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.

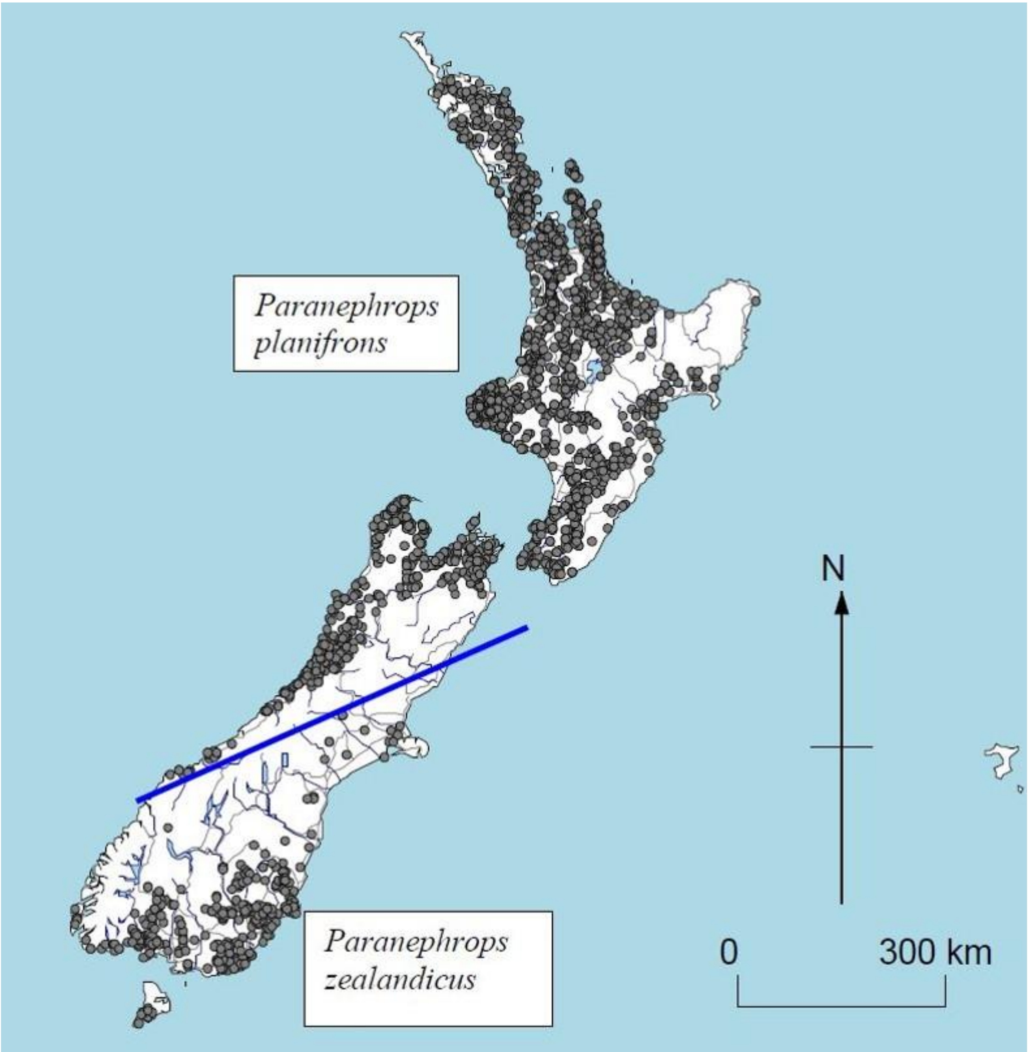


Figure 1: Approximate distribution of Aotearoa-NZ kōura species, separated by Kā Tiritiri o te Moana (Southern Alps). (Source: Parkyn & Kusabs 2007, also see McDowall 2005 & 2010 for more information).

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.

