): 309-340.

Kirk, R.M. (1991) River-beach interaction on mixed sand and gravel coasts: a geomorphic model for water resource planning. *Applied Geography*, 11(4): 267-287.

Kirk, R.M., Lauder, G.A. (2000) Significant coastal lagoon systems in the South Island, New Zealand. *Science for Conservation*, 146: 1-46.

Kohno, H., Ordonio-Aguilar, R.S., Ohno, A., Taki, Y. (1997) Why is grouper larval rearing difficult?: an approach from the development of the feeding apparatus in early stage larvae of the grouper, *Epinephelus coioides*. *Ichthyological Research*, 44(2): 267-274.

Kramer, D.L., Bryant, M.J. (1995) Intestine length in the fishes of a tropical stream: 2. Relationships to diet—the long and short of a convoluted issue. *Environmental Biology of Fishes*, 42(2): 129-141.

Lafferty, K.D., Harvell, C.D. (2014) The role of infectious diseases in marine communities. In: M.D. Bertness, J. Bruno, B.R. Silliman & J.J. Stachowicz (Eds). *Marine community ecology and conservation*. Sinauer Associates, Inc., Sunderland, MA: 85-108.

Lafferty, K.D., Hofmann, E.E. (2016) Marine disease impacts, diagnosis, forecasting, management and policy. *Philosophical Transactions of the Royal Society of London Series B. Biological Sciences*, 371(1689): 20150200.

Lambert, T.C., Ware, D.M. (1984) Reproductive strategies of demersal and pelagic spawning fish. *Canadian Journal of Fisheries and Aquatic Sciences*, 41: 1565-1569.

Land Air Water Aotearoa (2022) *Rakaia River at SH 1 north channel*. Available at https://www.lawa.org.nz/explore-data/canterbury-region/river-quality/rakaia-river-catchment/rakaia-river-at-sh-1-north-channel/. Accessed: 11 Aug 2022

Lane, H.S., Brosnahan, C.L., Poulin, R. (2022) Aquatic disease in New Zealand: synthesis and future directions. *New Zealand Journal of Marine and Freshwater Research*, 56(1): 1-42.

Last, J.M. (1978a) The food of four species of pleuronectiform larvae in the eastern English Channel and southern North Sea. *Marine Biology*, 45(4): 359-368.

Last, J.M. (1978b) The food of three species of gadoid larvae in the eastern English Channel and southern North Sea. *Marine Biology*, 48(4): 377-386.

Law, C.S., Bell, J.J., Bostock, H.C., Cornwall, C.E., Cummings, V.J., Currie, K., Davy, S.K., Gammon, M., Hepburn, C.D., Hurd, C.L. (2018) Ocean acidification in New Zealand waters: trends and impacts. *New Zealand Journal of Marine and Freshwater Research*, 52(2): 155-195.

Lawton, J.H., May, R.M. (1995) *Extinction rates*. Oxford University Press, Oxford, UK: 233p.

Lee, F., Perry, G.L.W. (2019) Assessing the role of off-take and source–sink dynamics in the extinction of the amphidromous New Zealand grayling (*Prototroctes oxyrhynchus*). *Freshwater Biology*, 64(10): 1747-1754.

Lee, T.M., Jetz, W. (2011) Unravelling the structure of species extinction risk for predictive conservation science. *Proceedings of the Royal Society B: Biological Sciences*, 278(1710): 1329-1338.

Marcogliese, D.J. (2008) The impact of climate change on the parasites and infectious diseases of aquatic animals. *Revue Scientifique et Technique*, 27(2): 467-484.

Margolis, L., Boyce, N.P. (1990) Helminth parasites from North Pacific anadromous chinook salmon, *Oncorhynchus tshawytscha*, established in New Zealand. *The Journal of Parasitology*: 133-135.

Marliave, J.B. (1986) Lack of planktonic dispersal of rocky intertidal fish larvae. *Transactions of the American Fisheries Society*, 115(1): 149-154.

