NIWA
Taihoro Nukurangi

Understanding Taonga Freshwater Fish Populations in Aotearoa-New Zealand

Prepared for Te Wai Māori Trust

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LEFT – (top to bottom) Grey mullet (Photo: NIWA), Stage II juvenile kōura (Source: Hopkins 1967), Kanakana with lamprey reddening syndrome (Photo: Jane Kitson);
MIDDLE – Headwaters of the Rākaia River Photo: Shannan Crow);
RIGHT – (top to bottom) Longfin eel (Photo: Stuart Mackay), Freshwater mussel (Photo: Ngaire Phillips), Black Flounder (Photo: Bob McDowall).

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Executive Summary

Te Wai Māori Trust is currently reviewing its strategic priorities and direction to assess whether its key priorities remain relevant to the Trust achieving its purposes. To inform their forthcoming Strategic Plan, Te Wai Māori Trust have commissioned NIWA to provide them with an update of a report that was prepared for them in 2006, a Freshwater Fisheries in New Zealand Environmental Scan (Te Wai Māori 2006). Since this scan was undertaken over 10 years ago, numerous freshwater fisheries-related advancements have occurred (including research, governance, management, monitoring and reporting advancements).

Te Wai Māori Trust requested that this review of current knowledge included: tuna (freshwater eels), piharau/kanakana (lamprey), kōura/kēwai (freshwater crayfish), whitebait, porohe (smelt), kanae (mullet), pātiki mohoao (black flounder), and kākahi/kāeo (freshwater mussels). While most of these species are only found in Aotearoa-NZ – īnanga, kōaro, shortfin tuna and piharau/kanakana are found elsewhere in the Southern Hemisphere. A desktop literature review of existing/available written materials and publicly available databases was completed to produce this report. No new analyses were undertaken. In this report, we have drawn upon the available literature to discuss what is currently known about each species in terms of:

- Understanding the life cycle of each species.
- Aotearoa-NZ distribution.
- State and trends in the relative abundance of populations (if known).
- Threat status, as determined by two methods: New Zealand Threat Classification System and the International Union for Conservation of Nature (IUCN).
- What we know about pressures on freshwater taonga species populations.
- Who has responsibilities for managing the fish/fishery.

To the best of our knowledge, a stocktake of our current understanding in regards to many of these taonga freshwater fisheries has not been undertaken since the late Dr Bob McDowall's book, *New Zealand Freshwater Fishes: A Natural History and Guide* that was first released almost 40 years ago, in 1978, and revised in 1990. Therefore, different sections of this report were co-authored and/or reviewed by a variety of individuals (including social scientists, fisheries scientists, fisheries managers, post-doc researchers, etc.,) who are currently working in these topic areas to ensure that the most recent literature and understanding of the current state of knowledge is captured. During this review we have come across various documents that have expressed where further research is required to address key gaps in our knowledge to improve freshwater taonga species management; such information/research gaps are identified in this report.

A multitude of organisations have certain functions and powers, and statutory responsibilities for factors that in turn influence freshwater taonga species populations. Each organisation is bound by its empowering legislation, or the legislation that it administers, which may or may not include specific references to the Treaty of Waitangi and/or Māori/cultural values. In addition, iwi and government co-governance and co-management contexts are constantly changing which in turn influences the way we manage and use these species at local, regional and national scales. Examples of policy drivers that seek to increase Māori participation in freshwater taonga species co-management includes Te Ture Whaimana, Te Awa Tupua, National Policy Statement for Freshwater

Management 2014, and the Vision Mātauranga Policy. Under an ideal freshwater taonga species management system, Māori would be involved in each of the six-resource management sub-functions identified by Pinkerton (1989) (i.e., inventory, assessment and research; allocative decision-making; policy making and planning (strategic and operational); implementation; monitoring and evaluation; and enforcement); however, this is seldom the case. In addition, the focus on who is to participate is of importance because fishing is typically a whānau and hapū activity. It follows that to be effective, management should be driven from the flax-roots; however, the current legislative context risks overlaying a different structure.

Key government agencies involved in freshwater taonga species management are releasing strategic and science planning documents that increasingly use language like: "*mātauranga-informed resource management and conservation outcomes", "understanding and encapsulation of aspects of mātauranga Māori", "integration of Te Ao Māori and mātauranga Māori into species recovery programmes".* The increasing use of terminology like this implies that Māori **must** be involved in partnership with key agencies to deliver on such policies/objectives (and we assume resourcing is also being allocated to achieve these goals), as only Māori can address and deliver on these needs.

There are currently no legislative provisions for Māori involvement in freshwater taonga species monitoring, evaluation and enforcement. Many iwi and hapū around Aotearoa-NZ have identified that there is a need to expand on existing biophysical monitoring programmes occurring in their catchments (if they are happening at all) to capture information regarding the state of hapū/whānau values and cultural uses to evaluate the success (or otherwise) of freshwater taonga species management/decision-making and restoration actions. Fit-for-purpose monitoring and evaluation programmes are essential for hapū/whānau to: measure success; support adaptive management; provide accountability; and engage communities. This report includes an overview of current funding sources that could be influenced/leveraged by Te Wai Māori to support new freshwater taonga species research, capacity/capability building of Māori communities, the implementation of fit-for-purpose monitoring programmes, and the evaluation of management/restoration actions.

1 Introduction

1.1 Te Wai Māori Trust

Te Wai Māori Trust[1] (TWMT) was established to advance Māori interests in freshwater fisheries, as part of the Māori Fisheries Settlement. The purpose of TWMT is to advance Māori interests in freshwater fisheries through:

- Undertaking or funding research, development and education.
- Promoting the protection and enhancement of freshwater fisheries habitat.
- Promoting the establishment of freshwater fisheries.
- Using resources to bring direct and indirect benefits to Māori in respect of their freshwater fisheries interests.

When using the terminology 'freshwater fisheries', TWMT describes this as including the species, habitat, surrounding land, water column, and water quality and quantity. Protecting Māori interests in freshwater fisheries ultimately means protecting habitat to ensure good quality water and abundant species. The long-term outcomes that TWMT are working towards include:

- Increased iwi and hapū capacity and capability in freshwater fisheries and their ability to control their freshwater fisheries.
- Fostered indigenous fisheries expertise, knowledge and understanding.
- Increased quality and a greater range of information available to iwi and hapū on freshwater fisheries and their interests thereof.
- Ensured that indigenous fisheries are well and can be enhanced.

1.2 Report Scope

Te Wai Māori Trust is currently reviewing its strategic priorities and direction to assess whether its key priorities (see above) remain relevant to the Trust achieving its purposes. To inform their forthcoming Strategic Plan, TWMT have commissioned NIWA to provide them with an update of a report that was prepared for them in 2006, a Freshwater Fisheries in NZ Environmental Scan (Te Wai Māori 2006). Since this scan was undertaken over 10 years ago, numerous freshwater fisheries-related advancements have occurred (including research, governance, monitoring, regional and national state and trend reporting).

A desktop literature review of existing/available written materials and publicly available databases was completed to produce this report. No new analyses (e.g., state and trends of populations) were undertaken. This report includes:

- An assessment of the current knowledge of selected freshwater fisheries in Aotearoa-NZ. The species selected by TWMT for inclusion in this report are: tuna, piharau/kanakana, kōura/kēwai, whitebait, porohe, kanae, Pātiki mohoao, and kākahi/kāeo (Table 1).

[1] http://waimaori.maori.nz/home.htm

- An assessment of the current state of selected freshwater fisheries in Aotearoa-NZ.
- Commercial and environmental management issues associated with these indigenous freshwater species and the rivers, streams and lakes that support them.

The report does not re-present the extensive mātauranga Māori pertaining to these species, or how Māori communities historically utilised and managed these fisheries as this information has been collated in Waitangi Tribunal documents (e.g., Waitangi Tribunal 1988; 1997; 1998, White 1998, Cunningham et al. 2016) and publications such as Hiroa (1921), Best (1929), Marshall (1987) and McDowall (2011).

To the best of our knowledge, a stocktake of our current understanding in regards to some of these taonga freshwater fisheries has not been undertaken since the late Dr Bob McDowall's book, *New Zealand Freshwater Fishes: A Natural History and Guide* that was first released almost 40 years ago, in 1978, and revised in 1990. Therefore, different sections of this report were co-authored and/or reviewed by a variety of individuals (including social scientists, fisheries scientists, post-doc researchers, fisheries managers, etc.,) who are currently working in these topic areas to ensure that the most recent literature and understanding of the current state of knowledge is captured.

Table 1: Freshwater taonga species included in this report. We recognise that whānau and hapū across Aotearoa-NZ have an extensive range of names for their freshwater taonga species. In this report we have drawn on the most commonly used names as the heading for each section. To be able to identify the different freshwater fish whānau you need to know a little bit about fish anatomy. The main features used to describe different species covered in this report are shown in McDowall (2000) and are reproduced in Appendix A.

Te Reo (used in this report)	English	Species[2]
Tuna	Longfin eel Shortfin eel	*Anguilla dieffenbachii* *A. australis*
Piharau/Kanakana	Lamprey	*Geotria australis*
Kōura/Kēwai	Freshwater crayfish	*Paranephrops planifrons* *P. zealandicus*
Īnanga Kōaro Kōkopu	Whitebait Īnanga Kōaro Banded kōkopu Giant kōkopu Shortjaw kōkopu	*Galaxias spp.* *Galaxias maculatus* *G. brevipinnis* *G. fasciatus* *G. argenteus* *G. postvectis*
Porohe	Common smelt Stokell's smelt	*Retropinna* *Stokellia anisodon*
Kanae	Grey mullet Yellow-eyed mullet	*Mugil cephalus* *Aldrichetta forsteri*
Pātiki mohoao	Black flounder	*Rhombosolea retiaria*
Kākahi/Kāeo	Freshwater mussel	*Echyridella menziesii* *E. aucklandica* *E. onekaka*

[2] NIWA has produced some freshwater fish taxonomic identification keys to help identify species: https://www.niwa.co.nz/sites/niwa.co.nz/files/sites/default/files/key_to_native_fish_families.pdf and https://www.niwa.co.nz/sites/niwa.co.nz/files/import/attachments/freshwater_fish_families.pdf

1.2.1 Structure of this Report

The report is divided into the following sections for each group of freshwater taonga species:

- Sections 3–10: tuna, piharau/kanakana, kōura/kēwai, whitebait, porohe, kanae, pātiki mohoao, and kākahi/kāeo.

We have then drawn upon the available literature to discuss each species in terms of (Figure 1):

- Understanding the life cycle of each species.
- Aotearoa-NZ distribution.
- State and trends in the relative abundance of populations (if known).
- Threat status, as determined by the Department of Conservation (DOC) and the International Union for Conservation of Nature (IUCN).
- What we know about pressures on freshwater taonga species populations.
- Who has responsibilities for managing the fish/fishery.

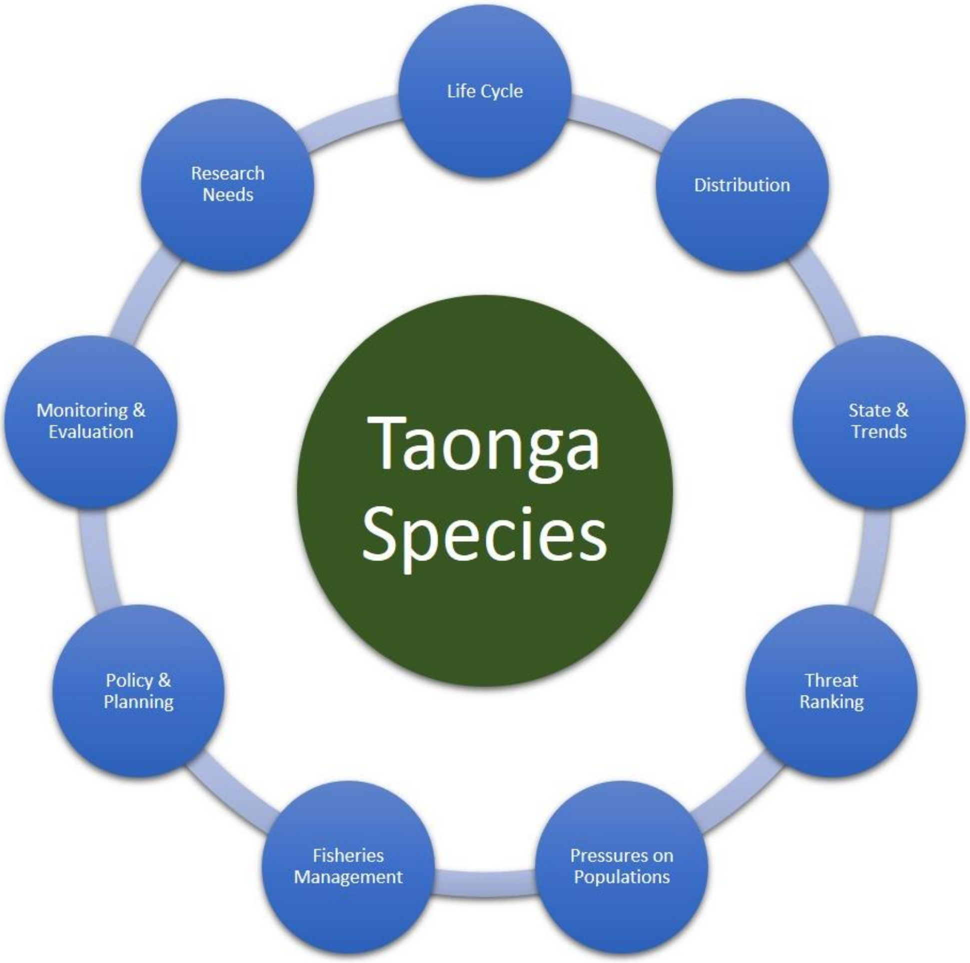

Figure 1: **Structure of this report.** For each taonga freshwater species we have summarised the current state of knowledge for as many of the sub-sections (outer blue circles) as possible. Policy and planning, monitoring and evaluation, and research needs are covered in Sections 11, 12, and 15 respectively.

In Section 11 we introduce the legislative framework within which the management and restoration of freshwater taonga species sits, and provide a few examples of how Māori have sought to increase their participation and input into freshwater planning, policy and management over the last 10–15 years.

There are currently no legislative provisions for tangata whenua involvement in freshwater monitoring and evaluation and enforcement. Many whānau, hapū and iwi have identified that there is a need to complement and/or expand existing biophysical monitoring programmes to be more inclusive of Māori values and interests. In Section 12 we introduce some of the types of information whānau, hapū and iwi are gathering to evaluate the success (or otherwise) of taonga species management and restoration actions.

Aotearoa-NZ's unique co-governance and co-management context provides an internationally innovative opportunity to co-develop new methods, tools and knowledge that support taonga species protection, restoration and economic development. In Section 13 we touch on some of these opportunities. An overview of funding sources that could be influenced/leveraged by Te Wai Māori to support taonga species research, build the capacity/capability building of Māori communities and scientists, and support the implementation of restoration actions are collated in Section 14.

Te Wai Māori Trust understand that for some of the species they have requested information about (e.g., smelt, pātiki, mullet), that very little research and/or monitoring of the fishery has been undertaken. These information gaps are identified in Section 15.

1.2.2 Unavoidable Scientific Language – Diadromous and Land-locked

Aotearoa-NZ has a diverse range of freshwater fish species, many of which are small, nocturnal and secretive. Only one species that was present when Pākehā arrived here in the mid-19th century has become extinct, the Upokororo or grayling (*Prototroctes oxyrhynchus*) (McDowall 2011). Understanding a species' life cycle is critical for fisheries management. Of the 38 freshwater fishes native to our rivers and lakes, over half need to be able to travel (or migrate) between the ocean and freshwater to complete their life cycle successfully. Some of the dominant migration periods for our indigenous freshwater fish species are provided in Smith (2014). Seventeen of these species are 'diadromous' or 'sea run', meaning they migrate between freshwater and saltwater during some part of their life cycle (for more information see McDowall 1990 and Smith 2014). **Diadromous** species can be split into three categories:

- **Catadromous** species (e.g., tuna and īnanga) – live in freshwater, but migrate to sea to spawn, with larvae returning on ocean currents and enter freshwater as juveniles (e.g., glass eels and whitebait).
- **Anadromous** species (e.g., piharau/kanakana) –where adults live at sea and then migrate upstream from the sea to spawn in fresh water. For these species, the larvae rear in fresh water before migrating out to sea as juveniles.
- **Amphidromous** species (e.g., large galaxiids and common smelt) undertake a migration between fresh and salt water for a purpose other than breeding. In general, adults breed in the fresh water environment, with larvae rearing at sea, and then migrating upstream into freshwater as juveniles several months later for growth to adulthood. Although a large proportion of common smelt populations are amphidromous, they also form anadromous

populations, where larvae and juveniles rear in marine or estuarine waters and adults migrate into freshwater to spawn.

Several diadromous species have also formed **land-locked** populations overtime (e.g., due to man-made barriers and/or translocations) – where no marine phase is required (e.g., common smelt and kōaro).

Wherever possible, we have tried to avoid the use of scientific/technical language in this report. Where we have not been able to do this, we have provided a glossary of the abbreviations and scientific terminology in Section 17.

2 Approach

There is no centralised source of consistent information gathered on the state of taonga species populations at the local, catchment or national level. Although standardised methods have been published for selected life stages, habitats and/or procedures (e.g., Joy et al. 2013, Walsh et al. 2016), we generally lack repeatable and robust methods to assess the state of our indigenous freshwater fish populations across all life stages and all habitat types. In addition, efforts to monitor freshwater taonga species populations across the country are generally fragmented between government agencies, regional councils, universities, Crown Research Institutes, consultancies, industry and community groups.

To compile this report, we have drawn on publicly available research (e.g., journal papers, books, client reports), Ministry for Primary Industries (MPI) Fisheries Assessment Reports and Plenary Reports (for eel, mullet and flounder commercial fisheries), DOC research and guidelines, and web-based information resources like Kaitiaki Toolz[3], Tuna Information Resource[4], Guide to restoring kōura in lakes, rivers and streams[5], and the Atlas of New Zealand Freshwater Fishes[6]. Outside of the regular assessments commissioned by MPI for selected commercial fisheries, typically the studies accessed were discrete bodies of work; with very few publicly available studies or monitoring datasets being generated for a site, catchment, or region over multiple years.

In addition, we have used the New Zealand Freshwater Fish Database[7] (NZFFD) which records the occurrence of fish in fresh waters of Aotearoa-NZ, including major offshore islands. These data are contributed voluntarily by organisations such as NIWA, Fish and Game councils, DOC, regional councils, environment consultants, universities, and interested individuals.

The approaches used to populate the freshwater taonga species distribution, state and trends, and threat status sub-sections of this report are described in more detail below.

2.1 Distribution Maps

The NZFFD was used to prepare distribution maps for each fish species. The NZFFD was accessed on 22 May 2017 and contained 42,133 records of fish occurrence from throughout Aotearoa-NZ. Each of these records contained information on sampling location, date, sampling method and the fish population. We used all the observations available (i.e., all fishing methods and dates) to display the presence/absence of each species for all the NZFFD records.

While no data are available in the NZFFD for kākahi populations, we present distribution maps produced by Marshall et al. (2014) for these species.

[3] https://www.niwa.co.nz/freshwater/management-tools/water-quality-tools/kaitiaki-tools
[4] https://www.niwa.co.nz/te-kuwaha/tools-and-resources/tuna-information-resource
[5] https://www.niwa.co.nz/freshwater-and-estuaries/management-tools/restoration-tools/guide-to-restoring-k%C5%8Dura-freshwater-crayfish-in-lakes-rivers-and
[6] https://www.niwa.co.nz/freshwater-and-estuaries/nzffd/NIWA-fish-atlas
[7] This free database can be accessed via: https://www.niwa.co.nz/our-services/online-services/freshwater-fish-database

2.2 Trends in Relative Abundance

Trends in the relative abundance of four taonga freshwater fish species (kōura, kōaro, longfin and shortfin eels) are presented in this report based on the recent analysis by Crow et al. (2016). The Crow et al. (2016) report was commissioned by the Ministry for the Environment (MfE) and used to inform "Our fresh water 2017" about the state of Aotearoa-NZ's fresh waters (MfE & Statistics NZ 2017).

As mentioned previously, efforts to monitor taonga species populations across the country are generally fragmented across multiple agencies, consultancies, researchers and communities. There is no central data management system that contains/collates the datasets required to robustly assess the state and trends of freshwater taonga species populations, across all habitats, in Aotearoa-NZ. Outside of the commercial eel fishery, the best information source we have at this time is the NZFFD; however, the methods used, quality, and extent of data contained in this database is dependent on the organisations and individuals contributing information and the purpose of their investigation – which is not recorded in the database. We recognise that the use of the data contained in the NZFFD comes with a series of limitations; including that the data contained within this database is not representative of all freshwater habitats because of the limitations associated with sampling methods. To account for some of the limitations in the NZFFD data, Crow et al. (2016) drew on a variety of statistical approaches to try and address some of the biases that come with using the data contained in the NZFFD.

Crow et al. (2016) used the NZFFD to generate trends in the relative abundance of 11 freshwater fish species from 1977–2015; excluding lake populations. They used generalised linear models (GLM) to reduce the influence of sampling bias on these trends, to make the results more reliable. The plots from Crow et al. (2016) are reproduced in this report; where each plot shows how 'probability of capture'[8] changes through time. The simple linear regression lines are fitted over three time periods as requested by the client (i.e., MfE): 1977–2015, 1977–1994 and 1995–2015.

To identify if 'probability of capture' through time is increasing (getting better) or decreasing (getting worse) Crow et al. (2016) also completed simple linear regression calculations using two different techniques. The first technique was the Sen Slope Estimator (SSE), while the second technique was a weighted version of the SSE. The weighted SSE (called WSSE hereafter) assigned a weighting value based on the size of the confidence intervals[9] (CI) for the probability of capture estimates for years (i.e., the weight was higher for pairs of slopes that, collectively, had narrower confidence intervals). In the WSSE, pairs of years that collectively have small CIs are weighted more heavily than pairs of years that collectively have large CIs because we were more confident in these probability of capture values.

Following suggestions of Larned et al. (2015), SSE and WSSE trends are described as being **indeterminate** (CI of the slope include zero) or inferred with confidence (CI of the slope did not include zero). We refer to SSE and WSSE slopes for which a positive direction was inferred with confidence as an **increasing trend**, and SSE and WSSE for which a negative direction was inferred with confidence as a **decreasing trend** (Appendix B).

[8] Using probability of capture as an index of relative abundance rather than raw presence/absence data from the NZFFD reduced the influence of confounding variables (e.g., sampling method) on temporal trends (Crow et al. 2016).
[9] A confidence interval is a range of values we are fairly sure our true value lies within.

Both WSSE and SSE results are presented in this report because, together, they help us understand whether or not we can be confident in the analysis and detect a trend over time (either increasing or decreasing) – or if we cannot detect a trend.

2.3 Threat Status[10]

New Zealand Threat Classification System

The freshwater fish 2013 threat rankings were used in this report to provide information on each species' threat status (Figure 2). In this process, species are assessed by panels that are made up of people from the Aotearoa-NZ scientific community. The assessments use two measures: (1) Population size (number of breeding adults or area of habitat occupied); and (2) Population trend (rate of decline or increase). For species with stable populations, the panel also considers whether or not they have declined historically[11].

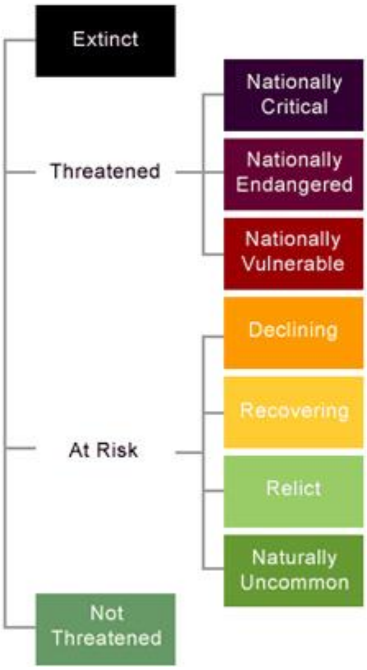

Figure 2: Categories used by the New Zealand Threat Classification System to assess the conservation status of species according to the risk of extinction they face within Aotearoa-NZ. (Source: http://www.doc.govt.nz/nature/conservation-status/).

In this report we include the current threat ranking along with the qualifier used by Goodman et al. (2014) to classify the fish species into the threat category. The NZFFD (McDowall & Richardson 1983) as well as unpublished DOC survey and monitoring data were the primary sources of information used by Goodman et al. (2014) to examine the distribution and abundance of freshwater fish taxa.

IUCN Red List

Species threat rankings are also assessed by the International Union for Conservation of Nature (IUCN). These assessments are based on data currently available for the species across its **entire global range**. Assessors must take full account of past and present literature (published and grey)

[10] Please note that the recent work of Crow et al. (2016) did not inform these sub-sections of the report.
[11] More detail about this method used can be found at: http://www.doc.govt.nz/nature/conservation-status/.

and other reliable sources of information relating to the taxon[12]. Threat rankings assigned by the IUCN were also used in this report[13] (Figure 3). No IUCN rankings are currently available for our tuna species because these assessments are yet to be completed.

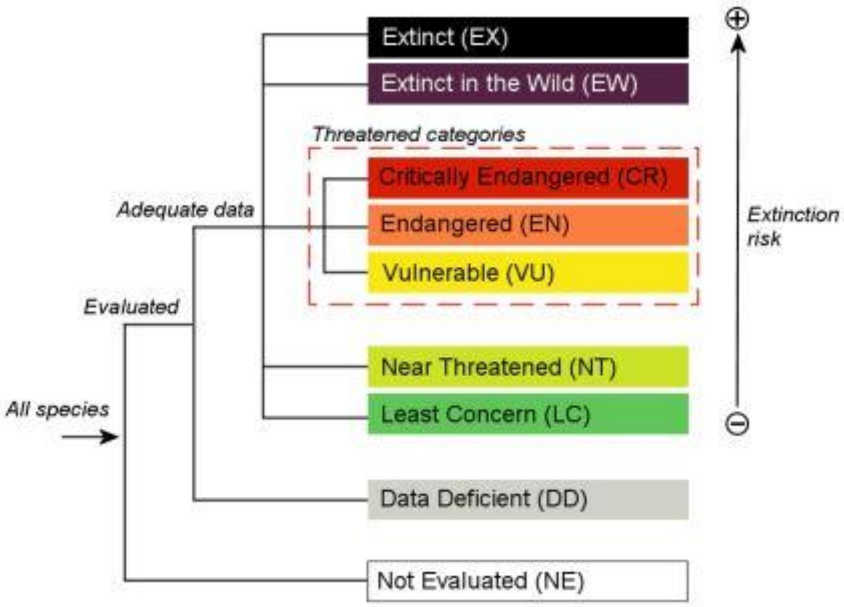

Figure 3: Categories used by the IUCN Red List. (Source: IUCN 2012).

[12] More detail about this method used can be found at: http://www.iucnredlist.org/technical-documents/assessment-process
[13] These rankings are also available at: http://www.iucnredlist.org/

3 Tuna (Freshwater Eels)

Family: Anguilla

Species: *Anguilla australis, Anguilla diffenbachii*

There are currently 18 recognised species/subspecies of freshwater eels worldwide (Tesch 2003), distributed in both tropical (around the equator) and temperate (between the tropics and polar circles) zones, with some species overlapping between these two zones. Recent studies indicate that tropical eels make much shorter migrations (c. 100's km) to spawn in areas near their freshwater habitats when compared to the long distances travelled by temperate (e.g., Aotearoa-NZ) eels (c. 1000's km) (Aoyama 2009).

Māori have an extensive knowledge of tuna. It is not the place of this report to collate and publicise the extensive body of mātauranga Māori that has been actively practised over centuries by whānau, hapū and iwi. While our tuna species are often characterised in terms of biophysical science (family, genus, species), mana whenua have an extensive range of classifications for tuna related, for example, to appearance, colouration, season of the year, size, behaviour, locality, and palatability. According to science, three tuna species occur in Aotearoa-NZ (Figure 4); the longfin (*Anguilla dieffenbachii*), which is only found in Aotearoa-NZ; the shortfin (*A. australis*), which also occurs in eastern Australia and the Pacific; and the Australian speckled longfin[14] (*A. reinhardtii*), which has recently been confirmed as present in Aotearoa-NZ, and is also found in Australia and New Caledonia.

Longfins are distinguished from shortfins by the length of the dorsal (top) fin; when viewed side on, the dorsal fin is longer than the anal (bottom) fin, and extends well forward past the end of the anal fin. In shortfins, the dorsal and anal fin ends are almost the same length (Figure 4). The Aotearoa-NZ longfin is one of the largest eel species in the world (Tesch 2003) and can get to more than 50 kg (Potts 1882, Cairns 1941, Graham 1956). Shortfins do not grow as large as longfins. The Australian speckled longfins look like our longfins but have black blotches all over their body, except for their belly (Figure 4). Although the habitat of the Australian longfin overlaps that of the *A. dieffenbachii*, it is thought that there is little danger that the Australian longfin will edge out *A. dieffenbachii* because researchers believe that each eel species has a single spawning ground. It is thought that the arrival of *A. reinhardtii* in Aotearoa-NZ will continue to be erratic and intermittent, although the confirmed presence of several year classes suggests their migration to Aotearoa-NZ is not an isolated event (Jellyman et al. 1996, McDowall et al. 1998, Chisnall 2000a).

3.1 Life Cycle

To complete their life cycle, tuna must be able to move freely between fresh water and the ocean, spending extended periods in marine, estuarine, and freshwater habitats. The freshwater eel has a larval stage known as leptocephalii, which is only found in the ocean. These transparent leaf-shaped larvae are transported to Aotearoa-NZ using near-surface ocean currents. After encountering the continental shelf the larvae transform into the transparent and actively swimming 'glass eels' which are approximately 55–70 mm. Once glass eels (Figure 6) have entered a catchment, each catchment effectively contains a separate population of eels. Once in freshwater, glass eels develop into darker pigmented juvenile eels known as elvers. After reaching suitable habitat, tuna grow, often for several

[14] Confirmed in 1997, from 19 eels caught in the Waikato River.

decades, before maturing and beginning the return trip to their oceanic spawning grounds (Figure 5, Table 2).

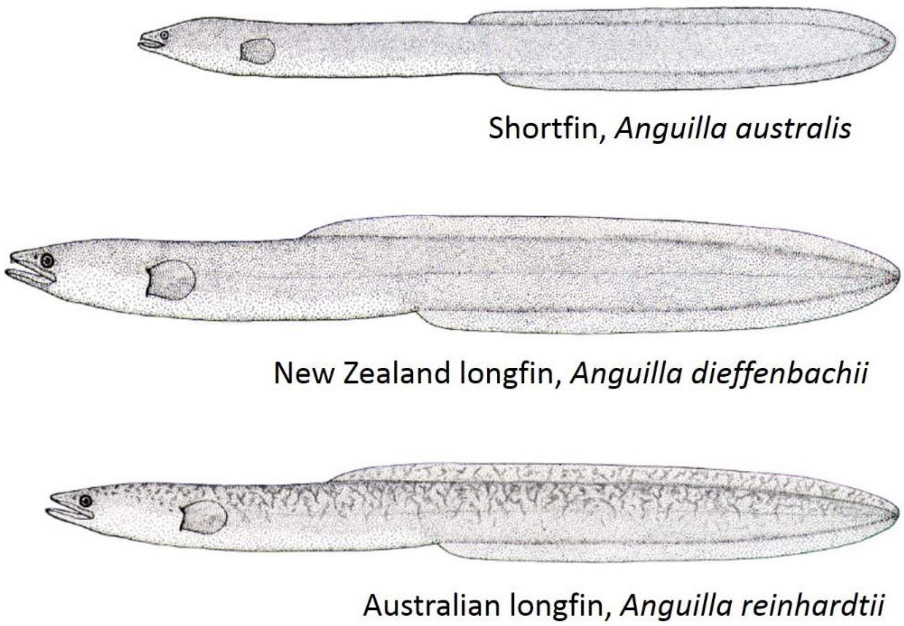

Figure 4: According to science three freshwater eel species occur in Aotearoa-NZ; (top) the shortfin (*A. australis*); (middle) the endemic longfin (*A. dieffenbachii*); and (bottom) the Australian longfin (*A. reinhardtii*) which was confirmed in Aotearoa-NZ in 1997 but is relatively rare. (Diagrams: Bob McDowall).

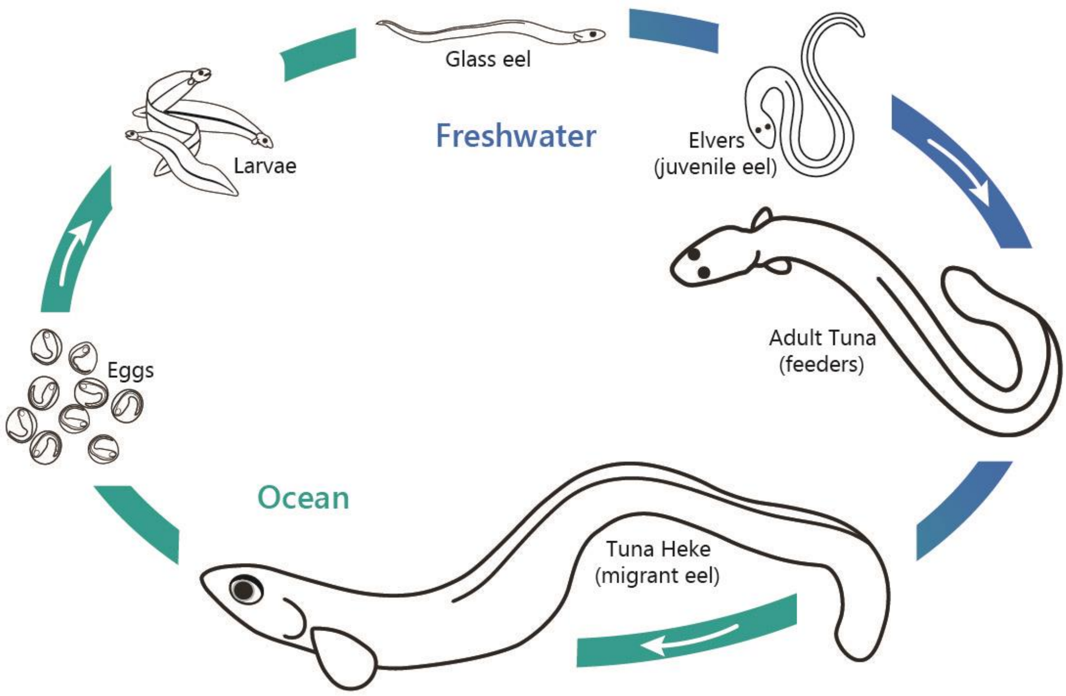

Figure 5: Freshwater eel life-cycle showing the marine (green) and freshwater (blue) life stages. (Source: Aarti Wadhwa).

Table 2: Key features of each tuna life stage. (References include: Cairns 1941; 1942, Burnet 1952, Jellyman 1977, Jellyman 1979, Jellyman & Todd 1982, Jellyman & Ryan 1983, Chisnall 1987; 1989, Chisnall & Hayes 1991, Chisnall & Hicks 1993, Chisnall & Kalish 1993, Glova et al. 1998, Jellyman et al. 1999, Chisnall et al. 2002, Jellyman et al. 2002, Jellyman & Tsukamoto 2002, McCleave & Jellyman 2002, Jellyman & Lambert 2003, Tesch 2003, Graynoth & Niven 2004, Graynoth & Taylor 2004, McCleave & Jellyman 2004, Davey & Jellyman 2005, Jellyman & Tsukamoto 2005, August & Hicks 2006, Graynoth et al. 2008a; 2008b, Jellyman & Tsukamoto 2010, Jellyman & Arai 2016).

Life stage	Key features	Key habitats	Agencies with responsibilities
Fertilised egg	• Spawning occurs in spring (September to November). • The exact spawning locations of *A. australis* and *A. diffenbachii* are yet to be determined. Likely to occur somewhere in the southwest tropical regions of the Pacific Ocean, from north-west of Fiji to just west of Vanuatu for *A. australis*. • Fertilised eggs develop and hatch rapidly in the ocean.	• Pacific Ocean – In deep water.	• New Zealand Ministry of Foreign Affairs and Trade (MFAT) (international agreements on ocean governance and fisheries management, e.g., UN Convention on the Law of the Sea). • Environmental Protection Agency (EPA) (e.g., managing environmental effects of restricted activities in NZ's Exclusive Economic Zone and Continental Shelf).
Larvae (leptocephalii)	• Transparent, leaf-shaped. • Spend 9–12 months in the plankton before arriving on the coast of Aotearoa-NZ. • Transported closer to Aotearoa-NZ using near-surface ocean currents.	• Pacific Ocean to Aotearoa-NZ continental shelf. • Planktonic.	• As above.
Glass eel	• Transparent. • Glass eels are the product of a 5,000 km migration by adults, the act of spawning itself, and the uncertainties of a 6-month larval life at sea. • About 50–65 mm in length. • Generally arriving in Aotearoa-NZ waters between August and December. • Numbers of glass eels arriving at river mouths are subject to considerable year-to-year variation. • Entry into fresh water often correlated with lunar phase and spring tides, and occurs mainly at night. • Length and weight declines in both species of glass eels as the season progresses.	• Aotearoa-NZ continental shelf to fresh waters. • Lower reaches of waterways open to the sea. • Small eels seem to favour runs and riffles of waterways where the substrate is coarse and the current is swift.	• MPI (e.g., lower size limit, special permits, exotic pests, biosecurity, fish passage). • Regional councils (e.g., land use change/management as it affects water quality, biosecurity, fish passage, habitat, ecological flows, point source discharges, pollution events, esplanade areas, flood control, gravel extraction, drain clearance). • District councils (e.g., land use zoning, land use change/management, esplanade areas). • DOC (e.g., fish passage, exotic pests, habitat, national parks, conservation estate, scientific reserves, research/collection permits, grazing licences for riparian areas, and marginal strips). • Land Information New Zealand (LINZ) (e.g., administration incl. use of riverbeds, fairway maintenance).
Elver	• Pigmentation covers 100% of the juvenile eel's body. • About 70–150 mm in length. • Migrate upstream during summer (when temperatures reach about 17°C), sometimes over several years. • Use surface tension to surmount damp, vertical surfaces, such as waterfalls.	• Fresh waters. • Elvers of both longfins and shortfins are common in swiftly flowing gravelly rapids and riffles, where they live and feed amongst the gravel. • Small shortfins (<100 mm) prefer water <0.5 m deep.	• MPI (e.g., as above). • Regional councils (e.g., as above). • District councils (e.g., as above). • DOC (e.g., as above). • LINZ (e.g., as above).

Table 2: Continued.

Life stage	Key features	Key habitats	Agencies with responsibilities
Pre-reproductive adults	• Opportunistic feeders and eat a diverse range of food, including stream insects, terrestrial insects, snails, earthworms, kōura, fish, small birds. Size of their prey depends largely on the gape (mouth) size of eels. Large eels are often the top predator in freshwater ecosystems. • Have poor eyesight, are sensitive to strong light, and are active nocturnal foragers. Food and prey are located primarily by odour detection, using a consistent behavioural response to flow, which results in direct upstream movement toward the odour source when in an odour plume. • Flooded river margins are also important feeding grounds for eels, particularly shortfins. • Eel growth rates are highly variable. High growth rates may occur where food is abundant, but can be very poor in highly modified habitats with high recruitment/high densities. • Eels are not born a particular sex, it is determined as they get older by the environment they are living in. The environment and the number of individual eels who share that same environment contributes to determining the sex of an eel, with females tending to be more common at lower eel population densities. This may be due to large female eels being cannibalistic feeders, and this habit may also influence the distribution of eels. Without this ecological relationship, a higher density of smaller eels can induce sexually immature juveniles to become male. This may have implications not only on inter-related species, but also on the number of female eels contributing to the spawning population. • Large eels, particularly longfins, play an important role in determining the population structure of eels, including species composition, sex ratios and size distribution.	• Eels occupy a wide variety of freshwater habitats, including, coastal estuaries, lakes, wetlands, rivers, mountain streams and alpine tarns. • As eels grow larger, many move upstream/further inland, they hide beneath overhanging banks and logs. • Larger eels (>300 mm) of both species are commonly associated with cover, such as macrophyte beds, willow roots, overhanging banks, in-stream debris and shade. • Several studies describe the behaviour of eels as having a "home range". • Shortfins prefer slower flowing, lowland and coastal waters. • Longfins penetrate further inland and prefer faster flowing water and stony substrates. • As eels increase in size the preference is for deeper water; eels >499 mm generally prefer water almost twice as deep.	• MPI (Quota Management System, upper and lower size limits, number of fishing licenses, catch limits, exotic pests, biosecurity, fish passage, mātaitai reserves, co-management, bylaws). • Iwi/hapū/rūnanga (e.g., customary harvest, mātaitai reserves, co-management, bylaws). • Regional councils (e.g., land use change/management as it affects water quality, biosecurity, fish passage, habitat, ecological flows, point source discharges, pollution events, esplanade areas, flood control, gravel extraction, drain clearance). • District councils (e.g., land use zoning, land use change/management, esplanade areas). • DOC (e.g., fish passage, exotic pests, habitat, national parks, conservation estate, scientific reserves, research/collection permits, grazing licences for riparian areas, and marginal strips). • LINZ (e.g., administration incl. use of riverbeds, fairway maintenance).

Table 2: Continued.

Life stage	Key features	Key habitats	Agencies with responsibilities
Adult migrant	• Once eels become migrants they stop feeding. • Female eels from the same species grow larger and are older than males at maturity. • Precise trigger that causes eels to develop into migrants is not well known, but high fat content that provides sufficient energy to develop gonads (reproductive organs) and cover the long distance to spawning grounds appears to be essential. • External features change to better cope with oceanic conditions, including: the head becomes flatter and slender, belly lightens to a grey or silver colour, the pectoral fins and eyes enlarge. • Shortfin males tend to migrate in February and March, followed soon after by the shortfin females. Longfin males migrate during April, and longfin females during late April and May. • Shortfins generally migrate at a younger age than longfins, and are smaller than longfins when they migrate. • Males (both species) are smaller and migrate at an earlier age than females. Males do not need to be large to produce a large quantity of sperm, so they grow rapidly to a size that enables them to migrate to the spawning ground. • Larger female eels are much more fecund (contain more eggs) than smaller female eels. • The size difference between males and females is strategically important. Fecundity has been estimated at between 1.5 and 3 million eggs in migrant shortfin females 500–800 mm in length while large migrant longfin females (1,400–1,600 mm length) may contain over 20 million eggs. • Migration to oceanic spawning grounds probably takes many months (not a straight line, they are also diving down between about 200 m and 700 m depth each day). • Spawning grounds located somewhere in the southwest tropical regions of the Pacific Ocean, potentially the South Fiji Basin. • The adults do not return to Aotearoa-NZ and are thought to die at or near the spawning ground.	• Fresh waters to the ocean.	• MPI (e.g., Quota Management System, upper size limits, special permits, exotic pests, biosecurity, co-management, bylaws). • Iwi/hapū/rūnanga (e.g., customary harvest, mātaitai reserves, co-management, bylaws). • Regional councils (e.g., land use change/management as it affects water quality, biosecurity, fish passage, habitat, ecological flows, point source discharges, pollution events, esplanade areas, flood control, gravel extraction, drain clearance). • District councils (e.g., land use zoning, land use change/management, esplanade areas). • DOC (e.g., fish passage, exotic pests, habitat, national parks, conservation estate, scientific reserves, research/collection permits, grazing licences for riparian areas, and marginal strips). • LINZ (e.g., administration incl. use of riverbeds, fairway maintenance). • MFAT (international agreements on ocean governance and fisheries management, e.g., UN Convention on the Law of the Sea). • EPA (e.g., managing environmental effects of restricted activities in NZ's Exclusive Economic Zone and Continental Shelf).

Figure 6: (Left) A glass eel; and (Right) Mixture of glass eels and elvers. The dark pigment spots (called melanophores) appear on the skin as the glass eel continues to grow and change into the next stage of their life cycle when they become completely brown and are known as elvers. (Photos: [Left] NIWA, [Right] Joe Potangaroa).

Each species is assumed to consist of a single genetic stock despite occupying broad geographic ranges. Shortfins from Australia and Aotearoa-NZ show small but significant differences in their form/shape (Jellyman 1987, Watanabe et al. 2006), but whether these small differences are a result of spawning in separate areas is unknown. On the weight of current evidence this seems unlikely, meaning that the species should be recognised and managed as a single trans-Tasman one. In contrast, the Aotearoa-NZ longfin is only found in this country and our offshore islands, meaning there is no reserve stock or "buffer" should numbers on mainland become seriously depleted (Jellyman 2013).

3.2 Distribution

Longfins are found throughout Aotearoa-NZ, including the Chatham Islands, from the coast to any upstream habitat they can reach. Although longfin were recorded as present in the Auckland Islands during the 19th century, they have not been found there since (McDowall 1990). There are a few areas of the country where longfins have been observed very frequently, including Taranaki, between Manukau Heads and Warkworth (North Auckland), West Coast of the South Island and top of the South Island (Figure 7).

Shortfins are less widely distributed across Aotearoa-NZ. Shortfin eels are generally found in lowland rivers, streams, lakes, swamps and estuaries (Figure 7). Shortfin eels are predominantly located close to the ocean in the South Island, but are found further inland in the top-half of the North Island. In particular, shortfins are commonly encountered throughout the Waikato Region through to the south of Auckland. It is usually the most common species where eel populations are very dense, and they generally do not travel as far upstream as longfin (McDowall 1990). *A. australis* is also found in Australia (East Coast), Tasmania, New Caledonia, Lord Howe and Norfolk Islands (McDowall 1990).

Figure 7: Locations of NZFFD records where: (Left) Longfin eels, and (Right) Shortfin eels, are present (black circles) and absent (grey circles).

3.3 State and Trends in Abundance

3.3.1 Method Recap

To account for some of the limitations in the NZFFD data, Crow et al. (2016) drew on several statistical approaches to address some of the biases that come with using this dataset. To identify if the 'probability of capture' for a taonga freshwater species through time appears to be increasing (getting better), decreasing (getting worse) or staying the same, Crow et al. (2016) completed simple linear regression[15] calculations (how does X relate to Y?) using two different techniques.

The first technique was the Sen Slope Estimator (SSE), while the second technique was a weighted version of the SSE. The weighted SSE (called WSSE hereafter) assigns a weighting value based on the size of the confidence intervals[16] (CI). In the WSSE, pairs of years that collectively have small CIs are weighted more heavily than pairs of years that collectively have large CIs because we were more confident in these probability of capture values.

Both WSSE and SSE results are presented in this report because, together, they help us understand whether or not we can be confident in the analysis and detect a trend over time (either increasing or decreasing) – or if we cannot detect a trend.

3.3.2 Tuna Results

The SSE slope for **longfin eels** was indeterminate over the 1977–2015 period, while the WSSE slope showed a median (± 95% CI) decreasing trend of 0.09 (± 0.06) %/year (Figure 8). The estimated probability of longfin capture for each year displayed high levels of variance between years. For example, over 2010–2015, values close to both the highest and lowest probability of capture values were observed.

Both SSE and WSSE showed increasing trends for **shortfin eels** over the 1977–2015 period (Figure 8). The SSE results suggested that shortfin probability of capture was increasing at a median (± 95% CI) rate of 0.13 (± 0.02) %/year, while WSSE results suggested that shortfin probability of capture was increasing at a median (± 95% CI) rate of 0.18 (± 0.01) %/year.

In summary, the high levels of variance in the longfin eel data meant that the two trend analyses over the full-time series available (1977–2015) were not in agreement and did not show a strong trend in either direction; while for shortfin eels both methods agree that population trends are increasing (Crow et al. 2016).

[15] Simple linear regression is a statistical method that allows us to summarise and study relationships between two continuous (quantitative) variables.
[16] A confidence interval is a range of values we are fairly sure our true value lies within.

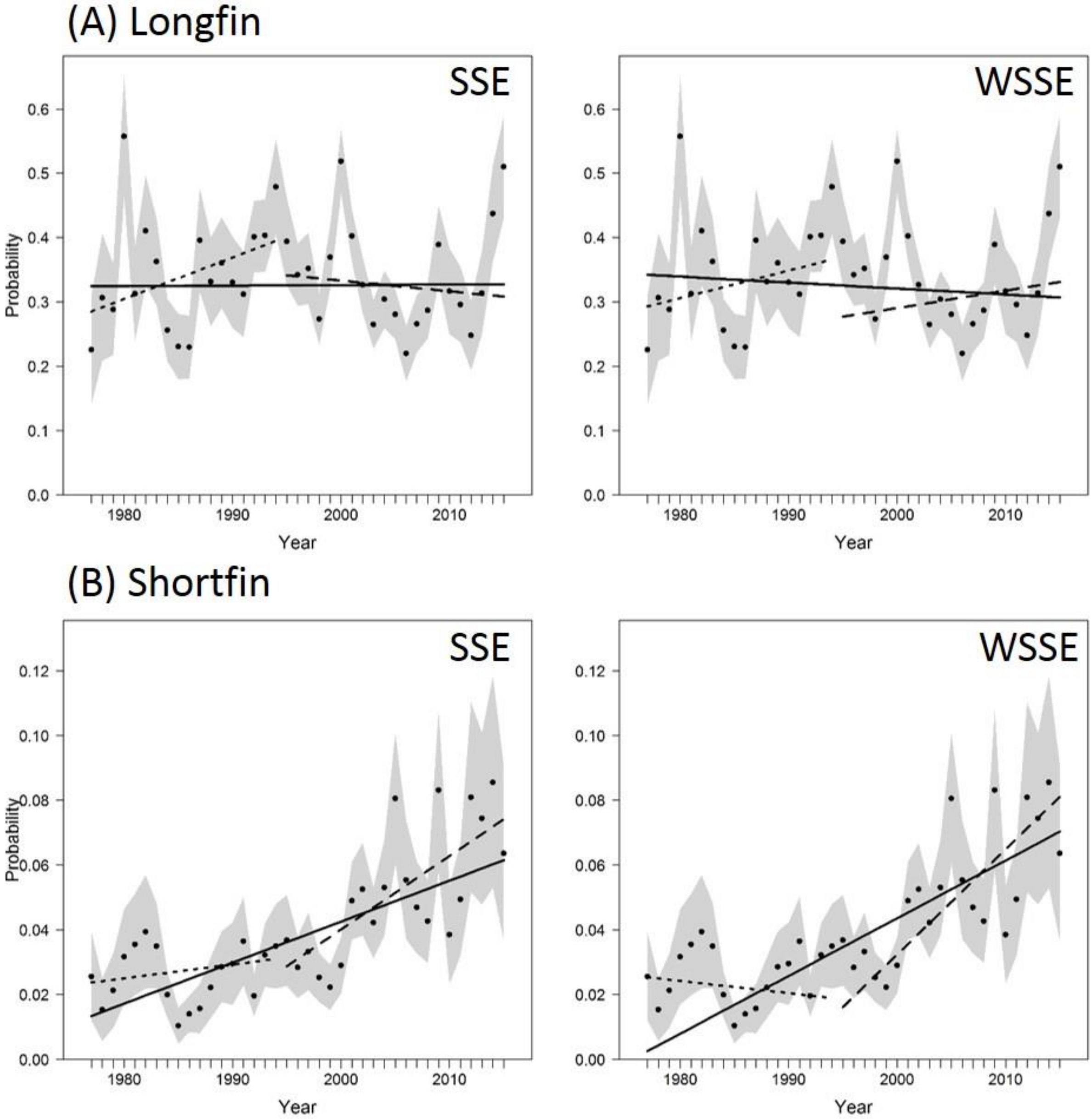

Figure 8: Change in the probability of capture of longfin (A) and shortfin (B) eels associated with year using data from the NZFFD. Plots show 'probability of capture' for each year (black circles) and 95% CI (grey shaded area). SSE (left) and WSSE (right) are shown for 1977–2015 (solid black line), 1977–1994 (dotted black line) and 1995–2015 (dashed black line). (Source: Crow et al. 2016).

3.3.3 Trends in Elver Recruitment

The past few decades have seen a decline in the recruitment of Northern Hemisphere species of freshwater eels. Eels recruit into Aotearoa-NZs rivers as transparent glass eels in their first year of life and spend some time in estuarine reaches before moving upstream. Elvers, the next stage in the life-cycle, are 1–4 years old and move upstream as they grow older. In Aotearoa-NZ, there are indications that the huge elver runs that were both witnessed (e.g., Best 1929) and filmed (Hayward & Hayward 1992) prior to the 1960s are no longer seen. It is not known how present recruitment relates to historical runs, but since 1995 MPI has been monitoring elver recruitment (e.g., Martin & Bowman 2016).

Monitoring elver catches at sites where trap-and-transfer operations (e.g., Figure 9) are undertaken provides an opportunity to track the relative abundance of elvers over time. Provided data are collected in a consistent manner each year, it can be used to determine overall trends in recruitment. Recruitment is predominantly monitored by trapping elvers at hydroelectric dams and other man-made structures (e.g., weirs). Estimates of the numbers of elvers (by species) arriving at hydroelectric dams on several Aotearoa-NZ rivers are recorded by stakeholders, mostly (but not exclusively) as part of resource (operating) consent conditions. The datasets generated are currently compiled by NIWA under contract to MPI. Every two to three years this data is collated into reports for MPI which are publicly available. Elver trapping data are one of the information sources used by MPI to **monitor trends in eel recruitment** and inform eel management at a national scale.

Figure 9: Elver trap-and-transfer activities. (Left to right) Elver trap at Karāpiro dam; An example of an elver ramp; Estimating the total elver catch using a sub-sample; and Transfer of elvers into transportation tanks for release. (Photos: Mike Martin and Jacques Boubée).

Over the last 25 years, elver data has been recorded from 22 sites in Aotearoa-NZ (Figure 10), but most of these data have inconsistencies due to modifications to the trapping arrangements or time periods where data were not collected (e.g., structures being modified). NIWA developed standard methods for the trapping and transfer of elvers and recording of the catches in the early 1990s (Martin et al. 2007). Elver trapping has occurred consistently in a standardised manner at six main sites, and these form the basis of the elver abundance time series. The time series of data collected from the main sites varies from 5 years (Wairua Falls) to 22 years (Karāprio Dam).

Longfin and shortfin elver recruitment at a site is temporally variable with abundance varying two-fold between some years; overall there has been no consistent trend in recruitment across the main sites (Figure 11 & 12). Matahina Dam and Karāpiro Dam both show similar annual patterns over the 15 years of continuous data collection. Pātea Dam also has high levels of recruitment variability, but the most recent longfin catch index in 2015–16 is more than double that of next highest year in 2007–08. Shortfin recruitment at the Pātea Dam decreased from 2005–2011, but has steadily increased each year after this. In contrast, Piripaua longfin and shortfin catches have remained very stable during the early 2000's and have increased markedly over the last five years. Data across all sites have been used by Martin and Bowman (2016) to conclude that there has been no decline in recruitment over the last 25 years.

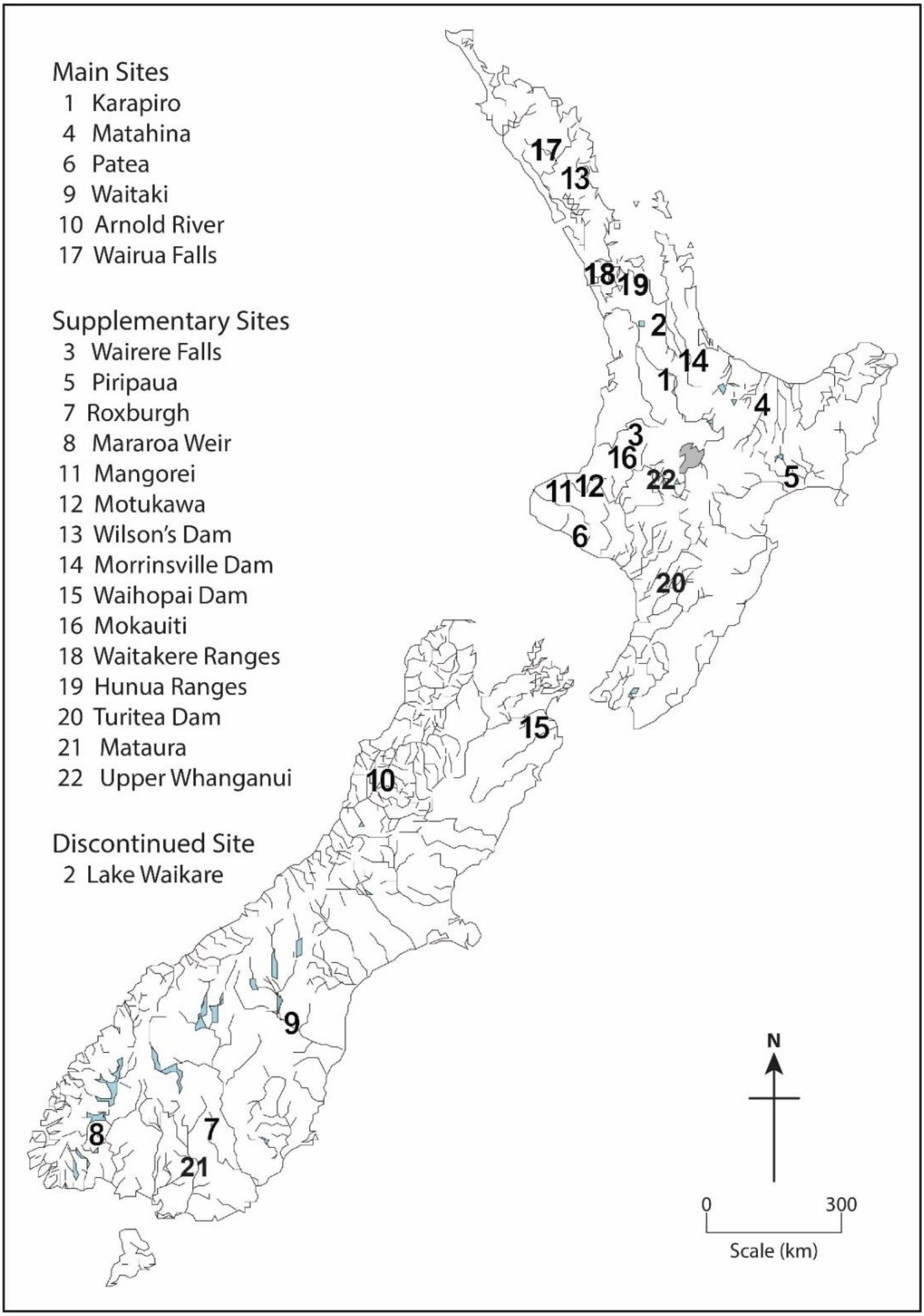

Figure 10: Locations of the 22 sites where elver trapping has occurred in Aotearoa-NZ over the last 25 years. Main sites have elver data collected each year, while supplementary sites have data collected intermittently. (Source: Martin & Bowman 2016).

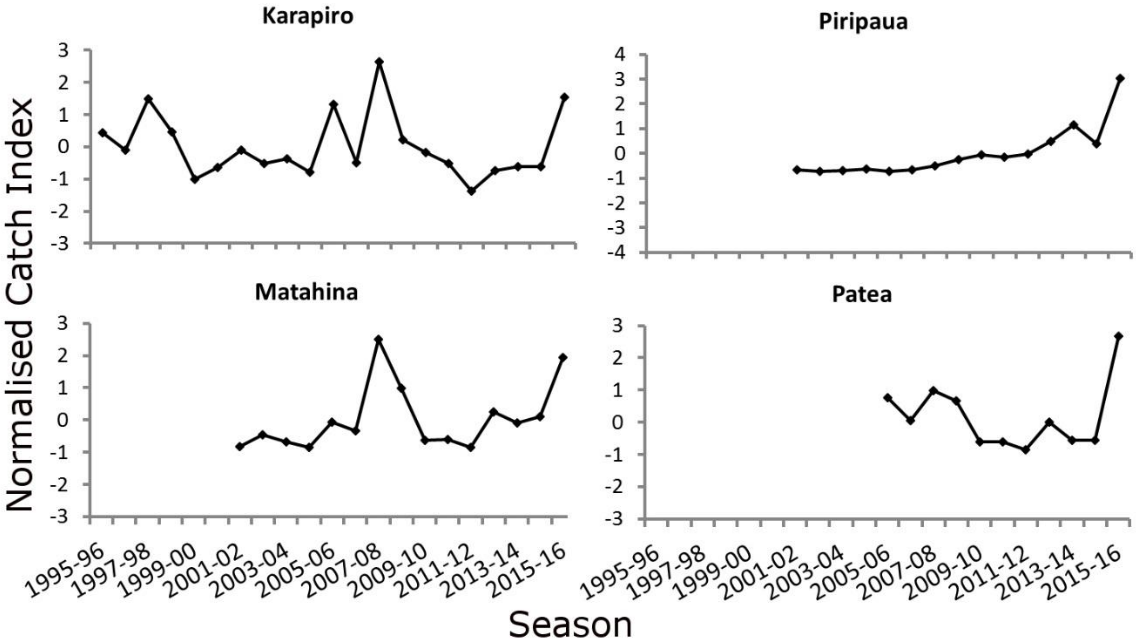

Figure 11: Index of relative abundance for longfin elver catches from 1995–96 to 2015–16. (Source: Martin & Bowman 2016). Because of the variability between sites and years, elver catch records were normalised following the method of Durif et al. (2008), and a "normal" catch index was calculated for each species, season, and location (MPI 2017).

