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Conservation, ecology and management of migratory galaxiids and the whitebait fishery

A summary of current knowledge and information gaps

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Cover: Juvenile īnanga (*Galaxias maculatus*). *Photo: Mike Hickford.*

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Executive summary

New Zealand has five migratory galaxias species – īnanga (*Galaxias maculatus*), kōaro (*Galaxias brevipinnis*), banded kōkopu (*Galaxias fasciatus*), giant kōkopu (*Galaxias argenteus*) and shortjaw kōkopu (*Galaxias postvectis*). The juveniles of the five species constitute the New Zealand whitebait fishery. A sixth, non-galaxias species – the common smelt (paraki, *Retropinna retropinna*) – is also included in the definition of whitebait in the regulations.

The species and the fishery are managed by the Department of Conservation (DOC) under several pieces of legislation. Regional Councils also play a role in the conservation of these species through managing the adverse effects of resource use on habitat and water quality.

This report summarises current knowledge about migratory galaxiids and the whitebait fishery. Where possible, published literature has been used; where published literature is not available and unpublished reports are accessible these have been cited. Personal communications have also been referenced where unpublished reports or data are not available, but research has been carried out.

Key conclusions of this collation of research and identification of information gaps are:

- The habitat and distribution of all five species are well researched and experts can largely describe their 'preferred' adult habitat and also the habitat conditions they tolerate.
- Excluding īnanga, the spawning habitats of the four other species – kōaro, banded kōkopu, giant kōkopu and shortjaw kōkopu – are poorly documented.
- There is very little conclusive research about the effect of harvest on the five species. Some attempts have been made to collect catch data, but these have largely been unsuccessful and/or inaccurate.
- Recent studies have increased knowledge about the catch composition of species nationally, the spawning habitats of two galaxias species and the ecology and biology of īnanga whitebait migrations.
- There is still a limited understanding of the stock structure and life history of the species, with recent studies suggesting these may vary greatly between species and regions.
- Very little information is available on the larval phase of the migratory galaxiids – where they develop (freshwater or marine environments), their swimming ability, diet and the threats and pressures these tiny fish are subject to.
- The pressures on and threats to these species are relatively well known and documented, although the magnitude of each impact on each species is not well understood.

Critical to the conservation and management of these species and the fishery is collating existing information and identifying gaps, so that decision making about future management can be better informed.

Introduction

New Zealand has five migratory galaxias species – īnanga (*Galaxias maculatus*), kōaro (*Galaxias brevipinnis*), banded kōkopu (*Galaxias fasciatus*), giant kōkopu (*Galaxias argenteus*) and shortjaw kōkopu (*Galaxias postvectis*). The transparent juveniles of these five galaxias species, which move upstream in large shoals mainly in spring, form New Zealand's iconic whitebait fishery. The *Whitebait Fishing Regulations 1994* and the *Whitebait Fishing (West Coast) Regulations 1994* include the young or fry of a sixth species – the common smelt (paraki, *Retropinna retropinna*) in their definition of whitebait. Smelt, however, are viewed by whitebaiters as 'second-class whitebait' (McDowall 1984). The 'true' whitebait species are the migratory galaxiids and these are the focus of this report; however, some data on smelt are also presented.

Management of populations and the whitebait fishery (juveniles) is complex due to the migratory life-cycle of the five species and the many threats and pressures they face at different phases in their lives. Migratory behaviour varies both within and between species depending on the rivers and regions they are migrating from and back into (McDowall & Eldon 1980; Richardson et al. 1994; Boubēe et al. 1997; Rowe & Dean 1998; Baker & Montgomery 2001a; Richardson et al. 2001; Baker & Smith 2015; Egan 2017).

Adults live in most of New Zealand's freshwater habitats from lowland wetlands to high-altitude tarns. They vary from approximately 8–10 cm long (īnanga) up to 60 cm long (giant kōkopu). Some species can migrate considerable distances inland due to their ability to 'climb' large waterfalls as juveniles. All five species have documented land-locked populations, but some species form land-locked populations more frequently than others.

Fishing for whitebait takes place in the lower reaches and mouths of rivers and streams. Methods vary according to location, efficiency, access, tradition and other factors. The fishing community comprises recreational, indigenous, resident, transient and commercial components. As an example, whitebaiting can range from a visitor 'catching a feed' using a scoop net in various places at a river mouth as waves and tides permit to a resident whitebaiter fishing from an elaborate and expensive whitebait stand on a large river who then sells their catch to a whitebait company.

The Department of Conservation (DOC) manages the whitebait fishery by way of two sets of regulations that have evolved and had several iterations since the early 1900s. DOC is also responsible for the conservation and management of the adult whitebait species (the migratory galaxiids) through functions in the Conservation Act 1987 and the Freshwater Fisheries Regulations 1983. Regional Councils also have a role in protection and management of galaxiid species through managing adverse effects of resource use on habitat quality (Willis 2014).

This report summarises current knowledge about migratory galaxiids and the whitebait fishery and identifies where more research is required.

Migratory galaxiid biology and ecology

The migratory galaxiids – īnanga, kōaro, banded kōkopu, giant kokopu and shortjaw kōkopu – are diadromous (spending portions of their life-cycles in both fresh and salt water). More specifically, they are amphidromous (migrating between fresh and salt water, but not for spawning purposes) (McDowall 1990). Adults live and spawn in freshwater habitats (with the exception of īnanga, which spawn in estuarine habitat; McDowall 1990). All five species can also form non-diadromous populations whereby they complete their life-cycles in freshwater, although this occurs less commonly than diadromous behaviour for some species. Once laid, eggs develop for approximately 3–4 weeks before larvae hatch and are swept downstream into estuarine, marine or lacustrine habitats where they feed and grow for 4–6 months (McDowall et al. 1975, 1994; McDowall & Kelly 1999); juvenile fish (also commonly known as whitebait) then move back upstream to adult habitat.

Spawning

The spawning seasons of the whitebait species are generally well known, as are the spawning habitat preferences of īnanga. However, there is only limited knowledge of the habitats utilised for spawning by the other four whitebait species. In addition, the extent of variation in timing of the spawning season is still not well understood for all species. It is likely that spawning for each species varies throughout New Zealand – between the two main islands, regions and rivers. Temporal variation from year to year also occurs. Tables 1 & 2 summarise current knowledge about the spawning seasons and habitat of each of the five migratory galaxias species.

Table 1. Spawning season and known and potential spawning habitats of New Zealand's five migratory galaxias species (Petrove et al. (DOC) unpubl. report; Smith 2015).

SPECIES	SPAWNING SEASON	KNOWN SPAWNING HABITAT	OTHER POTENTIAL HABITATS
Īnanga	December to July (peak March to June).	Dense vegetation that retains moisture (McDowall 1990; Mitchell 1990; Baker 2006; Hickford & Schiel 2011a; Hickford et al. 2017). Plant species that are favoured for spawning include: • *Carex* species • Creeping bent (*Agrostis stolonifera*) • Mercer grass (*Paspalum distichum*) • Kikuyu (*Pennisetum clandestinum*) • Wandering willie (*Tradescantia fluminensis*) • Raupo (*Typha orientalis*) • Tall fescue (*Schenorus phoenix*) • Wīwī (*Juncus edgariae*), • Yorkshire fog (*Holcus lanatus*) • *Tradescantia albiflora* (plant most commonly used by īnanga for spawning in Lower Waikato (C. Annandale, pers. comm.). Spawning occurs in areas that are inundated on spring tides in tidal regions of rivers, with peak spawning occurring within or near the saltwater wedge (area of saline protrusion during high tide).	• No spawning site for lacustrine īnanga has been documented so no specific vegetation or flow regimes have so far been identified.
Kōaro	April to August (peak April and May).	Gravels and leaf litter on the margins of adult habitat during elevated flows. (Kusabs 1989; Duffy 1996; McDowall 1990, Allibone & Caskey 2000). Spawning sites have been recently located in riffle habitat on the underside of boulders (P. Fisher (NCC) and J. Goodman (DOC) unpubl. data).	• Among bankside vegetation (sedges, rushes and grasses) in elevated flows.
Banded kōkopu	March to August (peak May and June).	Tightly packed gravels and leaf litter on the margins of adult habitat during elevated water flows.	• Adults also occur in urban and agricultural streams, so spawning is likely to occur amongst exotic vegetation and rank grasses in elevated water flows **and/or** • Among cobble or boulder substrates at base flows as has recently been found for kōaro (P. Fisher (NCC) & J. Goodman (DOC) unpubl. data).
Giant kōkopu	April to August (peak May and June).	Spawning occurs adjacent to adult habitat on low-gradient banks among streamside vegetation inundated when water flows are elevated (Franklin et al. 2015). Vegetation documented as spawning habitat to date are: • *Carex secta*, • Wandering willie (*Tradescantia fluminensis*), • Yorkshire fog (*Holcus lanatus*).	• Adults also occur in forested streams alongside banded kōkopu so spawning is likely to occur amongst gravels and leaf litter in elevated flows **and/or** • Among cobble and boulder substrates at base flows as has recently been found for kōaro (P. Fisher (NCC) & J. Goodman (DOC) unpubl. data).
Shortjaw kōkopu	April to July (peak May and June).	Tightly packed gravels and leaf litter on the margins of adult habitats during elevated flows (Charteris et al. 2003).	• Among bankside vegetation (sedges, rushes and grasses) in elevated flows **and/or** • Among cobble or boulder substrates at base flows as has recently been found for koaro (P. Fisher (NCC) and J. Goodman (DOC) unpubl. data).

Table 2 Summary of spawning and migration timing for New Zealand's five migratory galaxias species (re-created from Smith 2014).

			Summer			Autumn			Winter			Spring		
			Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Species	**Migration direction**	**Life-stage**												
Īnanga	Upstream	Juvenile						Range	Range	Range	Peak	Peak	Peak	Peak
	Downstream	Larvae	Range	Range	Range	Peak	Peak	Peak	Peak	Peak	Range		Range	Range
	Spawning	Adult	Range	Range	Range	Peak	Peak	Peak	Peak	Range		Range	Range	Range
Kōaro	Upstream	Juvenile										Peak	Peak	Range
	Downstream	Larvae						Peak	Peak	Range	Range	Range		
	Spawning	Adult					Peak	Peak	Range	Range	Range			
Banded kōkopu	Upstream	Juvenile	Range								Range	Peak	Peak	Range
	Downstream	Larvae				Range	Range	Range	Peak	Peak	Range	Range		
	Spawning	Adult				Range	Range	Peak	Peak	Range	Range			
Giant kōkopu	Upstream	Juvenile	Range										Range	Peak
	Downstream	Larvae						Range	Peak	Peak	Range	Range		
	Spawning	Adult						Range	Peak	Peak	Range	Range		
Shortjaw kōkopu	Upstream	Juvenile										Range	Range	Range
	Downstream	Larvae							Range	Peak	Peak	Range		
	Spawning	Adult						Range	Peak	Peak	Range			

Key: Range (light grey) Peak (dark grey)

Although īnanga spawning sites have been widely described across New Zealand, for the four other whitebait species spawning has only been identified in a handful of locations. Significant advances were made in the knowledge of banded kōkopu, kōaro and shortjaw kōkopu spawning habitat in the early 2000s (Allibone & Caskey 2000; Charteris et al. 2003). Allibone and Caskey (2000) recorded kōaro egg masses on boulders and gravel just above the base flow, indicating that spawning occurred in a fresh or flood. Charteris et al. (2003) recorded 16 spawning sites for banded kokopu and shortjaw kōkopu in Taranaki streams. Spawning sites were found amongst leaf litter and gravel on stream margins. In 2013, Franklin et al. (2015) recorded the first known spawning site for giant kōkopu amongst rank grasses adjacent to adult habitat. A second spawning site for giant kōkopu was located in the Awaawaroa Wetland on Waiheke Island in 2016 (C. Baker, NIWA, pers. comm.). As with other migratory species, the giant kōkopu spawned during periods of elevated water flows.

Uncharacteristic spawning sites for kōaro were located in 2017 (P. Fisher, Nelson City Council (NCC) & J. Goodman, DOC, unpubl. data) and again in 2018 (P. Fisher, NCC, pers. comm.). Kōaro eggs were found in riffle habitat on the underside of submerged rocks. This finding, while very different to other recorded spawning sites for kōaro, is similar to non-migratory galaxias spawning sites (N. Dunn, DOC, unpubl. data). Discovering spawning sites located within the stream channel for kōaro is an indication that the other four migratory species may have flexibility in their spawning behaviour.