Martin, W.R. (1949) The mechanics of environmental control of body form in fishes. *University of Toronto Studies, Biological Series No. 58. Publications of the Ontario Fisheries Research Laboratory*, 70: 1-91.

McDowall, R.M. (1968) The application of the terms anadromous and catadromous to the southern hemisphere salmonoid fishes. *Copeia*, 1968(1): 176-178.

McDowall, R.M. (1976) The role of estuaries in the life cycles of fishes in New Zealand. *Proceedings of the New Zealand Ecological Society*, 23: 27-32.

McDowall, R.M. (1983) Nothing new under the sun. *Freshwater Catch: Quarterly Supplement to Catch*, 19: 15-17.

McDowall, R.M. (1990a) Conservation of New Zealand's freshwater fishes. *New Zealand Freshwater Fisheries Report*, 116: 1-62.

McDowall, R.M. (1990b) *New Zealand freshwater fishes: a natural history and guide*. Heinemann Reed, Auckland: 553p.

McDowall, R.M. (1993) Implications of diadromy for the structuring and modelling of riverine fish communities in New Zealand. *New Zealand Journal of Marine and Freshwater Research*, 27(4): 453-462.

McDowall, R.M. (2008) Diadromy, history and ecology: a question of scale. In: S. Dufour, E. Prévost, E. Rochard & P. Williot (Eds). *Fish and Diadromy in Europe (ecology, management, conservation)*. Springer Netherlands, Dordrecht: 5-14.

McDowall, R.M. (2010a) *New Zealand freshwater fishes: an historical and ecological biogeography*. Springer, Dordrecht: 449p.

McDowall, R.M. (2010b) Why be amphidromous: expatrial dispersal and the place of source and sink population dynamics? *Reviews in Fish Biology and Fisheries*, 20(1): 87-100.

McDowall, R.M., Eldon, G.A. (1980) The ecology of whitebait migrations (Galaxiidae: *Galaxias* spp.). *New Zealand Ministry of Agriculture and Fisheries, Fisheries Research Bulletin*, 20: 1-172.

McMillan, H.M. (1951) *The osteology and relationships of the family Retropinnidae Gill; including studies on life history, systematics, and ecology, with particular reference to*

Retropinna anisodon Stokell 1941. M.Sc. thesis. University of New Zealand. Christchurch: 114p.

McMillan, H.M. (1961) An addition to the knowledge of the fish, *Retropinna anisodon* Stokell (Retropinnidae). *Transactions of the Royal Society of New Zealand Zoology*, 1(10): 139-144.

McMillan, P.J., Francis, M.P., James, G.D., Paul, L.J., Marriott, P., Mackay, E., Wood, B.A., Stevens, D.W., Griggs, L.H., Baird, S.J., Roberts, C.D., Stewart, A.L., Struthers, C.D., Robbins, J.E. (2019) New Zealand fishes. A field guide to common species caught by bottom, midwater, and surface fishing. *New Zealand Aquatic Environment and Biodiversity Report*: 295p.

McSweeney, S.L., Hart, D.E., Todd, D.J., Kennedy, D.M. (2016) Changes in the frequency and duration of closures of the Opihi Hapua following construction of the Opuha Dam. *Journal of Coastal Research*, 75(10075): 88-92.

Melbourne, B.A., Hastings, A. (2008) Extinction risk depends strongly on factors contributing to stochasticity. *Nature*, 454(7200): 100-103.

Miller, R.R., Williams, J.D., Williams, J.E. (1989) Extinctions of North American fishes during the past century. *Fisheries*, 14(6): 22-38.

Ministry for the Environment & Stats NZ (2020) *New Zealand's Environmental Reporting Series: Our freshwater 2020*. Ministry for the Environment & Stats NZ, Wellington: 90p.

Moyle, P.B., Brown, L.R., Durand, J.R., Hobbs, J.A. (2016) Delta smelt: life history and decline of a once-abundant species in the San Francisco Estuary. *San Francisco Estuary and Watershed Science*, 14(2): 1-30.