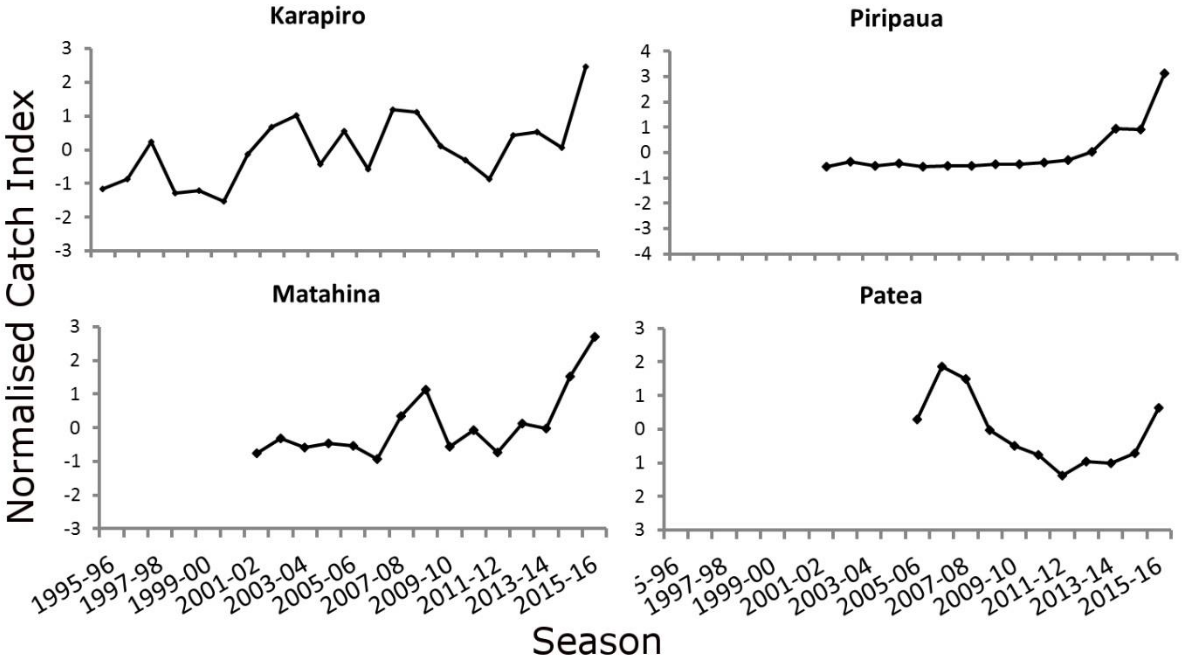

Figure 12: Index of relative abundance for shortfin elver catches at selected hydro dams from 1995–96 to 2015–16. (Source: Martin & Bowman 2016). Because of the variability between sites and years, elver catch records were normalised following the method of Durif et al. (2008), and a "normal" catch index was calculated for each species, season, and location (MPI 2017).

3.4 Threat Rankings

The latest New Zealand Threat Classification System assessment classified shortfins as being 'Not Threatened', while longfins are classified as 'At Risk–Declining' (Goodman et al. 2014). The shortfin classification was based on an increasing population (over what time period they used is unknown), while the longfin classification was based on a declining population of 10–70% in two generations (i.e., 80 years). The Australian longfins were considered to have a secure overseas population and were not assessed. The IUCN threat rankings are yet to be completed for Aotearoa-NZ eels (Table 3).

Table 3: Threat rankings for Aotearoa-NZ tuna species according to the New Zealand Threat Classification System and IUCN. (see Section 2.3 for more information about these assessment methods).

Species	DOC Ranking	IUCN Ranking
Longfin (*A. dieffenbachii*)	At Risk–Declining	Not assessed
Shortfin (*A. australis*)	Not Threatened	Not assessed

3.5 Pressures on Populations

In Aotearoa-NZ, although longfins are still one of the most common freshwater fish, there are concerns about the scarcity of very large specimens. Multiple factors are likely to be impacting eel populations around the world, including changes in oceanic currents, habitat loss, over-exploitation of adult stocks, mortality and migration delays experienced by upstream and downstream migrants at barriers, parasites and diseases, predation, and pollutants (e.g., Castonguay et al. 1994, Haro et al. 2000, Arai 2014, Jacoby et al. 2015, Belpaire et al. 2016). The potential implications of climate (and climate change), particularly on species with marine life stages, also needs to inform our long-term thinking (e.g., Bonhommeau et al. 2008).

Key pressures on Aotearoa-NZ eel populations include habitat loss, loss of connectivity for migrations between the sea and freshwater habitats, land and infrastructure management and harvest (commercial, recreational and cultural). Other pressures may arise from competition (e.g., with exotic fish species such as catfish and koi carp), predation on the vulnerable juvenile stages in rivers and lakes, toxins, diseases and parasites, and marine factors (e.g., food availability) influencing the survival of larvae, growth and recruitment of glass eels to river mouths (Figure 13) (e.g., Miller & Tsukamoto 2017). The impact of these latter factors is currently unknown.

3.5.1 Loss of Habitat

Since European settlement there have been many changes in land use in Aotearoa-NZ, with large areas being cleared for human habitation and agriculture. Statistics NZ (2008) categorises three main land uses: production, conservation, and urban development. Over one-third of land is legally protected for conservation purposes, with the remaining majority being used for primary production. Urban and rural residential developments cover a small but growing area. Land-use change varies in scale, with some alterations occurring at the catchment level and others at a much smaller, microhabitat scale. The effect of land-use change on our taonga species are multi-layered affecting the temperature, light, water quality and geomorphology of ecosystems. For example, it is estimated that wetlands that once covered at least 670,000 ha before European settlement have now been reduced to about 100,000 ha (MfE 1997). Within the Waikato catchment alone, the loss of wetlands was estimated to be 84% between 1840 and 1976 (McDowall 1990). Much of this drainage pre-dated the commencement of commercial eel fishing, but nonetheless resulted in a huge loss of tuna habitat.

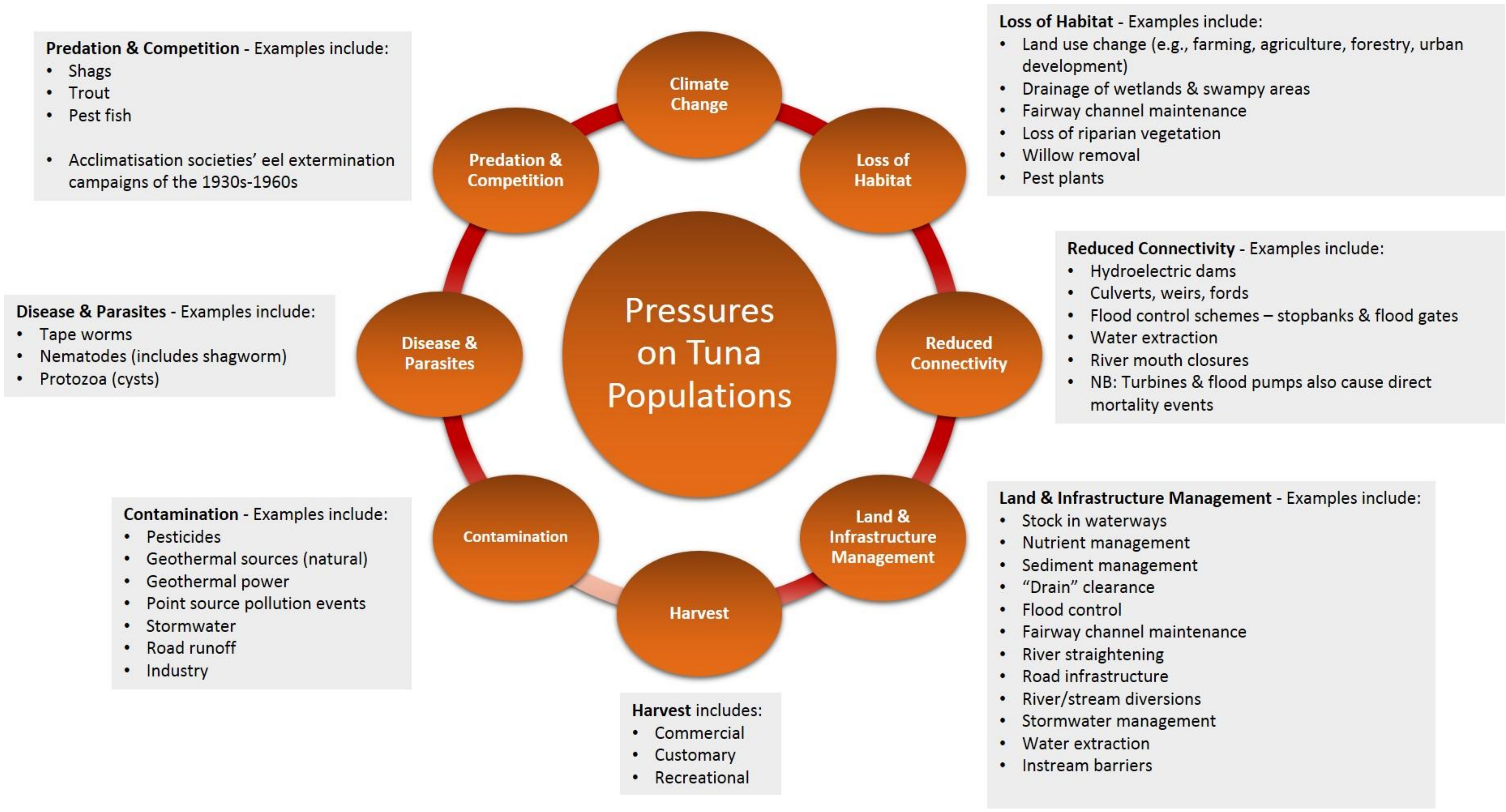

Figure 13: **Examples of some of the pressures on Aotearoa-NZ tuna populations.**

Being a somewhat lowland species, shortfins have been particularly affected by **drainage of wetlands** and channelisation of rivers. Shortfins are also the species that responds most to flooding and feeds extensively in newly inundated areas (Jellyman 1989, Chisnall & Hayes 1991, Chisnall 2000b), and channelization of waterways has reduced such feeding opportunities (Chisnall 1989). The biomass of larger eels is directly related to the amount of suitable cover (Burnet 1952), so the loss of cover by such practices as macrophyte removal and channelisation of waterways, together with siltation, reduces the quality of habitat available to both species. That said, Hicks and McCaughan (1997) found that the conversion of land from forest to pasture resulted in an increase in the abundance of shortfins. It is thought that access to pasture may also provide eels with an additional food source of terrestrial invertebrates (Chisnall 1987, Chisnall & Hicks 1993). Sedimentation may reduce food availability in pasture sites by clogging instream substrates (Hanchet 1990) which is also supported by the work of Jowett and Richardson (1990) who found higher invertebrate biomass was associated with coarse sediments. Sedimentation may also impact juvenile eels who are known to refuge in subterranean substrates (Cairns 1950).

Willows on the margins of streams and rivers are known to provide habitat that is often used by both longfin and shortfin eels. This is important in both an ecological and a commercial sense, as the **removal of riparian willows** from streams and rivers, without replacement with a suitable alternative (e.g., Figure 14) could adversely affect both the amount of habitat available to eels, and the number of large eels available to fishers. Few studies have explicitly examined the importance of willows for fish in our waterways (Glova & Sagar 1994). To date, very few scientific studies on willow-removal effects have been conducted and any documentation/evaluation of rehabilitation projects that include willow removal are equally scarce (Wagenhoff & Young 2013).

Figure 14: Examples of willow removal activities in the Tauweru River catchment. (Photos: Erica Williams). Willows were brought to Aotearoa-NZ in early 1800s from Europe or Asia and widely planted for bank stability. Of the 10+ willow (*Salix*) species/varieties, Crack willow (*S. fragilis*) and Grey willow (*Salix cinerea*) are very invasive and can live for 100 years. It is illegal to propagate or plant crack willow in Aotearoa-NZ (NZ Landcare Trust 2015).

Willow removal will cause short- to medium-term effects that potentially pose risks to taonga species and the ecosystems that support them. Some of the risks are associated with: (1) The removal of willows that have retained large amounts of fine sediment and organic matter; (2) The removal of willows that have modified their environment as ecosystem engineers; (3) The loss of important functions that riparian vegetation fulfils until the native vegetation is re-established, and (4) The removal process itself (Wagenhoff & Young 2013).

A preliminary NIWA scoping study investigating the weights of eels in willowed and non-willowed reaches of three waterways (Jellyman & Glova 1998) found that:

- Longfins more than 220 g were much more abundant in willowed compared to non-willowed reaches.
- Longfins less than 220 g were of roughly similar abundance and density in willowed and non-willowed reaches.
- No shortfins more than 220 g were caught in non-willowed reaches, and only moderate numbers were found in willowed stretches.
- Shortfins caught in the three study streams were predominantly less than 220 g, and these were five times more abundant in the willowed reaches.

The main reason that riparian willows appear to provide habitat for eels is that, being a nocturnal species, eels use willows during the day to avoid light. Eels are generally known as secretive and "cover-loving" and large eels are frequently associated with overhung banks and dense instream cover such as logs and debris. For juveniles, features of the substrate are very important, but larger eels require more complex cover like debris clusters and undercut banks and the availability of such cover will largely determine the density of large eels.

3.5.2 Reduced Connectivity

One of the greatest threats to indigenous fish populations that follow a diadromous life cycle are barriers that prevent or delay migrations between freshwater and marine environments. Connectivity between habitats can be critical to ensuring the long-term success of fish populations (Lake et al*.* 2007, Fullerton et al*.* 2010). Barriers to migration can restrict access to habitats required for foraging and feeding, predator avoidance, shelter, and spawning (Gibson et al*.* 2005). Lack of access to these habitats, particularly for obligate migratory species, can ultimately lead to a reduction in recruitment, population decline, and a loss of biodiversity (e.g., Jellyman & Harding 2012).

In Aotearoa-NZ, **hydroelectric facilities** (e.g., Figure 15) currently produce about 61% of the country's electricity needs and hydro generation is predicted to continue to be a significant source of energy in the future (Ministry of Economic Development 2003). Anthropogenic barriers and hydroelectric dams in particular are some of the factors thought to have contributed to the decline of eel populations worldwide. Hydroelectric dams impact upon tuna in two ways: (1) By obstructing the upstream migration of glass eels and elvers; and (2) By adversely affecting the safe passage of mature eels downstream.

Minimum flows released from dams are now routinely set as part of resource consents to ensure that habitat for resident fish populations are maintained below the dam, as well as providing passage for migratory fish. However, to ensure that upstream migrating fish can pass over the dam and utilise habitat upstream, the installation of passage facilities may be required. Passage facilities should aim to permit passage for all upstream migrating fish that occur within a catchment, except for those considered to be pest fishes (e.g., DOC 2010) and those situations in which a conservation case can be made for not permitting access. Passage for those upstream migrating fish who have historically been recorded in a catchment and who could reasonably be expected to require passage should also be catered for. A variety of upstream passage facilities have been installed in Aotearoa-NZ, including: (1) Substrate ramp passes (also known as fish ladders); (2) 'Nature-like' fish ways; (3) Fish lifts and locks; and (4) Engineered fish passes. The choice of facility installed depends upon the fish species requiring passage and characteristics of the barrier, such as head height, available space and economic resources (Paterson 2010a).

Figure 15: **The Waitaki Dam.** (Photo: Shannan Crow). The Waitaki Hydroelectric Power Scheme consists of eight power stations from Lake Tekapō to Lake Waitaki. Mahinga kai is a value that lies at the heart of Ngāi Tahu culture and identity. More than 30 different species were once gathered across 160 sites in the Waitaki catchment, about 70% of which once sustained tuna. As the most commonly gathered food source, tuna remain a taonga that whānau want to see restored across the catchment. Eighty-one percent of the catchment is now located above the lower-most Waitaki dam, and without fish passage throughout the catchment, is essentially lost as habitat to support tuna populations and mahinga kai values (Tipa & Associates 2015).

In general, small eels are very good climbers and can use surface tension to climb damp walls of **culverts, weirs and fords** as long as the surface is moist and there is a continuous climbing surface (i.e., with no breaks or overhang). Most problems occur when eels encounter barriers that have been designed and/or installed incorrectly; resulting in very strong water flows through the structure and scouring out the stream at the downstream end creating an overhanging perch that the eels cannot climb. In many catchments, smaller-scale obstructions, such as weirs and culverts, are the most common artificial barriers and thus may have a greater influence on taonga species population dynamics. For example, of the estimated 3.6 culverts per 100 hectares in the Waikato Region, 36% or 1.3 out of 100 hectares were a barrier to all fish at all flows (i.e., to tuna, as well as other species). As the catchment area for the lower Waikato River below Karāpiro (excluding the major lakes) is approximately 6,500 km^2, approximately 8,500 culverts could be limiting elver recruitment. Some of these culverts will be more serious barriers than others because they restrict access to larger amounts and/or quality of habitat upstream and/or are not passable at all flows (Watene-Rawiri et al. in press).

Mortality at Hydroelectric Dams and Flood Pumps

Given that factors out in the ocean that may adversely affect eel reproduction and migration are beyond our control, options to support the long-term sustainability of our tuna populations should be focused around maximising the number of eels, particularly large longfin females, that can safely reach the sea. By far one of the most serious issues for taonga species resource managers to address in the immediate future is the significant loss of pre-migrant and migrant eels as they pass through and are killed by turbines at flood control schemes and hydroelectric dams throughout Aotearoa-NZ.

Once eels reach sexual maturity they begin their downstream migration. Where barriers such as **hydroelectric dams** are present, passage can be at best interrupted or blocked, but in most cases passage results in serious injury or death (Figures 16 & 17). Since longfins are the species that penetrate farthest inland, the installation of hydroelectric dams has impacted this species the most by compromising their upstream access.

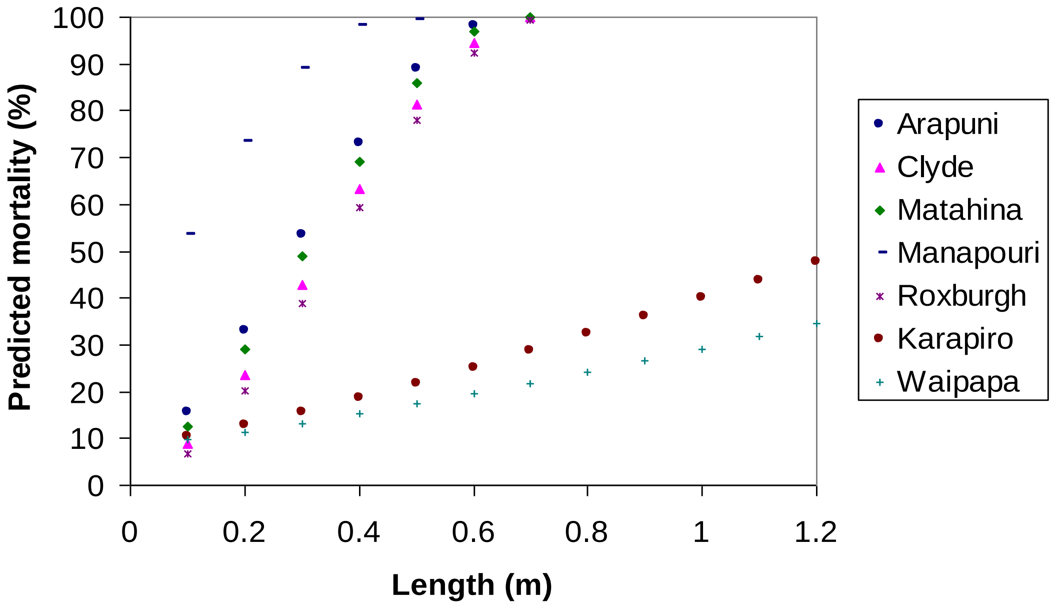

Figure 16: Estimated mortality of migrating eels of varying lengths, for different hydroelectric stations in Aotearoa-NZ. The lower mortalities of Karāpiro and Waipapa are due to different turbine types compared to other stations. (Source: Jellyman 2013). While there have been no specific studies of turbine mortality in Aotearoa-NZ, generic relationships can be used to estimate the probability of death, considering variables such as the size of the eel, speed of rotation, head of water, and type of turbine. Large female longfin eels are at very high risk in such situations (Mitchell & Boubée 1992, Larinier & Travade 2002).

Figure 17: Tuna death row – Some examples of the dead eels that result from hydroelectric operations in Aotearoa-NZ. (Photos: Ben Chisnall, Mike Holmes, Jacques Boubée).

Information on the timing of downstream migrating adults has been successfully used to reduce mortality for a variety of fish species at dams and other passage barriers (Benstead et al. 1999, Achord et al. 2007). In cases where downstream migration can be predicted, implementing mitigation activities such as targeted netting (Boubée et al. 2001), spillway opening (Watene et al. 2003, Watene & Boubée 2005), or bypass opening (Boubée & Williams 2006) has resulted in reduced injury and mortality rates. However, predicting migration is difficult, especially in rivers whose flow patterns are regulated by storage and generation schedules (Haro et al. 2003).

When downstream migrant eels are confronted with a dam, studies (e.g., Durif et al. 2003, Watene et al. 2003) have shown that they spend time searching along the headrace, presumably for an unobstructed pathway downstream. Some eels that are unable to find a pathway have been shown to return upstream, often to the location where they were residing previously (Watene et al. 2003). Many migrants impinge on screens or enter station intakes, and are killed during passage through the turbines (see Figure 17).

At present, none of the hydroelectric dams in Aotearoa-NZ has been specifically equipped to protect the downstream migration of sexually mature eels. However, some retrofitting and mitigation activities have been implemented in the last ten years to protect and/or safely pass migrants (e.g., Wairere Falls Power Station, Boubée & Williams 2006). Ceasing generation completely during major downstream migration events, whilst also providing permanent bypass facilities and protective measures at intakes is the ultimate way of providing safe downstream passage for tuna. Some of the options available to operators to facilitate the safe downstream passage of eels at hydroelectric dams include: (1) Ceasing generation and actively spilling during migration events; (2) Installation of fish friendlier turbines; (3) Installation of physical and behavioural deterrents; (4) Installation of bypasses (e.g., Wairere Falls/King Country Energy); and (5) Trapping large eels above hydro stations and transferring them to locations downstream that are safe from harvest and have open access to the sea (e.g., Manapōuri and upper Waitaki/Meridian Energy) (Paterson 2010b).

Connectivity within many Aotearoa-NZ catchments has been substantially altered by **stop banks, floodgates** and **pumping stations.** In the lower Waikato alone it is estimated that about half of the 32,000 hectares of floodplain has been protected by stop banks, which in turn has markedly reduced natural floodplain habitat. Each station generally has a gravity flap/floodgate (Figure 18) which is designed to prevent flows from the main river channel entering the pockets during elevated river levels. During floods, much of the land behind stop banks is actively pumped (in some cases the upstream land is below the receiving water so the pumps are operated more often). At pumping stations the downstream migration of large adult migrant eels is impeded in two ways: (1) Eel mortality through entrainment in scheme pumps; and (2) Impediments to migrant movement into the main river channel during periods of oxygen depletion in the pocket areas following significant storm events (where the river has spilled into the pockets).

Eel mortality events have been observed by both fishermen and tangata whenua during flood events, for example in the Hikurangi Repo (Wairua River catchment), where Chetham and Shortland (2009) describe the rivers downstream of the pumps "*churning with white mutilated bodies of eels*"… and "*estimated that each pump kills 100 of kilograms, if not tonnes of eel over a 24 hour period"* (Alan Gardiner, pers. comm. in Chetham & Shortland 2009). There is also evidence of chopped mature eels downstream of the pump stations (Figure 18). Whangārei District Council are undertaking investigations on eel movements through the Mountain Pump Station in the Hikurangi Swamp Scheme (Twose 2016).

Figure 18: Examples from the Hikurangi Swamp Scheme. (A) A pump station inlet; (B) Flood gates on a pump station outlet; and (C) Some of the tuna killed by one of the Hikurangi pump stations during a flood event in March 2017. (Photos: Jacques Boubée, Alan Halliday). For more information about this particular tuna mortality event, see https://www.maoritelevision.com/news/regional/whangarei-water-turbines-kill-eel-numbers.

In the Waikato, apart from one Archimedes screw pump which only operates at very high flows, the remaining 65 flood pump stations installed do not allow the safe downstream passage of adult tuna (Watene-Rawiri et al. in press). Replacing or modifying flood pumps to make them tuna friendly would allow the safe escape of adult spawners, for example, from an estimated 600 km of waterways in the lower Waikato (i.e., 6% of the total length of waterways downstream of Karāpiro Dam). We understand that the Waikato Regional Council are currently doing some research into the use of passive integrated transponder tags and acoustic hydrophones to document eel movement and mortality through non-gravity fed axial pumping stations in the lower Waikato River catchment. An update on this work will be presented at the forthcoming New Zealand Freshwater Sciences Society Conference to be held University of Waikato in November 2017.

To remedy the adverse effect of flood pumps on downstream migrating tuna it will be necessary to install a safe downstream passage route and fine screens (20 mm spacing or less) to prevent the tuna from entering each pump. In the future behavioural barriers (e.g., light, electricity) could be considered if shown to be effective. The screens need to have enough surface area so the through-screen water velocities remain below 0.5 m/s and do not cause the tuna to impinge on the screens. Screens may require automated screen cleaners to ensure their efficiency. At tide and flood gates, safe downstream passage routes can be provided by either: (1) One or more flap gates that provide a safe route once the downstream water level recedes (note that a mechanism to keep this flap gate open at low flows is essential and when the gate is closed it must not delay the migration); (2) One or more tuna-friendly pumps such as a Ventura pump or an Archimedes Screw pump; or (3) Catch/trap and transfer of adult migrants (Watene-Rawiri et al. in press).

3.5.3 Land and Infrastructure Management

Much of the low-lying land in Aotearoa-NZ requires drainage to be used for pastoral purposes. Beentjes et al. (2005) collated information on the extent of **drain cleaning practices** (e.g., Figure 19) throughout Aotearoa-NZ; the total estimated length of waterways cleaned in Aotearoa-NZ each year is about 15,500 km, most of which (66%) are drains, followed by stock water races and natural waterways (12 %) (Beentjes et al. 2005). However, in unrated catchments, landowners can carry out their own drain clearance activities (within the region's respective rules), so the length of cleared waterways could be much larger than this.

Beentjes et al. (2005) state that three councils carry out nearly half the total length of waterways cleaned in Aotearoa-NZ: Waikato Regional Council (22%), Selwyn District Council (16%), and Environment Southland (11%). The frequency with which waterways are cleaned is highly variable, ranging from several times per year to once every 10 years, or as required, and most common methods used are herbicide spray and mechanical excavation (Beentjes et al. 2005).

Figure 19: Drain clearance activities in the Hikurangi Repo. (Photo: Whangārei District Council).

There are few published studies in Aotearoa-NZ that have attempted to quantify or document the effects of mechanical or chemical drain cleaning on mortality of tuna (e.g., Allibone & Dare 2015) and the results are inconclusive. Anecdotal evidence indicates that eels are frequently scooped out of drains by mechanical excavators and that some operators dump them on the bank side where they die if they are unable to return to the watercourse. Complaints from the public about destructive and poorly monitored land management practises are turning up in the media more frequently (e.g., [17], [18], [19]). Drain Maintenance Technical Guidance (Greer et al. 2015) has been produced by DOC for RMA and concession applications and provides the following recommendations for conditions and mitigation activities of relevance to longfin tuna:

[17] Sediment cleaning under review (http://www.stuff.co.nz/marlborough-express/news/5594063/Sediment-cleaning-under-review);

[18] Council apologises after dozens of dead eels found in protected pond (https://www.tvnz.co.nz/one-news/new-zealand/council-apologises-after-dozens-of-dead-eels-found-in-protected-pond-6245239); and

[19] The destruction of the river erosion control programme (http://wairarapareviews.kiwi.nz/environmental/river-erosion-programme/).

- During weed cutting and mechanical excavation operations the consent holder shall ensure any stranded fish, kōura and kākahi are returned to the waterway. All fauna shall be released upstream of the affected section of waterway, or, where this is impractical (e.g., appropriate upstream release sites cannot be easily accessed), in a downstream section of the waterway that is below the mixing zone and does not have elevated levels of suspended sediment—to avoid exposing fauna to sediment-induced anoxia (lack of oxygen) when returned to the water.
- If a species listed as threatened under the New Zealand Threat Classification System is recovered during excavation or weed cutting in a waterway that is not previously known to contain that species, works in the area the fish was discovered shall cease immediately.
- If Threatened or At Risk (i.e., longfin tuna, lamprey, īnanga, shortjaw kōkopu, giant kōkopu, and kōaro) fish are known to be present in the waterway, or the waterway is known or expected to contain a large fish population, a person shall be present at all times to return any stranded fish to the waterway.

3.5.4 Contamination and Safe to Eat

While fish are an important part of a balanced and healthy diet, nearly all fish species contain traces of metals like mercury and other contaminants (that occur both naturally and because of human activities) that may build up over time and pose a risk to human consumers. Many toxic contaminants are stored in the lipids (or fats) of biota and can biomagnify up through the food chain, increasing the risk to humans of consuming long-lived, higher predatory animals, such as tuna. Generally, bioaccumulative contaminants of most concern include organochlorine pesticides (especially DDTs and dieldrin), polychlorinated biphenyls (PCBs) and dioxins (particularly near timber treatment plants), pentachlorophenol, and selected heavy metals such as mercury, arsenic, cadmium, and lead.

A range of chemical contaminants enter our waterways, including direct inputs from industrial and municipal wastewater discharges, and indirectly via diffuse source inputs and natural background inputs of geothermal contaminants. Geothermally-derived arsenic (As) and mercury (Hg) naturally enter catchments like Taupō-nui-a-Tia, Waikato River, Te Arawa Lakes, Kaituna River, and Waiaruhe River. For example, a major point source of geothermally-derived contaminants enters the upper Waikato catchment from the Wairakei Geothermal Power Station, and much of these contaminants are thought to accumulate in the sediments of Lake Ohakurī. There are several other locations down river including Mangakino, Hamilton and Waikare where small natural geothermal sources may still be producing naturally-derived metal contaminants (NIWA 2010).

Mercury is of concern because of its ability to biomagnify through the food chain. Surveys of trout from the Waikato River in the 1990's found that Hg levels exceeded health regulations in only 11 of the 285 fish sampled; however, comparison with accepted daily intake values indicated that some sites "could conceivably pose some threat to human health". Eels live considerably longer than trout (30–50+ years versus five years), so could potentially accumulate more Hg than trout and be of greater risk to high consumers. In addition to metal contaminants, it is known that quantities of DDT and other pesticides were historically used throughout Aotearoa-NZ to control grass-grub on pasture and lice in cattle. At this stage, it is not clear if these residues are potential sources of concern and if so which catchments are most affected. To date "contaminants in kai" risk assessment studies, which also considers the actual consumption rates of whānau, have been completed with the Te Arawa Lakes Trust, Te Rūnanga of Arowhenua and the Te Waihora Management Board (e.g., Stewart et al. 2011, Phillips et al. 2014, Stewart et al. 2014).

3.5.5 Disease and Parasites

All fish carry pathogens and parasites usually at some cost to the fish. Fish can be exposed to various pathogens and/or parasites depending on the habitat they are living in or at different stages of their life cycle (i.e., fish are exposed to different parasites depending on their diet which may change as they get bigger). In Aotearoa-NZ there has been little transfer of new organisms, brought into the country by introduced species, into native fishes (Boustead 1982, Duignan et al. 2003).

Across all our indigenous fish fauna a total of 65 different species of parasites have been reported, six of which are introduced (Hine et al. 2000). To date 36 different parasite species have been reported in Aotearoa-NZ shortfin and longfin eel populations (e.g., Hewitt & Hine 1972, Hine 1978, Hine et al. 2000, Duignan et al. 2003). Over the last 30 years infectious diseases have not been observed to have caused a significant morbidity or mortality event in our indigenous fish populations (Duignan et al. 2003). However, to the best of our knowledge, there is no regular surveillance programmes monitoring the incidence of pathogen/parasite prevalence in our freshwater taonga species populations; the last survey occurred around 2003 (Duignan et al. 2003). The presence/absence of visible parasites could be monitored by communities using the parasite infestation index outlined in Richardson (1998), where each individual eel examined receives a parasite infestation ranking: 0 = No parasites present externally or internally; 1 = One or two parasites present; 2 = Numerous parasites present; 3 = Heavy parasite infestation. Some examples of a few of the parasites observed in tuna from Tai Tokerau, Waikato and Murihiku waterways are shown in Appendix C.

3.5.6 Predation and Competition

Longfin eels are the largest and longest-lived fish in our fresh waters, and where they are present, and large enough, they are the top predator. Tuna are opportunistic feeders, usually eating anything they can find. What they eat depends on their size (and the size of their mouth), the habitat occupied, and the prey available. Tuna are usually more active at night and rest during the day. Feeding slows down during cold temperatures (less than 10°C). Small eels eat a range of invertebrates, including small insect larvae, worms, snails, midges, shrimp, molluscs and crustaceans, although small eels themselves are predated upon by larger eels and birds (e.g., shags, herons). As their mouths get bigger, tuna eat larger animals such as kōura, fish, small birds, mice and rats (e.g., Jellyman 1996, Sagar & Glova 1998).

As previously mentioned, flooded river margins are important feeding grounds for eels. During a flood, eels will move out of the main river channel to the margins where they will feed on organisms not usually found in the water, like earthworms, spiders and beetles (Chisnall 1987; 2000b).

Introduced fish such as trout, perch, gambusia, rudd, catfish, koi carp, and tench continue to spread within Aotearoa-NZ. These pest species can impact eel populations through competition for food resources, degrading habitat and reducing biodiversity (Rowe 2004).

3.5.7 Acclimatisation Societies

As a result of European settlement, acclimatisation societies were set up to facilitate, implement and maintain a host of plant and animal introductions into Aotearoa-NZ waterways, including salmon and trout, for the benefit of recreational fishers. McDowall (2011) contends that even if Māori were consulted at the time (they generally weren't), no one could have predicted the way acclimatisation societies and trout populations proliferated and impacted Aotearoa-NZ's indigenous fisheries; thus, impacting whānau who relied on taonga freshwater fish species for food and made living long distances inland possible for many.

Eels were promoted by these societies as the enemy of trout. For example, in 1933, a acclimatisation society ranger advised *"Where infestation is bad it is possible to wade up a stream beheading the eels in one's stride."* In 1943, the Wellington Acclimatisation Society printed on their fishing licenses that *"Every angler should make war on eels."* (Parliamentary Commissioner for the Environment 2013, and references therein). Acclimatisation societies, with the support of government agencies, declared tuna to be 'public vermin', launching massive extermination campaigns in some regions from the 1930s to 1950s. For example, in South Canterbury, the Acclimatisation Society reported the death of 4,270 eels in 1934 using eel baskets that had been distributed to farmers. During the 1960's, although the intensive eel destruction campaigns had finished, many regions still had a bounty on eels, to encourage people to kill them (Jellyman 2013). Research was carried out on the effect of eels on a trout population which showed that the presence of eels, especially longfins, was useful in stopping trout from becoming over-populated and having fisheries stocked with numerous small, stunted trout rather than fewer large trout of angling size (Burnet 1968), so eels actually helped to maintain a higher value trout fishery. This knowledge effectively stopped the bounty system on eels (Jellyman 2013).

Extermination campaigns killed hundreds of thousands of eels, which were heaped on riverbanks to die, or were buried. Because eels are relatively long-lived and only spawn once in their lifetimes, the impacts of these acclimatisation societies misguided and hugely destructive campaigns are still being felt today.

3.5.8 Harvest

Commercial

The commercial eel fishery in Aotearoa-NZ began in earnest in the late 1960s and expanded rapidly until the early 1970s, peaking at slightly over 2,000 t in 1972 (Figure 20). Jellyman (2013) describes the development of the commercial eel fishery in three phases: (1) An exploitation phase (1965–1980); (2) A consolidation phase (1980–2000); and (3) A rationalization phase (2000 to 2012).

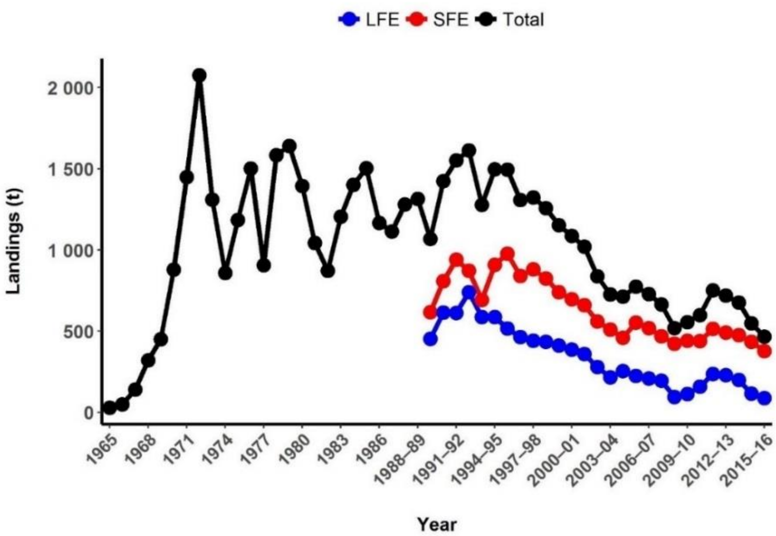

Figure 20: Total eel landings from 1965 to 2015–16, as well as separate shortfin and longfin landings from 1989–90 to 2014–15. Prior to 1988-89, the data points represent estimates for the period prior to the introduction of Eel Catch Landing Return forms, and were generated by pro-rating the unidentified eel catch by the longfin to shortfin ratio (see MPI 2017 for more information). (Source: MPI 2017).

The exploitation phase was characterised by rapid expansion of the industry, a proliferation of processing factories, and generally large export volumes of a relatively low-value product. There were few management constraints. In the early 1990s, 23 processing factories operated (Jellyman 1993), and there was no limit on catches or the number of commercial fishing licences issued. An initial minimum size of 150 g introduced in 1981 was increased to 220 g in 1992, in an endeavour to improve marketability and yield-per-recruit (Jellyman 2013).

During the consolidation phase, there were some concerns about localised overexploitation and MPI implemented two constraints to reduce the pressure on eel stocks: (1) The exclusion of part-time commercial fishers from the industry (in 1982); and (2) A moratorium on the issuing of new licences in 1988. Associated with the licence freeze was a voluntary agreement by the eel industry not to increase fishing effort beyond that of the late 1980's. To assist with this, a legal loophole that enabled multiple fishers to operate from a single fishing permit was closed in 1997. Towards the end of this phase, fishery managers encouraged cooperative management planning by industry and Māori (Te Waka a Maui me ona Toka Mahi Tuna 1996), which resulted in a series of regional management plans for the South Island (e.g., Arai Te Uru, South Canterbury/Waitaki, Te Tau Ihu Mahi Tuna) (see Figure 24). These plans formed the information base for the entry of eels into the Quota Management System (QMS) (Jellyman 2013). However, the committees that were formed to develop these plans also considered a much broader range of impacts on local eel fisheries, and made several recommendations (e.g., existing or potential barriers provide structures which will permit the passage of large eels) that have not yet been realised (Jellyman 2013). Like marine species, Māori received 20% of the commercial quota, and in recognition of the historical importance of eels to them, catch allocations were also made for customary purposes (another 20% of the Total Allowable Catch [TAC]). Iwi control or hold approx. 50% of North Island eel quota[20].

In response to growing concerns about the long-term sustainability of harvest levels, especially of longfins, in the rationalisation phase MPI have taken actions to reduce catches, including changes in the minimum size, an increase in reserve areas, removal of part-time fishers, a moratorium of fishing licences, and reductions in Total Allowable Commercial Catches (TACC's). The fyke nets used by fishermen are highly efficient, and research has indicated that baited nets can consistently remove more than half the longfins (in experimental reaches c. 200–300 m) within a single night's fishing (Jellyman & Graynoth 2005). Also, being ecologically dominant, large longfins are more vulnerable to capture than smaller longfins. Several reviews and research programmes have highlighted the vulnerability of longfins, and the need to implement more conservative management practices to avoid substantial reductions in this fishery (Chisnall & Hicks 1993, Jellyman et al. 2000, Hoyle & Jellyman 2002, McCleave & Jellyman 2004, Jellyman 2009). A 4 kg upper size limit, in place in the South Island commercial fishery since November 1995, was extended in March 2007 to include the North Island. Although this provides protection for large longfins, modelling has indicated that the probability of capture before this size is attained is very high (Hoyle & Jellyman 2002). However, given that only a third of the longfin habitat is fished, this regulation ensures eels growing up in unfished stretches and tributaries are not exploited when they enter the mainstem.

In recognition that eel stocks in some regions are showing signs of depletion, commercial eel fishers have sometimes voluntarily forgone opportunities to catch their annual entitlements to assist stocks to rebuild (Jellyman 2013). A voluntary logbook programme in the South Island has shown that large numbers of longfins more than 4 kg are caught and released by commercial fishers.

[20] https://www.eelenhancement.co.nz/

A recent study suggests that roughly one-third of the available longfin habitat is currently commercially fished (Beentjes et al. 2016) (Figure 21). Approximately 40% of the longfin eel habitat was estimated to be impacted by both hydroelectric dams and commercial fishing. Beentjes et al. (2016) recently interviewed 53 commercial eel fishers who indicated that their effort had declined in the last 5 to 10 years. This is due to a range of factors including denied access to fishing grounds; an ageing demographic, with fishers retiring or not prepared to fish marginal or difficult to access areas; a decline in the marketability and price of longfin eels compared to shortfin; and requirement to return large eels (over 4 kg). In recent times, there has been a marked reduction in the number of eel processing sites and the remaining sites are: (1) Mossburn Enterprises[21] (Invercargill), New Zealand Eel Processing Company Limited (NZ Eel) (Te Kauwhata), and (3) Levin Eel Trading Ltd[22] (Levin).

Despite the exploitation, there is little evidence that shortfins are declining nationally (Beentjes & Bull 2002, Jellyman 2009). As shortfin males seldom exceed the minimum commercial size of 220 g, the commercial shortfin fishery is effectively for females only (except for the fishery for male silver eels in Te Waihora, where the size restriction is relaxed) (Jellyman 2013).

Recreational

In 1994 a daily bag limit of six eels was introduced throughout the country for recreational fishers. The recreational allowance applies to all individuals who are undertaking recreational fishing, with customary allowances only relating to fishing for customary purposes. Whilst a variety of fishing methods may be employed, including rod and line, only one fyke net per person is permitted. Net mesh size is regulated for recreational fishing, with fyke nets and hīnaki having a minimum mesh size of 12 mm. MPI produced a brochure in November 2008 for recreational fishers which recommends that shortfin eels greater than 60 cm in length and longfins greater than 75 cm in length are returned to the water unharmed if they are not being taken for food. Whilst a maximum size does not yet apply to the recreational sector, it has been raised by MPI as a possibility. There is currently no quantitative information available on the extent of recreational tuna harvest.

Customary

Both migrating eels and feeder (non-migrant) eels are captured in the customary fishery. A wide range of fishing methods have historically been employed to catch tuna, with methods varying by area, season and habitat. Examples of customary methods include hīnaki (eel pots), pā tuna (eel weirs), toi (bobbing without hooks), takahi tuna (trampling then catching with hands), rama tuna (using torch light), patu tuna (eel striking), matarau (spearing) and koumu (eel trenches) (Best 1929, Statistics New Zealand 2005). Whilst these methods and variations of these methods may still be used in the present day, much customary fishing now uses modern equipment such as fyke nets. The extent of customary harvest is currently unknown. In a review of eel usage in the King Country (using a postal questionnaire), Maniapoto (1998) noted that capture and usage of tuna for customary purposes could be considerable and estimated that the 45 marae in the rohe could need between 136–164 tonnes per annum. When reviewing the fisheries of Te Waihora, Jellyman and Smith (2008) noted that data supplied by Ngāi Tahu gave a customary harvest of tuna of up to five tonnes per year from this lake. While there are no records of total customary harvest of eels from throughout Aotearoa-NZ, Jellyman (2013) suggests that it could be considerably less than the quantities allowed for within the QMS.

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[21] http://www.waituna.co.nz/

[22] http://www.levineel.co.nz/

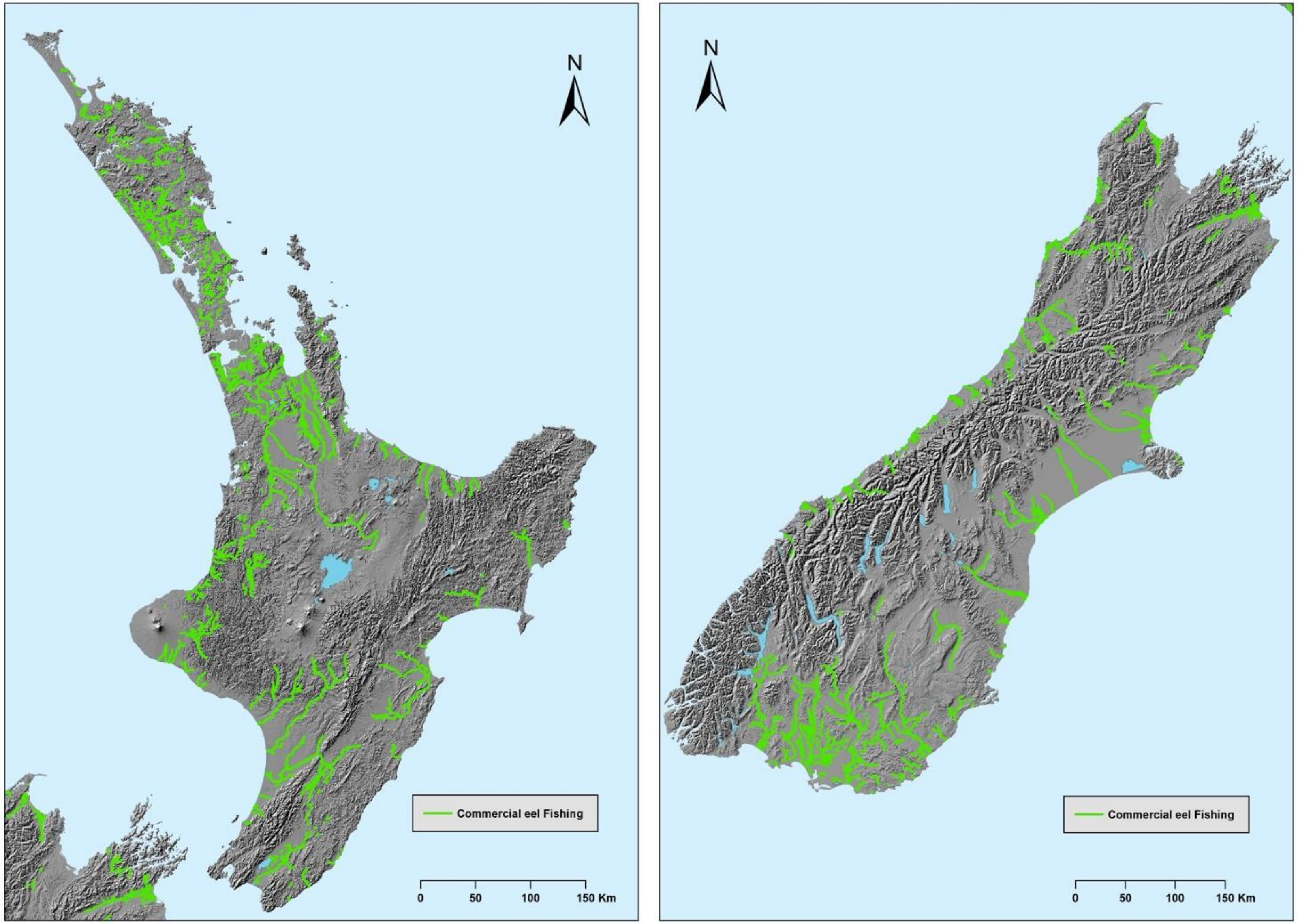

Figure 21: (Left) North Island, and (Right) South Island commercial fishing locations from the period of 2009–2014. Green areas show where commercial fishing occurred at least once. Please note that this analysis excluded lakes (Source: Beentjes et al. 2016).

3.6 Management

Because of their extensive migrations and relatively long life, tuna are a challenging fishery to manage and restore, notably because the relative importance and interaction between habitat, recruitment and fishing pressure have not been quantified. Furthermore, as there is no control on the life stages of tuna while at sea, the management and restoration of the tuna fishery has to rely on activities that enhance the population while in fresh water. In the freshwater domain, the roles and responsibilities for the sustainable management of tuna populations and their associated habitats are spread across a wide range of agencies (including iwi, DOC, MPI, and regional councils, see Table 2).

3.6.1 Ministry for Primary Industries

Commercial fisheries are managed under the QMS where individual transferrable quota for fish stocks is owned by private interests. The quantity of fish that can be taken by commercial fishers in one fishing year is the TACC. On behalf of the Crown, MPI promotes policies and regulations to manage the commercial eel industry in a sustainable manner. MPI is responsible for administering the Fisheries Act 1996 and the QMS, monitoring fishing activity and enforcing fishing rules.

Three main tuna harvest control measures are used by MPI to support the management of the Aotearoa-NZ tuna fishery. The first is that there are upper and lower harvest size limits (e.g., it is currently illegal to harvest an eel less than 220 g without a special permit from MPI). This management measure has been in place for a number of years and essentially prevents the harvest and export of juvenile eels (notably glass eels and elvers) for aquaculture purposes, while large female tuna are also protected from harvest. The second is that tuna harvest is controlled by the QMS which is adjustable across quota/fisheries management areas (Figure 22) as the need arises. The third is the establishment of reserve areas that are free from commercial harvest, although DOC has the discretion to grant fishing concessions in reserve areas under their control. A key component to ensuring the sustainability of eels is to maintain spawner escapement; as a sustainability measure, the Mōhaka, Mōtu and much of the Whanganui River catchments were closed to commercial fishing in early 2005 to aid spawning escapement (MPI 2017).

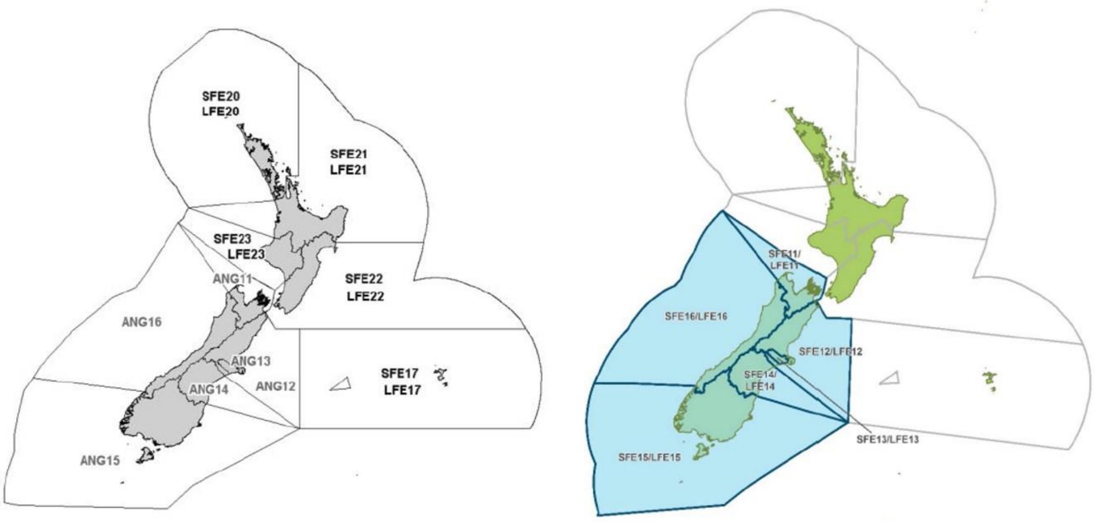

Figure 22: (Left) Current quota management areas for shortfin eel (SFE), longfin eel (LFE) and both species combined (ANG); and (Right) Proposed quota management areas for the South Island eel fishery (SFE11–16 and LFE11–16). (Source: MPI 2016; 2017).

Conventional fisheries assessment techniques (like those used for marine fisheries) are inappropriate for freshwater eel stocks because of their biology and stock structure, and consequently there are no formal stock assessment methods for freshwater eels in Aotearoa-NZ (Dunn et al. 2009). MPI currently relies on: (1) Elver recruitment at selected hydroelectric dams; (2) Commercial catch-per-unit-effort (CPUE) indices by species and Eel Statistical Area (ESA) (Figure 23); and (3) The proportion of longfin habitat impacted by commercial fishing and hydroelectric dams, to undertake cautioned assessments of longfin and shortfin stock status.

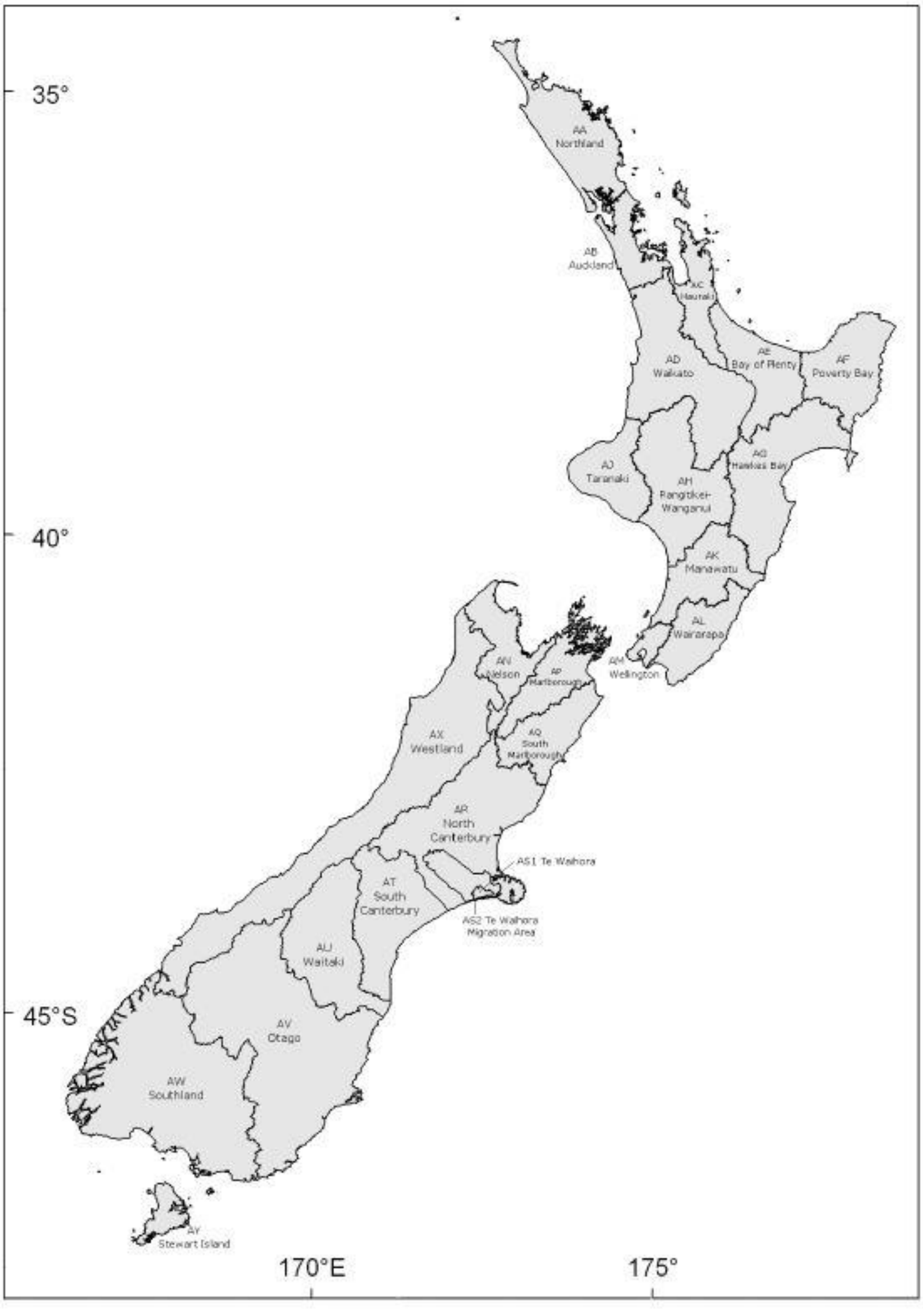

Figure 23: Eel Statistical Areas (ESAs) used for reporting catch from the commercial freshwater eel fishery and analysing trends. (Source: Beentjes et al. 2016).

MPI's current research on recruitment is aimed at establishing a time series of relative abundance of elvers at key locations in Aotearoa-NZ where the upstream passage is restricted by hydroelectric dams (e.g., Martin & Bowman 2016) (see Section 3.3). MPI also uses standardised catch-per-unit-effort (CPUE) analyses for commercial eel fisheries to inform fisheries management decision-making (e.g., Beentjes & Dunn 2015). MPI funds research into each of these areas on a regular basis, the results of which are reviewed by the Eel Working Group before publishing. For example, in August 2017, MPI received tenders to: (1) Standardise CPUE of elvers caught by electric-fishing in the Waikato region (EEL2017-02); and (2) Develop modelling approaches and data requirements for a GIS-based assessment of longfin eels (EEL2017-01).

The South Island eel fishery was introduced into the QMS on 1 October 2000 with shortfin and longfin species combined into six fish stocks (codes ANG11 to ANG16, Figure 22). The Chatham Island fishery was introduced into the QMS on 1 October 2003 with two fish stocks (shortfins and longfins separated into SFE17 and LFE17, respectively, Figure 22). The North Island eel fishery was introduced into the QMS on 1 October 2004 with eight fish stocks (four longfin stocks LFE20–23 and four shortfin stocks SFE20–23, Figure 22). A review considering the separation of South Island longfin and shortfin stocks to support improved management of each species has recently been completed, resulting in an overall reduction in the total 2016–17 TACC across both species (Clements & Associates 2016, MPI 2016) (Tables 4–6).

Table 4: TACCs (t) and reported landings (t) of shortfin eel (SFE) for 2015–16 and TACCs set for 2016–17. (Source: Clement & Associates Limited 2016).

Fish stock	2015–16 Actual TACC	2015–16 Reported landings	2016–17 TACC
SFE11	–	–	19
SFE12	–	–	20
SFE13	–	–	134
SFE14	–	–	10
SFE15	–	–	29
SFE16	–	–	30
SFE17	10	0	10
SFE20	86	51	86
SFE21	134	119	134
SFE22	94	49	94
SFE23	23	10	23
Total	347	230	580

Unlike virtually all other commercial fisheries in Aotearoa-NZ, there is no fine scale reporting of eel catch using latitude and longitude coordinates and the finest spatial resolution of reporting is by Eel Statistical Areas (ESA) on the Eel Catch Effort Return which has been in use since 2001–02 (Beentjes et al. 2016). Eel Statistical Areas are broadly catchment based, but include multiple major river systems (Figure 23). The latest analysis of trends in commercial eel CPUE indices for all ESAs from 1990–91 to 2014–15 are provided in Appendix D (MPI 2017, Beentjes & McKenzie in prep).

In 2013, the **Parliamentary Commissioner for the Environment** (PCE) undertook a review of the longfin eel fishery (PCE 2013) in response to increasing public concern about the sustainability of the longfin eel fishery and the potential risk of extinction. An independent panel of three international experts was assembled to review the scientific information used to guide the management of Aotearoa-NZ's eel fisheries, particularly longfin eels (Haro et al. 2015). The panel considered each of the sources of information and analyses currently used for monitoring trends and assessing tuna stock status, noting the limitations of each and, in most cases, making recommendations for improvement. They also suggested possible supplementary information that could be collected to further strengthen current monitoring. The panel recommended a comprehensive assessment that integrates conventional fisheries information with non-fisheries information, such as the impact of habitat degradation, pollution and other non-fisheries causes of mortality (e.g., hydroelectric dams).

Table 5: TACCs (t) and reported landings (t) of longfin eel (LFE) for 2015–16 and TACCs set for 2016–17. (Source: Clement & Associates Limited 2016).

Fish stock	2015–16 Actual TACC	2015–16 Reported landings	2016–17 TACC
LFE11	–	–	1
LFE12	–	–	1
LFE13	–	–	1
LFE14	–	–	1
LFE15	–	–	52
LFE16	–	–	25
LFE17	1	0	1
LFE20	19	6	19
LFE21	32	9	32
LFE22	21	4	21
LFE23	9	1	9
Total	82	21	163

Table 6: TACCs (t) and reported landings (t) of South Island eels (ANG) for 2015–16. (Source: Clement & Associates Limited 2016). See Tables 4 and 5 for a breakdown of the 2016–17 TACCs for South Island eels.

Fish stock	2015–16 Actual TACC	2015–16 Reported landings	2016–17 TACC
ANG11	40	2	–
ANG12	43	0	–
ANG13	122	109	–
ANG14	35	5	–
ANG15	118	64	–
ANG16	63	20	–
Total	420	201	0

3.6.2 Māori

Tangata whenua in the North and Chatham Islands may customarily fish under Regulation 27A, Fisheries (Amateur Fishing) Regulations 1986 in areas that are not yet covered by the Fisheries (Kaimoana Customary Fishing) Regulations 1998. Regulation 27A limits customary fishing activities to the taking of aquatic life for customary hui and tangi only, under authorisation of a Māori committee, marae committee, a Rūnanga, or Māori Trust Board. Regulation 27A does not adequately provide for the management of customary food gathering as required to by sections 10(b) and (c) of the Treaty of Waitangi (Fisheries Claims) Settlement Act 1992 because they were an interim mechanism to allow for some aspects of customary non-commercial fishing rights until regulations consistent with Section 10 of the Settlement Act are made and in use by tangata whenua.