Īnanga spawning database

The īnanga spawning database evolved from a data-set collected during a nationwide survey to locate spawning grounds that was commissioned by DOC in 1987. Data were collated by NIWA (National Institute of Water and Atmospheric Research) and entered into the Īnanga Spawning Database up until 2002 (Taylor 2002). After 2002, various individuals and organisations continued to collect information on īnanga spawning sites; however, the data is in many different formats and not collated into a central database. Figure 1 shows the location of spawning sites and observed spawning events that were entered to the spawning database, as well as some additional known spawning locations located after 2003.

Figure 1. Location of īnanga (*Galaxias maculatus*) eggs and īnanga spawning events entered in the Īnanga Spawning Database, with additional sites added post-2003.

At the 2012 Freshwater Sciences Society Conference, a meeting was held to discuss re-establishing the use of a national database to collate spawning site data. This project is led by the University of Canterbury and is in collaboration with DOC, NIWA, Aquatic Ecology Ltd, local councils and community groups.

In 2017, existing entries in the database were filtered, digitalised and entered into a GIS layer. This layer was initially published through SeaSketch (https://www.seasketch.org/#projecthomepage/55

92ddefeefa812d4d013909/survey/5632889fe837f22f06b6e032) but the database now resides on the NatureWatch NZ online platform (http://naturewatch.org.nz/projects/inanga-spawning-sites).

Restoration of spawning sites

In recent times there has been a significant increase in knowledge about the habitat types that each of the migratory galaxias species spawn in (Hickford & Schiel 2013; Charteris et al. 2003; Franklin et al. 2015; P. Fisher (NCC) & J. Goodman (DOC) unpubl. data). However, aside from īnanga, only a few spawning sites are known for each of the other four species. As a result, restoration of spawning sites for īnanga is far more advanced than for any of the four other migratory galaxiids (Taylor 2002; Richardson & Taylor 2002; Hicford & Schiel 2011a, b; Hickford & Schiel 2013; Hickford et al. 2017).

Īnanga spawning sites are located in lowland sections of streams and rivers (McDowall 1990; Richardson & Taylor 2002; Taylor 2002; Hickford & Schiel 2011a, b; Hickford & Schiel 2013; Hickford et al. 2017). These are also the sections that are most affected by modification due to urbanisation, agriculture, horticulture and forestry and thus many spawning sites are degraded. Excluding stock from spawning sites, particularly in the spawning season, as well as ensuring urban waterways retain appropriate stream-side vegetation that is not mown to the edge has been identified as being important for successful restoration (Richardson & Taylor 2004; Hickford & Schiel 2014). Methodology has been developed to identify the location of īnanga spawning sites within a river catchment, with most eggs being found within 100 m of the saltwater wedge (the upstream point at which denser and heavier salt water overlays lighter fresh water) in streamside vegetation (Richardson & Taylor 2002; Taylor 2002). Observations have been made at spawning sites about the importance of a low-gradient waterway with slow moving runs, as well as gently sloping banks for successful spawning (Richardson & Taylor 2004). Thus, with good knowledge of the gradient of stream banks, water velocity and the vegetation type that īnanga spawn in, many īnanga spawning sites have been located and successfully restored through planting and fencing by various organisations, individuals and groups (Hans Rook. pers. comm.; Mitchell 1994; Hickford & Schiel 2014). An inventory of all sites that have restoration projects would be useful to gain an understanding of the extent and success of these projects and to learn from them.

Recent research by Hickford & Schiel (2013) found that īnanga will also utilise artificial spawning habitat if it is installed. Three artificial habitat types – straw bales, straw tubes and moss tubes – were tested in degraded and intact īnanga spawning sites. Īnanga spawned in all three artificial habitats, with eggs surviving through the entire spawning season. Hickford and Schiel (2013) concluded that deciding what type of artificial habitat should be used to aid īnanga spawning involved a trade-off between durability and cost. Since this study concluded, straw bales have generated the most interest and use, with several different groups installing this type of artificial habitat to increase īnanga spawning. Hickford and Schiel (2013) cautioned that the use of artificial spawning habitat should not be an alternative to restoring riparian vegetation; they suggested that straw bales should be used alongside other restoration techniques such as planting, fencing and modifications to watercourse bank topography.

Migration and dispersal

In late winter and spring, shoals of whitebait (juvenile galaxiids) migrate upstream from the marine and estuarine environments (where they have spent 4–6 months growing from their larval stage) into freshwater streams, rivers, lakes and wetlands. The shoals can be a mix of the five species; however, the peak migration of each species is thought to occur at different times (Table 2). For example, peak migration for kōaro is thought to be in September, while it is November for giant kōkopu (McDowall 1999; McDowall & Kelly 1999). The timing of whitebait migration also varies throughout the country and from season to season. For example, whitebait have been recorded in the Waikato River in May (C. Annandale, DOC, pers. comm.).

The main migration period for all species is thought to be from August through to November (McDowall 1965; McDowall 1968); however, it is thought that smaller numbers of whitebait will migrate throughout the year.

Baker and Montgomery (2001a) found that banded kōkopu whitebait in tank trials were attracted to the pheromones (odours) released by adult banded kōkopu. This attraction was species-specific, as the whitebait were not attracted to the pheromones of kōaro or īnanga. A similar study by Baker & Hicks (2003) found that īnanga juveniles were attracted to the odour of adult īnanga, as well as adult banded kokopu and kōaro; whereas kōaro juveniles were only attracted to the odour of kōaro adults. A laboratory study by Baker (2003) found that the presence of adult pheromones would cause banded kōkopu whitebait to override an avoidance response to suspended sediment. These studies indicated that juvenile banded kōkopu used pheromones as a cue to migrate upstream to find suitable adult habitat. Rowe et al. (1992) also found evidence for stream selection in kōaro whitebait within Bay of Plenty rivers, suggesting that adult pheromones may also be used as a migration cue by this species.

The degree to which individuals move between adjacent catchments is not well known, although recent studies are showing that regional population structuring is occurring (Egan 2017; Augspurger 2017; Yungnickel 2017; B. David, Waikato Regional Council (WRC), pers. comm.; J. Goodman, DOC, unpubl. data). Greater spatial coverage is needed to determine whether more stocks exist across New Zealand. Currently, Īnanga are the only species that have good spatial coverage in studies. The stock structure of kōaro and kōkopu has only been examined in discrete locations (e.g. the Waikato River and West Coast of the South Island), but this work is providing preliminary evidence for spatial differences in size and age at migration that show similar patterns to Īnanga (Yungnickel 2017). Genetic analysis indicates that there is enough mixing of individuals between rivers and 'stocks' to ensure that speciation is not occurring (J. Goodman, DOC, unpubl. data). However, continual loss of habitat creating greater fragmentation of 'stocks' may reduce mixing and therefore genetic exchange in the future.

The characteristics of galaxiids also vary across their key migration period. Egan (2017) has shown that although there is some river-to-river variation, īnanga size and age generally declines over the course of their migration period (and over the whitebaiting season – August/September to November). Egan (2017) concluded that these temporal trends are related to early- and later-migrating īnanga being derived from different spawning events. Too few studies on the other migratory galaxiid species exist to discern temporal trends in age and hatch dates for them. However, as īnanga captured later in the fishing season (October/November) are smaller in size and have less condition than those captured in August and September, the whitebait fishery may be exploiting the better-conditioned fish, leaving poorer quality juveniles to repopulate the īnanga populations, with possible long-term impacts on population dynamics (Egan 2017).

Habitats

The general habitat requirements of the five migratory galaxias species are well known for the adult phases of these species. Less is known about specific habitat requirements of whitebait (transparent juveniles) and post-whitebait juveniles (pigmented juveniles); and very little is known about larval habitat requirements. Table 3 summarises what is presently known about habitat requirements of larvae, juveniles and adults. Restoring degraded habitat has been attempted at various scales (e.g. at in-stream, riparian and catchment levels); however, follow-up monitoring to understand whether restoration has been effective doesn't often occur. More research and long-term monitoring are required to provide guidance about how to effectively restore habitat.

Table 3. Habitat requirements of adult, juvenile and larval phases of the five migratory galaxias species that comprise the whitebait fishery. Summarised from Petrove et al. (unpubl. DOC report).

Īnanga		
Adult	**Juveniles**	**Larvae**
• Found in slow-flowing lowland rivers, streams, lakes and wetlands • Occupy pools, backwaters and slow-moving runs. • Capable of moving through fast-flowing water. • Associated with marginal vegetation and instream cover e.g. aquatic macrophytes, emergent and over hanging vegetation and debris. • Avoid habitat that is turbid for extended periods. McDowall 1990; Sagar 1993; McDowall 2000; Rowe et al. 2000; Jowett 2002; Jowett et al. 2009	• Shallow edge habitat/side braids. • Inundated floodplains where zooplankton are an important food source. • Avoid suspended sediment. • Less-tolerant of low dissolved oxygen levels than adults. Boubee et al. 1997; Dean & Richardson 1999; Ryder & Keesing 2005; Catlin 2015.	• Pelagic ocean phase for 4–6 months. • Length of time at sea varies regionally throughout New Zealand. • May grow into juveniles in freshwater or estuarine environments depending on region and river productivity. • Landlocked larvae may grow into juveniles in lake habitat. • Found on coastline and sometimes long distances out to sea; however, recent research looking at otolith microchemistry showed that īnanga larvae commonly stay inshore rather than dispersing long distances. • Probably planktonic living at or near the water surface. McDowall 1990;Taylor & Kelly 2001; Hicks 2012; Egan 2017
Kōaro		
Adult	**Juveniles**	**Larvae**
Rivers • Small streams in steep catchments, but also in main-stem of medium-to-large rivers (e.g. Braided Rivers in Canterbury). • Associated with cobble substrates and utilise boulders and cobbles for cover. • Have been found using log jams for cover in some habitats. • High forest cover in riparian zone and catchment. • Found at high elevations. Known as riffle dwellers although have been found in pools and backwaters. Woods 1963; McDowall 1980; Rowe 1981; Sagar & Eldon 1983; Main et al. 1985; Moffat & Davidson 1986; Main 1988; McDowall 1990; Hayes 1996; Chadderton & Allibone 2000; Bell 2001; Eikaas et al. 2005; Leathwick et al. 2008; McEwan 2009; McEwan & Joy 2014. ***Lakes*** • High-altitude tarns to lowland lakes. • Occupy both the lake itself and tributary streams. • Have been observed utilising underground spring habitat in Lake Rotoaira. • Benthic dwellers in lakes. Michaelis 1982; McDowall 1988; McDowall 1990; Rowe 1993; Rowe 1994; Rowe et al. 2002;	***Rivers*** • Observed resting for several days in gravelly shallows of main-stem rivers. • Avoid medium–high levels of suspended sediment. • Little documented about juvenile kōaro habitat. McDowall 1990; Boubee et al. 1997. ***Lakes*** • Limnetic (occupy open surface waters). • Found in lake margins. • Either migrate into lake tributaries or remain in lake. • Utilise rock crevices and organic debris on the lake bed for cover. Stokell 1955; McDowall 1990; Young 2002; Meredith-Young & Pullen 1977.	***Rivers*** • Spend 3–6 months living a pelagic lifestyle either in local inshore waters or dispersing more widely. McDowall & Suren 1995; Charteris & Ritchie 2002; Hicks 2012. ***Lakes*** • Larvae are pelagic. • Possibly undertake small movements between stream and lake environments in relation to diel cycle. • Found at variable depths. • Likely move to littoral (surface) zone when 30–35 mm in length. Exact oceanic/lake/estuary conditions and locations are unknown. However, recent research by Augspurger (2017) Taylor et al. 2000; Rowe et al. 2002.
Banded kōkopu		
Adult	**Juveniles**	**Larvae**
• Most common in small first- and second-order streams. • Can be found in deep water of large streams.	• Juveniles found in shallow runs and riffles close to adult habitat. McDowall 1990; Baker & Smith 2007.	• Spend 4–6 months living a pelagic lifestyle either in local inshore waters or dispersing more widely.