Moyle, P.B., Hobbs, J.A., Durand, J.R. (2018) Delta smelt and water politics in California. *Fisheries*, 43(1): 42-50.

MPI, N. (2019) Situation and outlook for primary industries 2019, Ministry for Primary Industries: 30p.

O'Driscoll, R.L. (1998) Feeding and schooling behaviour of barracouta (*Thyrsites atun*) off Otago, New Zealand. *Marine and Freshwater Research*, 49(1): 19-24.

O'Reilly, J.E., Maritorena, S., Mitchell, B.G., Siegel, D.A., Carder, K.L., Garver, S.A., Kahru, M., McClain, C. (1998) Ocean color chlorophyll algorithms for SeaWiFS. *Journal of Geophysical Research: Oceans*, 103(C11): 24937-24953.

Olden, J.D., Hogan, Z.S., Zanden, M.J.V. (2007) Small fish, big fish, red fish, blue fish: size-biased extinction risk of the world's freshwater and marine fishes. *Global Ecology and Biogeography*, 16(6): 694-701.

Pankhurst, N.W., Munday, P.L. (2011) Effects of climate change on fish reproduction and early life history stages. *Marine and Freshwater Research*, 62(9): 1015-1026.

Parrott, A.W. (1957) *Sea anglers fishes of New Zealand*. Hodder & Stoughton, London: 176p.

Peña, R., Dumas, S. (2005) Effect of delayed first feeding on development and feeding ability of *Paralabrax maculatofasciatus* larvae. *Journal of Fish Biology*, 67(3): 640-651.

Pepin, P., Dower, J.F. (2007) Variability in the trophic position of larval fish in a coastal pelagic ecosystem based on stable isotope analysis. *Journal of Plankton Research*, 29(8): 727-737.

Pepin, P., Penney, R. (2000) Feeding by a larval fish community: impact on zooplankton. *Marine Ecology Progress Series*, 204: 199-212.

Pepin, P., Penney, R.W. (1997) Patterns of prey size and taxonomic composition in larval fish: are there general size-dependent models? *Journal of Fish Biology*, 51: 84-100.

Pinkerton, M.H., Sutton, P.J.H., Wood, S. (2019) Satellite indicators of phytoplankton and ocean surface temperature for New Zealand. *NIWA Client Report 2018180WN*, Prepared for the Ministry for the Environment: 87p.

Prugh, L.R., Hodges, K.E., Sinclair, A.R., Brashares, J.S. (2008) Effect of habitat area and isolation on fragmented animal populations. *Proceedings of the National Academy of Sciences*, 105(52): 20770-20775.

Rayner, M., Dunphy, B., Lukies, K., Adams, N., Berg, M., Kozmian-Ledward, L., Pinkerton, M., Bury, S. (2021) Stable isotope record from a resident New Zealand seabird community suggests changes in distribution but not trophic position since 1878. *Marine Ecology Progress Series*, 678: 171-182.

Reis, G.J., Howard, J.K., Rosenfield, J.A. (2019) Clarifying effects of environmental protections on freshwater flows to - and water exports from - the San Francisco Bay Estuary. *San Francisco Estuary and Watershed Science*, 17(1): 1-22.

Reynolds, J.D., Dulvy, N.K., Goodwin, N.B., Hutchings, J.A. (2005) Biology of extinction risk in marine fishes. *Proceedings of the Royal Society B: Biological Sciences*, 272(1579): 2337-2344.

Reynolds, J.D., Jennings, S., Dulvy, N.K. (2001) Life histories of fishes and population responses to exploitation. In: J.D. Reynolds, G.M. Mace, K.H. Redford & J.G. Robinson (Eds). *Conservation of exploited species*. Cambridge University Press, Cambridge: 147-168.

Ripple, W.J., Wolf, C., Newsome, T.M., Hoffmann, M., Wirsing, A.J., McCauley, D.J. (2017) Extinction risk is most acute for the world's largest and smallest vertebrates. *Proceedings of the National Academy of Sciences*, 114(40): 10678-10683.