Consequently, in late 2008 the Fisheries (Kaimoana Customary Fishing) Regulations 1998 were amended to extend their coverage to include aquatic life (that are subject to the Fisheries Act 1996) in fresh water for the North and Chatham Islands, and permits tangata tiaki/kaitiaki to be appointed to manage all non-commercial customary fishing. The Ngāi Tahu Claims Settlement Act 1998 promulgated the development of the Fisheries (South Island Customary Fishing) Regulations 1999. These regulations encompass fisheries resources in freshwater and marine environments (that are subject to the Fisheries Act 1996). The nine South Island iwi accepted that freshwater fisheries were included in the Settlement Act 1992, and are identified as tangata whenua under the Fisheries (South Island Customary Fishing) Regulations. Under these regulations, tangata tiaki manage all non-commercial customary fishing resources and can apply for mātaitai reserves. Tangata whenua with appointed tangata kaitiaki under the customary fishing regulations can apply for the establishment of freshwater mātaitai reserves (e.g., reaches of the Okarito Lagoon, Lake Wairewa, Temuka/Opihi River, Waihao River, Mataura River, Waikawa/Tumu Toka[23], also see Section 11.1.1) to manage all non-commercial fishing within the reserve by recommending by-laws.

In both the North and South Islands, there are areas in which commercial fishing is prohibited in recognition of the special value of these areas for customary non-commercial purposes. In the South Island, Lake Waiwera and its tributaries have been set aside exclusively for Ngāi Tahu. Other areas, such as the lower Pelorus River, Taumutu (Te Waihora), Wainono Lagoon and its catchment, the Waihao catchment, the Rangitata Lagoon and the Ahuriri Arm of Lake Benmore, have been set aside as non-commercial areas. In the North Island, commercial fishing is prohibited from Lake Ōmāpere, Lake Horowhenua, the Taharoa lakes, Whakakī Lagoon, Lake Poukawa, Arahura River, lakes Kohangapiripiri and Kohangaterā and associated catchments (Jellyman & Sykes 2009, MFish 2009, McDowall 2011). In addition, as a sustainability measure, the Mōhaka, Mōtu and parts of the Whanganui River catchments have been closed to commercial fishing to aid spawning escapement (MFish 2009). Some iwi groups have also placed a moratorium on the harvest of longfin eels as they are concerned about declining stocks (e.g., Te Tai Hauāuru Forum, Kawe 2014).

Fisheries in the **lower Waikato River catchment** (from Te Pūaha to Karāpiro Dam) are co-managed by Waikato-Tainui and the Crown, under the Waikato-Tainui (Waikato River) Fisheries Regulations 2011[24]. This co-management approach is one of the strategies put in place to achieve the overarching purpose of Waikato-Tainui Raupatu Claims Settlement Act 2010[25] - "*to restore and protect the health and wellbeing of the Waikato River for future generations*". Waikato-Tainui Fisheries Bylaws have recently increased the minimum harvest size to 300 g for shortfins and 400 g

[23] Source: http://www.nabis.govt.nz/Map.aspx (Mataitai Reserve Boundary Layer)
[24] http://www.legislation.govt.nz/regulation/public/2011/0294/latest/DLM3930995.html.
[25] http://www.legislation.govt.nz/act/public/2010/0024/latest/DLM1630002.html

for longfins. In addition, lower and upper size limits, seasonal fishing bans on major migration pathways, and protection of all female migrant longfins have been put in place by Waikato-Tainui and the Crown through the Waikato-Tainui Fisheries Bylaws[26].

Prior to the entry of tuna into the QMS, regional eel management committees across the South Island prepared Eel Management Plans[27] (Figure 24). Some of these plans were recognised and accorded the status of Iwi Management Plans (IMPs). As mentioned in Section 3.5.8, each plan represents a valuable resource because it lists issues associated with their respective catchments, including identifying where passage is impeded. These plans were updated in 2006–2008.

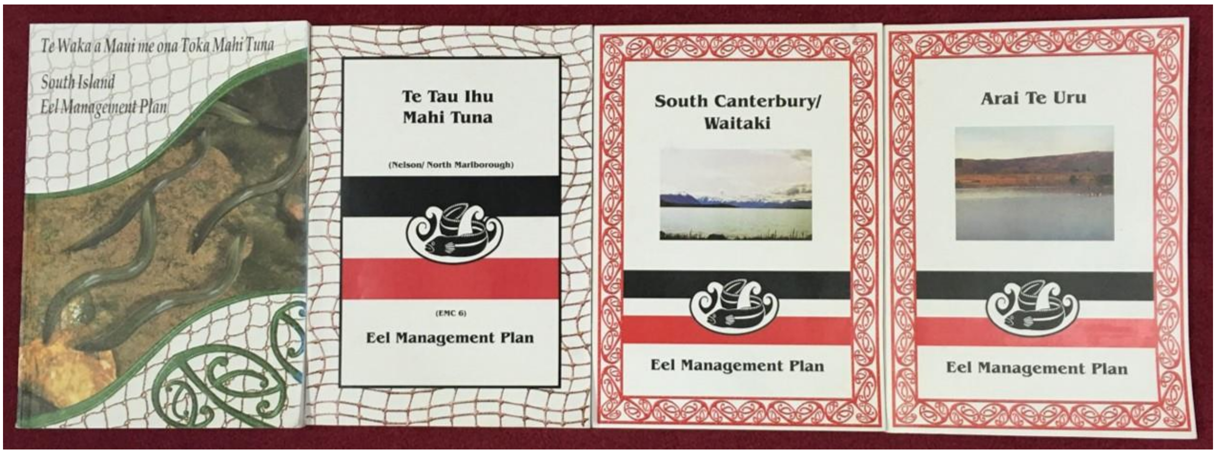

Figure 24: Example of some of the South Island Eel Management Plans prepared by regional eel management committees in the late 1990s, prior to the introduction of tuna into the QMS.

3.6.3 Department of Conservation

Longfin eels are listed as one of the 150 priority threatened species listed in DOC's draft **Threatened Species Strategy** (see Section 11.2). DOC has responsibilities under the Conservation Act 1987 to protect indigenous freshwater fish and freshwater habitats and recreational freshwater fisheries. This allows for the management of native fish directly, and for advocacy on behalf of fish and their habitats. DOC also administers the Freshwater Fisheries Regulations 1983, which include provisions for fish passage and control of noxious fish and has the responsibility to ensure that activities (like commercial fishing) carried out in protected areas it manages (e.g., Reserves and Conservation Areas) are consistent with the purposes for which those areas are held. Regulation 42 of the Freshwater Fisheries Regulations 1983 prevents fish passage from being impeded by an instream structure unless written approval for the structure is given by the Director General of DOC. Regulation 43 requires those seeking to construct dams to seek approval or dispensation from the Regulations by notifying the Director General, who may require that a fish pass is also constructed.

Fonterra is a partner with DOC in the Living Water[28] partnership which is focusing on the restoration of five catchments (Kaipara Harbour: Hikurangi Catchment; Firth of Thames/Tīkapa Moana: Pūkorokoro/Miranda Catchment; Waikato Peat Lakes: Areare, Ruatuna, Rotomānuka; Te Waihora/Lake Ellesmere: Ararira/LII Catchment; and Awarua-Waituna: Waituna Catchment). DOC has also set an ambitious 10-year stretch goal of restoring 50 freshwater ecosystems, mountains to the

[26] http://www.fish.govt.nz/en-nz/Maori/Waikato-Tainui+Fisheries+Area+Bylaws.htm
[27] There is one plan for the South Island, plus plans for Te Tau Ihu, North Canterbury, Te Waihora, South Canterbury-Waitaki, Arai Te Uru, Te Tai Poutini and Murihiku.
[28] https://www.livingwater.net.nz/

sea[29]. However, it is difficult to source documentation to confirm which catchments DOC are focusing on, and where there will be components of interest to Te Wai Māori and iwi/hapū around the country.

3.6.4 Regional and District Councils

Councils operate under numerous pieces of legislation that give them responsibilities for freshwater taonga species management (and their associated ecosystems, including the marine environment), including Local Government Act 2002, Biosecurity Act 1993, Soil Conservation and Rivers Control Act 1941 (and several special statutes), Reserves Act 1977, etc. Regional Councils are also responsible for many local statutes such as those that govern drainage and flood control, e.g., Taieri River Improvement Act 1920.

Under the Resource Management Act 1991 (RMA), there is also a general requirement for consent authorities to ensure that Aotearoa-NZs resources are managed in a sustainable manner and this broad definition includes ensuring fish passage. As such, two pieces of legislation are available to ensure fish passage throughout Aotearoa-NZ, but enforcement of the legislation has generally been weak and there are many structures currently in existence which affect fish passage in Aotearoa-NZ. Te Wai Māori recently commissioned a report that outlines the names of consent holders for a several hydroelectric dams across the country, the current conditions of consent as they relate to fish passage, and when the resource consent is up for renewal (LMK Consulting Ltd 2014). One difficulty, however, is the number of barriers that are created by the erection of structures that are classed as a permitted activity because they may only be 1–3 metres in height. Although seen as being small in scale they can impede passage and add to the cumulative loss of access to habitats within a catchment.

3.7 Aquaculture

Since 2004, much of the North Island eel quota has been purchased by Māori-owned companies (e.g., Moana New Zealand, formerly Aotearoa Fisheries), making Māori the largest North Island eel quota owners. The commercial wild-eel fishery supplies both a domestic and export market and has an estimated export value of $6.1 M (MPI 2009). In Belgium, Germany, Hong Kong, Italy, Republic of Korea, Netherlands, Taiwan, USA and the UK there is demand for our eels, which are provided in various forms, including frozen, smoked and live. In Japan, freshwater eels are considered a delicacy and importing eels has become increasingly important considering declines in Japan's domestic eel catch (Statistics NZ 2005, Shiraishi & Crook 2015, Okamoto 2016). However, due to size and quality issues, our wild-caught eels do not consistently have access to premium value Asian markets.

On a global scale, the market demand for eels as a foodstuff is high and declines in northern hemisphere wild-eel production have meant that aquaculture is now the primary source of eels for human consumption. Internationally, eel farming is responsible for over 90% of all *Anguilla* production worldwide, and is based on on-growing wild-caught glass eels (Shiraishi & Crook 2015). Recently there has been a large global increase in the price and harvest of glass eels for aquaculture (FAO 2014). Glass eel shortfalls for large Asian eel producers has renewed interest in farming other Anguillid species and aquaculture is now being supplied by glass eels harvested from new or previously lesser-exploited *Anguilla* populations from around the world (Crook & Nakamura 2013).

[29] http://www.doc.govt.nz/about-us/our-role/corporate-publications/statement-of-intent-archive/statement-of-intent-2015-2019/statement-of-intent-20152019-full-content/

Internationally, at present, all eel aquaculture relies on the collection of disease and parasite-free glass eels from the wild. Eel aquaculture has been linked to the decline of Northern Hemisphere eel stocks; however, it should be noted that these countries harvest eels across all stages of their unique life cycle (including glass eels, adults and migrants). Glass-eel harvests have been implicated in the decline of wild eel stocks and setting sustainable limits for exploiting new populations requires assessment of the impacts pre-exploitation. However, in countries such as Indonesia, trade in tropical glass eel species has started with little or no scientific or management assessments pre-exploitation (Arai 2014, Nijman 2015).

In Aotearoa-NZ, several organisations sought to participate in land-based eel aquaculture during the 1970–1980s, but they were not commercially successful (Beckett 1975, Jellyman & Coates 1976, Sorrenson 1981). While previous ventures/research has demonstrated the feasibility of eel on-growing, one of the most significant bottlenecks to the development of an industry is the difficulty in obtaining an adequate supply of glass eels for on-growing. Currently, it is illegal to possess eels less than 220 g, except under special permit, and commercial access to shortfin glass eels will require changes in fisheries regulations and the support and approval of Māori, fisheries managers, communities and other stakeholders (Quigley & Baines 2014).

There are iwi, hapū and Māori organisations who are seeking to participate in eel aquaculture at various scales and for different purposes (including restoration [e.g.,30]) ranging from small ventures to large commercial-scale ventures for supplying international markets. The opportunity to develop a tuna aquaculture industry has been a priority for some parties for some time (e.g., Te Puni Kōkiri 2009), and is specifically mentioned in 2015–2016 regional growth study reports for Te Tai Tokerau (MPI 2015a), Bay of Plenty (MPI 2015b), Manawatū-Whanganui (Horizons Regional Council 2016) and the Manawatū-Whanganui Māori Economic Development Strategy (Māori Economic Strategy Group 2016). Some groups have instigated research into the potential sustainability of shortfin glass eel harvest – as the datasets required to responsibly inform this discussion will need to be developed over multiple years (e.g., Williams et al. 2016). To the best of our knowledge, except for an on-going initiative funded by DOC in the Ashley catchment, there are no medium to long-term glass eel monitoring programmes being undertaken in Aotearoa-NZ.

Recognising that the aspirations of some hapū and iwi organisations are not always solely economically driven, the prospect of a potentially secure supply and ready access to farmed tuna attracts them to investigate their options in regards to small/local scale on-growing for customary benefit (e.g., marae-based on-growing for consumption and restoration, e.g., Muaupoko[31]). At the other end of the scale, some iwi are opposed to glass eel-based aquaculture, e.g., the Fisheries Accord between the Minister of Fisheries, the Chief Executive of the Ministry of Fisheries and Waikato-Tainui signed on 20 October 2008[32] stipulates at 5.1 (b) *that the parties agree to establish mechanisms to provide for Waikato-Tainui to protect elvers and glass eels within the Waikato River from exploitation*. The Waikato-Tainui Environmental Plan[33] re-enforces these protective measures for glass eels.

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[31] http://www2.nzherald.co.nz/the-country/news/article.cfm?c_id=16&objectid=11724285 and http://www2.nzherald.co.nz/the-country/news/article.cfm?c_id=16&objectid=11809727 and http://www2.nzherald.co.nz/the-country/news/article.cfm?c_id=16&objectid=11905252 and http://www2.nzherald.co.nz/the-country/news/article.cfm?c_id=16&objectid=11737502

[32] http://www.fish.govt.nz/NR/rdonlyres/EF84647D-571D-4926-8690-13A913DD1B64/0/WaikatoTainuiFisheriesAccordfinal20Oct2008.pdf

[33] http://www.wrrt.co.nz/wp-content/uploads/EBook_FINAL_EP_Plan_sp.pdf

Glass-eel harvest potentially has implications for the sustainability of shortfin eel stocks. In this country, very little research has been done to investigate the effects of glass-eel removal and alternate commercial eel harvest scenarios (e.g., reducing the commercial catch of adult eels) (Jameson undated, Te Wai Māori 2006). It is thought that large scale glass-eel harvesting is likely to reduce elver densities. However, this *may* have little impact on adult eel stocks and the numbers of migrants escaping to sea to breed. The PCE illustrates this concept by explaining "if the numbers of elvers going up a river is reduced, the remaining elvers may have a better chance of finding food and surviving" (PCE 2013). For example, juvenile eels in three small coastal streams experienced high mortality rates at lengths of 300–400 mm. This may be a natural population bottleneck caused by competition with larger eels either for food or for instream cover as they move from being elvers occupying river substrates to live with larger adult eels in other instream habitats (Graynoth et al. 2008a).

Early research conducted by NIWA included the development of techniques for pond-based fattening of large eels (Chisnall & Martin 2002). In the research project, Rapid Commercialisation of New Aquaculture Species (C01X0301), NIWA developed techniques to transport glass eels, and on-grow shortfin eels in a brackish water environment to market size in less than one year (e.g., Kearney et al. 2004, Watene 2004, Kearney et al. 2008, Hirt-Chabbert 2011, Kearney et al. 2011). While there are still some challenges to address in the optimisation of on-growing of glass eels, this component of the potential commercialisation model is the relatively easy part. The most significant research questions to overcome are in relation to social/cultural license to operate, glass eel recruitment (i.e., security of supply), adaptive eel fisheries management options (i.e., sustainability) and the development of economic models that consider both economic viability and environmental sustainability to advise regulation change and alternate fisheries management approaches. Graynoth (2008a) and Graynoth et al. (2015) recommend that fisheries managers, iwi/Māori and stakeholders come together to prepare a list of issues and questions to help researchers design and develop fit-for-purpose glass eel harvesting/fisheries assessment models. In particular, modellers need information on the potential future of adult eel commercial fishing, proposed glass-eel harvesting strategies, and stock enhancement programmes (Graynoth et al. 2015).

An alternate approach to the production of eels for human consumption is the hatchery production of glass eels for on-growing (i.e., artificially breeding and growing eels in the laboratory). Although this has been pursued for some time, to the best of our knowledge international researchers have found it difficult and this approach remains in the development stage in Japan (e.g., Tanaka et al. 2001) and Taiwan. The captive breeding of shortfin eels is also being attempted in Aotearoa-NZ at the Mahurangi Technical Institute[34]. Based on the information available to date it is unlikely that artificial production of glass eel on a commercial scale will be achieved in the short to medium term.

[34] http://mti.net.nz/research-a-consultancy-at-mti-mahurangi-technical-institute-of-warkworth/research-projects-at-mti-mahurangi-technical-institute-of-warkworth

4 Piharau / Kanakana (Lamprey)

Family: Geotriidae

Species: *Geotria australis*

Lampreys are sometimes referred to as "primitive fish-like animals" (McDowall 1990) as they differ from true bony fishes in not having jaws, paired fins, swim bladders and true bones (they are cartilaginous) (Figure 25). While they lack features that characterise bony fishes, they do have seven pairs of external gill openings, and a third (or pineal) "eye" which is sensitive to light and is involved with the control of hormone production. Lamprey and hagfish (known as cyclostomes or agnathans) are the only living jawless vertebrates (Figure 26). Over 360 million years old, lampreys swam past herds of drinking dinosaurs, and have survived at least four mass extinctions. The brain of the lamprey is believed to be the closest example of our primal vertebrate ancestors, and lampreys provide important insight into the evolution of fins, jaws and the skeleton, plus vertebrate motor control, and immunology (Baker 2014).

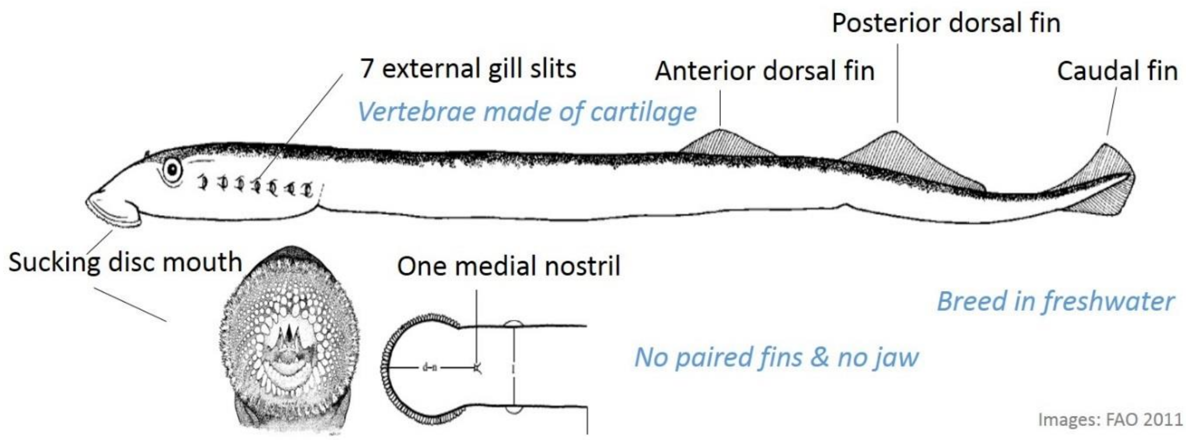

Figure 25: Key features of a lamprey. (Source: Kitson 2015).

4.1 Life Cycle

Not only are lamprey physiologically different from other Aotearoa-NZ fish, they also have a unique and specialised life history which requires them to complete parts of their life cycle in both the marine and freshwater environments (Figure 27).

In Aotearoa-NZ, adult lamprey grow to about 450–750 mm in length and migrate from the sea into fresh water between April and October each year (McDowall 2000). Upon entering fresh water, adults cease feeding as they travel upstream. Upstream migrations of more than 240 km have been recorded (James 2008) and mostly occur at night and are associated with the receding flood waters of both small and large flood flows. Lamprey spend up to 18 months in fresh water maturing sexually before spawning (James 2008, Baker et al. 2017). A male and female lamprey will make a nest underneath a large boulder (Figure 28), where the pair will spend seven weeks guarding and caring for the eggs after spawning (Baker et al. 2017). At present, it appears that the male has an active role in caring for the developing larvae and assists in hatching. Based on limited observations, the role the female takes during nesting is uncertain. However, both sexes survive spawning for three months, which is the longest documented post-spawning survival of any lamprey species worldwide.

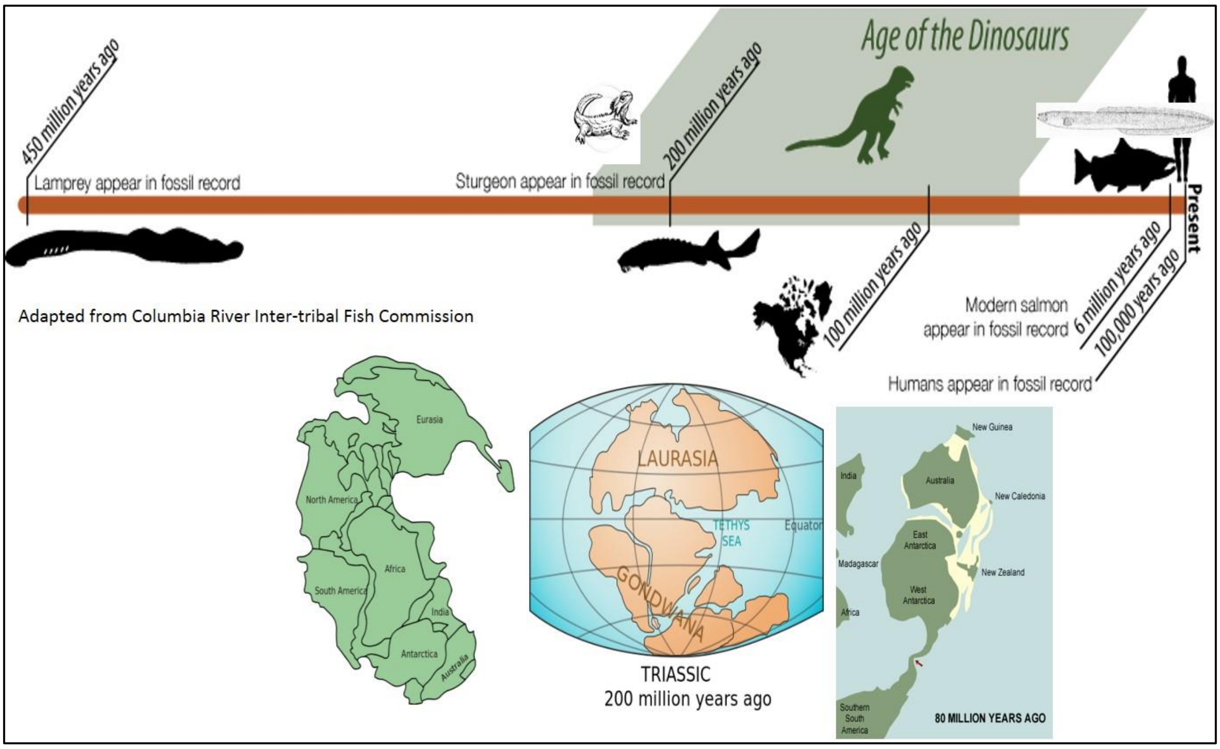

Figure 26: Visualisation of the evolutionary history of lamprey, compared to tuatara and tuna. (Sources: Kitson 2015, Baker & Kitson 2016).

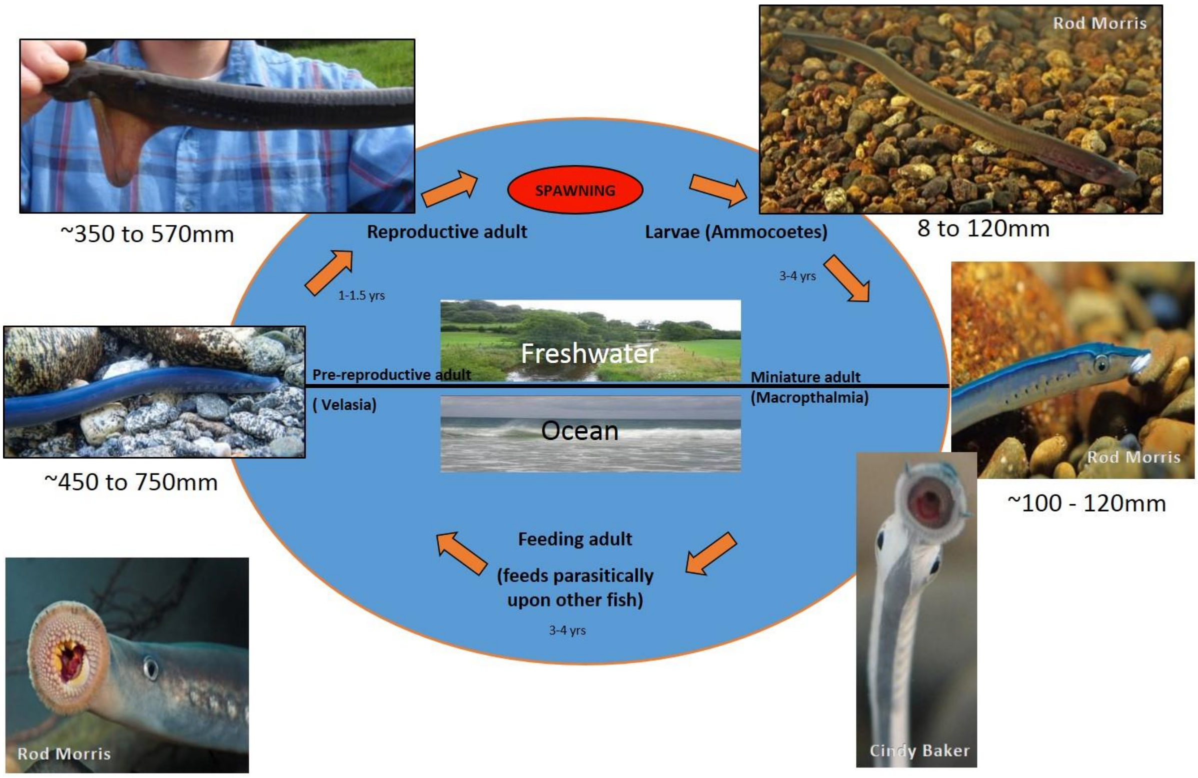

Figure 27: Life cycle of the lamprey. (Source: Cindy Baker).

Figure 28: Kinloch Stream, Banks Peninsula: Examples of the type of headwater stream habitat spawning lamprey seem to prefer. The yellow arrow indicates boulders where lamprey spawning nests have been located underneath. This is the first time lamprey spawning nests have been located in the Southern Hemisphere (Photos: Cindy Baker).

Their eggs hatch in fresh water, where the ammocoetes (larval lamprey) remain until metamorphosis (thought to be at least four years) (Figure 29). Ammocoetes are a dull brown colour, have no eyes, and live in burrows in the substrate while filter-feeding microorganisms from the water. These juveniles reside in soft sediment burrows often in backwaters or stream margins where flow is gentle, near adult spawning habitat (Jellyman & Glova 2002).

Figure 29: (Left) Overturned boulder showing lamprey egg mass; and (Right) Close up of lamprey eggs. See Baker et al. (2017) for more information. (Photos: [Left] Cindy Baker, [Right] Shannan Crow)

It may take more than four years for the ammocoetes to grow from less than 8 mm long at hatching to about 100 mm; at this size, they transform to a miniature adult form, known as macropthalmia. The transformation includes colouration to a brilliant blue and silver, the development of eyes, and the development of a sucking disk and teeth. Once transformed, macropthalmia juveniles head out during winter and spring to the open ocean to grow into pre-reproductive adults. At sea, they attach onto the gills or flesh of other fish and marine mammals and live as parasites (McDowall 1990). Very little is known about the distribution of the marine phase, but they are thought to travel large distances before returning to fresh water to spawn. Their complete life history is estimated to take nine years.

Piharau/kanakana is native to the Southern Hemisphere; however, very little research has been completed into Southern Hemisphere stocks to confirm they are indeed all one species. Previous studies in the 1980's suggest the pouched lamprey may indeed comprise different stocks (Neira et al. 1988). This knowledge gap has implications for management, for example, if Aotearoa-NZ lamprey are in fact a different genetic stock there is no fall back for replenishing populations from other countries should fish stocks significantly decline.

Environmental attributes that are important for supporting lamprey populations are summarised in Figure 30. Research is seeking to address several key knowledge gaps, including, the timing of adult spawning migrations, the chemical cues (pheromones) used by adult lamprey to select spawning (breeding) streams (Stewart et al. 2011, Stewart & Baker 2012), the location of the spawning nests (Baker et al. 2017), and the distribution of populations (Baker et al. 2016a; 2016b). This research has shown that lamprey migrate mainly at night, although there were some movements during the day. Most of this movement is linked with high river flows and floods. Most fish have been found in faster flowing waters and when lamprey are not migrating they tend to hide underneath large rocks/boulders within the stream. The fact that adult lamprey seek out cover during the day was well known to Māori who used a range of techniques that exploited this behaviour, including laying fern fronds which kanakana use as cover and can then be harvested by hand.

- **Physical habitat**
  - Habitat heterogeneity (pool, run & riffle)
  - Hydraulic habitat (depth, velocity)
  - Substrate composition (fine sediments for ammocoetes, boulders for spawning)
  - Cover for adults (e.g. undercut banks, boulders, large wood debris)
- **Organic detritus**
- **Flow regime**
  - Floods/freshes as migration cues
  - Flood magnitude to enable passage past obstacles
  - Fine sediment deposition and movement (impacts on ammocoete habitat)
  - Habitat provision at low flows (reduction of ammocoete habitat)
- **Pheromone cues**
- **Fine sediment**
- **Water quality**
  - Temperature, dissolved oxygen (DO), pH, ammonia, nitrate toxicity
  - Other toxicants (e.g., heavy metals)
- **Habitat connectivity (passage between ocean & spawning sites)**

Figure 30: Environmental attributes that are important for supporting lamprey populations. The text contained in the red boxes indicates where NIWA (and partners) are currently undertaking MBIE-funded research in a five-year programme called Habitat Bottlenecks for Freshwater Fauna (Source: Baker & Kitson 2016).

4.2 Distribution

The NZFFD records contain a mixture of juvenile and adult observations. The largest numbers of lamprey observations in the South Island are located around Banks Peninsula, Otago, Southland and the West Coast. Most of the observations in the North Island are located around Wellington, Hamilton and Taranaki (Figure 31). That said, lamprey are not commonly recorded in the NZFFD and the use of this database to describe lamprey distribution comes with a few caveats. The low numbers of observations recorded in the NZFFD are likely to be due to the difficulties in capturing this species. Juveniles occupy the substrates of river beds and are difficult to capture with an electric-fishing machine. Adults migrating back from the sea to spawn also bury themselves in river substrates and are difficult to capture. Thus, lamprey tend to be underrepresented in standard fish surveys so their distribution may be more extensive that the NZFFD suggests.

4.3 State and Trends in Abundance

Lamprey state and trends in abundance were unable to be assessed by Crow et al. (2016) because of a lack of sufficient observations in the NZFFD. NIWA have developed a pheromone sampler that absorbs the chemical odours released by larval lamprey and this could be used as a proxy for population abundance measures in the future; however, to date this approach has only been trialled in a few places (e.g., Baker et al. 2016a; 2016b).

Lamprey are an important taonga species and a prized delicacy for many Māori communities. In the past, they were seasonally abundant in many Aotearoa-NZ rivers and they were at times taken in huge quantities. Only fresh run lamprey were taken, as they were considered to be inedible after they had moved further inland (once their heads enlarged and a pouch formed below the eye). Lamprey were dried to provide food in winter and they were also used in bartering. In places along the Whanganui River, utu piharau are still used to capture this traditional fishery. The efforts and knowledge of piharau/kanakana fishers could be one way to address the lack of information on species abundance and distribution. Concern over the state of the customary fishery has led some mana whenua to initiate examining customary harvest methods as a way to monitor lamprey abundance (e.g., Te Ao Marama Inc and Waikawa Whanau 2010, Kitson et al. 2012).

4.4 Threat Ranking

The latest New Zealand Threat Classification System assessment classified *G. australis* as being 'Threatened–Nationally Vulnerable', with a total area of occupancy ≤100 ha (1 km^2), and predicted population decline of 10–50% (Goodman et al. 2014). In 2014, IUCN assessed *G. australis* as being 'Data Deficient' stating there is "no specific information is available on the population of this species, although it has undoubtedly declined through recent history" (Closs et al. 2014) (Table 7).

Table 7: Threat rankings for Aotearoa-NZ lamprey species according to the New Zealand Threat Classification System and IUCN. (see Section 2.3 for more information about these assessment methods).

Species	DOC Ranking	IUCN Ranking
Geotria australis	Threatened–Nationally Vulnerable	Data Deficient[35]

[35] http://www.iucnredlist.org/details/197275/0

Figure 31: Locations of NZFFD records where lamprey are present (black circles) and absent (grey circles). Locations of lamprey include both adult and juvenile (i.e., macropthalmia and ammocoete) stages of the life cycle.

4.5 Pressures on Populations

To date there has been very limited research undertaken in Aotearoa-NZ investigating key drivers influencing presence, distribution, and density of lamprey populations in our waterways. As a significant portion of their life cycle occurs out in the marine environment where we have little control, while they are in fresh water, habitats for their sensitive juvenile life stages and sexually maturing adults need to be provided for. Lamprey also need free passage between the ocean and fresh waters to be successful (Figure 32).

From the work undertaken to date, maintaining migration cues may have an important control over adult populations and successful breeding within waterways. Northern Hemisphere sea lamprey have been shown to select spawning streams based on a migratory pheromone mixture released by larvae living upstream as well as a sex pheromone released by males at the nest sites (Johnson et al. 2015). Studies show migratory adults in Aotearoa-NZ are attracted to the same pheromone mixture as that identified for the Northern Hemisphere sea lamprey. Field investigations have also found that stream selection by migratory lamprey matches the relative level of larval pheromone cue present (C. Baker, unpub. data). Therefore, we need to be aware of pressures that impact water flows (e.g., abstraction) and the ability of lamprey to detect/follow migratory pheromones as this could reduce adult entry and breeding within waterways.

4.5.1 Loss of Habitat

Although spawning has only been documented in one stream within Aotearoa-NZ, the boulder habitat utilised for spawning and nesting is expected to have been reduced nationwide through conversion of most of forest to farmland (Closs et al. 2014) and the installation of hydroelectric dams. If lamprey can't adapt to spawning in other habitats, which is the focus of current NIWA research, this will have had a profound effect on the distribution and abundance of this species, as it has on other freshwater fish species (Closs et al. 2014). Should adults be forced to travel further upstream to find suitable spawning habitat, this could in turn negatively impact the condition of the adults.

4.5.2 Reduced Connectivity

The main threats to this species include the installation of hydroelectric dams, which has affected the abundance and distribution of this species by preventing access to large parts of its former upstream range (James 2008). Trap and transfers from below dams to areas upstream may benefit this species (Closs et al. 2014, Baker et al. 2016b). Although lamprey are able to climb short vertical surfaces (Figure 33), poorly designed instream barriers like culverts, weirs and fords can impact the upstream migration of adult fish.

4.5.3 Parasites, Disease and Predation

In the spring of 2011, Lamprey Reddening Syndrome (LRS) (Figure 34) was observed to cause a mass mortality of pre-reproductive adults during their upstream migration in the Mataura River catchment, Southland. The cause of this syndrome is yet to be discovered, but LRS may pose a real threat to declining lamprey populations in Aotearoa-NZ as it occurs across Southland, which is where adult lamprey are thought to be in the highest abundance (Closs et al. 2014). Lamprey Reddening Syndrome has been observed in Southland, Otago, Canterbury and Taranaki.

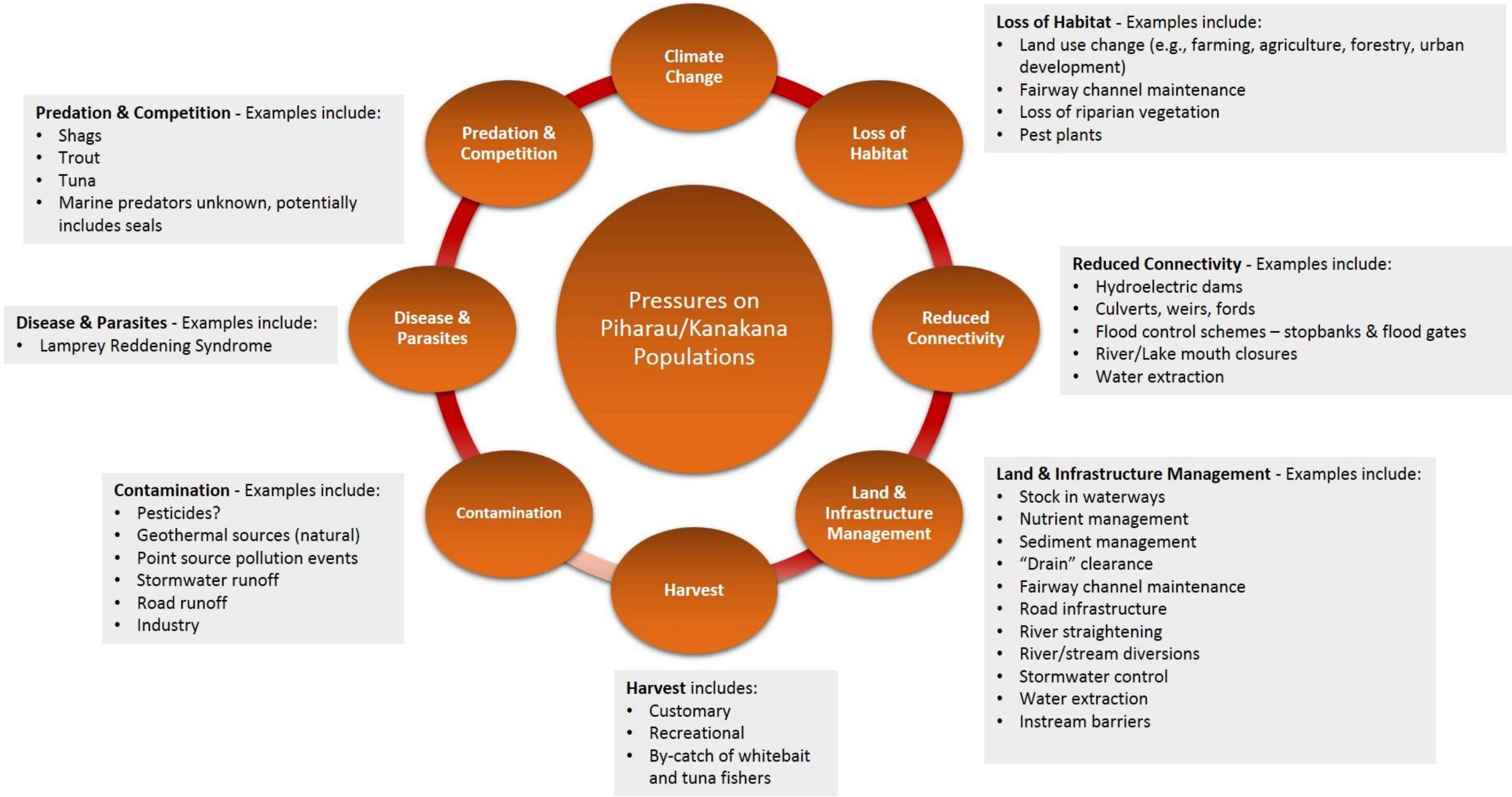

Figure 32: Examples of some of the pressures on Aotearoa-NZ piharau/kanakana populations.

Figure 33: Piharau/kanakana using their circular mouth to climb vertical surfaces. (Photos: Andrew Thomas).

Figure 34: Lamprey Reddening Syndrome. (Photo: Jane Kitson).

As of December 2013, MPI ruled out all known exotic organisms as a causative agent and laboratory results support the hypothesis of a multifactorial cause for LRS observed in lamprey in Southland rivers; no exotic or emerging pathogen has been detected in affected kanakana and several key pathogens of concern have been ruled out. The pathology of LRS is consistent with effects of significant mechanical damage but the cause of such damage is unknown.

It is possible that trout predation on juveniles is a threat to lamprey populations (B. David, pers. obs. in Closs et al. 2014). There are also accounts of lamprey being preyed upon by tuna and seals (J. Kitson, pers. comm.). Lamprey can be caught as bycatch in whitebait (J. Kitson, pers. comm.) and commercial eel (Brangenburg et al. 2013) nets. Threats to the adult marine stage are unknown but are likely to include predation, and potentially, the accumulation of contaminants.

4.6 Management

No commercial fishery for lamprey exists in Aotearoa-NZ. Lamprey have a daily bag limit of 30 in Southern and Fiordland areas, through the Amateur Fishing Regional Fisheries (Southland and Sub-Antarctic Areas Amateur Fishing) Regulations 1991 (MPI undated). The **Ngāi Tahu Claims Settlement Act** prohibits the targeted commercial harvest of "Kanakana/Ute – southern lamprey (*Geotria australis*)". The **Ngāti Ruanui and Ngāti Mutunga** Treaty settlements specifically prohibit the commercial harvest of lamprey within their Protocol areas unless the Minister can demonstrate a commercial harvest is sustainable.

In Southland, the two mātaitai that encompass fresh water (Mataura and Waikawa/Tumu Toka) were put in place over areas of significant kanakana customary fisheries. Bylaws for the Mataura River Mātaitai Reserve prohibits the taking of kanakana without customary authorisation from the reserve's tangata tiaki/kaitiaki. Current research (see Figure 29) in the Waikawa/Tuma Toka Mātaitai reserve will inform future bylaws.

Lamprey are listed as one of the 150 priority threatened species listed in DOC's draft **Threatened Species Strategy** (see Section 11.2).

Te Wai Māori Trust are seeking to facilitate a multi-agency roopu (e.g., iwi, MfE, DOC, NIWA) to develop a piharau/kanakana Restoration Strategy that will progress research initiatives to improve knowledge and management of piharau/kanakana, and support and facilitate greater iwi involvement.

5 Kōura / Kēwai (Freshwater crayfish)

Family: Parastacidae

Species: *Paranephrops planifrons* and *P. zealandicus.*

Kōura are thought to have a very ancient whakapapa, perhaps dating back before the breakup of Gondwanaland about 80 million years ago (Cooper & Millener 1993, McDowall 2005). McDowall (2005) states that a series of geological, climatological, historical, and anthropogenic events (e.g., erosion of Kā Tiritiri o te Moana, central North Island volcanism) have contributed in both space and time to the current distributions of *Paranephrops* in Aotearoa-NZ.

It is thought that there are two species of kōura or kēwai in Aotearoa-NZ, which are separated by the Southern Alps. *Paranephrops planifrons* is found in the North Island and in the northwest of the South Island and *P. zealandicus* is distributed along the eastern side of the South Island and on Stewart Island (Figure 35). Apte et al. (2007), however, have shown the taxonomy of the stocks of *Paranephrops* to be rather more complex than the long-accepted scenario of two distinct species, and suggest that further taxonomic study is required.

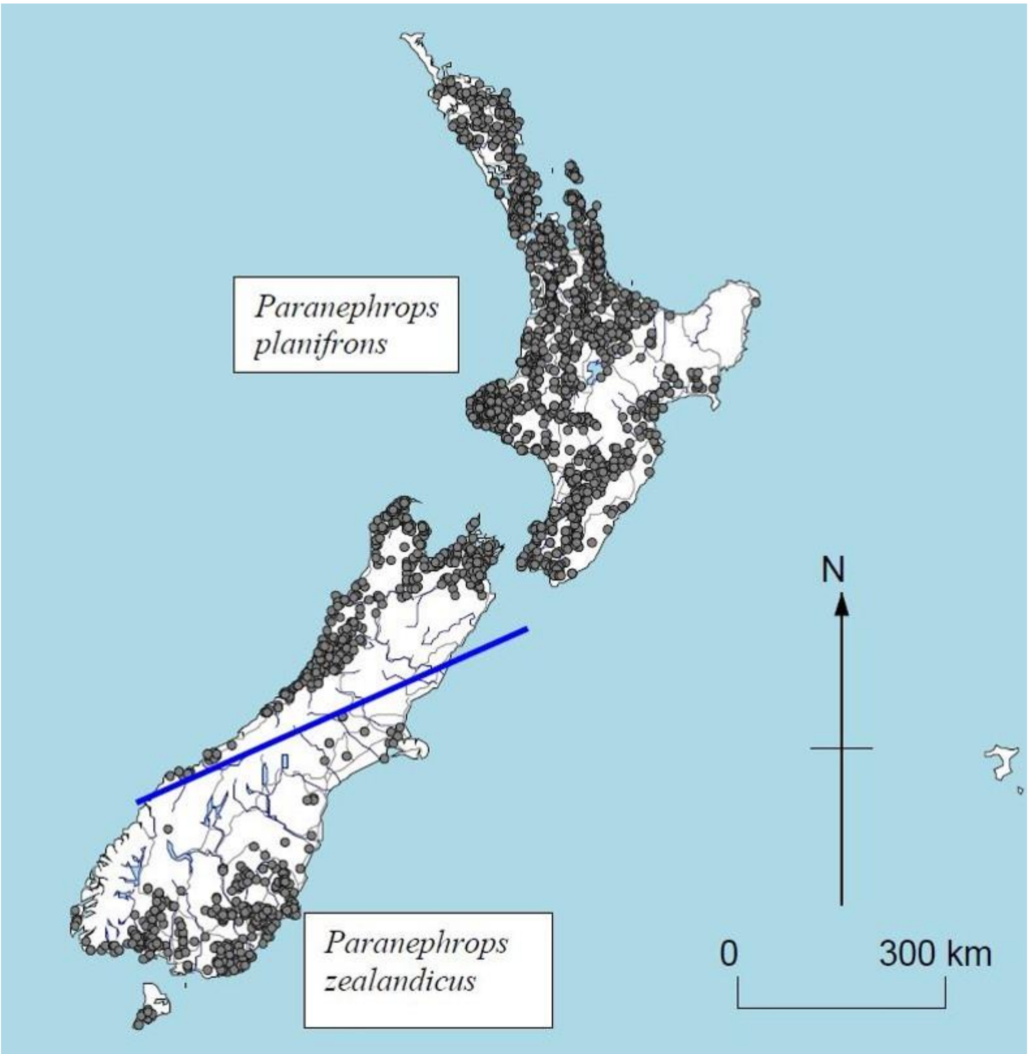

Figure 35: Approximate distribution of Aotearoa-NZ kōura species, separated by Kā Tiritiri o te Moana (Southern Alps). (Source: Parkyn & Kusabs 2007, also see McDowall 2005 & 2010 for more information).

Kōura live in freshwater streams, lakes, ponds, and swamps. In streams and rivers, kōura seek cover during the day. They typically shelter between stones, under woody debris and they also can burrow into mud. Kōura living in swamps will sometimes burrow deep into the mud when the swamps dry out over summer, waiting until the water returns to re-emerge. Some kōura can live on the bottom of very deep, clear lakes in the South Island at depths of up to 60 metres. Kōura are opportunistic predators, detritivores and scavengers that eat many kinds of organic matter in their habitat, from live fish, to carrion and vegetable detritus. Snails, chironomids (midge larvae) and mayflies are important components of the kōura diet (Whitmore et al. 2000, Hollows et al. 2002). Feeding in lakes tends to be concentrated in the littoral zone where more food is often found.

5.1 Life Cycle

Some of the basic anatomy of a kōura is illustrated in Figure 36. The duration and timing of the kōura life cycle depends on the environment that it is living in. Like all crustaceans kōura moult their external skeleton as they increase in size. During moulting they become soft for several days as the new outer shell hardens. Calcium is an important mineral that kōura need during this process. They get the calcium they need from small stones in their intestine (called gastroliths), eating their discarded skeleton, and absorption from their diet and water.

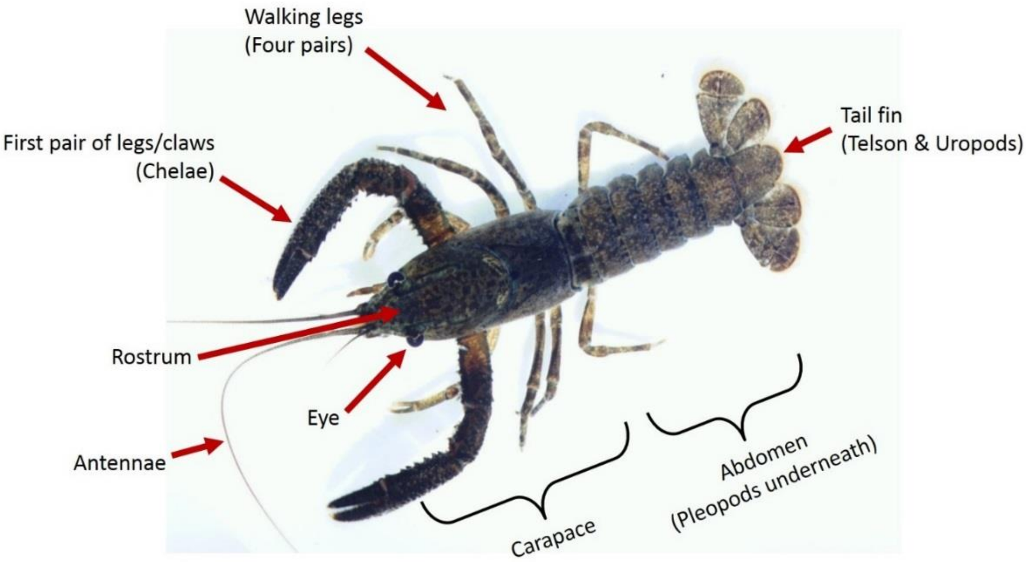

Figure 36: Key features of a kōura. (Photo: Ian Kusabs).

Mating is thought to occur soon after the females have moulted. Males lay a spermatophore (a capsule full of sperm) between the 3rd and 4th pairs of walking legs on the females. Females pass the eggs through the spermatophore (i.e., external fertilisation) and attach them to their pleopods (swimming legs) under their abdomen (Figure 37). Over four weeks the spermatophore slowly dissolves. When the female is carrying eggs (egg-bearing) this stage is also called “in berry” or gravid. The eggs change from khaki green to brown, then deep red during development. From spring and early summer, depending on temperature, the eggs hatch into juveniles (Figure 37) that are carried by the mother for up to three weeks (although this is variable between individuals) and undergo two moults before they become independent (Hopkins 1967). In the Te Arawa Lakes, Kusabs et al. (2015a) found egg-bearing females throughout the year, although only occasionally during the summer months.

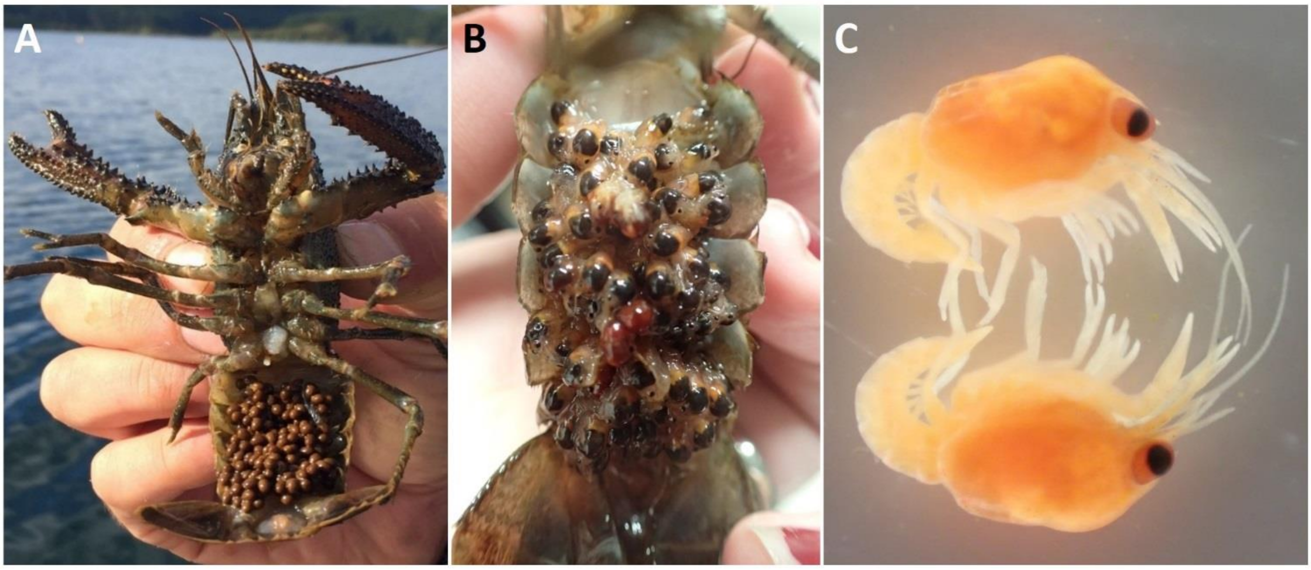

Figure 37: (A) A female kōura carrying eggs; (B) Juvenile kōura starting to hatch; and (C) One-day old kōura. (Photos: [A] Steph Parkyn, and [B & C] Karen Thompson).

Female kōura can carry between 20 and more than 300 eggs, attached by threads to the pleopods under their abdomen. Once hatched, juvenile kōura cling to their mother's abdomen using their rear legs until they have reached a carapace length of about 4 mm. The total duration of breeding from peak egg laying to the release of juveniles is estimated to be 28 weeks for the autumn–winter period and 19 to 20 weeks in spring–summer breeding groups for Northern lake populations (Devcich 1979) (Figure 38); and 25 to 26 weeks for Northern stream populations (Hopkins 1967), and up to 60 weeks for Southern kōura in stream populations (Whitmore 1997). Warmer water temperatures speed up the egg development process (Jones 1981a).

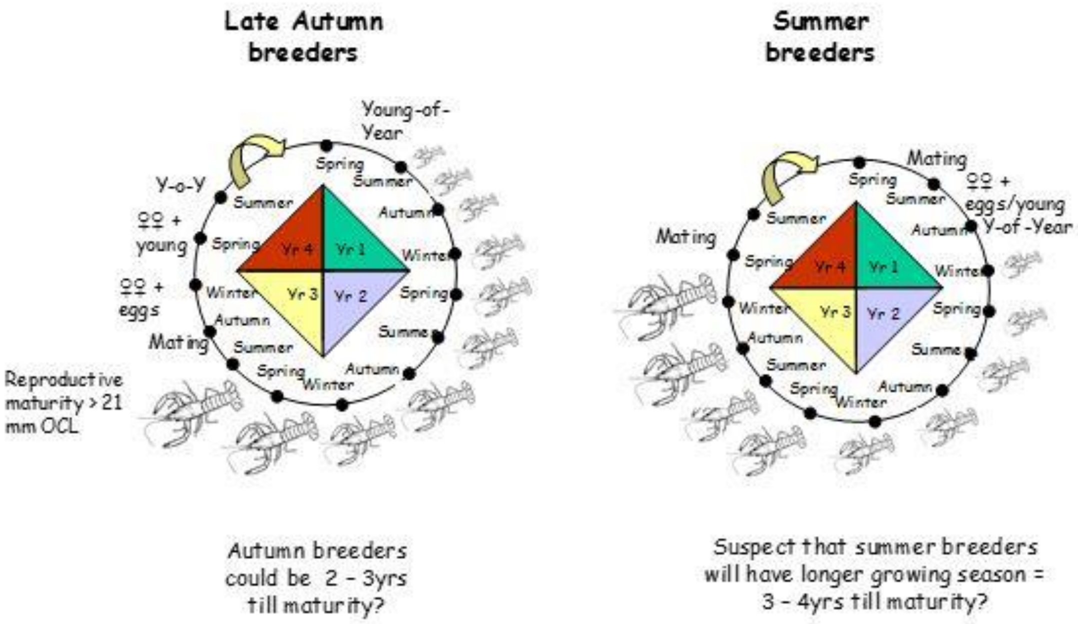

Figure 38: Kōura life history in Lake Rotoiti. (Source: Devcich 1979). YoY = Young of Year. Kōura length is determined using the Orbit-Carapace Length (OCL) which measured from behind the eye to the end of the carapace along the top and centre of the back.

Juveniles that enter the population in spring or early summer are likely to grow larger in their first year than those that leave the female in late summer as they have the advantage of growth through the summer months. *Paranephrops planifrons* is thought to mature in 18 months to 2 years in streams (Jones 1981b, Parkyn 2000), depending on temperature, while Devcich (1979) estimated that *P. planifrons* probably matured in their third year in lakes. *Paranephrops zealandicus* females in a stream in eastern Otago were not reproductively active until 6+ years (Whitmore 1997).

Kōura fecundity/fertility increases with Orbit-Carapace Length (OCL) (Kusabs et al. 2015a). Size at onset of breeding (maturity) seems to depend on growth rate, where kōura larger than 20 mm OCL are likely to be able to reproduce (Devcich 1979, Kusabs et al. 2015a).

5.2 Distribution

Kōura are one of the most widespread and commonly observed species in the NZFFD (Figure 39). *Paranephrops planifrons* is known from several nearshore islands around Aotearoa-NZ, including Great Barrier, Great Mercury, Kapiti, and D'Urville Islands (McDowall 2005). Although kōura are fairly widespread and abundant in certain locations, there are also areas of the country where they are sparse and/or populations have established due to translocation (e.g., Lake Georgina in the upper Rakaia River catchment, McDowall 2005). This species is found at all altitudes, but is less commonly found in the central North Island (with the exception of the Te Arawa and Tūwharetoa lakes), the East Cape, Canterbury and Fiordland regions. Very high numbers of observations have been recorded around Taranaki and Auckland.

The central North Island has been influenced by sometimes massive volcanic eruptions for at least 50,000 years. Effects on freshwater biota are likely (McDowall 1996) and may be more widespread than for terrestrial biota owing to the erosion of ash into river headwaters — its downstream effects flushing far beyond zones of original deposition (Cudby 1977, Spiers & Boubeé 1997). This would have affected kōura populations and their general absence east to northeast of Taupō-nui-a-Tia is a probable outcome (McDowall 2005). The absence of kōura along the central to lower west coast of Te Wai Pounamu is thought to be due to the effects of glaciation on stream biota, as also reflected by a lack, or restricted distributions, of non-diadromous fish species (McDowall 2005).

Paranephrops zealandicus is very sparsely distributed across the central Canterbury Plains. McDowall (2005) states that while this could be natural (low success in moving north across the plains after the formation of the Southern Alps), it could also be due to anthropogenic influences. Kōura were reportedly more abundant in the region in the 1960s, when they were found widely in stock water races across the countryside (McDowall 2005). Over the last 150 years, there has been extensive wetland drainage and intensive pastoral development, as well as the widespread introduction and maintenance of predatory exotic salmonid fish populations in this region.

Figure 39: Locations of NZFFD records where kōura are present (black circles) and absent (grey circles).

5.3 State and Trends in Abundance

5.3.1 Method Recap

To account for some of the limitations in the NZFFD data, Crow et al. (2016) drew on several statistical approaches to address some of the biases that come with using this dataset. To identify if the 'probability of capture' for a taonga freshwater species through time appears to be increasing (getting better), decreasing (getting worse) or staying the same, Crow et al. (2016) completed simple linear regression[36] calculations (how does X relate to Y?) using two different techniques.

The first technique was the Sen Slope Estimator (SSE), while the second technique was a weighted version of the SSE. The weighted SSE (called WSSE hereafter) assigns a weighting value based on the size of the confidence intervals[37] (CI). In the WSSE, pairs of years that collectively have small CIs are weighted more heavily than pairs of years that collectively have large CIs because we were more confident in these probability of capture values.

Both WSSE and SSE results are presented in this report because, together, they help us understand whether or not we can be confident in the analysis and detect a trend over time (either increasing or decreasing) – or if we cannot detect a trend.

5.3.2 Kōura Results

Kōura showed a median (± 95% CI) increasing SSE trend of 0.04 (±0.02) %/year from 1977–2015, but the WSSE trend was indeterminate (Figure 40). In summary, the high levels of variance in the kōura data, particularly in the mid-1990s, meant the two trend analyses over the full-time series available (1977–2015) were not in agreement and neither approach showed a strong trend in either direction (Crow et al. 2016).