Continued on next page

Table 3 continued

• Occur in backwaters with in-stream cover. • Pool and slow- to medium-flowing run habitat. • Most commonly found at low to medium elevations, but known to be good climbers, so can be found inland in some rivers. • Associated with woody debris and undercut banks, sometimes boulders and cobbles used for cover. Main 1988; Hanchett 1990; McDowall 1990; Jowett et al. 1998; Rowe et al. 1999; Chadderton & Allibone 2000; Rowe & Smith 2003; West et al. 2005; Baker & Smith 2007		• Exact oceanic/lake/estuary conditions and locations are unknown McDowall 1990; Charteris et al. 2003).
Giant kōkopu		
Adult	**Juvenile**	**Larvae**
• Wetlands, Lakes, lagoons, small-to-medium streams/rivers. • Usually found at low elevations. Don't penetrate far inland. • Pools of varying depth or slow-flowing runs. • Back-waters used occasionally. • Usually found in association with riparian vegetation and instream cover (e.g. submerged wood, debris dams, undercut banks). • Utilise different habitat for feeding and resting. McDowall 1990; Caskey 1997; Jowett et al. 1998; Bonnet 2000; Chadderton & Allibone 2000; Bonnet et al. 2002; Bonnet & Sykes 2002; David et al. 2002; Whitehead et al. 2002; David 2003; David & Closs 2003; David & Stoffels 2003; Hansen & Closs 2005; Baker & Smith 2007; Jowett & Richardson 2008; McDowall 2011.	• Similar overall habitat to adults. • Microhabitat for juveniles varies from adults (e.g. riffles and small shallow fast-flowing backwaters next to riffles). Bonnett & Sykes 2002; David et al. 2002; Whitehead et al. 2002.	• Pelagic stage for 4–6 months in the ocean, lowland lakes or estuaries. • Larval habitat can be marine, estuarine or freshwater. • Exact oceanic/lake/estuary conditions and locations are unknown. McDowall 1990; David et al. 2004; Hicks 2012.
Shortjaw kōkopu		
Adult	**Juvenile**	**Larvae**
• Small-to-medium rivers. • One population confirmed as recruiting from the Mangatawhiri Reservoir in the Hunua Ranges. • Associated with large cobble and boulder substrates. • Utilise instream debris and undercut banks in absence of substrate cover. • Often found in streams in podocarp/hardwood forest and rarely found in beech forest streams. • Use deep, swift-flowing habitats during the day and move to slower-flowing pools at night. Taylor & Main 1987; Taylor 1988; West 1989; McDowall 1990; Swales & West 1991; McDowall et al. 1996; McDowall 1997; Bowie & Henderson 2002; Goodman 2002; McEwan 2009; Smith et al. 2012; McEwan & Joy 2014.	• Found in similar habitat to adults; however, microhabitat is shallower and in stream margins. McDowall et al. 1996; Goodman 2002; McEwan 2009.	• Pelagic stage for 4–6 months in the ocean and one record of a lake-recruiting population. • Exact oceanic/lake/estuary conditions and locations are unknown. Charteris et al. 2003; Smith et al. 2012.

Status and distributions of migratory galaxiid populations

The five migratory galaxias species that comprise the whitebait fishery are found throughout New Zealand; however, some species are absent or rare in some regions (Figs 2–6). The New Zealand Freshwater Fish Database (NZFFD) (McDowall & Richardson 1983) contains fish observations from New Zealand freshwater ecosystems and has over 35 000 records (Table 4; Fig. 7). The NZFFD contains records dating back to the early 1900s and is contributed to by a wide range of individuals, groups, universities and organisations. Figures 2–6 show the distribution of the five species for the past 41 years; records are grouped from 1976–95 and 1995–2017. Table 4 lists the number of records for each of the five species in these two-year groups. The maps and number of records are presented to provide a general picture of where each species is found and how common or rare they are relative to each other. Figure 7 is included to demonstrate that New Zealand is relatively well surveyed and therefore the gaps in species distribution shown in Figs 2–6 are true gaps, and not the product of a lack of survey effort. Leathwick et al. 2008 used data from the NZFFD to build a model to predict the location of freshwater fish. The model had a high level of predictive performance for where fish were, or should be, present. This model may thus be useful for helping to understand potential contraction of distribution of the migratory species but does not provide information on trends in abundance.

Crowe et al. (2016) discuss the biases present in the data contained in the NZFFD; for example, differences in habitats surveyed, methods used and environmental conditions. The variability generated by these differences require standardisation of data to be undertaken. Crow et al. (2017) found insufficient accurate data to generate standardised trends for any of the whitebait species, except for kōaro. Once data was standardised, kōaro were predicted to be declining by 0.05% (+/− 0.02%; CI 95%) per year (Crowe et al. 2017). A comprehensive New Zealand-wide network of monitoring sites is required to gather accurate, long-term information about population trends for the five migratory galaxias species.

Īnanga are the most wide-spread and abundant (Fig. 2) of the migratory galaxias species and are found in a wide variety of habitats mostly in close proximity to the coast (McDowall 1990). Kōaro, while being more common and abundant on the west coasts of the North and South Islands, are found throughout both islands (Fig. 3). Kōaro can be found at great distances and altitudes inland due to their climbing ability; they are also able to form land-locked populations in lakes (Main 1988; McDowall 1990; Rowe et al. 2002). Banded kōkopu are found throughout New Zealand (Fig. 4) and, like īnanga, they are more commonly found near the coast but sometimes reach moderate elevations due to their climbing ability. Although there are gaps in their distribution on the east coasts of both the North and South islands, they can be regionally common or abundant in some east coast regions (Main 1988; McDowall 1990). Giant kōkopu and shortjaw kōkopu have patchier distributions in comparison with the other three species. Giant kōkopu are also largely absent from the east coasts of both Islands (Fig. 5) but are found in high numbers in the southern South Island around Dunedin and Southland, particularly in association with large lakes or lagoons (McDowall 1990; David 2002). They are common or abundant in some regions of the west coasts of both Islands and there are significant populations associated with the Waikato River and Lakes system (McDowall 1990). Shortjaw kōkopu are almost entirely absent from the east coasts of both main islands (Fig. 6), and if they are present they are often in very low numbers (e.g. 1–2 individuals in a 200–400 m stream length). They are patchily distributed on the west coasts of both islands, with national strong-hold populations on the West Coast, Golden Bay and Abel Tasman National Park in the South Island and Taranaki in the North Island (McDowall 1990; McDowall et al. 1996; Bowie & Henderson 2002; Goodman 2002).

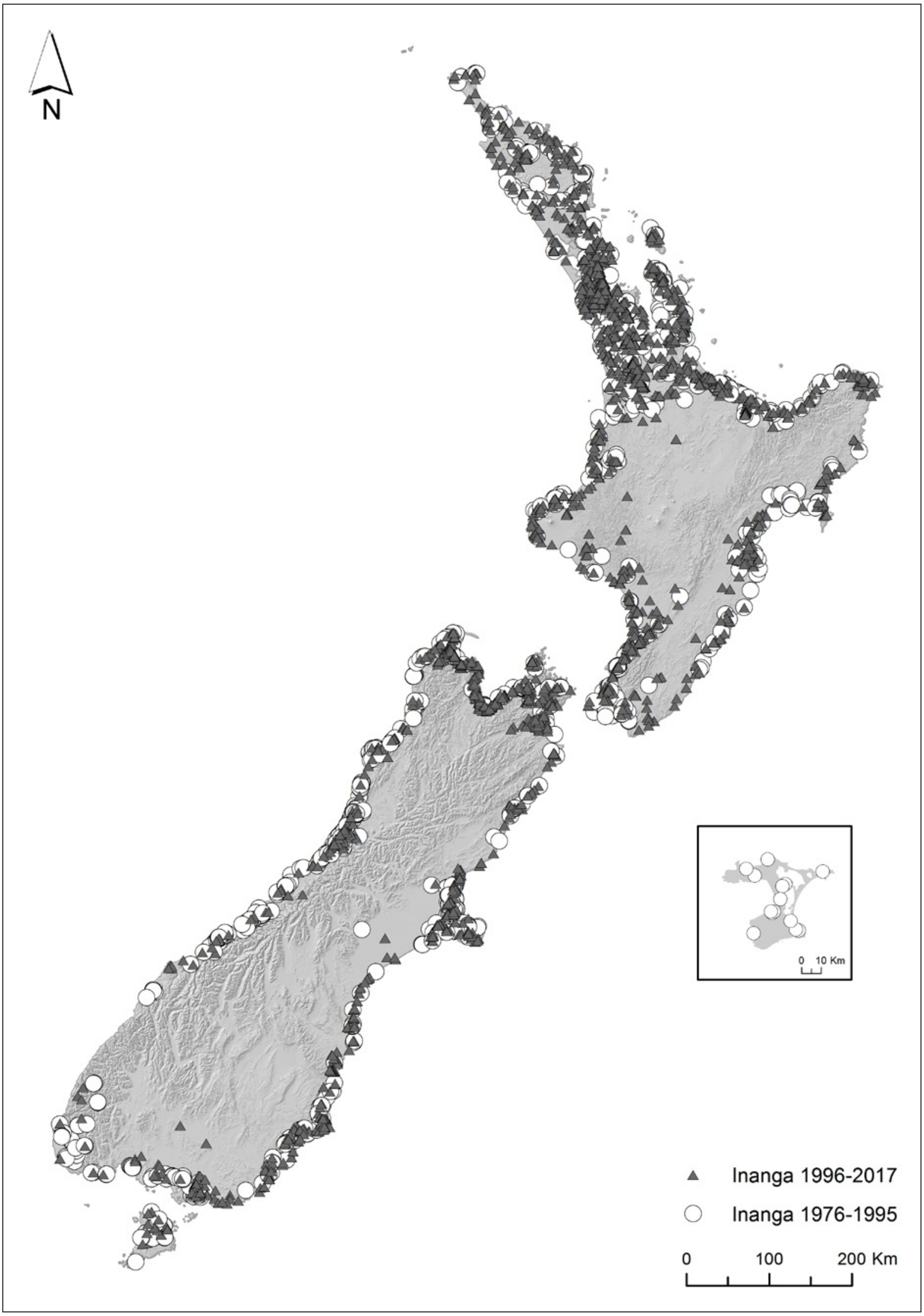

Figure 2. Distribution of īnanga (*Galaxias maculatus*) in New Zealand showing records for 1976–1995 and 1996–2017.

Figure 3. Distribution of kōaro (*Galaxias brevipinnis*) in New Zealand showing records for 1976–1995 and 1996–2017.

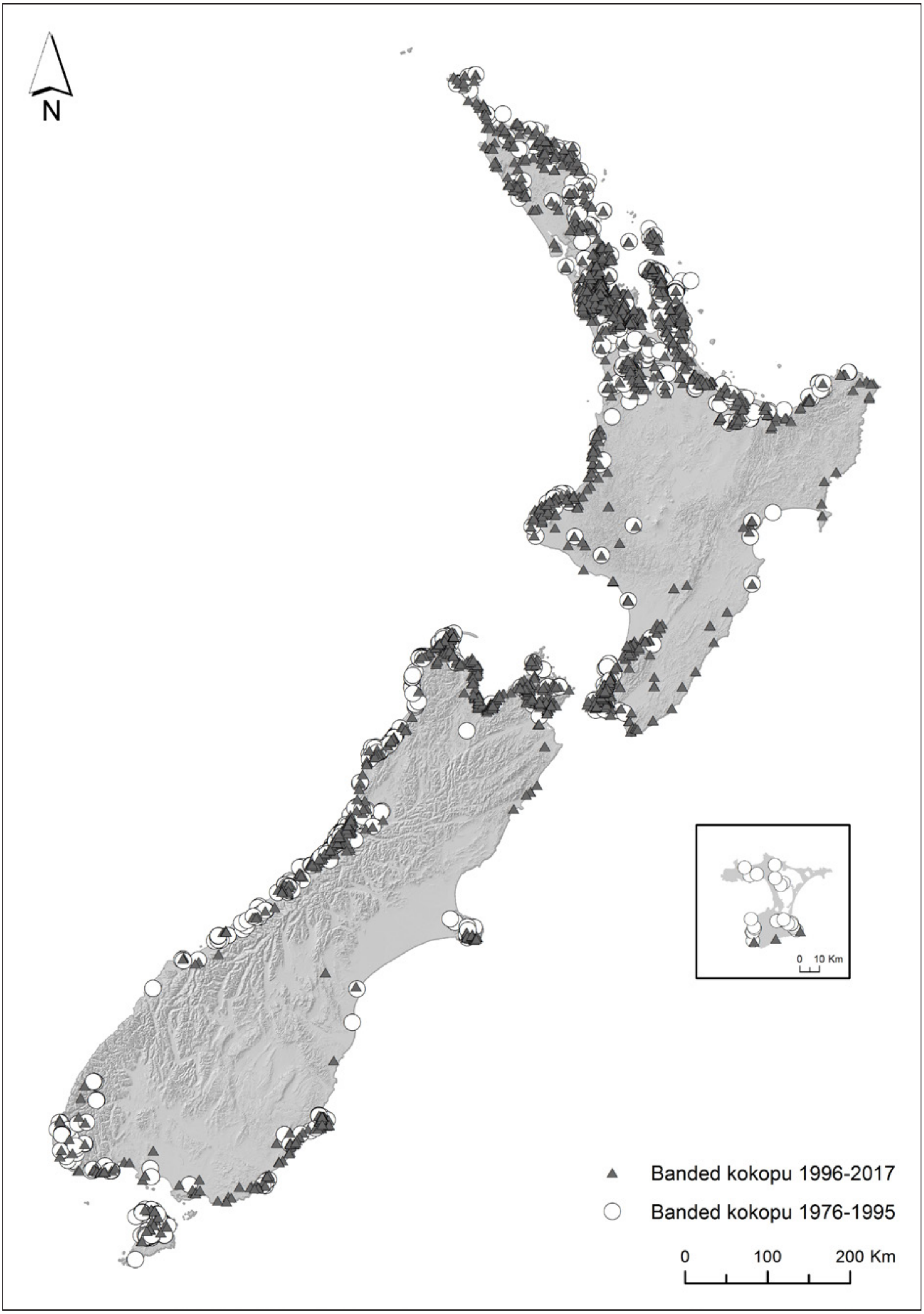

Figure 4. Distribution of banded kōkopu (*Galaxias fasciatus*) in New Zealand showing records for 1976–1995 and 1996–2017.