Roberts, C.M., Hawkins, J.P. (1999) Extinction risk in the sea. *Trends in ecology & evolution*, 14(6): 241-246.

Rowe, D.K., Dean, T.L. (1998) Effects of turbidity on the feeding ability of the juvenile migrant stage of six New Zealand freshwater fish species. *New Zealand Journal of Marine and Freshwater Research*, 32(1): 21-29.

Rowe, D.K., Suren, A.M., Martin, M., Smith, J., Smith, B., Williams, E. (2002) Lethal turbidity levels for common freshwater fish and invertebrates in Auckland streams. *NIWA Client Report ARC02283*, Prepared for Auckland Reginal Council: 37p.

Rutledge, M.J. (1991) Adult trout diet in the lower Waitaki River and tributaries, 1983-1986. *New Zealand Freshwater Fisheries Report No. 126*, Prepared for Electricorp: 18p.

Sagar, P.M., Eldon, G.A. (1983) Food and feeding of small fish in the Rakaia River, New Zealand. *New Zealand Journal of Marine and Freshwater Research*, 17(3): 213-226.

Sear, D.A., Jones, J.I., Collins, A.L., Hulin, A., Burke, N., Bateman, S., Pattison, I., Naden, P.S. (2016) Does fine sediment source as well as quantity affect salmonid embryo mortality and development? *Science of the Total Environment*, 541: 957-968.

Shaw, A., Kavalieris, L., Vennell, R. (1999) Seasonal and Inter-Annual Variability of SST off the East Coast of the South Island, New Zealand. *Geocarto International*, 14(3): 29-34.

Sherman, K., Smith, W., Morse, W., Breman, M., Green, J., Ejsymont, L. (1984) Spawning strategies of fishes in relation to circulation, phytoplankton production, and pulses in zooplankton off the northeastern United States. *Marine Ecology Progress Series*, 18: 1-9.

Shulmeister, J., Kirk, R.M. (1993) Evolution of a mixed sand and gravel barrier system in North Canterbury, New Zealand, during Holocene sea-level rise and still-stand. *Sedimentary Geology*, 87(3-4): 215-235.

Snieszko, S.F. (1974) The effects of environmental stress on outbreaks of infectious diseases of fishes. *Journal of Fish Biology*, 6(2): 197-208.

Soares, L.S.H. (1982) *Aspectos da biologia e ecologia de Isopisthus parvipinnis (Cuvier, 1830) (Perciformes:Sciaenidae) entre Cabo Frio e Torres, Brasil*. Dissertação de mestrado thesis. Universidade de São Paulo. São Paulo: 123p.

Stephens, R.T.T. (1984) *Smelt (Retropinna retropinna) population dynamics and predation by rainbow trout in Lake Taupo*. Ph.D. thesis. University of Waikato. Hamilton: 365p.

Stevens, C.L., O'Callaghan, J.M., Chiswell, S.M., Hadfield, M.G. (2021) Physical oceanography of New Zealand/Aotearoa shelf seas–a review. *New Zealand Journal of Marine and Freshwater Research*, 55(1): 6-45.

Stokell, G. (1936) The nematode parasites of Lake Ellesmere trout. *Transactions and Proceedings of the Royal Society of New Zealand.*, 66(1): 80-96.

Stokell, G. (1941) A revision of the genus *Retropinna*. *Records of the Canterbury Museum*, 4(7): 361-372.

Strona, G. (2022) *Hidden pathways to extinction*. Springer Nature, Cham, Switzerland: 237p.

Sutton, P.J.H. (2003) The Southland Current: a subantarctic current. *New Zealand Journal of Marine and Freshwater Research*, 37(3): 645-652.

The Press (1913) The fishing season. *The Press*, 20 December 1913, XLIX(14854): 8.

Thompson, G.M. (1892) Notes on sea fishes. *Transactions of the New Zealand Institute*, 21(1): 202-215.

Timaru Herald (2020) Conservation groups hunt rare 'at risk' Stokell's smelt. *Timaru Herald*, 3 December 2020.