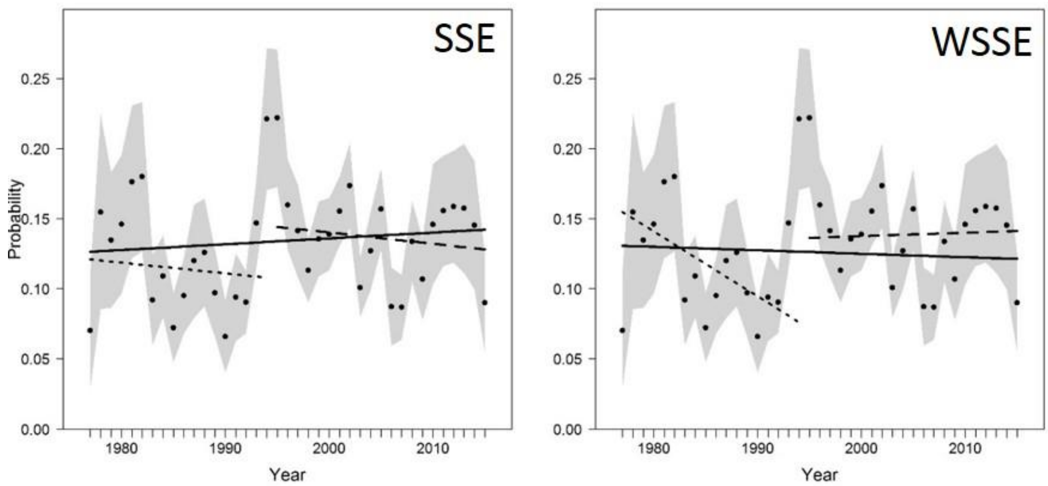

Figure 40: Change in the probability of kōura capture associated with year for the NZFFD data. Plots show the characteristic probability of capture for each year (black circles) and 95% CI (grey shaded area). SSE (left) and WSSE (right) are shown for 1977–2015 (solid black line), 1977–1994 (dotted black line) and 1995–2015 (dashed black line). CI = Confidence Interval. (Source: Crow et al. 2016).

[36] Simple linear regression is a statistical method that allows us to summarise and study relationships between two continuous (quantitative) variables.
[37] A confidence interval is a range of values we are fairly sure our true value lies within.

5.4 Threat Rankings

The latest New Zealand Threat Classification System assessment classified *P. planifrons* as being 'Not Threatened', while *P. zealandicus* are classified as 'At Risk–Declining'. The *P. zealandicus* classification was based on a declining population of 10–70% (Grainger et al. 2014) (Table 8). In 2010, *P. planifrons* and *P. zealandicus* was assessed by IUCN as 'Least Concern' due to their wide distribution (Table 8). However, this assessment recognised that there is no population information or systematic long-term records available for these species and that there is anecdotal evidence of declines in the abundance over time in both streams and lakes. IUCN recommends further research is needed to determine the abundance of these species, and whether they are being impacted upon by any major threat processes on local, national or global scales.

Table 8: Threat rankings for Aotearoa-NZ kōura species according to the New Zealand Threat Classification System and IUCN. (see Section 2.3 for more information about these assessment methods).

Species	DOC Ranking	IUCN Ranking
Paranephrops planifrons	Not Threatened	Least Concern[38] (Populations decreasing)
Paranephrops zealandicus	At Risk–Declining	Least Concern[39] (Populations stable)

5.5 Pressures on Populations

Pressures on kōura populations include habitat loss (wetland drainage, deforestation), land management practises (headwater stream captures and use of chemicals), water management practises (e.g., water abstraction, controlled flows), pollution and predation (particularly by introduced salmonids and pest fish species) (Usio & Townsend 2000, Whitmore et al. 2000, McDowall 2005, Parkyn & Kusabs 2007, Clearwater et al. 2014a). Localised droughts have also been shown to impact kōura populations, therefore climate change needs to be part of our thinking moving forward (Figure 41). Dr Ian Kusabs and NIWA have produced a decision support system (DSS) that shows what kind of restoration options are likely to help restore kōura populations, depending on what pressures are impacting populations locally (Figure 42).

5.5.1 Loss of Habitat

Kōura are found in native forest, exotic forest, and pastoral waterways, but very rarely in urban streams because of chemical pollution, increased flood flows from storm water inputs, and degradation of habitat. Kōura densities can be lower in pasture streams compared to native forest streams. Kōura tend to live longer in native forest streams because of cooler water, but grow faster in pasture streams with warmer water temperatures and more abundant invertebrate food (Parkyn et al. 2002).

Habitat cover (e.g., large wood, undercut banks, tree roots, leaf litter, cobbles and boulders) is extremely important for kōura as it provides shelter from predation and cannibalism (Parkyn et al. 2009). Kōura prefer pools and areas of slow or no flow. Deep habitat (pools in streams) may act as a refuge from terrestrial predators and collect leaves and other foods. At times of heavy flooding, forested streams with stable habitat from riparian vegetation (e.g., stable banks, tree roots, and pools) provide a better refuge for kōura populations than pasture streams dominated by unstable cover items such as cobbles and macrophytes (Parkyn & Collier 2004).

[38] http://www.iucnredlist.org/details/153750/0
[39] http://www.iucnredlist.org/details/153614/0

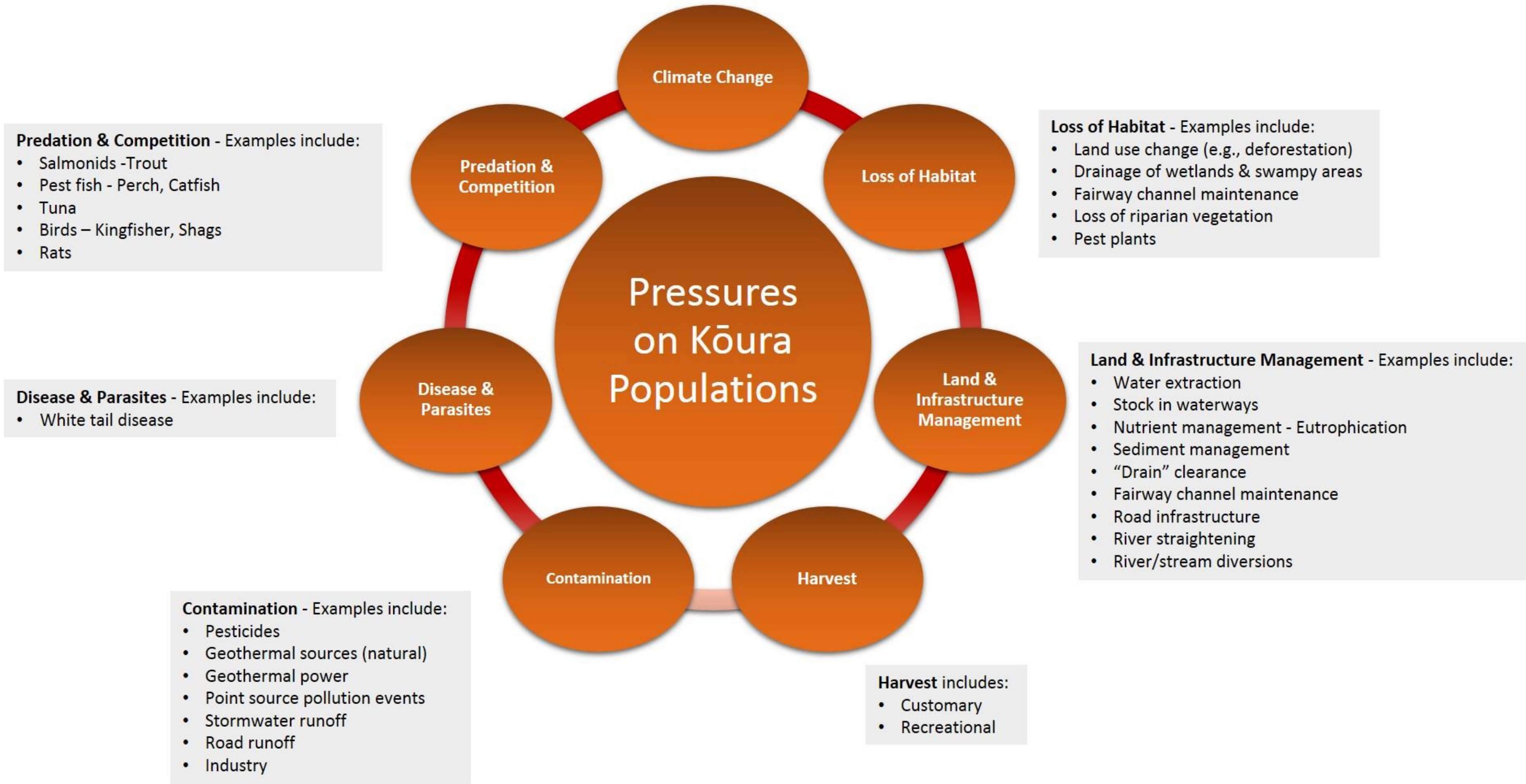

Figure 41: Examples of some of the pressures on Aotearoa-NZ kōura populations.

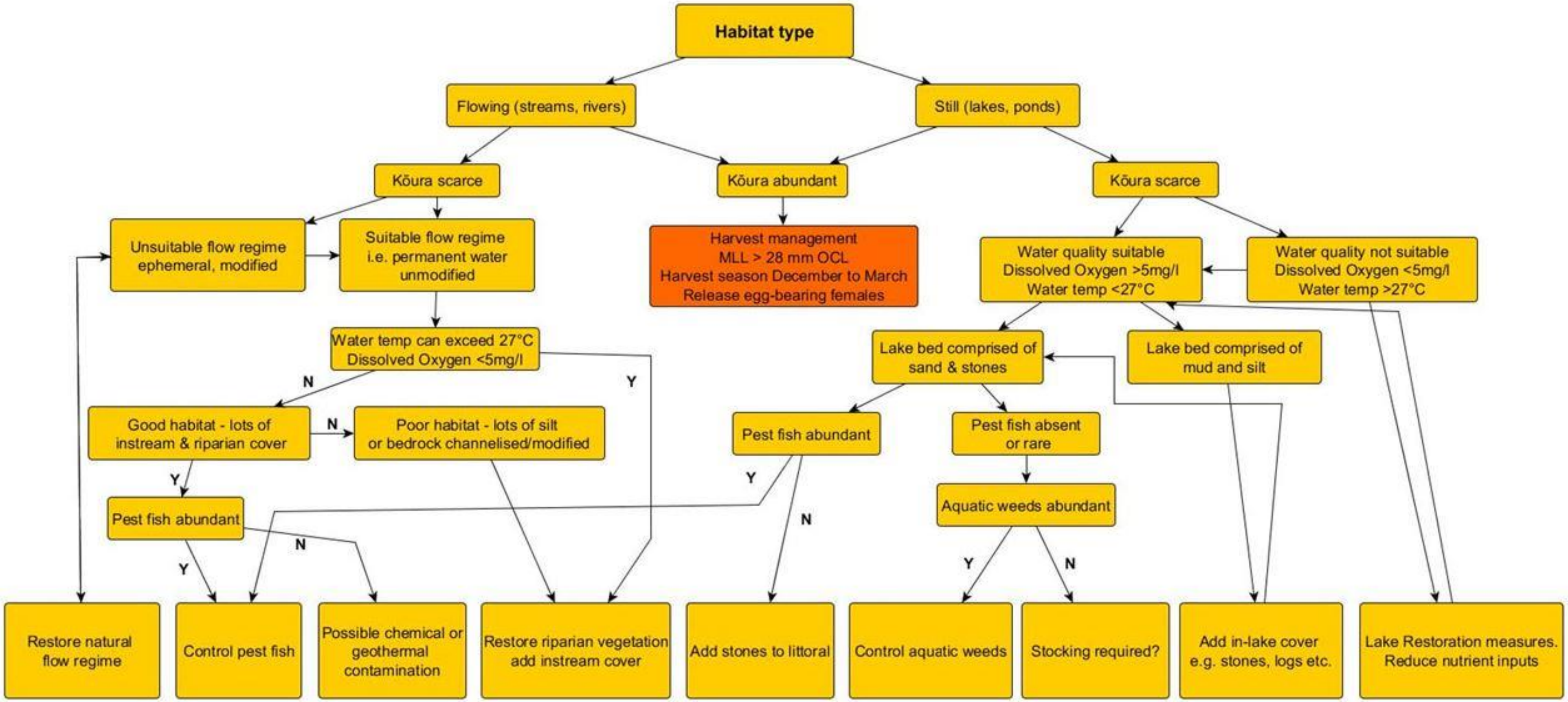

Figure 42: Generalised decision support system (DSS) for identifying causes of low kōura abundance in Aotearoa-NZ waterways. If the low abundance of kōura in your waterway is not related to a reduction in habitat, water quality, flow, it might be due to an event that has decimated the kōura populations such as a chemical spill or lake-turnover, i.e., rapid mixing of lake bottom waters high in toxic ammonia and sulphide with the rest of the lake when thermal stratification breaks down in autumn (Source: Dr Ian Kusabs & NIWA, https://www.niwa.co.nz/freshwater-and-estuaries/management-tools/restoration-tools/guide-to-restoring-k%C5%8Dura-freshwater-crayfish-in-lakes-rivers-and).

Kusabs et al. (2015b) found that kōura abundance and distribution in seven Te Arawa lakes was influenced by the combined effects of lake-bed sediments, lake morphology, and hypolimnetic conditions related to trophic state. Sediment particle size was identified as the strongest driver of kōura abundance and biomass, with kōura populations increasing with increasing sediment particle size. Kōura abundance was highest in lakes Rotomā, Rotorua and Rotoiti which had a high proportion of coarse lake bed substrates and low in lakes Ōkāreka, Rotokākahi, Tarawera and Ōkaro where lake bed substrates were comprised mainly of mud.

5.5.2 Water Quality and Contaminants

Kōura survival can be affected by high water temperatures, particularly for the southern species, *P. zealandicus*, where survival in laboratory experiments decreased as constant water temperatures exceeded 16°C, with 50% survival at 21°C after 12 weeks (Hammond et al. 2006). The northern species, *P. planifrons,* can tolerate higher temperatures, but optimum temperatures are likely to be less than 23°C. Kōura in lakes can be affected by periods of anoxia, e.g., they are now absent from Lake Ōkaro as this lake has no oxygen in its bottom waters during summer. The effects of elevated water temperature are worsened when combined with other stressors such as low dissolved oxygen (Albert et al. 2015).

Kōura, especially juveniles are affected by pollutants such as heavy metals or by toxins from cyanobacterial blooms (Clearwater et al. 2014b). Recent work has also established the sensitivity of juvenile kōura life stages to nitrate (Hickey et al. 2016). Preliminary surveys have found elevated concentrations of the heavy metals mercury and arsenic in kōura from selected locations within the Te Arawa fisheries area (Phillips et al. 2011, Phillips et al. 2014).

5.5.3 Predation

Crayfish are vulnerable to predation from introduced species that they have not evolved with (e.g., trout, catfish, and perch) (Barnes & Hicks 2003, Clearwater et al. 2014a). Kōura make up a large proportion of catfish diet in Taupō-nui-a-Tia (up to 80% in rocky areas). The introduction of perch to Lake Ototoa (South Kaipara) decreased crayfish populations by over 90% (Rowe 2014). In some South Island streams, brown trout have been a key factor affecting kōura abundance (e.g., Shave et al. 1994). Tuna are also known to eat kōura (e.g., Hicks 1997), and are especially likely to impact kōura populations when they are introduced into areas where they previously were rare or absent (Clearwater et al. 2014a). Terrestrial predators include shags, kingfishers and rats. Kōura may be scarce if they have been overfished, particularly in small streams.

5.5.4 Parasites and Disease

The most serious disease known to affect kōura in Aotearoa-NZ is white tail disease. This disease is caused by the microsporidian parasite *Thelohania contejeani*. This parasite causes degeneration of muscle in the tail area of the kōura and this turns the tail a pale white colour, leading to death soon after. Infected freshwater crayfish pose no human health risk, but the cooked flesh is mushy and unpleasant to eat (Ernslaw One Ltd 2016). This parasite has been recorded in Leith Stream (Dunedin) (Quilter 1976, Jones 1980), Taupō-nui-a-Tia (Jones 1980), and several Te Arawa Lakes (Lakes Rotoiti, Tarawera, Rotorua) (Devich 1979, I. Kusabs, unpub. data).

One of the biggest potential threats to Aotearoa-NZ kōura populations is the introduction of invasive crayfish and/or crayfish plague[40] which has decimated populations in Europe (e.g., Vaeßen & Hollert

[40] https://en.wikipedia.org/wiki/Crayfish_plague

2015, Svoboda et al. 2017). This emphasises the importance of being vigilant in Aotearoa-NZ with regards to biosecurity and engagement with the EPA who could potentially receive requests to import non-native crayfish species in the future.

5.6 Management

The main agencies involved in the management of kōura are MPI (e.g., Fisheries Act 1996 and Biosecurity Act 1993) and DOC (e.g., Conservation Act 1987). There are no species-specific conservation measures in place for kōura. Various iwi around the country are progressing formal co-management arrangements to manage their kōura fisheries. Currently, kōura may legally be gathered for personal consumption up to a limit of 50 crayfish per day. However, the selling, trading or possession of kōura for the purposes of sale or trade is currently illegal, with the exception of freshwater crayfish produced by aquaculture. Any authorisations involving freshwater species (e.g., fish farming, transferring species) need to be approved by DOC, and in some cases agencies like MPI and iwi. For example, the **Ngāi Tahu Claims Settlement Act** prohibits the targeted commercial harvest of "Waikōura – freshwater crayfish (*Paranephrops* spp.)". Te Roroa have a fisheries protocol with MPI that lists freshwater crayfish as a taonga species (MPI undated).

In the past, Māori actively managed the kōura fishery through a combination of approaches such as rāhui, ownership rights based on ancestral fishing grounds, selective harvesting, and closed seasons (Hiroa 1921). Occasional releases (translocations) of kōura were also made into waterways to boost populations and ensure the long-term viability of the populations (e.g., McDowall 2005).

As part of the **Te Arawa Lakes Settlement Act 2006** the Crown has made regulations to empower the Trustees of the Te Arawa Lakes Trust to manage the customary and recreational harvest of selected fisheries (including kōura) in fourteen Te Arawa Lakes, but not the streams and rivers flowing into the lakes. The **Te Arawa Lakes (Fisheries) Regulations 2006**[41] cover non-commercial customary fishing within the Te Arawa fisheries area and do not provide for commercial fishing. The Act provides for the establishment of Komiti Whakahaere to manage the customary fisheries in accordance with Te Arawa tikanga and kawa. The Komiti Whakahaere are in the process of developing the Mahire Whakahaere or Te Arawa Lakes Fisheries Plan which is required under the Regulations to provide for the sustainable management of customary fisheries in the Te Arawa lakes. Several customary management changes are suggested in Kusabs et al. (2015a) to protect and enhance the Te Arawa Lakes kōura fishery, including: (1) Restricting access to the fishery; (2) Implementation of a minimum legal length; (3) Implementing closed fishing seasons; and (4) Protecting egg-bearing and soft-shelled (moulting) kōura.

5.7 Aquaculture

Land-based aquaculture is managed by MPI under the provisions of the Freshwater Fish Farming Regulations 1983 made under the Fisheries Act 1996. Freshwater crayfish aquaculture is at an early development stage in Aotearoa-NZ, with no farm currently producing large volumes of saleable stock (<500 kg combined total annual production in Aotearoa-NZ) (Ernslaw One Ltd 2016).

The practice of harvesting of wild stocks for the seeding of aquaculture ventures, and the possibility of direct commercial harvest have fuelled concerns for the sustainability of targeted populations (Whitmore et al. 2000). In 2015, there were 17 licensed freshwater crayfish farms but only four (all in the South Island) were in production. All are selling on the domestic market. Market feedback

[41] http://www.tearawa.iwi.nz/fisheries-regulations

indicates that there is export potential for kōura if consistent supply of large quantities can be achieved (Ernslaw One Ltd 2016).

In July 2013, a three-year research project, funded by MPI's Sustainable Farming Fund, investigated forest pond design, refuge creation, stocking densities, male to female ratios, animal health management, and water quality requirements for kōura aquaculture[42] (Ernslaw One Ltd 2016). Ernslaw One's initiative of farming kōura in the fire reservoir ponds of South Island forests has recently received attention in the media (Tait-Jamieson 2017[43]). Ernslaw One Ltd state that ponds should be aged (e.g., have riparian plantings and time for the water to clear) prior to stocking with freshwater crayfish. Ponds with flowing water tend to age quicker than static ponds but 18-24 months is usually required before you can stock a pond with freshwater crayfish. A good test of when a pond is ready is the presence of aquatic life, such as snails and water boatmen, and an absence of filamentous algae growth (Ernslaw One Ltd 2016).

Several rūnanga, hapū and iwi around Aotearoa-NZ are keen on investigating the aquaculture potential of this freshwater taonga species (e.g., Kitson et al. 2016).

[42] https://www.ngaitahuresearch.co.nz/keewaikoura/

[43] https://www.newsroom.co.nz/@living-room/2017/08/29/45024/sustainable-nz-crayfish-venture-wins-accolades

6 Whitebait

Family: Galaxiidae

Species: *Galaxias maculatus, Galaxias postvectis, Galaxias brevipinnis, Galaxias argenteus, Galaxias fasciatus*

The whitebait catch is made up of five separate fish species belonging to the family Galaxiidae. This ancient group of fishes is found throughout the cool-temperate regions of the Southern Hemisphere incorporating eight genera and about 50 species (McDowall 2006). Galaxiids are characterised as small (usually 40–150 mm, but up to 500 mm in some species) tubular fishes with no scales and only a single dorsal fin. The skin is thick and leathery and there is a strong spotted pattern in some species that is said to "resemble the Milky Way galaxy", hence the family name Galaxiidae (McDowall 1990). Galaxiids are rich in terms of the number of species that there are in Australasia (McDowall 1970, McDowall & Frankenberg 1981, McDowall 1990), with Aotearoa-NZ containing the greatest species diversity (about 35 species and two genera) (Waters et al. 2001, Waters & Wallis 2001, McDowall 2006).

In this section, we briefly introduce each of the five whitebait species that are the focus of this report, before going into more detail about their respective life cycles (Section 6.2), distribution (Section 6.2), and pressures on populations (Section 6.6).

Īnanga (*Galaxias maculatus*)

Adult īnanga (Figure 43) are the smallest of the five species, rarely getting bigger than 110 mm in length. Their silvery belly and forked tail make them easy to tell apart from the other galaxiids, except for their close relative the dune lake galaxias (also called dwarf galaxias, *G. divergens*). Īnanga is the most abundant whitebait species, probably comprising at least 90% of the total national catch (McDowall 1990). Although īnanga migrate well upstream in some rivers, this species is normally considered as a "lowland species" as they favour gently flowing and still waters such as estuaries, lowland streams, lagoons and backwaters (McDowall 1990). Land-locked populations of īnanga are found largely in the North Island (McDowall 1990).

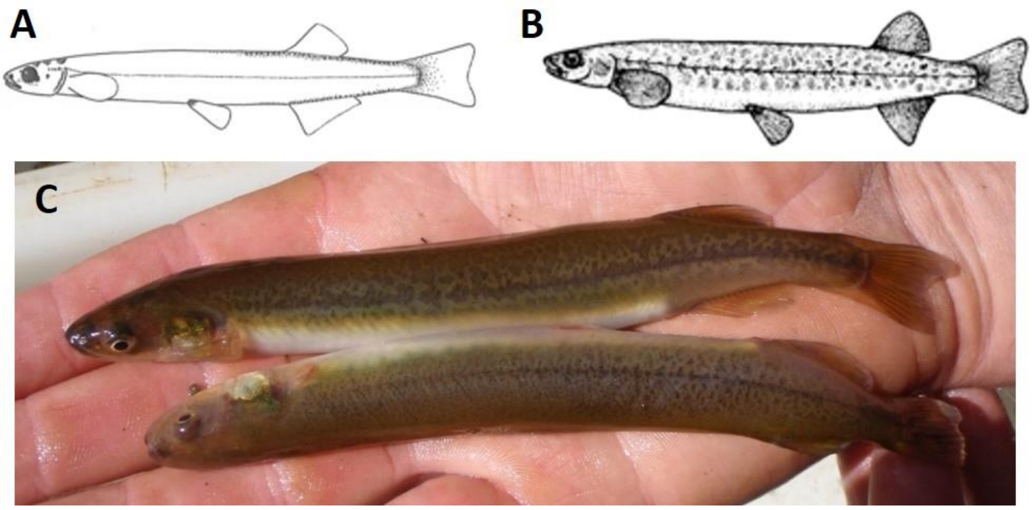

Figure 43: (A) Juvenile īnanga; (B) Adult īnanga; and (C) Adult īnanga caught from the Taumārere River, April 2008. (Diagrams: Bob McDowall; Photo: Bruce Davison).

Shortjaw kōkopu (*Galaxias postvectis*)

Shortjaw kōkopu (Figure 44) have an undercut jaw, with the lower jaw being shorter than the upper jaw. Another distinguishing feature of shortjaw kōkopu is the distinctive dark blotch on each side of their body just behind the gills. Shortjaw kōkopu are endemic to Aotearoa-NZ and do not occur on Stewart or Chatham Island. Although they make their way well inland in many catchments, they appear to be restricted to streams with native forest vegetation.

Even though it is widespread, the shortjaw kōkopu is probably the rarest of the whitebait galaxiids as it is unusual to capture more than a few fish at a given site. It is usually found in streams with large boulders in pools and is sometimes difficult to catch using conventional sampling methods. Because this fish has been so rarely encountered, little is known about its life history. In the Taranaki region spent (i.e., recently finished spawning) fish were first recorded in May by Allibone and Caskey (2000), while Charteris et al. (2003) found spawning occurred in June. In 2008, the first land-locked population was discovered in a reservoir within the Hunua ranges (Baker et al. 2008).

Figure 44: Shortjaw kōkopu caught from the Waikirikiri Stream, November 2008. (Photo: Bruce Davison).

Kōaro (*Galaxias brevipinnis*)

The kōaro is unlikely to be confused with the other diadromous whitebait species because of its shape. It is more elongate and slender shaped, almost like a tube (Figure 45). The sides and back are covered in a variable pattern of light patches and bands. Kōaro have the ability to make their way well inland and climb to high elevations in many river systems, and thus have a more widespread distribution than the other whitebait species. In addition to the mainland, they are also found on Chatham and Stewart Island, in Australia, and on the sub-Antarctic Auckland and Campbell Island. Rocky, tumbling streams are the preferred habitat of kōaro, and they are almost always found in streams with native bush catchments except for tributaries of upland lakes that may be above the bush line. To date the oldest age observed by West (1989) was 8+ years at 208 mm total length.

Although kōaro comprise part of the whitebait catch, they also form land-locked populations in lakes. Populations of land-locked kōaro are sustained by fish that complete their life cycle in fresh water and are found in many man-made and natural lakes. For example, kōaro populations occur in the catchments of many of the Te Arawa Lakes, Taupō-nui-a-Tia, Rotoaira, Manapōuri, Tekapō, Pukaki (Figure 46), and Wanaka. Lake kōaro populations were decimated by predation from introduced trout and are now much lower than in pre-European time, or have become extinct, e.g., Lakes Rotoehu and Rotomā (Rowe & Kusabs 2007).

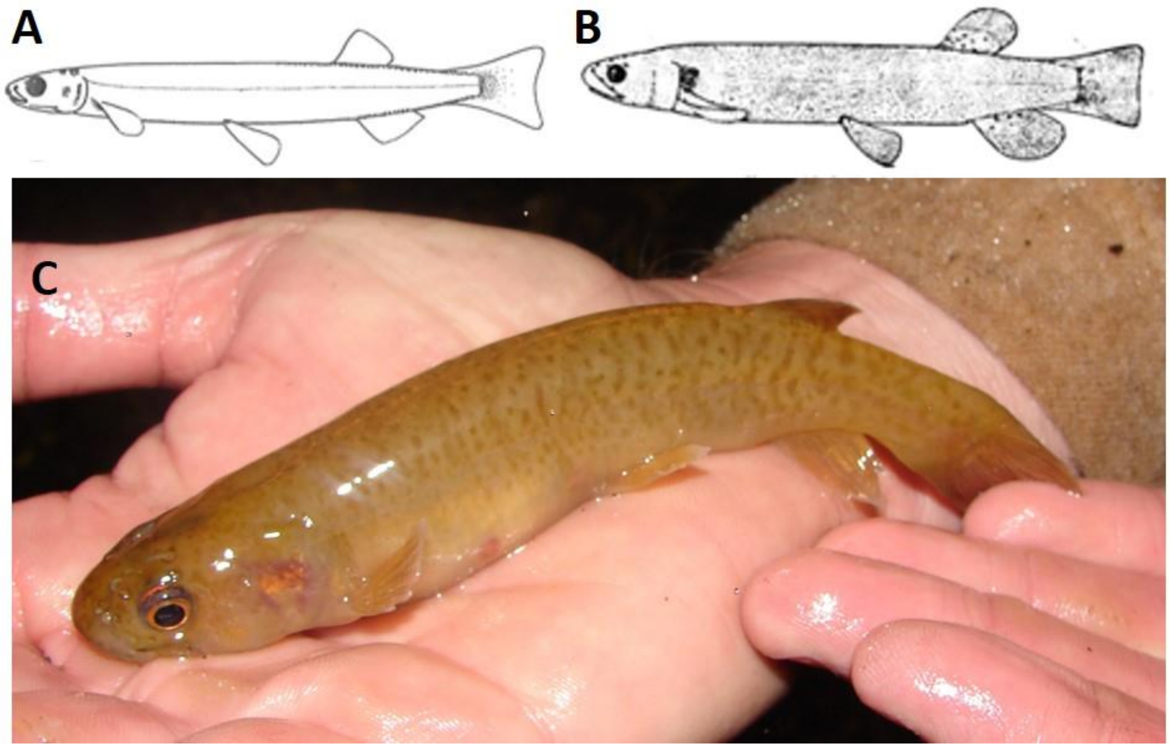

Figure 45: (A) Juvenile kōaro; (B) Adult kōaro; and (C) Adult kōaro caught from Te Hirau Stream, Lake Tarawera. (Diagrams: Bob McDowall; Photo: Shane Grayling).

Figure 46: Adult kōaro from Lake Pukaki, Waitaki River catchment. In this lake adult kōaro are pure white in colour, tinged with pink, due to the glacial silt present in the water and their habit of living in deep waters where the light does not penetrate (see Rowe 1999 and Graynoth 2011 for more information). (Photo: Dave Rowe).

Giant kōkopu (*Galaxias argenteus*)

As its name implies, the giant kōkopu (Figure 47) is the largest member of the Galaxiidae family. The golden spots and other shapes on the bodies of larger fish are very distinctive, although small specimens may be difficult to tell apart from banded kōkopu. Specimens of over 450 mm in length have been reported, although fish in the 200–300 mm range are far more common. To date the oldest age observed by West (1989) was a 7+ year old female (231 mm total length).

Giant kōkopu are uncommon in the whitebait catch and usually run late in the season. Giant kōkopu are primarily a coastal species and do not usually penetrate inland very far. They are endemic to Aotearoa-NZ and are also found on the major offshore islands. Like banded kōkopu and kōaro, they can establish land-locked populations. In streams, they prefer the slow flowing waters that occur in lowland runs and pools. They are also usually associated with some form of instream cover like overhanging vegetation, undercut banks, logs, or debris clusters. It is thought that they lurk quietly in this cover awaiting their prey, which ranges from kōura to terrestrial insects such as spiders and cicadas.

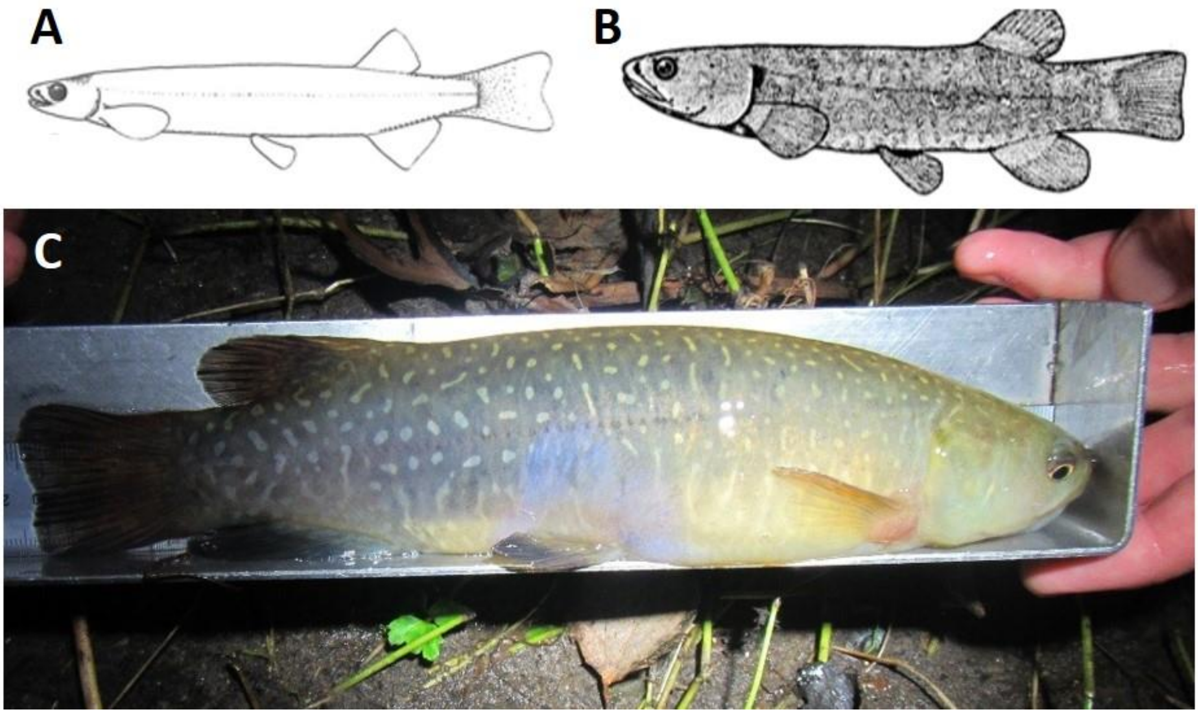

Figure 47: (A) Juvenile giant kōkopu; (B) Adult giant kōkopu; and (C) Adult giant kōkopu caught from Bankwood Stream, Hamilton. (Diagrams: Bob McDowall; Photo: Eimear Egan).

Banded kōkopu (*Galaxias fasciatus*)

Banded kōkopu (Figure 48) are generally the smallest of the five whitebait species when they are small have an overall golden colour. The juveniles are very good climbers and will often try and escape from buckets by clinging to and wriggling up the sides. Adult banded kōkopu can be distinguished from the other galaxiid species by the presence of the thin, pale, vertical bands along the sides and over the back of the fish. These bands begin to develop quite early, but similar bands also appear on juvenile giant kōkopu, and it is easy to confuse young fish of these species. Banded kōkopu commonly grow to over 200 mm.

Adult banded kōkopu usually live in the pools of small tributaries where there is virtually a complete overhead canopy of vegetation. This vegetation does not have to be native bush, however, and banded kōkopu happily live in urban streams and streams under exotic pine plantations so long as overhead shade is present. They only occur in pools where there is instream cover such as an undercut banks, large rocks or wood debris. They depend on terrestrial insects for a large proportion of their diet and can detect the small ripples made by moths and flies that become stuck on the water surface of the pool.

Although the juveniles are good climbers, banded kōkopu do not penetrate very far inland and are primarily a coastal species. They are also found on Chatham and Stewart Island. Banded kōkopu are rare along the east coast of the North Island south of East Cape and down the east coast of the South Island, but common elsewhere. This distribution is probably a result of intensive land development and the sensitivity of the juveniles to suspended sediments. Rivers containing glacial flour or eroding sedimentary catchments are not attractive to the whitebait of this species.

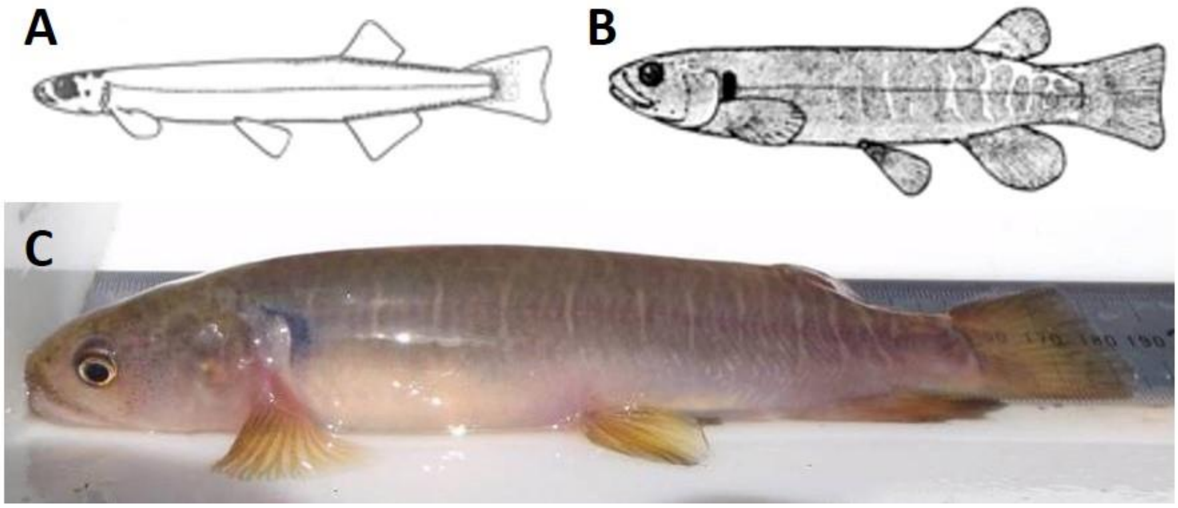

Figure 48: (A) Juvenile banded kōkopu; (B) Adult banded kōkopu; and (C) Adult banded kōkopu caught from the Kaikou River, November 2008. (Diagrams: Bob McDowall; Photo: Bruce Davison).

6.1 Life Cycle

Whitebait are diadromous as their life cycle is completed in marine and freshwater environments. Amphidromy is the specific type of diadromous migration that Galaxiids display which typically involves downstream larval transport, dispersal and development in the marine environment followed by inward migration of post-larvae (whitebait) to freshwater where most feeding and growth occurs (McDowall 1998). The life cycle and migrations of amphidromous species, of which there are at least 250 worldwide, are not well known (McDowall 2007). Studies of amphidromous species like whitebait are challenging because of the extensive larval period in the sea which often means larvae cannot be located or identified (Hickford & Schiel 2003).

Although the five Galaxiid species are largely considered diadromous, recent research shows there is considerable flexibility in their migration patterns and life histories. The chemistry of Galaxiid ear-bones (called otoliths) has been used to discern whether individuals completed their life in marine, estuarine or freshwater environments (also see Section 6.5.4). In Aotearoa-NZ, freshwater larval development has been documented for īnanga from coastal populations with downstream access to the sea and upstream access to lakes (Hicks 2012). Other studies have shown that īnanga larval development occurs exclusively in the marine environment; īnanga whitebait migrate directly from the sea to freshwater, spending little time in estuaries (Hicks et al. 2005). Evidence for freshwater larval development as opposed to marine larval development is also known for giant kōkopu (David et al. 2004), kōaro (Hicks 2012) and banded kōkopu (Tana & Hicks 2012).

Among the five-whitebait species, the spawning ecology/behaviours of **īnanga** are the most widely understood (Figure 49); however, research on the other species is being progressed (see following sections). For diadromous populations of īnanga, mature adults (50–125 mm in length) move downstream to their spawning sites (McDowall 1968), while land-locked populations move upstream to spawn (Pollard 1972). For īnanga that are diadromous, spawning occurs on riparian vegetation where the salt water wedge penetrates freshwaters at high tides (McDowall 1988). Spawning is linked to lunar and tidal cycles with most spawning occurring on spring-tide events. Cues like day length and seasonal changes in temperature are important for the onset of sexual maturity and spawning in īnanga (Barbee et al. 2011).

Figure 49: Diagram showing the life stages and habitats used by diadromous populations of īnanga. (Source: NIWA).

Īnanga spawn over an extensive period, from January in the south through to July in the north, with peripheral spawning also found outside of these ‘peak’ spawning times (Mitchell 1991, Taylor 2002, Hicks et al. 2013). The eggs are typically deposited 10–15 cm above the highwater mark, take 2–4 weeks to develop and require humid conditions for successful development (Hickford & Schiel 2011). Analysis of the hatch-dates of īnanga whitebait, as well as mature adults, confirms their extensive spawning period even though eggs are rarely observed year-round (Egan 2017).

Using gonad histological analysis, Stevens et al. (2016) showed that some īnanga can survive spawning but most die. Size at sexual maturity, body condition and gonad weight tend to decline throughout the spawning season (McDowall 1968, Barbee et al. 2011). These patterns might be related to multiple spawning events or that the reproductive dynamics of fish that are mature later in the year differ to those that mature earlier. Generally, larger females produce more eggs but there is considerable variation in egg production among individuals. For example, up to six-fold differences in egg production were found among females that were 80 mm in length (McDowall 1968).

Larval hatching is triggered by re-inundation of the eggs on the next tidal cycle, usually 3–4 weeks later. It is thought that larval hatching also occurs on flood flows although this has never been demonstrated (Rowe & Kelly 2009). Īnanga eggs can survive for up to 6 weeks in the vegetation but their viability declines with longer egg development times (Benzie 1968). Newly hatched larvae, on average 7 mm length, drift downstream to the marine environment. There are few observations of īnanga in this environment so little is known of their larval ecology.

Īnanga whitebait migrate to freshwaters during late-winter through spring, but can be observed in lower abundances throughout the year (McDowall et al. 1994). The average size at migration is 51 mm but this ranges from 36 mm to 60 mm throughout Aotearoa-NZ. They are on average 124 days old at inward migration but this can vary widely (60–187 days). Īnanga change into the adult form in the lower reaches of rivers, while adult growth and development occurs further upstream (McDowall 1968). They are an annual species with few individuals surviving to their second year (Egan 2017). Less is known about the life cycle of land-locked īnanga populations in Aotearoa-NZ. In Australia, land-locked populations spawn in littoral (lake shore) vegetation, larvae rear in the limnetic zone (lake surface waters away from shore) and adults live for up to four years (Chapman et al. 2006).

Shortjaw kōkopu spawn along bank margins during elevated flows (Charteris et al. 2003), but can be quite variable in the selection of their spawning sites/habitats. Spawning sites for shortjaw kōkopu have been shown to include a mixture of small vegetation, gravel and woody debris (Charteris et al. 2003).

In stream populations, **kōaro** spawning occurs during autumn/winter. Downstream drift of kōaro larvae was observed in May by Charteris et al. (2003) for Taranaki streams, but kōaro larvae have also been observed in March in South Island streams (McDowall & Suren 1995). Examination of hatch date distributions of returning kōaro whitebait to South Island rivers observed a spawning season of May through to July (McDowall et al. 1994). Kōaro deposit their eggs amongst marginal gravels and litter during periods of elevated stream flow (Allibone & Caskey 2000). The larvae hatch typically 3–4 weeks later if the eggs are re-inundated during high flow events. The hatched larvae (about 7–8 mm long) go to sea to feed and grow for about 17–20 weeks, then as whitebait (c. 45–50 mm long) migrate upstream in early spring (McDowall 1990). Lake populations of kōaro have a life history pattern similar to that of sea-going stocks, although the spawning season may vary (McDowall 1990).

Little is known about **giant kōkopu** spawning habits with the most information to date coming from studies on a single population in the Waikato region (Franklin et al. 2015). It is thought that giant kōkopu adults migrate to a common spawning site and lay their eggs in bankside vegetation (Figure 50). Currently, the known spawning vegetation is mostly *Tradescantia fluminensis* (wandering willie), an invasive perennial herb; but it is highly likely that giant kōkopu use other species of native and exotic grasses for spawning (Franklin et al. 2015). Spawning occurs during elevated flows following rainfall events and is not triggered by cues related to tidal cycles. Spawning has only been recorded from two sites in Aotearoa-NZ, an urban stream in Hamilton and at Awaawaroa Wetland on Waiheke Island. Spawning is known to occur from late April to late June (Franklin et al. 2015).

Similar to shortjaw kōkopu, **banded kōkopu** spawn along bankside margins during elevated flows (Charteris et al. 2003), but can be quite variable in the selection of their spawning sites/habitats. Spawning sites for banded kōkopu have been shown to include a mixture of small vegetation, gravel and woody debris (Charteris et al. 2003).

Figure 50: Giant kōkopu spawning site, Bankwood Stream, Hamilton. (Left) The pink tape marks the location of the only monitored spawning site of giant kōkopu in Aotearoa-NZ. Giant kōkopu eggs are mostly found on *Tradescantia fluminensis* (wandering willie) which is the most dominant bankside vegetation in this stream; (Right). A spawning aggregation of giant kōkopu. Spawning was witnessed for the first time by NIWA scientists in June 2017. Giant kōkopu spawned on rising and receding water levels following a significant rain event. The pink tape marks the location of eggs from a previous spawning event. (Photos: Eimear Egan).

How many eggs does it take to make a whitebait fritter?

Franklin (2014) draws on our current knowledge of the īnanga life cycle and the gauntlet negotiated by these fish (i.e., survival rates) to estimate how many whitebait eggs might be needed to eventually end up on our plates as fritters. He estimates that:

> "*An average sized adult female īnanga will lay around 2–3,000 eggs (McDowall 1984). Studies have shown that on average, only about 11% of eggs survive to hatch (Hickford et al. 2010). Once the eggs hatch and the larvae make it to sea, survival is very low. No data are available specifically for īnanga, but mortality of larval fish in the marine environment has been estimated to be more than 98% (Zeldis et al. 2005). On returning to freshwater, investigations have shown that around 30% of whitebait may be caught in the whitebait fishery (Baker and Smith 2014). An unknown number of these remaining fish then survive to adulthood and successfully spawn (let's assume 50%, but it has been suggested this is more likely to be less than 20%). If we assume a cup of whitebait (about 500 fish) is used to make a whitebait fritter, we can work out that it actually takes close to 650,000 eggs to make one whitebait fritter!*"

6.2 Distribution

Generally, most of the whitebait species are found close to the ocean, except for kōaro which can penetrate large distances inland (Figures 51–53). **Īnanga** are almost exclusively found within close proximity of the coast, particularly in the South Island but are largely absent from Fiordland (Figure 51).

Shortjaw kōkopu show specific distributions in the South and North Island. In the South Island, shortjaw kōkopu are only regularly found along the West Coast and along the top of the South Island. There are a few observations north of Kaikōura, but the remaining east coast of the South Island has no observations of this species. There are also a few observations of shortjaw kōkopu around the mouth of the Waiau River in Murihiku. The Waitakere ranges and Taranaki are the two areas in the North Island with the most observations of shortjaw kōkopu. There are a few intermittent records of this species at large distances inland around Whanganui National Park, Hamilton and Whakatāne (Figure 51). Yungnickel (2017) has identified shortjaw kōkopu whitebait from the Whakatāne River (Bay of Plenty), Rangitikei River (Manawatū-Whanganui), Orowaiti and Buller Rivers (Buller) and Waimea Creek (Westland) using genetic methods.

Kōaro are found across a wide variety of habitats and at high distances inland because of their climbing ability (McDowall 1990). Kōaro can climb vertical structures allowing them to reach high altitudes and account for most of the highest fish observations in the NZFFD. Kōaro also form land-locked populations (McDowall 1990), which are included in Figure 52 because it is not possible to separate diadromous from non-diadromous stock within the NZFFD. Most of the kōaro observations in the South Island have been recorded along the Southern Alps mountain ranges and the West Coast. Most of the observations of kōaro in the North Island are located along the Waitakere ranges and Taranaki (Figure 52).

Giant kōkopu (Figure 52) are a coastal species that appears to have a patchy distribution across Aotearoa-NZ. In the South Island, they are predominantly absent around Fiordland and along the East Coast (with the exception a couple of small streams), apart from the South Otago Region. The most records in the South Island have come from the West Coast region. The most records in the North Island have been recorded from around Wellington, Taranaki and the Waikato. There are also a few records from around South Auckland and Tauranga, but the remaining areas in the North Island have very few records of giant kōkopu.

Banded kōkopu have a very coastally restricted distribution, similar to īnanga, but not as widely spread throughout the country (Figure 53). Like giant kōkopu in the South Island (Figure 52), banded kōkopu are absent from North and South Canterbury, but are present around Banks Peninsula. They are commonly found South of Dunedin and along Westcoast of the South Island. In the North Island, banded kōkopu are commonly found north of Wellington and on the North Taranaki Coast. This species is also commonly found around Auckland and between Whakatāne and the Coromandel (Figure 53).

Figure 51: Locations of NZFFD records where (Left) īnanga and (Right) shortjaw kōkopu are present (black circles) and absent (grey circles).

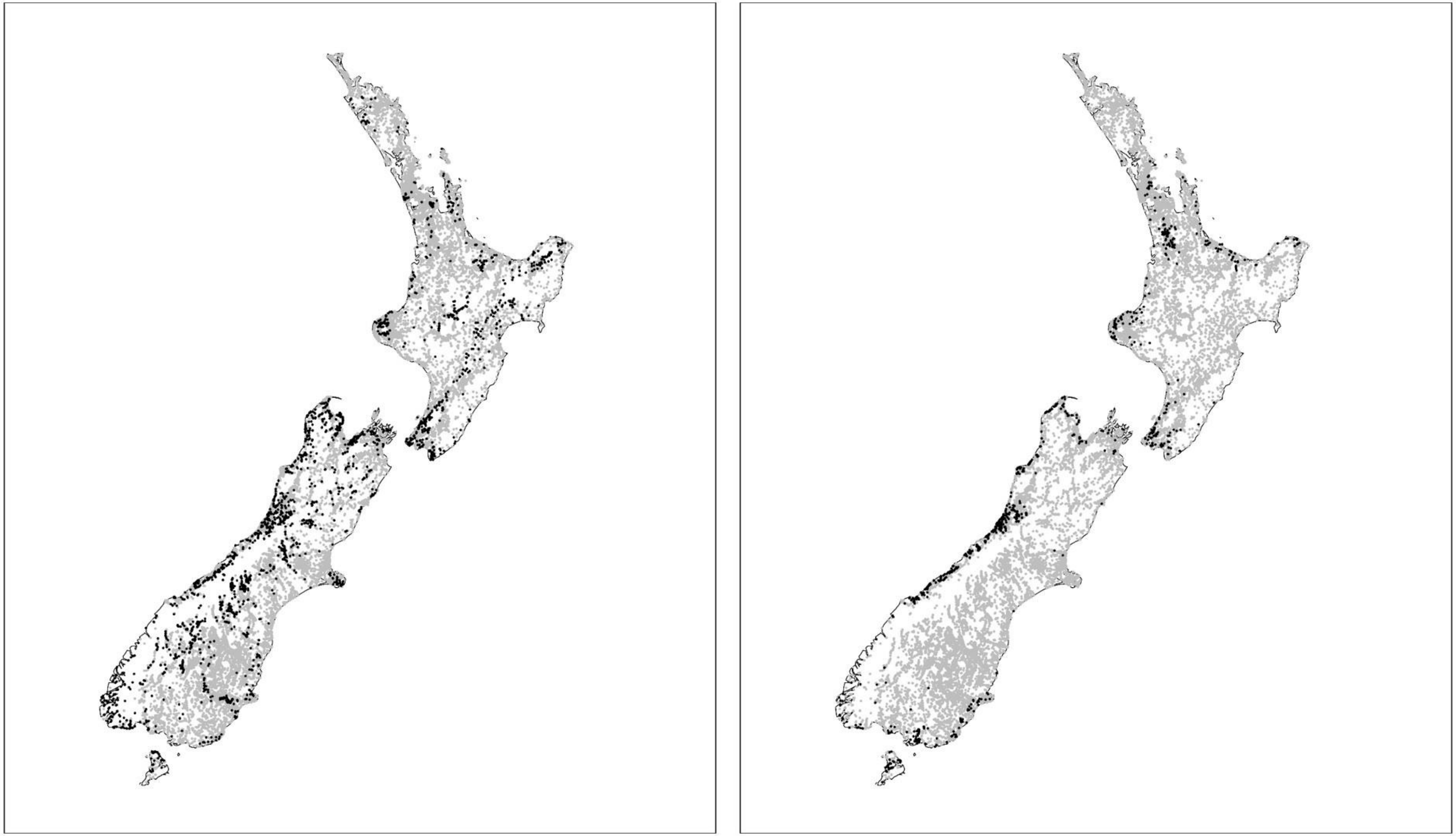

Figure 52: Locations of NZFFD records where (Left) kōaro and (Right) giant kōkopu are present (black circles) and absent (grey circles).

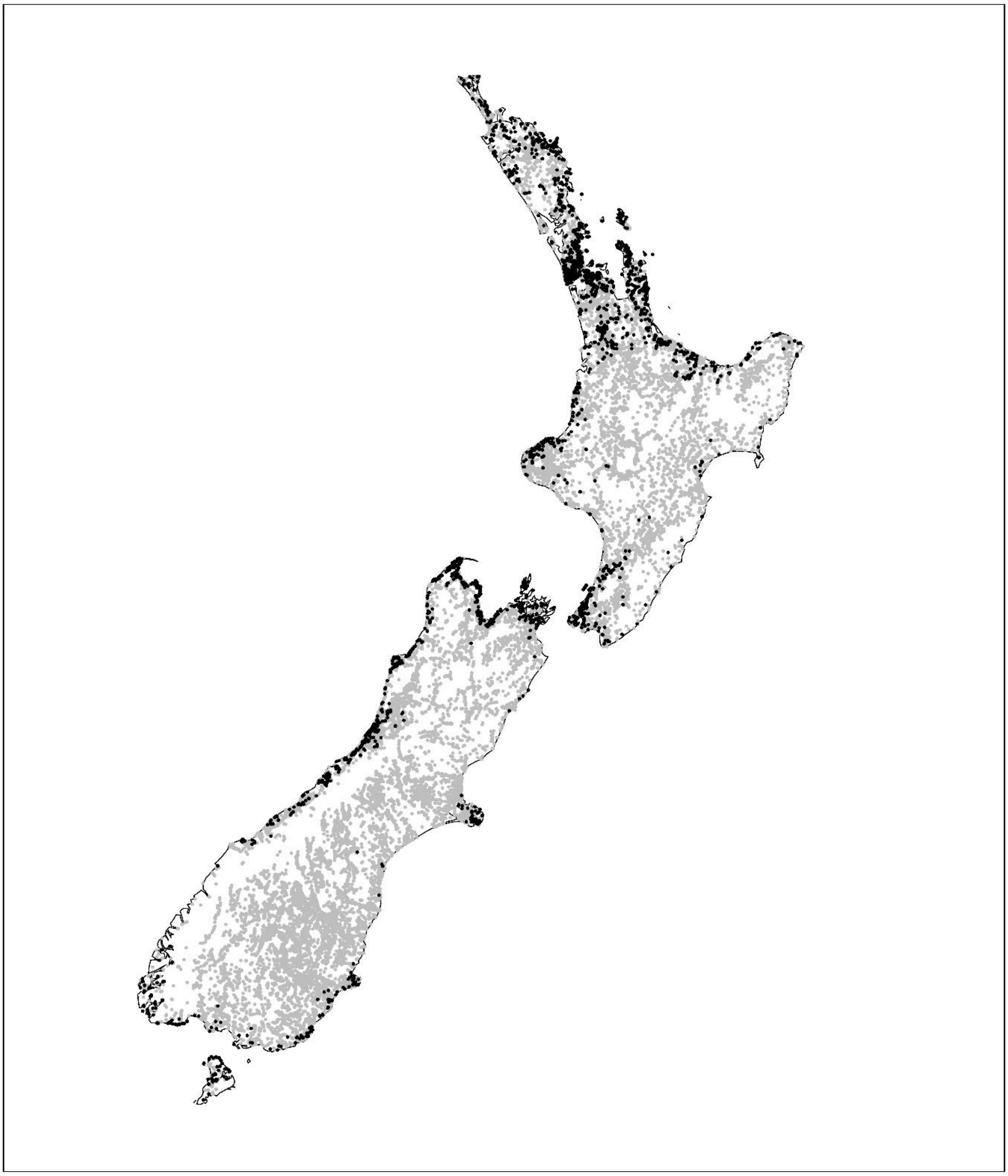

Figure 53: Locations of NZFFD records where banded kōkopu are present (black circles) and absent (grey circles).

6.3 State and Trends in Abundance

6.3.1 Method Recap

To account for some of the limitations in the NZFFD data, Crow et al. (2016) drew on several statistical approaches to address some of the biases that come with using this dataset. To identify if the 'probability of capture' for a taonga freshwater species through time appears to be increasing (getting better), decreasing (getting worse) or staying the same, Crow et al. (2016) completed simple linear regression[44] calculations (how does X relate to Y?) using two different techniques.

The first technique was the Sen Slope Estimator (SSE), while the second technique was a weighted version of the SSE. The weighted SSE (called WSSE hereafter) assigns a weighting value based on the size of the confidence intervals[45] (CI). In the WSSE, pairs of years that collectively have small CIs are weighted more heavily than pairs of years that collectively have large CIs because we were more confident in these probability of capture values.

Both WSSE and SSE results are presented in this report because, together, they help us understand whether or not we can be confident in the analysis and detect a trend over time (either increasing or decreasing) – or if we cannot detect a trend.

6.3.2 Kōaro Results

Kōaro was the only galaxiid species able to be assessed by Crow et al. (2016) using NZFFD records. While the SSE trend over the 1977–2015 period was indeterminate, the WSSE showed a decreasing trend. Weighted SSE results show that the probability of capture was decreasing at a median (±95% CI) rate of 0.05 (±0.02) %/year. In summary, the two trend analyses over the full-time series available (1977–2015) were not in agreement and did not show a strong trend in either direction; however, between 1995–2015 both analyses showed a decreasing trend (Figure 54) (Crow et al. 2016).

6.3.3 Lower Waikato River

In a review of the whitebait fishery in the lower Waikato River, Baker and James (2010) compared the annual catch estimated from commercial buyers records between 1930 and 1990 (Figure 55). Although there was some evidence of a decline between 1950 and 1980, more recent data suggest that the fishery has improved. However, these figures are highly variable and are considered to be of limited value for assessing the status of the fishery because annual purchases of whitebait will reflect fluctuations in demand and supply, as well as annual variations in the catch. Baker and James (2010) concluded that an historic decline in the fishery has probably occurred, although the magnitude and timing of this change is unknown. Baker and James (2010) concluded that a decline in whitebait has probably occurred in the Waikato River, as supported by knowledge of habitat decline in the Waikato River catchment (e.g., NIWA 2010), and anecdotal information of whitebait fishery decline from around Aotearoa-NZ (e.g., Hayes 1931, McDowall 1984).

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[44] Simple linear regression is a statistical method that allows us to summarise and study relationships between two continuous (quantitative) variables.
[45] A confidence interval is a range of values we are fairly sure our true value lies within.

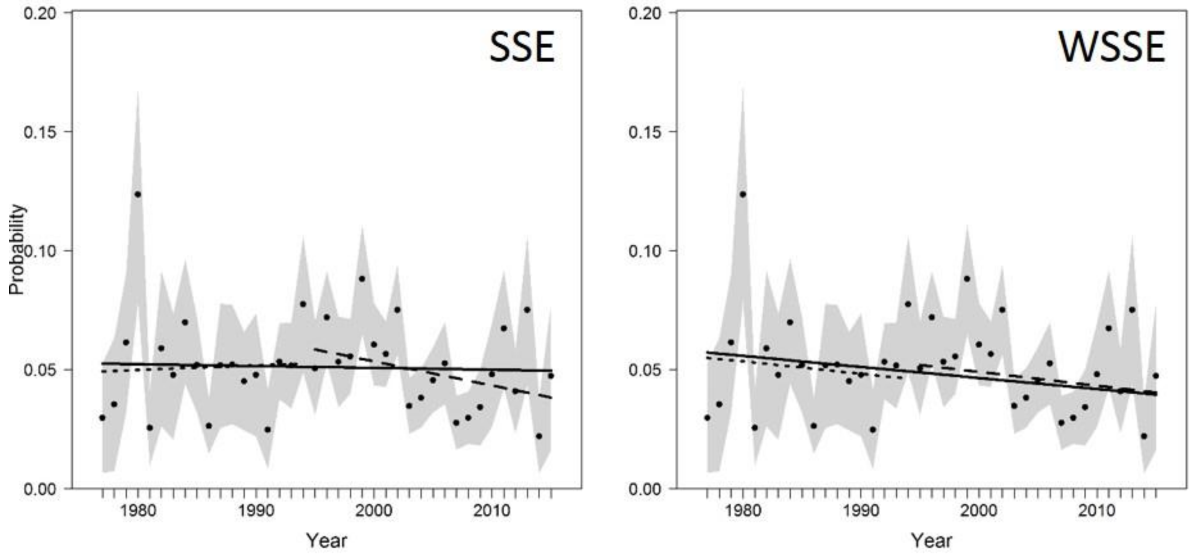

Figure 54: Change in the probability of kōaro capture associated with year for the NZFFD. Plots show the characteristic probability of capture for each year (black circles) and 95% CI (grey shaded area). SSE (left) and WSSE (right) are shown for 1977–2015 (solid black line), 1977–1994 (dotted black line) and 1995–2015 (dashed black line) (Source: Crow et al. 2016).

