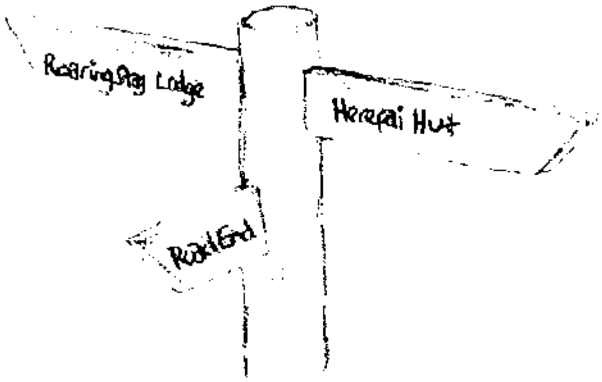
Shortjaw kokopu (*Galaxias postvectis* Clarke) distribution, habitat selection and seasonal activity in the northeastern Tararua Ranges



A thesis presented in partial fulfillment of the requirements
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Errata

Page 3 (and other occurrences): replace "Boubee" with "Boubée".

Page 4, line 5: replace "particular" with "particularly"

Page 4: footnote [2] is on page 5

Page 5, line 6: remove hyphen

Page 5, para 3, line 6: replace "predating" with "preying on"

Page 14, para 2, line 3: replace "fluorscine" with "fluorescein"

Page 16, para 3, line 8: replace "preformed" with "performed"

Page 18, Figure 2: add to caption "Pie segments are proportional to total number of fish of each species."

Page 19: Replace P values = 0.001 with < 0.001.

Page 20, para 2: replace "pfankuch" with "Pfankuch".

Page 40, Table 3. add to caption "Sample size, n = 67".

Page 48, abstract last line: replace "sit" with "site"

Page 57, line 4: replace "concordence" with "concordance"

Page 63, para 2: add "Reach length surveyed was 200 metres".

Page 68, para 2: replace "principle" with "principal"

Page 69, para 3: replace "elctrofished" with "electrofished"

Abstract

Freshwater fish communities were surveyed at 59 sites in the Mangatainoka, Makakahi and Ruamahanga catchments of the northeastern Tararua Ranges during 2000/01. At each site, habitat characteristics were recorded and fish identified by spotlighting over a 100 m reach. Benthic invertebrate samples were also collected from 50 of these sites. Shortjaw kokopu (*Galaxias postvectis* Clarke) occurred at 16 sites, located in the Mangatainoka and Makakahi catchments only. Ninty-five shortjaw kokopu were caught in total, ranging from juveniles (≤90 mm) to adults (>120 mm), with adults comprising approximately 75% of the population. Six other fish species were also recorded. Koaro (*G. brevipinnis* Günther), longfin eel (*Anguilla dieffenbachii* Gray), Cran's bully (*Gobiomorphus basalis* Gray), torrentfish (*Cheimarrichthys fosteri* Haast) and brown trout (*Salmo trutta* Linnaeus) all co-occurred with shortjaw kokopu; and a single banded kokopu (*G. fasciatus* Gray) was found in the Ruamahanga catchment.

Discriminant analysis found six habitat factors defined shortjaw kokopu presence. These were low percentages of debris jams, pasture and backwaters; high percentages of shrubs and riffles; and high conductivity. The invertebrate community also proved effective at predicting shortjaw kokopu presence. However, it appears that shortjaw kokopu are limited in distribution by recruitment rather than habitat. Different age classes of shortjaw kokopu were also found to use distinct microhabitats. Sand substrate, pool length, width at the top of the pool, velocity, gradient below the pool, and cobble in the habitat above the pool were found to discriminate between the age class microhabitats.

At three sites in the Mangatainoka River, surveys were undertaken monthly, for 16 months. Number of shortjaw kokopu observed was greatly reduced at all three sites during winter and at a maximum in autumn. This showed that shortjaw kokopu exhibited reduced activity rather than seasonal movements within the catchment.

Three methods for surveying fish communities were tested on shortjaw kokopu. Gee-minnow traps failed to catch any shortjaw kokopu, but electrofishing and spotlighting both proved effective. While spotlighting caught more shortjaw kokopu at more sites, no significant difference in performance was found between the two methods.

Acknowledgements

I am grateful to everybody who has influenced this project, especially to my supervisor, Dr Ian Henderson, who helped set the project up. While 3rd year limnology developed my interest in New Zealand's freshwater fish, it was Ian's inspiration for this project which made it happen. I am also incredibly grateful for his thorough editing skills and statistical know-how.

To Sjaan Charteris who was incredible support when things went to custard. Her thorough editing, her driving ambition for me to finish and her ability to keep me on the straight and narrow, ensured that I gave my best, managed my time efficiently, but maintained my sanity in the process. For that, I am sincerely thankful.

I would like to acknowledge the funding from the Department of Conservation and horizons.mw. The river-line run by horizons.mw proved incredibly beneficial, allowing trips to be planned efficiently.

I am incredibly grateful to my parents, Robbie and Robyn, and sister Cookie, who ventured into the field when volunteers were in short supply. They endured much hardship to see me fulfil my aspirations, tolerating some rough sleeping conditions, some long-nights in semi-freezing water, some sever bruising, and some long days hiking into remote, but incredibly picturesque locations.

To the Ecology Group, Massey University. Thankyou to all who ventured into the field, especially Kirsty Francis, Matt Wong, Cindy Jenkins, Debbie Kyngdon and Mark Hamer; and also to other volunteers, Callum Kay and Sarah Clarke, who were not always happy to be there, but were prepared to give up their time. Mike Joy and Russell Death had a lot of valuable advise; and Jens Jorgensen created some fine field equipment. Paul Barrett, Cathy Lake, Tracy Harris and Hayden Hewitt provided some excellent technical support; and Erica Reid, Barbara Just, Jodi Matenga and Diana Crow, all provided great administrative support.

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Finally, a special thank you to Jim and Bev Bryant, and my father Robbie, for their help rescuing my car when it broke down, middle of the night, middle of nowhere.

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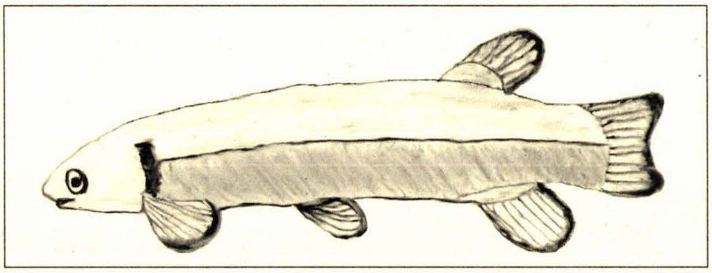
General Introduction



F.E. Clarke (1899) on shortjaw kokopu:

"The third westland species I enlarge upon, more frequently inhabits the sluggish and muddy-bottomed creeks, but is also found in company with Galaxias kokopu in the gravel-bottomed and some of the rocky creeks. In its proportions it somewhat approximates to the description of fasciatus, though it grows much larger, but seldom beyond 10 in. in length. It is not as hardy in the aquarium as G. kokopu, and has generally the same feeding habits, except that it does not take a surface-bait as well. Strange to say, it is seldom, if ever, troubled with the flesh-worms before mentioned. I have distinguished this one with the specific name of postvectis, on account of its perculiar and constant markings."

New Zealand has 36 recognized species of native freshwater fish, with two more recently discovered, but yet to be formally classified (R.M. Allibone (DoC[1]: Wellington) *pers. comm.* November 2001). Seven other species of marine wanderers also frequent freshwater from time to time (McDowall 2000). Of these 36 species, seven are members of the bully family (*Gobiomorphus* spp., Eleotridae), three of the eel family (*Anguilla* spp., Anguillidae), two of the smelt family (Retropinnidae) and 20 of the family Galaxiidae. The remaining four species are lamprey (*Geotria australis* Gray), torrentfish (*Cheimarrichthys fosteri*), black flounder (*Rhombosolea retiaria* Hutton) and the now extinct grayling (*Prototroctes oxyrhynchus* Günther).

Many of New Zealand's freshwater fish require access to both marine and freshwater, commonly known as diadromy. There are three forms of diadromy: catadromy, living in freshwater but migrating to sea to spawn (e.g. eels); anadromy, living at sea but migrating into freshwater to spawn (e.g. lamprey); and amphidromy, migration between marine and freshwater but not related to spawning (e.g. torrentfish) (McDowall 1990). The galaxiidae family comprises five diadromous and 15 non-diadromous species. The diadromous species (whitebait) exhibit either catadromy, i.e. inanga (*Galaxias maculatus* (Jenyns)) or amphidromy, i.e. giant kokopu (*G. argenteus* (Gmelin)), banded kokopu (*G. fasciatus*), shortjaw kokopu (*G. postvectis*) and koaro (*G. brevipinnis*).

Of the diadromous galaxiids, shortjaw kokopu are thought to be the rarest, listed as category A in the endangered species rankings (Molloy & Davis 1994). Sharing this endangered species rating are several New Zealand icons such as kiwi (*Apteryx* spp.), takahe (*Porphyrio mantelli hochstetteri*), black robin (*Petroica traversi*) and kakapo (*Strigops habroptilus*). Shortjaw kokopu are widely distributed throughout New Zealand, from Puysegur Point on the South Island's south coast, to Kaitaia in the north and Bay of Plenty in the east, but at any given location, they are generally found in very low numbers (approximately 1-3 fish per 100 m; McDowall 1990, McDowall *et al.* 1996). Several factors have been suggested that may explain the rarity of shortjaw kokopu. They may be confined to specific microhabitats that are rare (i.e. particular stream and substrate size), their activity patterns may not complement most survey methods (i.e. they are hard to find), they may be rare through over-harvesting of

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[1] Department of Conservation.

juvenile whitebait, manmade barriers to migration may affect access to adult habitat, or competition/predation by introduced trout may decrease populations.

A diadromous lifecycle, like that of shortjaw kokopu, is beneficial for many species as it allows them to distribute around New Zealand's coastline, colonizing many rivers. This can be impeded however, if the rivers contain barriers to whitebait migration. These barriers can be natural, i.e. waterfalls and dry reaches, or manmade, i.e. dams and weirs (McDowall 1984, 1990). A diadromous lifecycle may therefore place constraints on habitat selection.

Habitat quality is an important determinant of shortjaw kokopu presence (Williams & Given 1981, McDowall 1984, Swales 1991, McDowall *et al.* 1996). Many studies suggest forest cover of the stream is an important component of shortjaw kokopu habitat (McDowall *et al.* 1977, Eldon 1983, Eldon 1984, Nicoll 1984, Main 1987, McDowall 1990, 1996, 1997, McDowall *et al.* 1996). However, other studies on West Coast populations of shortjaw kokopu have shown that shortjaw kokopu avoid forests dominated by beech (*Nothofagus* spp; McDowall *et al.* 1977, McDowall *et al.* 1996, McDowall 1997, 2000). Removing this forest cover is thought to be a major cause of declining native fish populations (McDowall 1984, 1990, Rowe *et al.* 1999), however the effects of exotic forest are less clear. Recent studies have found populations of banded kokopu in mature exotic forests (Hicks 1998, Rowe *et al.* 1999, Rowe 2000), although unmodified native forest is still thought to be preferred (Rowe *et al.* 1999). In the short term, these exotic forests act like native forests, providing the overhead cover, humidity, and potential food supply required by banded kokopu. However, at a larger scale, exotic forests have several drawbacks. They have a limited lifespan (c. 25 years) before harvesting removes them, which in turn causes turbidity problems in the water (Rowe 2000). They also regulate the flow different to native forests, having higher flood peaks than native forest, but reducing water levels during dry periods (Hicks 1998). Banded kokopu, and galaxiids in general, are sensitive to turbidity (Boubee *et al.* 1997, Richardson *et al.* 1998, Rowe & Dean 1998, Richardson *et al.* 2001). Suspended sediments in the water restrict the migration of juvenile banded kokopu into these rivers (Boubee *et al.* 1997, Richardson *et al.* 1998, Richardson *et al.* 2001) and also restricting banded kokopu feeding (Richardson *et al.* 1998, Rowe & Dean 1998). Koaro were also found to avoid turbid habitats (Boubee *et al.* 1997, Richardson *et al.* 1998), but were better able to feed in these habitats (Richardson *et al.* 1998, Rowe & Dean 1998), which was attributed to their dispersal into glacial silt clouded rivers. Studies on the other diadromous galaxiids habitat, including shortjaw kokopu, are limited, but are suggested to be similar to the requirements of banded kokopu (Hicks 1998). Substrate type has also been identified as important for shortjaw kokopu, particular the presence of boulders and cobbles (McDowall 1990, 2000, McDowall *et al.* 1996). Fine sediments in the substrate may also be a problem for galaxiids through its impact on preferred prey (Main 1987, McDowall 1996, McDowall *et al.* 1996). However, more work is required on the habitat needs of shortjaw kokopu.

Migratory access is a problem that faces all diadromous fish, including shortjaw kokopu (McDowall 1984, 1990, 1998). Based on analysis of NZFFD[2] records from the South Islands, West Coast, McDowall (1998) suggested that most of New Zealand's diadromous fish are found at low altitudes and short distances inland. In contrast, non-diadromous species tend to be further inland and at higher altitudes. While some diadromous fish, including shortjaw kokopu, are capable of significant inland migrations, McDowall (1998) found that most individuals colonised suitable habitat at downstream sites. He reasoned that, particularly for shortjaw kokopu, this was because of abundance of suitable habitat near the coast. Joy *et al.* (2000) found a similar altitude relationship in Taranaki; however, shortjaw kokopu were found more commonly further inland. Jowett & Richardson (1995), Jowett *et al.* (1996) and Jowett *et al.* (1998) also found similar trends for shortjaw kokopu.

There are many methods used to survey fish communities, including those with shortjaw kokopu present. Electrofishing machines are an effective non-lethal means of surveying and identifying fish in an entire stretch of river, catching many of the species in the community. However, R.F.G. Barrier ((DoC: Wellington) *pers. comm.* October 2001) has suggested that electrofishing is not a good estimator of some galaxiid communities because many species are either not caught or only in small proportions relative to their true abundance. In the case of galaxiids, including shortjaw kokopu, daytime refuge may mean hiding under rocks, so electrofishing will still stun them, but may not extracted them from between rocks. For some diadromous galaxiids, especially shortjaw kokopu, spotlight surveying is a suggested better method (R.F.G. Barrier (DoC: Wellington) *pers. comm.* October 2001). This method allows nocturnal fish communities to be surveyed during their active period. Other methods of fish community surveying are the use of traps and nets. However, these require fish to move around to encounter the traps. Highly territorial or site attached species may be under-estimated by trapping. Shortjaw-kokopu are often found in the same or neighboring microhabitat between survey trips (e.g. Caskey 1999), so setting traps in one microhabitat may not catch the shortjaw kokopu from nearby microhabitats. However, more information is needed to determine the best method for shortjaw kokopu surveying.

Most native fish, including shortjaw kokopu, become harder to find during winter (Cadwallader 1975, R.F.G. Barrier (DoC: Wellington) *pers. comm.* October 2001). This is a problem in all survey methods, but especially in spotlight surveys, which require fish to be active within their habitat. Some salmonids are known to become nocturnal in low water temperatures (≤5°C), regardless of the length of daylight. However, diadromous galaxiids in New Zealand are already nocturnal (McDowall 1990). A non-diadromous galaxiid, *Galaxias vulgaris* Stokell, has been found to have peaks in activity relating to time since darkness fell. For the diadromous galaxiids, this may partially explain the perception that they are hard to find, surveys have been undertaken at the wrong times. Other observed patterns are of reduced activity during winter. However, for shortjaw kokopu, only seasonal growth rates have been studied (Caskey 1999), with annual activity pattern requiring investigation.

Introduced trout have often been described as a limiting factor on native fish distribution, including shortjaw kokopu (McDowall 1984, McDowall *et al.* 1996). While not excluding adult shortjaw kokopu from specific habitat, McDowall *et al.* (1996) argues that trout hold the competitive advantage and do prey on juveniles. Brown trout are known to feed on migrating whitebait shoals (McDowall *et al.* 1996); and while there is no direct evidence of trout predating shortjaw kokopu whitebait in particular, Eldon (1983) surmised that in rivers which support large numbers of shortjaw kokopu whitebait (e.g. Buller River), trout predation on shortjaw kokopu is

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[2] New Zealand Freshwater Fish Database, maintained by the National Institute of Water and Atmosphere (NIWA; McDowall & Richardson 1983).

highly probable. Unfortunately, this problem is difficult to control, especially for diadromous species with a need for sea access (McDowall 1984), so further work is needed into the effects trout have on different size classes of shortjaw kokopu.

1.1. Study Area

All study sites are located within a 100 km^2 region of the northeastern Tararua Ranges, North Island, New Zealand at approximately 40° 40′ S, 175° 30′ E. Three main catchments drain the study area, the northern flowing Mangatainoka and Makakahi Rivers, and the southern flowing Ruamahanga River. The Mangatainoka and Makakahi Rivers are tributaries of the Manawatu River, which flows to the west coast of the North Island, while the Ruamahanga feeds into Cook Strait. The lower Manawatu River has a series of barrage dams at several sites upstream of the Manawatu Gorge (Anonymous 2001) while the Ruamahanga has a barrage control gate at Lake Wairarapa.

All three rivers originate in the largely unmodified Tararua Forest Park. At lower altitudes, the canopy is dominated by red beech (*Nothofagus fusca*), intermixed with podocarp forest. At higher altitudes, red beech/podocarp forest is replaced by kamahi (*Weinmannia racemosa*) and leatherwood (*Olearia colensoi*) shrubs, in the Mangatainoka and Makakahi catchments, and by silver beech (*N. menziesii*) in the Ruamahanga (New Zealand Forest Service 1976). In the Tararua Ranges north of the main Mangatainoka catchment, all beech species are absent (Rogers & McGlone 1994). The Makakahi River also flows through an exotic tree plantation (*Pinus radiata*) at the park boundary.

The documented fish community of the three study rivers in the northeastern Tararua Ranges has been relatively unknown until early 1999 when a large population of shortjaw kokopu was discovered in the headwaters of the Mangatainoka River (Anonymous 1999) (Table 1). However, the Mangahao River, one of the neighboring catchments of the Manawatu River, has been heavily surveyed (Table 1). This is because of the desiltation process required for the power generation dam on the river (Boubée *et al.* 1995).

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Table 1. Fish species recorded from NZFFD records of the northern Tararua Ranges up to and including the discovery of a large population of shortjaw kokopu (Anonymous 1999).