Timaru Herald (2021) Reports of gull chicks dying near the Rangitata River. *Timaru Herald*, 13 January 2021.

Todd, D.J. (1983) *Effect of Low Flows on River Mouth Closure in the Opihi River*. M.Sc. thesis. University of Canterbury. Christchurch: 187p.

Todd, D.J. (1998) Rangitata River mouth dynamics study. *Tonkin & Taylor Ltd U98/01*, Prepared for Canterbury Regional Council: 26p.

Townsend, C., Simon, K. (2006) Consequences of brown trout invasion for stream ecosystems. In: R. Allen & W.G. Lee (Eds). *Biological Invasions in New Zealand*. Springer, Berlin: 213-225.

Trolove, P. (2021) Is Canterbury's Stokell's smelt doomed for extinction like the Delta Smelt of California?: 9p.

Uchihashi, K., Iitaka, Y., Morinaga, T. (1981) Swimming behaviour of adult *Oncorhynchus* from growing ground to spawning ground. *Fisheries Research Division Occasional Publication*, 30: 65-67.

Uchihashi, K., Iitaka, Y., Morinaga, T., Kikkawa, J. (1979) Acclimatization of king salmon, *Oncorhynchus tschawytscha* (Walbaum), into New Zealand. Progress of transplantation and its present status. *Memoirs of the Faculty of Agriculture of Kinki University*, 12: 221-243.

Ward, F.J., Boubee, J.A., Meredith, A.S., Northcote, T.G. (1989) Characteristics of common smelt, *Retropinna retropinna* (Richardson), of the Waikato River system. *New Zealand Journal of Marine and Freshwater Research*, 23(3): 345-355.

Warrick, J.A., DiGiacomo, P.M., Weisberg, S.B., Nezlin, N.P., Mengel, M., Jones, B.H., Ohlmann, J.C., Washburn, L., Terrill, E.J., Farnsworth, K.L. (2007) River plume patterns and dynamics within the Southern California Bight. *Continental Shelf Research*, 27(19): 2427-2448.

Webb, B.F. (1966) *A study in the biology of the fish population of the Avon-Heathcote estuary, Christchurch*. M.Sc. thesis. University of Canterbury. Christchurch: 304p.

Webb, B.F. (1973) Fish populations of the Avon-Heathcote estuary 3. Gut contents. *New Zealand Journal of Marine and Freshwater Research*, 7(3): 223-234.

Whitley, G.P. (1955) Opus CCC. *Australian Zoologist*, 12(2): 154-159.

Wilcove, D.S. (2010) *No way home: the decline of the world's great animal migrations*. Island Press, Washington: 256p.

Worm, B., Sandow, M., Oschlies, A., Lotze, H.K., Myers, R.A. (2005) Global patterns of predator diversity in the open oceans. *Science*, 309(5739): 1365-1369.

WWF (2020) Living planet report 2020 - bending the curves of biodiversity loss, WWF: 159p.

Yang, Z. (2007) Effect of timing of first feeding on survival and growth of obscure puffer (*Takifugu obscurus*) larvae. *Journal of Freshwater Ecology*, 22(3): 387-392.

Young, H.S., McCauley, D.J., Galetti, M., Dirzo, R. (2016) Patterns, causes, and consequences of anthropocene defaunation. *Annual Review of Ecology, Evolution, and Systematics*, 47(1): 333-358.

Zarfl, C., Lumsdon, A.E., Berlekamp, J., Tydecks, L., Tockner, K. (2015) A global boom in hydropower dam construction. *Aquatic Sciences*, 77(1): 161-170.

Zeldis, J.R., Hadfield, M.G. (2012) Freshwater dilution and transport in Canterbury Bight. *NIWA Client Report WLG2011-54*, Prepared for Environment Canterbury: 39p.

Zenkovich, V.P. (1967) *Processes of coastal development*. Oliver and Boyd, London: 738p.