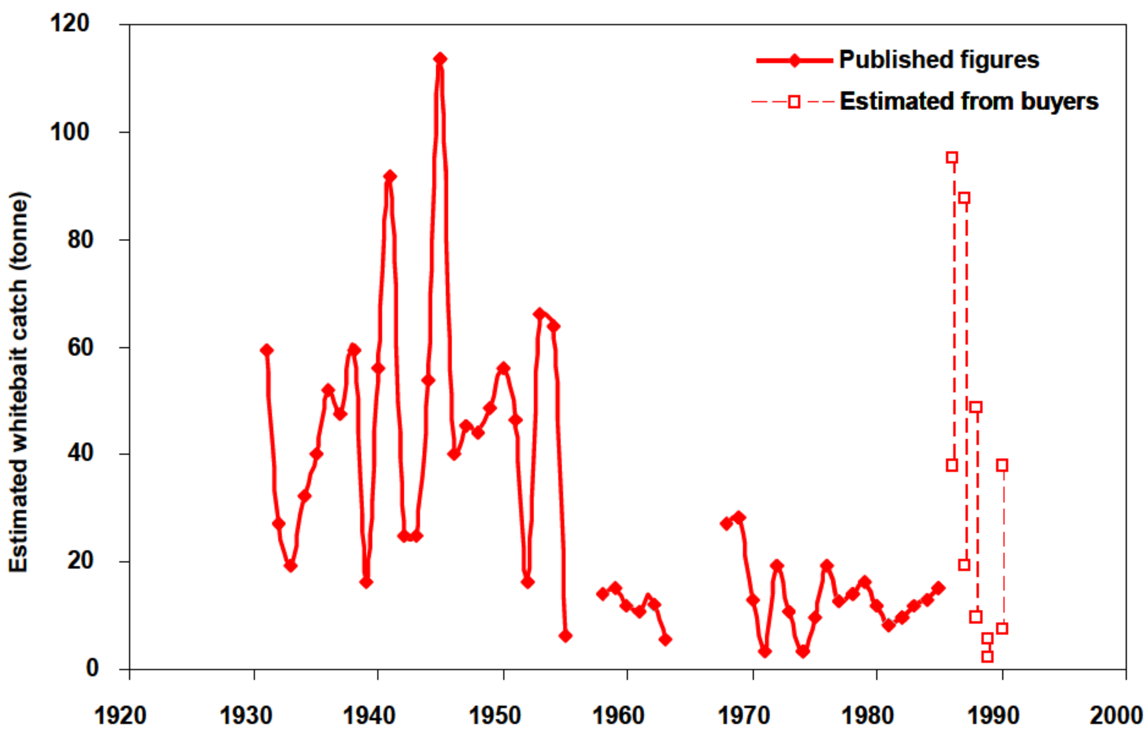

Figure 55: Estimated annual total catch of whitebait from the Waikato River (galaxiids plus smelt) based on: (1) Catch records from Marine Department records (1931–1973); (2) Records from an Auckland canning factory (1958–1963); and (3) Commercial buyers records (1975–1990). (Source: Baker & James 2010).

6.4 Threat Rankings

The latest New Zealand Threat Classification System assessment has classified īnanga, kōaro and giant kōkopu as 'At Risk – Declining'. Shortjaw kōkopu are classified as 'Threatened – Nationally Vulnerable' with 5,000–20,000 mature individuals, and a predicted population decline of 30–70%; and banded kōkopu are listed as 'Not Threatened' (Goodman et al. 2014) (Table 9).

In 2014 īnanga and kōaro were assessed by IUCN as being of 'Least Concern'. The panel recognised that īnanga remains widespread and abundant throughout its current range, but it acknowledged that this species has suffered from extensive habitat loss and deterioration throughout parts of its range which is likely to have had historical impacts on the Aotearoa-NZ population (David et al. 2014a). The panel noted that there is no information available on the global population trend of this species. The natural distribution of kōaro was recognised by the panel as fragmented throughout its range (probably due to habitat loss and degradation); however, it was noted that this species can penetrate well inland in many river systems and therefore have a more widespread distribution than the other large galaxiid species (David et al. 2014b) (Table 9).

The IUCN assessment panel have ranked shortjaw kōkopu as 'Endangered' (West et al. 2014a) as this species is sparsely distributed and is only known from a few sites in many areas. It is only found in specific habitats and is sometimes not found in neighbouring habitats, even though they appear very similar (West et al. 2014a). West et al. (2014b) ranked giant kōkopu as 'Vulnerable'. Although specific data on the rates of giant kōkopu population decline are unavailable, the panel assumed on the basis of past, existing and continuing human pressures that the population has experienced at least a 25% decline over the past 20 years. Furthermore, it is possible that large, old fecund specimens could be sustaining populations in the face of habitat loss and drain clearing mortalities and a 10–20 year lag may be weakening the current observations of a decline (West et al. 2014b). Banded kōkopu have been rated as being of 'Least Concern' because this species is widespread and locally abundant throughout its range and the population is considered relatively stable (West et al. 2014c) (Table 9).

Table 9: Threat rankings for Aotearoa-NZ whitebait species according to the New Zealand Threat Classification System and IUCN. (see Section 2.3 for more information about these assessment methods).

Common name	Species	DOC Ranking	IUCN Ranking
Īnanga	*Galaxias maculatus*	At Risk–Declining	Least Concern (Population trend unknown)[46]
Shortjaw kōkopu	*Galaxias postvectis*	Threatened–Nationally Vulnerable	Endangered (Population decreasing)[47]
Kōaro	*Galaxias brevipinnis*	At Risk–Declining	Least Concern (Population trend unknown)[48]
Giant kōkopu	*Galaxias argenteus*	At Risk–Declining	Vulnerable (Populations decreasing)[49]
Banded kōkopu	*Galaxias fasciatus*	Not Threatened	Least Concern (Population trend stable)[50]

[46] http://www.iucnredlist.org/details/197279/0
[47] http://www.iucnredlist.org/details/8813/0
[48] http://www.iucnredlist.org/details/197277/0
[49] http://www.iucnredlist.org/details/8817/0
[50] http://www.iucnredlist.org/details/197278/0

6.5 Pressures on Populations

Several pressures on whitebait populations have been identified (Figure 56), many of them are common to other freshwater taonga species. For example, the pressures outlined in Section 3.5.1–3.5.3 also apply to whitebait populations and will not be repeated below. Generally, most of the pressures operating on whitebait/galaxiids are poorly understood and do not have large amounts of supporting evidence for their effects. Potential pressures are, however, discussed below in relation to the limited information that is available.

6.5.1 Loss of Habitat

Habitat loss is likely to be the largest pressure on all whitebait species, but direct evidence for the impact of this pressure on whitebait populations is lacking. Historically, whitebait habitat is likely to have been reduced nationwide by swamp and wetland drainage. Wetland areas are important spawning habitat for some whitebait, but these areas have been reduced by an estimated 90% in Aotearoa-NZ (Hansforth 2011). These areas are particularly important for the dominant whitebait species (īnanga), which spawns on river/stream banks and wetlands among vegetation inundated by spring high tides. Aotearoa-NZs loss of wetlands means that most īnanga spawning is now likely to occur along river margins only.

Because shortjaw, giant and banded kōkopu are found in areas with lots of overhead cover, the extensive deforestation in Aotearoa-NZ is considered the biggest threat to these species. The amount of forest coverage is estimated to have been reduced from 85% to just 28% (Taylor & Smith 1997), which has undoubtedly influenced habitat availability of the kōkopu species.

6.5.2 Land and Infrastructure Management

Whitebait spawning habitat along river margins may also suffer from stock grazing and any flood control works. It has also been shown that egg densities and survival are reduced by 75% and 25%, respectively, if spawning grasses are disturbed (e.g., cut) several months prior to the spawning season (Hickford & Schiel 2014). In larger river systems, the removal of riparian vegetation and the installation of hard-structures for flooding and erosion control have reduced the availability of īnanga spawning habitat. This effectively creates “sink” populations whereby īnanga cannot access sufficient spawning habitat, diminishing the reproductive output of a given river and likely fragmenting population connectivity (Hickford & Schiel 2011). The specific spawning habitats of kōaro and the kōkopu species are not well known. As such, alteration of riparian margins or instream habitat has unknown consequences for these species (Franklin et al. 2015). Furthermore, īnanga and giant kōkopu repeatedly use the same spawning sites (spawning site fidelity) meaning that compromised spawning habitat can impact on reproductive output and egg survival over the course of an entire spawning season and multiple years (Franklin et al. 2015) resulting in localised depletions.

Increased suspended sediment associated with land use intensification and urban development is also likely to have impacted on whitebait abundance. Increased suspended sediment is thought to be a major contributor to the current global decline in freshwater fish biodiversity (Maitland 1995, Hazelton & Grossman 2009), which has also been shown to impact on Aotearoa-NZ fishes (Rowe & Dean 1998). Rowe and Dean (1998) found that feeding rates of banded kōkopu and īnanga decreased with increasing turbidity, suggesting that increased suspended sediment may reduce growth rates. In addition to reduced feeding ability, whitebait have also been shown to avoid high suspended sediment (Boubée et al. 1997).

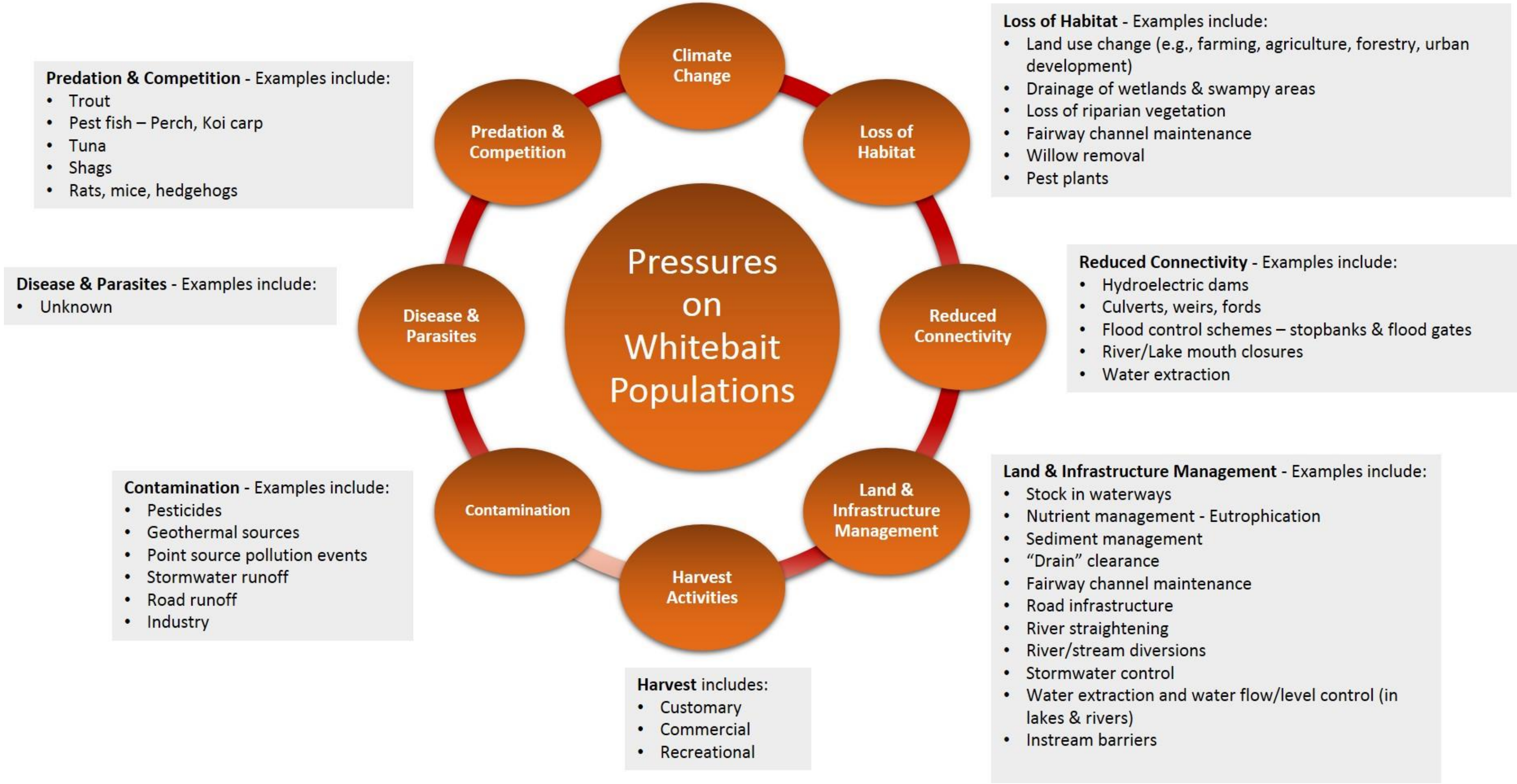

Figure 56: **Examples of some of the pressures on Aotearoa-NZ whitebait populations.**

There are few published studies in Aotearoa-NZ that have attempted to quantify or document the effects of mechanical or chemical drain cleaning on mortality of freshwater fish. Greer (2014) demonstrated that native fish abundance was reduced by 52% after mechanical excavation of macrophytes, but species diversity was not affected. Although partial macrophyte removal was still found to reduce fish abundance significantly, this technique might prevent large individuals of this species from leaving targeted waterways. In another study, Allibone and Dare (2015) found that giant kōkopu numbers declined from 18 fish to only 1, one year after drain clearance activities.

Modifications to the hydrological regime of rivers can impact negatively on populations of migratory Galaxiids at various stages of their life cycle. For example, flood flows stimulate the inward migrations of whitebait to rivers (McDowall 1995) with the largest runs often occurring after flood events. Low flows and less frequent flooding events may therefore delay or even limit the ability of whitebait to migrate in to freshwaters. The rate of upstream migration to the adult habitat, at least for īnanga, is influenced by stream flows among other factors such as water clarity (Allibone et al. 1999) and temperature.

Reduced flows can also affect spawning and egg survival for whitebait. Franklin et al. (2015) found that because of low winter rainfall in 2013, sufficient flows to re-inundate giant kōkopu eggs and stimulate larval hatching did not occur. Although the eggs remained alive for up to ten weeks in riparian vegetation, their viability decreased and high egg mortality rates ensued (Franklin et al. 2015). For non-diadromous populations of whitebait, higher flows are needed to stimulate up-stream migration for spawning (Chapman et al. 2006). Low flows may affect land-locked populations by restricting upstream movement for spawning. In catchments with high demands for water resources, management of flow variability is important for spawning success of kōkopu species (Charteris et al. 2003, Franklin et al. 2015) and is likely similar for kōaro.

Following hatching, amphidromous larvae are considered largely passive because of their small size and poorly developed sensory abilities (McDowall 2009). As such, their initial dispersal is dictated by hydrology and other abiotic conditions. For diadromous populations, the downstream transport of larvae may be affected by variation in flows (Charteris et al. 2003). Conversely, given the recent observations that kōaro larvae in lakes display strong signals to flows (J. Augspurger, pers. comm.), larval dispersal and thereby population connectivity is likely influenced by flows, but at present this is not well understood.

6.5.3 Predation and Exotic Species

The exotic species present in Aotearoa-NZ compete and predate on whitebait. Most of the predation pressure placed on whitebait by exotic species is likely to come from brown trout (McIntosh et al. 2010). Predation is likely to be especially high when sea-run/estuarine-living trout are present because these salmonids live in the lowland areas that most of the whitebait species occupy. Predation may be particularly high around the southern coasts of Aotearoa-NZ where ambient temperatures are lower and brown trout may be more anadromous (McDowall 1990). Glova (2003) presented evidence, from behavioural studies in a small stream simulator, that the number of īnanga declined when they shared the stream habitats with brown trout (255–390 mm long), and also that the galaxiids shifted their microhabitat with trout present. Presumably, this resulted in the galaxiids occupying less favourable microhabitats for drift feeding on invertebrates. Predation may also occur from rainbow trout and perch, but there is limited information on the direct effects of these exotic species.

6.5.4 Oceanic Conditions

Aotearoa-NZs oceanography is dynamic, with distinct temperature and productivity gradients associated with latitude, strong seasonal variation in abiotic conditions and complex ocean current systems (Murphy et al. 2001, Stevens & Chiswell 2006, Chiswell et al. 2015) (see Figure 57). The extensive distribution and protracted spawning time, observed for some of the diadromous Galaxiids, means larvae undoubtedly encounter a wide range of environmental conditions during their marine life phase. The effects of oceanic conditions on the larval ecology of Galaxiids is mostly unknown, largely because larvae are rarely captured *in situ*.

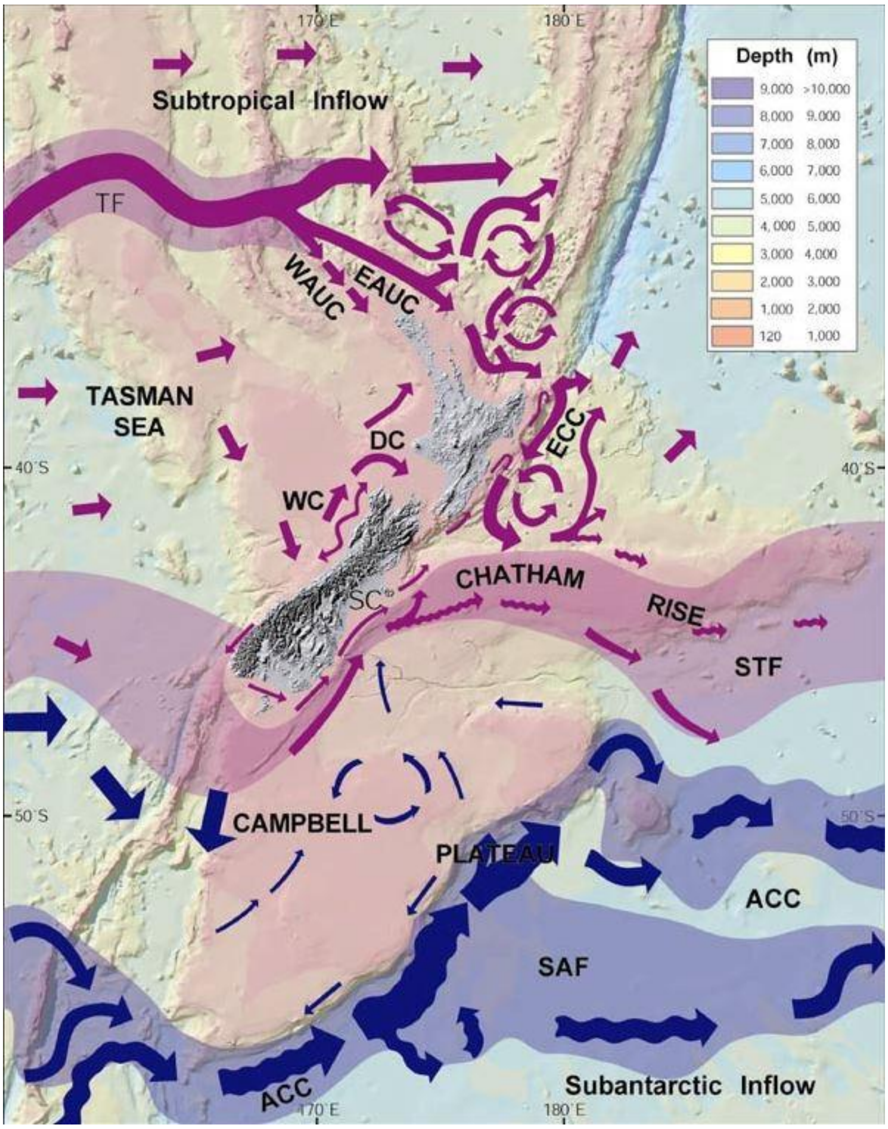

Figure 57: Ocean currents around Aotearoa-NZ. Three major water masses coming in from the west influence Aotearoa-NZ ocean currents: the Tasman Front (TF), the Subtropical Front (STF), and the Sub Antarctic Front (SAF). The Tasman and Subtropical fronts are relatively warm surface currents. The Sub Antarctic Front is cooler and is associated with the cold Antarctic Circumpolar Current (ACC) that hugs the deep ocean floor to the east of the Campbell Plateau and Chatham Rise. (Source: Stevens & Chiswell 2006).

Within and across years, variation in the abundance of returning whitebait is likely to be impacted on by oceanic conditions (Rowe & Kelly 2009) and is not solely influenced by processes occurring in the adult or spawning habitats (Hickford & Schiel 2013). Despite difficulties associated with understanding the marine larval phase, Egan (2017) took an alternative approach and reconstructed the larval growth phase of īnanga whitebait upon inward migration using their otoliths (Figure 58). Comparisons of īnanga growth histories within and among four regions (Canterbury, Buller, Golden Bay and Bay of Plenty) as well as among larval hatching times were done to examine geographical and temporal variation in marine growth. Results showed that īnanga whitebait in the Bay of Plenty were faster growing, migrate at a significantly younger age (95 days) and smaller mean size (36.5 mm) compared to īnanga in Canterbury that were slower growing, older at inward migration (mean age of 144 days) and larger (50.5 mm in length). There was little difference in marine growth rates, age or size at migration for īnanga in Buller and Golden Bay regions. These regional differences, and in some instances similarities, suggest that sea surface temperatures and productivity gradients are key environmental drivers of marine larval growth rate variation across Aotearoa-NZ.

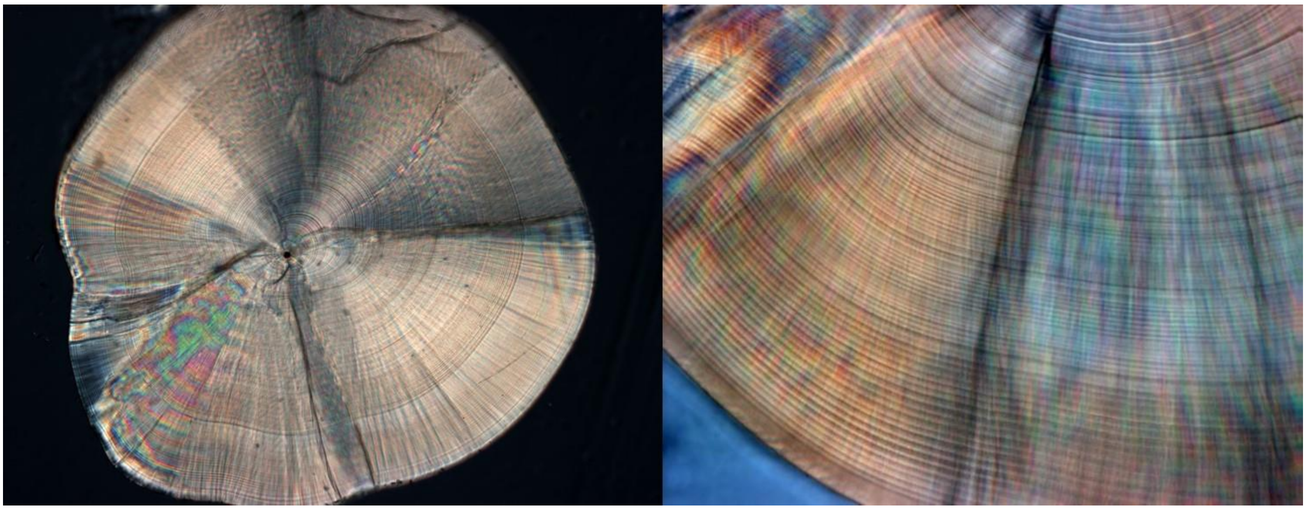

Figure 58: The otolith or ear-bone of an īnanga, viewed under a high-powered microscope. The dark lines are the rings that are deposited every day of its life. The number of rings are used to estimate īnanga age, while distances between each ring are used to examine growth rates. (Photos: Eimear Egan).

Egan (2017) showed there is a growth rate threshold for migration that is determined during 40–60 days of marine larval life. Īnanga with higher growth rates during this phase attained higher growth rates for the remainder of their life at sea and migrated at a younger age compared to slower growing larvae during this phase. Temperature is widely known to affect dispersal via its effects on growth and stage durations in fish (O'Connor et al. 2007) and is an important factor constraining īnanga growth rates, regulating larval dispersal duration with important ramifications for the connectivity of populations.

Furthermore, Egan (2017) found that the marine growth histories of īnanga vary with larval hatching times. Īnanga larvae hatched in the winter months grew faster during larval life and returned to freshwaters at a younger age than īnanga hatched during autumn across Aotearoa-NZ. Uncoupling between spawning/larval hatching and favourable oceanic conditions for growth and survival may result in high larval mortalities at sea of specific larval cohorts. This may partly explain some of the temporal variation seen in abundances of whitebait throughout the migration season. The larval-juvenile life stage of most freshwater fishes is the most susceptible phase to mortality, with more than 90 % of the juveniles dying (e.g., Hayes 1988). Identifying the sources of mortality for whitebait and the role oceanic conditions plays in regulating larval mortality is difficult. In addition, it is uncertain if mortality rates differ among species. Because of life-history differences among the whitebait species (e.g. larval size at hatch, yolk sac size, fecundity), it is plausible that larval-juvenile mortality rates differ accordingly but this is unresolved.

Climate change and associated changes to sea surface temperature and circulation patterns have been implicated in the decline of īnanga in south-west Australia (Barbee et al. 2011) but this is currently unknown for Galaxiids in Aotearoa-NZ. The implications of increasing sea levels on īnanga spawning habitat availability is currently being studied (Shane Orchard, University of Canterbury). It is important to recognise that much of what is known about the marine larval life of migratory Galaxiids, and relationships with ocean conditions is specific to īnanga. Species-specific studies are needed to understand if and how oceanic conditions impact on kōaro and kōkopu species. The application of new techniques like otoliths analyses alongside dispersal modelling will help address some of these knowledge gaps.

6.5.5 Harvest

Īnanga are the most abundant species in the whitebait catch, and kōaro are the second most abundant. Kōaro are usually the first species to run up the rivers after floods and are often referred to as “run bait” by fisherman because they are the first sign that a run of whitebait may be coming. Kōaro can be the most abundant species at certain times of the year in some West Coast rivers where habitat is ideal from this species (McDowall 1990). Banded and giant kōkopu run later in the season, with banded kōkopu often being referred to as golden bait because of their amber colour. Because of the later running of these species they are likely to be less susceptible to fishing pressures. Little is known about the timing of shortjaw kōkopu whitebait because they are can’t be easily distinguished from the other whitebait species. Non-whitebait species are accidentally caught by whitebaiters and are mostly regarded as “by-catch”. These species include smelt, freshwater shrimp, glass eels, adult eels, juvenile and adult bullies, yellow-eyed mullet and lamprey (Yungnickel 2017).

Despite whitebait supporting substantial commercial, recreational and customary fisheries, there is a very limited amount of information available on the extent or potential impacts of these harvests. The limited information available suggests that fishing pressure in large rivers can potentially reduce recruitment of whitebait. For example, a study on the Mōkau River used dye-stained whitebait to determine how many whitebait escaped past anglers' nets (Baker & Smith 2014). Baker and Smith (2014) found that fisherman captured between 3 and 27% of the tagged fish in the mainstem of the Mōkau River. Other studies on the Awakino River showed capture rates of up to 44% (Allibone et al. 1999), and the Operau River had catch rates between 6% and 23%. Overall, these results showed that whitebaiters can catch up to 45% of the run. A parallel study showed that only about 20% of the whitebait that escaped, survived to reach adulthood (Allibone et al. 1999). The differences in catch rates between the mainstem and the tributary site suggest that smaller streams are likely to have high catch rates. This is possibly because whitebait have a smaller area to evade capture in these small streams.

The limited data available on fishery catches makes it difficult to quantify the impact of harvests on the whitebait population. McDowall (1990) previously suggested that the whitebait population has almost certainly declined since human settlement, but this is likely to be have driven by multiple interacting effects such as those mentioned previously. When it comes to only quantifying the effect of harvest alone on the whitebait population, there is no data other than that outlined above.

However, we do know that fast-growing annual species are especially susceptible to over-exploitation and precise knowledge of their stock structure is imperative for sustainable fishery management (Aguera & Brophy 2011).

6.6 Management

6.6.1 Stock Structure

In Aotearoa-NZ rivers, whitebait fisheries are typically based on the juvenile, upstream migrant phase of five galaxiid species (includes īnanga, kōaro, giant kōkopu, banded kōkopu, shortjaw kōkopu) and smelt [e.g.,51]. A stock is defined as a "semi-discrete group of fish with definable genotypic, phenotypic and demographic attributes" (Begg et al. 1999). The whitebait fishery is currently managed as a single stock, despite these species having diverse distributions, habitat requirements and widely different life history traits (e.g., egg size, size and age at sexual maturity, fecundity, spawning times and migration patterns). Management as a single stock assumes that the five Galaxiid species show similar genetic, phenotypic and demographics characteristics throughout Aotearoa-NZ. It further assumes, for a given species (e.g., īnanga), that these characteristics are similar in the context of current fishery management practices. The existence of sub-populations and/or separate stocks has long been recognised as one of the priorities for the management of the whitebait fishery (McDowall 1999). However, a general lack of basic information on the biology and ecology of whitebait has made studies of stock structure difficult.

Genetic methods were used by Waters et al. (2000) to investigate the genetic structure of īnanga whitebait from five sites from the Cascade River in Westland to the Bay of Islands in Te Tai Tokerau. No genetic differences were found among these areas suggesting that īnanga larvae are widely dispersed with considerable population exchange during their marine life (Waters et al. 2000) and little evidence for different stocks. No genetic studies have been completed for the kōkopu species or kōaro, however, on-going research by Jane Goodman (University of Otago) is addressing some of these knowledge gaps.

It has long been speculated that there are multiple stocks of īnanga in Aotearoa-NZ based on "phenotypic" (physical characteristics) rather than "genotypic" (heritable genetic identity) features. In 1980, McDowall and Eldon suggested that sub-population structures of īnanga exist based on regional variation in whitebait size at inward migration (McDowall & Eldon 1980). Regional differences in age at inward migration further show spatial differences in early life history traits (McDowall et al. 1994, Rowe & Kelly 2009) giving more evidence for stock structure. McDowall (2003) showed that īnanga whitebait in the North Island have fewer vertebrae than those in the South Island, which might be indicative of larvae having resided in thermally distinct water masses, and thereby relatively discrete stocks. Hickford and Schiel (2016) showed that less than 3% of īnanga returned to their natal stream, which suggests there are significant levels of mixing between river systems and less evidence for river-specific stocks. Despite this mixing, there is evidence for discrete larval pools based on regional variation in otolith-chemical signatures between the west and east coasts of the South Island. This suggests that larval dispersal between these areas is limited (Hickford & Schiel 2016).

Further evidence for different īnanga stocks comes from analysis of otolith morphology and growth rates by Egan (2017). Although the exact origins of inward migrating īnanga are unknown, significant spatial differences in growth rates during the first ten days of life show there is a clear separation

[51] https://www.mpi.govt.nz/food-safety/community-food/whitebait/

between īnanga in the Bay of Plenty and South Island populations. Morphological analyses further show separation between the Bay of Plenty and Buller/Golden Bay regions. Egan (2017) suggested that oceanography (see Figure 57) and environmental conditions play an important role in the spatial structuring of populations among these regions. Although īnanga whitebait in Canterbury showed significantly different growth patterns to those in the Bay of Plenty, no morphological differences were detected between these regions. Egan (2017) suggested there may be extensive mixing of īnanga populations along the east coast of Aotearoa-NZ. Larval dispersal and mixing along the east coast was found for torrentfish, another amphidromous species (Warburton 2015). However, extensive mixing of īnanga along this coastline is speculative and was not resolved in the Egan (2017) study.

Greater spatial coverage is needed to ascertain if more stocks exist along with a better integration of multiple techniques like genetic and otolith analyses. Studies of the stock structure of kōaro and kōkopu species have not been done. However, there is preliminary evidence for spatial differences in size and age at migration that show similar patterns to īnanga (McDowall et al. 1994, Yungnickel 2017). Resolving the stock structure of kōaro and kōkopu species is important to ensure the sustainability of the whitebait fishery, especially considering kōaro and banded kōkopu comprise up to 25% of the whitebait catch in some parts of Aotearoa-NZ (Yungnickel 2017).

6.6.2 Agencies Involved in Management

The whitebait fishery has been described as “a highly dispersed activity, lightly regulated, and very lightly enforced” (McDowall 1991). Multiple agencies are involved in the management of the fishery and the processing of whitebait for human consumption. Rules around catching whitebait are set by DOC, while MPI’s role is to ensure that any processed whitebait is safe for human consumption[52].

Limitations/restrictions are in place on equipment and fishing season, but no restrictions have been made on catch size (e.g., weight of fish). There are **two different regulations** for fishing seasons: (1) From 15 August to 30 November for all areas except the West Coast of the South Island (and the Chatham Islands); and (2) From 1st December to the last day in February for the West Coast of the South Island. The season for the West Coast also places limits on the upstream limit where fishing can occur (limit is marked by “upper pegs” in the river banks) and by not allowing fishing in the hours of darkness.

At present, information on the number of fishers, catches, distribution and sales from this extensive customary and recreational fishery that occurs across the country is lacking. In the lower Waikato River alone Morris et al. (2013) recently identified 869 whitebait stands, 31% of which also had a small to large “bach” associated with the stand.

Whitebait is the only fish species in Aotearoa-NZ that can be sold by recreational fishers, and can reach prices as high as $130 a kilogram [e.g., 53&54]. Wild-caught whitebait has been sold commercially from various locations around the country since early European settlement, with the first canning factory established on the Waikato River in 1887. Wild-caught whitebait is being sourced for the commercial market from places like the West Coast (e.g., Cascade Whitebait), South Westland (Curly

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52 https://www.mpi.govt.nz/food-safety/community-food/whitebait/

53 http://www.stuff.co.nz/national/11021/Whitebait-snapped-up-at-130-a-kg
54 http://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=3594881

Tree's Whitebait), and "rivers of the east and west coast of the North Island"[55] (Hawkes Bay Seafoods).

There is little known about escapement before, after or during the fishing seasons. The lack of data on escapement and fishery catch means that there has never been any ability to relate catches to populations, estimate the impact of fishing on the stocks, or to monitor any of the fundamental aspects required for effective fishery management. The regulatory focus on equipment and fishing behaviour has been done to limit enforcement costs. It is more costly exercise to enforce/set and monitor quotas and/or daily limits on all rivers, than it is to set fixed limitations on the equipment and how it is used. Because the whitebait fishery includes some vulnerable and declining species, DOC have a challenge to manage the contrasting values between the fishery and the preservation of our native biodiversity.

Compliance for whitebait stands and associated structures are the responsibility of regional councils, under the Resource Management Act 1991, and in the case of the Waikato River, the **Waikato-Tainui Raupatu Claims (Waikato River) Settlement Act 2010** which recognises the traditional activity of fishing for whitebait, including the use of traditional whitebait stands (Morris et al. 2013, Mahuta et al. 2016). Other legislation and regulations of relevance to whitebait stands and associated structures includes the Building Act 2004, the Navigation Safety Bylaw 2009 (for the Waikato River), Land Act 1948 and Public Works Act 1981 (Morris et al. 2013) (Figure 59).

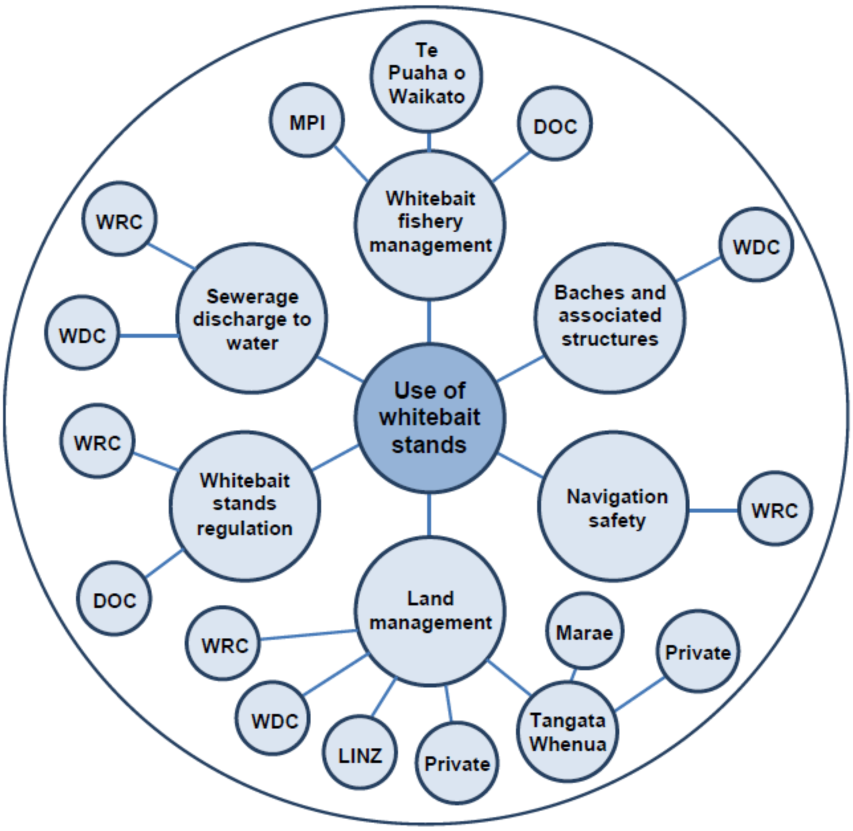

Figure 59: Some of the agencies involved in the management of the lower Waikato River whitebait fishery. Where WRC = Waikato Regional Council; WDC = Waikato District Council; LINZ = Land Information New Zealand. (Source: Morris et al. 2013).

[55] https://www.hawkesbayseafoods.co.nz/category/113396

All five whitebait species are presently managed by DOC, and with the exception of īnanga, are a included in DOC's, **large galaxiid recovery plan** 2003–2013 (DOC 2005), which outlined a number of options for recovery. This document is expected to be updated in the very near future. Giant and shortjaw kōkopu are listed as two of the 150 priority threatened species listed in DOC's draft **Threatened Species Strategy** (see Section 11.2).

Because kōaro can form land-locked populations, parts of this species range occur in protected areas where fishing is prohibited or does not occur. Historical land status changes have occurred with the creation of **three faunistic reserves** (Lake Chalice, Lake Christabel and Lake Rotopounamu), specifically to preserve lake-locked populations of kōaro (DOC 2005). This species is also covered within the 2009 Action Plan for South Australian Freshwater Fishes and it also occurs in several conservation reserves in South Australia.

A **national Īnanga spawning database** is presently being revived by the University of Canterbury in collaboration with NIWA, DOC, Aquatic Ecology Ltd, local councils and community groups (https://īnangaconservation.wordpress.com/īnanga-spawning-sites-seasketch/). The database aims to collate all existing information on īnanga spawning and assemble these data into one place in a consistent and accessible format. The database is open access and anyone can contribute data. The database contains information on the spatial locations of spawning observations along with associated environmental information for the site.

A **New Zealand Fish Passage Advisory Group**[56] convened by DOC has been established to develop, communicate, promote, and advocate for improved technical guidance and policy to support fish passage and connectivity of our waterways.

6.7 Aquaculture

Several individuals, organisations and partnerships are also involved in developing whitebait aquaculture. The late Charlie Mitchell developed an interconnected system of coastal ponds to spawn and rear whitebait, in a style akin to "ranching". Mahurangi Technical Institute have recently developed the technology to "close the life cycle" and breed whitebait in captivity and are now partnering with others to develop commercial whitebait farms and provide this product for market (e.g., Manāki Premium New Zealand Whitebait[57]) (Figure 60).

[56] http://www.doc.govt.nz/nature/habitats/freshwater/fish-passage-management/advisory-group/

[57] E.g., https://www.stuff.co.nz/business/farming/aquaculture/96142508/new-zealands-only-whitebait-farm-looks-to-protect-species-under-strain

Figure 60: Example of the whitebait products available via Manāki Premium New Zealand Whitebait. (Source: https://twitter.com/whitebaitnz/status/763165387877789696).

7 Porohe (Smelt)

Family: Retropinnidae

Species: *Retropinna, Stokellia anisodon*

There are two Aotearoa-NZ species in the Retropinnidae family, the common smelt (*Retropinna retropinna*) and Stokell's smelt (*Stokellia anisodon*) (Figure 61). This family of fishes, known as the southern smelts, is also found in Australia, but the two species we have here are unique to this country. Smelt are an impressive silver coloured with a pale amber to light olive coloured back and translucent muscle tissue (McDowall 1990). They are well known for the cucumber-type odour they omit. Smelt can be distinguished from other species by the presence of the adipose fin, a small fleshy lobe on their back between the dorsal fin and the tail. They also have scales, a distinctly forked tail, and the aforementioned cucumber-like smell. The two species that live in Aotearoa-NZ are very difficult to tell apart, and positive identification depends primarily on the size and number of the scales.

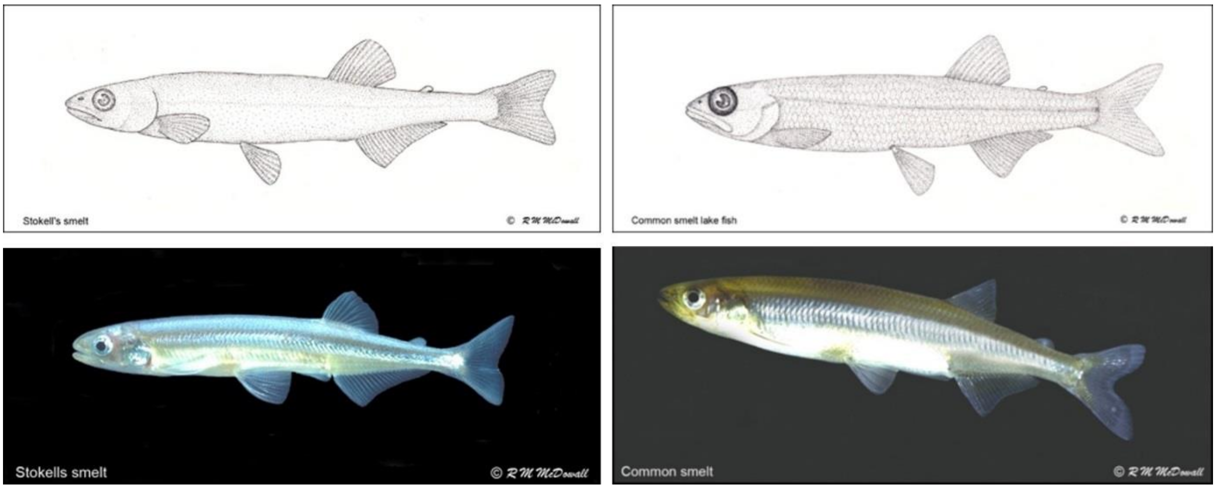

Figure 61: (Left) Stokell's smelt (*Stokellia anisodon*), and (Right) the common smelt (*Retropinna retropinna*). (Graphics and photos: Bob McDowall).

Smelt are a shoaling species, which means they swim in schools near the water surface. Thus, they are often seen out in the open in streams and lakes as they feed on drifting food organisms. They can appear in some very large numbers at river mouths throughout Aotearoa-NZ. In rivers, juvenile smelt are often captured by whitebaiters as they migrate upstream and mix with the whitebait, for example, in the lower Waikato River they are known as 'number two whitebait' (Mahuta et al. 2016).

The common smelt is widespread throughout Aotearoa-NZ including Stewart and Chatham Island. They live in flowing and still water, and there are both diadromous (sea-going) and non-diadromous (land-locked) populations in Aotearoa-NZ, although humans have established many of the latter. Smelt are good swimmers and will penetrate well inland into river systems that are not too steep (e.g., the Whanganui and Manawatū Rivers). They are particularly abundant in the Waikato River catchment. They can reach 165 mm, but more commonly do not exceed 120 mm.

Stokell's smelt superficially resembles the common smelt (Figure 61) but is sufficiently different to warrant a new genus name, *Stokellia*. Stokell's smelt has smaller scales than the common smelt and there are differences in the teeth that are used to tell the two species apart. The small, fleshy, adipose fin can be used to distinguish smelt from galaxiids, but smelt can be distinguished from the salmonids (which have an adipose fin) by the absence of a lateral line. Stokell's smelt are slightly smaller than common smelt, usually around 70–85 mm with a maximum length of around 100 mm.

7.1 Life Cycle

During a study of smelt populations within the Waikato River catchment, Booker (2000) identified three forms of smelt, based on life histories which have adapted to the different environments available to them since the hydroelectric dams have gone in: (1) Lacustrine (associated with lakes, e.g., Lake Taupō); (2) Reservoir (associated with the reservoirs, e.g., Lake Ōhakuri); and (3) Riverine/diadromous (have access between fresh water and the sea). Booker (2000) found that differences between forms and between populations occurred with changes in habitat structure and water quality. Differences include the number of gill rakers and vertebrae, size at maturity, maximum length and weight, fecundity, and relative density — as well as behavioural differences such as spawning period. Booker (2000) considered the reservoir form to be an intermediate form between the dwarfed Lake Taupō smelt and the larger diadromous form in the lower Waikato River.

In waterways where there are no significant barriers, common smelt is a diadromous species that usually spends most of its life at sea, with mature adults returning to fresh water to breed. Juveniles hatch in fresh water and migrate out to sea at around 15–30 mm in length before returning to spawn after they have matured. This species can live up to four years of age, maturing at one year with an average generation time of 1.5 years. The main elements of this riverine life cycle are duplicated in lake-dwelling smelt populations (Ward et al. 2005). Spawning takes place annually in shallow, sandy margins of lakes and sandy river banks; however, lake and riverine populations spawn at different times of the year.

Stokell's smelt is also a diadromous species that follows a similar life-history pattern to common smelt. Stokell's smelt probably spends most of its life in the marine environment and they only reach 1–2 years of age (McDowall 1990). They enter fresh water to spawn in late spring and summer, and can be extremely abundant at times. The adults are likely to die after spawning. The fry hatch out at around 5 mm in length and then little is known about their seaward migration and the marine phase of this species. Despite common smelt forming many land-locked populations throughout Aotearoa-NZ, Stokell's smelt are not thought to do the same.

7.2 Distribution

Common smelt are widely spread throughout Aotearoa-NZ and there are diadromous and land-locked populations throughout the country (Figure 62). Both diadromous and land-locked populations are included in the below plot because it is not possible to separate diadromous from non-diadromous stock within the NZFFD. Generally, the locations close to the ocean will be diadromous populations, but the records from inland areas (e.g., Te Arawa Lakes, Taupō-nui-a-Tia) will be land-locked populations because of stocking (Rowe & Kusabs 2007). Common smelt populations are intermittently found throughout the South Island, but are more commonly found in the North Island. The Waikato region appears to contain the highest numbers of common smelt observations in Aotearoa-NZ.

Stokell's smelt are only found in the Canterbury region, with only a few observations being recorded (Figure 62). It is likely that this species is more common than the NZFFD records represent, but they are simply under recorded because of the difficulties in identifying this species from common smelt. This means that some of the common smelt observations from Canterbury in the NZFFD may also include Stokell's smelt.

Figure 62: Locations of NZFFD records where (Left) common smelt, and (Right) Stokell's smelt are present (black circles) and absent (grey circles).

7.3 State and Trends in Abundance

Smelt state and trends in abundance were unable to be assessed by Crow et al. (2016). Trends in the relative abundance of common smelt and Stokell's smelt are not presently known.

Rowe and Kusabs (2007) explain that conventional sampling techniques (e.g., seine and fyke netting) are not effective for smelt population estimation because their catchability varies greatly with the weather (e.g., wind/wave action, cloud cover), the seasons, as well as with lake water conditions (e.g., temperature, turbidity). Mid-water trawling in lakes has been attempted and has limitations for daytime sampling; however, it may prove useful at night when smelt migrate to the surface waters of lakes and are likely to be more vulnerable to netting. Because of the lack of direct sampling methods for smelt population assessment, high frequency (200 kHz) echosounding was used to study their spatial distribution in the Te Arawa lakes (Rowe 1993; 1994; 2005, Rowe et al. 2001a; 2001b). This has been successful and we understand that acoustic methods are being used by Environment Bay of Plenty and DOC to estimate smelt populations in the Te Arawa Lakes and Taupō-nui-a-Tia.

7.4 Threat Rankings

The latest New Zealand Threat Classification System assessment classified *R. retropinna* as 'Not Threatened' and *S. anisodon* as 'At Risk – Naturally Uncommon' due to their restricted range (Goodman et al. 2014). In 2014, *R. retropinna* was assessed by IUCN as being of 'Least Concern'. Although this panel recognised that populations are likely to have undergone historical declines since the arrival of European settlers (from which they did not recover), they considered that the population has stabilised (Franklin et al. 2014) (Table 10).

Stokell's smelt is classified as being of 'Least Concern' by the IUCN threat ranking system because this species is extremely abundant locally within its limited range along the Canterbury coastline, although it is not common in smaller rivers (McDowall 2000). No information is available on population trends for this species (David et al. 2014) (Table 10).

Table 10: Threat rankings for Aotearoa-NZ porohe species according to the New Zealand Threat Classification System and IUCN. (see Section 2.3 for more information about these assessment methods).

Species	DOC Ranking	IUCN Ranking
Retropinna	Not Threatened	Least Concern (Populations stable)[58]
Stokellia anisodon	At Risk–Naturally Uncommon	Least Concern (Population trend unknown)[59]

7.5 Pressures on Populations

Several pressures on smelt populations have been identified (Figure 63), many of them common to whitebait species. Smelt are very sensitive to changes in their physical environment and are one of the most sensitive native fish species in Aotearoa-NZ (e.g., Hickey 2000, Rowe et al. 2002a, Landman et al. 2005).

[58] http://www.iucnredlist.org/details/197325/0
[59] http://www.iucnredlist.org/details/197327/0

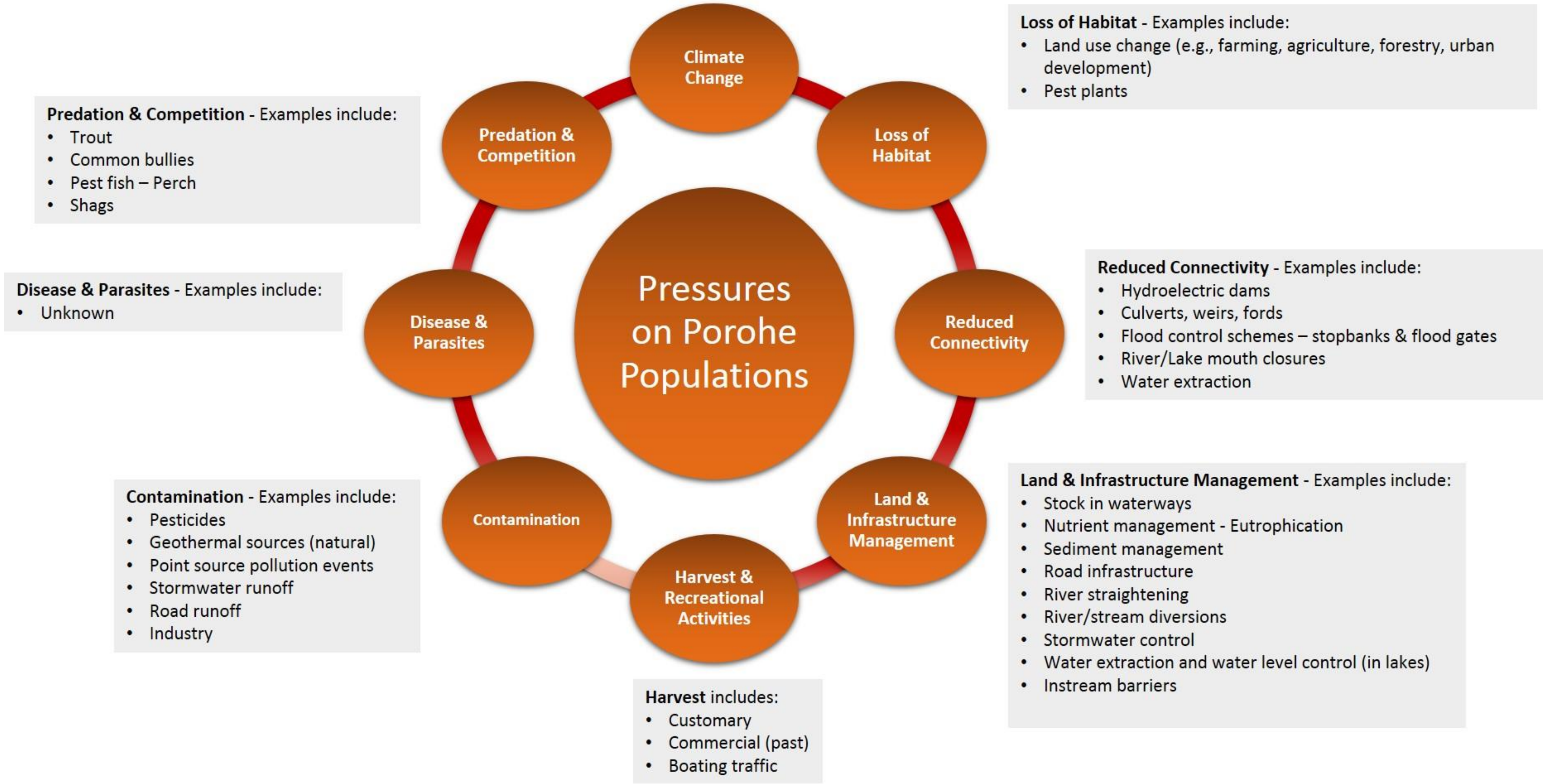

Figure 63: Examples of some of the pressures on Aotearoa-NZ smelt populations.

7.5.1 Land and Infrastructure Management

Smelt habitats are likely to be impacted by water abstraction, agricultural development and land-use changes resulting in the siltation of lowland spawning habitats in large rivers. Smelt are relatively more abundant in the clearer lakes than in the more productive, turbid ones (Peterson 1982, Rowe & Taumoepeau 2004). That said, increased turbidity does not appear to affect smelt directly as feeding rates are not reduced by turbidities up to 160 NTU (Rowe & Dean 1998, Rowe et al. 2002a). Although turbidity *per se* does not appear to affect smelt in lakes, the settling of silt, which is often responsible for increased turbidity, does. The suspended solids responsible for increased turbidity in lakes are thought to reduce spawning habitat for smelt by smothering sandy substrates with a layer of fine silt (Rowe & Taumoepeau, 2004). This either prevents smelt from spawning or results in increased egg mortality where spawning does occur (Rowe & Kusabs 2007).

Smelt recruitment has been shown to be reduced in the more productive, turbid lakes in the Rotorua district compared with the clear, less productive lakes (Rowe & Taumoepeau, 2004). Although field data on adult smelt abundance in the Te Arawa lakes are limited (Peterson 1982), they nevertheless support the suspected lower smelt abundance in the more productive lakes (Rowe & Kusabs 2007). The reduced recruitment of smelt in the more productive Te Arawa lakes has been attributed primarily to increased turbidity and the resultant siltation of sandy substrates, which degrades smelt spawning habitats on beaches (Rowe & Taumoepeau 2004). However, egg predation from the increased abundance of bullies may be an important contributing factor. Increased lake productivity not only increases siltation of lake beds by organic particulates, but it also increases both hypolimnetic de-oxygenation and the incidence of blue-green algae blooms. Hypolimnetic de-oxygenation, coupled with increased turbidity from high densities of planktonic algae, has been shown to reduce depth habitat for smelt in lakes (Rowe & Taumoepeau 2004). Increases in the trophic status of lakes therefore affect smelt in several ways, but the most important is likely to be a reduction in recruitment caused by high egg mortality (Rowe & Kusabs 2007).

Lake-level control may also affect smelt spawning habitat in lakes (Rowe et al. 2002b). The maintenance of clean sandy beaches in lakes is dependent on wave action (i.e., on exposure to prevailing winds and on fetch). In exposed areas of shoreline, wind patterns will have the main influence on smelt spawning habitat. However, in sheltered areas or small lakes, the presence of clean sandy beaches is more dependent on seasonal lake-level fluctuations which expose shorelines to desiccation and then re-inundate them, resulting in a clean sandy substrate. This natural cycle ensures that silt build up is minimised and more importantly, that macrophyte growth is restricted to deeper waters. When lake levels are controlled between very narrow limits (20 cm or less) macrophytes can be expected to invade shallow waters, reducing the inshore zone of sandy habitat (Rowe & Kusabs 2007).

7.5.2 Contaminants

Smelt are one of the most sensitive fish to handling, pollutants like ammonia, and stressors such as high water temperature. In some cases, they are as intolerant as the salmonids, which are often used as a benchmark species overseas for establishing water-quality guidelines to ensure fish are protected from human activities. Smelt have been promoted as an appropriate native species for establishing guidelines for Aotearoa-NZ waterways (Rowe & Kusabs 2007) and usually their presence indicates that the water quality is suitable for most other fish.

7.5.3 Predation

In most North Island lakes, smelt are the main prey species for trout and have been specifically introduced for that purpose. For example, smelt were not naturally present in Taupō-nui-a-Tia, they were introduced to support trout populations after they decimated the kōaro populations. A major threat to the smelt populations could be posed by the introduction of exotic fish. The main species of concern is perch (*Perca fluviatilis*). Because it is a limnetic piscivore (mainly eats fish), it could be expected to impact heavily on the inshore populations of smelt, bullies and kōura. Predation by perch would reduce these species especially in more productive lakes (Rowe & Kusabs 2007).

7.5.4 Other Factors

Rowe and Kusabs (2007) indicate that factors other than increased trophic status may also impact on smelt spawning habitats in lakes. For example, ski-lanes are often cited in the middle of clean sandy, shallow beaches around the lake and these beaches are intensively utilised over summer months by water-skiers. This use coincides with smelt spawning and may be inappropriate in some situations, due to the effects on eggs. Rowe and Kusabs (2007) express that there is a need to better coordinate between recreational use and smelt spawning requirements in the Te Arawa Lakes.

7.6 Management

In some rivers (e.g., the Waikato River), juveniles are captured by whitebait fishers as they migrate upstream and mix with galaxiids (Mahuta et al. 2016). There was a commercial harvesting operation of smelt on the Waikato River, and in the 1980's from the Ashburton Estuary, but this ceased shortly after starting. Commercial buyers of whitebait from the Waikato River purchased one to two tonnes of smelt per annum between 1974 and 1985 (Stancliff et al. 1988), but catches of smelt have declined in recent times (NIWA 2010). Between 1990 and 2005, annual purchases of smelt from the Waikato River were less than 0.25 tonnes per annum (Baker & James 2010). This decline was not due to a drop in smelt abundance in the river, and reflects the decreased importance of smelt in whitebait catches (NIWA 2010).

There are significant cultural harvests that still occur to this day in the Whanganui and Rangitīkei, with whānau still using traditional fishing methods (McDowall 2011).

There are currently no management or conservation initiatives for the smelt fishery in Aotearoa-NZ. If specific management guidelines for the smelt fishery were to be developed, this is likely to be within the jurisdiction of DOC given that they manage the whitebait fishery in Aotearoa-NZ.

8 Kanae (Mullet)

Family: Mugilidae

Species: *Aldrichetta forsteri, Mugil cephalus*

There are two members of the Mugilidae (or mullet) family in Aotearoa-NZ, the yellow-eyed mullet (*Aldrichetta forsteri*) and the grey mullet (*Mugil cephalus*) (Figure 64). Tangata whenua have named the mullet species according to their life cycle stage, and these names vary through-out the regions. For example, the juvenile and adult stage of yellow-eyed mullet are named maraua and makawhiti/aua respectively; and the juvenile and adult grey mullet are also named tīpara and kanae/kanae raukura respectively (Ngata 1993, Moorfield 2011).

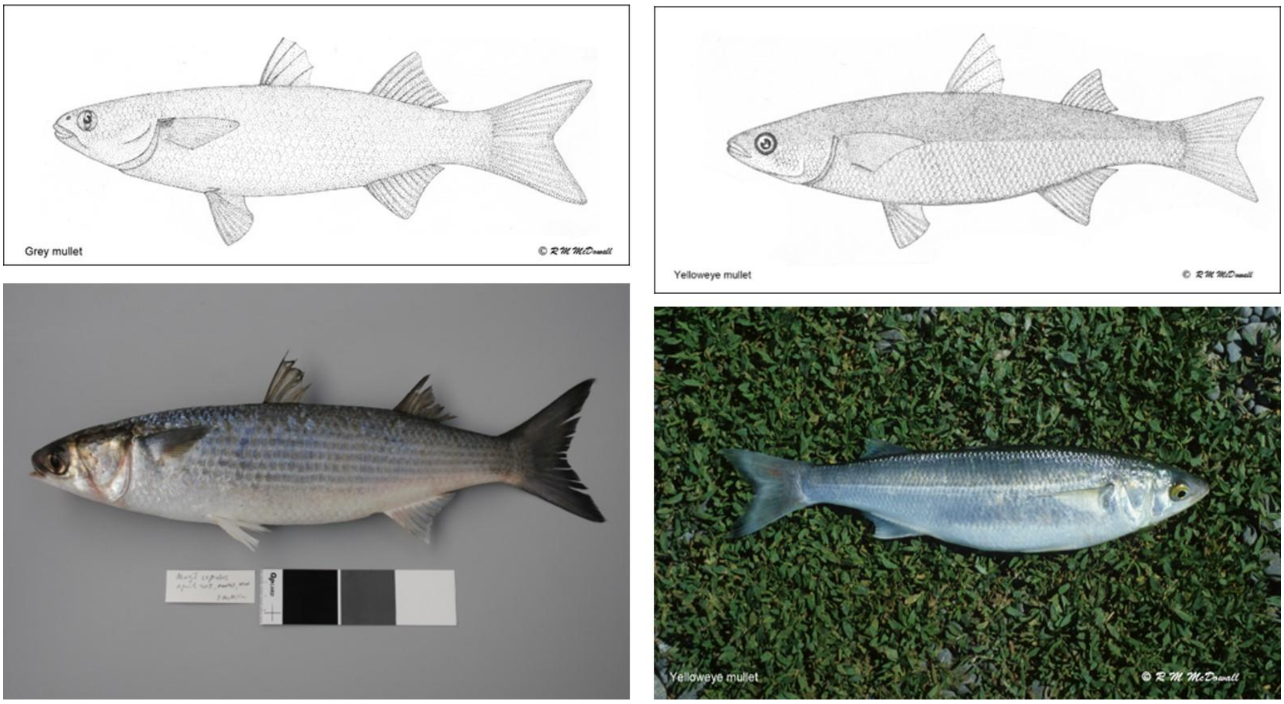

Figure 64: (Left) Grey mullet, and (Right) Yellow-eyed mullet. (Graphics and photos: Bob McDowall & NIWA).