Common name **Scientific name**	**Mangatainoka River**	**Makakahi River**	**Ruamahanga River**	**Mangahao River**
Lamprey *Geotria australis* Gray		✓		
Longfin eel *Anguilla dieffenbachia* Gray	✓		✓	✓
Shortfin eel *A. australis* Richardson	✓		✓	✓
Common smelt *Retropinna retropinna* (Richardson)	✓			
Shortjaw kokopu *G. postvectis* Clarke	✓			✓
Banded kokopu *G. fasciatus* Gray				✓
Koaro *G. brevipinnis* Günther	✓			
Dwarf galaxies *G. divergens* Stokell				✓
Brown mudfish *Neochanna apoda* Günther			✓	✓
Common bully *G. cotidianus* McDowall			✓	✓
Redfin bully *Gobiomorphus huttoni* (Ogilby)			✓	
Upland bully *G. breviceps* Stokell	✓	✓	✓	✓
Cran's bully *G. basalis* Gray				✓
Torrentfish *Cheimarrichthys fosteri* Haast	✓		✓	✓
Brown Trout *Salmo trutta* Linnaeus	✓	✓	✓	✓

In this study, habitat features and invertebrate communities that characterise the presence of shortjaw kokopu in the northeastern Tararua Ranges are investigated. Habitat characteristics are examined in relation to the presence of three age classes, particularly juvenile shortjaw kokopu. The seasonal activity of shortjaw kokopu, the associated fish community and the best method for surveying shortjaw kokopu is also examined.

This thesis is presented as four individual papers. This has resulted in some repetition in introductions and methods between chapters. Part of this work has also been partially presented in a report for the Department of Conservation (Bowie & Henderson 2002).

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2.

Distribution and habitat selection of shortjaw kokopu (*Galaxias postvectis*) in the northern Tararua Ranges

Abstract

Freshwater fish communities were surveyed at fifty sites in the Mangatainoka, Makakahi and Ruamahanga catchments in the northeastern Tararua Ranges. At each site habitat, invertebrate and fish communities were assessed. Shortjaw kokopu occurred in nine of the thirty-seven sites in the Mangatainoka and Makakahi catchments, but none were found in the Ruamahanga catchment. Shortjaw kokopu co-occurred with longfin eels, brown trout, Cran's bully and koaro. Shortjaw kokopu presence could be predicted by the invertebrate community composition and from habitat characteristics. Shortjaw kokopu were normally found in medium sized streams in native forest, with a high density of riffles and high conductivity. Discriminant Function Analysis accurately predicted shortjaw kokopu occurrences in the three river catchments. It appears that shortjaw kokopu are limited in distribution by recruitment rather than habitat.

Key Words: Shortjaw kokopu, *Galaxias postvectis*, distribution, habitat selection, Tararua Ranges, New Zealand.

2.1 Introduction

Shortjaw kokopu (*Galaxias postvectis*) occur in less than 2% of the NZFFD[1] records (McDowall *et al.* 1996a), yet their distribution ranges from Puysegur Point in the south, to Kaiatia in the north, along the length of the west coast, and across to the Bay of Plenty (McDowall 1990, 2000, McDowall *et al.* 1996a). Of the five species of diadromous galaxiidae, shortjaw kokopu are rarest and have been assigned category A threatened species status (Molloy & Davis 1994). Although most shortjaw kokopu records in the NZFFD are of single, or a few individuals, there are some concentrated local populations, particularly on South Island's West Coast, in Taranaki, and in the Bay of Plenty (McDowall 1990, 2000, McDowall *et al.* 1996a). Recent surveys also suggest Nelson/Marlborough (Studholme *et al.* 1999, Jack & Barrier 2000), the Manawatu River catchment (Anonymous 1999) and the South Coast of the North Island (Rebergen & Joy 1999) have sizable populations of shortjaw kokopu. Published information on habitat requirements indicates the need for forest cover (Eldon 1983, Main 1987, McDowall 1990, 1997), large substrate (Nicoll 1984, McDowall 1990, McDowall *et al.* 1996a), and pools (Eldon 1983, McDowall 1990, McDowall *et al.* 1996a).

Data in the NZFFD suggest shortjaw kokopu are predominantly found at low altitudes (≤125 m; McDowall 1998), and small distances inland (≤25 km; McDowall 1998), although exceptions are known (e.g. Caskey 1999, Studholme *et al.* 1999, Jack & Barrier 2000, Joy *et al.* 2000). Juvenile shortjaw kokopu can climb obstacles such as small waterfalls almost as well as koaro (*Galaxias brevipinnis*) (McDowall 1990), so these are not the cause of the limited inland distribution. McDowall *et al.* (1977) found that, on the West Coast of the South Island, shortjaw kokopu were generally present only in catchments where beech (*Nothofagus* spp.) was absent or only a minor component of the forest, with similar results reported by Main (1989), McDowall *et al.* (1996a) and McDowall (1997). Main (1987) found that large populations of shortjaw kokopu occur in streams with a large component of bouldery substrate (>256 mm).

The presence of shortjaw kokopu in the Mangatainoka River was first reported in February 1999 with 49 shortjaw kokopu observed by spotlight along a 500 m reach of a

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[1] New Zealand Freshwater Fish Database, maintained by the National Institute of Water and Atmosphere (NIWA; McDowall & Richardson 1983).

4^{th} order stream (Anonymous 1999). Two days earlier, 8 shortjaw kokopu had been electrofished from the same reach (I.M. Henderson (Massey University: Palmerston North) *pers. comm.* February 2000). This new population was as far or further inland (c.180 km) than other records in the Manawatu catchment, Kahuterawa Stream (c.89 km; NZFFD, McDowall *et al.* 1996a), and the Mangahao River (c.176 km; NZFFD, Boubee *et al.* 1995). Koaro and brown trout (*Salmo trutta*) were also found at the same location, koaro occupying the same section of stream, and brown trout downstream of this section (c. 200 m; M.K. Joy (Massey University: Palmerston North) *pers. comm.* February 2000).

In this survey I assess the distribution of shortjaw kokopu in the Mangatainoka River and adjacent catchments of the northeastern Tararua Ranges. I document the fish communities at these sites, assessing any associations between fish community and habitat characteristics, including invertebrate community composition. Finally, using three rivers, I build a model for predicting the occurrence of shortjaw kokopu based on habitat and invertebrate characteristics.

2.2 Methods

The survey was carried out at 50 sites in the northern Tararua Ranges, 25 in the headwaters of the Mangatainoka River, 12 in the Makakahi River, and 13 in tributaries of the Ruamahanga River. The study area comprises the upper reaches of the three river catchments (Figure 1). The Mangatainoka and Makakahi Rivers converge, join the Manawatu River, and flow to the west coast. The Ruamahanga River flows south to its river mouth. Within the study area, the three catchments are generally forested, dominated by beech intermixed with podocarp forest (New Zealand Forest Service 1976). After leaving the study area, the Mangatainoka and Makakahi Rivers travel 180 km; and the Ruamahanga 150 km before reaching the sea. Sites were selected on their suitability for spotlight surveys, including ease of access and presence of large pools, while ensuring wide coverage of the catchments. Each site comprised a 100 m reach without major tributaries converging.

At each site, a range of catchment, habitat and chemical measures were recorded. Catchment variables were obtained from a 1:50000 topographic map (NZMS 260 S25: "Levin", 1995). These measures were stream order (Strahler 1952), altitude and gradient. The gradient was assessed from the spacing of contour lines within the 100 m reach and the altitude estimated at the mid point.

Average width was estimated from five transects spread the length of the site. Average depth was recorded from five equally spaced points on each width transect; and velocity by timing the movement of fluorscine (BDH Laboratory Supplies: GPR™) dye along the length of the site. Substrate composition was recorded using the Wolman walk method (Wolman 1954) and the size categories in Table 1. Flow type, overhead cover, undercut banks, debris jams and riparian vegetation types were visually assessed on a percentage scale. The instream moss and periphyton cover were visually assessed on a 10-point scale (1 = least; 10 = most). Streambed stability was assessed using the bottom section of the pfankuch stability index (Pfankuch 1975, Death 1995). Conductivity (corrected to 25°C) and temperature were measured using an Orion (model 122) conductivity meter. Variation in conductivity due to rainfall and flow dilution was removed by using the residuals from a linear regression of conductivity and flow rates at a gauging station[2] approx. 7 km downstream on the Mangatainoka River.

Flow type was classified into backwater, pool, large pool, riffle, run and falls. Backwater was any area of still water connected to, but not influencing the main channel during base flow. Pools were slow moving water less than 5 m long or 1m deep, while large pools were greater than 5 m long or 1 m deep. Riffles were shallow swift broken water; runs were slow to moderately fast water with a calm or rippled surface; and falls were fast flowing water over a vertical drop.

Riparian vegetation types were classified into the percentage of podocarp, beech, shrubs, exotic, pasture, tussock and bare rock in the riparian zone. Podocarp, beech and shrubs describe the native species in the riparian canopy vegetation; shrubs included ferns and toetoe. Exotic were any introduced tree species including pines and gorse.

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[2] horizons.mw river monitoring system at Larsens Road.

Pasture and tussock were the introduced and native grasses, respectively; and bare rock was the unvegetated bank side margins.

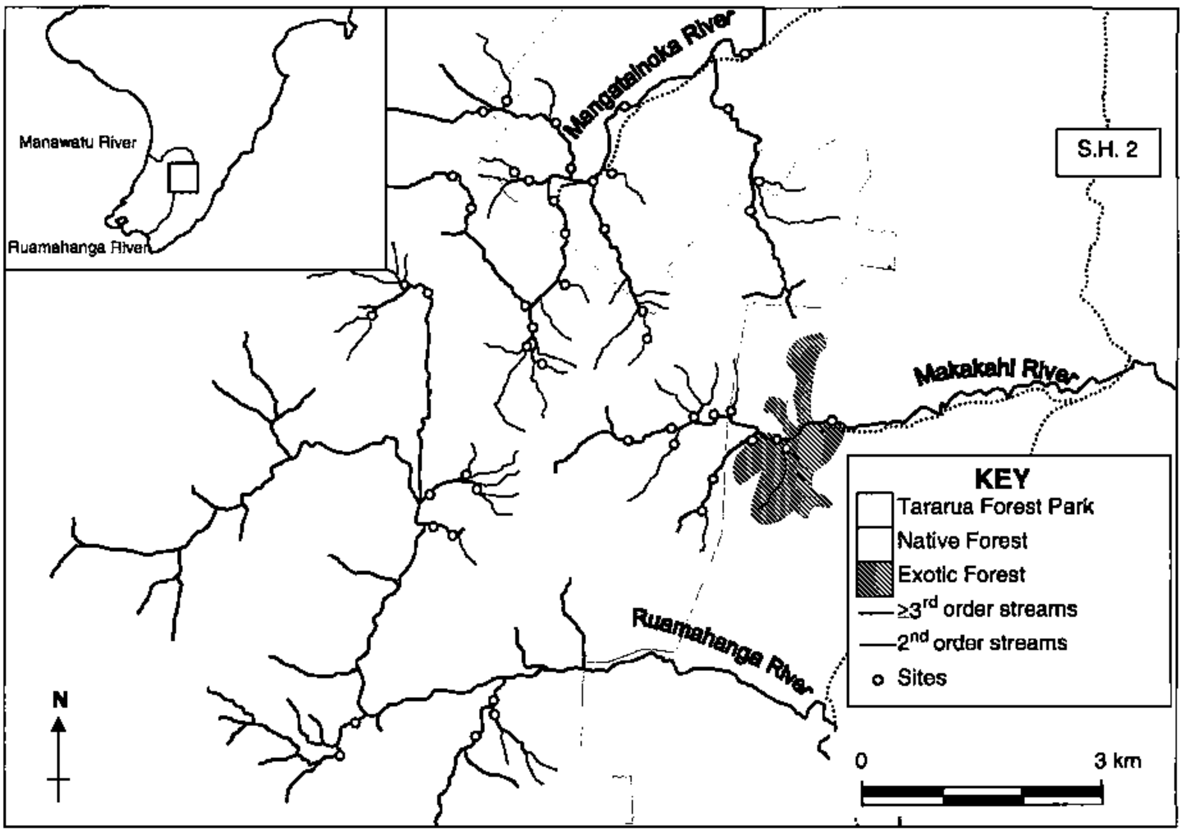

Figure 1. The sites on three rivers of a distribution and habitat selection survey on shortjaw kokopu in the northern Tararua Ranges.

A substrate size index was calculated from the percentage composition of size classes (Table 1) using:

$$\frac{B*8+LC*7+C*6+LP*5+P*4+LG*3+G*2+SG*1+S\,\&\,S*0}{Number\_of\_Rocks}$$

Table 1. Substrate size classes.

Boulders	(B)	> 256 mm
Large Cobbles	(LC)	128 – 256 mm
Cobbles	(C)	64 – 128 mm
Large Pebbles	(LP)	32 – 64 mm
Pebbles	(P)	16 – 32 mm
Large Gravel	(LG)	8 – 16 mm
Gravel	(G)	4 – 8 mm
Small Gravel	(SG)	2 – 4 mm
Coarse Sand	(CS)	1 – 2 mm
Sand & Silt	(S&S)	≤ 1 mm

A single sample of invertebrates was collected from a run or riffle within each site using a 500-μm mesh kick-net and disturbing the substrate for 30 s. Three locations within the habitat were disturbed for 10 s each. All invertebrate samples were preserved in a 10% formalin solution. Invertebrate samples were sorted and identified to a genus level using keys in Winterbourn & Gregson (1989), and counted. If the invertebrates were not insect larvae, then they were grouped as Oligochaetae, Crustacea, Platyhelminthes, *Potamopyrgus* spp. or mites.

Approximately 30 minutes after sunset, following completion of habitat assessment and invertebrate collection, a fish survey was carried out, using two observers with 30-watt spotlights, powered by 12 volt, 7 amp hour batteries. Two upstream and two downstream traverses of the reach were made, taking c. 20-30 minutes per site. All fish were identified under the spotlight beam and most galaxiids were caught in hand nets and measured. The length of galaxiids unable to be captured was estimated to ±20 mm. At low altitude sites, a selection of eels and bullys were also captured to ensure species identification. Brown trout and longfin eels (*Anguilla dieffenbachii*) life stage was assessed by eye to be either juvenile or adult. Cran's bully (*Gobiomorphus basalis*) and koura (*Paranephrops planifrons*) were counted but not measured.

2.2.1 Statistical analysis

Invertebrate taxa occurring at less than five sites (10% of sites) were excluded from statistical analysis and invertebrate counts were log transformed. For the Mangatainoka invertebrate community analysis, the five taxa of chironomids were combined and taxa that did not occur in at least four of the Mangatainoka sites (16%) were ignored. The relationship between fish community structure, and invertebrate communities and habitat variables were analysed using Canonical Correspondence Analysis (CCA) with PCORD (Version 4.17; McCune & Mefford 1995). A Monte-carlo test with 1000 iterations was preformed to test the significance of the correspondence. Stepwise Discriminant Analysis (SDA) was run on subsets of the data, building a model to predict presence or absence of shortjaw kokopu. The initial analysis used only the Mangatainoka River sites, the second level used the Mangatainoka and Makakahi Rivers (Manawatu Rivers), and the third level used the Manawatu Rivers and the

Ruamahanga River (complete data set). Each set of variables selected by the SDA was run through a Discriminant Function Analysis (DFA) to determine the accuracy of the model, followed by a test on a new set of data. Both the SDA and DFA were analysed using SAS (2000).

2.3 Results

Five native and one exotic species of fish were recorded. Native fish were found at 43 of the 50 sites (86%). Shortjaw kokopu occurred in only nine of the 50 sites surveyed (18%), in the Mangatainoka River (seven sites, 28%) and Makakahi River (two sites, 16%; Table 2). Densities of shortjaw kokopu at the nine sites ranged from 1 to 7 fish per 100 m, with a total of 32 recorded. Of these, 26 were found in the Mangatainoka catchment, and six in the Makakahi catchment (Table 3). Koaro were found at five sites, four on the Mangatainoka River, and one on the Ruamahanga River. At the same site on the Ruamahanga River, the only banded kokopu found in this survey was also recorded.

Brown trout and longfin eels were found in all surveyed catchments. Longfin eels were the most abundant and ubiquitous species, comprising 30-75% of the fish recorded in each catchment and present in all but seven sites. These seven sites were high altitude (> 565 m, three sites), small 2nd order streams (three sites), or a heavily eroded, unstable stream (one site). Brown trout and Cran's bully were recorded mostly in low altitude sites without much forest cover. In the Ruamahanga catchment, the only brown trout recorded, occurred at one of the higher altitude sites not inhabited by longfin eels. Cran's bully was found at nine sites, all of them low altitude, and all in the Mangatainoka and Ruamahanga Rivers. While not widely distributed, they often numerically dominated the sites where they did occur (Figure 2).

Table 2. Occurrence of fish species by river catchment.

River	No. sites	No. fish species	No. galaxiids	No. shortjaw kokopu	No. brown trout
Mangatainoka	25	5	46	26	13
Makakahi	12	3	6	6	4
Ruamahanga	13	5	5	0	1

Brown trout co-occurred with shortjaw kokopu at 3 sites (Figure 3), all of which were at the lower range of altitudes containing shortjaw kokopu. A chi-squared test showed no significant association (positive or negative) between brown trout presence and shortjaw kokopu presence ($\chi^2 = 0.7831$, $P = 0.3762$). Koaro and banded kokopu were never found co-occurring with brown trout.

Table 3. Species composition of all fish recorded from 50 sites.

Species	Total No. fish	No. occurrences	Average number fish per occurrence
Shortjaw kokopu (*Galaxias postvectis*)	32	9	4
Koaro (*Galaxias brevipinnis*)	24	5	5
Banded kokopu (*Galaxias fasciatus*)	1	1	1
Longfin eel (*Anguilla dieffenbachia*)	147	43	4
Cran's bully (*Gobiomorphus basalis*)	113	9	13
Brown trout (*Salmo trutta*)	18	12	2

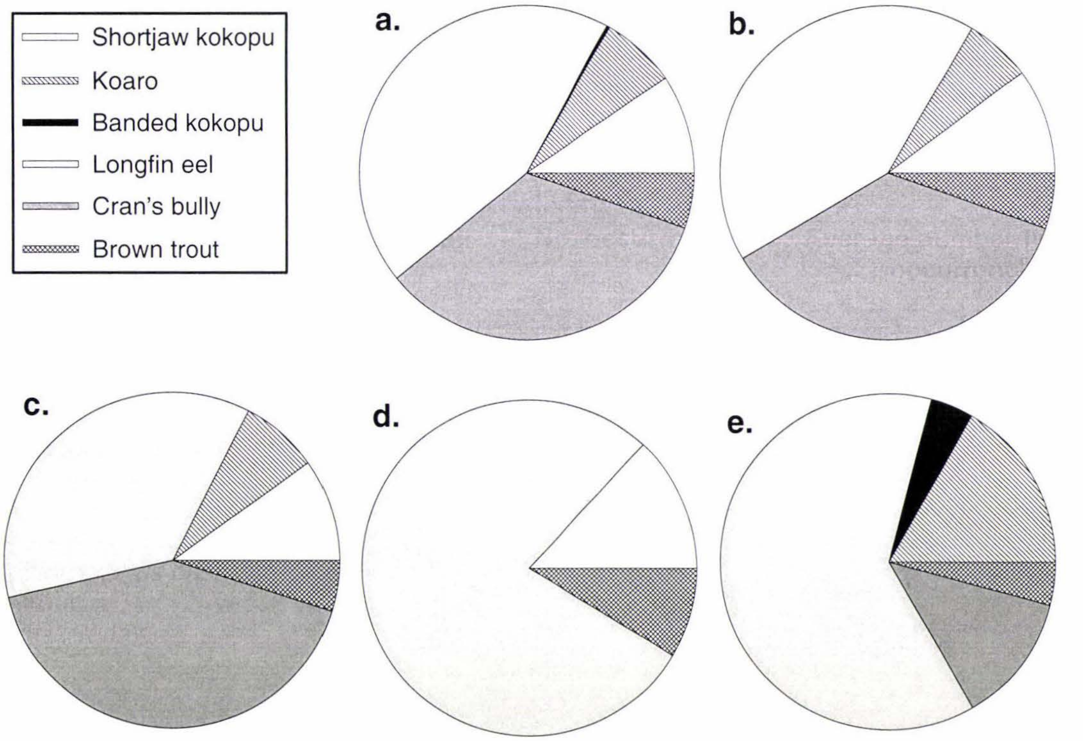

Figure 2. Distribution of the 6 fish species found in Mangatainoka, Makakahi and Ruamahanga River catchments. a. All rivers, b. Manawatu Rivers, c. Mangatainoka River, d. Makakahi River, and e. Ruamahanga River.