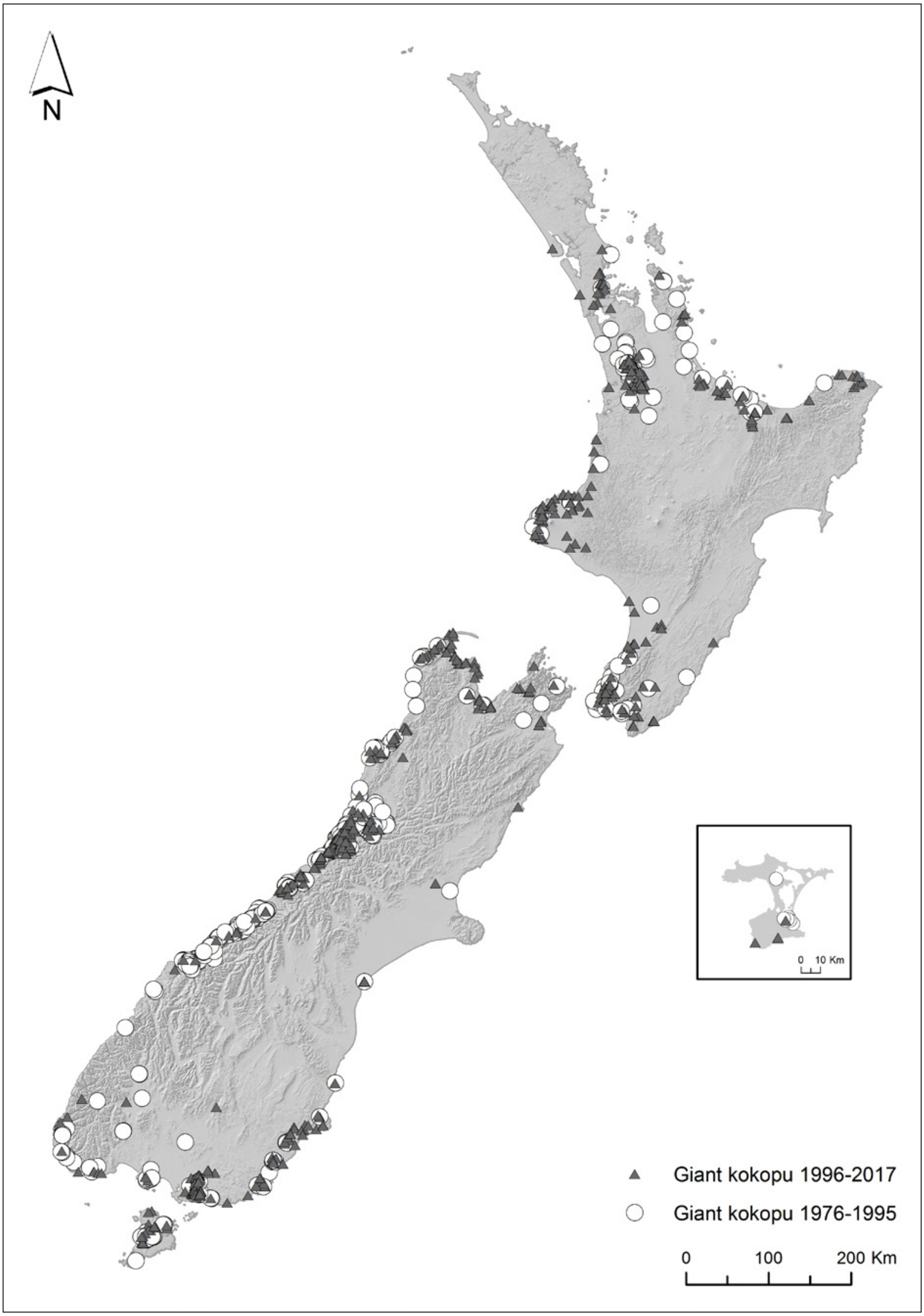

Figure 5. Distribution of giant kōkopu (*Galaxias argenteus*) in New Zealand showing records for 1976–1995 and 1996–2017.

Figure 6. Distribution of shortjaw kōkopu (*Galaxias postvectis*) in New Zealand showing records for 1976–1995 and 1996–2017.

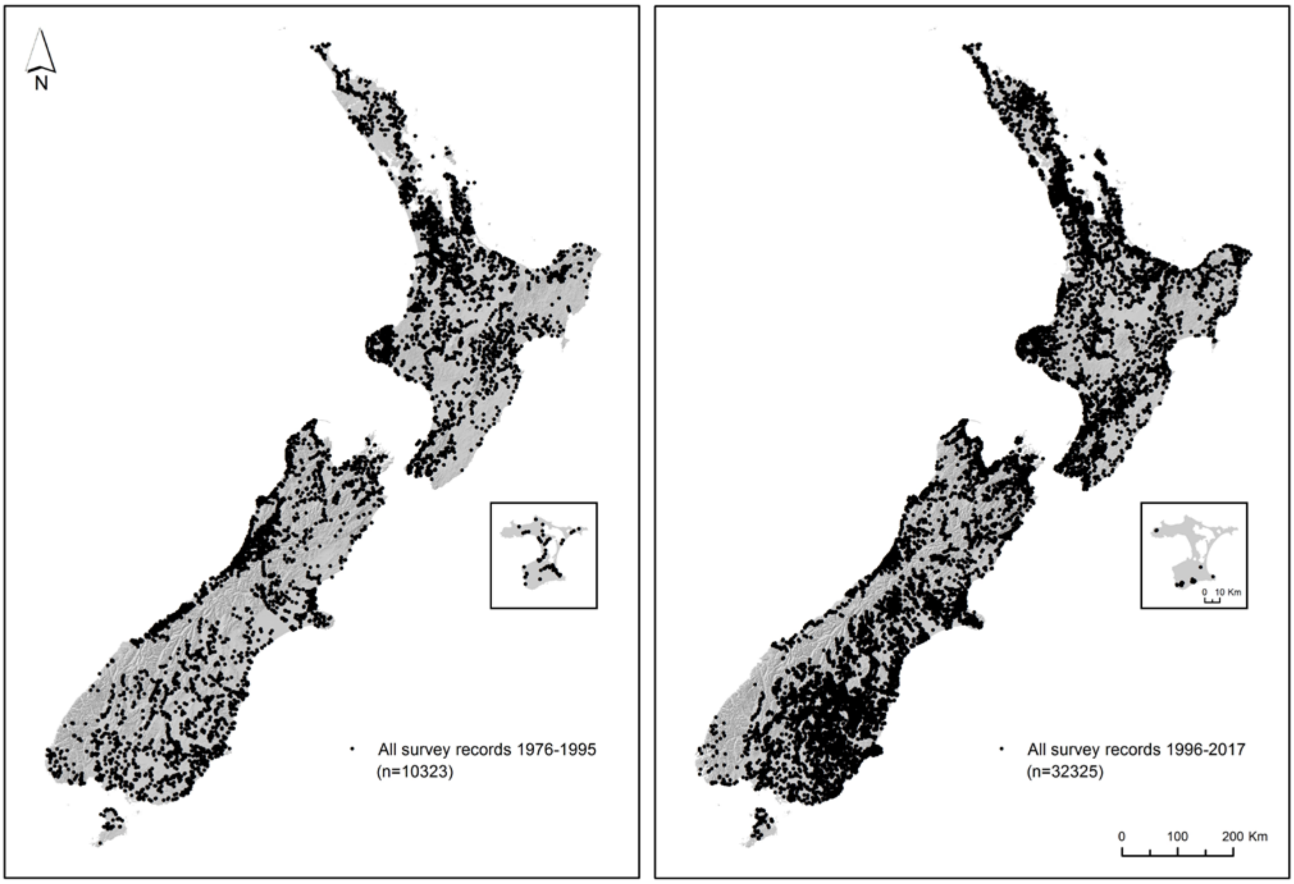

Figure 7. All records entered into the New Zealand Freshwater Fish Database from 1976 to 1995 and 1996 to 2017.

Table 4. Numbers of New Zealand Freshwater Fish Database records for the five migratory galaxias species grouped into time periods – prior to 1976, 1976–1995 and 1996–2017. The date of the earliest record is also provided, along with total freshwater fish records for the various periods.

SPECIES	EARLIEST RECORD	NUMBER OF RECORDS		
		PRIOR TO 1976	1976–1995	1996–2017
Īnanga	1922	260	1141	3080
Kōaro	1909	227	1035	2363
Banded kōkopu	1923	186	965	3262
Giant kōkopu	1949	61	423	850
Shortjaw kōkopu	1940	27	201	549
Total fish records	**1901**	**1506**	**10 323**	**32 325**

Conservation status of the migratory galaxiids

The Conservation status of the five migratory galaxias species has been ranked six times over the past 22 years using three iterations of the New Zealand Threat Classification System (Table 5; Molloy & Davis 1992; Molloy et al. 2002; Townsend et al. 2008). The six threat classifications listed for each of the five migratory galaxias species in Table 5 cannot be directly compared with each other due to differences in the three systems used. However, the 1991 and 1994 lists are comparable, as are the 2001 and 2004 lists and the 2009 and 2013 lists. Molloy & Davis (1992) scores taxa against criteria that assess population status, impact of threats, recovery potential, taxonomic distinctiveness, and their value to humans; and categorises species according to their priority for conservation action. The Molloy et al. (2002) and Townsend et al. (2008) classification systems do not assign management priorities, focusing instead on the level of threat of extinction each taxon faces.

The current New Zealand Threat Classification System (Townsend et al. 2008; https://www.doc.govt.nz/Documents/science-and-technical/sap244.pdf) is a national system co-ordinated by DOC. Panel chairs and members are experts in their fields and work at universities, research organisations, government and non-government organisations. The most recent published classification (Goodman et al. 2014) lists three species (īnanga, kōaro and giant kōkopu) as At Risk – Declining; one species (shortjaw kōkopu) as Threatened – Nationally Vulnerable and one species (banded kōkopu) as Not Threatened (Table 5; Townsend et al. 2008; Goodman et al. 2014). Classifications are based on population size and/or area of occupancy and the predicted rate of decline of each species. The classification system clearly states that the expert panel should take a precautionary approach to listing taxa and where the criteria might result in an inappropriate listing, the panel can designate the taxa to another category. More accurate long-term information about effective population size and population trends need to be collected for the migratory galaxiids.

Table 5. Threat classification listings for the five migratory galaxias species from 1991 to 2013 using three classification systems (Molloy & Davis 1992; Molloy et al. 2002; Townsend et al. 2008; Allibone et al. 2010; Goodman et al. 2014).