HUI/MEETING: Ashburton Water Management Zone Committee	
AGENDA ITEM NO: 10	**KAUPAPA/SUBJECT:** Committee Updates
KAITUHI/AUTHOR: Jaimee Grant	**WĀ/MEETING DATE:** 26 November 2024

Purpose

To update the Committee on actions from the previous meeting, relevant information, and upcoming engagement opportunities.

Recommendation

The Ashburton Water Management Zone Committee:

1. Receives the Committee Updates report.

Report

1. Progress Update on Review of CWMS Zone Committees

The information-gathering stage of the Canterbury Zone Committee Review 2024 (the review) has now been completed and the focus shifted to the development of advice and options for the future of local freshwater leadership in Canterbury.

On 30 August, the Canterbury Mayoral Forum nominated four Mayors to work with Environment Canterbury's Chair to workshop what local freshwater leadership the Mayoral Forum will support into the future. The participants are Mayors Mackle (Kaikōura), Bowen (Timaru), Black (Hurunui), and Mauger (Christchurch). Mayor Munro (Mackenzie) also joined the working group.

Also on 30 August, Te Rōpū Tuia agreed to nominate a similar number of mana whenua representatives to participate in these workshops. The representatives are Rik Tainui (Chairperson, Ōnuku Rūnanga) and Dardanelle McLean-Smith (Chairperson, Te Rūnanga o Waihao). Additionally, Environment Canterbury Councillors Korako and Cranwell participate in the working group.

The working group of Mayors, mana whenua representatives and Environment Canterbury's Chair and Councillors held workshops in late October and early November. These workshops focused on (i) core principles and functions for local freshwater leadership and engagement, and (ii) draft models for achieving these principles and functions. Feedback from the working group will help to refine advice and options for enabling future local leadership and engagement.

Draft advice and potential options are further discussed with staff from different territorial authorities across Canterbury to ensure that their feasibility and practical implications for district and city councils are considered.

Feedback from these workshops and engagements will be used to finalise advice and options. A Zone Committee Review final report will be presented to the Mayoral Forum's 29 November meeting for their decision. While the nature of this decision will be informed by the working group of Mayors and mana whenua representatives, it will likely include a decision on whether or not the Mayoral Forum continues to support the zone committee structure, and if not, what alternative models should be further explored before decisions in the first half of 2025.

This timing would enable further discussions within individual councils (noting any changes to the zone committee approach will require a decision by each individual council given these are joint committees), and for new structures to be put in place by the start of the 2025/26 year.

Table 1 provides agreed key dates and milestones for the review:

Table 1: CWMS Zone Committee review – key dates and milestones

Date	Milestone
Aug 2023	Mayoral Forum agrees to a review of zone committees
Dec 2023	Initial engagement with zone committee chairs and deputies (*completed*)
Apr 2024	Engagement with mayors, mana whenua and zone committees *(completed)*
May 2024	Workshop with Mayoral Forum (*completed)*
Jul – Aug 2024	Briefing and updates to key CWMS parties *(completed)*
Aug 2024	Progress update to Mayoral Forum *(completed)*
Sept – Oct 2024	Workshops with mayors, mana whenua representatives, and Environment Canterbury Chair *(completed)*
Nov 2024	Final Zone Committee Review report to Mayoral Forum

2. Environment Canterbury Representation review

The following is from the Environment Canterbury website:

Our Councillors represent different areas of Waitaha/Canterbury; two Councillors for each of the seven constituencies. Ahead of the next local body elections in October 2025, Council is proposing that we retain a largely similar representation arrangement to what is currently in place, with some minor boundary adjustments.

The adjustments:

Minor boundary adjustments to the Christchurch constituency boundaries to align with the current city ward boundaries

Altering the boundary of the Christchurch Central/Ōhoko constituency to exclude the Linwood Ward of Christchurch City, and to include the Papanui Ward of Christchurch City

Altering the boundary of the Christchurch North-East/Ōrei constituency to exclude the Papanui Ward of Christchurch City, and to include the Linwood Ward of Christchurch City.

You can view the adopted proposal map here and the public notice here (External link).