2.3.1.a Association of the fish community composition with habitat

Correlations between habitat and fish community was significant for both axes in all data sets. In the complete data set, axis 1 ($P = 0.001$) explains 21.4% of the variance and axis 2 ($P = 0.002$) explains 25.4%. In the Manawatu data set, axis 1 ($P = 0.001$) explains 34.2% and axis 2 ($P = 0.001$) explains 23.8%. In the Mangatainoka data set, axis 1 ($P = 0.001$) explains 47.3% and axis 2 ($P = 0.001$) explains 30.6%. Altitude is an important factor in all data sets, highly correlated with axis 1 or axis 2. Pasture, periphyton and run habitat are also important (Figure 4). Longfin eels show few associations with the habitat. The galaxiids show preference for more vegetative cover and higher altitudes, although banded kokopu only occur in the complete analysis due to the failure to find any in the Manawatu catchments. Cran's bully and brown trout show preference for open streams with run habitat.

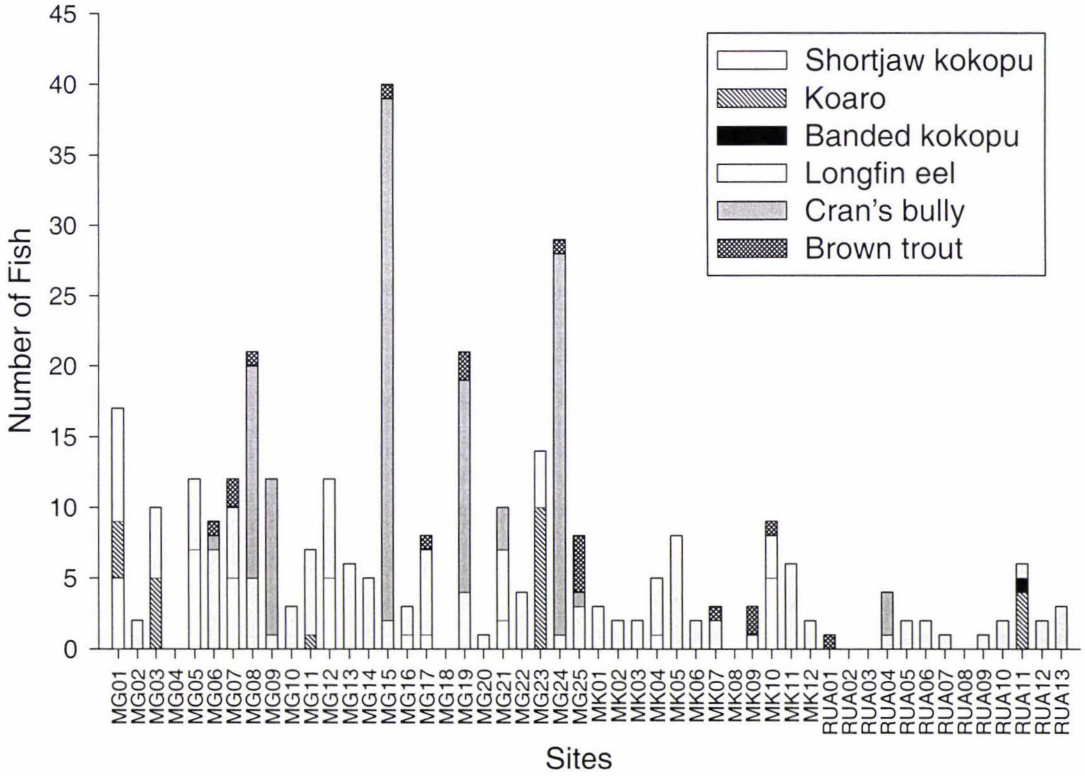

Figure 3. Number of fish found at each survey site in a study of shortjaw kokopu distribution in the northern Tararua Ranges. Abbreviations are: MG01-MG25 = Mangatainoka River sites, MK01-MK12 = Makakahi River sites, and RUA01-RUA13 = Ruamahanga River sites.

2.3.1.b Association of the fish community composition with invertebrates

Correlations between invertebrate and fish community structure was significant for both axes in each data set. In the complete data set, axis 1 ($P = 0.001$) explains 27.8% of the variance and axis 2 ($P = 0.003$) explains 15.8%. In the Manawatu data set, axis 1 ($P = 0.001$) explains 35.8% and axis 2 ($P = 0.001$) explains 26.2%. In the Mangatainoka data set, axis 1 ($P = 0.001$) explains 42.2% and axis 2 ($P = 0.001$) explains 30.8%. *Zelandobius* spp. is correlated with axis 1 for all data sets (Figure 5). *Aphrophila* spp., Chironomidae and *Oxyethira* spp. are also strongly correlated with axis 1 or axis 2. Longfin eels show no distinct associations with any invertebrate community. The galaxiids all show a positive association with *Zelandobius* spp., and negative associations with *Oxyethira* spp. Cran's bully and brown trout are negatively associated with *Zelandobius* spp.

2.3.2 Predicting Shortjaw Kokopu presence

2.3.2.a Developing the Mangatainoka River model

Habitat model

High instream stability (i.e. low pfankuch score) was the strongest predictor of shortjaw kokopu presence. High percentage riffle and low percentage run were also selected by the stepwise analysis. Using these three variables, six sites were misclassified. Five sites were incorrectly predicted to have shortjaw kokopu present. The predicted probabilities of shortjaw kokopu occurrence in these cases were relatively low ($P = 0.55$, 0.56, 0.58, 0.61 and 0.74). One site was incorrectly predicted to not have shortjaw kokopu ($P = 0.63$).

Invertebrate model

Occurrence of *Aphrophila* was the best predictor for the presence of shortjaw kokopu. Other important variables were the presence of *Zephlebia* mayflies, *Tanytarsus* chironomids and *Zelandobius* stoneflies; and absence of *Nesameletus* mayflies, *Polypedilum* chironomids and *Aoteapsyche* caddisflies. Perfect prediction for shortjaw kokopu was achieved.

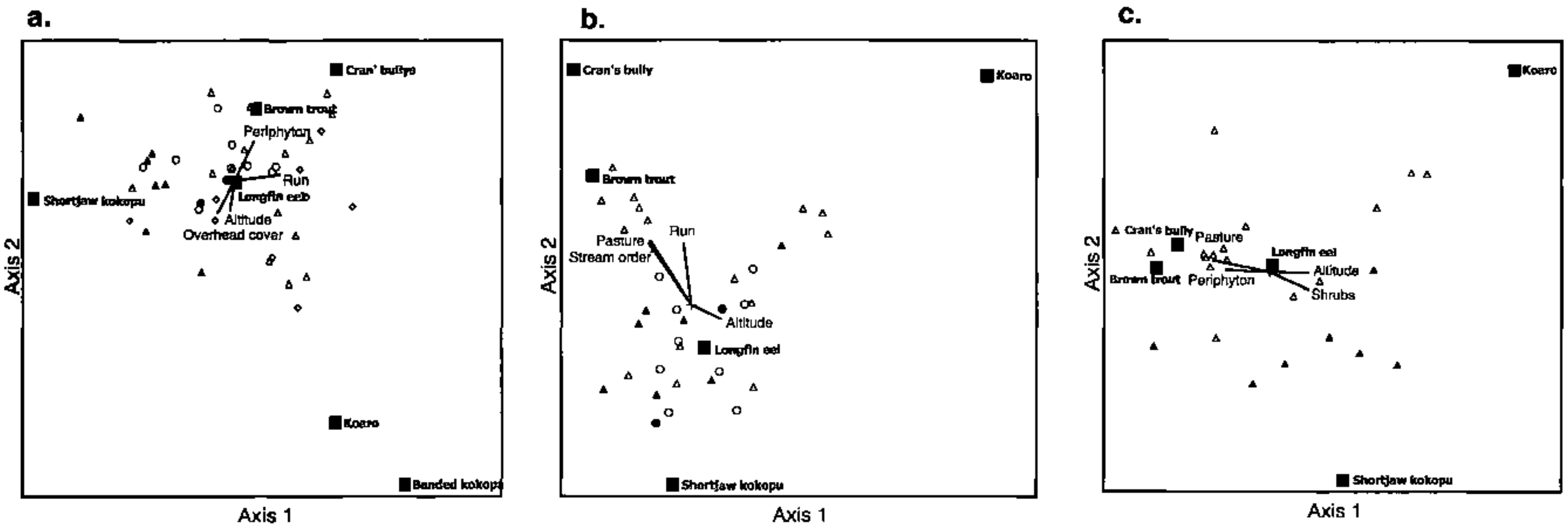

Figure 4. Canonical Correspondence Analysis of fish communities and habitat variables in: a. complete data set; b. Manawatu data set; and c. Mangatainoka data set. △ = Mangatainoka River, ○ = Makakahi River and ◇ = Ruamahanga River. Shaded symbols represent shortjaw kokopu presence. Large squares are the fish community associations (■). Vectors show the highest four correlations between habitat variables and ordination axes.

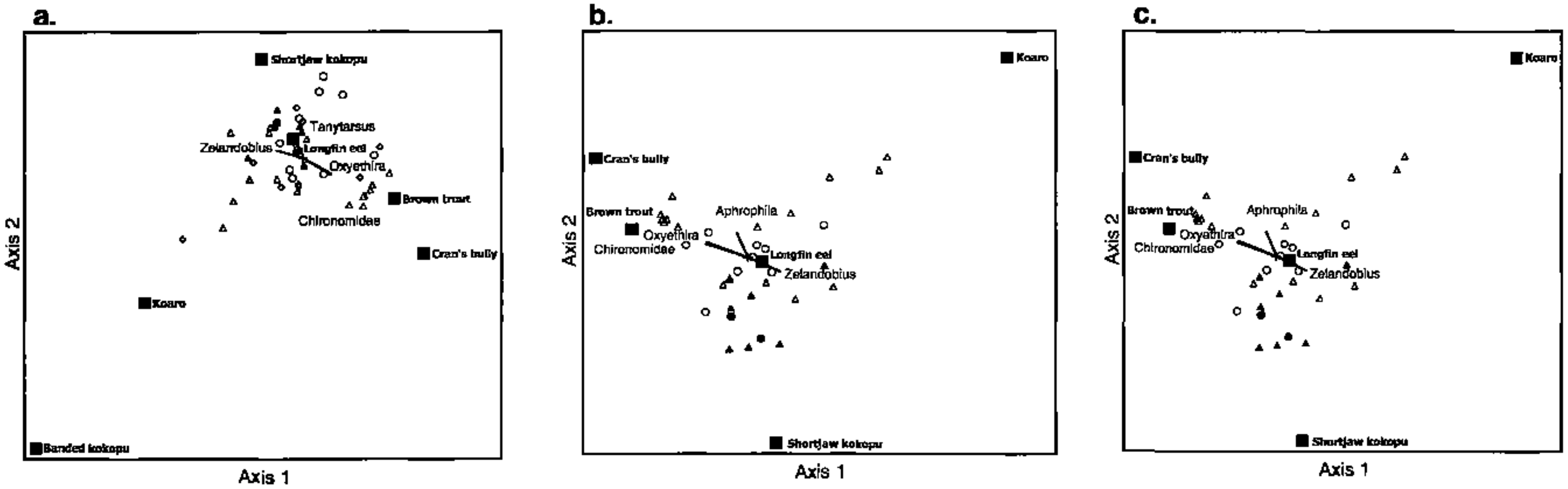

Figure 5. Canonical Correspondence Analysis of fish and invertebrate communities in: a. complete data set; b. Manawatu data set; and c. Mangatainoka data set. △ = Mangatainoka River, ○ = Makakahi River and ◇ = Ruamahanga River. Shaded symbols represent shortjaw kokopu presence. Large squares are the correlations between fish species and the ordination axes (■). Vectors show the highest four correlations between habitat variables and ordination axes.

Combined habitat and invertebrate model

Eight variables were selected as indicators for the presence of shortjaw kokopu. Presence of *Aphrophila* was the best indicator, followed by high percentage beech forest, presence of *Zephlebia*, high percentage riffle habitat, absence of *Peritheates* midges, high pfankuch score, absence of *Hydrobiosella* caddisflies and high altitude. Perfect prediction for shortjaw kokopu presence was achieved.

Testing the models on Makakahi River data

A discriminant model based on habitat variables alone misclassified 50% of sites. Five cases were predicted of shortjaw kokopu occurrence (P = 0.60, 0.60, 0.73, 0.89, 1.0) and one predicted absence (P = 0.61). Discriminant models based on invertebrate variables and the combined variables both misclassified two sites with shortjaw kokopu incorrectly to be absent (P = 1.0, 1.0).

2.3.2.b Developing the Manawatu Rivers model

Habitat model

Low pfankuch score (Figure 6) was the only predictor for the presence of shortjaw kokopu. Fourteen sites were incorrectly predicted, 13 predicted shortjaw kokopu to be present (P = 0.55-0.68) and one predicted shortjaw kokopu to be absent (P = 0.81).

Invertebrate model

Occurrence of *Helicopsyche* caddisflies was found to be the strongest predictor of shortjaw kokopu presence. The other important variables were the absence of *Stenoperla* stoneflies, Eriopterini crane flies and *Polypedilum*; and the presence of *Tanytarsus*. Eleven misclassifications occurred, all predicting shortjaw kokopu to be present (P = 0.97-1.0).

Combined habitat and invertebrate model

Fourteen variables predicted the presence of shortjaw kokopu. These were the absence of Eriopterini, *Stenoperla*, *Nesameletus*, *Hydrobiosella* caddisflies and *Deleatidium*; presence of *Tanytarsus*, *Helicopsyche* and *Archichauliodes* dobsonflies; low percentage debris jam, pasture and backwater; high percentage shrubs, riffles and high conductivity. High pfankuch was the first predictor chosen by the stepwise procedure, but was later removed. No sites were misclassified with these variables.

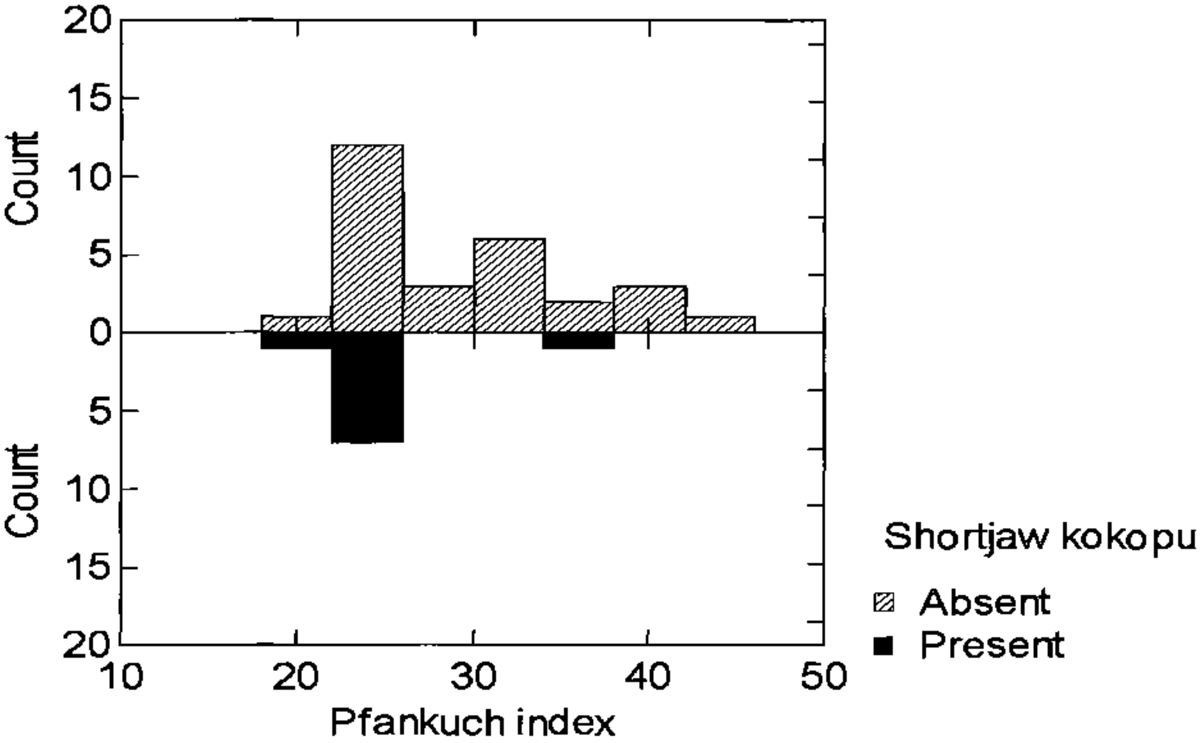

Figure 6. The presence of shortjaw kokopu declines as instability (pfankuch score) rises in the Manawatu Rivers.

Testing the models on Ruamahanga River data

No site in the Ruamahanga River contained shortjaw kokopu, however, the habitat model misclassified 11 of 13 sites (P = 0.51-0.79). Twelve of 13 sites were misclassified using the invertebrate model (P = 1.00). However, perfect classification was achieved using the combined model.

2.3.2.c Developing the complete model

Habitat model

High conductivity, low percentage debris jams, pasture, podocarp, altitude and run; and high percentage riffles were identified as good predictors of shortjaw kokopu (Plate 1). One misclassification occurred predicting shortjaw kokopu to be present (P = 0.96).