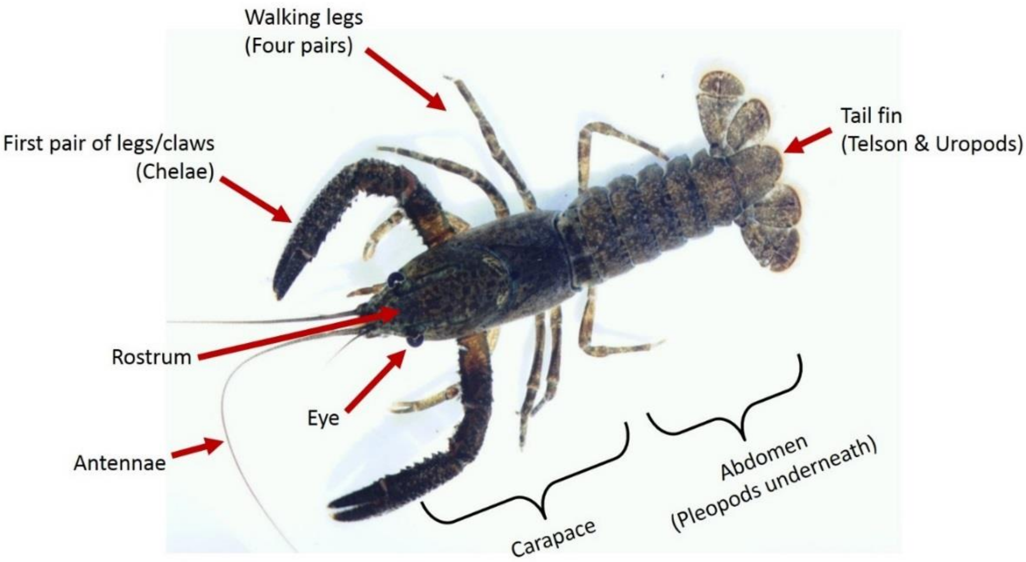


Figure 2: Key features of a kōura. (Photo: Ian Kusabs).

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.

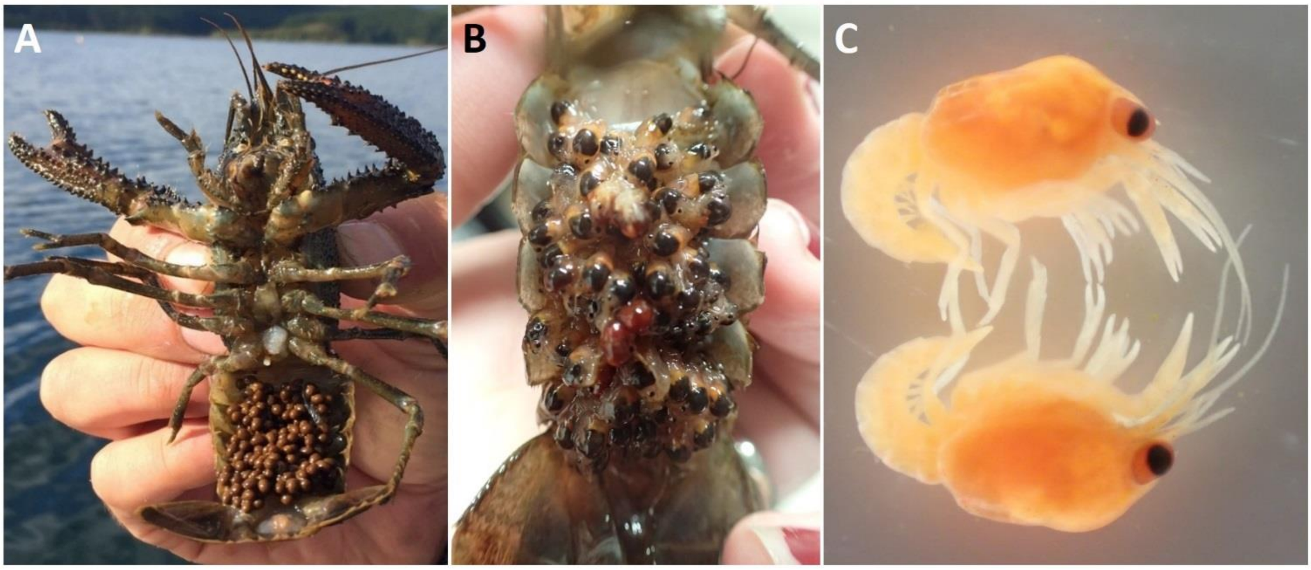


Figure 3: (A) A female kōura carrying eggs; (B) Juvenile kōura starting to hatch; and (C) One-day old kōura. (Photos: [A] Steph Parkyn, and [B & C] Karen Thompson).

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).