Both mullet species are common in river estuaries and lowland lakes, with grey mullet able to penetrate upstream and become resident dozens of kilometres up rivers. Yellow-eyed mullet occur all around Aotearoa-NZ and they are also found in western and eastern Australia. They are never found far from the coast. Grey mullet have a worldwide distribution and Aotearoa-NZ is at the southern limit of their range. Although they are not usually associated with cooler waters, previous studies found them in mean monthly water temperatures as low as 7–9°C within the Waikato catchment (Wells 1984).

All mullets, including grey and yellow-eyed mullet, have two dorsal fins, and the first one is tall with four obvious spines. They also have large, easily dislodged scales. Aotearoa-NZ mullets belong in two separate genera based on the presence of an adipose eyelid. This is a thick fleshy eyelid that forms an oval, vertical slit over the pupil on the grey mullet. Grey mullet also lack the bright yellow eye found on the appropriately named yellow-eyed mullet.

8.1 Life Cycle

Some mullets are catadromous, they spawn at sea and the larvae are initially marine (Metcalfe et al. 2002), this includes the yellow-eyed and grey mullet. The yellow-eyed mullet may spend considerable time in fresh water, for example, they are found throughout the year in Te Waihora and the Waikato River (Paulin & Paul 2006), but their spawning takes place in the sea. Yellow-eyed mullet usually move upstream into low elevation rivers and coastal/brackish lakes, seldom much beyond tidal influence (McDowall 2000). Fish are also known to move in and out of estuaries on a tidal cycle, suggesting that it is possible for emigration of immature fish to occur frequently throughout the year (Crow & Bonnett 2013).

Within Te Waihora, emigration of ripening yellow-eyed mullet adults (fish larger than 220 mm) occurs at specific times of the year (April to June); however, as movement into brackish and fresh water is not compulsory for this species, it is quite likely that recruitment of larger fish could occur during almost any month of the year (Crow & Bonnett 2013). In the sea, larvae and juveniles are found in the neuston (very surface of the ocean), up to at least 18 km from the shoreline (Tricklebank 1988, Kingsford & Choat 1989). They are most abundant in open water and around drift algae from November to March (Tricklebank 1988). High densities have also been observed in the slicks of internal waves, which has been suggested as a mechanism promoting on-shore movements (Kingsford & Choat 1986). Yellow-eyed mullet have a maximum life cycle of about seven years and growth rate varies between sites and sexes (e.g., Thompson 1957, Potter et al. 1990, Curtis & Shima 2005).

Similar to yellow-eyed mullet, grey mullet must return to the sea to spawn, but have been found at all times of the year in fresh water including Lake Waahi and the Waikato River at Huntly (Wells 1984). Both sexes of grey mullet mature at three years at an average size of 33 cm fork length for males and 35 cm fork length for females, and females spawn in northern Aotearoa-NZ between November and February (Haggit et al. 2008). Recent work on adult grey mullet has found fish of up to 19 years of age and greater than 4 kg in populations thought to be unfished (Morrison et al. unpubl. data), but in fished populations ages largely range from 3 to 8 years, with an average fish weight around 0.7–1.0 kg.

Estuaries act as nurseries for juvenile grey mullet. Habitat associations within these include intertidal seagrass meadows in the Kaipara Harbour (Morrison et al. 2014), and more widely the use of mangrove habitats (Morrison et al. 2014). This mangrove association may not be obligate (essential), as high density nurseries have also been found in estuaries without mangroves, e.g., in Kāwhia Harbour (Morrison et al. 2014). It may simply be that the biogeographic distribution of mangroves and juvenile grey mullet overlap, with both preferring warm temperate waters, and muddier upper estuary environments. Mangrove habitats appear to provide poorer foraging opportunities, suggesting there may be a trade-off between shelter from predators (e.g., mangrove forests) and food supply (non-mangrove habitats) operating (Morrison et al. 2014). Most of Aotearoa-NZ's upper North Island estuaries support juvenile grey mullet, but range widely in their importance, in terms of the number of juveniles each estuary supports. Larger and muddier estuaries tend to be more important overall (Morrison et al. 2016).

Adult grey mullet are capable of moving large distances, e.g., adult fish tagging work has shown movements between the Waikato River and the Manukau Harbour (Hore 1988). Grey mullet stocks include both estuarine/marine and freshwater populations, with large numbers of adults being found in freshwater systems. Research using grey mullet otoliths (ear-bones) to undertake elemental chemistry has found most grey mullet sampled from fresh water appear to reside there permanently (high barium and low strontium concentrations are markers for fresh water, the converse for marine), with some potential migrations back to the sea (Gorski et al. 2015, Morrison et al. unpubl. data). As most sampling methods commonly used in freshwater systems are not suited to catching adult grey mullet, it is likely that the true numbers/biomass of grey mullet in freshwater systems are greatly under-represented. For example, using a specialist electro-fishing boat, Hicks et al. (2010) sampled beside the Huntly Power Station (Waikato River) and found grey mullet to be the second most abundant fish present in waters 0.3–2 m deep, with an average density of 0.82 per 100 m^2. The most abundant species was the invasive species, koi carp.

8.2 Distribution

Yellow-eyed mullet are present in coastal areas across Aotearoa-NZ, including Rakiura/Stewart Island, but are not commonly recorded in the NZFFD (Figure 65). They are less abundant in the south of Aotearoa-NZ (Francis et al. 2011). The low level of occurrence in the NZFFD of yellow-eyed mullet (and grey mullet) may be associated with difficulties capturing this species in the lowland/estuarine areas they occupy, where some commonly used sampling methodologies are inefficient (e.g., hand-based electric-fishing, fyke nets).

South Island NZFFD yellow-eyed mullet observations are mostly recorded around Canterbury, Otago, Nelson and along the West Coast. North Island observations are mostly around Paraparaumu, Taranaki, Hamilton and Tauranga. Grey mullet is more commonly found in the North Island than the South Island (Figure 65). The only NZFFD observations for grey mullet in the South Island are around Nelson and Blenheim, while the North Island records are primarily in the Waikato Region. Most of the records are from the Waikato River, where they are found as far inland as Karāpiro Dam (where further upstream movement is blocked) and the neighbouring Waipā River as far as Te Kūiti.

8.3 State and Trends in Abundance

Mullet are not commonly recorded in the NZFFD and therefore state and trends in abundance were unable to be assessed by Crow et al. (2016). For almost 20 years the total TACC for grey mullet has been set at 1,006 tonnes, while the total TACC for yellow-eyed mullet has been set at 68 tonnes since 2001–02.

Grey mullet populations are perceived to be declining over time (e.g., Te Onewa Consultants 2015, Morrison et al. 2016). Indeed, the commercial fishery declined historically, and it was one of the first marine fisheries to be 'investigated'; however, the lack of information on mullet biology limited historical conclusions (Paulin & Paul 2006). More recent investigations into the fishery has indicated decline in catches, and again, there is insufficient knowledge of mullet biology on which to base an estimate of the sustainable yield and inform management (Paulin & Paul 2006). It was further recommended that stock assessments of grey mullet should attempt to take the historical information of significant grey mullet declines into account to better inform fisheries management (MacDiarmid et al. 2016).

There is no available trend information for yellow-eyed mullet populations in Aotearoa-NZ.

Figure 65: Locations of NZFFD records where: (Left) Yellow-eyed mullet, and (Right) Grey mullet are present (black circles) and absent (grey circles).

8.4 Threat Rankings

The latest Conservation Status Assessment classified yellow-eyed and grey mullet as being 'Not Threatened' (Goodman et al. 2014). In 2012, the IUCN ranked grey mullet as being of 'Least Concern' due to its widespread distribution throughout the tropics and sub-tropical seas to warm temperate regions (Kottelat & Freyhof 2012). Similarly, yellow-eyed mullet was considered by the IUCN assessment panel to be widespread (including Southern Australian waters) and locally abundant throughout coastal areas, and therefore of Least Concern (David et al. 2014) (Table 11).

Table 11: Threat rankings for Aotearoa-NZ kanae species according to the New Zealand Threat Classification System and IUCN. (see Section 2.3 for more information about these assessment methods).

Species	DOC Ranking	IUCN Ranking
Grey mullet *(Mugil cephalus)*	Not Threatened	Least concern (Population trend stable)[60]
Yellow-eyed mullet *(Aldrichetta forsteri)*	Not Threatened	Least concern (Population trend stable)[61]

8.5 Pressures on Populations

Pressures on the grey mullet fishery include disrupted fish passage (e.g., river and lake connections to the sea), disconnection/fragmentation of habitats, habitat degradation (including sedimentation), predation, and harvest. Environmental mismanagement and key knowledge gaps (stock size, biomass, biology) have also been identified as barriers to effective mullet fisheries management (Rowe & Graynoth 2002, Paulin & Paul 2006, IKHMG 2010, Te Onewa Consultants 2015, Morrison et al. 2016).

Grey mullet (estuaries) and yellow-eyed mullet (estuaries, sheltered coastal embayments) nursery habitats are sensitive to sediment impacts (MfE 2010). Habitat access is another major issue during migration and feeding. Fish access to rivers and lakes (via outlet streams/estuaries) is required during their migration between freshwater and marine environs to complete their life cycle. As mullet are not strong swimmers they are only found in lakes where there is a low-gradient outlet stream connecting the lake to the sea or river mainstem. Migration into shallow coastal lakes by juveniles and adults is also associated with feeding, and therefore lake/river mouth closures; in-stream dams and weirs can affect mullet populations (e.g., Rowe & Graynoth 2002).

The lack of basic biological information has been highlighted as a key issue for grey mullet fisheries management (IKHMG 2010, Te Onewa Consultants 2015, Morrison et al. 2016). Conflicts surrounding grey mullet state and trends have been exacerbated by a lack of definitive scientific knowledge of national stock dynamics, for example, it is not known to what degree fish move between the various estuaries, and broader areas, within the commercial fishery boundary. Therefore, the spatial scale within which to effectively manage this fishery remains unclear (Morrison et al. 2016).

There is a growing body of knowledge on adult grey mullet movement between marine and freshwater systems, and juvenile estuarine habitat use. Recent genetic research has found evidence of genetic diversity across grey mullet populations throughout Aotearoa-NZ, and suggests that grey mullet populations in Aotearoa-NZ are composed of several different but spatially mixed genetic groups, which in turn suggests these groups have different spawning times and natal homing behaviours (Brito, in review).

[60] http://www.iucnredlist.org/details/135567/0
[61] http://www.iucnredlist.org/details/197036/0

For yellow-eyed mullet, some spawning and/or recruitment periods have been documented, with work to date largely focussed on the South Island (e.g., McDowall 1995, Jellyman 2012, Crow & Bonnett 2013).

8.5.1 Harvest

Mullet are regarded as a valuable food fish, which are harvested by customary, recreational, and commercial user groups. Grey mullet in particular provided an important food resource for pre-European Māori in Northland, and supported one of Aotearoa-NZ's first commercial fisheries (Paulin & Paul 2006). Grey mullet has been harvested commercially since the mid-1880s (e.g., Paulin & Paul 2006) and increased fishery accessibility and improved technologies have put increasing pressure on mullet populations. In addition, grey mullet inhabits easily accessible areas (e.g., only requires small row boats or sailing dories for access), which leads to an easily caught fishery (MacDiarmid et al. 2016, Morrison et al. 2016). In many parts of the world mullet are farmed commercially, but in Aotearoa-NZ the majority of the market is supplied from fishers operating on the Kaipara and Manukau harbours (Morrison et al. 2016). A reduction in grey mullet availability in various North Island bays and estuaries has resulted in conflict between commercial and non-commercial sectors (Morrison et al. 2016).

Grey mullet is a popular recreational species, particularly in the area from east Auckland, across Bay of Plenty and Northland to West Auckland (GMU1, Figure 66). In 1987, the relative levels of commercial and amateur catch of this species in the Manukau Harbour and the lower Waikato River was estimated by a tagging study (note, only a small number of fish were tagged). The results showed that 38% of tags returned were from amateur fishers, suggesting that recreational use of the resource was relatively high. Several recreational fishing surveys have included this species (e.g., Teirney et al. 1997, Bradford 1998, Boyd et al. 2004) with an annual recreational extraction from GMU1 in the order of 100–150 tonnes; most of the commercial catch also occurs in GMU1 (Figure 67, Table 12). According to the latest fisheries assessment report, the annual commercial catches from GMU1–10 have been lower than the annual TACC set since its inception into the QMS in 1986 (MPI 2017a).

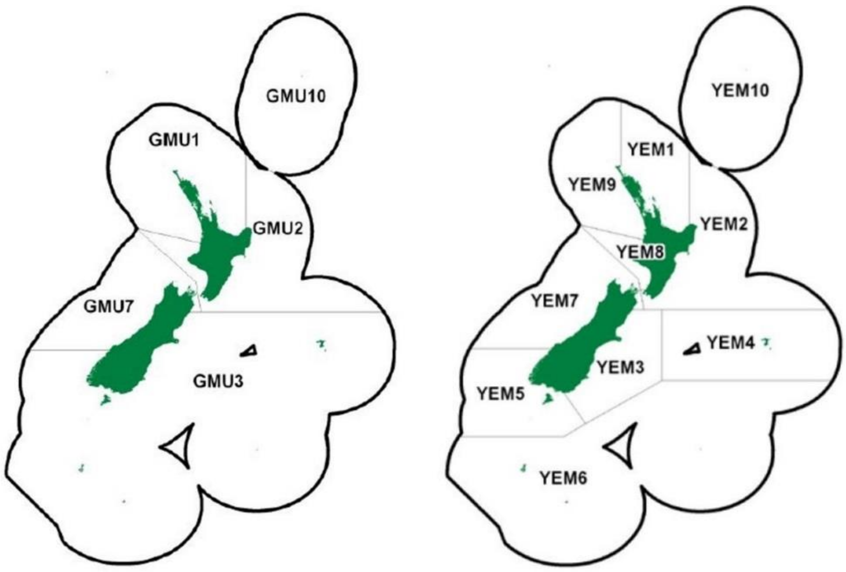

Figure 66: Commercial fish stock areas for: (Left) Grey mullet (GMU); and (Right) Yellow-eyed mullet (YEM). (Source: MPI 2017a).

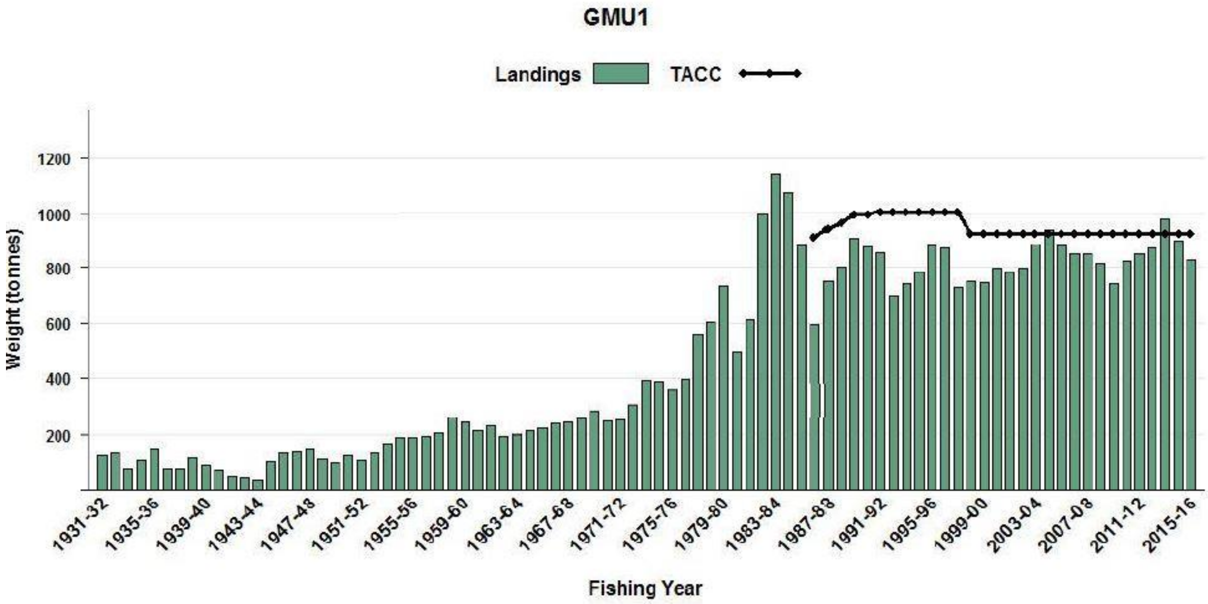

Figure 67: Reported grey mullet commercial landings and TACC for the main fish stock, GMU1 (Source: MPI 2017a).

Table 12: TACCs (t) and reported landings (t) of grey mullet for 2015–16 (Source: MPI 2017a) and TACCs set for 2016–17. (Source: Clements & Associates Ltd 2016).

Fish stock	2015–16 Actual TACC	2015–16 Reported landings	2016–17 TACC
GMU1	925	827	925
GMU2	20	< 1	20
GMU3	30	0	30
GMU7	20	0	20
GMU10	10	0	10
Total	1,006	827	1,006

Recent surveys have found a higher number of recreational fishers reportedly harvest yellow-eyed compared to grey mullet (Wynne-Jones et al. 2014). This likely coincides with the wider availability and abundance of yellow-eyed mullet compared to grey mullet (Francis et al. 2011). Yellow-eyed mullet are a popular recreational species throughout Aotearoa-NZ, particularly in YEM1 (Figure 66). Estimated numbers of fish and harvest tonnages for yellow-eyed mullet taken by recreational fishers between 1991 and 1999 are presented (MPI 2017b), but there are several sources of uncertainty in this dataset. Commercial catches of yellow-eyed mullet have generally been below the TACC in each fisheries management area since it was introduced into the QMS on 1 October 1998 (MPI 2017b) (e.g., YEM1, Figure 68, Table 13). No quantitative information is available on the current level of customary non-commercial harvest of grey or yellow-eyed mullet (MPI 2017a; 2017b).

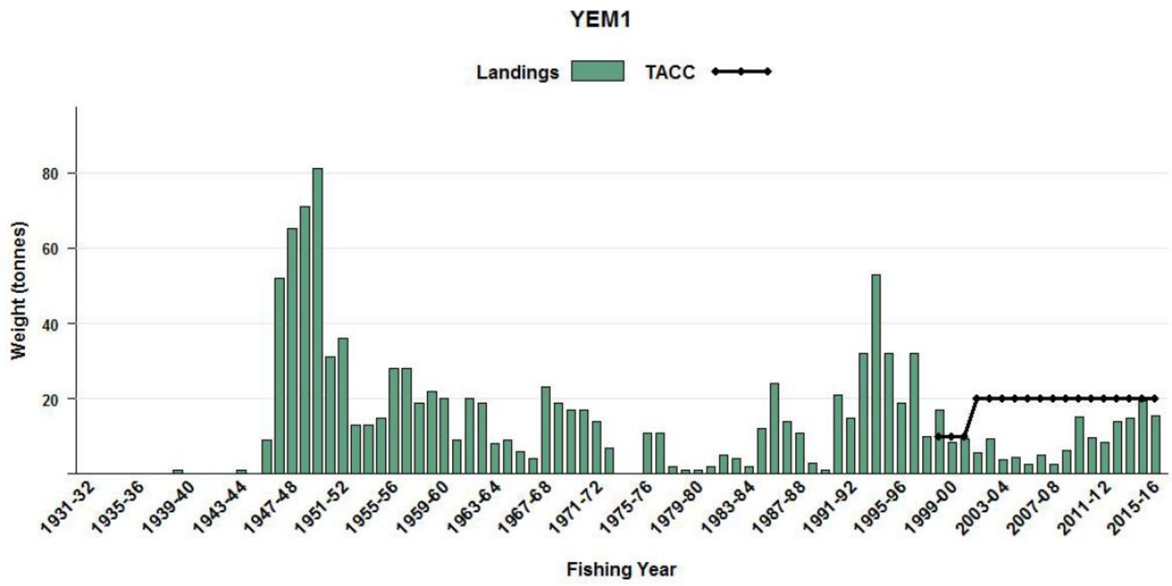

Figure 68: Reported yellow-eyed mullet commercial landings and TACC for one of the two main fish stocks; YEM1. (Source: MPI 2017b).

Table 13: TACCs (t) and reported landings (t) of yellow-eyed mullet for the most recent fishing year (Source: MPI 2017) and TACCs set for 2015–16. (Source: Clements & Associates Ltd 2016).

Fish stock	2015–16 Actual TACC	2015–16 Reported landings	2016–17 TACC
YEM1	20	16	20
YEM2	2	0.03	2
YEM3	8	6	8
YEM4	0	0	0
YEM5	0	0.02	0
YEM6	0	0	0
YEM7	5	0.2	5
YEM8	3	1.5	3
YEM9	30	9	30
YEM10	0	0	0
Total	68	32	68

8.6 Management

The grey and yellow-eyed mullet fisheries are managed by MPI. Grey and yellow-eyed mullet are managed within the GMU and YEM quota management areas, respectively (Figure 66). The grey mullet fishery is currently managed across five GMU quota management areas. GMU1–3 are also divided into sub-stocks (e.g., east coast and west coast) for the purposes of fisheries stock assessments. Since 1998–99 the total TACC for grey mullet has been set at 1,006 tonnes. Yellow-eyed mullet are currently managed across nine quota management areas, but compared to grey mullet, are less commonly targeted by the commercial fishery. Since 2001–02 the total TACC for yellow-eyed mullet has been set at 68 tonnes. MPI (2017b) states that estimates of current and reference biomass for yellow-eyed mullet are not available, and it is not known if recent catch levels are sustainable.

The recreational fishery generally operates within fishery regulations which include daily bag limits, size restrictions and equipment specific rules (drag nets) specific to each fisheries management area. In GMU1, the max daily limit for grey mullet is 30 fish per person, with a minimum set net mesh size of 90 mm and drag net mesh size of 85 mm. There is no daily bag limit for yellow-eyed mullet, but recreational fishers must have a minimum set net mesh size of 25 mm and drag net mesh size of 25 mm.

A customary allowance (per annum) of 100 tonnes for grey and yellow-eyed mullet, respectively, has been provided for by MPI (MPI 2017a; 2017b).

9 Pātiki Mohoao (Black flounder)

Family: Pleuronectidae

Species: *Rhombosolea retiaria*

The black flounder (Figure 69), pātiki mohoao (*Rhombosolea retiaria*), is the only member of the flatfish family, or Pleuronectidae, that is a truly freshwater species. Other members of the family, such as the yellow-belly flounder (*Rhombosolea leporina*), occasionally wander into the lower reaches of rivers, but do not usually stay there. As their name implies, the flatfishes are indeed flat, and have adopted a habit of laying on their sides down on the substrate. Both eyes are on their dorsal or upper side to improve their field of view. Because of their shape, flounders are unlikely to be confused with other fish species except other flatfishes. The black flounder is easily distinguished from other flatfishes by its colouration; the top of the fish is usually dark-coloured with numerous, obvious brick-red spots. Flounders can grow to about 450 mm in length, although 200–300 mm fish are most common.

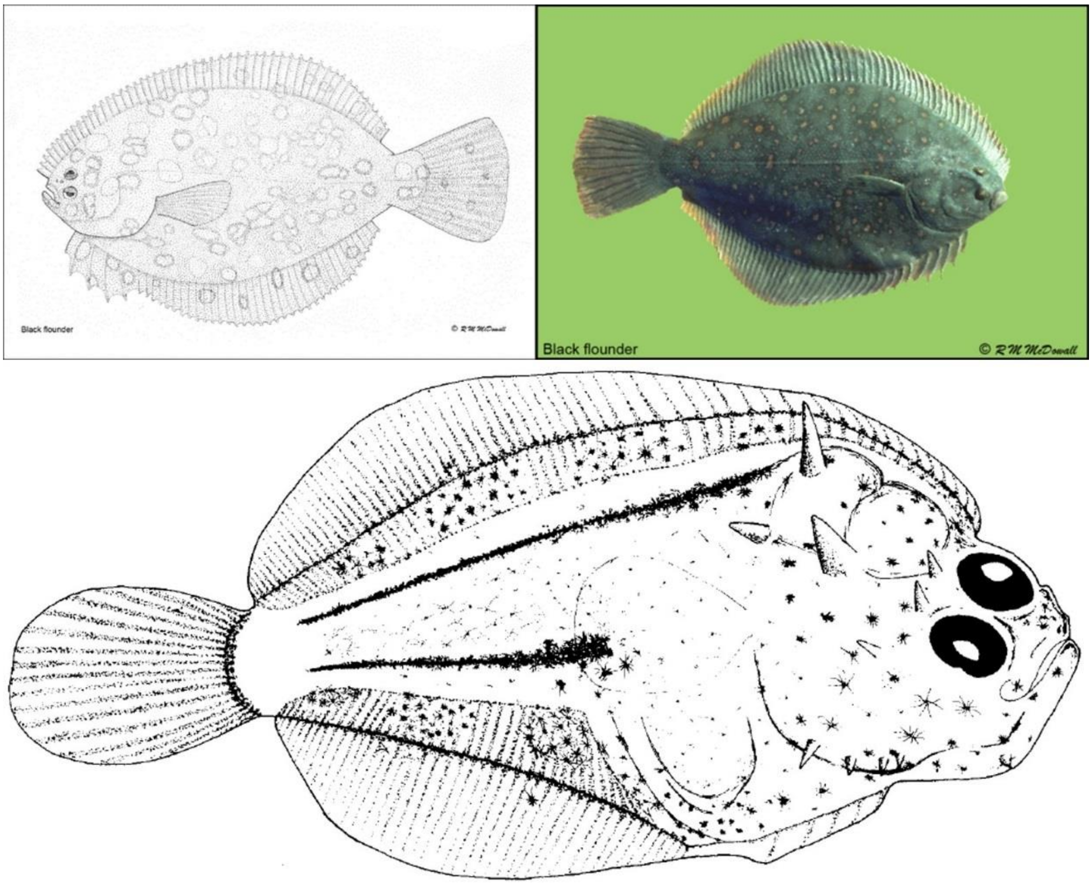

Figure 69: (Top) The adult black flounder (*Rhombosolea retiaria*); and (Bottom) Juvenile black flounder, c. 10 mm in length. (Sources: [Top] Bob McDowall; [Bottom] Roper [1979] in Eldon & Smith [1986]).

The black flounder is found throughout Aotearoa-NZ and is unique to this country. They are primarily a coastal species, although they can penetrate well inland if the river gradient is not too steep and specimens have been recorded more than 100 km inland in some river systems. Black flounder are a carnivorous species and probably eat a variety of bottom dwelling insects and molluscs. They are also known to feed on whitebait during the spring migration.

9.1 Life Cycle

Little is known about the life cycle of the black flounder. The larvae are undoubtedly marine, but where and when spawning takes place is not known. Site-specific knowledge has increased for the timing of black flounder spawning and recruitment. Although estuaries may play a minor and temporary role in the lives of black flounder, they are an essential habitat in their life histories that must be considered in management (McDowall 1976).

Black flounder appear to mature more rapidly than other flatfish, with nearly mature fish known to congregate in some habitats in July and August (Crow & Bonnett 2013). In general, adults probably mature and migrate to sea during winter (June/July) (McDowall 1995) and newly metamorphosed larval flounder recruit into fresh waters during spring (October to December) (McDowall 1995, Jellyman 2012). Most Aotearoa-NZ research on black flounder has been conducted in Te Waihora because it supports a significant commercial fishery and evidence suggests that spawning in fresh water is due to fish not achieving full ripeness in the lake as well as the observation of large between-year fluctuations in the annual catches of juveniles (Crow & Bonnett 2013). To the best of our knowledge, spawning and recruitment periods for black flounder are known for some South Island locations (e.g., Te Waihora, Waimakariri Lagoon, Waitaki River, and Rakaia River lagoon) but have not been recorded for other locations around Aotearoa-NZ.

9.2 Distribution

Black flounder are more commonly recorded in the South Island than in the North Island (Figure 70). They have not been reported from Chatham Islands or Stewart Island. Black flounder are more common in colder waters, and are seldom seen in the upper North Island. This species is located in lowland areas that are difficult to sample, which may account for the low numbers of observations in the NZFFD. The Canterbury and Otago coast lines contain most of the black flounder observations in the South Island, while coastlines in Hawke's Bay and the South Taranaki Bight contain most of the North Island observations (Figure 70).

9.3 State and Trends in Abundance

Black flounder state and trends in abundance were unable to be assessed by Crow et al. (2016). There is very little information on the abundance and distribution of this species in Aotearoa-NZ estuaries and rivers.

Black flounder is thought to be widespread, but with relatively few records from northern areas (McDowall 2000), probably due to its preference for cooler waters. Abundance fluctuates from year-to-year in some areas owing to mouth closure of systems (e.g., Te Waihora), which may prevent entry to fresh water by small juveniles (McDowall 2000). Given the short lifespan of this species (which is also typical of other flounder species) there are only a few year classes in the population. This means that natural fluctuations in year-class strength (typical of all marine spawning fish) results in highly variable adult populations. Such variations would be worsened by mouth closures in lakes like Te Waihora (David et al. 2014).

Historically, a commercial fishery for black flounder operated in Lake Wairarapa, but came to an end as catches declined to uneconomic levels. This ecosystem connects to the sea via the Ruamāhanga River which flows into Lake Ōnoke; this whole system is intermittently closed to the sea by a coastal bar, which may limit the supply of larvae/juveniles into the system from the sea. Lake Wairarapa has also been subjected to significant environmental degradation, and has water control gates at its southern end that are sometimes closed (there is a small opening for fish passage). Juvenile black flounder of 2–7 cm length have been found in Lake Ōnoke, up in shallow tidal channels on the north-western side of the lake (M. Morrison, pers. obs.).

Figure 70: Locations of NZFFD records where black flounder are present (black circles) and absent (grey circles).

9.4 Threat Rankings

The latest New Zealand Threat Classification System assessment classified black flounder as being 'Not Threatened' (Goodman et al. 2014). In 2014, the IUCN ranked black flounder as being 'Data Deficient' expressing that very little is known about the population of this species (Table 14).

Table 14: Threat rankings for Aotearoa-NZ black flounder according to the New Zealand Threat Classification System and IUCN. (see Section 2.3 for more information about these assessment methods).

Species	DOC Ranking	IUCN Ranking
Black flounder *(Rhombosolea retiaria)*	Not Threatened	Data Deficient (Population trend unknown)[62]

9.5 Pressures on Populations

Pressures on black flounder populations include poor water quality, disconnection between river and sea, water flows, and introduced/exotic species (e.g., Minns 1990). The hydrological values in waterways and estuaries must be maintained so that migration is not hindered, or prevented; and so that pollution and habitat modifications which affect the movements of fishes are kept to a minimum (McDowall 1976). Downstream-upstream linkages are crucial to guarantee a full, reproductive life cycle for migratory fish like black flounder. Other pressures may include increased sediment and contaminant inputs into waterways and the construction of barriers to fish passage (e.g., Tempero 2013). Additionally, drought can strike Aotearoa-NZ rivers at almost any time of the year, and depending on the severity (e.g., in association with water abstraction) can be an issue for these fisheries, and requires informed river flow management (McDowall 1995).

Most of the regional councils recognise the use of coastal drains by fish and wildlife, and usually avoid maintenance during spawning, nesting, and migration periods (Hudson & Harding 2004). However, these key periods of activity are not known for black flounder, therefore potentially limiting the protection to these fish. Further knowledge of black flounder habitats, migration, and impacts (natural and anthropogenic) are required to guide improved fisheries management.

9.6 Management

Black flounder is managed as part of the 'flatfish' group, which includes eight species in total, rather than having species-specific management. These are: the yellow-belly flounder, *Rhombosolea leporina* (YBF); sand flounder, *Rhombosolea plebeia* (SFL); black flounder, *Rhombosolea retiaria* (BFL); greenback flounder*, Rhombosolea tapirina* (GFL); lemon sole, *Pelotretis flavilatus* (LSO); New Zealand sole, *Peltorhamphus novaezeelandiae* (ESO); brill, *Colistium guntheri* (BRI); and turbot, *Colistium nudipinnis* (TUR) (MPI 2017).

Although black flounder is included in the QMS, the data available are not representative of the total catch because the black flounder data are grouped with other flatfish (FLA) species that are marine-based. In the commercial fishery, TACC's have been set for all five FLA (Figure 71); however, this does not include black flounder caught in fresh waters. Flatfish are shallow water species, and commercially these fish are mainly taken by targeted inshore trawl and Danish seine fleets around the South Island. Important fishing areas for black flounder are located within the Canterbury Bight, which sits within the much larger fisheries management area, FLA3, and only the New Zealand sole (*Peltorhamphus novaezeelandiae*) status is reported separately for this zone (MPI 2017).

[62] http://www.iucnredlist.org/details/197304/0

Recreational and customary allowances have been set for flatfish in FLA1 but not the other four FLA areas (FLA2, 3, 7, and 10) (Ministry of Fisheries 2007). Within the recreational fish regulations, there is a size limit, maximum daily limit per fisher, and a minimum net mesh size.

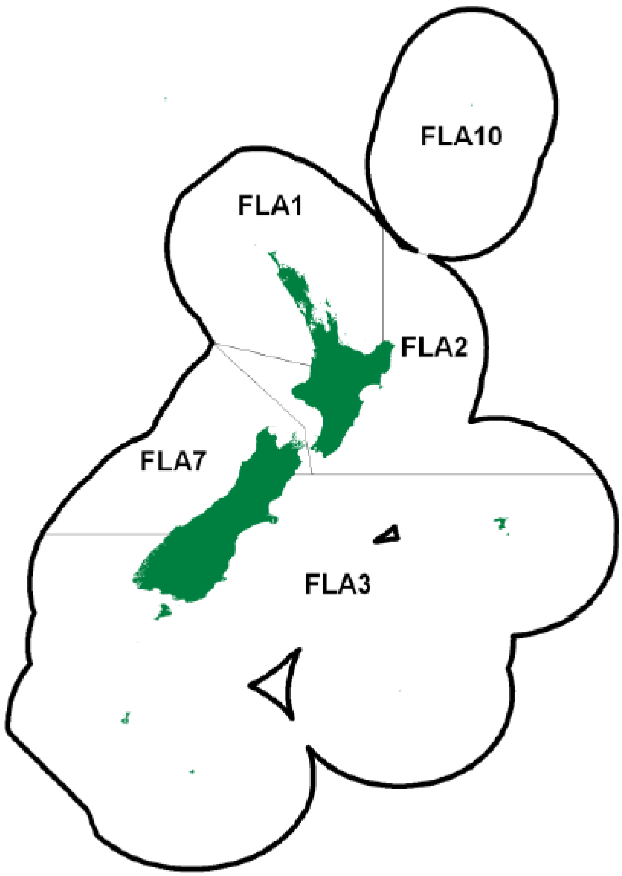

Figure 71: Commercial fish stock areas for "flatfishes". This includes *Colistium nudipinnis, Peltorhamphus novaezelandiae, Colistium guntheri, Rhombosolea retiaria, Rhombosolea plebeia, Rhombosolea leporina, Rhombosolea tapirina*, and *Pelotretis flavilatus* (Source: MPI 2017).

10 Kākahi / Kāeo (Freshwater mussels)

Family: Hyriidae

Species: *Echyridella menziesii, Echyridella aucklandica, Echyridella onekaka*

Freshwater mussels are widespread throughout Aotearoa-NZ, in habitats ranging from small, fast-flowing streams to rivers and lakes. *Echyridella menziesii* (Figure 72), previously known as *Hyridella menziesi*, is one of three species of freshwater mussels native to Aotearoa-NZ. Shell morphology can vary significantly in response to environmental conditions, which has complicated freshwater mussel taxonomy in Aotearoa-NZ for over 100 years. That is, until the research of Fenwick (2006) and Marshall et al. (2014) which provided clear taxonomic designations for Aotearoa-NZ freshwater mussels. Freshwater mussels have a unique relationship with a midge (or chironomid, *Xenochironomus canterburyensis*) (Figure 72), because the larvae develop within the layers of the freshwater mussel shell (Forsyth 1983). The midge larvae can sometimes be seen in "blisters" on the inside of the shell. Roper and Hickey (1994) found that dead chironomids can become embedded and result in severe shell deformities and flaking. Shell morphology appears to also vary with water quality, flow, and wave action, making it difficult in some locations to tell the species apart (Phillips 2006).

Figure 72: (Left) The kākahi, *Echyridella menziesii*; and (Right) The chironomid, *Xenochironomous canterburyensis*. The chironomid larvae can sometimes develop within the layers of the kākahi shell and is visible as "blisters" on the inside of the shell (Photos: [Left] Ngaire Phillips; and [Right] Mark Fenwick).

Freshwater mussels are filter-feeders (e.g., Figure 73), as well as deposit-feeders, and feed on a variety of suspended particulates in the water, including bacteria, phytoplankton, detritus and micro-zooplankton, as well as deposited organic material (e.g., dead plankton, fine silt). Freshwater mussels lack the byssal threads (or "beard") that some marine mussel species use to attach themselves to substrates; instead they usually partially bury themselves into soft sediments. In some instances, kākahi leave tell-tale trails in the soft substrates when they move along the bottom of lakes, rivers and streams.

10.1 Life Cycle

Kākahi have a unique life cycle (Figure 74) that relies on fish to be successful. Briefly, males release their sperm into the water in spring where it is taken in by the females to fertilise their eggs which are held inside a special brood pouch in the gill. The tiny eggs develop into larvae known as glochidia (less than half a mm long) and shaped like a "pac-man" (Figure 75). In spring and summer the glochidia are released into the water column, possibly when the female senses the presence of a suitable fish host. The larvae attach themselves to a host fish (including fish like kōaro, tuna, bullies, banded kōkopu) using a little tooth on their shell edge. The best attachment location is thought to be the gill, but they are often found on the fin tips, lips and skin of fish. The glochidia are parasites on the fish host (Fritts et al. 2013) while they transform completely into a juvenile mussel. After about two or three weeks they drop off the fish, presumably into soft, sandy sediments in lake and river beds to develop further.

Figure 73: (Left) Kākahi in the Styx River showing the inhalant (Kai In) and exhalant siphons (Waste Out) that the mussels use to filter feed; and (Right) Close up view of the inhalant siphon. (Photos: [Left] Duncan Gray and Greg Burrell; [Right] Sue Clearwater). The photo on the right shows the inhalant siphon fringed with tentacle-like papillae that help sort food from other particles. Particles are delivered to the gill (glimpsed in white inside the inhalant siphon) which generates the feeding current (approximately 1 litre per mussel per hour) and does further food-sorting and delivery to the mouth.

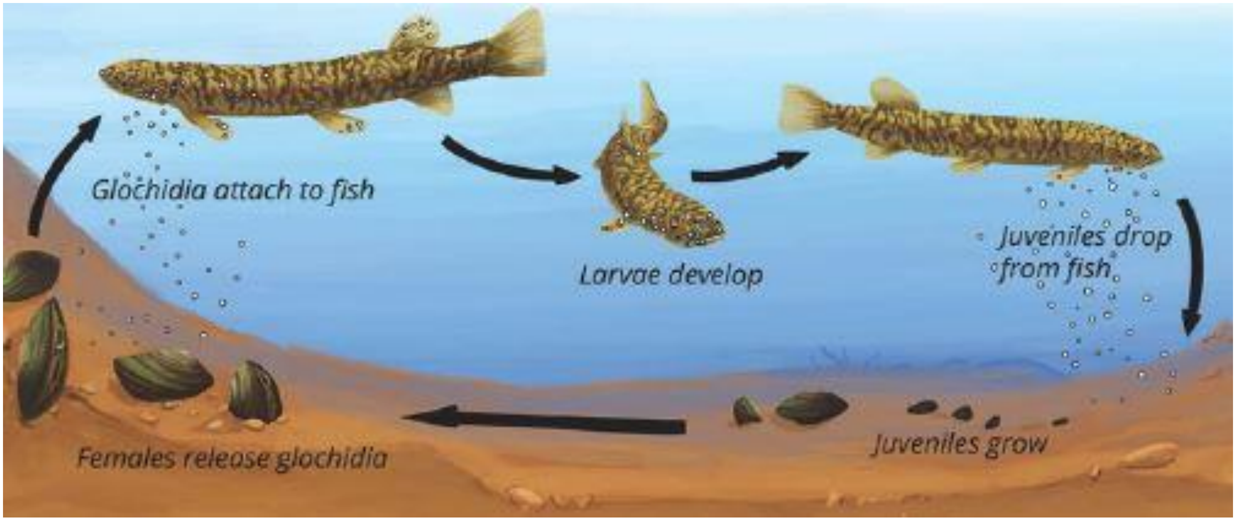

Figure 74: Life cycle of the kākahi. (Source: Rainforth 2014) While kōaro is shown as the fish host in this graphic, where present, species like tuna and common bullies can also fulfil this role in the kākahi life cycle.

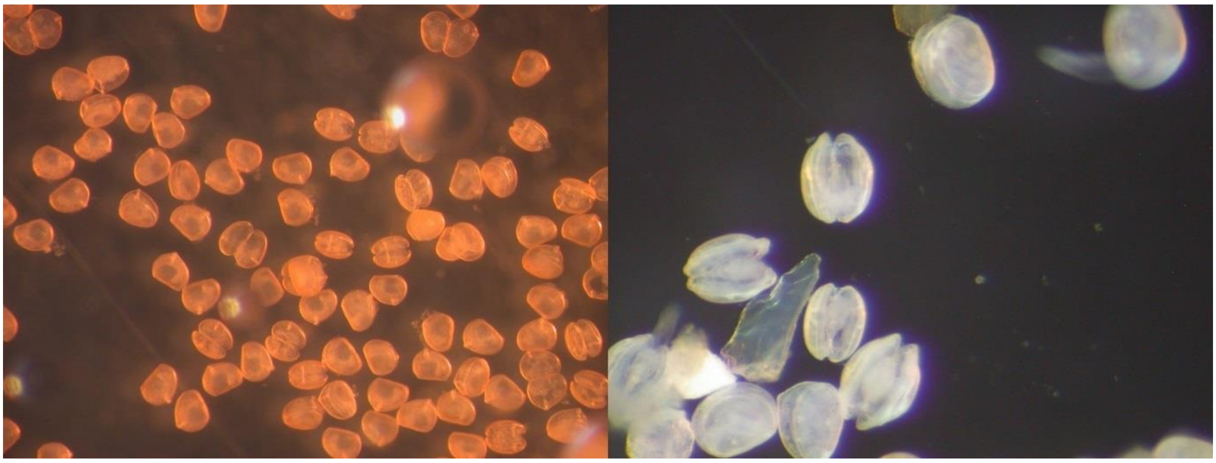

Figure 75: The glochidium (plural glochidia) is the microscopic larval stage of kākahi. (Photos: [Left] Brian Smith; and [Right] Karen Thompson).

In Aotearoa-NZ, *E. menziesii* longer than 30 mm dominate population studies and it is rare to find juvenile mussels (Grimmond 1968, James 1985, Roper & Hickey 1994). Adult freshwater mussels can live a long time and individuals of more than 100 mm length have been recorded in previous studies (Ogilvie 1993, Sorrell et al. 2007). Populations in Lake Waipori had a mean age of 20–25 years old (Grimmond 1968), with some individuals aged at over 50 years. In other locations, the oldest mussels were 13 years old (61 mm) in Taupō-nui-a-Tia (James 1985) to 33 years (84 mm) in the Waikato River (Roper & Hickey 1994). The long-life span of freshwater mussels can be problematic because adult mussels may be present in a lake or river but might not be a viable, self-sustaining population because of low juvenile survival. This would be known as a "geriatric" population at risk of local extinction. There is potential that juvenile mussels occur in a different habitat (upstream) from the adults and undergo a migration into adult habitat as they develop (Phillips 2006). For example, Grimmond (1968) found juvenile mussels near the mouths of inflowing rivers.

10.2 Distribution

Echyridella menziesii is widespread throughout Aotearoa-NZ, and is locally common in some places. To date *E. aucklandica* has mostly been found in northern Aotearoa-NZ and *E. onekaka* has a very restricted range in northwest Nelson (Figure 76).

Now that the research of Fenwick (2006) and Marshall et al. (2014) has provided clear taxonomic designations for Aotearoa-NZ freshwater mussels, more research is required to confirm the distribution of *E. aucklandica* that has an interesting and somewhat bizarre distribution from the north of the North Island to the south of the South Island but with vast gaps between populations. These species also often occur together (in other words, side-by-side in the sediment) which may indicate that their ecological relationship is more complex than is currently understood. For example, recent surveys have shown the two species, *E. menziesii* and *E. aucklandica,* are usually found within one location (e.g., Lake Wairarapa, Lake Hauroko, west coast Waikato streams) (Marshall et al. 2014, Greater Wellington Regional Council 2015, Hamer et al. 2015).

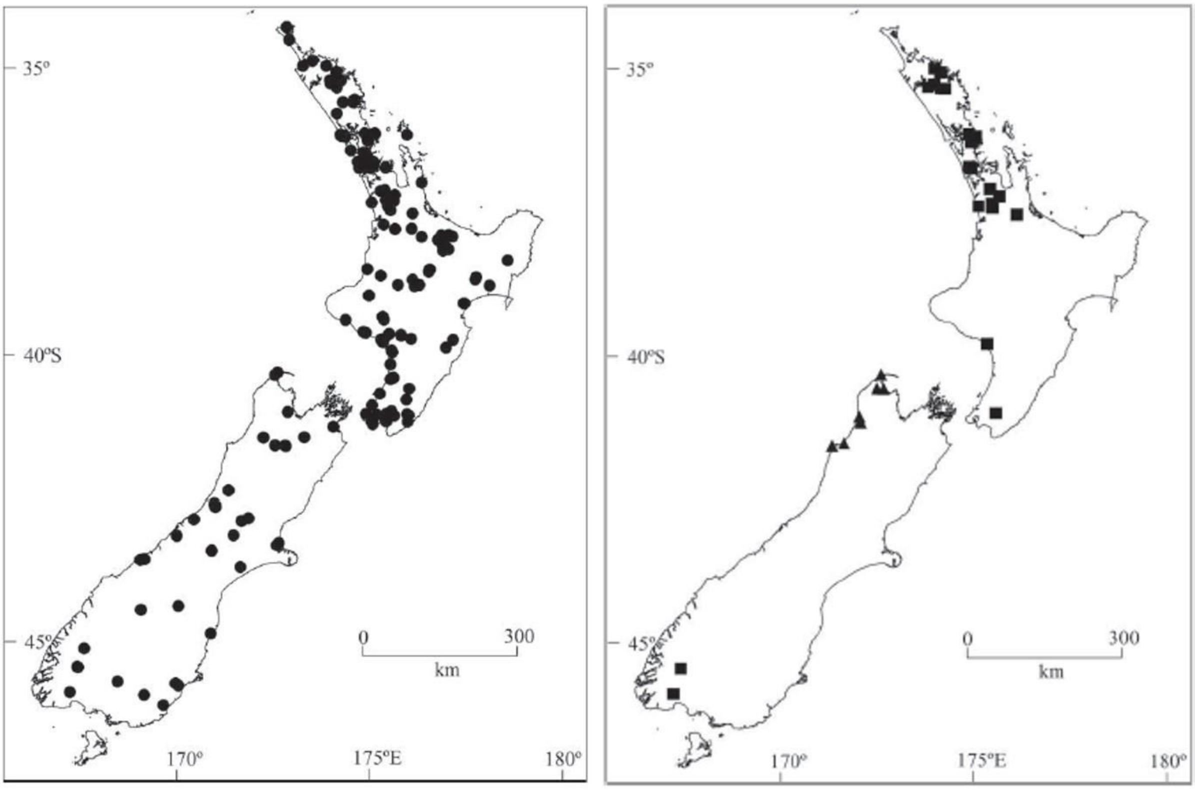

Figure 76: Distribution of *E. menziesii* (Left), and (Right) *E. aucklandica* (squares) and *E. onekaka* (triangles). (Source: Marshall et al. 2014).

10.3 State and Trends in Abundance

Kākahi state and trends in abundance were unable to be assessed by Crow et al. (2016) as freshwater mussel abundance is not recorded by the NZFFD.

Kākahi once formed extensive beds in lakes and rivers, and were harvested as a food by pre-European Māori. Many customary fishers perceive that there has been a decline in the abundance of kākahi (e.g., NIWA 2010). Trends in the relative abundance of the three freshwater mussel species are not presently known. This is largely associated with species identification challenges and an absence of information on the abundance of each species.

Surveys of freshwater mussel populations are sometimes undertaken as part of small research or restoration projects (e.g., James 1985, Ogilvie & Mitchell 1995, Happy 2006, Butterworth 2008, Rainforth 2008, Greater Wellington Regional Council 2015), and resource consent and biosecurity evaluation/monitoring processes (e.g., Kusabs 2006, Sorrel et al. 2007, Otago Regional Council 2013, Hofstra 2013; 2015, Baker et al. 2014). Together these studies, and similar unpublished data sources, suggest that freshwater mussel populations are being lost from many shallow lakes and small streams, especially those affected by urban and agricultural development. To the best of our knowledge, there is no one organisation or centralised data management system collating the information for the benefit of assessing state and trends in freshwater mussel distribution and abundance in the future.

10.4 Threat Rankings

Freshwater mussels are under threat and are declining, both in Aotearoa-NZ and worldwide (Walker et al. 2001). Recognition of the potential threats to kākahi populations is reflected in the New Zealand Threat Classification System assessment (Grainger et al. 2014). Because *E. onekaka* has a restricted range, this species has been classified as 'At Risk – Naturally Uncommon' with an additional qualifier of Data Poor as very few live populations have been identified (S. Clearwater, unpubl. data). *Echyridella menziesii* has been classified as 'At Risk – Declining' with a total area of occupancy >10,000 ha (100 km^2), and predicted decline 10–70%. *Echyridella aucklandica* has been classified as 'Threatened – Nationally Vulnerable' with ≤15 subpopulations, ≤500 mature individuals in the largest subpopulation, a predicted decline 10–50%, and with 'recruitment failure' and 'sparse' as qualifiers (Grainger et al. 2014) (Table 15).

In 2013, the IUCN ranked *E. menziesii* as being of 'Least Concern'; however, they recognise that there is very little information on juveniles and rates of recruitment, which means it could take a while to notice any decline in populations. The species is thought to be in decline due to reduced recruitment of riverine populations, and lowland lake populations are also likely to be in decline, however some large upland lake populations may be stable (Moore 2013) (Table 15). IUCN have also ranked *E. onekaka* as being of 'Least Concern' because this species has a restricted range (northwest Nelson). Despite potential localised threats, no major declines are known for this species, and it is expected to be present in many locations (based on separate sub-basins). Development in the area is low, and Moore (2013) considered that much of the known range falls within a Protected Area. That said, the range for this species has only been characterized from specimens held in Te Papa Tongarewa (Museum of New Zealand), most of which were collected in the first half of the 20th century (Table 15).

Table 15: Threat rankings for Aotearoa-NZ kākahi according to the New Zealand Threat Classification System and IUCN. (see Section 2.3 for more information about these assessment methods).

Species	DOC Ranking	IUCN Ranking
Echyridella menziesii	At Risk–Declining	Least Concern[63] (Populations decreasing)
Echyridella aucklandica	Threatened–Nationally Vulnerable	Not assessed
Echyridella onekaka	At Risk–Naturally Uncommon	Least Concern[64] (Unknown population trend)

10.5 Pressures on Populations

To date there has been limited research undertaken in Aotearoa-NZ investigating key drivers influencing presence, distribution, and density of kākahi in streams, rivers and lakes. Aotearoa-NZ based studies have investigated kākahi ecology (James 1985; 1987, Roper & Hickey 1994, Butterworth 2008, Cyr et al. 2016, Collier et al. 2017), reproduction (Clearwater et al. submitted), growth and energetics (Grimmond 1968, Nobes 1980), contaminants (Hickey et al. 1995; 1997, Clearwater et al. 2012; 2014), and potential use of kākahi for bioremediation (e.g., Ogilvie & Mitchell 1995, Phillips 2007). The decline of freshwater mussels both nationally and internationally has been attributed mainly to the loss and degradation of suitable habitat through land use and land management activities, and the loss of host fish species upon which the completion of their life cycle depends (Figure 77).

[63] http://www.iucnredlist.org/details/198678/0
[64] http://www.iucnredlist.org/details/198679/0

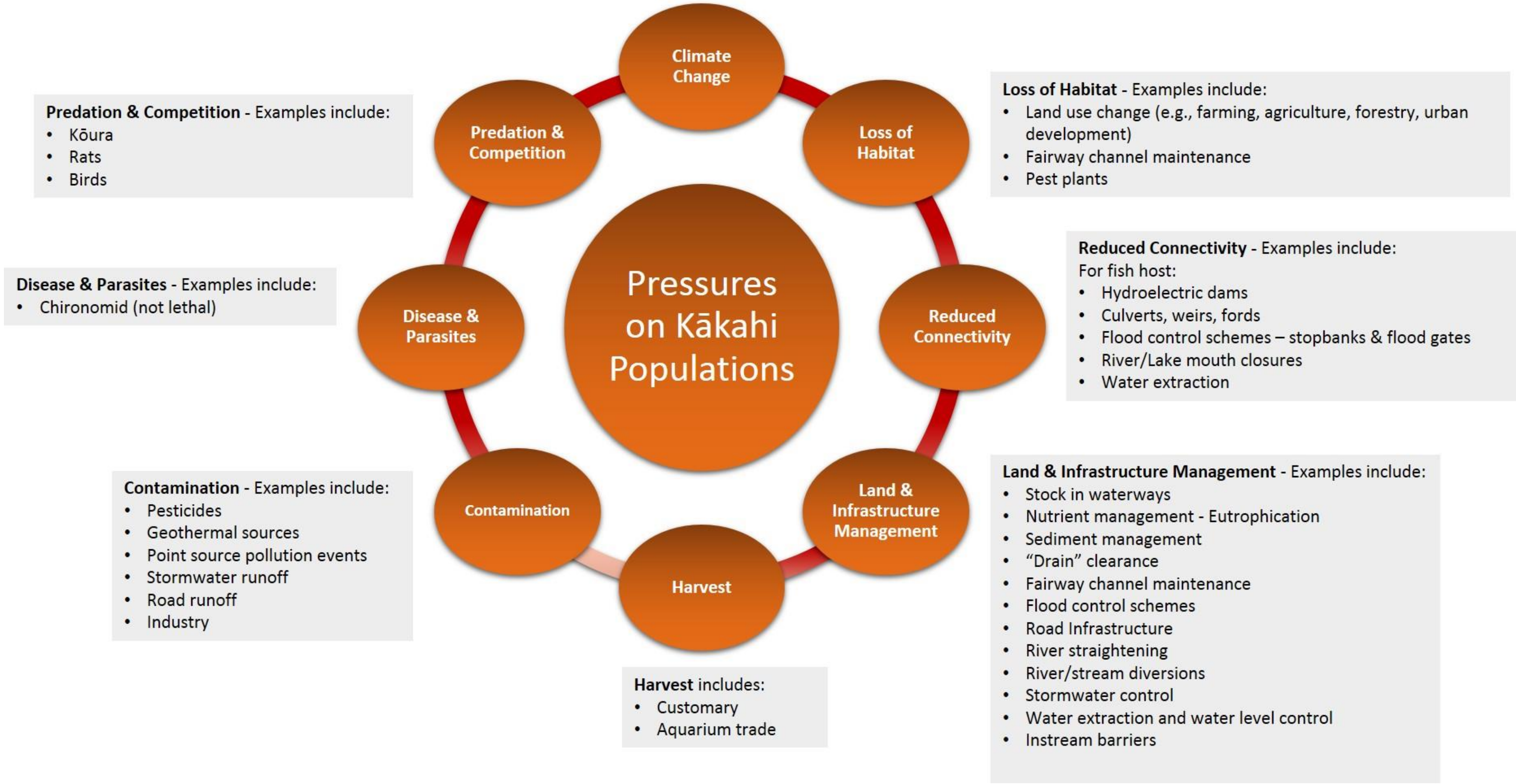

Figure 77: Examples of some of the pressures on Aotearoa-NZ kākahi populations.

10.5.1 Land and Infrastructure Management

Several physical factors influence the density of mussels. Sediment type and stability have been suggested as dominant factors, but bed slope, wave action, temperature, oxygen availability and presence of toxins are also important (James et al. 1998, Butterworth 2008). The presence of macrophyte beds is also known to limit the available habitat for kākahi (James 1985). Although kākahi need sediment to bury in, increased fine silt and organic matter has been found to impact mussel filtration rates (James 1985; 1987, Rainforth 2008). For more information about the pressures on fish host populations, which also impact kākahi populations in waterways where they coexist, please see Sections 3.5 and 6.5.

There are few published studies in Aotearoa-NZ that have attempted to quantify or document the effects of mechanical or chemical drain clearing on mortality of kākahi. Photographic evidence of this permitted activity occurring in a Murihiku catchment indicates that kākahi are scooped out of drains by mechanical excavators (Figure 78) and dumped on the stream/drain bank where they die.

Figure 78: Drain clearing activities in a Murihiku catchment impacting waikākahi (freshwater mussel) populations. (Photos: Jane Kitson). During this incident, in just over 500 m of stream drain clearing, over 200 waikākahi between 65–110 mm were removed from this tributary, which was also close to a nohoanga and mātaitai reserve (J. Kitson, unpub. data.).

Drain Maintenance Technical Guidance (Greer et al. 2015) has been produced by DOC for RMA and concession applications and provides the following recommendations for conditions and mitigation activities of relevance to kākahi:

- During weed cutting and mechanical excavation operations the consent holder shall ensure any stranded fish, kōura and kākahi are returned to the waterway. All fauna shall be released upstream of the affected section of waterway, or, where this is impractical (e.g., appropriate upstream release sites cannot be easily accessed), in a downstream section of the waterway that is below the mixing zone and does not have elevated levels of suspended sediment—to avoid exposing fauna to sediment-induced anoxia (lack of oxygen) when returned to the water.
- If a species listed as threatened under the New Zealand Threat Classification System is recovered during excavation or weed cutting in a waterway that is not previously known to contain that species, works in the area the fish was discovered shall cease immediately.

- If Threatened or At Risk fish are known to be present in the waterway, or the waterway is known or expected to contain a large fish population, a person shall be present at all times to return any stranded fish to the waterway.

The relocation of freshwater mussel populations impacted by land management activities is mandatory in North America. It is possible that diggers drivers and landowners do not know much about the life cycle of kākahi, or that they are listed as 'At Risk' species. A targeted education campaign could help to improve this situation in the future.

10.5.2 Water Quality and Contaminants

Butterworth (2008) found that the highest densities of kākahi in Lake Rotokākahi consistently occurred at intermediate depths (5 and 10 m) compared with shallower (1 m) and deeper (15 m) sites encompassed by each transect. Dissolved oxygen, temperature and algal fluorescence were the most highly correlated variables with *E. menziesii* density and biomass in the lake. These results have important implications for other deep lakes where eutrophication has resulted in a trend of declining dissolved oxygen in deeper waters when these lakes undergo seasonal thermal stratification.

Surveys have found elevated concentrations of the heavy metals mercury and arsenic in kākahi from selected locations within the upper Waikato River and Te Arawa fisheries areas (Hickey et al. 1995, Phillips et al. 2011, Phillips et al. 2014). In Harts Creek, a tributary of Te Waihora, the lead concentration in kākahi (1.96 mg/kg) was at the maximum limit of 2 mg/kg set by Food Standards Australia New Zealand, suggesting potential concern in respect to lead concentrations in these freshwater mussels (Stewart et al. 2014). While kākahi are consumed by whānau members today, they are not as popular or as important as they were in the past (e.g., Tipa et al. 2010). This may be due to the taste of the kākahi rather than a decline in harvestable quantities. However, their known propensity to accumulate pollutants may prejudice the opinion of harvesters (I. Kusabs, pers. comm., Walker et al. 2001, Tipa et al. 2010) and this may be another reason why kākahi are no longer exploited by Māori on a large scale.

10.5.3 Predation

Kōura have been reported to prey on juvenile mussels (C. Hickey, unpubl. data). It is likely that birds and fish take this species, as reported for other mussel species internationally (e.g., Zahner-Meike & Hanson 2001). Rats also predate kākahi, with records of "bitten off" shells from Lake Rototoa, Lake Harihari and in some Northland lakes, shell piles/middens from Lake Tūtira (Figure 79, Hofstra 2013).

Figure 79: Evidence of rat predation on kākahi. (Left) Lake Rotoroa, and (Right) Lake Tūtira. (Photos: Mary de Winton and John Clayton, respectively).

10.5.4 Aquarium Trade and Pond Enthusiasts

MPI (undated) notes that small quantities of kākahi are taken for personal use, mostly for home aquaria or back yard ponds and also for consumption. Kākahi are a desirable species because of their ability to filter out large amount of algae in ponds and many pond enthusiasts recommend adding a few mussels into the pond for that purpose. This species is also used in the aquarium trade, although the scale is unknown (Moore 2013).

10.6 Management

The main agencies involved in the management of kākahi are DOC (e.g., Conservation Act 1987) and Regional Councils (e.g., Resource Management Act 1991, Soil Conservation and Rivers Control Act 1941). There are no species-specific conservation measures in place for kākahi. There is a daily combined bag limit of 50 that applies to shellfish that do not have specific limits, such as freshwater crayfish, freshwater mussels and freshwater shrimp (MPI undated).

Environment Canterbury have a project to map all records or habitats of threatened freshwater species (fish, mussels and crayfish) with a view to providing bespoke protection for them within their planning framework. Stage 1 of this project is to create a database of known historical and current populations across Canterbury. Stage 2 involves field work to assess if historical populations remain and the health of current populations (e.g., Figure 80). Stage 3 will involve either the development of planning rules to protect populations or the instigation of population restoration and protection initiatives (Gray 2015).