Invertebrate model

The occurrence of *Aphrophila* and *Coloburiscus* and absence of *Austroperla* stoneflies were the best predictors of shortjaw kokopu presence. Eleven misclassifications occurred, seven predicting shortjaw kokopu to be present (P = 0.56-0.85) and four predicting absent (P = 0.53-0.78).

Plate 1. Sites that shortjaw kokopu were present on the Mangatainoka (a, b, c, d, e & f) and Makakahi Rivers (g & h).

Combined habitat and invertebrate model

Ten variables predicted shortjaw kokopu presence. These were a high percentage of shrubs and beech; high conductivity and stream order; low percentage run and undercut banks, small average stream widths; absence of Eriopterini and *Austroperla*; and presence of *Coloburiscus*. Absence of *Aphrophila* and low percentage of debris jams were the first predictors selected by the stepwise procedure, but were later removed. This model achieved perfect prediction.

2.4 Discussion

Given the previous discovery of a large population of shortjaw kokopu within the Mangatainoka catchment (Anonymous 1999), the sparse distribution and low numbers of shortjaw kokopu found in other headwater reaches of the Mangatainoka catchment was unexpected. Many of the surveyed reaches had habitat characteristics matching those described in literature as suitable for shortjaw kokopu, such as large substrate (Nicoll 1984, McDowall 1990, McDowall *et al.* 1996a), forest cover (Eldon 1983, Main 1987, McDowall 1990, 1997), and pool habitat (Eldon 1983, McDowall 1990, McDowall *et al.* 1996a). Koaro were also expected to be more widespread in the survey. However, their appearance at the upper limits of shortjaw kokopu range may account for their apparent limited dispersal throughout the northern Tararua Ranges. The survey was designed for shortjaw kokopu, and while the larger main rivers were also surveyed, smaller streams at high altitude where koaro are more commonly found, were not always as easily accessible. Streams where koaro or banded kokopu occurred were often incorrectly predicted to contain shortjaw kokopu by discriminant models. The appearance of banded kokopu in the survey, living in close proximity to koaro, was unexpected. Their lack of occurrence in the Mangatainoka or Makakahi catchments suggested the northeastern Tararua Ranges were beyond the limits of dispersal for this species. However, banded kokopu are regarded for their migratory abilities (McDowall 1990, 2000), almost as much as koaro. Banded kokopu and shortjaw kokopu do co-occur on western slopes of the Tararua Ranges, however, in tributaries draining into the Manawatu River, such as the Kahuterawa Stream (NZFFD).

Longfin eels were the most widely distributed fish species, not surprisingly as they are known in virtually all accessible rivers in New Zealand (NZFFD, McDowall 1990, 2000). Longfin eels were found in most habitat types, excluding some high altitude sites and small 2nd order streams. Most of these streams often have accessibility problems, such as culverts, waterfalls or subterranean flows; but a brown trout were found in one of these high altitude streams. In the Manawatu Rivers, brown trout were restricted to the low altitude rivers, found in most of the streams with pastural vegetation, but also in the low altitude bush covered streams. The survey in February 1999 (Anonymous 1999) recorded a large brown trout less than 200 m below the convergence of the two 4th order streams where shortjaw kokopu were present (I.M. Henderson (Massey University: Palmerston North) *pers. comm.* February 2000). So while brown trout were expected in the main river, and other large branches, their occurrence in smaller streams was not expected. The single record of brown trout in the Ruamahanga catchment was unusual. Brown trout were observed in the Ruapae Stream, a tributary of the Ruamahanga River that was surveyed, at high altitude. It seems unusual that brown trout were not observed in larger tributaries downstream. Some of these streams were observed to have significant waterfalls bordering the main river, but others were much more accessible to migrating trout and found to contain Cran's bully which had a close association with trout in Mangatainoka streams. Cran's bullies were not as widely distributed as the other fish species, but were numerically as abundant as longfin eels in the Mangatainoka catchment. Cran's bully was restricted to low altitude large rivers. This was the only non-migratory native fish found.

Shortjaw kokopu were found co-occurring with most other fish species, except banded kokopu. Longfin eels were found at all sites containing shortjaw kokopu, whereas koaro, brown trout and Cran's bullys were only found co-occurring with shortjaw kokopu in some sites. Furthermore, at no site did brown trout and Cran's bully's co-occur with koaro or banded kokopu.

2.4.1 Fish Communities

Canonical Correspondence Analysis showed distinct associations between fish communities and invertebrate communities or habitat variables. All the galaxiid species showed preferences for forested habitat at higher altitudes, a trait shared with the stonefly *Zelandobius* spp. Cran's bully and brown trout were associated with large open low altitude farmed streams, supporting cased caddisflies, *Oxyethira* and *Aphrophila*. Sites that contained shortjaw kokopu were quite distinct from other sites based on the Mangatainoka River analysis, but became less so as more rivers were included. This could mean that the Ruamahanga River with sites containing suitable habitat but lacking shortjaw kokopu, is having an effect on the analysis. If this were the case, then we would not have expected to get perfect prediction from either the Manawatu River model or the complete river model.

Generally, shortjaw kokopu were found at low to mid altitudes in the Manawatu catchments. Their downstream range overlaps with brown trout, and the upstream range, in some cases overlaps with koaro. While there was no overlap for koaro and brown trout, in some sites, the two ranges were less than 100 m apart. Longfin eels were present at all sites containing shortjaw kokopu, koaro, banded kokopu or Cran's bully, and at all but one site containing brown trout.

2.4.2 Shortjaw kokopu prediction models

The shortjaw kokopu prediction models varied in effectiveness with up to 38% of sites misclassified with habitat models and 30% with invertebrate models. The habitat variables were chosen to allow rapid identification of site viability for shortjaw kokopu. While requiring numerical processing following collection, habitat variables were much less time- consuming than invertebrate sampling which needed sorting and identifying, but required less effort collecting samples in the field. A combined approach yielded the best results, but required more effort; however perfect prediction ensued.

A true test of the models is to make predictions on sites not used to build the model. This was undertaken in two stages, using the Mangatainoka model to predict shortjaw kokopu occurrence in the Makakahi River, and using the Manawatu model to predict shortjaw kokopu occurrence in the Ruamahanga River. The Makakahi River had not been previously surveyed for fish communities but has the same downstream factors (common Manawatu stem) as the Mangatainoka River. Headwater tributaries of the Ruamahanga River have many site-specific habitat variables similar to sites in the Mangatainoka and Makakahi headwaters. However, the Ruamahanga River catchment does not share the same coastline, river mouth or lower river as the other two rivers.

The failure of the Mangatainoka model to correctly predict shortjaw kokopu occurrence in the Makakahi River shows that the Mangatainoka is not indicative of shortjaw kokopu in the northeastern Tararua Ranges. By incorporating the Makakahi River into the model, the Manawatu model gains more predictive power, correctly classifying the Ruamahanga River sites. The model built from the complete data set also has perfect prediction but is untested due to a lack of a wider data set. However, both predictive models had several variables in common, particularly aspects of the habitat. Shortjaw kokopu presence is associated with high percentage shrubs, high conductivity and low percentage debris jams, although debris jams were later removed in the complete model. High proportion of shrubs in the riparian zone is associated with stable forested sites, matching described trends in the literature (Eldon 1983, Main 1987, McDowall 1990, 1997), whereas debris jams, also associated with forested catchment, seem to go against described trends (R.F.G. Barrier (DoC[3]: Wellington) *pers. comm.* October 2001). Conductivity is an unexpected predictor, particularly as the three catchments are adjacent and share similar vegetation and geology (New Zealand Forest Service 1976), which are thought to regulate conductivity. Northern limits of red beech in the Tararua Ranges occur in the Mangatainoka headwaters (Rogers & McGlone 1994), but red beech is dominant throughout the study area. Mudstone is present in the catchments of some of the lower Mangatainoka study sites (Stevens 1974); however, all sites containing shortjaw kokopu were in entirely greywacke catchments. Therefore, substrate and vegetation are not controlling conductivity. In this case, higher conductivity appears to be an indication of greater ground water influence rather than run off, which is a sign of greater flow stability.

Eriopterini occurred in many 2nd order streams but also in large open canopied streams in the survey, contrasting the typical habitat of shortjaw kokopu. Previous shortjaw kokopu diet analysis (Main 1987, McDowall 1996, McDowall *et al.* 1996b) has found that aquatic diptera larvae make a minor component of shortjaw kokopu diet and thus this may be a reason why absence of Eriopterini predicted shortjaw kokopu presence, although other diptera larva, *Aphrophila*, were positively associated with shortjaw kokopu presence.

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[3] Department of Conservation.

The failure to find shortjaw kokopu in the Ruamahanga catchment is difficult to explain. Although shortjaw kokopu are normally found in catchments with river mouths on the western coast of New Zealand (McDowall 1990), recent surveys have located several populations of shortjaw kokopu in streams both east and west of the Ruamahanga River mouth (Rebergen & Joy 1999, McDowall 2000). Therefore, river mouth access does not appear to be restricting shortjaw kokopu from accessing the Ruamahanga River. There are several point sources of pollution affecting the river, particularly urban settlements, the Waingawa freezing works and the International Timber Processors Ltd in Masterton, a floodgate controlling the water level in the lower Ruamahanga River, and a grade control weir at Te Ore Ore. However, these alone do not explain the lack of shortjaw kokopu in the Ruamahanga River. The occurrence of two other diadromous galaxiid species in the Ruamahanga River of similar migrating ability (McDowall 1990) implies that other factors must be influencing shortjaw kokopu numbers. A pollution barrier to shortjaw kokopu migration in the Ruamahanga is a less likely explanation since banded kokopu, present in the upper Ruamahanga, are the most sensitive of the migratory galaxiid to turbidity, toxins, and suspended solids (Richardson 1997, West *et al.* 1997, Richardson *et al.* 1998, Rowe & Dean 1998, Jowett & Boustead 2000). Similarly, shortjaw kokopu are thought to be as good or better at passing waterfalls and manmade structures as banded kokopu (Jowett *et al.* 1998, Joy *et al.* 2000), so a physical barrier in the lower Ruamahanga seems unlikely.

In contrast, banded kokopu were not found in the upper reaches of the Mangatainoka and Makakahi Rivers but they are known from lower altitude tributaries of the Manawatu River (*pers. obs.*, M.K. Joy (Massey University: Palmerston North) *pers. comm.* February 2000, NZFFD, McDowall *et al.* 1996a). A reason for this may be a series of barrage dams between the Manawatu Gorge, and the Mangatainoka, and Makakahi River headwaters (Anonymous 2001). However, brown trout have been found to pass these barriers, and the appearance of juvenile (55-80 mm) galaxiids, both koaro and shortjaw kokopu (*pers. obs.*) shows that some migratory galaxiids are able to pass these structures. These barrage dams are less than six years old and given the expected life span of banded kokopu, at least nine years (McDowall 1990), if these structures were preventing migration of banded kokopu we would still expect to see some adults remaining in the upper catchment if it was suitable habitat. McDowall

(1998) found there appeared to be a 'saturation point' for shortjaw kokopu migration. He proposed that the absence of shortjaw kokopu from many inland tributaries of West Coast rivers was due to a lack of recruiting juveniles and that only the closest habitat was being colonized. This theory could apply to shortjaw kokopu in the Ruamahanga River. If so, it would be expected to find shortjaw kokopu in tributaries closer to the sea, such as the Tauherenikau or Waiohine River.

Shortjaw kokopu habitat in the northeastern Tararua Ranges is characterized by high stability, large substrate, 3rd-4th order streams, relatively low altitudes (340-430 m), with unmodified native forest canopy cover. Streams not having this combination of features are unlikely to have shortjaw kokopu present. Likewise, invertebrates, particularly the occurrence of *Coloburiscus*, *Zelandobius* and *Tanytarsus*, and the absence of the open stream invertebrates, such as Eriopterini, *Aphrophila*, *Aoteapsyche*, and *Elmidae* are useful predictors of shortjaw kokopu. Shortjaw kokopu were always found co-occurring with longfin eels, occasionally in the presence of brown trout, but more often in areas where brown trout are absent, and other galaxiid species, such as koaro occur.

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3. Seasonal activity of shortjaw kokopu (*Galaxias postvectis*) in the northern Tararua Ranges

Abstract

Freshwater fish communities were surveyed monthly at three sites over a 16 months period in the Mangatainoka River and a tributary in the northeastern Tararua Ranges. Shortjaw kokopu (*Galaxias postvectis)* and longfin eels (*Anguilla dieffenbachii*) occurred in all sites, koaro (*G. brevipinnis*) in the two upper sites, brown trout (*Salmo trutta*) and Cran's bully (*Gobiomorphus basalis*) in the lower site. The number of shortjaw kokopu observed varied between months with greatly reduced numbers during winter and rising to a maximum in autumn. The variation in observed numbers is considered to be due to changes in activity rather than the seasonal movement of shortjaw kokopu within the catchment as the monthly pattern of numbers observed are the same at each site. Shortjaw kokopu did not show seasonal movement, instead having lower activity during colder months.

Key Words: Shortjaw kokopu, *Galaxias postvectis*, seasonal activity, Tararua Ranges, New Zealand.

3.1 Introduction

Shortjaw kokopu are the rarest of the five species of the diadromous galaxiidae in New Zealand (McDowall 1996), occurring in 2% of NZFFD[1] records (McDowall *et al.* 1996a). Shortjaw kokopu are normally found in unmodified, predominantly podocarp, forest streams (Eldon 1983, Main 1987, McDowall 1990, 1997). They are most commonly found in pools and runs (Eldon 1983, McDowall 1990, McDowall *et al.* 1996a), often above large falls; and areas where large boulder and cobble substrate dominate (Nicoll 1984, McDowall 1990, McDowall 1996). Shortjaw kokopu are often considered a solitary species, found in small numbers, with only one or two individuals in any given reach. This has contributed to their category A classification (Molloy & Davis 1994) in the endangered species lists, along with their wide ranging (McDowall 1990, McDowall *et al.* 1996a, McDowall 2000) but sporadic distribution (McDowall 1996).

Surveys of shortjaw kokopu populations are often conducted during warmer, summer periods, avoiding the inconveniences of winter (e.g. Caskey 1999, Studholme *et al.* 1999, Jack & Barrier 2000). However, these are generally qualitative surveys of occurrence at one time. Repeat surveys for most galaxiids, including shortjaw kokopu, are not often reported. Only Caskey (1999) has studied seasonality in shortjaw kokopu populations, focusing on growth rates over the year, particularly comparing winter and summer growth rates. Unlike some salmonid species that have been found to have either a diurnal or nocturnal activity pattern, dependent on both water temperature and photoperiodity (Fraser *et al.* 1995, Whalen *et al.* 1999), shortjaw kokopu are generally only nocturnally active (McDowall 1990). A seasonal pattern of nocturnal activity, with lowest activity in winter, has been documented in the Canterbury galaxias (*Galaxias vulgaris*) (Cadwallader 1975b) and shortjaw kokopu are expected to show a similar pattern (R.F.G Barrier (DoC[2]: Wellington) *pers. comm.* October 2001).

In this survey, I examine the effect that season has on observed numbers of shortjaw kokopu. By comparing seasonal patterns in three sites encompassing the extremes of

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[1] New Zealand Freshwater Fish Database, maintained by the National Institute of Water and Atmosphere (NIWA; McDowall & Richardson 1983)

shortjaw kokopu range in the Mangatainoka catchment, it will be possible to distinguish changes in activity from seasonal migration within the catchment as causes of any variation.

3.2 Methods

Surveys were carried out on three reaches of river in the headwaters of the Mangatainoka River, and one of its tributaries (Figure 1). The three sites were selected to encompass the distribution of shortjaw kokopu in the Mangatainoka River (Chapter 2). All three sites had predominantly red beech canopy, although the lower site was where the river left the cover of the native bush. Sites differed in stream size, with the upper site including the confluence of two 3rd order stream (Table 1). The lower site was 1300 m below the middle site, and the upper site a further 300 m upper from the middle site.

At all sites the general flow pattern of the river was of a pool-riffle-run sequence, although falls were also present. Substrate was mainly large boulders (≥256 mm) and cobbles (128-256 mm).

Table 1. Characteristics of the three seasonal survey sites in the northeastern Tararua Ranges.

Site	Stream order	Altitude (m)	Gradient (m/200 m)	Number of pools and runs
Upper	3rd & 4th	453	25	29
Middle	4th	401	13	19
Lower	5th	344	12	17

At each site a 200 m reach was searched for approximately 90 minutes allowing two upstream and two downstream traverses. In each sampling period, two observers with 30 watt spotlights, powered from 12 volt 7 amp hour batteries were used. All pools and runs were coded, so that the location of the fish could be recorded from month to month. Where possible, size was also recorded to identify individual fish. Size was treated as an

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[2] Department of Conservation.

indication of age class (Studholme *et al.* 1999). During April and May, captured fish were also assessed for their reproductive status using the definitions in Charteris (2002). Surveys were carried out under low flow conditions to maintain consistent visibility in the water. From the fifth monthly survey onwards, water temperature was recorded at the conclusion of each survey.

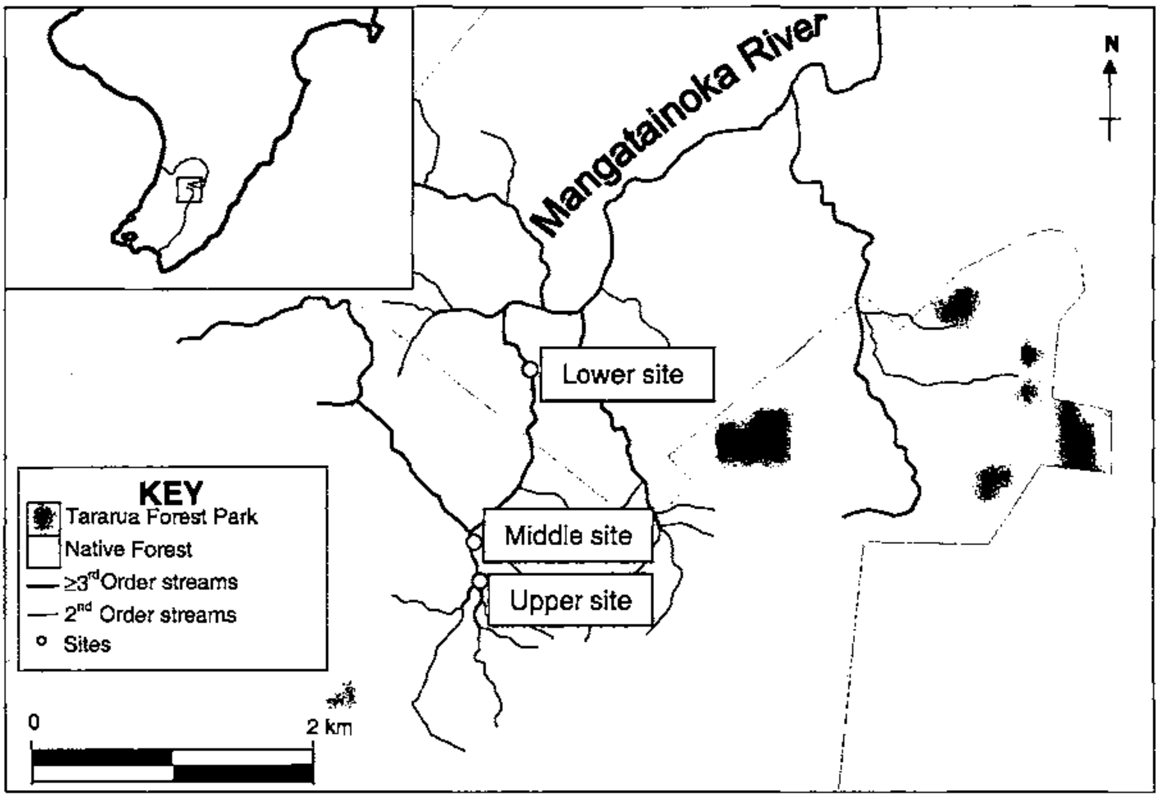

Figure 1. Location of sites used in a seasonal survey of shortjaw kokopu activity in the northeastern Tararua Ranges.