What happens now:

The Council's final proposal is now open for appeals and objections until 25 November 2024. Any person who made a submission on the Council's initial proposal may lodge an appeal against the Council's decision. An appeal must relate to the matters raised in that person's submission.

Any person who objects to the final proposal may lodge an objection to the Council's final proposal. Any objection must identify the matters to which the objection relates. Any appeals or objections to the final proposal will be referred to the Local Government Commission for review.

The Local Government Commission will also be required to review the Council's proposal as some constituencies do not meet the population per member requirements set out in the Local Electoral Act 2001.The Local Government Commission will hold hearings, if required, and make its final determination on Council's representation arrangements by April 2025.

To lodge an appeal or objection on the final proposal, email haveyoursay@ecan.govt.nz (subject: Representation Review) by 5pm on 25 November 2024.

For more information, go to:

Your representation – Defining the lines I https://haveyoursay.ecan.govt.nz/representation-review

3. Methven Lions Club Garden of Harmony – grant variation request

In September, a request for a grant variation was received for the Methven Lions Club's (MLC) Garden of Harmony project where funding was to go towards the purchase of native plants.

MLC then advised a Landscape Concept Plan and associated planting plan are required to secure the proposed site and requested a variation for the funding to go towards the plans instead of the plants.

MLC have since advised that they have funding for the plans, so a variation is no longer required for that purpose. However, a variation to the end date of the agreement is now required to allow for the plans to be completed which will in turn, push the planting timeframe out.

4. Rakitata Revival Update

The Revival Strategy drafted by the inter-agency partnership group is currently being reviewed by the Steering Group. Once the approach has been agreed, the draft will be updated and put to the community for consultation, before the final document is endorsed by each partner agency. The timeline for this is to be confirmed.

The partnership group continues to share updates, including stories of river champions, via the Rakitata River Revival community newsletter. You can read previous editions and sign up to the mailing list on the Department of Conservation website: https://www.doc.govt.nz/news/newsletters/rakitata-river-revival-community-newsletter/

5. Actions from previous meetings/workshops:

#	Received	Who	What
1.	27/08	J Grant	Query to ECan - The Ashburton Lyndhurst Irrigation hearing noted that the Hakatere/Ashburton hāpua is degraded. The Committee requests an Environment

			Canterbury staff member to come and present to the Committee on: 1. What factors considered to determine if an area is degraded e.g. ecology, TLI, etc. 2. What reports were used to determine Hakatere/Ashburton hāpua was degraded? (were there any others besides the three sent: NIWA Anecdotal state of river mouth users; Science Summary - hāpua fish survey 2020-21; NIWA report - potential drivers of the decline of hāpua fish populations *Refer to Agenda Item 9.*
2.	22/10	J Grant	Rangitata River Revival Strategy - update for Ashburton Zone Committee request *Refer to Committee Update #4 in this document.*
3.	22/10	J Grant	Request for information on Environment Canterbury's Dry Summer Plan.
4.	22/10	J Grant	For 2025 agenda: A plan review on the Ashburton river in 2027 and wanted to know if this is being considered. Include in the agenda for next year: 1. Is there a plan review planned 2. What are we doing about it.

6. Zone Committee Calendar 2025

The 2025 CWMS Zone Committees schedule is yet to be finalized. Meetings typically follow the previous year's cycle unless the Zone Committee decides otherwise. Adjustments to meetings and workshops can be made as needed provided they work within the provisions of the Council Standing Orders.

Ashburton Water Zone Committee meetings and workshops are generally held during the last week of the month, subject to changes for scheduling conflicts or other agreements. The CWMS Zone Committee review may also affect the schedule.

Based on the 2024 meeting schedule, the first quarter for 2025 would be:

- **Tuesday, 28 January 2025 – 1 pm-3 pm** – note councils and staff, zone committee members and community may be unavailable.
- **Tuesday 25 February 2025 – 1 pm-3 pm**
- **Tuesday 25 March 2025 – 1 pm-3 pm**

The Committee would need to determine whether these would be meetings, workshops or other. The first meeting of the year is when the Chair and Deputy Chair are appointed by committees.