Figure 80: Freshwater mussel populations in the lower Styx River, August 2017. (Photos: Duncan Gray and Greg Burrell).

Various iwi around the country are progressing formal management arrangements for their kākahi fisheries. For example, the **Ngāi Tahu Claims Settlement Act** prohibits the targeted commercial harvest of “Kākahi/Koaru – freshwater mussels”. As part of the **Te Arawa Lakes (Fisheries) Regulations 2006** the Mahire Whakahaere or Te Arawa Lakes Fisheries Plan is required under the

Regulations to provide for the sustainable management of customary fisheries, including kākahi, in the Te Arawa lakes.

During the 2014 Freshwater Sciences Society Conference a group of freshwater scientists and stakeholders met and agreed upon the content of a New Zealand Freshwater Mussel Conservation Strategy intended to enable/add momentum to the efforts of various organisations to understand and restore our three species of native freshwater mussels and their habitat. At this conference '**Freshwater Mussel Conservation Aotearoa**' was formed to provide a communication network about mussel-related activities and to address the first part of the strategy to "work together – increase cooperation and communication amongst entities that study, manage, conserve or restore freshwater mussels". The nine key goals of the New Zealand National Freshwater Mussel Conservation Strategy as suggested by the Freshwater Mussel Conservation Aotearoa group are listed in Table 16. The strategy that this informal group suggests is based on the National Strategy for the Conservation of Native Mussels developed in North America (National Native Mussel Conservation Committee 1997, Haag & Williams 2014).

Table 16: Goals of the New Zealand National Freshwater Mussel Conservation Strategy, 9 September 2015. (Adapted from Haag & Williams 2014).

Goal No.	Description
1	Work together, increase cooperation and communication amongst entities that study, manage, conserve or restore freshwater mussels.
2	Increase knowledge of mussel population status and trends, including: a. Develop basic monitoring protocols (e.g., community groups). b. Develop detailed monitoring protocols for use nationally. c. Include traditional and local knowledge. d. Provide website for both presence/absence records, and data collection tailored to national protocols. e. Provide website on mussel information, updates (e.g., quarterly) on this process and contacts.
3	Grow knowledge of their biology (especially reproduction and host requirements) and habitat requirements (especially for juveniles).
4	Protect and reverse the decline of quality mussel habitat
5	Determine what are the key mechanisms of mussel decline in shallow lakes; what are the mechanisms of their probable decline in streams? Develop restoration guidance from the findings of this research.
6	Enhance public and government understanding and support for freshwater mussel conservation and habitat protection (e.g., flagship species for water conservation?)
7	Develop and trial techniques for holding and translocating large numbers of adult mussels.
8	Develop and trial techniques for reseeding juveniles on a large scale.
9	Increase available funding levels and develop other means to increase mussel conservation efforts.

11 Influencing Government Policy and Planning

Consideration of the Aotearoa-NZ legislative framework, within which the management of fresh water sits, illustrates one of the challenges that Māori face when seeking a management or governance role. It may be unclear which management agency is best able to help Māori realise the outcomes sought. A multitude of organisations have certain functions and powers, and statutory responsibilities for different aspects of freshwater management (Table 17). Each is bound by its empowering legislation, or the legislation that it administers, which may or may not include specific references to the Treaty of Waitangi and/or Māori values. Table 17 also illustrates why Māori participation in freshwater taonga species management requires a broader focus than the RMA (Tipa et al. 2016).

Table 17: Some of the agencies with statutory responsibilities for freshwater taonga species management (and their associated ecosystems, including the marine environment) in Aotearoa-NZ. (Adapted from Tipa et al. 2016).

Agency	Source of Statutory Powers and Duties
Ministry for Environment	• Environment Act 1986 (plus Acts in the Schedule, including Fisheries Act 1996). • Resource Management Act 1991 (includes national policy statements, national environmental standards and regulations). • Environmental Reporting Act 2015.
Regional Councils	• Resource Management Act 1991. • Local Government Act 2002. • Rating Powers Act 1988. • Biosecurity Act 1993. • Soil Conservation and Rivers Control Act 1941 (and a number of special statutes). • Reserves Act 1977. • Marine and Coastal Area (Takutai Moana) Act 2011. • Marine Pollution Act 1974. • Civil Defence Emergency Management Act 2002. • Land Transport Act 1993. • Maritime Transport Act 1994. • Regional Councils are also responsible for many local statutes such as those that govern drainage and flood control, e.g., Taieri River Improvement Act 1920.
District and City Councils	• Resource Management Act 1991. • Local Government Act 2002. • Rating Powers Act 1988. • Reserves Act 1977.
Department of Conservation	• Conservation Act 1987 (plus Acts in the First Schedule including Wildlife Act 1953 and National Parks Act 1981). • Resource Management Act 1991.

Table 17 Continued.

Agency	Source of Statutory Powers and Duties
Ministry for Primary Industries	• Fisheries Act 1996. • South Island Fisheries (Customary Fishing Regulations) 1998. • Fisheries (Kaimoana Customary Fishing) Regulations 1998. • Māori Fisheries Act 2004. • Treaty of Waitangi (Fisheries Claims) Settlement Act 1992. • Biosecurity Act 1993.
Mandated Iwi Organisations (MIOs), Recognised Iwi Organisations (RIOs), TOKM group	• Māori Fisheries Act 2004.
Tangata whenua/hapū	• Fisheries Act 1996 (Taiapure Provisions). • South Island Fisheries (Customary Fishing Regulations) 1998. • Fisheries (Kaimoana Customary Fishing) Regulations 1998. • Māori Fisheries Act 2004.
Iwi specific legislation	Examples include: • Te Rūnanga o Ngāi Tahu Act 1996. • Ngāi Tahu Claims Settlement Act 1998. • South Island Fisheries (Customary Fishing Regulations) 1998. • Treaty of Waitangi Fisheries Settlement Act 1992. • Waikato-Tainui Raupatu Claims (Waikato River) Settlement Act 2010. • Te Arawa Lakes Settlement Act 2006. • Te Arawa Lakes (Fisheries) Regulations 2006. • Nga Wai o Maniapoto (Waipa River) Act 2012 . • Te Awa Tupua (Whanganui River Claims Settlement) Act 2017.
Fish and Game NZ Councils	• Conservation Act 1987. • Resource Management Act 1991.
Environmental Risk Management Authority	• Hazardous Substances and New Organisms Act 1996.
Ministry of Foreign Affairs and Trade	• Territorial Sea, Contiguous Zone, EEZ Act 1977. • United Nations Convention on the Law of the Sea (UNCLOS). • Continental Shelf Act 1964.
Statistics New Zealand	• Environmental Reporting Act 2015.

A number of key drivers over the past 10–15 years have sought to increase Māori participation in freshwater planning, policy and management. The Waitangi Tribunal has articulated several resource-specific principles, including that the spiritual and cultural significance of a freshwater resource to Māori can only be determined by tangata whenua. Treaty of Waitangi settlements are playing a critical role in providing the legislative foundation for a range of co-governance and co-management institutional arrangements for the governance and management of fresh water and the active implementation of rehabilitation strategies and actions to meet Māori and community aspirations (e.g., Te Ture Whaimana – Waikato River, Te Awa Tupua – Whanganui, Te Arawa Lakes) (Tipa et al. 2016).

An iwi management plan (IMP) is prepared by an iwi, iwi authority, rūnanga or hapū. IMPs are often holistic documents that cover more than resource management issues under the RMA. Much like council plans, IMPs may include issues, objectives, policies and methods relating to ancestral taonga, such as rivers, lakes, seabed and foreshore, mountains, land, minerals, wāhi tapu, wildlife and biodiversity, and places of tribal significance. These plans are often used by iwi/hapū to express how the sustainable management of natural resources can be achieved based on cultural and spiritual values. They often detail how the iwi/hapū expect to be involved in the management, development and protection of resources, and outline expectations for engagement and participation in RMA processes. These plans must be taken into account when preparing or changing regional policy statements and regional and district plans. However, many resource management agencies that attempt to recognise cultural values and practices, still find it difficult to understand what these represent and how to adequately or appropriately recognise and provide for them (Tipa & Teirney 2003).

Māori inclusion in freshwater management decision-making up to 2014 has largely been under existing RMA 1991 provisions, namely Section 6(e), 7(a) and 8 requiring local government to consult with iwi or tangata whenua. Part 2 of the Resource Management Act refers to the relationship Māori have with the environment. The recent creation of Mana Whakahono-a-Rohe agreements legislatively requires councils to engage with iwi/hapū on a range of resource management matters and come to mutually agreed outcomes. Given these provisions, Māori expect resource managers to recognise and provide for their cultural beliefs and practices and that they are included and actively involved in environmental management processes (Tipa & Teirney 2006).

Since 2009, new reforms of the RMA, recommendations to Government on reforms for freshwater management in NZ (including the Land and Water forum), the National Policy Statement for Freshwater Management (NPS-FM) and the National Objectives Framework (NOF), reinforced by Treaty settlements, have provided significant legislative and policy frameworks to increase Māori involvement, identify values and interests, improve recognition of indigenous relationships and rights, to adopt a more 'collaborative' approach to freshwater management. The NPS-FM identifies the Treaty of Waitangi as the guiding foundation for successful Crown-iwi/hapū relationships. Objective D1 of the NPS-FM sets out Māori/tangata whenua roles and interests in the freshwater space: *"To provide for the involvement of iwi and hapū, and to ensure that tangata whenua values and interests are identified and reflected in the management of fresh water including associated ecosystems, and decision-making regarding freshwater planning, including on how all other objectives of this national policy statement are given effect to".* A Māori values framework, Te Mana o te Wai was introduced in the NPS-FM in 2014, and in 2017 the NPS-FM was updated[65] to clarify the meaning of Te Mana o te Wai in freshwater management (MfE 2017a):

- Te Mana o te Wai is the integrated and holistic well-being of a freshwater body.
- Upholding Te Mana o te Wai acknowledges and protects the mauri of the water.

[65] http://www.mfe.govt.nz/sites/default/files/media/Fresh%20water/nps-freshwater-ameneded-2017.pdf

- This requires that in using water you must also provide for Te Hauora o te Taiao (the health of the environment), Te Hauora o te Wai (the health of the waterbody) and Te Hauora o te Tangata (the health of the people).
- Te Mana o te Wai incorporates the values of tangata whenua and the wider community in relation to each water body.

What still needs to be determined is the meaning of “involvement”, or “identified and reflected” and whether this is a stronger commitment than “recognise and provide for” or to “take account of”. Because these terms are newly introduced within the NPS-FM, case law has not been established. Importantly, the NPS-FM refers to decision making and the need to involve Māori. It still needs to be determined whether this will remove some of the inequalities in the existing system. For example, a fisheries scientist may give evidence at a hearing as an “expert”. An experienced Māori fisher/harvester, using mātauranga Māori, may give evidence at the same hearing, on the same subject, but may be seen as a cultural adviser and not an “expert”. This may impact the weight given to each piece of evidence by the decision makers.

Pinkerton (1989) identifies six resource management sub-functions, namely: (1) Inventory, assessment and research; (2) Allocative decision-making; (3) Policy making and planning (strategic and operational); (4) Implementation; (5) Monitoring and evaluation; and (6) Enforcement. Although these constituent sub-functions are common to many resource management agencies, under an ideal system, tangata whenua would be involved in each of the constituent management sub-functions. In practice, however, this is seldom the case (Table 18) as the involvement of tangata whenua across all sub-functions requires that several practicalities are addressed (Tipa et al. 2016).

The focus on who is to participate is important because fishing is typically a whānau and hapū activity. It follows that to be effective, management should be driven from the “flax-roots”. However, the legislation that is listed in Table 18 risks overlaying a different structure. Figure 81 confirms that many of the management functions are afforded to iwi authorities thus introducing a top-down philosophy. This moves the onus from the agency to internal iwi processes to ensure that the aspirations of whānau and hapū for participation are realised.

Another key aspect to be considered when reviewing Aotearoa-NZ’s legislation is the meaning of participation. Arnstein’s (1969) ladder of participation remains a sentinel description of levels of participation that has, as its lowest level, non-participation in a system that is expert-led engagement, with a one-way flow of information and limited power-sharing or opportunities to input to decision-making. Figure 81 also identifies consultation — which some Māori still seek — as a form of tokenism. Increasingly, Māori are developing partnerships, seeking delegated authority, and are assuming responsibility for aspects of taonga species management. However, a number of issues are still to be resolved. Figure 81 confirms that the recognition of mātauranga Māori, and its utilisation is essential to enable the transition to a two-way flow of information. Further, the status of Māori as advisors and not necessarily experts has been previously mentioned and needs to be corrected for acceptable co-solutions to be developed.

Table 18: Provision for the participation of Māori in freshwater resource management across selected legislations. In this table Māori participation in freshwater resource is broken down according to the six resource management sub-functions identified by Pinkerton (1989) (see Section 11). Although these constituent sub-functions are common to many resource management agencies, under an ideal system, tangata whenua would be involved in each of the constituent management sub-functions. (Source: Tipa et al. 2016).

Legislation	Inventory, Assessment and Research	Allocative Decision-making	Policy Making and Planning	Implementation	Monitoring and Evaluation	Enforcement
RMA 1991	Iwi authorities consulted	Iwi authorities Iwi authority can be Heritage Authority	Iwi authorities Iwi authority can be Heritage Authority	Iwi authority in relation to Section 33. Hapū or iwi in relation to joint management Iwi authority can be Heritage Authority	–	–
Conservation Act 1987	Iwi authorities consulted	Tangata whenua representative on Conservation Board	Iwi authorities	–	–	–
Heritage New Zealand Pouhere Taonga Act 2014	Tangata whenua	Māori Heritage Council assists Heritage NZ develop and reflect a bicultural view in the exercise of its powers and functions	–	–		–
Fisheries Act 1996	Māori consulted. Tangata whenua to participate and have input: (i) non-commercial interest in the stock concerned; or (ii) an interest in the effects of fishing on the aquatic environment in the area concerned	Tangata whenua and iwi in relation to customary (Part 9). Iwi entity for commercial interests	Māori consulted. Tangata whenua to participate and have input: (i) non-commercial interest in the stock concerned; or (ii) an interest in the effects of fishing on the aquatic environment in the area concerned	Tangata whenua and iwi in relation to customary (Part 9)	–	–

Table 18: Continued.

Legislation	Inventory, Assessment and Research	Allocative Decision-making	Policy Making and Planning	Implementation	Monitoring and Evaluation	Enforcement
Treaty of Waitangi (Fisheries Claims) Settlement Act 1992	Iwi entity	Iwi authority and iwi entity in relation to commercial. Tangata whenua in relation to customary.	Iwi entity	Iwi entity	–	–
Local Government Act 2002	Consult with Māori	Māori	–	–	–	–
Māori Fisheries Act 2004	Iwi entity	Iwi entity	Iwi entity	Iwi entity	–	–
Foreshore and Seabed Act 2004	–	Whānau hapū or iwi can apply for customary rights order	–	Whānau, hapū or iwi undertake customary activity	–	–
Wildlife Act 1953	"Representatives of Māori" are consulted	–	–	–	–	–
Māori Commercial Aquaculture Claims Settlement Act 2004	Iwi entity	Iwi entity	Iwi entity	Iwi entity	–	–

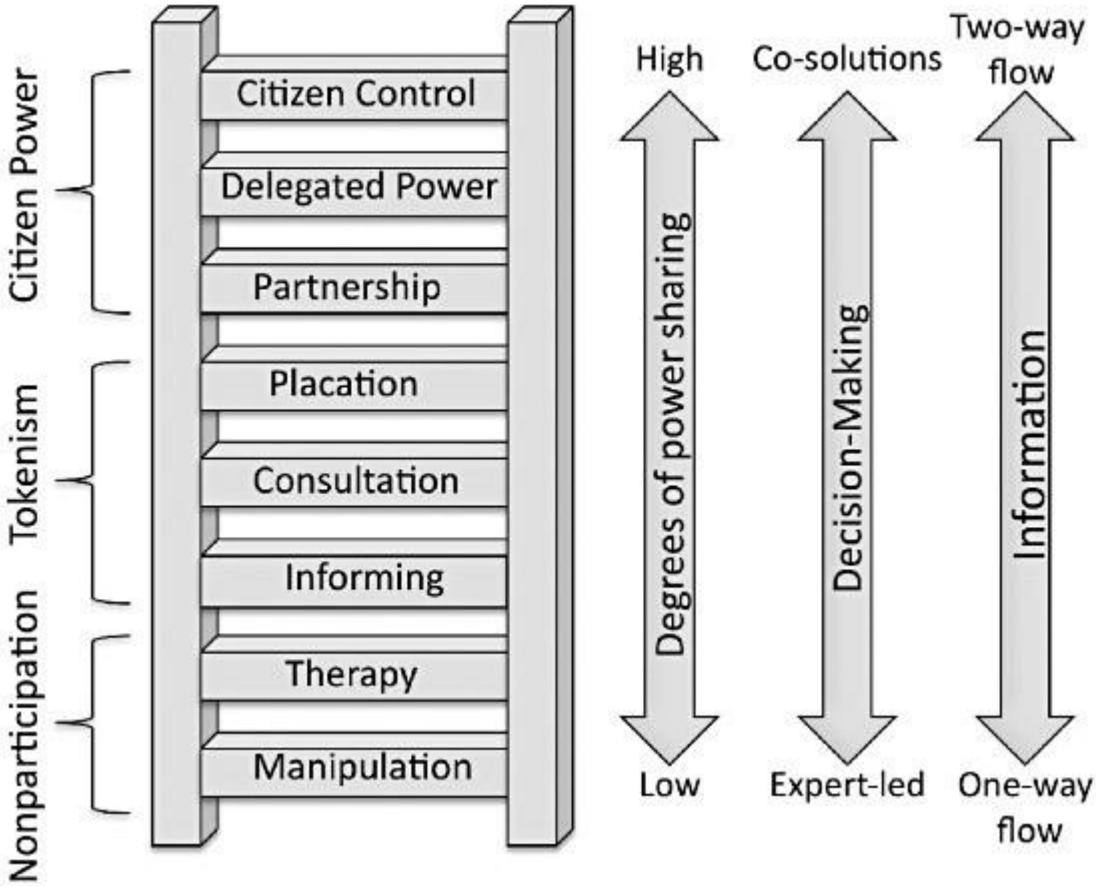

Figure 81: Arnstein's ladder of citizen participation and degree of power sharing. (Source: Arnstein 1969, adapted by Tseng & Penning-Rowsell 2012).

11.1.1 Mātaitai Reserves

Under Section 10 of the Treaty of Waitangi (Fisheries Claims) Settlement Act 1992 there is an obligation on the Crown to develop regulations that recognise and provide for customary food gathering by Māori and the special relationship between tangata whenua and places of spiritual and cultural importance. One management mechanism that has enabled tangata whenua to contribute to the management of taonga species is establishing mātaitai reserves (areas where the tangata whenua manage all non-commercial fishing by making bylaws) pursuant to the provisions of the Fisheries (Kaimoana Customary Fishing) Regulations 1998 and the Fisheries (South Island Customary Fishing) Regulations 1999.

Several mātaitai have been established to date to enable tangata whenua to manage freshwater areas, with the first being established in the Mataura River. In addition to the Mataura River, freshwater mātaitai reserves are currently located in reaches of the Okarito Lagoon, Lake Wairewa, Temuka/Opihi River, Waihao River and Waikawa River. These reserves are all located in the South Island. Non-commercial fishing in mātaitai is managed by tangata kaitiaki/tiaki (mandated tangata whenua representatives) through the making of bylaws that can cover:

species that can be taken

quantity of each species that can be taken size limits relating to each species to be taken

the method by which each species can be taken

area or areas in which the species can be taken, and

any other matters the tangata kaitiaki/tiaki considers necessary for the sustainable management of fisheries resources. If no bylaws have been made, then the amateur fishing regulations will apply.

The constraint with this mechanism, however, is that management is confined to specific species within a defined area. It is not a mechanism that enables management of the many factors that impact the fish/fishery.

11.1.2 Maniapoto Māori Trust Board and the Waipā Catchment Plan

The Maniapoto Special Project, Maniapoto Environmental Management Plan[66] and He Mahere Ika: Maniapoto Upper Waipā River Fisheries Plan 2015[67] provides an example of how iwi/whānau aspirations for the improved management of freshwater ecosystems and taonga species populations within their rohe can inform and strengthen **regional policy and planning processes**.

In 2012, the Crown acknowledged the relationship between Maniapoto and the Waipā River with the enactment of the **Ngā Wai o Maniapoto (Waipā River) Act 2012**. Under the Act, Maniapoto achieved co-governance and co-management arrangements specific to the Waipā River and its catchment. The co-management framework contains mechanisms that enable Maniapoto to better manage natural resources in the Upper Waipā River Catchment. A Primary Industries Accord between Maniapoto and the Crown underpinned the development of a the Maniapoto Upper Waipā River Fisheries Plan 2015 that defines specific objectives in relation to fisheries matters and guides the implementation of Maniapoto Fisheries Regulations (in development). The plan provides for the protection, restoration and enhancement of the fisheries resources of the Waipā River catchment. The Minister for Primary Industries must have particular regard to the Plan when making sustainability measures that relate to the Upper Waipā River (Watene-Rawiri et al. 2015).

The Maniapoto Special Project was a joint project between the Maniapoto Māori Trust Board (MMTB) and MfE and was undertaken alongside the development of the Waikato Regional Council's (WRC) Waipā Catchment Plan (WCP). The declining abundance and distribution of freshwater taonga species was specifically expressed as a concern by Maniapoto whānau during the project. A report describing Maniapoto whānau aspirations, values, issues and priorities for the restoration of the Waipā River was produced (Tipa et al. 2014). This report identified how the suggested responses of Maniapoto whānau related to the draft Waipā catchment plan, which was reviewed by WRC staff and accommodated in the final WCP where possible (Table 19).

The Maniapoto Māori Trust Board also directs all parties seeking funding annually from the Waikato River Authority for restoration projects within their rohe to express how their project explicitly aligns with, and supports, the Maniapoto Environmental Management Plan.

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[66] http://www.maniapoto.iwi.nz/ko-ta-maniapoto-mahere-taiao-maniapoto-environmental-management-plan/
[67] https://www.waikatoregion.govt.nz/assets/PageFiles/21886/Maniapoto_-_Fish_Plan.pdf

Table 19: Responses suggested by Maniapoto whānau to address issues around declining populations of taonga species in the Waipā catchment. Summary of responses, suggested prioritisation, organisational responsibilities and links to the Waipā catchment plan. The order of implementation includes actions/responses that should occur immediately (Priority 1) and those that should occur as soon as possible (Priority 2). Once MMTB are confident that initiatives identified as priority 1 and 2 are in the process of being adopted, priority 3 actions are to be addressed as corresponding opportunities arise (Source: Tipa et al. 2014).

Response No.	Responses suggested by Maniapoto whānau	Priority No.	Responsibility	How responses relate to the Waipā Catchment Plan (WCP)
49	Require site level assessments prior to any development activity.	1	WRC, MMTB	This is outside of the scope of the WCP and is an issue for the Regional Plan review and resource consent processes.
50	Prohibit development or disturbance in any area adjacent to or within fish habitats.	1	WRC, MMTB	This is outside of the scope of the WCP and is an issue for the Regional Plan review and resource consent processes.
37	Describe preferred habitat and environmental conditions for taonga and kai species throughout their life cycle.	2	WRC, MMTB	This is not covered by the WCP. However, this information will need to be collated to inform the Healthy Rivers: Plan for Change/Wai Ora: He Rautaki Whakapaipai.
38	Assess fish habitat and water quality limitations in the Waipā.	2	WRC, MMTB	Section 4.2.3, Action 8 will identify data deficient locations for taonga fish species in the Waipā catchment (above Toa's bridge) and implement a programme to better understand the distribution of these species. Action 9 will develop a robust fish survey method(s) for use in the Waipā mainstem and non-wadeable tributaries. The involvement of tangata whenua in the development of this method is not specifically referred to in the WCP.
40	Develop, implement and monitor species-specific restoration projects.	2	WRA, MMTB	Strategy 4.2.3, Action 7 to develop and implement projects to protect and restore riparian habitat for taonga species such as kōkopu, piharau, tuna and kōura; Action 12 to investigate potential of using lateral inundation areas of rivers/streams for promoting native fish productivity; Action 18 is an investigation to determine the response of indigenous aquatic species to in-stream enhancement structures. Species like watercress and kākahi/kutae (freshwater mussels) are not specifically referred to in the WCP. Species specific monitoring could be incorporated into the whole of catchment monitoring implementation plan (Section 4.2.8, Action 3) and monitoring undertaken as part of Section 4.2.5, Action 6 ("monitor catchment water quality and ecosystem health including science and cultural health indicators").
41	Improve knowledge and importance of lamprey, locate and protect spawning areas.	2	WRC, MMTB, DOC	This is not covered by the WCP. New research is required.
45	Support projects to control key predators / competitors.	2	WRC, MMTB, DOC, WRA	This is generally not in the plan with the exception of Strategy 4.2.3, Action 12 that will investigate potential of using lateral inundation areas of rivers/streams for promoting native fish productivity over that of exotic species.
47	Identify areas within the rohe where development activities should be prohibited.	2	WRC, MMTB	This is outside of the scope of the WCP and is an issue for the Regional Plan review.

Table 19: Continued.

Response No.	Responses suggested by Maniapoto whānau	Priority No.	Responsibility	How responses relate to the Waipā Catchment Plan (WCP)
43	Improve fisheries habitat by fencing riparian areas to stabilise banks and planting native vegetation.	2	WRC, MMTB, WRA	Section 4.2.1, Action 15 refers to the implementation of new riparian enhancement programmes along sections of the Mangapiko, Waipā and Mangapu catchments. Section 4.2.2, Action 11 refers to working with industry to promote stock exclusion from all waterways, karst systems, indigenous forests, wetlands and puna. Section 4.2.3 refers to protecting / restoring indigenous biodiversity. Action 7 refers to the implementation of projects to protect/restore riparian habitat for taonga species. The key waterways to enhance include areas of the Firewood Creek, Kaniwhaniwha, Mangakara and Mangatutu catchments. Action 22 refers to work with Ngā Whenua Rāhui[68] to restore and protect priority wetlands, lakes, under represented indigenous habitats and large intact indigenous habitats on Māori Multiple Owned Land Blocks. Section 4.2.4, Action 4 refers to the implementation of opportunities to retire and re-vegetate areas in the upper catchment.
48	Identify a mosaic of areas within the rohe at the strategic scale where development activities are restricted.	2	WRC, MMTB. DOC	This is outside of the scope of the WCP and is an issue for the Regional Plan review.
51	Identify and pursue capacity building initiatives.	2	MMTB, WRA	While capacity building is not generally covered by the plan, Strategy 4.2.6, Action 1 refers to the development and implementation of educational programmes in partnership with Enviroschools, Wai Māori and other initiatives to involve school children in understanding and caring for the Waipā catchment.
52	Restoring or creating new adult tuna habitat.	2	WRC, MMTB, WRA	See responses 40, 41 and 42.
39	Investigate contaminants in kai species.	3	WRA, MMTB	This is not covered by the WCP.
44	Develop, evaluate, implement methods for introducing adults and/or juveniles into areas.	3	MMTB, WRA	This is not in the WCP. The focus of the current plan is on improving habitat and connectivity for taonga species so that populations are able to increase naturally.
46	Investigate new technologies like fish farming/ranching.	3	MMTB, WRA	This is not in the WCP. The focus of the current plan is on improving habitat and connectivity for taonga species so that populations are able to increase naturally.
53	Revise tuna catch regulations.	3	MPI, MMTB	This is outside of the scope of the WCP.

[68] Ngā Whenua Rāhui is a contestable Ministerial fund established to facilitate the voluntary protection of indigenous ecosystems on Māori-owned land. http://www.doc.govt.nz/getting-involved/run-a-project/funding/nga-whenua-rahui/nga-whenua-rahui-fund/

Table 19: Continued.

Response No.	Responses suggested by Maniapoto whānau	Priority No.	Responsibility	How responses relate to the Waipā Catchment Plan (WCP)
42	Identify priorities to maintain and improve fish passage and connectivity.	3	WRC, MMTB	Section 4.2.3, Actions 10 and 11 refer to the identification and improvement of fish passage in the catchment. Collectively, the implementation of the following actions (in addition to the fish passage actions listed above) should improve connectivity and therefore increase available/accessible habitat for several taonga species: - Review priority streams/rivers with a consideration for factors such as stability, flood passages, corridor formation, water quality, in-stream habitat, access and culturally important sites (Strategy 4.2.1, Action 13). - Develop and implement a programme for the protection and restoration of Waipā wetlands, including a funding strategy, and provide incentives for protection at these sites (Strategy 4.2.2, Action 3). - Work with industry to promote stock exclusion from all waterways (Strategy 4.2.2, Action 11). - Identify additional priority indigenous habitats and potential linkages to enable a comprehensive ecological network to be managed in the Waipā catchment (Strategy 4.2.3, Action 1). - Develop and implement projects to protect and restore riparian habitat for taonga species such as kōkopu, piharau, tuna and kōura (Strategy 4.2.3, Action 7). - Investigate potential of using lateral inundation areas of rivers/streams for promoting native fish productivity (Strategy 4.2.3, Action 12). - Work with TAs during district plan reviews to ensure maintenance of indigenous biodiversity and protection of significant natural areas (Strategy 4.2.3, Action 19). - Work with mana whenua to identify cultural knowledge of flooding and its relationship with their values of rivers and streams. This may include areas that flooded historically that could be recreated as food gathering or flood retention areas (Strategy 4.2.4, Action 9). - Invite tangata whenua and other stakeholders to review annual consented WRC river management programmes to ensure cultural and environmental values are retained and enhanced (Strategy 4.2.4, Action 10). - Develop plans to restore access, mahinga kai and other cultural uses of the awa. Customary resources are restored where access exists (Strategy 4.2.5, Action 5).

11.2 Government Priorities and Science Strategies

The 'national direction' sets out a list of topics that Government intends to address nationally using RMA legislative tools — National Policy Statements (NPSs), National Environmental Standards (NESs) and regulations — to guide how specific resources should be managed to protect the environment, strengthen the economy and enable New Zealanders to provide for their social and cultural well-being. (MfE 2017b). Table 20 outlines what national guidance is currently being progressed and when that guidance might be completed. An updated list of national direction priorities will be published in late 2017/early 2018.

Table 20: List of current national direction priorities of relevance to supporting the health and wellbeing of taonga species populations. (Source: MfE 2017b).

Topic	Indicative date of completion	Description
Freshwater management (amendments to the NOF)	The amendments will come into force on 6 September 2017	Potential amendments to clarify how existing policies are to be applied.
Biodiversity	Late 2018	Set out objectives and policies about managing natural and physical resources to maintain indigenous biodiversity.
Stock exclusion from water bodies	Public consultation was held from 23 February to 28 April 2017	A nationally consistent approach to exclude stock from water ways, starting with dairy cattle and pigs, and ultimately applying to beef cattle and deer.
Plantation forestry	The National Environmental Standards for Plantation Forestry will come into effect on 1 May 2018	Nationally consistent rules to manage plantation forestry with more efficiency and certainty, and maintain or improve environmental outcomes[69].
Pest control	New regulations came into force on 1 April 2017	Simplifying the regulatory regime for certain toxins used to manage pest mammals and fish by removing duplication between the Resource Management Act and other legislation, including the Hazardous Substances and New Organisms Act.

An issue for Māori, however, is the length of time it may take to implement many of these new national directions. For example, the requirement to monitor water takes was established in 2014 but the extent of implementation remains unclear.

Over the last two years several Government organisations have released strategies to provide the science-based evidence to inform policy development, regulations and decision-making. The National Statement of Science Investment[70] sets out the Government's strategy for the public science and innovation system over the period 2015–2025. The integration of the **Vision Mātauranga policy**[71] across all Ministry of Business, Innovation and Employment (MBIE) investment priority areas provides clear opportunities to secure funding required to develop capacity and capability for iwi and

[69] It is noted that many forestry owners hold Forestry Stewardship Certification which includes social, cultural and environmental standards.
[70] http://www.mbie.govt.nz/info-services/science-innovation/pdf-library/NSSI%20Final%20Document%202015.pdf
[71] http://www.mbie.govt.nz/info-services/science-innovation/pdf-library/vm-booklet.pdf

hapū, investing in the development of skilled people and organisations undertaking research that supports: (1) Indigenous innovation: contributing to economic growth through distinctive science and innovation; (2) Taiao/environment: achieving environmental sustainability through iwi/hapū relationships with land and sea; (3) Hauora/health: improving health and social wellbeing; and (4) Mātauranga: exploring indigenous knowledge and science and innovation.

Regional and unitary councils have a dedicated Research, Science and Technology Strategy called Research for Resource Management[72]. The Strategy was last updated in June 2016 and sets out high level research priorities to assist research providers to formulate research proposals that are relevant to council resource management needs. Regional and unitary councils research priorities are summarised in Table 21. In additional, freshwater taonga species resource management, monitoring and evaluation priorities could be promoted via the following council Special Interest Groups (SIGs)[73]: Surface Water Integrated Management (SWIM); Land Managers Group, Land Monitoring Forum (LMF); Biosecurity, Biodiversity; Coastal Management; and Policy Managers.

The **Ministry for Primary Industries** Science Strategy: Rautaki Putaiao[74] released in 2015 sets out the strategic science outcomes for the MPI Science System for the next five years. The future aspirations of MPI include an improved capability and capacity for working with Māori perspectives, tikanga and mātauranga Māori, which will better enable iwi/Māori to use their mātauranga and undertake kaitiakitanga to achieve better outcomes for all. MPI outline critical areas of science output needs for MPI's areas of responsibility which includes: (1) Understanding of Māori socio-economic aspirations including agribusiness; and (2) Increased productivity within environmental and societal constraints including those related to Māori agribusiness. MPI have expressed a commitment to ensuring staff have basic skills in te reo, understand the Treaty of Waitangi, tikanga and mātauranga Māori, and understand the implications of this for their science work; and that science advice criteria and policy documents include Māori perspectives and mātauranga as appropriate.

In July 2016, **MfE and DOC** released a discussion paper about the Conservation and Environment Science Roadmap[75]. The roadmap identifies some of the big issues and possible research directions we can take over the next 20 years, organised around a set of 12 themes, and a series of key research questions that if answered will help government address the challenges and opportunities we will face. The 12 themes are: Climate change; Integrated ecosystems and processes; Freshwater ecosystems and processes; Land ecosystems and processes; Coastal and marine ecosystems and processes; Urban ecosystems and processes; Populations and species; Biosecurity; Mātauranga Māori; Social and economic dimensions; Informatics, modelling and monitoring; and New and emerging technologies. MfE are currently in the process of compiling and analysing public submissions into a report. In relation to Theme 9 of the the Conservation and Environment Science Roadmap, Mātauranga Māori, the key questions proposed are:

1. What are the exemplars of mātauranga-informed resource management and conservation outcomes? Is it feasible or appropriate to scale these up?;

[72] http://www.envirolink.govt.nz/assets/Uploads/RC-RST-Strategy-June-2016.pdf
[73] http://www.envirolink.govt.nz/assets/Uploads/Reg-SIG-Network-Sructure-Chart-May-2018.pdf
[74] https://www.mpi.govt.nz/document-vault/10172
[75] http://www.mfe.govt.nz/sites/default/files/media/About/conservation-environment-science-roadmap-discussion-paper_0.pdf

2. How can Māori organisations, through increased connectivity between science research and mātauranga Māori, improve resource management, sustainability and conservation outcomes?;

3. In valuing our natural capital what and how can we learn from Māori that would promote a more holistic approach to sustainable management?; and

4. What functions and powers are Māori organisations currently implementing and undertaking to promote sustainable development of our natural resources that could be enhanced through research?

In May 2017, DOC released their draft **Threatened Species Strategy**[76] that sets out the Government's plan to halt the decline of threatened species and restore them. The draft Strategy identifies 150 priority (threatened and at risk) species and sets targets to achieve by 2025. The goals of the Strategy include the integration of Te Ao Māori and mātauranga Māori into species recovery programmes by 2025, and the support of research, particularly through the New Zealand's Biological Heritage[77] National Science Challenge, to increase understanding in regards to data deficient species. Of Aotearoa-NZ's 53 native freshwater fish species, 21 are currently listed as Threatened and one as Data Deficient. Of these, 14 freshwater fish are included in the 150 priority threatened species listed in the draft Threatened Species Strategy (Table 22).

[76] http://www.doc.govt.nz/pagefiles/169845/threatened-species-strategy-draft.pdf
[77] http://www.biologicalheritage.nz/

Table 21: Regional council strategic priorities for research, science and technology. This list complements each of the Councils' Special Interest Groups (SIGs) that have identified more detailed strategies (see Research for Resource Management, Regional Council Research, Science and Technology Strategy 2016).

Priority No.	Area	Summary description	Specific references to supporting outcomes for Māori communities and/or freshwater taonga species
1	Better science utilisation	Two research themes: (1) Decision making systems, including community values-setting and accounting, and management policy design and evaluation; and (2) Develop operable approaches to assessments of resources or aspects of the environment as stocks and services.	Mātauranga Māori needs to be embedded in all research planning and should not be seen as a separate work area as it is relevant to all the environmental domains managed by Councils. The need is to develop agreed frameworks and processes for the integration that embeds and devolves the required activities through the organisations, and then continues to provide specific support for Mātauranga Māori needs corporately to ensure the legislative and partnership requirements are achieved.
2	Policy effectiveness	Better approaches for assessing effectiveness and efficiencies of policy, including a tool that can model and evaluate the likely impact of a full range of policy options.	The understanding and encapsulation of aspects of mātauranga Māori into Council science, policy formulation and review, including monitoring and reporting of activities, is an evolving need for Councils.
3	Integrated land and water science for enhanced sustainable production	Increased research effort into understanding the interactions between soil, land use and water is required. Need a clear understanding of the science so as to apply additional National Objectives Framework attributes in a defensible and well-considered manner.	Encapsulating mātauranga Māori alongside traditional science advice for community discussions is a high priority.
4	Biosecurity/Biodiversity	Five research goals: (1) Halt and reverse decline of native biodiversity and protect natural habitats; (2) Reduce land use and invasive species impacts in freshwater and marine ecosystems; (3) Ensure integrity of ecosystem services and natural capital; (4) Improve environmental outcomes through increased community awareness; and (5) Anticipate and plan for future risks.	All applicable.
5	Hazard risk management	Better tools to address hazards and reduce consequent societal risks.	
6	Coastal	There is a need for consistency amongst councils for national state of the environment monitoring and reporting. To manage ecosystems and resources we need to quantify change and understand how the coastal marine area, associated organisms and habitats, respond to various stressors.	Research is needed on ways in which customary knowledge can be captured, in accordance with tikanga Māori, and incorporated into coastal and marine monitoring and management frameworks.
7	Retaining and building science capability and capacity	Ensure that central Government decision makers understand what is required in science capability and capacity now and in the future, and that all forms of excellence in science are supported.	

Table 22: Fourteen freshwater fish listed as priority species in the draft Threatened Species Strategy. (Source: DOC 2017).

Scientific name	Common name	Family	Conservation status
Included in current report			
Anguilla dieffenbachii	Longfin eel	Anguillidae	At Risk – Declining
Galaxias argenteus	Giant kōkopu	Galaxiidae	At Risk – Declining
Geotria australis	Lamprey	Geotriidae	Nationally Vulnerable
Galaxias postvectis	Shortjaw kōkopu	Galaxiidae	Nationally Vulnerable
Not included in current report			
Galaxias sp.	Clutha flathead galaxias	Galaxiidae	Nationally Critical
Galaxias "Teviot"	Teviot flathead galaxias (Teviot River)	Galaxiidae	Nationally Critical
Galaxias aff. *cobitinis* "Waitaki"	Lowland longjaw galaxias (Waitaki River)	Galaxiidae	Nationally Critical
Neochanna burrowsius	Canterbury mudfish	Galaxiidae	Nationally Critical
Galaxias "Nevis"	Nevis galaxias (Nevis River)	Galaxiidae	Nationally Endangered
Galaxias aff. *Paucispondylus* "Manuherikia"	Alpine galaxias (Manuherikia River)	Galaxiidae	Nationally Endangered
Galaxias anomalus	Central Otago roundhead galaxias	Galaxiidae	Nationally Endangered
Galaxias eldoni	Eldon's galaxias	Galaxiidae	Nationally Endangered
Galaxias pullus	Dusky galaxias	Galaxiidae	Nationally Endangered
Cheimarrichthys fosteri	Torrentfish	Cheimarrichthyidae	At Risk – Declining

12 Māori Participation in Taonga Species Monitoring and Evaluation

While all of the initiatives touched on in Section 11 are positive, the challenge remains — given the plethora of agencies, legislation, new initiatives, and the varying levels of experience of agencies engaging with Māori, where should whānau, hapū and iwi invest their capacity in order to realise their aspirations in regards to improved taonga species co-governance and co-management? One avenue that has not been fully explored in Aotearoa-NZ is using Audit New Zealand[78] and the processes prescribed in the Local Government Act 2002, the Public Finance Act 1989 and the Crown Entities Act 2004 to hold local government, crown agencies and crown entities to account for their delivery to Māori. These bodies are required to develop Statements of Performance that are audited by Audit New Zealand. Ensuring input to the Statement of Performance is a mechanism that would enable implementation to be audited and reported.

There are currently no legislative provisions for tangata whenua involvement in freshwater monitoring and evaluation and enforcement (Table 18). Many iwi and hapū around Aotearoa-NZ have identified that there is a need to expand on existing biophysical monitoring programmes occurring in their catchments to capture information regarding the state of iwi/hapū values and cultural uses to evaluate the success (or otherwise) of management decision making and restoration actions. Monitoring and evaluation is essential for:

- Measuring success: Assessing progress of freshwater policy, local management and restorative actions (e.g., Te Ture Whaimana, Whakaora Te Waihora) towards achieving outcomes sought by Māori (e.g., Tipa 2015, Williamson et al. 2016, Tipa et al. 2017).
- Supporting adaptive management (e.g., Figure 82): Ongoing reviews of progress allow strategies to be adapted to meet targets if the expected progress does not occur. Such reviews are essential as Māori enter, for example, regional council limit-setting processes. Without monitoring programmes and formal reviews, the risk is that an adaptive cycle may never be triggered. This has the potential to influence how Māori approach a limit-setting process. Without monitoring, which is a core component of adaptive management, Māori may be forced to take a precautionary approach.
- Providing accountability: Agencies will need to provide transparency and accountability for actions they choose to fund (e.g., Williamson et al. 2016).
- Engaging communities: Community-based environmental monitoring programmes assist individuals, community groups and organisations to actively participate in caring for their surrounding environmental resources and assets. Such initiatives provide the coordination, networks, knowledge, training and support required by communities to monitor, track and respond to issues of common concern (McKenzie et al. 2000, Whitelaw et al. 2003, Conrad & Daoust 2008, Henwood & Henwood 2011).

Worldwide, community involvement regarding the identification of relevant indicators to monitor progress towards environmental management goals is increasingly recognised within literature by academics and environmental managers alike as an important component of sustainable and effective management (e.g., Leach et al. 1999, Fraser et al. 2006, Whitelaw et al. 2003, Jollands &

[78] http://www.auditnz.govt.nz/

Harmsworth 2006, Reed et al. 2008). A shift towards participatory 'bottom-up' approaches combined with conventional 'top-down' systems is evident internationally. This is largely due to the failure of 'top-down' systems to realise sustainable environment management (Fraser et al. 2006, Sharpe & Conrad 2006).

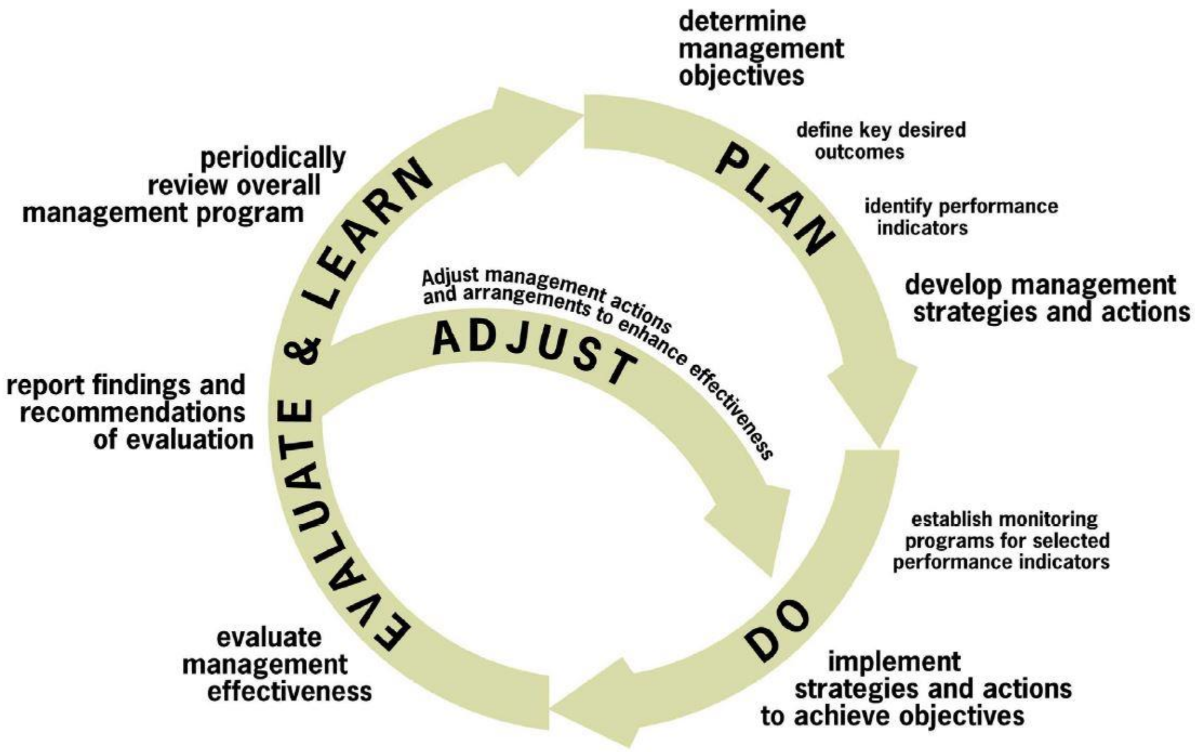

Figure 82: Adaptive management cycle for the Tasmanian Wilderness World Heritage Area. (Source: Jones 2005). This framework is also promoted in the Hurunui District Plan (Revision August 2017)[79], for example, "each biodiversity management plan should include a process for evaluating the effectiveness of management actions (i.e., through monitoring) and adjusting the management actions to enhance their effectiveness. This should include periodical reviews of the overall management programme, including the management objectives".

Tipa and Teirney (2003) developed the Cultural Health Index (CHI) methodology to help facilitate the participation of Māori in land and water management processes and decision making. The CHI recognises that only Māori can provide the clarity needed when dealing with Māori spiritual and cultural issues and supports application of the Treaty of Waitangi principle that *"the spiritual and cultural significance of a freshwater resource to Māori can only be determined by the tangata whenua who have traditional rights over the river"* (Tipa & Teirney 2003). A range of environmental monitoring and evaluation approaches have been developed and/or adapted for use by Māori communities. These have been summarised previously in publications such as Harmsworth and Awatere (2011), Nelson and Tipa (2012) and Awatere and Harmsworth (2014). However, Māori also need to know that contemporary resource managers support the use of tools like these, recognise the validity of the data collected, and will respond to the information provided (Tipa & Teirney 2003).

The development of environmental reporting frameworks that acknowledge cultural values, and provide a role for iwi and hapū nationwide in implementation and interpretation, would be a

[79] http://lep.hurunui.govt.nz/#!Rules/0/15/1/0

significant step forward for Aotearoa-NZ. For example, the development and implementation of Cultural Health Indicators for the Waikato River is clearly outlined as one of the objectives required to achieve Te Ture Whaimana[80], the Vision and Strategy for the Waikato River. While there are costs involved for agencies, including iwi/hapū organisations, the co-benefits of providing for long-term iwi/hapū monitoring programmes include:

- The identification and articulation of iwi and hapū values and perspectives of freshwater ecosystems across a range of spatial scales to help build understanding within resource management agencies.
- The identification and articulation of environmental-cultural changes through time from an iwi and hapū perspective.
- The development and long-term retention of Māori capability and capacity.
- The recording and dissemination of local environmental information can increase understanding of the role of kaitiakitanga as a social practice, and its relationship to waiora and hauora in sustainable environmental restoration as observed by Henwood and Henwood (2011).
- In some instances, the revitalisation of mātauranga Māori amongst generations who have been alienated from their catchments (e.g., raupatu, private land ownership, establishment of national parks, etc.).

The methodologies underpinning the datasets generated by agencies like MfE and regional councils to monitor the state of the environment (e.g., MfE & Stats NZ 2017) have taken years of development, with contributions from an international community of scientists and practitioners. The same courtesy needs to be extended to the development of cultural monitoring approaches as it will take time (and resourcing) to develop all the approaches/methodologies that will be required to generate the holistic datasets (qualitative and quantitative) required by iwi and hapū around the motu (e.g., protocols for the evaluation of ‘safe to eat’, ‘safe to harvest', and the state of sites of significance).

Māori-driven cultural monitoring programmes would significantly add value to regional environmental monitoring initiatives which are typically focused on water quality attributes, by providing a more holistic and integrated assessment of freshwater health and wellbeing. The revitalisation of the Te Arawa-Tūwharetoa tau kōura (Kusabs & Quinn 2009) is often used as an example of how mātauranga Māori and Māori-driven monitoring and research needs can significantly add to our understanding and inform improved management of freshwater taonga species. For example, until recently, there was a lack of quantitative information on kōura abundance and ecology which made it difficult for Te Arawa Lakes Trust to manage kōura populations in the Te Arawa lakes. The recent adaptation and use of the Te Arawa-Tūwharetoa tau kōura for monitoring (Kusabs 2006, Kusabs & Quinn 2009, Kusabs & Butterworth 2013) and research purposes (Kusabs & Butterworth 2011, Kusabs et al. 2015a) has significantly increased understanding of kōura populations in the Te Arawa lakes. Several customary management changes are suggested in Kusabs et al. (2015b) to protect and enhance the kōura fishery, including: (1) Restricting access to the fishery; (2) Implementation of a minimum legal length; (3) Implementing closed fishing seasons; and (4) Protecting egg-bearing and soft-shelled kōura. A modification of the tau kōura has also been

[80] http://www.waikatoriver.org.nz/wp-content/uploads/2011/07/Vision-and-Strategy.pdf

successfully trialled in rivers and streams in the Waikato River catchment (Clearwater et al. 2014, Kusabs et al. submitted) where individual whakaweku can be used as a kōura monitoring tool and, like the tau kōura method, have significant advantages over other monitoring tools in many situations[81].

12.1 Potential Approaches

The consolidation of existing historical sources of knowledge is an important resource for the design and interpretation of future taonga species research and monitoring studies (Tipa 2013). Methods to capture the mātauranga to underpin taonga species research and monitoring by iwi and hapū includes semi-structured interviews, focus groups, cultural value mapping, wānanga, collation of oral histories (e.g., treaty submissions and historical literature), and customary fisher observations (e.g., diaries). This collation of historical knowledge sources and the input of contemporary customary fishers will determine the social, cultural, environmental and economic aspirations (or targets) for taonga species populations in different catchments/sub-catchments (e.g., establish biomass of tuna required on an annual basis to supply hui, tangi, koha and the day-to-day consumption of whānau) and provide the underpinning framework for iwi and hapū environmental/fisheries management plans, monitoring programmes and future research priorities.

Mātauranga Māori and other qualitative and scientific methods can then be used to fill in spatial and temporal details (e.g., abundance and distribution of taonga species). In addition to tools like the CHI and Mauri compass (Ruru 2014), iwi and hapū around Aotearoa-NZ are complementing these approaches by drawing on biophysical methods and indicators as part of their monitoring and research initiatives. These could include both 'action' indicators and 'state' indicators. State indicators describe the health and wellbeing of taonga species populations, but can be affected by long time lags, be subject to high natural variability making trends difficult to detect for many years, and/or are very expensive to measure. Therefore, for example, the Waikato River Independent Scoping Study (NIWA 2010) also recommended the use of action indicators as surrogates to complement direct indicators of the state. Action indicators describe how far a management or restoration action (or suite of actions) has been carried out (e.g., to reduce the impact of a key pressure on taonga species populations, such as the provision of downstream passage for tuna heke). Action indicators can also be used to audit whether responses are being undertaken as envisaged.

To monitor the health and wellbeing of taonga species populations, several indicators have been used by Māori organisations/communities, or have been suggested as potential approaches. Examples are provided in Table 23.

[81] https://www.niwa.co.nz/our-science/freshwater/research-projects/all/restoration-of-aquatic-ecosystems/monitoring_koura/protocol

Table 23: Indicators that have been used by Māori organisations/communities, or have been suggested as potential approaches, to monitor the health and wellbeing of taonga species populations. Methodology development, or the adaptation of an existing approach to another species/attribute area, is required for some of the potential indicators suggested. In this table, we haven't included potential indicators for smelt, black flounder or mullet populations as there appears to be very few, if any, monitoring studies/tools that have been designed with community/public use in mind. See Nelson and Tipa (2012) and Harmsworth et al. (2016) for more information about indicators, frameworks and tools in use across the country to systematically record, collate and report on the cultural health and wellbeing of significant sites, natural resources (e.g., cultural flows, plants), and environments (e.g., wetlands).

Attribute area	Potential indicators	Examples include (Preference given to research/monitoring studies undertaken by, or in partnership with, Māori organisations/communities)
TUNA		
Recruitment/juvenile abundance	• Glass eel catch per unit effort • Species composition • Number of elvers transferred above hydro-dams • Provision of upstream passage at barriers	August & Hicks (2008), Ruru (2008), Jellyman et al. (2009), NIWA (2010), Williams et al. (2013), Williams et al. (2016), Martin & Bowman (2016)
Population abundance and distribution	• Species composition • Presence / absence of preferred species at sites of importance to fishers • Catch per unit effort • Ability to supply preferred species at marae events • Provision of passage at barriers	Henwood (2010), NIWA (2010), Williams et al. (2009, 2011 & 2013), Tipa (2013), Williams & Smith (2016)
Tuna health	• Size and age distribution (and preferred size for harvest) • Condition index • Parasites • Habitat quality (e.g., Tuna Habitat Quality Index) • Pest fish presence/absence	Richardson (1998), Williams et al. (2009), Williams et al. (2013), Holmes et al. (2015), Holmes (2016), Williams & Smith (2016)
Emigration/reproductive success	• Sex ratio • Catch per unit effort (tuna heke harvesters) • Provision of downstream passage at barriers • Size limits, reserve areas and/or no-fishing times to protect some migrants	Potential for kaitiaki who continue to actively harvest the tuna whakaheke to increase understanding of the specific timing and size of migration events for each species/sex exiting their waterways
Safe to eat	• USEPA risk assessment	Stewart et al. (2014)
Safe to harvest	• Ability to use preferred harvest method at preferred locations (including access), including pest plant nuisance growths • Water level/flow (including cultural flow preferences and safety considerations, e.g., impacts of hydro-ramping) • Water quality (including water clarity, cyanobacteria, *E.coli*) • Bank stability • Sedimentation	Tipa & Nelson (2012), Tipa & Associates (2013), Tipa & Associates (2015)

Table 23: Continued.

Attribute area	Potential indicators	Examples include (Preference given to research/monitoring studies undertaken by, or in partnership with, Māori organisations/communities)
WHITEBAIT		
Recruitment/juvenile abundance	• Catch per unit effort • Species composition • Ratio of exotic to native plant species (for spawning and riparian cover) • Provision of upstream passage at barriers • Water level/flow	NIWA (2010), Mahuta et al. (2016)
Population abundance and distribution	• Presence / absence at sites of importance to fishers • Catch per unit effort • Ability to supply preferred species at marae events • Provision of upstream passage at barriers	NIWA (2010), Mahuta et al. (2016)
Whitebait health	• Parasites • Condition index • Habitat quality • Changes in the length of time that fish can be stored • Changes in smell and taste	Richardson (1998), Mahuta et al. (2016)
Reproductive success	• Extent of spawning habitat available – NB: variety of habitats, including lower river reaches, streams and lakes, to be considered depending on species and catchment • Extent of spawning habitat protected (from stock and predators) • Water level/flow	DOC īnanga spawning database
Safe to eat	• USEPA risk assessment	To the best of our knowledge, no one has completed a risk assessment for whitebait / galaxiid consumers
Safe to harvest	• Ability to use preferred harvest method at preferred locations (including access) including pest plant nuisance growths • Number of whitebait stands – traditional, registered, unregistered • Whitebait stand "warrant of fitness" (including indicators for human waste, rubbish, and state of structure) • Water level/flow (including cultural flow preferences and safety considerations, e.g., impacts of hydro-ramping) • Water quality (including water clarity, cyanobacteria, *E.coli*) • Bank stability • Sedimentation	NIWA (2010), Morris et al. (2013), Tipa & Associates (2013)

Table 23: Continued.

Attribute area	Potential indicators	Examples include (Preference given to research/monitoring studies undertaken by, or in partnership with, Māori organisations/communities)
PIHARAU/KANAKANA		
Recruitment/juvenile abundance	• Rearing habitat quality • Water level/flow	New research project underway, see Section 4
Population abundance and distribution	• Catch per unit effort • Provision of upstream passage at barriers • Ability to supply marae events	Potential for customary fishers who continue to actively harvest the lamprey migration to increase understanding of the specific timing and size of adult migration events over time, e.g., Te Ao Marama Incorporated & Waikawa Whānau (2010), Kitson et al. (2012)
Piharau/kanakana health	• Parasites and disease	Kitson (2015), Kitson et al. (2015)
Reproductive success	• Spawning habitat quality • Water level/flow	New research project underway, see Section 4
Safe to eat	• USEPA risk assessment	To the best of our knowledge, no one has completed a risk assessment for piharau/kanakana consumers
Safe to harvest	• Ability to use preferred harvest method at preferred locations (including access) • Water level/flow (including cultural flow preferences and safety considerations, e.g., impacts of hydro-ramping) • Water quality (including water clarity, cyanobacteria, *E.coli*) • Bank stability • Sedimentation • Pest plant nuisance growths	Tipa & Associates (2013), Baker & Kitson (2016)

Table 23: Continued.

Attribute area	Potential indicators	Examples include (Preference given to research/monitoring studies undertaken by, or in partnership with, Māori organisations/communities)
KŌURA		
Recruitment/juvenile abundance	• Catch per unit effort • Rearing habitat quality • Predator presence • Ratio of exotic to native plant species	Kusabs & Quinn (2009), Kusabs et al. (submitted)
Population abundance and distribution	• Presence / absence at sites of importance to fishers • Catch per unit effort • Predator presence • Ability to supply marae events	Kusabs & Quinn (2009), NIWA (2010), Clearwater et al. (2014), Severne et al. (2015), Kusabs et al. (submitted), https://www.niwa.co.nz/our-science/freshwater/research-projects/all/restoration-of-aquatic-ecosystems/monitoring_koura/protocol
Kōura health	• Size (measured as orbit-carapace length) distribution (and preferred size for harvest) • Parasites and disease	Kusabs & Quinn (2009), Clearwater et al. (2014), Kusabs et al. (2015a)
Reproductive success	• Sex ratios • Size at onset of breeding • Number of females in berry	Kusabs et al. (2015b)
Safe to eat	• USEPA risk assessment	Phillips et al. (2011), Phillips et al. (2014), Stewart et al. (2014)
Safe to harvest	• Ability to use preferred harvest method at preferred locations (including access) • Water level/flow (including cultural flow preferences and safety considerations, e.g., impacts of hydro-ramping) • Water quality (including water clarity, cyanobacteria, *E.coli*) • Pest plant nuisance growths	Tipa & Associates (2013), Severne et al. (2015)

Table 23 : Continued.

Attribute area	Potential indicators	Examples include (Preference given to research/monitoring studies undertaken by, or in partnership with, Māori organisations/communities)
KĀKAHI		
Recruitment/juvenile abundance	• Presence / absence of juvenile life stages • Density • Rearing habitat quality • Predator presence • Provision of fish passage between adult populations and juvenile rearing habitats	Clearwater et al. (submitted)
Population abundance and distribution	• Species composition • Presence / absence of preferred species at sites of importance to fishers • Density • Ability to supply preferred species at marae events	McEwan (2013)
Kākahi health	• Size and age distribution (and preferred size for harvest) • Condition index • Parasites • Habitat quality • Predator presence/absence • Pest plant presence/absence	McEwan (2013)
Reproductive success	• Sex ratio • Size distribution • Presence (and abundance) of preferred fish host • Provision of passage (for fish host) at barriers	
Safe to eat	• USEPA risk assessment	Stewart et al. (2014)
Safe to harvest	• Ability to use preferred harvest method at preferred locations (including access) • Water level/flow (including cultural flow preferences and safety considerations, e.g., impacts of hydro-ramping) • Water quality (including water clarity, cyanobacteria, *E.coli*) • Bank stability • Sedimentation • Pest plant nuisance growths	Tipa & Associates (2013), Severne et al. (2015)

13 Equity in Access to Data and Data Management Systems for Māori

Hapū, iwi, community-based groups and schools are providing an increasingly important resource for monitoring and managing Aotearoa-NZ's natural resources and are involved in a wide range of formal and informal monitoring programmes. The types of information being recorded includes variables such as pressures on the environment; access; degree of modification; willingness to harvest; wāhi tapu; water quality, native vegetation; the presence, abundance and diversity of native birds, plants and fish species; the health of culturally significant resources, as well as the presence of exotic species (e.g., Clayton et al. 2011, Harmsworth & Awatere 2011, Nelson & Tipa 2012).