Shortjaw kokopu, koaro, longfin eel, brown trout, Cran's bully and torrentfish have all been recorded in the Mangatainoka River (Chapters 2 & 4). Any juvenile bullies were treated as Cran's bully because that is the only species positively identified from the Mangatainoka River headwaters (Chapter 2, NZFFD, M.K. Joy (Massey University: Palmerston North) *pers. comm.* February 2000).

The data was grouped into seasons of three months *a posteriori*, allowing months to be sorted based on shortjaw kokopu activity. The first two months of survey, August and September 2000, were treated as a trial period, with the analysis of seasons based on subsequent seasonal data. The division of 14 monthly surveys into seasons meant spring and summer had four replicates, while autumn and winter only had three.

3.2.1 Statistical analysis

A two-way analysis of variance (ANOVA) was used to compare shortjaw kokopu numbers among sites and seasons. Posthoc pairwise comparisons of the main effects were performed using Bonferroni tests. Fishers Least Squared Difference (LSD) tests were used to assess between season differences. All statistical analyses were carried out using (SAS 2000).

3.3 Results

The largest population of shortjaw kokopu was found at the middle site, with 27 shortjaw kokopu being counted in a single sampling period (February 2001). Brown trout were not present at this site (Table 2), however, koaro were found in small numbers. The upper site had the least number of shortjaw kokopu with a maximum of 10 observed in one sampling period (December 2001). Brown trout were also absent from this site, but koaro were much more abundant with 16 koaro found during one sampling period (April 2001). The lower site had large numbers of shortjaw kokopu, with 19 being observed on two occasions (January 2001 & April 2001). Shortjaw kokopu commonly co-occurred with brown trout in the lower site with a maximum of six being observed in one sampling period (February 2001). However, koaro were absent from the lower site. Cran's bully were only present at the lower site, with a maximum of six counted during one sampling period (April 2001). Longfin eels were present at all sites. Although generally in low numbers, 15 were counted in one sampling period at the upper site (February 2001), a maximum of 10 at the middle site (February 2001), and 10 at the lower site (October 2001).

Table 2. Fish species observed at the seasonal survey sites in the northeastern Tararua Ranges between August (2000) and November (2000).

Site	Shortjaw Kokopu	Koaro	Longfin eels	Brown Trout	Cran's Bully
Upper	✓	✓	✓		
Middle	✓	✓	✓		
Lower	✓		✓	✓	✓

3.3.1 Seasonal activity

As there was a marked decline in the number of shortjaw kokopu observed in May, this was designated as the start of winter. Seasonal changes in observed numbers followed a similar pattern in all five species of fish and at all three sites (Figure 2). Numbers were highest during summer and autumn but dropped during winter, following water temperature trends. Generally, the observed presence of the different fish species followed the water temperature changes, although time lags occurred between the changes in water temperature and the activity response of different fish species. Longfin eels appeared to most closely followed the temperature changes, with shortjaw kokopu and koaro both exhibiting slightly delayed responses to temperature change. During the October 2001 survey, three unidentified juvenile bully were found in the lower reach.

3.3.2 Shortjaw kokopu

Seasonal variation in the number of shortjaw kokopu observed was similar at the three sites (Figure 3). The highest numbers of shortjaw kokopu were observed in autumn or summer, and the lowest in winter (Figure 4).

Shortjaw kokopu were found in large congregations (≥4 fish) in five pools and runs (Table 3) on 10 different survey trips (Table 4). No pool or run was observed to contain shortjaw kokopu in all 16 survey occasions, but most had shortjaw kokopu recorded on more than three occasions (Table 4).

Table 3. Distribution of pool occupancy by shortjaw kokopu over 14 months in the Mangatainoka catchment.

	No. of shortjaw kokopu per pool						
	0	1	2	3	4	5	6
Minimum	67	–	–	–	–	–	–
Maximum	18	21	14	9	1	0	4
Mode	62	4	1	–	–	–	–

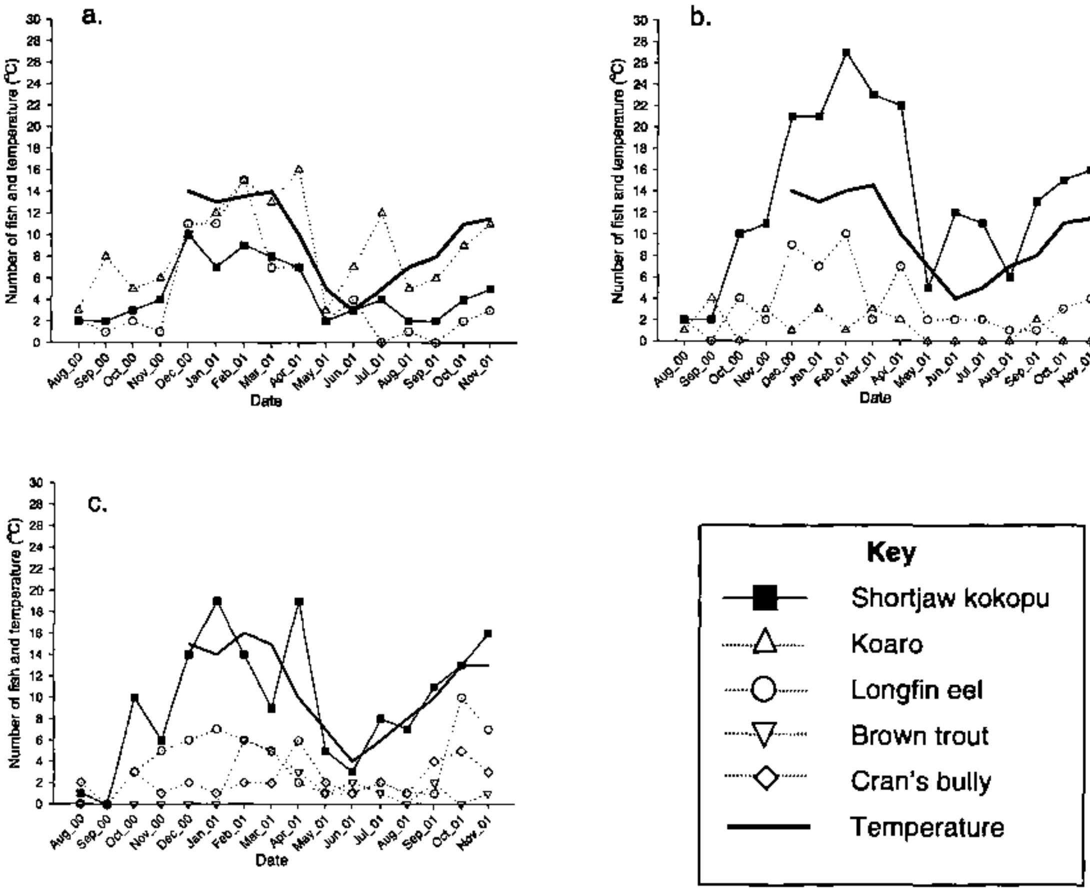

Figure 2. Number of fish observed and the temperature recorded monthly over a 16 month period at a. upper site; b. middle site; and c. lower site.

Table 4. Monthly distribution of pool occupancy by shortjaw kokopu in the Mangatainoka catchment.

	No. of shortjaw kokopu in pool							Total No.
	0	1	2	3	4	5	6	seen
August 2000	62	5						5
September 2000	63	4						4
October 2000	50	12	4	1				23
November 2000	54	6	6	1				21
December 2000	41	14	8	3			1	45
January 2001	44	13	6	1			3	47
February 2001	38	19	5	3	1	1		47
March 2001	43	15	6	1	1		1	40
April 2001	37	20	4	5		1		48
May 2001	56	10	1					12
June 2001	51	15	1					17
July 2001	52	13		1			1	22
August 2001	56	9	1		1			15
September 2001	51	9	5	1	1			26
October 2001	50	7	7	1	2			32
November 2001	49	7	6	3	1	1		37

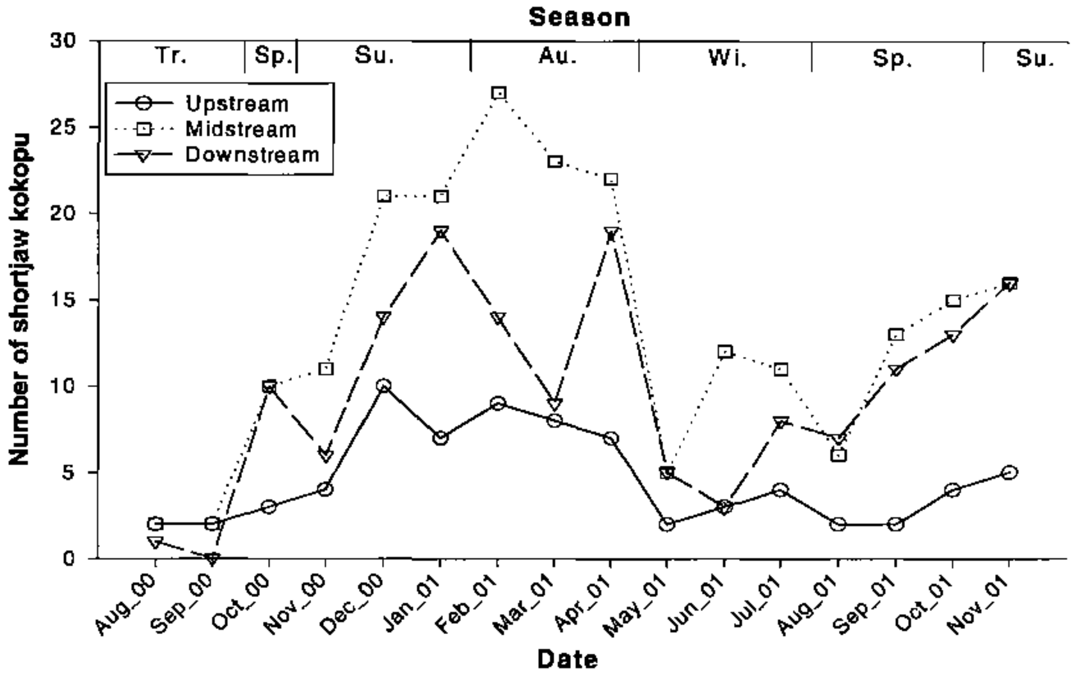

Figure 3. Monthly changes in the number of shortjaw kokopu observed at three survey sites in the Mangatainoka catchment. Seasons are Tr. trial; Sp. spring; Su. summer; Au. autumn; and Wi. winter.

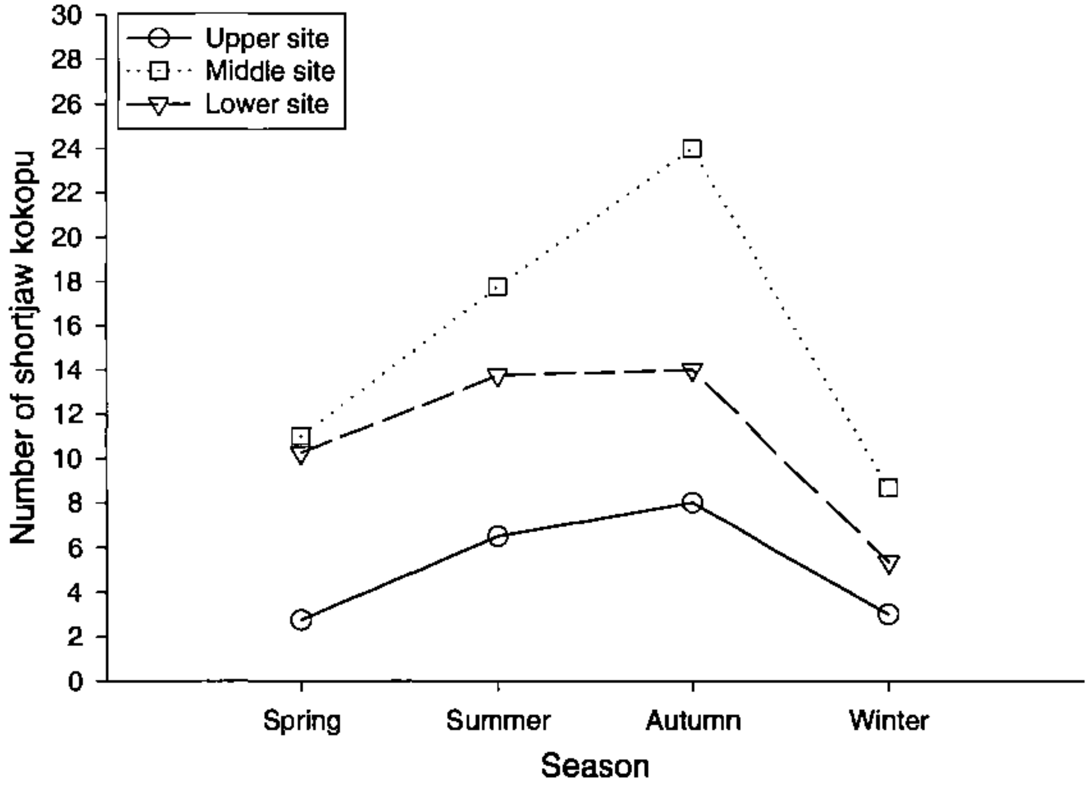

Figure 4. Seasonal variation in mean number of shortjaw kokopu observed per survey at three sites in the Mangatainoka catchment.

3.3.3 Analysis of shortjaw kokopu activity

Shortjaw kokopu numbers differed between sites ($F_{2,30} = 30.7$, $P < 0.001$). The upper site had lower numbers than the middle and lower sites (Bonferroni, $P \leq 0.001$, 0.010). However, there was no significant difference between middle and lower sites there was no significant difference (Bonferroni, $P = 0.118$). Shortjaw kokopu numbers also differed between seasons ($F_{3,30} = 14.59$, $P < 0.001$), although between summer and autumn, and winter and spring there was no significant difference (Table 5). There was no significant interaction between season and site ($F_{6,30} = 1.71$, $P = 0.153$).

Table 5. Statistical significance between seasons, significant differences found by a Fishers LSD test, ($P \leq 0.05$) are shown in bold.

	Spring	Summer	Autumn
Summer	0.059		
Autumn	**0.006**	0.264	
Winter	0.403	**0.012**	**0.001**

3.4 Discussion

There has been much research into the migration and diurnal activity patterns of freshwater fish species, particularly the anadromous salmonid species of the northern hemisphere. Temperature, photoperiodity and spate occurrence have often been identified as the principle determinants of salmonid migration and diurnal activity (e.g. Whalen *et al.* 1999, Fraser *et al.* 1995, Young 1998). Seasonal activity of galaxiidae species is less studied, with most work being carried out on non-diadromous species, particularly *Galaxias vulgaris* (e.g. Cadwallader 1975a, Cadwallader 1975b).

All of the sites had reduced shortjaw kokopu activity during winter. Seasonal migration would have implied one of the sites had greater shortjaw kokopu activity during the winter and a significant site-season interaction would have been found. As this was not observed, seasonal migration seems unlikely. The same shortjaw kokopu were also found in the same pools when activity levels increased again. So, shortjaw kokopu must exhibit a limited activity pattern during winter. They may bury themselves in substrate, requiring less effort to hold position during flooding events, or remain in their daytime refuge, allowing a limited feeding period during part of the night to retain condition. As some shortjaw kokopu are found year round, it seems likely that they remain in daytime refuge; however, immediately following a flood, more shortjaw kokopu are active (*pers. obs.*).

All of the species present in the Mangatainoka River and tributary, except Cran's bully, showed similar activity patterns over the 16 month studied. The reductions in activity all occurred around May. For the galaxiid species, this is the estimated spawning time (McDowall 1990), with spawning activity observed in Taranaki populations of shortjaw kokopu (S.C. Charteris (Massey University: Palmerston North) *pers. comm.* June 2001), which would explain the continued high activity levels through until May, beyond the period when temperature changes most rapidly. Longfin eels, however, are catadromous, spawning at sea (McDowall 1990), so do not need to maintain activity until a spawning period. Cran's bully showed similar activity throughout the year, although an increase occurred in early October when some juvenile bullies were found.

During late autumn (April 2001), most large shortjaw kokopu were found in a ripe state, but by the start of winter (May 2001), most were spent. This is consistent with the paucity of adult shortjaw kokopu observed in May (2001), when only sub-adult fish were found. The larger fish may have been recovering from the energy expenditure associated with spawning.

Koaro were only found above the range of brown trout, but did not become a dominant species in the fish community until shortjaw kokopu started to become fewer in number near the top of their range. Where shortjaw kokopu were less dominant, koaro utilized the pools and runs much more. Chadderton & Allibone (2000) have also described koaro as riffle dwellers while other fish species were present, but utilizing all habitat types when the other fish species reached their upstream distribution limits, which they called a "community controlled" effect.

Brown trout were not observed at the lower site until January 2001. A cause of this may have been a large flood during October 2000. This flood affected the Mangatainoka headwaters, reconstructing many of the headwater tributaries by moving around boulders and large logs, replacing some pools with riffles. This occurred at all three survey sites. The lower site, however, had been worse hit, due to the much greater water flow, and this may have displaced brown trout from the fish community, requiring many months to return to pre-flood levels.

Shortjaw kokopu were never active in any pool or run for all 16 monthly surveys. However, eight pools and runs had shortjaw kokopu activity for more than 10 monthly surveys, and 15 for more than eight monthly surveys. The May (spawning) period may account for the greater shortjaw kokopu observance in some pools and runs, but not others (S.C. Charteris (Massey University: Palmerston north) *pers. comm.* June 2001). On this occasion, mostly sub-adult fish were observed in this survey, but not many of the large fish that were present in earlier months. Generally, these same fish 'reappeared' in the same pools in later months. However some did not, either moving into new, unrecorded habitats, or possibly dying. Of these, two were greater than 240 mm long and most were greater than 210 mm.