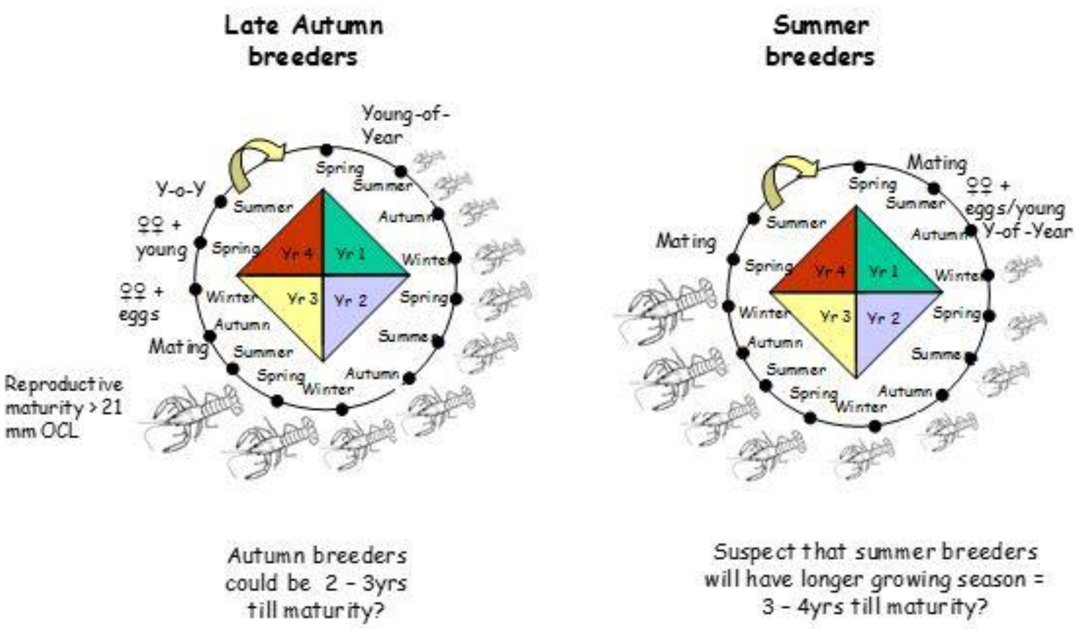


Figure 4: Kōura life history in Lake Rotoiti. (Source: Devcich 1979). YoY = Young of Year. Kōura length is determined using the Orbit-Carapace Length (OCL) which measured from behind the eye to the end of the carapace along the top and centre of the back.

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 5: 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[1] 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[2] (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).

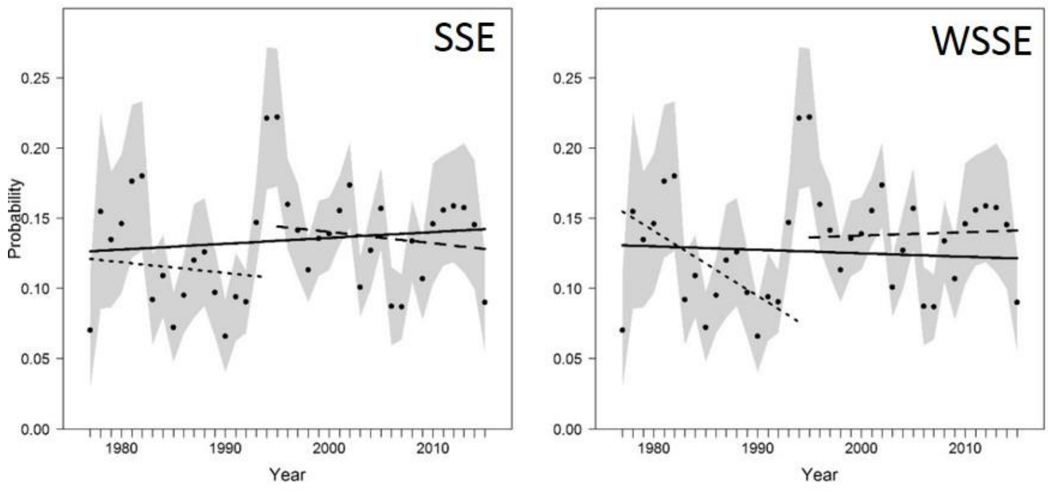


Figure 6: Change in the probability of kōura capture associated with year for the NZFFD data. Plots show the characteristic probability of capture for each year (black circles) and 95% CI (grey shaded area). SSE (left) and WSSE (right) are shown for 1977–2015 (solid black line), 1977–1994 (dotted black line) and 1995–2015 (dashed black line). CI = Confidence Interval. (Source: Crow et al. 2016).