To support decision-making processes in the long term there is an opportunity to co-design and co-develop data management systems to securely store datasets being gathered by hapū and iwi through-out the country. For example, Te Rūnanga o Ngāi Tahu have been developing and using the State of the Takiwā system since 2004 (Pauling 2004). The State of the Takiwā (now called Takiwā) is a Microsoft Access database that has been specifically developed to assist Te Rūnanga o Ngāi Tahu to gather, store, analyse, and report on environmental and cultural information in relation to significant sites (e.g., wāhi tapu), taonga and mahinga kai to help make better decisions on how to manage these into the future (Pauling 2008). Various organisations are in the process of independently developing web-based applications to help members capture field monitoring data, including eel population information. For example, Ngāti Rangi have used Cyber tracker to build a freshwater monitoring application for iwi members to use. The application extends Ngāti Rangi's monitoring ability from its two staff members to all interested iwi members, greatly increasing the amount of monitoring the iwi can do while also ensuring quality data (Rainforth 2014). Another example involves Ngāi Tahu whānau who are participating in the trap-and-transfer of migrant eels from the upper Waitaki River catchment to below the lowermost Waitaki dam. They record their data using an app that is uploaded to a central database.

As technologies that are useful to Māori become relatively cheap there is likely to be increasing interest in the development of purpose-built applications (e.g., upload and sharing of images, video, and other kinds of data) that guide and facilitate the collection of environmental information of relevance to hapū and iwi. Members of the public are also investing money to develop user-centric applications, for example, Fish4All[82] a Recreational Fishing Reporting App. In response to the recent release of the Fish4All app MPI have responded that "Ideas like this app have real potential, but before focusing on one approach we need to think carefully about what sort of information this type of tool can gather and how to make best use of it"[83] (Anthony 2014).

There is a need for a strong focus on equity in access to environmental data and the delivery of improved data management, knowledge visualisation, and communication tools that increase the capability and capacity of hapū and iwi. Recognising the Treaty partnership, and the interrelated high level government initiatives currently underway, effective freshwater management in Aotearoa-NZ should be built on a platform of equitable knowledge exchange (local experiential, indigenous and scientific). The development of data management infrastructure for hapū and iwi will require inter-disciplinary expertise that can represent cultural knowledge systems whilst being able to move

[82] http://www.fish4all.co.nz/
[83] http://www.stuff.co.nz/business/small-business/63976748/fisherman-develop-app-to-log-catch

beyond data “standardisation and validation” barriers implicit in science-based data management frameworks.

The development of information delivery infrastructure and knowledge visualisation tools for hapū and iwi will need to be an iterative, adaptable and flexible process (there is no one-size-fits-all). The infrastructure required to securely store hapū and iwi monitoring data will need to be interoperable, user-centric, with the ability to “plugin” additional data sources (e.g., water quality) as required. The process to develop hapū- and iwi-specific information aggregation, analysis and visualisation tools will need to be cognisant of the freshwater decision-making context, intellectual property agreements, and the audience that the knowledge is being used to inform (Williams et al. 2014).

14 Funding Landscape

An overview of funding sources that could be influenced/leveraged by Te Wai Māori to support taonga species research, capacity/capability building of Māori communities and scientists, and the implementation of restoration actions are summarised in Appendix E.

Relatively few funding sources recognise and/or enable Māori organisations to strategically drive or be the lead recipient of medium to large projects. The medium to large-sized projects are required to enable Māori to develop intergenerational capability/capacity and address taonga species related issues at the spatial and temporal scales required to support outcomes. In addition, co-funding requirements, which can range between 20–50% of the total project costs, can be difficult for Māori communities to raise and/or effectively communicate in funding applications.

15 Research Needs

Noble et al. (2016) contends Cultural Keystone Species (CKS) (akin to Taonga Species) provide focal points for identifying and monitoring key cultural and subsistence ecosystem services that affects the resilience of both Indigenous and non-Indigenous peoples. In supporting social groups that culturally and economically rely upon these species, Noble et al. (2016) contends that we will also increase the potential for better management and regulation of broader ecosystem health. This is because many CKS are also ecological keystones that underpin key ecosystem processes that provide resistance and resilience of fresh waters to environmental disturbances. Indigenous communities must be actively involved in the management of these species to balance competing needs and values. This approach has the potential to bolster long-term sustainability of freshwater social-ecological ecosystems through the formal recognition and inclusion of Indigenous peoples in the management of CKS around the world (Noble et al. 2016).

The rehabilitation of lost cultural, environmental and economic values and services is a key outcome of numerous Treaty of Waitangi Settlements. Māori are playing an increasingly critical role in co-management of our freshwater resources, including taonga species populations. Despite the advances made through Treaty settlements, the key to effective integration of Māori interests and values into freshwater resource management remains full iwi/hapū participation and a commitment from agencies to collaboration and strong, enduring relationships. This extends to organisations who wish to undertake research on freshwater taonga species.

During this review we have come across various documents that have expressed where further research is required to address key gaps in our knowledge about freshwater taonga species populations. We have taken the opportunity to collate these suggested research directions in Table 24.

Table 24: Some of the research directions required to address key gaps in our knowledge and improve freshwater taonga species co-management. These suggestions are listed in no particular order and have been drawn from the literature and the experiences of the reviewers/co-authors.

Area	Research needs include
Baselines	➢ There is a surprising lack of basic baseline population abundance and distribution information available for our freshwater taonga species, outside of the commercial eel fishery.
Climate change	➢ Impacts of weather and climate variability and change on taonga species populations and the ecosystems that support them.
Cumulative effects and tipping points	➢ Time lags and cumulative impacts of environmental pressures and harvest on taonga species "tipping points" - when populations can no longer support social, cultural, environmental and economic interests (e.g., at what point does eutrophication turn from being a beneficial to kōura and kākahi (provision of higher quantities of food) to causing decline in kōura and kākahi numbers). ➢ Cumulative effects of ecosystem-wide and long-term temporal factors influencing taonga freshwater species populations.
Land use and land management practises	➢ Land-use and land management effects on taonga species populations (including alterations to freshwater inputs into coastal marine environments). ➢ Quantify the impacts of flood control schemes, hydro dams, drain clearance and gravel extraction activities on taonga species populations.
Water quantity	➢ Flow requirements, including flow variability, to support taonga species populations across all stages of their life cycle (including habitats that lie outside of 'active' riverbed channels, e.g., puna, wetlands, oxbows). ➢ Cumulative effects of anthropogenic water level alterations/flow variability (short and long-term) on populations of taonga freshwater species ki uta ki tai (including coastal/marine life history phases).
Water quality	➢ Effects of degraded water quality on taonga species populations (including cyanotoxins).
Pest fish and plants	➢ Impacts of didymo on taonga freshwater species (and safe to harvest/customary harvest preferences). ➢ Impacts of exotic macrophytes and exotic fish species on taonga freshwater species.
Recruitment/juvenile abundance	➢ Very little is known about the marine life stage requirements of tuna, whitebait, lamprey, mullet, black flounder (including migration pathways, diet, predators). ➢ Relationships between the number of juvenile taonga species (e.g., īnanga) entering a river and the abundance of adults. ➢ Drivers influencing the densities, distributions and habitat preferences of juvenile taonga species life stages. ➢ Recruitment/abundance trends for all taonga species (across spatial and temporal scales). ➢ Characterise larval production relative to adult kōkopu populations. ➢ What is the distribution of larval kanakana/piharau and does their habitat preferences change with size? Do catchment management practices (e.g., drain clearing) remove larval habitats and larvae, which in turn reduces the cue needed for adult fish to enter the stream to spawn? ➢ Understanding the impact of lake openings on juvenile taonga species recruitment. ➢ Determine impacts of degraded waterways on the mortality rates of juvenile taonga species (e.g., due to reduced food availability and predation). ➢ The timing of recruitment of black flounder is not completely understood. Little is known about the life cycle of the black flounder. ➢ Continuing support is needed to improve juvenile kākahi "grow-out" in laboratory cultures to supply restocking, research and biofiltration efforts – the initial break-throughs have been made, but refinement is needed to expand capacity. ➢ Improvements to laboratory-based juvenile kōura grow-out techniques are needed to improve survival of this early life stage and support aquaculture, restocking and research.

Table 25: Continued.

Area	Research needs include
Population abundance and distribution	➢ Studies that increase knowledge of the geographical distribution and location of remaining populations (especially kākahi species, black flounder). ➢ Internationally it is known that a proportion of any eel population may reside in estuaries, lagoons and coastal waters, rarely, if ever entering freshwaters. The level of estuarine habitat use by Aotearoa-NZ tuna populations is currently unknown. ➢ Examine impacts of removing large female longfin eels on ecosystems. ➢ Determine the influence of modified landscapes on kōkopu production. ➢ Are North and South Island lamprey forming separate populations? ➢ What host species do lamprey feed on whilst in the ocean and how does this influence their dispersal and subsequent re-entry to freshwater? ➢ The current distribution of kōaro in lakes is poorly understood. The number of extant stream populations of adults is unknown and surveys are required to identify the streams where tributary populations are still present and can be secured (e.g., through removal of trout, protection of riparian vegetation, and/or maintenance of stream habitat) to provide safe sanctuaries for this species. ➢ Evidence for the role of smelt in the decline of kōaro in lakes is still circumstantial. More conclusive proof of this is required. ➢ The habitat preferences and seasonal movements of adult kōaro in lakes are poorly understood. For example, they once made use of subterranean springs in the Te Arawa Lakes, but whether this was for spawning or to find refuge from hot summer water temperatures in lakes is not yet clear. ➢ A method of accurately assessing smelt abundance is a fundamental management tool. It is required to identify the main factors affecting smelt abundance and to determine the success or not of any restoration measures. Acoustic methods have been developed but will require calibration. ➢ Identification skills need to be improved when it comes to Stokell's smelt, because it is highly likely that this species is regularly recorded as common smelt. This is because the two species are difficult to tell apart in the field. ➢ Fundamental information on smelt population dynamics in lakes is lacking. For example, in the Te Arawa Lakes it is not known whether smelt numbers are limited in autumn by a reduction in planktonic food supply or by heavy trout and shag predation. Shags may play an important role in controlling smelt numbers in shallow lakes such as Rotorua, but not in the deeper lakes where smelt schools can evade predation by moving into deeper water during the day. ➢ Variations in year class strength related to either climate-related variations in spawning success and/or to variations in growth and mortality rates are also likely to have a large impact on smelt abundance. The role of these factors in smelt population abundance needs to be determined. ➢ There is very little information on the abundance and distribution of black flounder in our estuaries and rivers. ➢ The relative importance of water quality vs habitat quality vs predation effects on determining kōura abundance needs to be quantified. ➢ Interaction between kōura and macrophyte beds is a poorly investigated area. ➢ The interaction between kōura and elver stocking rates in hydrolakes with trap and transfer programmes is a poorly investigated area. ➢ A suite of national taonga freshwater species monitoring protocols and data management systems should be developed for different environments (e.g., shallow/deep lakes, rivers, wadeable streams), purposes (e.g., presence/absence *vs.* population characterisation), and users (e.g., community groups, councils, fisheries managers).
Parasites and disease	➢ To the best of our knowledge, there are no regular surveillance programmes monitoring the incidence of pathogen/parasite prevalence in our freshwater taonga species populations. ➢ Impacts of parasites and disease (e.g., in populations/areas of high stocking rates) of taonga species populations.

Table 25: Continued.

Area	Research needs include
Reproductive success	➢ Determine effects of pollutants on taonga species life stages, e.g., flame retardants, pharmaceuticals, endocrine disrupter chemicals, nanoparticles. ➢ There are concerns about a decline in the number of large longfin female eels in Aotearoa-NZ's fishery and what impact this might have on spawning escapement. An assessment of the size and age structure of eel populations in the 1990s emphasises that the number of large (>700 mm) female longfins has significantly reduced in comparison to observations made prior to, or during, the 1970s. The length frequency distributions of eels caught by commercial fishers in recent years throughout the country shows that fewer large eels are being caught. The level of egg production to ensure sufficient recruitment of Aotearoa-NZ tuna populations is currently unknown. ➢ Sexual development in the longfin is considerably more advanced than the shortfin at the beginning of migration, suggesting that the longfin spawning grounds may be much closer than those of the shortfin. The exact location of tuna spawning grounds is unknown. ➢ The exact proportion of eels escaping to spawn from fished and unfished areas is unknown. ➢ Examine whitebait escapement under different levels of exploitation. ➢ Identify and quantify giant kōkopu spawning habitats. ➢ Identify the areas important to adult lamprey relating to the 15 months adults spend in the freshwater environment. What is the habitat used by adult kanakana when maturing prior to spawning? Where are lamprey spawning? Does this vary between stream systems? ➢ Increase knowledge of the variables that influence kōaro life history in lakes. The most important of these is whether or not kōaro spawn within lakes, and if so, what physical conditions (depth, substrate etc.,) are needed for this. If spawning is only possible in inlet streams, loss of stream spawning habitat may prove to be a significant limiting factor in lakes where most of the catchment has now been converted to pasture. ➢ The location, size and use of beach spawning habitats by smelt. Spawning habitat is thought to be the main physical bottleneck controlling smelt density in lakes and knowledge of this is required to underpin management decisions on smelt conservation. ➢ Mullet place-specific spawning habitats. ➢ We need to increase our understanding of kōura breeding, recruitment and survivorship in different types of lakes/streams in order to be able to predict the effects of harvesting (should revitalising kōura harvest be an aspiration of iwi/hapū). ➢ Determine whether the host-parasite relationship between kākahi and native fish is transferable to introduced fish species. ➢ Develop techniques to produce juvenile freshwater taonga species in the laboratory and/or farm-reared populations (e.g., for research, restoration and/or commercial aquaculture purposes).
Restoration	➢ Optimum approaches (e.g., densities) for effective taonga species translocation and/or restocking, including the identification of source populations, monitoring and evaluating success.
Extent of harvest	➢ There are no regular surveys of recreational and customary harvest for most of the freshwater taonga species included in this report. ➢ Establish a monitoring programme for black flounder commercial harvest. ➢ Examine the impact of whitebait harvest on the abundance of mature adult īnanga.
Safe to eat	➢ A risk assessment process that is relevant to customary harvesters and consumers has been developed with whānau from Te Arawa, Arowhenua and Te Waihora, and could be applied more widely. This approach will provide information about the probable nature and distribution of the health risks for consumers associated with various contaminants and contaminant levels in taonga freshwater species.
Safe to harvest	➢ Development of a holistic approach to support iwi/hapū/whanau to monitor/evaluate this is required.

16 Acknowledgements

In addition to published journal papers and client reports, NIWA web-based information sources like Kaitiaki Toolz[84], Tuna Information Resource[85], Guide to restoring kōura (freshwater crayfish) in lakes, rivers and streams[86], and the Atlas of New Zealand Freshwater Fishes[87] were used to compile this report. We would like to thank the authors of these resources, including Bob McDowall, Jody Richardson, John Quinn, Ian Kusabs, Ngaire Phillips, Don Jellyman and Jacques Boubée, for the use of these materials.

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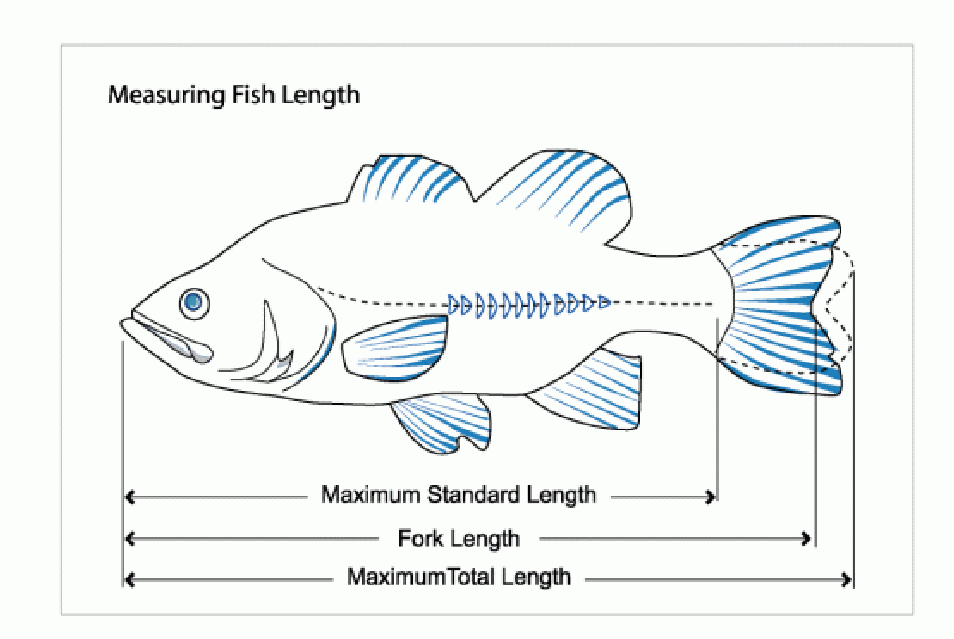
[84] https://www.niwa.co.nz/freshwater/management-tools/water-quality-tools/kaitiaki-tools
[85] https://www.niwa.co.nz/te-kuwaha/tools-and-resources/tuna-information-resource
[86] https://www.niwa.co.nz/freshwater-and-estuaries/management-tools/restoration-tools/guide-to-restoring-k%C5%8Dura-freshwater-crayfish-in-lakes-rivers-and
[87] https://www.niwa.co.nz/freshwater-and-estuaries/nzffd/NIWA-fish-atlas

17 Glossary: Abbreviations and Scientific Terminology

Adipose eyelid	Is the thick fleshy eyelid that forms an oval, vertical slit over the pupil on the grey mullet.
Alkaline	Having a pH greater than 7.
Amphidromous	Undertake a migration between fresh and salt water for a purpose other than breeding
Anadromous	Anadromous fishes spend most of their adult lives at sea, but return to fresh water to spawn (e.g., piharau/kanakana).
Anoxic	Depleted of oxygen.
Catadromous	Catadromous fishes spend most of their adult lives in fresh water and return to the sea to spawn (e.g., tuna).
CHI	Cultural Health Index.
CKS	Cultural Keystone Species.
Climate change	Research suggests that New Zealand is likely to experience changes in the occurrence of droughts, rainfall patterns and evaporation rates which in turn are likely to impact water flows and water availability. Irrigation pressures are likely to increase on the east of both main islands and in some areas water quality is likely to deteriorate due to lower flows in rivers and streams. Higher water temperatures are also likely to increase the frequency of algal blooms.
Confidence interval (CI)	A confidence interval is a range of values we are fairly sure our true value lies within.
CoRE	Centres of Research Excellence.
Cyanobacteria / cyanotoxins	The blooms of certain algal species pose a risk to public (human and animal health) as the chemicals (cyanotoxins) released into the water when the cyanobacteria (blue-green algae) die are toxic.
DDS	Decision support system.
Diadromous	Describes fish that spend portions of their life cycles partially in fresh water and partially in salt water. These represent both anadromous and catadromous fish.
Dissolved oxygen (DO)	Dissolved oxygen (DO) is an indicator of the health of freshwater ecosystems and is a measure of the amount of oxygen dissolved in water. Typically the concentration of dissolved oxygen in surface water is less than 10 mg/l (unit conversion 1 g/m^3 = 1 mg/l = 1 ppm). Fish and other aquatic life require dissolved oxygen to breathe. Water should be >80% saturated with dissolved oxygen for aquatic plants and animals to thrive in it. When dissolved oxygen levels are depleted, aquatic animals can become stressed and die. Oxygen depletion is commonly caused by organic pollutants breaking down in waterways, elevated water temperatures or night-time respiration by dense algal blooms in nutrient-rich waters. Under natural conditions, dissolved oxygen levels will fluctuate, sometimes considerably, over a daily (or diurnal) period.
DOC	Department of Conservation.
Dorsal fin	The fin on the back (or top) of a fish.
DSS	Decision Support System.
EPA	Environmental Protection Authority.
ESA	Eel Statistical Area.
FLA	Flatfish.

Fork length	Is the length of a fish measured from the tip of the snout to the end of the middle caudal/tail fin ray.



(Source: http://www.fsl.orst.edu/geowater/FX3/help/9_Fish_Performance/Measures_of_Fish_Length.htm)

Genera	A group of organisms ranking above a species and below a family.
GLM	Generalised Linear Models.
GMU	Grey mullet.
Homing	Is the ability of an animal to navigate towards an original location through unfamiliar areas.
Hypolimnion	The lower layer of water in a stratified lake, typically cooler than the water above and relatively stagnant.
IMP	Iwi Management Plan.
IUCN	International Union for Conservation of Nature.
Land-locked	Fish population cut off from the sea and now confined to a lake or reservoir where it has adapted over time to complete its life cycle in that waterbody.
LFE	Longfin eel.
Limnetic zone	Is the well-lit, open surface waters in a lake, away from the shore.
LINZ	Land Information New Zealand.
Littoral (of lakes)	Near the lake shore.
Macrophyte	An aquatic plant large enough to be seen by the naked eye.
MBIE	Ministry of Business, Innovation and Employment.
MFAT	Ministry of Foreign Affairs and Trade.
MfE	Ministry for the Environment.
Microsporidian	Microsporidia are a group of spore-forming unicellular (one celled) parasites.
MMTB	Maniapoto Māori Trust Board.
MPI (and MFish)	Ministry for Primary Industries (formerly comprised of the Ministry of Fisheries).

Natal homing	Is the homing process by which some adult animals return to their birthplace to reproduce.
NES	National Environmental Standard.
Neuston	Small aquatic organisms inhabiting the surface layer of the ocean.
Non-diadromous	A fish that spends their whole life in fresh water.
NPS	National Policy Statement.
NPS-FM	National Policy Statement for Freshwater Management.
NTU	Turbidity values are generally reported in Nephelometric Turbidity Units (NTU).
Nutrients	Aquatic plants need different nutrients for growth, including nitrogen (N) and phosphorus (P). However, increased levels of these nutrients in waterways can cause excessive plant growth rates, which can lead to blooms of algae and nuisance weeds. Excessive algal or weed growth can reduce the ability to use water bodies and affect stock, fish and other aquatic animals. The level of nutrients in our rivers is influenced by natural factors such as catchment geology, rainfall and river flow patterns. However, land use also has a large influence. In urban waterways the main source of nutrients is human wastewater (sewage) while in rural environments, agricultural fertilisers, stock manure and urine are the major non-point sources of N and P. The erosion of soil also contributes significant amounts of soil-bound P to waterways. The primary indicators of nutrient concentrations are N, P and ammoniacal nitrogen.
NZFFD	New Zealand Freshwater Fish Database https://www.niwa.co.nz/our-services/online-services/freshwater-fish-database
OCL	Orbit-Carapace Length.
Otolith	Otoliths are more commonly known as the “ear bones” of fish, and are located directly behind the brain of bony fishes, including freshwater eels. They are hard calcium carbonate structures which help with balance and hearing/detection. Otoliths can be used to age fish.
Parasite	A relationship between species, where one species, the parasite, benefits at the expense of the other, the host.
Pathogen	A microorganism, such as a virus, bacterium, prion, fungus or protozoan, that causes disease in its host.
PCE	Parliamentary Commissioner for the Environment.
Plankton	Small microscopic organisms drifting/floating in fresh water (e.g., diatoms, protozoans, small crustaceans).
pH	This is the measurement of the hydrogen-ion concentration in the water. A pH below 7 is acidic (the lower the number, the more acidic the water, with a decrease of one full unit representing an increase in acidity of ten times) and a pH above 7 (to a maximum of 14) is basic (the higher the number, the more basic the water). Typically, natural fresh waters have a ‘normal’ pH range from 6.5 to 8.5. High pH values tend to facilitate the solubilisation of ammonia (NH_3 – which is toxic), heavy metals and salts, whereas low pH levels tend to increase carbon dioxide and carbonic acid concentrations. Lethal effects of pH on aquatic life typically occur below pH 4.5 and above pH 9.5.
Pheromone	Is a chemical substance produced and released into the environment by an animal that affects the behaviour or physiology of others of its species.
QMS	Quota Management System.
Recruitment (of fish)	Is the number of fish surviving to enter the fishery, or to some life history stage such as settlement or maturity.

Relative abundance	As it is often difficult to identify the total number of fish in a population (known as absolute abundance), a relative measure of the weight or number of fish in a stock, a segment of the stock (e.g., the spawners), or an area (relative abundance), is used instead.
RMA	Resource Management Act.
SIG	Regional Council Special Interest Group.
SFE	Shortfin eel.
SOB	Size at Onset of Breeding.
SSE	Sen Slope Estimator.
Suspended solids (SS)	Suspended solids (SS) is the amount of particulate matter that is suspended within the water column, where the values are typically reported in mg/L. High concentrations of non-filterable residue increases turbidity, thereby restricting light penetration. Suspended material can result in damage to fish gills. Settling suspended solids can also cause impairment to spawning habitat by smothering fish eggs.
SWIM	Regional Council Special Interest Group – Surface Water Integrated Management.
TAC	Total Allowable Catch.
TACC	Total Allowable Commercial Catch.
Taxonomy	Branch of science concerned with the classification of organisms.
Turbidity	Soil erosion is a common cause of low levels of water clarity in Aotearoa-NZ rivers and streams. This may be due to poorly managed farmland (e.g., unprotected stream banks and sediment run-off from paddocks). Urban development and harvesting of plantation forestry can also produce high volumes of sediment run-off. Natural factors (e.g., geology) can also determine clarity. For example, the low level of clarity in the Waipaoa River is caused by the geology of the catchment. Visibility of more than 10 m is common in the country's clearest rivers (the upper Motueka, Clutha, and Monowai Rivers). Turbidity is a measurement of the suspended particulate matter in a water body which interferes with the passage of a beam of light through the water. Materials that contribute to turbidity are silt, clay, organic material, or micro-organisms. Turbidity values are generally reported in Nephelometric Turbidity Units (NTU). Pure distilled water would have non-detectable turbidity (i.e., 0 NTU). High levels of turbidity reduces light penetration; therefore, it impairs photosynthesis of submerged vegetation and algae. In turn, the reduced plant growth may suppress fish productivity.
USEPA	United States Environmental Protection Authority.
Water clarity	Water clarity is how far you can see through the water. Turbidity and water clarity are closely and inversely related. It provides an indication of the levels of suspended sediment (i.e., fine soil particles which remain in the water for a considerable period of time without contact with the bottom). High water clarity indicates low levels of suspended sediment. A river or lake with low clarity will have murky water, which may indicate significant erosion in the catchment (producing suspended sediment) or abundant algal growth in the water. Murky water prevents sunlight penetrating (light penetration), and sediment can smother aquatic habitats affecting the feeding and spawning of fish and other animals, as well as the growth rates of plants.

Water temperature	If water temperatures increase beyond their usual ranges for too long, plants and animals in waterways can become stressed and die. Low elevation streams and rivers in Aotearoa-NZ typically have a water temperature that fluctuates within the range 10–20°C across seasons. The water temperature in unshaded shallow streams may rise to nearly 30°C in the peak of summer. Temperature changes can be caused by changes in climate or by human activities such as removing stream-bank vegetation, storing water in dams or discharging heated or cooled water after it has been used in industrial processes (for example, in power generation). Taking too much water from a river or stream can also increase its temperature.
WCP	Waipā Catchment Plan.
WSSE	Weighted Sen Slope Estimator.
YEM	Yellow-eyed mullet.

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Introduction

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Research Needs

Nobel, M., Duncan, P., Perry, D., Prosper, K., Rose, D., Schnierer, S., Tipa, G., Williams, E., Woods, R., Pittock, J. (2016) Culturally significant fisheries: social-ecological keystones in freshwater ecosystems. *Ecology & Society*: 22. Available via: http://www.ecologyandsociety.org/vol21/iss2/art22.

Appendix A Identification of Fishes

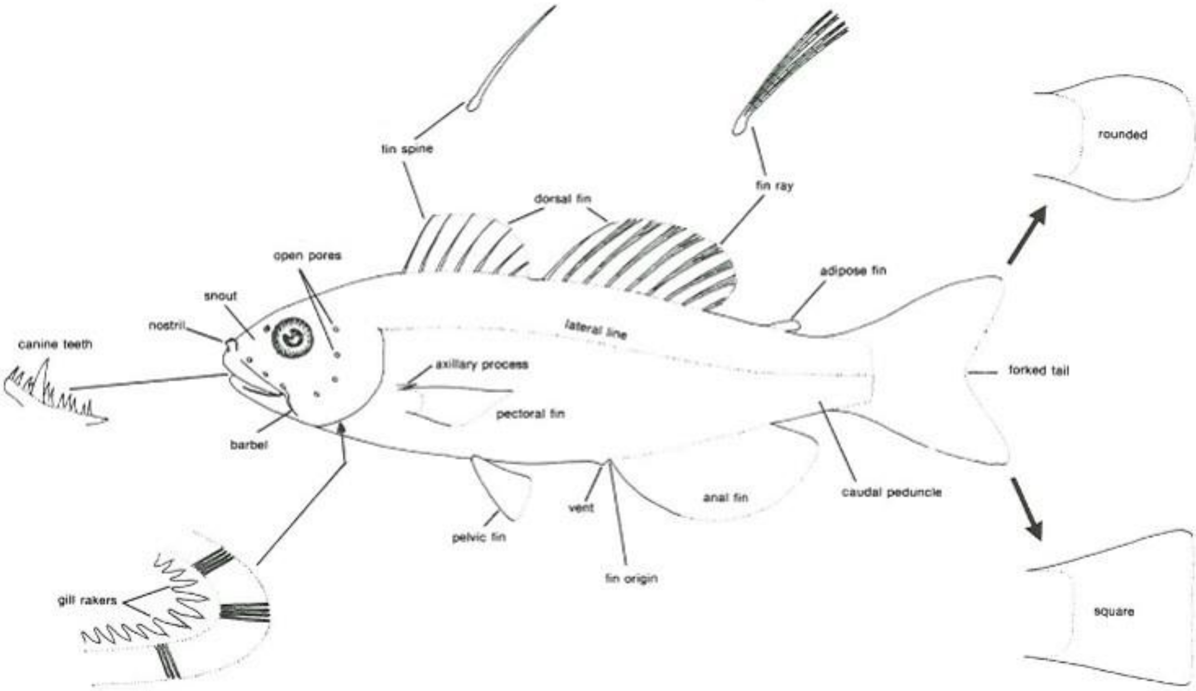

Figure A1: Key features of fish anatomy that are used for identification. (Source: McDowall 2000).

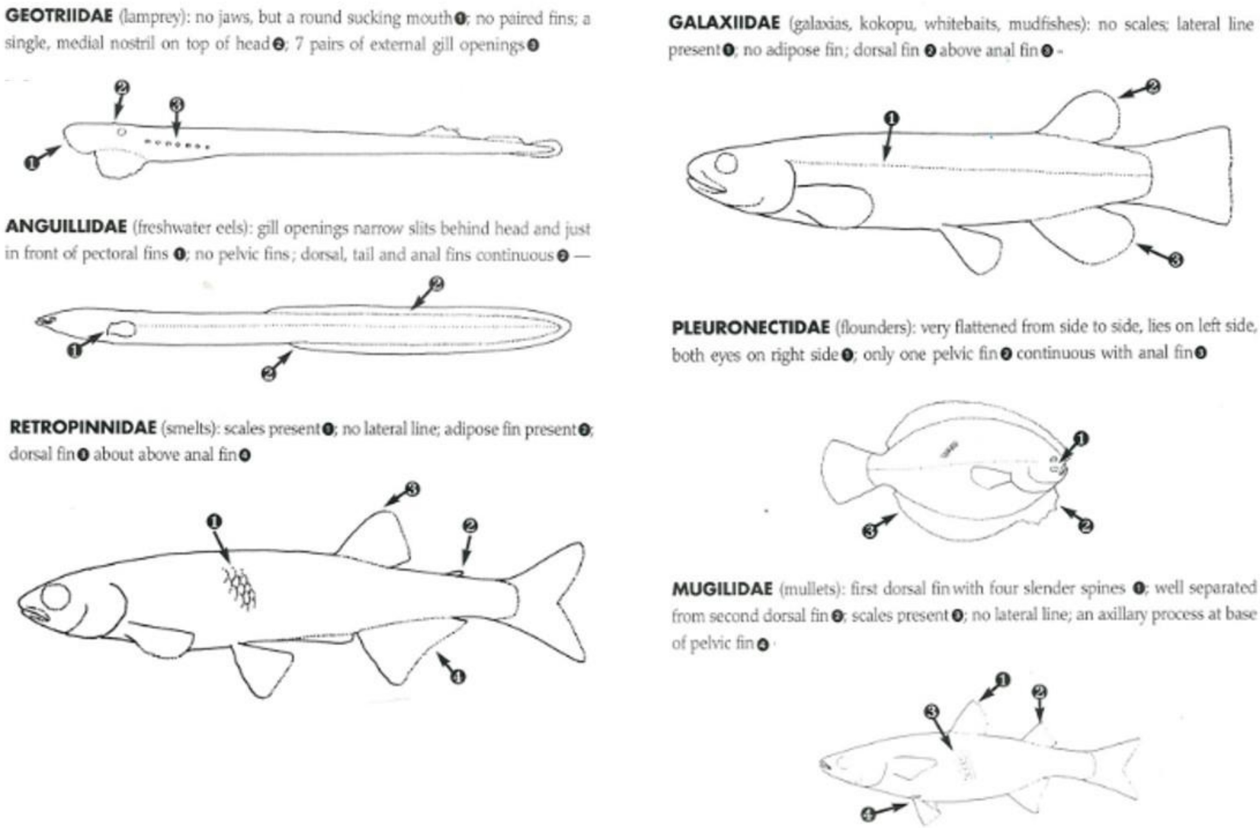

Figure A2: Key features used for the identification of the fish species contained in this report. (Source: McDowall 2000).

Appendix B Sen Slope Estimator Results

Crow et al. (2016) used the NZFFD to generate trends in the relative abundance of 11 species from 1977–2015. The authors also used generalised linear models (GLM) to reduce the influence of sampling bias on these trends, making the results more reliable. The plots from Crow et al. (2016) are reproduced in the present report for all fish where results are available. Each plot shows how the characteristic probability of capture changes through time (produced from the GLM), along with three simple linear regression lines. The simple linear regression lines are fitted over three time periods: 1977–2015, 1977–1994 and 1995–2015. Crow et al. (2016) also completed the simple linear regression calculations using two different techniques. The first technique was the Sen Slope Estimator (SSE), while the second technique was a weighted version of the SSE. The weighted SSE (called WSSE hereafter) assigned a weighting value based on the size of the confidence intervals for the probability of capture estimates for years (i.e., the weight was higher for pairs of slopes that, collectively, had narrower confidence intervals). Both WSSE and SSE results were presented by Crow et al. (2016) because they were used to check for consistency in trend results, which is reproduced here. Therefore, the present study shows two plots for each species: one plot showing the SSE results over the three time periods and one plot showing the WSSE results of the three time periods.

For simplicity, we only provide descriptions of the SSE and WSSE results over the 1977–2015 time period because this long-term trend is the most informative for understanding the trends in the fishery. Following suggestions of Larned et al. (2015), SSE and WSSE trends are discussed as being indeterminate [confidence intervals (CI) of the slope include zero] or inferred with confidence (confidence intervals of the slope did not include zero). We refer to SSE and WSSE slopes for which a positive direction was inferred with confidence as 'increasing trends', and SSE and WSSE for which a negative direction was inferred with confidence as 'decreasing trends'.

Table B1: The SSE and WSSE results for the 1977–2015 time period. This table expresses the slope (both SSE and WSS) in units of annual rates of change in probability of capture as %/year. Results are only shown for the species that are included in the present report. CI = Confidence Interval. (Source: Crow et al. 2016).

Species	Sen Slope Estimator (SSE)				Weighted Sen Slope Estimator (WSSE)			
	Slope (%/year)	CI Includes zero	Lower CI	Upper CI	Slope (%/year)	CI Includes zero	Lower CI	Upper CI
Kōaro	-0.01	TRUE	-0.02	0	-0.05	FALSE	-0.07	-0.03
Kōura	0.04	FALSE	0.02	0.07	-0.02	TRUE	-0.06	0.01
Longfin eel	0.01	TRUE	-0.06	0.09	-0.09	FALSE	-0.17	-0.03
Shortfin eel	0.13	FALSE	0.11	0.14	0.18	FALSE	0.17	0.19

Appendix C Example of Pathogens and Parasites Observed in Tuna

Table C1: Examples of pathogens and parasites observed in Aotearoa-NZ tuna populations. While many fish parasites/pathogens are sometimes difficult to see with the naked eye, there are some observations that can be contributed by communities who harvest eels. The presence/absence of visible parasites could be monitored by communities using the parasite infestation index outlined in Richardson (1998), where each individual eel examined receives a parasite infestation ranking between 0 and 3 (Photos: Jacques Boubée, Erica Williams, Jane Kitson).

	Description	Photo
Species	Longfin	
Pathogen/parasite	Nematode, *Anguillicola (novaezelandiae?)*	
Site of infection	Swim bladder	
Location	Kaikou River	
Observer	Erica Williams, Jacques Boubée	
Date	November 2008	
The life cycle begins when the adult nematode releases thousands of eggs in the eel's swim bladder. The eggs pass through the digestive tract and the larvae emerge in the water and settle on the bottom. They are eaten by their intermediate host, which could be a copepod or a fish. The larva reaches its infective stage within the intermediate host. The host is eaten by an eel, and the nematode finds its way from the digestive tract to the swim bladder. An eel with an advanced parasite load shows symptoms such as bleeding lesions and swim bladder collapse. The eel becomes more susceptible to disease, its rate of growth slows, and if the infestation is severe enough, it may die. Since the swim bladder is the buoyant organ which allows the eel to swim, a severe infestation can hamper its ability to reach its spawning grounds (Source: Wikipedia). **Monitoring suggestion:** Record the number of worms seen. According to scale suggested by Richardson (1998) this eel would receive a ranking of 1.		
Species	Longfin	
Pathogen/parasite	Unidentified	
Site of infection	Stomach wall	
Location	Mangakāhia River	
Observer	Erica Williams, Jacques Boubée	
Date	February 2013	
Observation: Black marking along body cavity. Feels like gritty sand. Cause not diagnosed. **Potential action:** Take photos and preserve sample in 75% alcohol or 4% formalin. Send photo/sample to the National Centre for Biosecurity and Infectious Disease (http://www.ncbid.govt.nz/) for identification. **Monitoring suggestion:** According to scale suggested by Richardson (1998) this eel would receive a ranking of 2.		

Table C1: Continued.

	Description	Photo
Species	Shortfin	
Pathogen/parasite	Protozoa, *Myxobolus* sp.	
Site of infection	Skin	
Location	Lake Arapuni	
Observer	Jacques Boubée	
Date	February 2012	
Cysts (up to 8 mm in diameter) and pits caused by burst cysts occurs on eel throughout the country although infection as severe as the one shown on the photograph are rare (Hine & Boustead 1984). **Monitoring suggestion:** According to scale suggested by Richardson (1998) this eel would receive a ranking of 3.		
Species	Shortfin	
Pathogen/parasite	Shagworm, *Eustrongylides* sp.	
Site of infection	Stomach, intestine	
Location	Lake Whakamaru	
Observer	Jacques Boubée	
Date	February 2012	
The intermediate stage of this worm is passed in the body-cavity and the flesh of fishes, and maturity is reached in predatory birds. The immature worms, which are red in colour and attain a maximum length of approximately 60 mm are usually coiled in cysts attached to various organs within the body-cavity of the fish, but most frequently to the outer surface of the stomach (Stokell 1936). **Monitoring suggestion:** According to scale suggested by Richardson (1998) this eel would receive a ranking of 3.		
Species	Unidentified juvenile eel	
Pathogen/parasite	Unidentified	
Site of infection	Unidentified	
Location	Oreti River	
Observer	Jane Kitson	
Date	February 2013	
Observation: Large distension and reddening. Cause not diagnosed. **Potential action:** Take photos and preserve sample in 75% alcohol or 4% formalin. Send photo/sample to the National Centre for Biosecurity and Infectious Disease (http://www.ncbid.govt.nz/) for identification. **Monitoring suggestion:** According to scale suggested by Richardson (1998) this eel would receive a ranking of 2.		

Appendix D Trends in Shortfin (SFE) and Longfin (LFE) CPUE indices by ESA

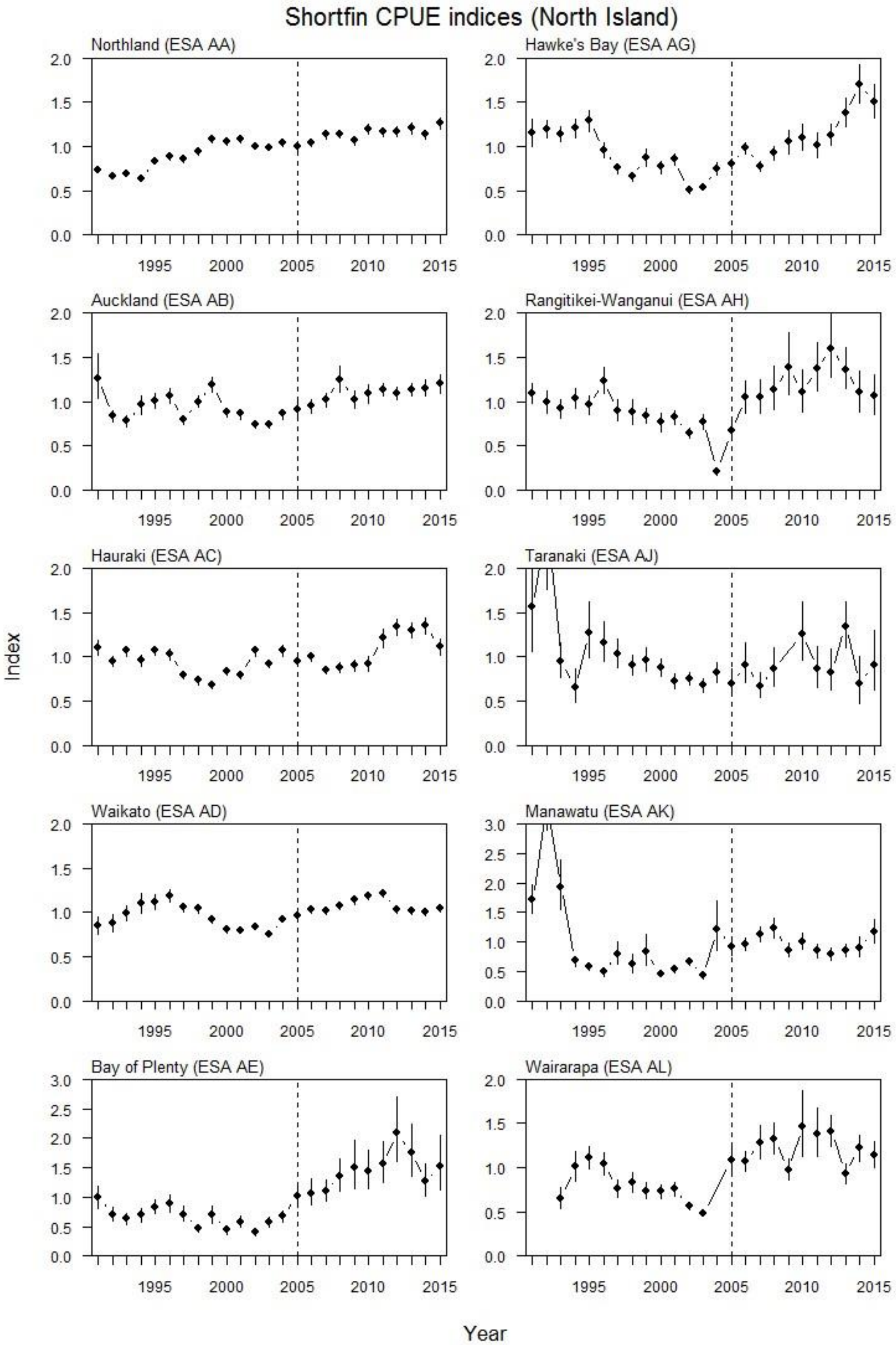

Figure D1: Trends in North Island shortfin CPUE indices for all North Island ESAs from 1990–91 to 2014–15, except Poverty Bay (AF) and Wellington (AM) where there was insufficient data. Vertical dotted line indicates the introduction to the QMS in 2004–05. (Source: MPI 2017; from Beentjes & McKenzie in prep).

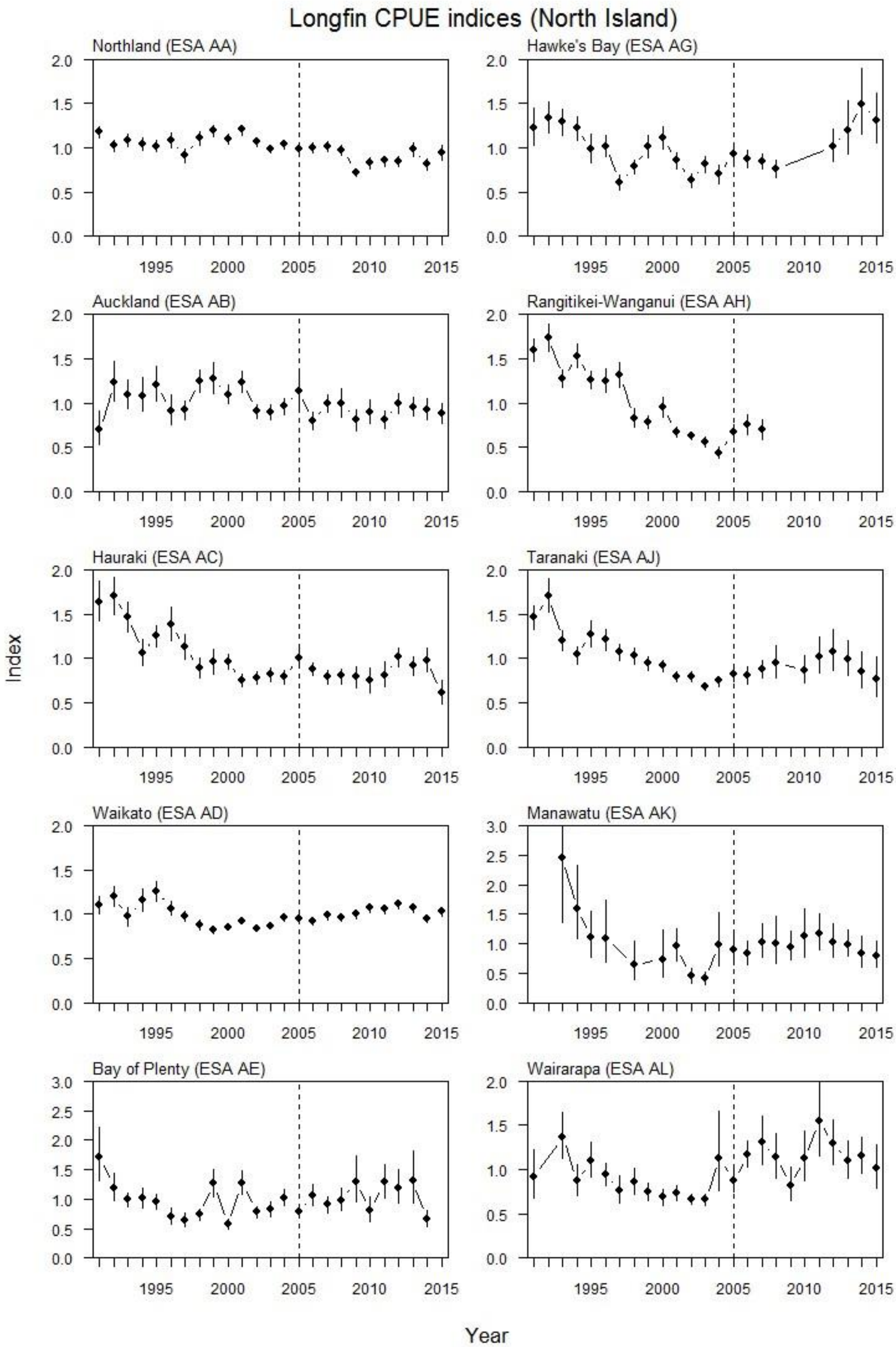

Figure D2: Trends in North Island shortfin CPUE indices for all North Island ESAs from 1990–91 to 2014–15, except Poverty Bay (AF) and Wellington (AM) where there was insufficient data. Vertical dotted line indicates the introduction to the QMS in 2004–05. (Source: MPI 2017; from Beentjes & McKenzie in prep).

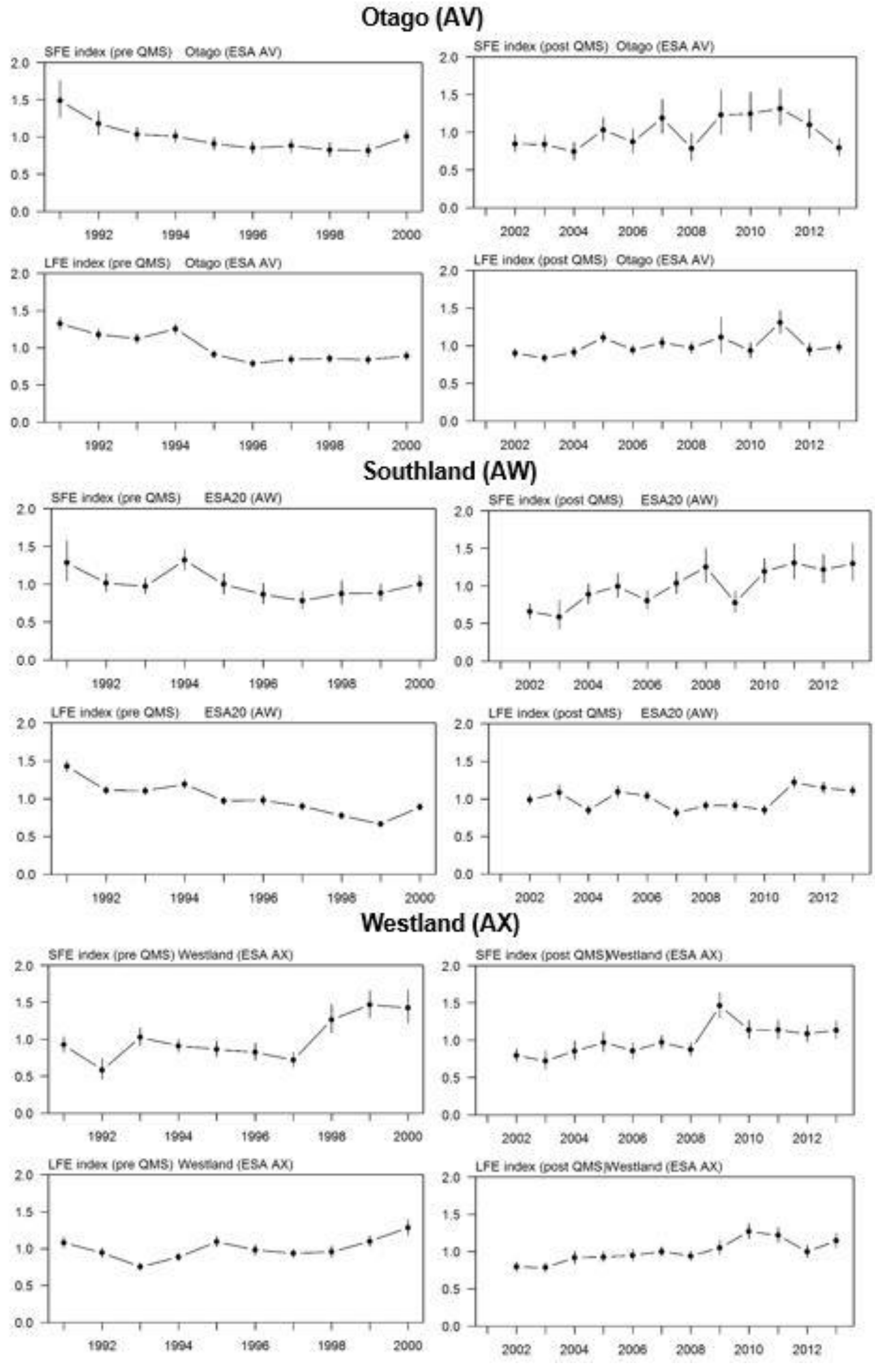

Figure D3: Trends in South Island shortfin and longfin CPUE indices for key ESAs: Otago (AV), Southland (AW), and Westland (AX). Separate indices are presented for pre-QMS (1991–2000) and post-QMS (2002–2013). SFE = shortfin eel; LFE = longfin eel. (Source: Beentjes & Dunn 2015, MPI 2017).

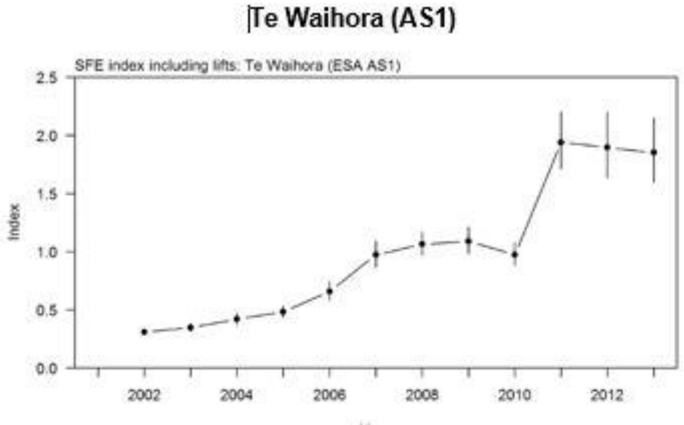

Figure D4: Te Waihora shortfin CPUE indices for AS1 (outside migration area) from 2001–02 to 2012–13. SFE = shortfin eel; ESA = Eel Statistical Area. (Source: Beentjes & Dunn 2015, MPI 2017).

Appendix E Funding Landscape

Table E1: An overview of funding opportunities that could be influenced/leveraged by Te Wai Māori to support freshwater taonga species research, capacity/capability building of Māori communities and scientists, and the implementation of restoration actions.

Fund	Description	Agency	Recipients	Website
Performance-based Research Fund	Funds research and research-based teaching in tertiary education organisations based on the measured quality of research.	Tertiary Education Commission	Tertiary education organisations	http://www.tec.govt.nz/funding/funding-and-performance/funding/fund-finder/performance-based-research-fund/
Centres of Research Excellence (CoREs)	Funds for co-operative tertiary research in areas of research strength. A total of 10 CoRES have been funded to 2020. Of these, only Ngā Pae o te Māramatanga has the potential to development new capacity/capability/knowledge of benefit to freshwater/marine environmental research.	Tertiary Education Commission	CoRE partnerships	http://www.tec.govt.nz/funding/funding-and-performance/funding/fund-finder/centres-of-research-excellence/
Marsden Fund	Encourages leading researchers to explore new ideas that may not be funded through other funding streams and fosters creativity and innovation within the research, science and technology system.	Royal Society of NZ	Researchers	https://royalsociety.org.nz/what-we-do/funds-and-opportunities/marsden
Crown Research Institute	Direct core funding enables Crown Research Institutes to contribute to the outcomes of their Statements of Core Purpose. For example, in 2015/16 NIWA's Freshwater and Estuaries Centre and Te Kūwaha (Māori Environmental Research) received $4.05M and $0.5M respectively.	MBIE	CRIs	e.g., https://www.niwa.co.nz/sites/niwa.co.nz/files/NIW11984_SCI2015_11F_web.pdf
National Science Challenges	Are significant mission-led investments that focus on defined issues of national importance. The National Science Challenges that should be open to supporting taonga species research priorities (doesn't mean that they are) include: New Zealand's Biological Heritage; Sustainable Seas; Our Land and Water; and The Deep South.	MBIE	NSC collaborations, includes public and private research organisations	http://www.mbie.govt.nz/info-services/science-innovation/national-science-challenges

Table E1: Continued.

Fund	Description	Agency	Recipients	Website
Endeavour Fund	Research that has high potential to positively transform New Zealand's future, economically, environmentally and socially, and give effect to Vision Mātauranga, in line with MBIE's National Statement of Science Investment 2015–2025.	MBIE	Research organisations	http://www.mbie.govt.nz/info-services/science-innovation/investment-funding/how-we-invest/endeavour-fund
Vision Mātauranga Capability Fund	Invests in development of skilled people and organisations undertaking research to unlock the innovation potential of Māori knowledge, resources and people.	MBIE	Research organisations; precedents for iwi/hapū/Māori leadership	http://www.mbie.govt.nz/info-services/science-innovation/investment-funding/current-funding/2017-vmcf-investment-round
Science in Society	Invests in encouraging greater engagement with science and technology across all sectors of New Zealand to ensure the public can benefit from advances in science and technology and deliver on the objective and outcomes of *A Nation of Curious Minds.*	MBIE	Communities of interest; precedents for iwi/hapū/ Māori leadership	http://www.curiousminds.nz/actions/
Envirolink Tools	Envirolink is a regional council driven funding scheme. It funds research organisations to provide regional councils with advice and support for research on identified environmental topics and projects. The scheme aims to support regional councils in two areas of environmental management: adapting management tools to local needs, and translating environmental science knowledge into practical advice.	MBIE	Research organisations	http://www.envirolink.govt.nz/
Fisheries Research	Funds stock assessment, aquatic environment and biodiversity research that underpin MPI and ministerial decisions to meet the requirements of the Fisheries Act, relevant policy and international obligations.	MPI	Research organisations, via MPI working groups, e.g., Eel Working Group	Via MPI Working Group processes
Customary Fisheries Research	To assist customary fisheries managers to undertake fisheries research. It's also to enable tangata whenua who are working towards gazettal, or are currently gazetted, under the Kaimoana Customary Fishing Regulations 1998 or the South Island Customary Fishing Regulations 1999.	MPI	Communities of interest	https://www.mpi.govt.nz/funding-and-programmes/Māori-in-the-primary-industries/customary-fisheries-research-fund/

Table E1: Continued.

Fund	Description	Agency	Recipients	Website
Sustainable Farming Fund	Supports applied research and extension projects led by farmers, growers, or foresters (e.g., tuna and kōura aquaculture).	MPI	Communities of interest; precedents for iwi/hapū/ Māori leadership	https://www.mpi.govt.nz/funding-and-programmes/farming/sustainable-farming-fund/
Freshwater Improvement Fund	Commitment over 10 years to improve the management of New Zealand's lakes, rivers, streams, groundwater and wetlands. It supports projects that help communities manage fresh water within environmental limits. Preference given to "vulnerable catchments" impacted by primary industries. Covers 50% of the total project cost.	MfE	Communities of interest, including regional councils and DOC. Precedents for iwi/hapū/ Māori leadership	http://www.mfe.govt.nz/more/funding/freshwater-improvement-fund Summary of projects funded in 2017: http://www.mfe.govt.nz/more/funding/freshwater-improvement-fund/freshwater-improvement-fund-projects
Community Environment Fund	Empowers New Zealanders to take environmental action by funding projects that: strengthen environmental partnerships; raise environmental awareness; and encourage participation in environmental initiatives in the community.	MfE	Communities of interest	http://www.mfe.govt.nz/more/funding/community-environment-fund/about-cef
Community Fund	Fund is directed at practical, on-the-ground projects. These projects aim to maintain and restore the diversity of our natural heritage and enable more people to participate in recreation, enjoy and learn from our historic places, and engage with and value the benefits of conservation.	DOC	Communities of interest	http://www.doc.govt.nz/doc-community-fund
Ngā Whenua Rāhui Fund	This fund supports the protection of indigenous ecosystems on Māori-owned land while honouring the rights guaranteed to landowners under Te Tiriti o Waitangi. The principles of the fund are geared towards the owners retaining tino rangatiratanga.	DOC	Māori land owners	http://www.doc.govt.nz/nwrfund
Mātauranga Kura Taiao Fund	This fund supports hapū/iwi initiatives to retain and promote traditional Māori knowledge and its use in biodiversity management.	DOC	Māori	http://www.doc.govt.nz/get-involved/funding/nga-whenua-rahui/matauranga-kura-taiao-fund/
Wai Ora Fund	This fund enables iwi and Māori to promote and advance freshwater fisheries development, research and education.	Te Wai Māori	Māori	http://www.waiMāori.Māori.nz/research/purpose.htm

Table E1: Continued.

Fund	Description	Agency	Recipients	Website
Waikato River Authority	This annual fund supports projects to restore the health and wellbeing of the Waikato River catchment.	Waikato River Clean-up Trust	Communities of interest	http://www.waikatoriver.org.nz/
Community Trusts	Fund is directed at practical, on-the-ground projects.	Regional Community Trusts	Communities of interest	e.g., Wellington Community Trust ()
Reconnecting Northland	Reconnecting Northland is the first large-scale ecological restoration programme in Aotearoa-NZ, focusing on the wellbeing of our people and our land.	WWF-NZ, NZ Landcare Trust, Tindall Foundation	Communities of interest	http://reconnectingnorthland.org.nz/about/
Habitat Protection Fund	This fund supports communities to run projects that conserve and restore New Zealand's natural environment - freshwater, coastal, wetlands, forest and dunelands. Gives preference to projects that are working to protect areas of high conservation value.	World Wildlife Fund (WWF), Tindall Foundation	Communities of interest	http://www.wwf.org.nz/what_we_do/community_funding/habitat_protection_fund/
Philantrophic trusts	A range of trusts provide funds for environmental causes. Many are members of Philanthropy NZ.	–	Communities of interest	http://philanthropy.org.nz/grantmaker-members/