Grouping the monthly data by seasons was useful to provide 'replication' for the statistical analysis but it may obscure some of the seasonal patterns. Only one night was surveyed each month, so even with ungrouped data, sudden changes in activity will be observed. This is particularly important in May. Although classified as winter due to the surveyed activity levels, May is the main month of spawning for shortjaw kokopu (S.C. Charteris (Massey University: Palmerston North) *pers. comm.* June 2001). The survey occurred late in the month, following the spates associated with spawning in the Mangatainoka catchment. At this time, the activity levels were low, but had the survey been carried out in early May, the activity levels may have been as high as in April.

In conclusion, shortjaw kokopu have greatest activity during summer and autumn, and least during winter. While there was a difference between sites, this was consistent for the entire study, showing that shortjaw kokopu have a reduced activity period during winter, and don't show a seasonal movement pattern. The reduced activity in shortjaw kokopu appears to commence following spawning, particularly in the adult fish.

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4.

Evaluation of three methods for surveying shortjaw kokopu (*Galaxias postvectis*) in the northern Tararua Ranges

Abstract

Freshwater fish communities were surveyed at six sites in the Mangatainoka catchment in the northeastern Tararua ranges. At each site, spotlighting, electrofishing, and gee-minnow trapping were tested for their effectiveness in locating shortjaw kokopu (*Galaxias postvectis*). Eleven shortjaw kokopu were caught by spotlighting, three by electrofishing, but none with gee-minnow traps. Also caught were brown trout (*Salmo trutta*), longfin eels (*Anguilla dieffenbachii*), Cran's bully (*Gobiomorphus basalis*), torrentfish (*Cheimarrichthys fosteri*) and koura (*Paranephrops planifrons*). There was no significant difference in the number of fish observed per site by spotlighting and electrofishing.

Key Words: Shortjaw kokopu, *Galaxias postvectis*, electrofishing, spotlighting, gee-minnow traps, Tararua Ranges, New Zealand.

4.1 Introduction

Shortjaw kokopu (*Galaxias postvectis*) are considered rare, occurring in less than 2% of NZFFD[1] records (McDowall *et al.* 1996b). Shortjaw kokopu are diadromous and found throughout most of New Zealand, yet have a Category A threatened species status (Molloy & Davis 1994). This is because of their sporadic distribution (mostly ≤3 fish at any location; McDowall 1996) and their supposed habitat needs; streams with boulders and pools in podocarp dominated native forest (Main 1987, McDowall 1990, 2000, McDowall *et al.* 1996a)

A possible factor contributing to the apparent rarity of shortjaw kokopu is that people may be looking in the wrong places, using the wrong methods. Most of the NZFFD records are from more accessible lowland sites, using electrofishing. While there is no doubt that electrofishing is a useful method for surveying fish communities, including shortjaw kokopu (Eldon 1983, McDowall 1990), spotlighting is becoming increasingly popular because of its effectiveness in locating night-active fish that occupy pools (Studholme *et al.* 1999, Jack & Barrier 2000).

Shortjaw kokopu have only recently been reported from the upper Mangatainoka catchment (Anonymous 1999). In a 500 m reach of a 4th order stream eight shortjaw kokopu were electrofished (I.M. Henderson (Massey University) *pers. comm.* February 2000) and 49 observed by spotlighting.

In this survey, I compare the effectiveness of three methods of surveying shortjaw kokopu. Spotlighting, electrofishing and trapping were used at the same six sites in a standardized order.

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[1] New Zealand Freshwater Fish Database, maintained by the National Institute of Water and Atmosphere (NIWA; McDowall & Richardson 1983).

4.2 Methods

Six sites were selected on streams of 3rd-5th order in the Mangatainoka River headwaters (Figure 1). All but one of the sites was within 100 m of locations where shortjaw kokopu had previously been observed (Chapter 2 & 3).

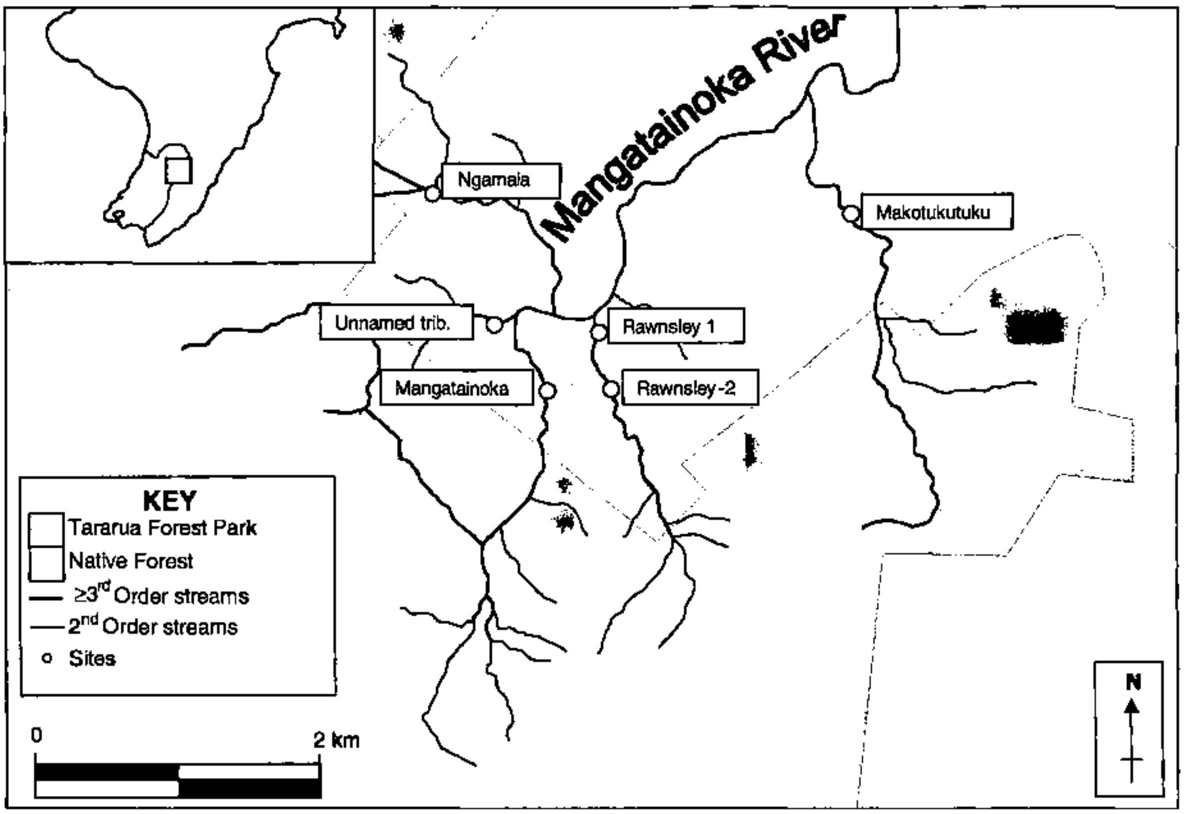

Figure 1. Location of study sites in the northeastern Tararua Ranges used to compare survey methods for shortjaw kokopu.

Habitat characteristics (similar to Chapter 2) were recorded and an initial spotlight survey carried out in four runs, two upstream and two downstream, over a 100 m reach. The following day these sites were electrofished in two passes, using a Kainga: EFM300 electrofishing machine. Later that night, starting 30 minutes after dark and at least four hours after the electrofishing runs, a second spotlight survey was carried out and 10 unbaited gee-minnow traps were placed in pools throughout the 100 m reach. The following morning, these traps were removed. The first two sites spotlighted at the start of the experiment were spotlighted again at the end to check for any differences over time. At all times, two observers were present. Spotlighting used 30 watt bulbs powered by 12 volt 7 amp hour batteries. All observations took place in the first week of June 2001.

4.2.1 Statistical analysis

Because the numbers of fish observed per site were small (0-9 total fish, 0-3 shortjaw kokopu), non-parametric statistics were used; Wilcoxon signed rank test for paired comparisons of methods within sites, and Friedmans test for a comparison of three repeated measures within sites. When comparing the effectiveness of methods for shortjaw kokopu, sites where the species was never recorded were excluded from the analysis. All analyses were performed on the total number of fish and then shortjaw kokopu alone. All of the analyses were done using SAS (2000).

4.3 Results

Five fish species were caught during the experiment (Table 1). Shortjaw kokopu were numerically dominant, with a total of nine fish caught from four sites. Longfin eels (*Anguilla dieffenbachii*), brown trout (*Salmo trutta*), Cran's bully (*Gobiomorphus basalis*), torrentfish (*Cheimarrichthys fosteri*) and koura (*Paranephrops planifrons*) were also caught.

Spotlighting identified most species at more sites than either electrofishing or gee-minnow traps (Figure 2). The only torrentfish caught was by electrofishing. Gee-minnow trapping caught only one fish, a Cran's bully, and three koura. With only one fish captured, gee-minnow trapping has been excluded from the rest of the analysis.

4.3.1 Effectiveness of the Methods

There was no significant difference in the total number of fish observed per site between spotlighting and electrofishing (Wilcoxon: $z = 1.51$, $P = 0.131$) (Figure 3). One more shortjaw kokopu was observed spotlighting than electrofishing, but this was not a significant difference (Wilcoxon: $z = 0.58$, $P = 0.564$).

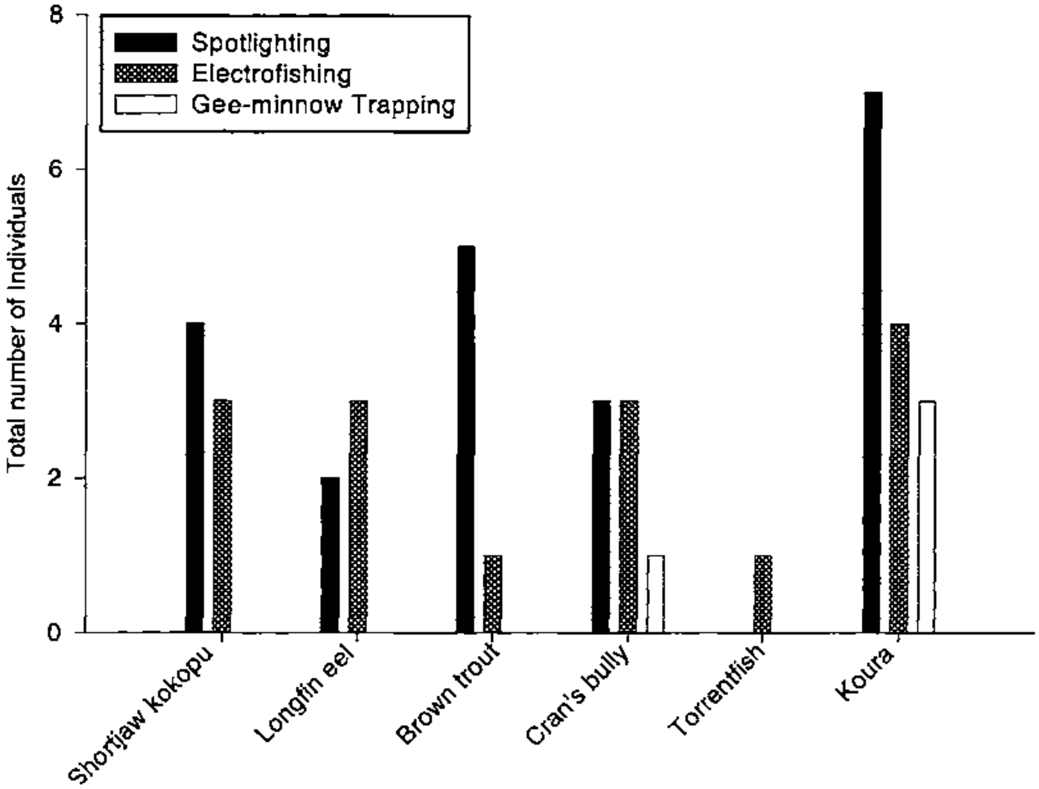

Figure 2. Number of fish caught using three survey methods in the northern Tararua Ranges.

4.3.2 Effect of electrofishing on spotlight surveying

The total number of fish observed did not differ significantly in the two spotlight surveys before and after electrofishing (Wilcoxon: z =-0.378, P = 0.705). Although less shortjaw kokopu were observed by spotlighting after electrofishing in two out of four sites, this was not significant (Wilcoxon: z = 0.38, P = 0.705).

4.3.3 Changes in fish caught using spotlighting, over time

No significant variation was observed among the three sampling occasions (Friedman: s = 6.5, P = 0.197) (Figure 4).

Table 1. Number of fish or koura recorded during each stage of an experiment comparing survey methods in the northern Tararua Ranges.

Site	Method	Shortjaw kokopu	Longfin eel	Brown trout	Cran's bully	Torrentfish	Koura
Rawnsley-1	Spotlight-1	1					2
	Electrofishing		1				
	Spotlight-2		1		1		
	Gee-minnow						
	Spotlight-3*	1	3				2
Rawnsley-2	Spotlight-1	1	1				
	Electrofishing	1					2
	Spotlight-2						2
	Gee-minnow						1
	Spotlight-3*	3					4
Makotukutuku	Spotlight-1		1	2	5		1
	Electrofishing			1	1		
	Spotlight-2	1	1	2	1		1
	Gee-minnow				1		1
Ngamaia	Spotlight-1						1
	Electrofishing						
	Spotlight-2			1			1
	Gee-minnow						
Un-named trib.	Spotlight-1				1		3
	Electrofishing				1		2
	Spotlight-2				1		3
	Gee-minnow						1
Mangatainoka	Spotlight-1	1		3			
	Electrofishing	2	2			1	
	Spotlight-2	3		2			
	Gee-minnow						
No. of different individuals		9	5	6	7	1	11

* Repeated spotlight surveys occurred at two sites to ensure consistency over time

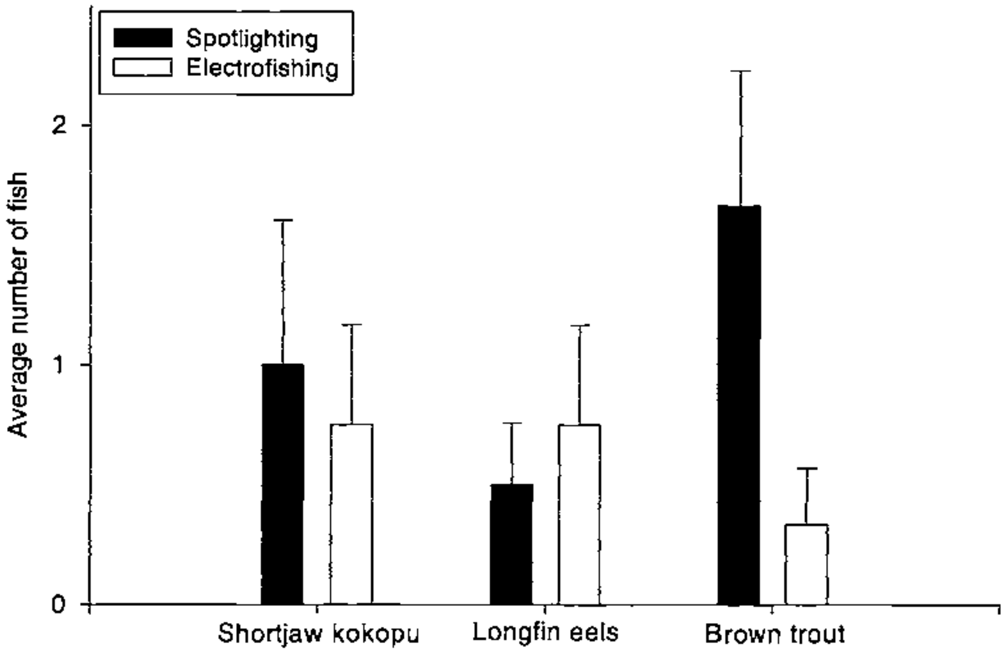

Figure 3. Average number per site of the three most common fish species, using electrofishing and spotlighting (sites where a species was never observed are excluded). Error bars are: +1 SE.

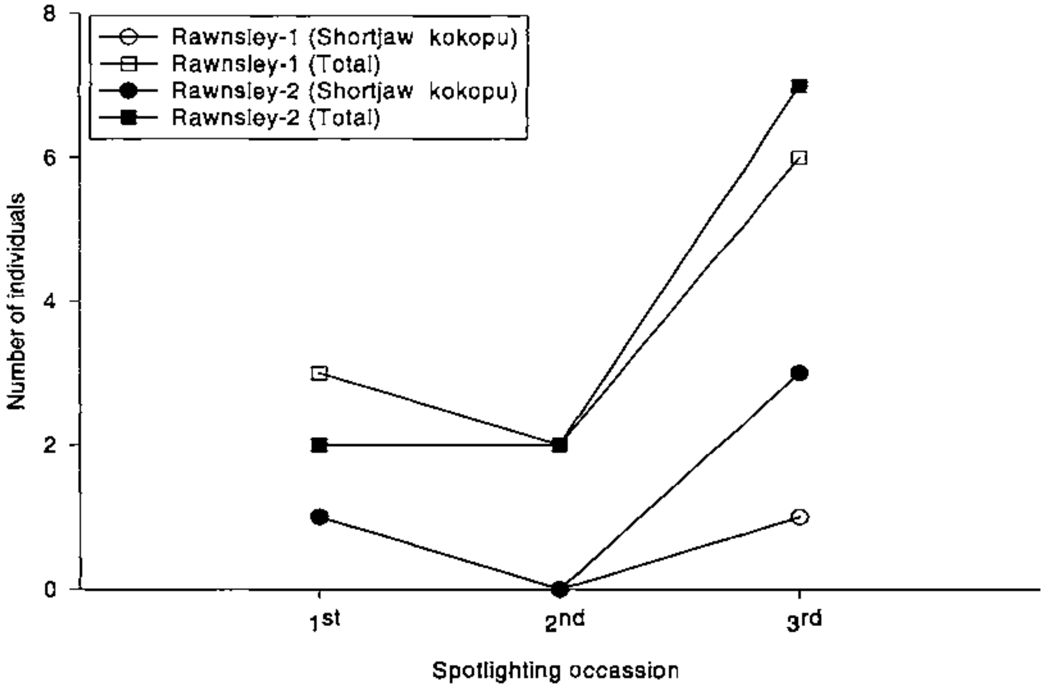

Figure 4. Changes in the fish community at two sites during the week of the experiment for the best survey method for shortjaw kokopu.