SPECIES	CLASSIFICATION SYSTEM AND ASSESSMENT YEARS					
	TOWNSEND et al. 2008		MOLLOY et al. 2002		MOLLOY & DAVIS 1992	
	2013	2009	2004	2001	1994	1991
Īnanga	At Risk – Declining	At Risk – Declining	Not Threatened	Not Threatened	Not listed	Not listed
Kōaro	At Risk – Declining	At Risk – Declining	Not Threatened	Not Threatened	Category C	Category C
Banded kōkopu	Not Threatened	Not Threatened	Not Threatened	Not Threatened	Category C	Category C
Giant kōkopu	At Risk – Declining	At risk – Declining	Gradual Decline	Gradual Decline	Category B	Category B
Shortjaw kōkopu	Threatened – Nationally Vulnerable	At risk – Declining	Sparse	Gradual Decline	Category A	Category B

Management of adult migratory galaxiids

The New Zealand large galaxiid recovery plan (DOC 2005), covered four of the five migratory species – shortjaw kōkopu, giant kōkopu, kōaro and banded kōkopu. The recovery plan set out DOC's goals and objectives for the conservation of the large galaxiids from 2003 to 2013. This plan was one of three freshwater fish recovery plans, and one of many such plans that DOC has prepared with the intention of helping with resource allocation as well as serving as discussion points for other interested parties. Threats and pressures to the large galaxiid species were outlined and time-bound management actions and research gaps were identified to counteract impacts and improve security of populations. Many of the objectives and goals of the plan were about improving knowledge of distribution and abundance of the large galaxiids; other goals included ensuring migratory pathways were maintained, advocating for the protection of habitat, public awareness, and collaboration with iwi, other organisations, research institutes and community groups. An assessment of the success of this plan is underway and the outcome of this is expected to be available at the end of 2018.

More recently, DOC has begun a process of prioritisation incorporating species and ecosystems. Species streamed for management – either Threatened, At Risk or Conservation Dependent in the New Zealand Threat Classification system – have been prioritised for management. Within each species, a proportion of populations or subpopulations have been prioritised to ensure their long-term persistence. Significant subpopulations of migratory galaxiid species (īnanga, kōaro, banded kōkopu, giant kōkopu and shortjaw kōkopu) streamed for management have been identified; the next step in the process is to incorporate them into the wider context of the prioritisation project underway.

The whitebait fishery

Legislation

Whitebait is defined under Section (2) of the *Whitebait Fishing Regulations 1994* and Section (2) of the *Whitebait Fishing (West Coast) Regulations 1994* as 'the young or fry of inanga (*Galaxias maculatus*), koaro (*G. brevipinnis*), banded kokopu (*G. fasciatus*), giant kokopu (*G. argenteus*), shortjaw kokopu (*G. postvectis*), and common smelt (*Retropinna retropinna*)'. However, the migratory galaxiids (īnanga, kōaro, banded kōkopu, giant kōkopu and shortjaw kōkopu) are considered 'true' whitebait by both biologists and whitebaiters.

In all areas of New Zealand except the West Coast (South Island) and the Chatham Islands, the whitebait fishing season is between 15 August and 30 November (inclusive). The West Coast season is 1 September to 14 November (inclusive) and the Chatham Island season runs from 1 December to the last day of February (inclusive). In addition to the season, whitebait fishing is restricted to certain hours of the day and the type, number and size of nets used.

DOC is also responsible for the conservation and management of the adult whitebait species (the migratory galaxiids) through functions in the *Conservation Act 1987* and the *Freshwater Fisheries Regulations 1983*. Regional Councils also have a role in protection and management of species through managing adverse effects of resource use on habitat quality (Willis 2014).

A brief history of the whitebait regulations

The *Whitebait Fishing (West Coast) Regulations 1994* and the *Whitebait Fishing Regulations 1994* have evolved from a series of complex and largely locally-oriented regulations first implemented in 1894.

In 1911, recognition was given to the unique West Coast whitebait fishery. In 1922 there was pressure to enforce a restricted season on the West Coast. The Chief Inspector of Fisheries stated that 'in the past the regulations had been mainly for the purpose of adjusting matters between fishermen rather than for the conservation of the species' and went on to say that it was as important to ensure survival of the species as it was to allow for sustainable use (McDowall 1984).

Whitebait fishing regulations were gazetted in 1932; they included provisions that recognised the special West Coast fishery. This special recognition of the West Coast fishery continued through several iterations of the regulations, including introducing the concept of conservation areas which are listed in the current *Whitebait Fishing (West Coast) Regulations 1994*. Conservation areas or closed areas were added to by DOC in 1994 and 1995.

The 1932 regulations also enforced seasonal limitations – 1 July to 14 November in the North Island and 1 August to 16 December in the South Island. In 1951 there was a further reduction in season length, which was shortened by 1 month in the North Island and 1½ months in the South Island. By 1981 the West Coast season had been shortened to a 15 November end date.

DOC assumed responsibility for the whitebait fishery from the Ministry of Agriculture and Fisheries in 1990 and applied the regulations that were already in place – the *Fisheries (West Coast Whitebait Fishing) Regulations 1985* and the *Fisheries (Amateur Fishing) Regulations* which regulated the fishery outside the West Coast. There were several minor changes to the regulations up until 1994.

The most recent review of the regulations began in 1990 and concluded in 1996 with a summary of DOC's management of the whitebait fishery by McDowall (1996). The review was targeted at the *Whitebait Fishing (West Coast) Regulations*. DOC released a discussion document in October 1990 titled 'West Coast whitebait management review – a public discussion document'. The discussion document outlined principles of management, the reasons for the review, the issues to be addressed and included a questionnaire. DOC received 195 submissions and 164 questionnaire responses; at the time there were approximately 700 licensed whitebait standholders registered with DOC (Rankine & Hill Ltd 1991). The issues most frequently reported by respondents were habitat protection, control of fishing, closed areas, back pegs, season length, fishing methods and whitebait licensing (Rankine & Hill Ltd 1991).

The review of the regulations in 1994 recommended that the West Coast season end on 31 October to protect the migration of giant kōkopu, one of the more threatened whitebait species, as scientific research indicated that the peak migration for this species on the West Coast was in November. This did not come into force, as consultation on changing the season was considered to be inadequate.

McDowall (1996, p. 34) in his concluding remarks in 'Managing the New Zealand whitebait fishery: a critical review of the role and performance of the Department of Conservation' states that 'I have little doubt that controversy over regulation of the whitebait fishery will recur'. Twenty-four years on from the last review of the whitebait fishery in 1994, similar concerns are being raised in 2018 about the management of the whitebait fishery.

McDowall (1996) suggested four key issues for DOC to address in order to minimise recurring controversy:

- Clarify its philosophical approach to managing the fishery;
- Be consistent in describing its approach as 'precautionary' (if that is the chosen descriptor);
- Clearly define what this means; and
- Ensure that all options for changes in the regulations are clearly articulated in discussion documents made available to whitebaiters for comment, if further reviews occur.

Since 1996 there have been no attempts to review the regulations. DOC's approach to the management of the fishery has largely remained unchanged, focussing on compliance and law enforcement of the regulations.

Whitebait identification, catch composition, catch size and size of whitebait runs

Whitebait identification

Yungnickel (2017) carried out research on the species composition of whitebait catches from around New Zealand. This research builds on earlier work carried out by McDowall & Eldon (1980) which studied species composition and created identification keys for whitebait. Genetic markers and morphological features have also been used in past research to differentiate the five migratory galaxias species that comprise whitebait (Dijkstra & McDowall 1997; Charteris & Ritchie 2002). However, it is particularly difficult to distinguish shortjaw kōkopu and kōaro whitebait, as they have similar morphological features (McDowall & Eldon 1980; Dijkstra & McDowall 1997). Table 6 outlines the characteristics used by Yungnickel (2017) to differentiate the five migratory galaxias species in their whitebait (Juvenile) phase. Yungnickel (2017) reported that in some samples it was more difficult to distinguish between species and in these cases size ranges played an important part in identification. Some individual identifications were

Table 6. Distinguishing features of juveniles of the five migratory galaxias species (Yungnickel 2017).

SPECIES	IDENTIFICATION
Īnanga	• Small mouth. • Cleft of mouth reaching before or to the anterior edge of eye. • Dorsal fin directly above the anal fin. • Mottled pigmentation along lateral line. • Melanophores forming parallel lines along the ventral surface. • Lower and upper jaw even. • Slim body shape. • Often longer than other species
Kōaro	• Shorter lower jaw. • Anal and dorsal fin offset (more in some individuals than others). • Opaque white in colour. • Cleft of mouth reaching to the anterior edge of the eye or up to one-third past. • A bulge in the parallel line of melanophores on the ventral surface. • Longer in length than banded kōkopu. • North Island individuals have a slender body shape compared with South Island individuals that have a broader body shape.
Banded kōkopu	• Small mouth. • Cleft of mouth reaching to the anterior (front) edge of or one-quarter past the eye. • Slim body shape in comparison with giant kōkopu and kōaro. • Anal and dorsal fins opposite each other. • A bulge in the parallel line of melanophores on the ventral surface. • Small size range in comparison with other species in sample
Giant kōkopu	• Body lengths often intermediate between those of banded kōkopu and kōaro in the same catch. • Anal and dorsal fins opposite each other. • Large eye relative to head. • Usually broader in shape in comparison with kōaro and banded kōkopu. • North Island – cleft of mouth varying from in front of to one-quarter to one-third past the eye; in the Waikato River, the mouth commonly stops before the eye (C. Baker, pers. comm.). • South Island – mouth generally one-third to halfway past the eye. • A bulge in the parallel line of melanophores on the ventral surface. • Often a short distance between the anal and caudal fins. • Intermediate in length between banded kōkopu and kōaro
Shortjaw kōkopu	• Usually have a distinctly shorter lower jaw, but not always. • Cleft of mouth reaches to or before the anterior of the eye. • Short distance between the anal and caudal fins. • Similar in length to kōaro but much stockier on the West Coast of the South Island. • Offset of anal and dorsal fins (varied). • A bulge in the parallel line of melanophores on the ventral surface

confirmed using genetic analysis. The distinguishing features identified by Yungnickel (2017) require close examination in a laboratory, particularly for some species. Identifying whitebait and distinguishing one species from another in the field is difficult, especially to the untrained eye.

Status of the whitebait fishery

There are several anecdotal accounts of dramatic declines in whitebait catches recounted in McDowall's whitebait book (McDowall 1984). Most of these anecdotal accounts are historic, with more recent accounts of decline being in relation to the decline in abundance of adults and contractions in their distributions.

Published or otherwise publicly available catch records for the whitebait fishery are very limited. In the past, DOC has made attempts to collect whitebait catch data via the West Coast Whitebaiters Association, surveys of fishers on rivers, providing catch diaries to whitebaiters to submit to DOC and through local buyers. However, such attempts have been largely unsuccessful (DOC, unpubl. reports). It should also be noted that any catch data that has been gathered would be difficult to compare between years as other factors, such as climatic conditions and fishery effort, would not remain equal. In a review of the West Coast Whitebait fishery undertaken in 1991 there was a general perception that the fishery was in decline and overfishing was a possible cause (Rankine & Hill Limited 1991).

There is a general agreement and perception among whitebaiters and scientists that there are large fluctuations in whitebait runs from year to year; and that different regions experience good and bad seasons in different years. This points to a very complex pattern of recruitment, especially when there are five species to consider, along with confounding biotic and abiotic factors influencing migration and catch size.

Catch composition

The species compositions of whitebait catches from around New Zealand vary regionally, within seasons and sometimes between seasons (McDowall 1965; Rowe & Kelly 2009; Yungnickel 2017). McDowall (1965) and Yungnickel (2017) reported that the overall catch composition of whitebait samples they analysed were dominated by īnanga, with kōaro whitebait being the second largest contributor (Table 7). It should also be noted that in some rivers in some months of the whitebait fishing season, smelt are captured in very high numbers (Yungnickel 2017). The composition of whitebait captured is very much dependent on the region, river and time within the season that they were captured (McDowall 1965; Yungnickel 2017; Egan et al. 2018). Yungnickel (2017) found the highest within-region variability in species composition in the Buller Region. Both McDowall (1965) and Yungnickel (2017) reported finding that whitebait catches on the east coasts of New Zealand had higher proportions of īnanga. This is likely related to the type of in-stream habitat as well as the riparian and catchment vegetation. Egan et al. (2018) assessed the catch composition of whitebait in the Waikato River and found that between years there was little difference in the proportion of each of the species captured; whereas there was obvious variation in the composition within each season (Fig. 8). Similar patterns to that found by Egan et al. (2018)

Table 7. Summary of the five migratory galaxias species caught as whitebait and their proportion of the catch (%) (from Yungnickel 2017 and McDowall 1965).