[1] Simple linear regression is a statistical method that allows us to summarise and study relationships between two continuous (quantitative) variables.
[2] 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 1: 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[3] (Populations decreasing)
Paranephrops zealandicus	At Risk–Declining	Least Concern[4] (Populations stable)

5.5 Pressures on Populations

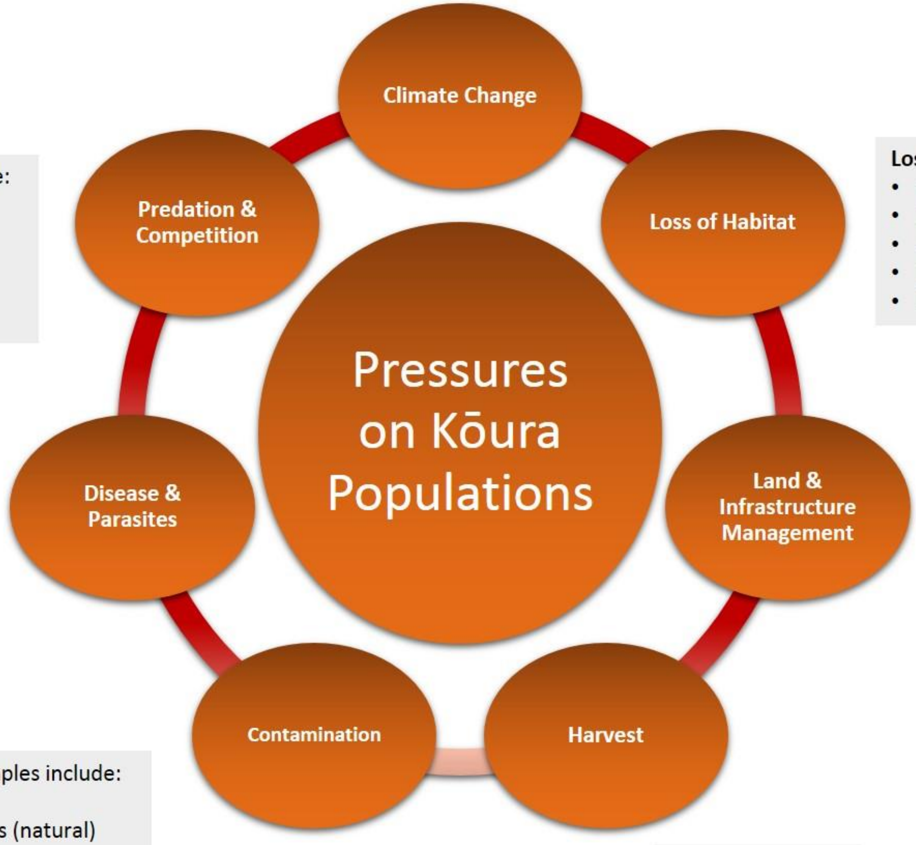
Pressures on kōura populations include habitat loss (wetland drainage, deforestation), land management practises (headwater stream captures and use of chemicals), water management practises (e.g., water abstraction, controlled flows), pollution and predation (particularly by introduced salmonids and 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).

[3] http://www.iucnredlist.org/details/153750/0
[4] http://www.iucnredlist.org/details/153614/0



Predation & Competition - Examples include:
- Salmonids -Trout
- Pest fish - Perch, Catfish
- Tuna
- Birds – Kingfisher, Shags
- Rats

Loss of Habitat - Examples include:
- Land use change (e.g., deforestation)
- Drainage of wetlands & swampy areas
- Fairway channel maintenance
- Loss of riparian vegetation
- Pest plants

Disease & Parasites - Examples include:
- White tail disease

Land & Infrastructure Management - Examples include:
- Water extraction
- Stock in waterways
- Nutrient management - Eutrophication
- Sediment management
- “Drain” clearance
- Fairway channel maintenance
- Road infrastructure
- River straightening
- River/stream diversions

Contamination - Examples include:
- Pesticides
- Geothermal sources (natural)
- Geothermal power
- Point source pollution events
- Stormwater runoff
- Road runoff
- Industry

Harvest includes:
- Customary
- Recreational

Figure 7: Examples of some of the pressures on Aotearoa-NZ kōura populations.