4.4 Discussion

Most surveys that have identified shortjaw kokopu, have been undertaken with electrofishing machines (Eldon 1983). However, recent studies have suggested that spotlighting for shortjaw kokopu, observing them during their active period, is a much more effective method (Studholme *et al.* 1999, Jack & Barrier 2000). During the day, shortjaw kokopu are difficult to find, either preferring riffle-run habitat (Eldon 1983, McDowall 1990, McDowall *et al.* 1996a), or burrowing into the substrate. While electrofishing can identify the presence of shortjaw kokopu given favorable conditions, there are often times when the method is unable to capture any shortjaw kokopu, but a subsequent spotlight survey identifies large numbers (*pers. obs.*), regardless of operator experience. This was found at two of my sites and at a further two sites, fewer shortjaw kokopu were found while electrofishing than spotlighting. Gee-minnow traps did not catch any shortjaw kokopu.

Main *et al.* (1985) and Taylor & Main (1987) found gee-minnow traps to be ineffective for use with most large galaxiids, although they have been used successfully in Waikato, particularly surveying banded kokopu (R. Fowler (Kingett Mitchell & Associates Ltd: Auckland) *pers. comm.* May 2001). Non-migratory galaxiids are more prone to capture with gee-minnow traps (Main *et al.* 1985). Gee-minnow traps have been highly successful with other smaller galaxiids, non-migratory brown mudfish (*Neochanna apoda*; K.A. Francis (Massey University: Palmerston North) *pers. comm.* August 2000) and Canterbury mudfish (*N. burrowsius* (Phillips); M. Bonnett (NIWA: Christchurch) *pers. comm.* May 2001).

Shortjaw kokopu were expected to be more efficiently surveyed using spotlighting than electrofishing (I.M. Henderson (Massey University: Palmerston North) *pers. comm.* February 2000, M.K. Joy (Massey University: Palmerston North) *pers. comm.* February 2000). In this study, no significant difference was found, but sample sizes are very small. The only torrentfish was found during an electrofishing survey, however. Torrentfish are much more difficult to find with spotlights in their preferred riffle habitat. The other species found in the survey, tend to spend their active periods in pools, and so are easier to observe with spotlights.

Electrofishing is known to be an intrusive method of surveying fish communities (Burnet 1952, Knewstubb 1979, Sharber & Carothers 1988, Elley 1994, Snyder 1995, Nielsen 1998, Beaumont *et al.* 2000). The effect of the electric currents have been suggested to have an influence on the community for an undefined period after the electrofishing event (Beaumont *et al.* 2000), leaving some species in a state of daze, and other species in a state of greater activity. From this experiment, a dazed state was still exhibited by brown trout in the follow up spotlight survey, but all other species of fish observed during the second spotlight survey had resumed normal activity. Furthermore, following the electrofishing event, shortjaw kokopu were still found occupying the same pools, although they were electrofished from riffles at either end of the pool.

This experiment was conducted in early June when activity is lowest (Chapter 3). In the week before the experiment, snow fell in the upper headwaters of the Mangatainoka River with an extended period of rain before that, so river temperatures were at their annual low. Therefore, our experiment maybe biased towards electrofishing, as this is less dependant on activity level of the fish than spotlighting or gee-minnow traps.

Although this analysis found neither electrofishing nor spotlighting to be the best method for surveying fish communities, and especially shortjaw kokopu, there are several reasons why a particular method may be used over others. Electrofishing and spotlighting require a similar amount of time to effectively survey a reach. Electrofishing has the advantage that it can be done during the day, minimizing the potential for becoming lost which can be especially important if the location requires walking a significant distance from a road or other track. Electrofishing is also less dependant on activity levels of fish, being able to pull fish out from hiding places at any time of the day, any time of the year and any temperature. Spotlighting is less harmful on the fish and less likely to disturb their natural behaviour. The other advantage with spotlighting is that it is less harmful on surveyors, whereas a mistake with an electrofishing machine could have lethal effects. Both have the potential for drownings to occur, however.

In conclusion, spotlighting appeared to catch greater numbers of shortjaw kokopu at more sites than electrofishing, but this could not be confirmed statistically. Gee-minnow trapping was clearly less effective than either of the other methods. However, because few fish were found in this experiment the power of the statistical tests is low. I used non-parametric statistics because with the small counts of fish per site, assumptions of normality for parametric statistics are not met. However, because of the low level of replication (number of sites), perfect concordence of ranks within sites would be needed for probability ≤ 0.05 with non-parametric statistics. Larger experiments should be carried out using a greater number of sites containing shortjaw kokopu to confirm the difference in effectiveness of spotlighting and electrofishing for shortjaw kokopu. However, finding a large number of sites with shortjaw kokopu is often difficult; so logistically, it may be better to combine results from a number of studies to evaluate the effectiveness of electrofishing and spotlighting for surveying shortjaw kokopu.

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5. Habitat selection by juvenile, sub-adult and adult shortjaw kokopu (*Galaxias postvectis*) in the northern Tararua Ranges

Abstract

Shortjaw kokopu were surveyed at sixteen sites in the Mangatainoka and Makakahi catchments in the northeastern Tararua Ranges. At each site, habitat and fish communities were assessed. At three sites, microhabitat features relating to each reach were also recorded. Ninety-five shortjaw kokopu were found comprising 76% adults, 13% sub-adults and 12% juveniles. At the reach scale, presence of debris jams and low proportion of shrubs in the riparian vegetation were associated with presence of non-adult shortjaw kokopu; while the microhabitats characteristics in pools where non-adult shortjaw kokopu were observed were: presence of sand substrate, small pool length, large width at the top of the pool, no velocity, steep gradient below the pool and absence of silt. Proportion of sand substrate, pool length, width at the top of the pool, velocity, gradient below the pool, and cobble in the habitat above the pool were found to best discriminate between the microhabitat preference of the three size classes.

Key Words: Shortjaw kokopu, *Galaxias postvectis*, size class, habitat selection, Tararua Ranges, New Zealand.

5.1 Introduction

Shortjaw kokopu (*Galaxias postvectis*) are a diadromous endemic freshwater fish (McDowall 1990) listed as a Category A threatened species (Molloy & Davis 1994). This status has been assigned because of their small populations sizes (≤3 fish per location; McDowall 1996), and their sporadic distribution (McDowall 1996). However, because the populations are so small, little work has been done on the habitat characteristics of different size classes of shortjaw kokopu, or if there is co-existence between these size classes.

Adult shortjaw kokopu are found in bouldery streams of podocarp dominated forest (Eldon 1983, McDowall 1990, McDowall *et al.* 1996a). Adults spawn in these habitats, with eggs maturing on the bank, and newly hatched larvae washing down to sea where they mature for up to six months (McDowall 1990). The juvenile shortjaw kokopu migrate, as whitebait, from the sea back into adult habitat (McDowall 1990). When they begin migration they are less than 60 mm in length (McDowall & Eldon 1980), and the first records of larger shortjaw kokopu are normally sub-adults, greater than 90 mm long (Studholme *et al.* 1999). Adults can grow to more than 260 mm long. The only study published to date describing the habitat of juvenile shortjaw kokopu (Jack & Barrier 2000), found that they occupy riffles at night, as opposed to the adult habitat of pools (Caskey 1999, Studholme *et al.* 1999, Jack & Barrier 2000).

A large population of shortjaw kokopu was found in the Mangatainoka River in February 1999 (Anonymous 1999). At the time 49 shortjaw kokopu were observed within a 500 m reach of 4th order stream; above the limits of trout dispersal, but co-occurring with koaro. A range of sizes from newly migrated juveniles through to much larger older fish (≥9 years; McDowall *et al.* 1996a) were found and while different size classes were found in the same reaches, they were not always present in the same microhabitats (I.M. Henderson (Massey University: Palmerston North) *pers. comm.* February 2000).

In this survey, I assess the habitat requirements of three age/size groups of shortjaw kokopu found in the Mangatainoka and Makakahi Rivers. I test this at two levels, macrohabitat, comparing characteristics from reach to reach, and microhabitat, comparing pool-to-pool habitat preference.

5.2 Methods

Macrohabitat data was recorded from sixteen sites and microhabitat data at three sites (Table 1).

Table 1. Date and location of size class habitat surveys.

Scale	River	Date of survey	No. of sites	No. of shortjaw kokopu
Macrohabitat	Mangatainoka	Aug 2000 - Nov 2001	3	54
	Mangatainoka	Jan - May 2001	7	26
	Mangatainoka	June 2001	4	9
	Makakahi	March 2001	2	6
Microhabitat	Mangatainoka	Aug 2000 - Nov 2001	3	54

Macrohabitat variables

All surveys were undertaken in reaches of pool-riffle-run flow type, with variable vegetation cover, from heavily forest canopy to a light sporadic gorse cover. Average width was estimated from five transects spread the length of the site. Average depth was estimated from five measurements taken at each width transect; and velocity was measured by timing the movement of fluorescein (BDH Laboratory Supplies: GPR™) dye along the length of the site. Substrate composition was estimated using the Wolman walk method (Wolman 1954) and the substrate size categories as defined in Chapter 2. Using the formula in Chapter 2, a substrate size index was calculated. Habitat type, overhead cover, undercut banks, debris jams and vegetation types were visually assessed using a percentage scale; moss and periphyton using a 10-point scale (1 = least; 10 = most). Streambed stability was assessed using the bottom section of the pfankuch table (Pfankuch 1975), following Death (1995). Habitat type was assigned into six categories; backwater, pool, large pool, riffle, run or fall, based on the definitions in Chapter 2.

Microhabitat Variables

The microhabitat data was based on individual pool or run usage by shortjaw kokopu. On each sampling occasion, fish size and location to the nearest sequentially numbered pool or run was recorded. In each location, habitat variables were recorded as for the macrohabitat analysis, however, to save time, substrate was now visually assessed using the size classes in Table 2; and velocity was recorded using a velocity head rod. Gradient was measured over 10 m at either end of the pool using an abney level. Substrate composition, vegetation cover and velocity were also measured at either end of the pool. Specific parts of pools or runs where juvenile shortjaw kokopu were found were also recorded. Measurements were made of the specific location where the juveniles were observed. At each of these the depth, substrate size and velocity was recorded.

Table 2. Substrate size classes

Boulders	> 256 mm
Cobbles	64 – 256 mm
Pebbles	16 – 64 mm
Gravel	2 – 16 mm
Sand	1 – 2 mm
Mud/Silt	< 1 mm

Fish surveys were undertaken at least 30 minutes after sunset following the completion of habitat assessment. Spotlighting was carried out by two observers using 30 watt spotlights that were powered by 12 volt, 7amp hour batteries. Four spotlighting runs, two upstream, and two downstream were completed. The shortjaw kokopu were separated into size classes based on size as described by Studholme *et al.* (1999), i.e. juvenile ($\leq$ 90 mm), sub-adult (90-120 mm) and adult (> 120 mm).

5.2.1 Statistical analysis

In the reaches with shortjaw kokopu present, a two-group Stepwise Discriminant Analysis (SDA) was conducted on the macrohabitat site information and the fish species co-occurring with shortjaw kokopu. The SDA determined variables that describe non-adult, juvenile or sub-adult shortjaw kokopu habitat based on the occurrence of these size classes within these reaches. A two group SDA was also run on the microhabitat data associated with shortjaw kokopu presence, describing habitat for the same size classes. A three-group SDA was conducted on microhabitat associations between classes. Discriminant Function Analyses (DFA) were run using each of these SDA selected variables. All statistical analysis was carried out using SAS (2000).

5.3 Results

Shortjaw kokopu occurred in 16 reaches of the 59 surveyed (Chapter 2, 3 & 4), 14 on the Mangatainoka River and two on the Makakahi River. Ninety-five shortjaw kokopu were recorded and ranged in size from 60 to 280 mm with most between 140 and 170 mm (Figure 1). Juvenile shortjaw kokopu accounted for 11.6% of the records (11 fish), sub-adults 12.6% (12 fish) and adults 75.8% (72 fish).

Brown trout (*Salmo trutta*), koaro (*Galaxias brevipinnis*), longfin eels (*Anguilla dieffenbachii*) and Cran's bully (*Gobiomorphus basalis*) were also found co-occurring with shortjaw kokopu. Longfin eels occurred at every site shortjaw kokopu were present, often in the same pools. Other species were more restricted in their distribution. Koaro occurred at the upper extent of the shortjaw kokopu distribution, while brown trout and Cran's bully occurred at the lower extent of shortjaw kokopu distribution. Cran's bully co-occurred with shortjaw kokopu at four sites (25%), brown trout at six sites (37.5%), and koaro at three sites (18.8%).

5.3.1 Macrohabitat analysis

Given the presence of shortjaw kokopu at a site based on habitat variables (Chapter 2), non-adult shortjaw kokopu habitat was characterized by a high percentage debris jams and low percentage shrubs. This returned one misclassification. Juvenile shortjaw kokopu presence was explained by 14 factors with greater velocity being most important. Other factors found to be important were low percentage beech, pasture, run, overhead cover and exotic forest; high percentage streamside bare rock and shrubs; with small stream order, small average width and smaller rock size (gravel to large pebbles compared with cobbles and boulders). Higher altitude was also included, but was later removed by the stepwise procedure. The fish community was also an important characteristic with the presence of koaro and absence of longfin eels and brown trout being selected by the analysis. These factors yielded perfect prediction of juvenile shortjaw kokopu occurrence. Sub-adult shortjaw kokopu required two factors, more debris jam and beech vegetation, returning only one misclassification.

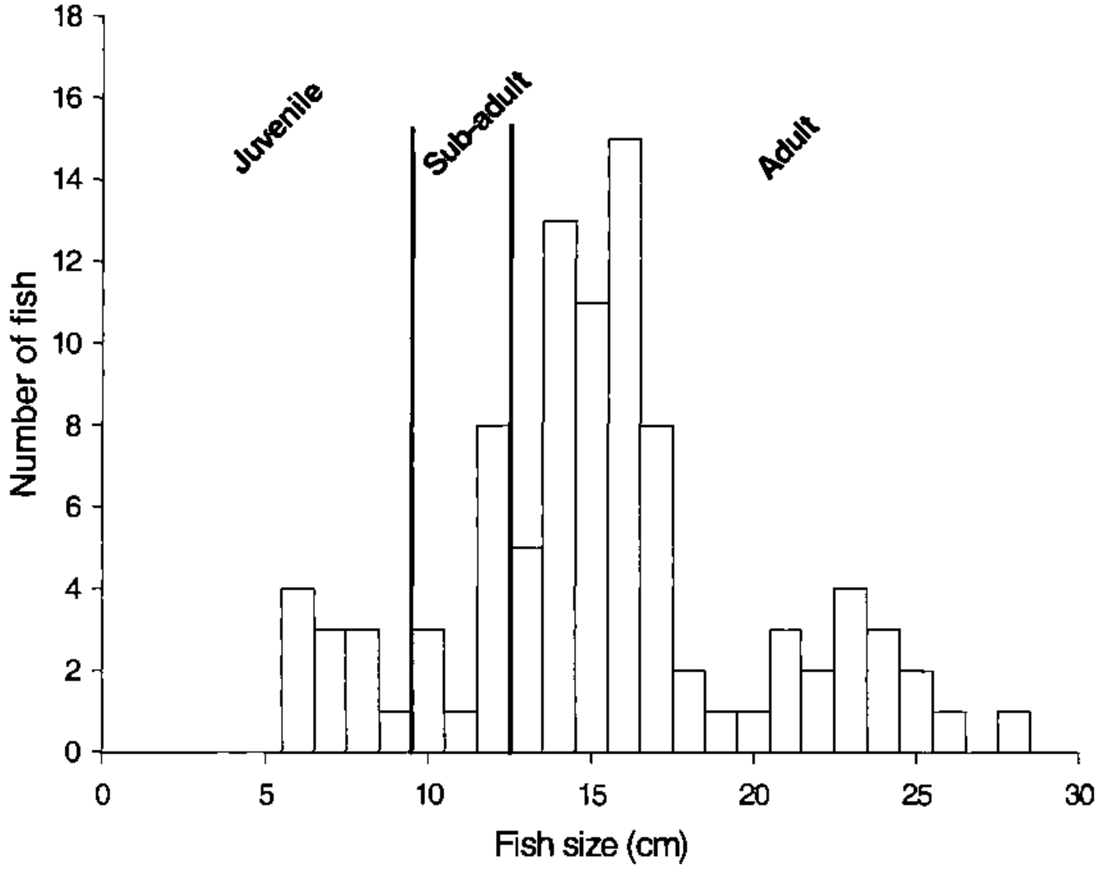

Figure 1. Size frequency of shortjaw kokopu recorded in the Mangatainoka and Makakahi catchments between January and June 2001.

5.3.2 Microhabitat analysis

Fifty-four of the 95 shortjaw kokopu analysed for macrohabitat characteristics, were also analyzed for microhabitat characteristics. These consisted of eight juveniles, nine sub-adults, and 37 adults. Steep gradient in the habitat below the pool, large proportion of sand substrate, small pool length, greater width at the top of the pool, no velocity in the middle of the pool and no silt in the pool characterized non-adult shortjaw kokopu. Juveniles were characterised by shallow average depth at the lower end of the pool and large proportions of sand substrate. The gradient of the habitat below the pool was the first selected variable, but was later removed by the stepwise procedure. Sub-adults were characterised by shallow average depth at the top end of the pool and greater width near the lower end of the pool. The three-group SDA found six habitat characteristics to be important: the gradient of the habitat below the pool, pool length, width at the top of the pool, velocity in the middle of the pool, proportion of cobbles in the habitat above the pool, and proportion of sand in the pool (Figure 2). Forty of 54 microhabitat locations were correctly classified by the SDA (Table 3).

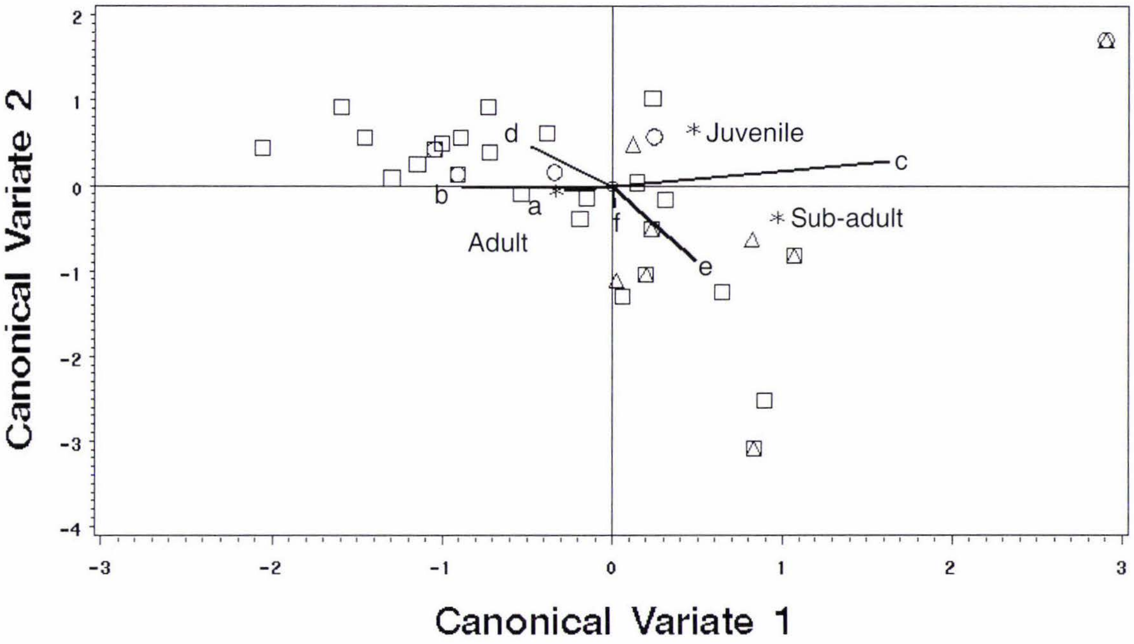

Figure 2. Three-group discriminant analysis of microhabitat of adult, sub-adult and juvenile shortjaw kokopu. Stars (✳) show the correlation of the three size classes with the two canonical variates. The vectors are correlations of habitat variables with canonical variates: a. gradient in the habitat below the pool; b. pool length; c. width at top end of pool; d. velocity in the middle of the pool; e. cobbles in the habitat above the pool; and f. sand in the pool. Squares (☐) represent adult occurrence, triangles (△) represent sub-adults and circles (○) are juvenile occurrence.