SPECIES	PROPORTION OF WHITEBAIT CATCH (%)	
	2016 (Yungnickel 2017)	1965 (McDowall 1965)
Īnanga	88.20	85.2
Kōaro	5.00	9.7
Banded kōkopu	6.60	<5.1
Giant kōkopu	0.03	<5.1
Shortjaw kōkopu	0.01	<5.1

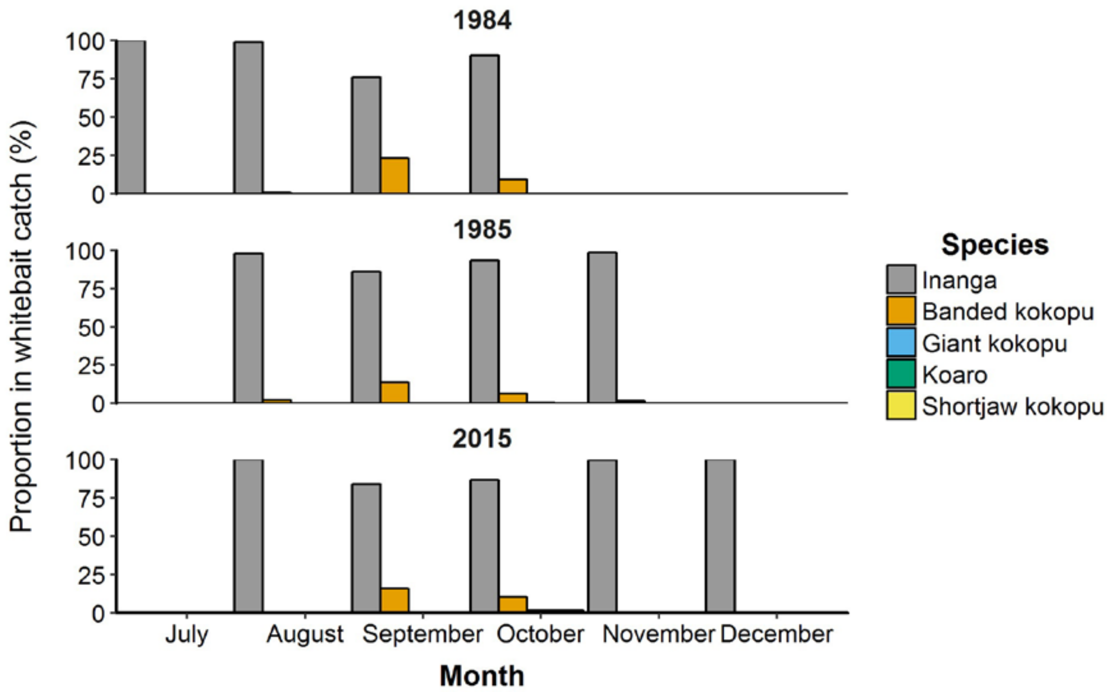

Figure 8. The proportion of migratory galaxias species in the whitebait catch on the Waikato River in 1984, 1985 and 2015. Data redrawn by Egan et al. (2018) from Stancliff et al. (1988a) and Yungnickel (2017).

in the Waikato River were recorded for other rivers and regions by Yungnickel (2017). During September and October, greater proportions of non-īnanga species were observed in whitebait samples. Kōaro were found in most rivers on the West Coast and in Buller during September, and banded kōkopu were present mainly in Waikato rivers. Giant kōkopu and shortjaw kōkopu whitebait were observed in low proportions in samples throughout Yungnicel's 6-month study. The highest proportions of giant kōkopu and shortjaw kōkopu whitebait were recorded in November and were predominately from rivers on the west coasts of both the North and South Islands (Yungnickel 2017). Yungnickel (2017) also noted that giant kōkopu and shortjaw kōkopu were recorded from catches taken from rivers with a high proportion of forest cover in their catchment.

Capture rates

There is some evidence that fishing pressure in large rivers can potentially reduce recruitment of whitebait. For example, Allibone et al. (1999) stained whitebait to study their upstream migration patterns and examine the probability of recapture within the Awakino River. Whitebaiters captured between 1% and 45% of marked fish contingent upon river flow and tidal height. A similar study on the Mōkau River found that whitebaiters captured between 3% and 27% of the marked fish migrating up the mainstem of the river (Baker & Smith 2015). Similar studies on the Oparau River resulted in catch rates between 6% and 23% (Baker & Boubée 2003). Overall, these studies indicate that whitebaiters can catch anywhere between 1% and 45% of whitebait runs.

The influence of river flow on migration and capture rates was also examined by Baker & Smith (2015). It was found that increasing river flow was positively correlated with the recapture rates of whitebait. This supports the earlier study of McDowall & Eldon (1980) who suggested that larger whitebait catches would be expected after floods when river flow is higher and the river is more turbid. In addition, Baker & Smith (2015) found that recapture rates were positively correlated with increasing water velocities around the edge of the whitebait trap. Juvenile galaxiids prefer low-velocity waters for migration (<0.1 m/s; McDowall & Eldon 1980), and fish often move upstream in the low-velocity surface waters (≤1.0 m deep) along riverbank margins (Stancliff et al. 1988b). As tidal waters recede, river flows produce stronger water velocities around whitebait traps for fish to negotiate. Baker and Smith (2015) found that once water velocities around fishermen's traps exceeded 0.1 m/s, marked increases in whitebait recapture rates were seen. Higher flows are generally associated with higher turbidity (Hicks et al. 2004) and this could also reduce the ability of fish to visually detect the trap, leading to increased catches.

The relationship between whitebait catches and numbers of whitebaiters has been used to examine the effects of varying fishing pressure on whitebait catches. In the Rakaia and Waitaki Rivers in Canterbury, Unwin (1983) found that the total daily catch of whitebait was positively correlated with the daily count of whitebaiters. Furthermore, 40% of whitebait caught in the Rakaia River were taken over 3 days during Labour weekend (Unwin 1983). In several Bay of Plenty rivers, the daily mean number of whitebaiters was positively correlated with the daily mean total catch of whitebait (Saxton et al. 1987). On the Awakino River, Boubée et al. (1992) documented that the numbers of whitebaiters increased on weekends and during spring tides.

Reported catches of whitebait are highly variable and reliable long-term data is extremely difficult to obtain. In the Awakino River, the highest daily individual catch was 16.8 kg for the 9 years of records, but mostly catches did not exceed 3 kg (Boubée et al. 1992). Based on data collated since 2000, Waikato River whitebaiters tend to catch more than 1 kg of bait on 50% of the days they fish, and more than 10 kg of whitebait on 9% of days fished (NIWA unpubl. data). Anecdotal evidence suggested that 2014 was an extremely productive season for whitebait in the Waikato River. Several whitebaiters reported that catches were the best in over 50 years, and an article in the Waikato Times suggested single hauls of up to 70 kg were achieved in the most lucrative whitebait season in more than 15 years.

More research and analysis is required to understand what impacts whitebaiting has on the five migratory galaxias species and accurately delineate the extent of these impacts.

Estimating the size of whitebait runs

There is very little information recorded in the literature on the size of whitebait runs throughout New Zealand. To gain an accurate understanding of the quantity of whitebait migrating upstream research would need to be undertaken to collect data from an extensive number of rivers throughout New Zealand across several years.

Allibone (2012) used mark-recapture studies in the Mokihinui River in 2010 to estimate the catch rate of whitebait. A maximum catch rate of 40% and average catch rate of approximately 30% were calculated. It was estimated from these figures that the total whitebait catch during the 2010 season on the Mokihinui River was 2–2.5 tonnes, which equates to approximately 3 million whitebait individuals. The escape rate was 70% on average, equating to approximately 7 million whitebait individuals migrating upstream. Allibone (2012) compared this with catches reported in the 1990s in the Mokihinui River and suggested that the much lower catch rates recorded in 2010 may indicate a substantial decline in the fishery or could just be the result of yearly variations.

Surveys of whitebaiters and public perceptions of the whitebait fishery and its management

Survey of West Coast whitebaiters

A survey of West Coast whitebaiters was carried out in 2010 by Chris Auchinvole (MP for the West Coast Tasman electorate at the time; C. Auchinvole unpubl. report). Nineteen questions were posed, and the survey was distributed by the West Coast Whitebaiters Association during the 2010 West Coast whitebait season. Questions were asked about where whitebaiting was undertaken, where people lived, whether they were commercial or recreational, how often they fished, what type of gear they used and what they thought about the current rules. Of the people surveyed, approximately 56% lived on the West Coast and the other 44% came from elsewhere. The majority of whitebaiters identified themselves as recreational (81%), while only 18% considered themselves to be commercial operators. When asked if there should be one set of rules for New Zealand or one set of rules for the South Island or neither, there was a reasonably even split between all three options. Slightly more whitebaiters thought there should be one set of regulations for New Zealand (38%). In regard to licensing, which does not occur currently, 55% of whitebaiters thought they should not be licensed. Whitebaiters were also asked whether they were satisfied with the existing regulations – 51% were satisfied and 49% were not satisfied. Surveys such as this should be regularly repeated and extended to other regions of New Zealand.

Whitebaiter diaries

There have been various attempts by researchers and managers to obtain catch data from whitebaiters. McDowall (1996) stated that accurate catch records have always been difficult to obtain, and this situation remains unchanged. In 1964, the Marine Department (who at the time managed the whitebait fishery) made a new regulation that required all commercial whitebaiters who fished from registered sites on the West Coast to submit their daily catches for the season to them. However, this regulation was abandoned after only 2 years because of the difficulty in enforcing it (McDowall 1996). Between 1970 and 2018 there have been no official attempts to collect whitebait catch information. There have, however, been various attempts to obtain catch information by way of providing whitebaiters with diaries to record their catch These have all been undertaken at a local level (e.g. Waikato, Otago, West Coast). This information, while interesting, is not comprehensive enough to allow any conclusions to be drawn.

Public perception surveys

In 2013, the public perceptions survey carried out by Lincoln University included a section on freshwater fish, with questions specifically relating to whitebait (Hughey et al. 2013). Whitebaiters were asked the number of days they attempted to catch whitebait in 2012. Forty-six of the 71 people who responded spent an average of 10 days whitebaiting. Of the respondents who went whitebaiting, most were from Taranaki, followed by Wellington and then Bay of Plenty. Specific questions relating to whitebait were asked; specifically: how threatened do they consider whitebait to be? What is their perception of change in whitebait numbers over the last 10 years? How important is it to have healthy whitebait populations and what activities are having the greatest detrimental impact on whitebait? The results of the survey showed that the majority of respondents (approx. 73%) thought that whitebait are ‘extremely’ or ‘somewhat’ threatened and most people (68%) thought that there are ‘much less’ or a ‘little less’ whitebait than 10 years ago. Seventy-five percent of respondents to the survey thought that whitebait are ‘very’ or ‘somewhat’ important to New Zealand. Loss of spawning habitat, water pollution and overfishing were the three most cited causes of decline by respondents. The authors concluded that, overall, there was a high level of concern from respondents with regard to the whitebait fishery and conservation status of the five migratory galaxias species. Further exploratory questions with regard to funding riparian plantings and fencing suggested that respondents were in favour of a user-pays system for whitebaiting; i.e. a licensing system. The authors also asked out respondents to rank seven management options for whitebaiting. Three options were the most favoured: introduced a daily 5 kg limit, shortening the season by 2 weeks and making it illegal to have traps in nets. These options were more favoured by non-whitebaiters than whitebaiters. The least preferred of the seven management options were making it illegal to sell whitebait and introducing afternoon fishing only. This study is probably the most comprehensive survey of the public in relation to their views and perceptions of the whitebait fishery and species. There is a clear need to undertake more research of this nature.

Threats and pressures affecting the five migratory galaxias species and the whitebait fishery

Impeded fish passage

Instream man-made structures negatively impact freshwater fish by impeding upstream and downstream passage, altering habitat and impacting stream processes (Franklin et al. 2018). Movement between freshwater rivers, streams and lakes and estuarine or marine environments is vital for migratory galaxiids to complete their lifecycle. This impacts on the species themselves as well as the whitebait fishery.

Fish passage barriers directly or indirectly affect migration in a number of ways. They cause:

- Changes in water depth and velocity, leading to conditions unsuitable for fish to swim through
- Physio-chemical changes e.g. reduced dissolved oxygen and increased water temperature
- Alterations to where and when sediment is deposited, as well as erosion of banks
- Removal or alteration of natural habitat and replacement with artificial habitat
- Fragmentation of habitat

Table 8 summarises the known and potential adverse effects of instream barriers on freshwater habitats and migratory galaxiids.