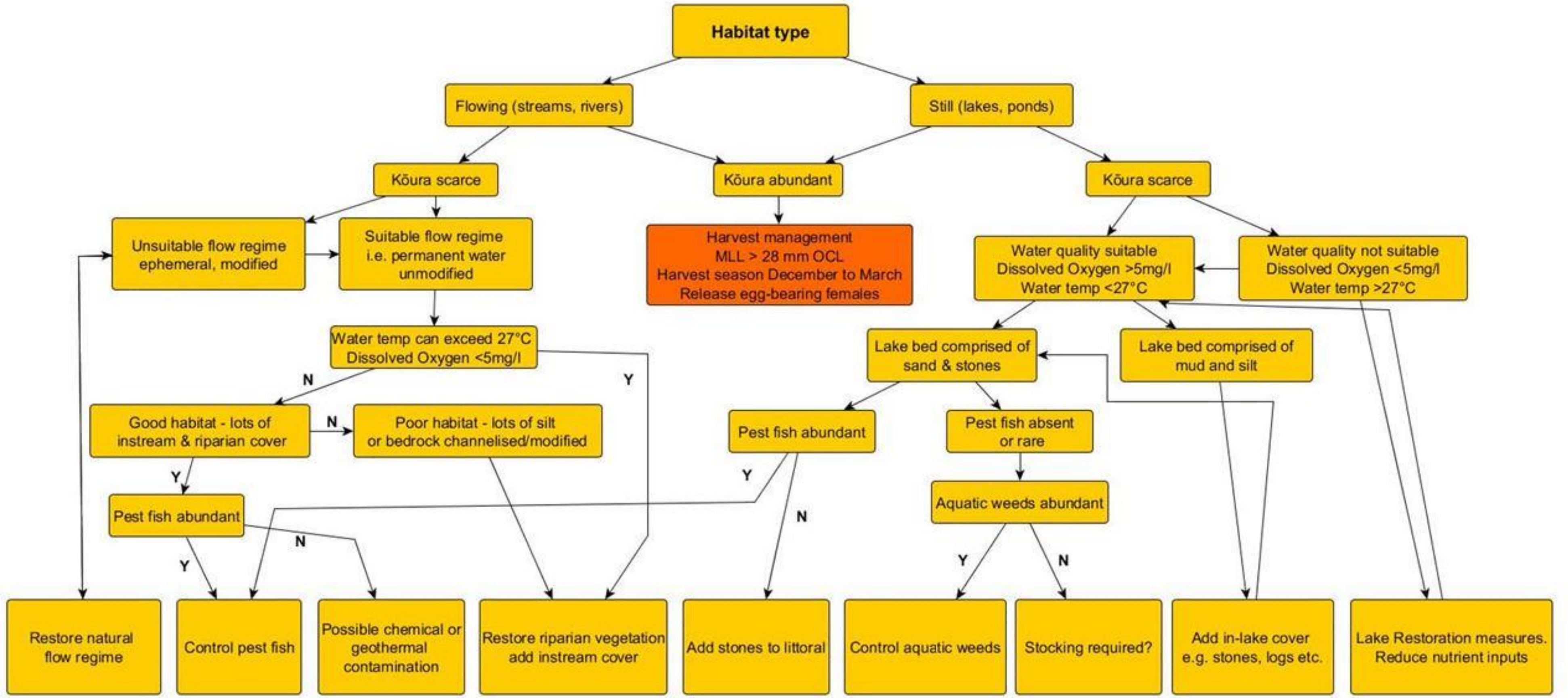


Figure 8: Generalised decision support system (DSS) for identifying causes of low kōura abundance in Aotearoa-NZ waterways. If the low abundance of kōura in your waterway is not related to a reduction in habitat, water quality, flow, it might be due to an event that has decimated the kōura populations 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[5] which has decimated populations in Europe (e.g., Vaeßen & Hollert 2015, Svoboda et al. 2017). This emphasises the importance of being vigilant in Aotearoa-NZ with

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

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

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

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[7] (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[8]). 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).

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

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