Habitat degradation

Loss and degradation of habitat is one of the major pressures impacting on the distribution and abundance of migratory galaxias species (McDowall 1990; Swales & West 1991; Sagar 1993; Jowett 2002). There has been significant loss of and degradation to lowland habitats with a loss of more than 90% of New Zealand's wetland habitat (Ausseil et al. 2008, 2011). the migratory galaxias species, particularly shortjaw kōkopu, giant kōkopu, banded kōkopu and kōaro, are associated with native forest (Main 1988; Hanchet 1990; McDowall et al. 1996). Thus the historic widespread loss and degradation of riparian and catchment vegetation in New Zealand has had a large impact on their current distribution and abundance. Although current removal of riparian and catchment vegetation is less extensive than historic clearance, it still occurs and has localised impacts on subpopulations.

Table 8. Instream barrier types and their known and potential adverse effects on fish passage (summarised from Franklin et al. 2018).

BARRIER TYPE	ADVERSE EFFECTS
Tide gates and pump stations	• Remove tidal fluctuations • Reduce salinity • Reduce water velocity • Increase sediment deposition • Lower dissolved oxygen • Increase water temperatures • Increase abundance of exotic fish and lower abundance and diversity of native fish • Physically block passage upstream Boys et al. 2012; Jellyman & Harding 2012; Franklin & Hodges 2015; Scott et al. 2016; Birnie-Gauvin et al. 2017; Franklin et al. 2018
Culverts, weirs and dams	• Alter downstream flow • Change position and type of erosion and sediment deposition • Alter physical habitat • Change water quality • Change upstream habitat in response to increasing water depth, increased fine sediment deposition, decreased water velocity and alterations in water quality • Increase abundance of exotic fish and lower abundance and diversity of native fish • Physically block fish passage upstream MacDonald & Davies 2007; Doehring et al. 2011; Boys et al. 2012; Cocchiglia et al. 2012; Franklin & Bartels 2012; Jellyman & Harding 2012; Scott et al. 2016; Birnie-Gauvin et al. 2017; Franklin et al. 2018.

Land-based human activities such as farming, forestry, urban development and mining have caused decreased water quality throughout New Zealand's freshwater ecosystems. Sedimentation caused by farming and forestry has been shown to change recruitment patterns, swimming ability and decrease density and diversity of freshwater fish populations (McDowall & Eldon 1980; Saxton et al. 1987; Ryan 1991; Richardson et al. 2001a; Richardson & Jowett 2002). Boubee et al. (1997) studied the behaviour of six native freshwater fish species in relation to suspended sediment and found that banded kōkopu were particularly sensitive to suspended solids, kōaro were slightly less sensitive and īnanga appeared to have a reasonably high tolerance. Banded kōkopu and īnanga juveniles, however, had reduced feeding levels at relatively low levels of sedimentation (Rowe & Dean 1998). Cadmium has been shown to effect migration behaviour of banded kōkopu (Baker & Montgomery 2001b). Ammonia appears to have less effect on whitebait (Richardson 1997). However, the ability of īnanga to detect highly toxic levels of ammonia was poor (Richardson et al. 2001b).

There are few published studies in New Zealand that have attempted to quantify or document the effects of mechanical or chemical drain cleaning on mortality of freshwater fish. Although the results are inconclusive and there were cofounding factors, a study by Allibone & Dare (2015) found that giant kōkopu numbers declined from 18 fish to only 1, a year after drain clearance activities. Greer et al. (2012) and Greer (2014) found that dissolved oxygen (DO) levels declined rapidly following macrophyte clearance and remained low for several days. He suggested that high mortality rates of giant kōkopu may occur due to these low DO levels and associated sediment re-suspension if fish could not move out of the area. Drain clearing occurs extensively in the Waikato and Southland Regions and is increasingly occurring on the West Coast. As land use changes to more intensive dairy farming, the impacts of drain clearing on giant kōkopu are expected to be severe (West et al. 2014).

Decreased water flows

Water abstraction affects the available habitat, water temperature, food availability and also migratory cues by changing the magnitude and frequency of different flow regimes. Flood flows stimulate the inward migrations of whitebait to rivers, with the largest runs often occurring after flood events (McDowall 1995). Water abstraction and river regulation can reduce the volume of freshwater entering the sea, which may delay or even limit whitebait migrations into fresh water. The upstream migration rate of īnanga has been shown to be influenced by stream flow, among other factors (such as water clarity; Baker & Smith 2015), and temperature (Bannon & Ling 2004). For diadromous populations, the downstream transport of larvae may be affected by variation in flows (Charteris et al. 2003).

Reduced flows can also affect spawning and egg survival for whitebait and, therefore, management of flow variability is important for spawning success. For example, Franklin et al. (2015) found that because of low winter rainfall in 2013 in the Waikato Region, sufficient flows to re-inundate giant kōkopu eggs and stimulate larval hatching did not occur. Although the eggs remained alive for up to 10 weeks in riparian vegetation, no eggs survived through to hatching that season.

Following hatching, whitebait larvae are largely passive because of their small size and poorly developed sensory abilities (McDowall 2009); however, many fish species inherently display rheotaxis and will orient themselves into the flow (Montgomery et al. 1997). Recent observations suggest that kōaro larvae in lakes display rheotaxis and will actively move against the flow (Augspurger 2017). Downstream transport may also be actively controlled by larval fish. Within the Waikato River, Meredith et al. (1989, 1992) found a diel pattern in smelt migrations, and Baker & Bartels (2011) suggested that larval smelt were not simply passively drifting downstream; rather, they were actively staying within the main river flow during their migration to the sea. Therefore, larval dispersal and thereby population connectivity may be influenced by flows.

Harvest (whitebaiting)

McDowall (1968) suggested that since the 1920s, fishing pressure has increased, meaning individual catches have declined and so there is a perception that the fishery is in decline. Long-term depletion of stocks has compromised the integrity of the whitebait fishery such that up to 1968, few rivers satisfied the local demands and requirements of whitebaiters (McDowall 1968).

Very little is known about the quantum of impact that whitebait fishing has on the five migratory galaxias species and the whitebait fishery. There are many confounding factors that impact migratory galaxias distribution and abundance; for example, habitat loss and degradation, instream structures impeding up- and down-stream migrations, introduced species and water quality. There have been no comprehensive studies researching the level of impact that each of these have of population dynamics. However, mark-recapture studies have been undertaken in an attempt to quantify harvest impacts. These suggest up to 45% of whitebait migrating up river and streams can be captured dependent upon river size, fishing pressure and environmental conditions (Allibone et al. 1999; Baker & Boubée 2003; Baker & Smith 2015).

The West Coast of the South Island has a list of rivers in the Whitebait Fishing (West Coast) Regulations 1994 where whitebait fishing is excluded. Research is currently being carried out by the University of Canterbury to assess the effectiveness of these closed areas (M. Hickford pers. comm.). This research will provide valuable insight into potential impacts of whitebait fishing on migratory galaxiid populations and direction on where more research might be needed with respect to closed areas. The location of rivers closed to fishing has significant implications for management and conservation of the migratory galaxiids and the whitebait fishery.

Introduced species

There is little published research on the impacts of introduced species on the five migratory galaxias species, including on the whitebait (juvenile) phase. Trout are frequently implicated as having detrimental effects on migratory galaxiid populations; however, there is currently a lack of published data to support this (McIntosh et al. 2010). There is anecdotal evidence of trout predating on whitebait in estuarine areas/river mouths as they move upstream as well as suggestions of competition between adult trout and migratory galaxiids for habitat and food resources (McDowall 1990, McDowall 1991; Goodman 2002; C. Annandale pers. comm.). Glova (2003) found in a mesocosm (a controlled outdoor experimental system) that the number of īnanga declined when they shared the stream habitats with brown trout (*Salmo trutta*) (255–390 mm long), and also that the galaxiids shifted their microhabitat use with trout present. Hayes (1996) found that kōaro displayed different feeding patterns in habitat with and without trout. Trout and galaxiids have similar diets so competition for food resources may occur (Kusabs & Swales 1991; McDowall 2006). McDowall (1991) suggested that the question of how introduced species impacted on the migratory galaxiids needs to be addressed; however, this question still remains largely unanswered.

Mice have been shown to be active predators of īnanga eggs laid amongst the intertidal vegetation lining the Mokau River (Baker 2006), but this predation did not appear to be a major cause of egg mortality in field studies in Canterbury (Hickford et al. 2010). Rowe et al. (2007) showed that gambusia (*Gambuisa affinis*) nipped the fins of īnanga in a laboratory study at water temperatures between 15° and 25°C, resulting in immobilisation and death of the īnanga. However, the īnanga were held in tanks where they could not seek refuge from the gambusia and currently there are no field studies to support this finding.

The invasive algae didymo (*Didymosphenia geminata*) was found in New Zealand freshwater ecosystems in 2004. In response to the didymo incursion DOC worked with Biosecurity NZ (now Ministry for Primary Industries) to make whitebaiters aware of the threat didymo posed to freshwater ecosystems and species. Whitebaiters were reminded of the threat didymo posed and urged to clean nets and other gear between waterways to prevent its spread.

Climate change

Climate change and associated changes to sea surface temperature (SST) and oceanic circulation patterns have been implicated in the decline of Galaxias maculatus in southwest Australia (Barbee et al. 2011). However, impacts of changing sea surface temperatures on larval whitebait in New Zealand have not been investigated. Shears and Bowen (2017) recently showed there has been increasing 'tropicalisation' of the coastal environment in New Zealand over the last 50 years, which may have implications for the marine life phase of whitebait, particularly growth rates. Research at the University of Canterbury is currenting investigating the implications of increasing sea levels, coincident with climate change, on īnanga spawning habitat availability.

Variable and extreme weather conditions associated with climate change can affect spawning success and abundance. Droughts frequently occur on the east coast of New Zealand during later summer and autumn, and their probability of occurrence is predicted to increase with climate change. Droughts can affect the spawning success and larval migration to the sea for migratory galaxiid species (e.g. Franklin et al. 2015). Īnanga eggs are particularly sensitive to temperature fluctuations (Hickford & Schiel 2011b) and may be more susceptible to mortality under drought conditions. Flooding can increase īnanga egg mortality rates as the eggs are covered in silt (Stancliff et al. 1988a) and, therefore, smothering of eggs could also occur for kōkopu species spawning in bankside vegetation during elevated flows. Changes in the frequency, timing and magnitude of flood events that are predicted with climate change may alter the reproductive cues used by kōaro and kōkopu species (Charteris et al. 2003), but this remains to be seen.

Other studies have examined the influence of water temperature on the size of smelt and īnanga that have recruited into the Waikato River. Across 8 years (2004–12, with the exception of 2006), Baker & Franklin (2012) identified significant negative correlations between mean ambient water temperature in the Waikato River (January–June) and mean smelt length and weight (Fig. 9). Ambient river temperatures accounted for approximately 66–68% of the between year variation

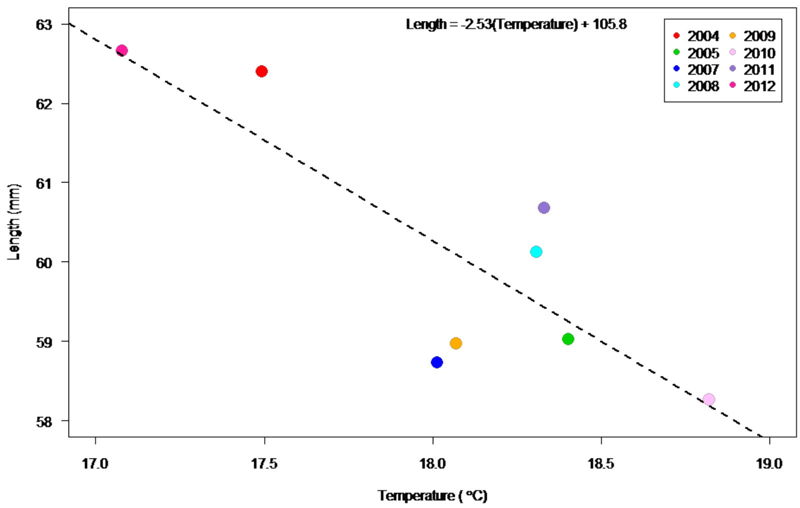

Figure 9. Scatter graph of mean smelt length and mean daily water temperature for the January to June survey period. The dashed line shows the linear regression relationship between the two variables (r^2 = 0.68; p = 0.011). (Source: Baker & Franklin 2012).

in smelt length and weight. Given that smelt size will be a function of a wide range of variables such as flow, food availability, predation and competition, this is a relatively good indication that broad-scale drivers of ambient river conditions are a primary control on overall smelt size in the Waikato River. In support of Baker & Franklin (2012), Baker et al. (2017) have documented (across another 8-year period, 2010–17) a similar inverse (negative) correlation between mean ambient water temperature in the Waikato River and īnanga length ($P < 0.05$) (Fig. 10). Data indicates that when spring/summer water temperatures are high, īnanga will be smaller than in years with cooler spring/summer temperatures. These types of relationships suggest that climate change could impact growth, condition and fecundity of whitebait species.

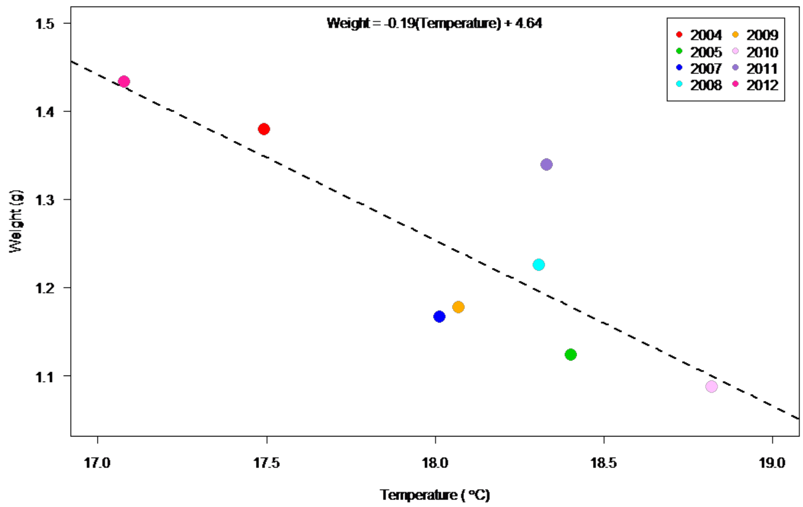

Figure 10. Scatter graph of mean smelt weight and mean daily water temperature for the January to June survey period. The dashed line shows the linear regression relationship between the two variables (r^2 = 0.66; p = 0.014). (Source: Baker & Franklin 2012).

Research underway

Several research projects are underway to investigate aspects of the whitebait fishery and its component species. These include:

- Recruitment of giant kōkopu in the Waikato River (B. David, Waikato Regional Council).
- The effectiveness of areas closed to fishing on the West Coast (MBIE Habitat Bottlenecks programme, University of Canterbury).
- The genetic/population structure of four migratory galaxias species around New Zealand (J. Goodman, University of Otago in collaboration with DOC).
- Effects of land use changes on giant kōkopu spawning habitat and population production (NIWA, MBIE Habitat Bottlenecks programme).
- Swimming abilities of key whitebait species and hydraulic conditions chosen during migration (NIWA, MBIE Habitat Bottlenecks programme).

Information gaps

There has been a general increase in knowledge about the five migratory galaxias species that comprise the whitebait fishery (Fig. 11). Figure 11 was reproduced from McDowall (1991) and dotted lines have been added to show the approximate level of understanding in 2018 for each of the nine categories McDowall (1991) summarised. Adult habitat ‘preferences’ are reasonably well known; however, gaps in knowledge still exist in relation to land-locked or non-migratory adult populations. There are still large gaps in knowledge about the habitat requirements for spawning, and also for whitebait (juveniles), post-whitebait juveniles and larval fish. Recent research has started to increase our understanding of the recruitment dynamics of the five species through studies on otoliths, catch composition and genetic analysis. However more research and analysis is still required to understand the complexities of each of the five species in different rivers and regions, as well as from year to year.

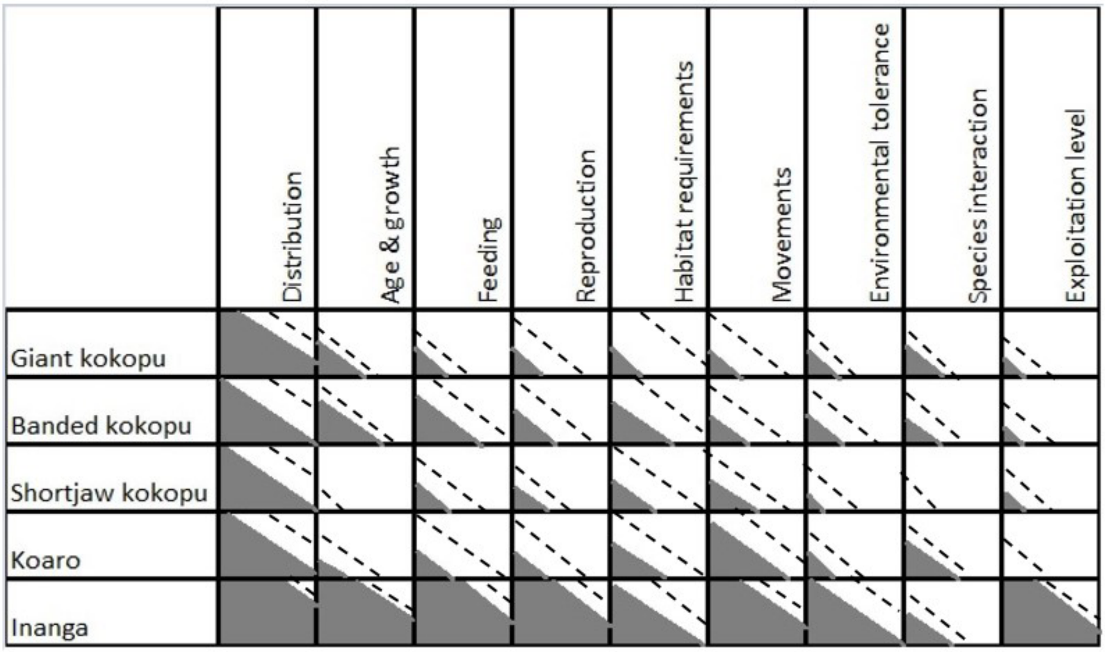

Figure 11. Diagrammatic representation of the level of information known for the five migratory galaxias species that comprise the whitebait fishery in relation to life-history, habitat and whitebaiting pressure (reproduced from McDowall 1991). Grey-shaded areas represent level of knowledge in 1991; dotted lines indicate current level of knowledge in 2018.

There is still very little known about the larval phase of the migratory galaxiids and therefore not much is known about the threats and pressure on these tiny fish. A large gap in knowledge still exists about the number of people whitebaiting, where they whitebait and how much they catch and therefore the magnitude of the impact whitebaiting has on the five migratory galaxias species. It is therefore still very difficult to make accurate conclusions about decline rates of juveniles. The NZFFD (McDowall & Richardson 1983) provides good information about the general distribution and relative abundance of species; however, defining precise decline rates using the NZFFD is challenging due to biases and variability in the data it contains. A long-term nationwide monitoring network remains a gap that needs to be filled in order to obtain good population trend information for the migratory galaxiids.

The particular threats and pressures affecting the migratory galaxiids are generally readily identifiable. However, the magnitude of the impact each has on each of the five species at the difference phases of their life-cycles requires more research and analysis.

Table 9 summarises knowledge and research gaps across different work areas for the migratory galaxiids. However, it is not exhaustive and there are likely to be other areas where more information is needed.

Table 9. Summary of information gaps for the five migratory galaxias species comprising the whitebait fishery and areas where more research is required.

ISSUE	INFORMATION GAP
Recruitment	• The existence and extent of facultative diadromy (flexibility of completing entire life-cycle in freshwater even when there is unimpeded access to the seas versus utilising the marine environment as larval fish). • Attraction pheromones (odour) and positive feedback loops (e.g. the degree to which the absence of adult conspecifics (same species) in some habitats influences recruitment) • Relationship between whitebait condition and subsequent recruitment into freshwater habitats (i.e. are larger, better-conditioned whitebait that occur early in the fishing season more successful at recruitment?). • Relationship between the number of whitebait entering a river and the abundance of adult fish in the river.
Spawning	• Further research into spawning behaviour and habitats to refine knowledge and understand the breadth of habitat types the species spawn in (i.e. there are very few recorded spawning sites for giant kōkopu, shortjaw kōkopu, kōaro and banded kōkopu). Searching in-stream habitat as well as stream banks for eggs for all species (including īnanga) to increase knowledge of the breadth of habitat that can be utilised for spawning). • Impacts of flow variability on egg survival and hatching for kōaro and kōkopu species, especially populations using elevated flows for spawning (e.g. water abstraction creates changes in the timing, duration and magnitude of high and low flows). • Variation in timing of spawning of all species locally, regionally and nationally.
Larval fish	• Basic knowledge of larval biology and ecology.Impacts on larval fish in the ocean and freshwater environments. • Migration pathways and how they differ between east and west coast populations and North and South islands.The impacts of man-made structures and chemical barriers to the downstream migration of larval fish.
Ecology	• Ecology of kōaro occupying isolated tarns (particularly reproductive ecology). • Ecology and biology of land-locked/non-migratory populations of all species. • Impacts of exotic fish species on whitebait growth, abundance and spawning success. • Stock structure investigations for all five migratory galaxias species. Currently, īnanga is the only species investigated nationally and spatial coverage is still limited. Given the evidence for regional stocks, this is a key research gap across the five species.
Habitat restoration	• The effectiveness of artificial habitats.Impacts of degraded water quality and point source pollutants (including emerging contaminants for urban populations). • Impacts of increased sedimentation and drain clearing activities.
Fish passage	*Water intakes* • Assessment of impingement/escapement rates relative to water velocities. • Influence of mesh size on impingement and entrainment rates. • How effective are gravel bunds and rock groynes at preventing/minimising native and exotic fish impingement? • What is the timing (seasonal or circadian) of key migrations for juveniles of different fish species? *Barrier remediation* • What is the efficacy of existing and new retrofit solutions for culvert andweirs to enhance whitebait species passage? • How do we determine appropriate turbulence, water velocities and attraction flow to motivate fish passage? • Effectiveness of fish-friendly tidegates and the effect of different gate geometry on whitebait passage. • Impacts of flood control schemes on whitebait distribution and abundance. *Biology* • Investigate the swimming, climbing and jumping abilities of different whitebait species to enable effective fish pass designs.
Climate change	• Impacts of increased water temperatures on whitebait species biology and ecology. • Impacts of climate variability on whitebait species biology and ecology.
Whitebait fishery	• Collect baseline data on catch-per-unit effort to provide an indication of temporal trends in the fishery and the ability to quantify any change or decline. • Quota management for commercial and recreational catches. • Type of nets used – effectiveness of set nets/sock nets versus scoop nets. • Will implementing closed areas help conserve the species? • Guidance structures – remove or retain. • Impacts of shortening the fishing season to protect rarer whitebait species that migrate in late October and November.

Conclusion

There has been a large increase in research in the past 20 years on the biology and ecology of the five migratory galaxias species; however, there are still significant gaps in knowledge. The habitat requirements of adult migratory galaxiids can be described but there is still very little information on spawning habitats (with the exception of īnanga) and juvenile (whitebait) habitat. Knowledge about all aspects of larval fish life-history remains one of the largest gaps.

The general distribution of all five migratory galaxias species is relatively well known; however, quantifying decline in distribution and abundance requires implementation of a long-term national monitoring system.

Recent research has increased our knowledge about whitebait with respect to the species composition in whitebaiters' catches, and how long īnanga spend in estuarine or marine environments as larval fish. This research and genetic research that is underway is pointing towards different population structures or 'stocks' around the country for each species. This could have significant implications for management.

There is very little long-term data about the whitebait fishery. More information is required about the number of whitebaiters, where they operate and how much they catch. There have been various attempts historically and in recent times to gather data on aspects of the fishery; however, these have largely been locally based and not long term.

Threats and pressures on the species and the fishery have been identified. Quantifying decline and attributing it to any of the various threats and pressures on the species and fishery is very difficult with our current level of understanding.

Critical to the conservation and management of these species and the fishery is collating what knowledge we have and identifying research gaps to inform decision making about future management. It is hoped that this report will form the basis of discussions about future management of the five migratory galaxias species and the whitebait fishery they support.

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