Table 3. Prediction results from a three-group SDA run on the microhabitat data.

		Actual		
		Adult	Sub-Adult	Juvenile
Predicted	Adult	27	2	0
	Sub-adult	4	5	0
	Juvenile	6	2	8

5.3.3 Specifics Habitat Features

Eight juveniles were recorded in the microhabitat survey, with two pairs occupying the same locations. The habitat of juveniles was more distinct than the other size classes, and a close analysis of field notes revealed that they were often found in exactly the same part of the pool from month to month. During normal flow conditions, juveniles were always in areas of zero flow hidden behind large rocks, either in backwaters or protected areas of pools. Their local patches of habitat were dominated by small substrate, normally sand or gravel, but not silt. Juveniles were found co-occurring in the same pools as brown trout and koaro. Longfin eels were only found co-occurring with a juvenile once, although they were found in the same pool at different times of the year.

Criteria of site selection for adult shortjaw kokopu may be the availability of nest habitat. A single galaxiid nest was found during the microhabitat survey (Appendix 1), however, koaro are also present in this reach, so I am not confident it is of shortjaw kokopu origin.

5.4 Discussion

Previous surveys elsewhere have found shortjaw kokopu populations with around a 12% sub-adult: 88% adult ratio (Table 4). These surveys generally don't account for juvenile shortjaw kokopu because they are either not observed or a very small proportion of the population. In the Mangatainoka River, however, by including juveniles in the ratio, the adult percentage decreases (12% juveniles: 13% sub-adults: 75% adults).

Table 4. Previously document age structures shown by shortjaw kokopu in different regions of New Zealand.

Surveyors	Region	No. of fish	Adults (%)	Sub-adults (%)
Caskey (1999)	Taranaki	62	95	5
Studholme *et al.* (1999)	Golden Bay	96	83	17
Jack & Barrier (2000)	Marlborough and Kaikoura	176	90	10
My study (2001)	Northern Tararua Ranges	84*	86	14

*excluding juveniles.

Most of the Mangatainoka shortjaw kokopu population were adults, with a large proportion being between 140 and 170 mm long, similar to populations studied in Taranaki (Caskey 1999) and Golden Bay (Studholme *et al.* 1999), but smaller than populations studied in Marlborough and Kaikoura (Jack & Barrier 2000), which were generally greater than 200 mm.

Brown trout are known predators of migrating whitebait (McDowall *et al.* 1996), competitors and predators of older shortjaw kokopu (McDowall *et al.* 1996), and one of the principle suspected agents of native fish decline in New Zealand (McDowall 1984). However, brown trout did co-occur with all size classes of shortjaw kokopu, although with juveniles in only three occurrences, all in shallow parts of pools, with small substrate and plenty of available refuges.

In Chapter 2, I described a discriminant function of 11 variables that accurately predicted shortjaw kokopu presence at the reach scale. In this chapter, I determined the specific habitat characteristics of different size classes of shortjaw kokopu.

The SDA for predicting juvenile shortjaw kokopu selected a large number of habitat variables. This suggests that juveniles are less particular about the reaches that they occupy, possibly because the microhabitat factors are more important than the macrohabitat factors for juvenile shortjaw kokopu. An obvious trend for juveniles is the need for smaller streams, shown by the characteristics small stream order, smaller average width and greater co-occurrence with koaro, which were only found in small streams in this survey. They also tend towards habitat with bare-rock streamside, less beech, less overhead cover, and smaller average rock size. Juvenile shortjaw kokopu were also negatively associated with brown trout and longfin eels. This is not surprising as both are potential predators of juvenile shortjaw kokopu. It is also not surprising that exotic vegetation and pasture are negatively associated, as both were closely linked with presence of brown trout (Chapter 2).

The macrohabitat needs of sub- and non-adults seem to contrast the juvenile macrohabitat characteristics, especially the differences in riparian shrub. Sub-adult shortjaw kokopu require a complete forested canopy cover, while juveniles require less cover, living either in the edge zone bordering the forest, or in areas with light-wells above the stream. In the Mangatainoka catchment, the streams bordering the forested canopy were inhabited by brown trout; however, some juvenile shortjaw kokopu were present. Juveniles were also present in the tributaries above the range of brown trout, in areas of light wells. The ability for juvenile shortjaw kokopu to climb (McDowall 1990, 2000) is advantageous, allowing them to reach these locations bypassing barriers such as falls.

A surprising result from the microhabitat analysis is the synergistic effect that the combined, non-adult size classes have. Individually, juvenile and sub-adult shortjaw kokopu SDA's selected two habitat traits each, but when combined, non-adult habitats were discriminated by six different habitat traits and gave much better prediction results. Generally, non-adult shortjaw kokopu need small, calm pools with a steep gradient in the habitat below the pool. The characteristic of a sandy substrate seems to contradict the perceived trend of shortjaw kokopu habitat with predominantly large cobbles and boulders substrate (Nicoll 1984, Main 1987, McDowall 1990, McDowall *et al.* 1996). However, this is probably a by-product of calm waters, allowing the sand to settle and create beds. Several adult shortjaw kokopu were also found in quite silty pools, from month-to-month, especially prior to May (Chapter 3). This could be an indication of spawning happening in those pools (S.C. Charteris (Massey university: Palmerston North) *pers. comm.* June 2001), as they were all backwaters which many fish are found in around spawning time (May), adjacent to where nests may be located (Appendix 1).

Five of the six variables that characterize non-adult habitat (two-group SDA) also define the between group size class habitat differences (three-group SDA). The new variable, percentage cobble in the habitat above the pool, could be an indication of daytime habitat. Boulders seem to be quite common throughout all sites, so more cobble in the habitat would imply a larger overall substrate size. Others have reported a similar need for large substrate (Nicoll 1984, Main 1987, McDowall 1990, McDowall *et al.* 1996), observing that this is their refuge when disturbed, and often the same places they are elctrofished from during daytime surveys (*pers. obs.*).

The inability of these variables to perfectly predict adult or sub-adult habitat shows us that there is no distinct pattern to shortjaw kokopu habitat selection, at least not in adult fish. Only juvenile shortjaw kokopu seem to have distinct habitat usage, sub-adults less so, but adult shortjaw kokopu seem to inhabit a broad range of habitat characteristics.

The juvenile macrohabitat closely matched the microhabitat characteristics, indicating a need for small streams. However, the sub- and non-adult macrohabitat showed little similarity to the microhabitat characteristics. A problem with macrohabitat analyses is that it is a broad analysis of the reach, while the microhabitat is much more detailed. It may be particular characteristics of this that the size classes are utilising, and these components may be lost in the macrohabitat analysis. Generally, juvenile shortjaw kokopu show distinct macro- and microhabitat usage to sub-adults, but there is little distinction in habitat characteristics between juveniles or sub-adults and adults.

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Synthesis

Shortjaw kokopu are sparsely distributed in the northeastern Tararua Ranges. Of the sites that contained shortjaw kokopu, common characteristics were native forest riparian vegetation, riffle habitat, high conductivity, few debris jams and high stability. Juvenile shortjaw kokopu showed some differences in microhabitat preferences from sub-adult shortjaw kokopu. Adult use a wide range of microhabitat types, including some with juveniles and sub-adults present. Shortjaw kokopu were more active during summer and autumn than during winter and spring; and shortjaw kokopu were more effectively surveyed using spotlighting or electrofishing than using gee-minnow traps.

The distribution and habitat selection surveys (Chapter 2) were undertaken during summer and autumn using spotlights. The results in Chapter 3 showed that these are the seasons when shortjaw kokopu are most active and most likely to be observed. The results from Chapter 4 show that spotlighting is the method that is likely to find more shortjaw kokopu present in more sites. Therefore, shortjaw kokopu are genuinely rare in the northeastern Tararua Ranges. These results also show the importance of conserving habitat specifically for shortjaw kokopu. The Tararua Forest Park provides adequate habitat conservation to maintain a population of shortjaw kokopu in the Mangatainoka River headwaters. However, this forest park contains many river catchments, with many different habitat characteristics. Small conservation reserves, based on single river catchments, may not be able to support populations of shortjaw kokopu because the habitat does not support them, the microhabitat characteristics are not meet, or nest habitat is not present. Therefore, to effectively conserve shortjaw kokopu, it is vital to know where they live and how many of them are found in the population. These findings give a start. Habitat traits are important, but so is survey timing and methodology.

Summer and autumn were shown to be the time when shortjaw kokopu are most active (Chapter 3). Therefore, surveys for shortjaw kokopu should be undertaken during these seasons. After this time, following spawning, most shortjaw kokopu activity appears to be of sub-adult and juvenile fish. However, this decrease in adult activity may prove beneficial for locating nests. While no seasonal movement was noted between reaches, some shortjaw kokopu may have changed microhabitats, moving into neighboring pools or runs in different seasons. This may have happened during autumn as shortjaw kokopu moved into pools for spawning. This would account for particular pools showing greatly reduced activity following spawning as the fish returned to their original pools. During this study, the continued occurrence of shortjaw kokopu in a pool during summer and autumn, but no observations during winter, led to the discovery of a galaxiid nest. For the conservation of shortjaw kokopu, protecting nest habitat is vital. However, to use the activity patterns to find these requires a continuous survey regime, pinpointing pools or runs where shortjaw kokopu show greater activity during summer and autumn, but reduced or no activity following spawning.

Spotlight surveys found more shortjaw kokopu in more sites (Chapter 4). Electrofishing also proved to be an effective method for surveying shortjaw kokopu, although this study found electrofishing only identified shortjaw kokopu in half of the sites that spotlighting found them to be present. However, the comparison of methods took place in early June when shortjaw kokopu activity is low. This may have biased the results towards electrofishing because this method does not rely on the fish to be active. Gee-minnow trapping proved to be the least effective method for surveying shortjaw kokopu. However, one of the problems with this method may be the size of the holes, not allowing larger fish to become trapped. This method also requires fish to be active; and as it was tested in mid winter, the results are not indicative of summer or autumn shortjaw kokopu activity. Gee-minnow traps may be better suited for locating juvenile shortjaw kokopu, which could fit through the entry holes. However, as juvenile shortjaw kokopu use specific microhabitats with still water, hidden behind large rocks, the gee-minnow traps would need to be set in these areas. Unfortunately, juvenile shortjaw kokopu also tended to occur in small streams, which in this study were also some of the further streams to walk to. To efficiently survey an area with gee-minnow traps may require many traps, and to transport these into remote streams may be inapplicable.

The conservation of shortjaw kokopu habitat is a critical component of conserving shortjaw kokopu. However, to conserve the right shortjaw kokopu habitat means knowing which areas these are so surveys for shortjaw kokopu are needed. It is also important to ensure that the survey method and timing are appropriate, so shortjaw kokopu are more likely to be detected if they are present. It is critical to ensure that all stages of the shortjaw life cycle can be conserved, including nest habitats; and that no barriers impede the migrating fish.

Appendix 1

Finding a galaxiid nest in the northern Tararua ranges

On the 8th of June 2001, a nest of galaxiid eggs was found in a headwater tributary of the Mangatainoka River, Tararua Ranges (27249E, 60533N: NZMS 260 S25). The stream is a 4th order tributary draining from an altitude of less than 740 m.

Between August 2000 and November 2001, monthly surveys were undertaken at three sites in the Mangatainoka headwaters for shortjaw kokopu (*Galaxias postvectis*) (Chapter 3). The nest was in the middle site, where the largest number of shortjaw kokopu had been found. Koaro (*G. brevipinnis*) and longfin eels (*Anguilla dieffenbachii*) were also present at this site.

The nest site is 1.6 km upstream from the bush edge and at an altitude of 400 m. The forest cover is predominantly red beech (*Nothofagus fusca*), and kamahi (*Weinmannia racemosa*) with occasional podocarps. The under-storey consists of seedlings of the canopy trees, predominantly red beech, with many native shrubs and ferns also present. The riparian margin has many tree ferns (*Cyathea* spp. and *Dicksonia* spp.) present under the red beech canopy.

The nest was located next to a deep pool (max. 1450 mm), with an average depth of 530 mm. The pool is 7.2 m long, with an average width of 5.3 m. The pool substrate is mainly large boulders (35%) and cobbles (20%), but with pebbles (20%), gravel (15%) and sand (10%) present. The vegetation around the pool is dominated by red beech in the canopy, and tree ferns in the under-storey, and provides 35% cover of the stream. The average water velocity at low flow over the 200 m reach was 0.11 ms^{-1}. The closest riffle is 4 m upstream, where another pool flows through a narrow gut into the large pool. The riffle is 0.3 m in length, with a fall of 0.1m. The pool has most of its flow down the true right bank, with flood events keeping this bank clear of vegetation. A 1st order stream feeds into the pool from the true left bank.

The immediate area (1 m radius) around the nest is 60% shaded by riparian vegetation. Moss is also quite common. The substrate is mainly boulders (30%) and cobbles (40%), with the remainder pebbles (25%) and gravel (5%). Several large boulders enclose the area. This prevents any flow entering the area (0 ms^{-1}). This enclosed area is 1.5 m long, average 0.9 m wide and 120 mm deep. The enclosed area occurs on the true left bank (Plate 1), 2 m above the 1st order stream.

The nest was in a hole 350 mm wide, 120 mm high, and 250 mm deep; situated under the trunk of a large tree fern (Plate 1), 550 mm above the base water level. Inside the hole, the substrate was soil with the lower trunk of the tree fern, and part of its root system protruding from the ceiling. It was to these roots, and the trunk, that the eggs (approx. 50) were attached.

Shortjaw kokopu and koaro are the only galaxiid species known in the Mangatainoka River headwaters (Chapter 2). While these two galaxiids and longfin eels are known from the reach, only shortjaw kokopu and longfin eels were observed in the pool adjacent to the nest (Figure 1). Longfin eels were recorded on two sampling occasions; however, shortjaw kokopu were seen in 10 out of 16 monthly surveys. Up to six shortjaw kokopu were observed in the pool at one time.

During surveys in May and June, no shortjaw kokopu were observed in this pool but they were observed in neighboring pools. The absence of fish from a normally occupied pool was the impetus for a search for spawning sites.

Five eggs were taken for analysis, but failed to hatch. The following month, 15th July, the hole was again searched, but no eggs were found.

The location of the nest away from the main flow means that even during severe spates, the nest would have been protected from the water current. A gauging station (part of the horizon.mw river monitoring system) approximately 15 km downstream, recorded increased water levels (approx. twice base flow) on the 19th through to 26th of May, 10th through to 12th of June and some smaller events later in June, with another large event on the 26th of June. The event in late May is the probable cause for so few eggs to be found in the nest, normally nests have approximately 600 eggs (S.C. Charteris (Massey University: Palmerston North) *pers. comm.* June 2001), with the event in mid June stimulating hatching for the rest of the eggs.

Plate 1. The location of a galaxiid nest, found on the Mangatainoka River. The habitat in the pool beside the nest (a) and around the entrance to the nest (b). The arrow ⇨ denotes the position of the nest.

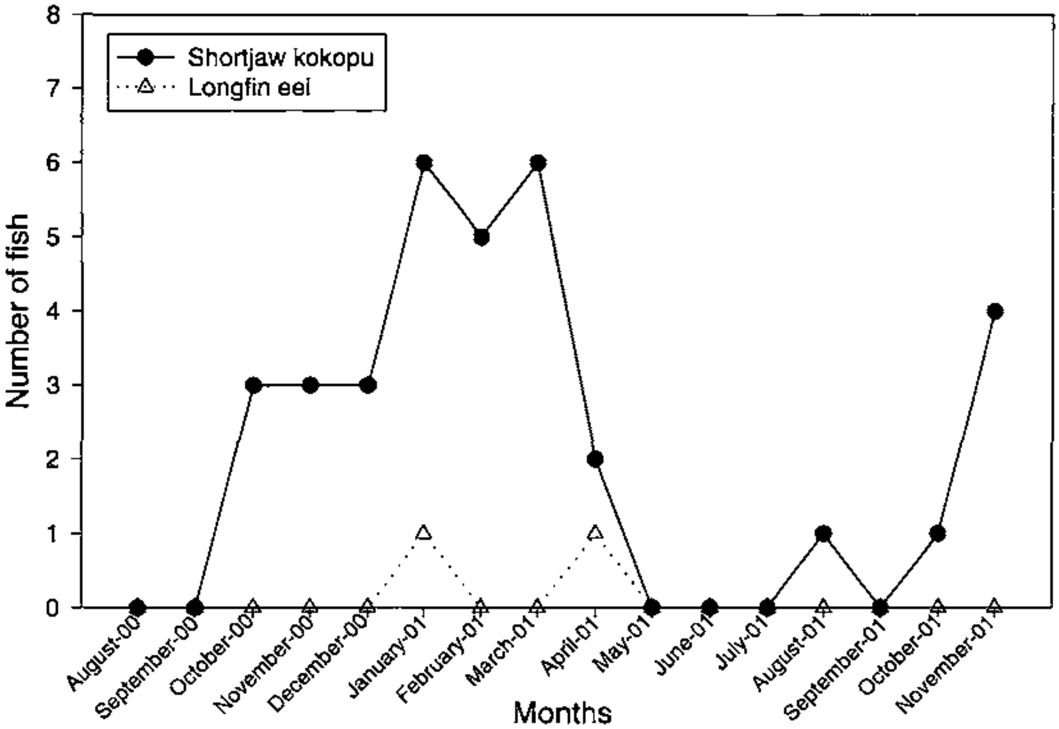

Figure 1. Monthly observations of fish in the pool adjacent to a galaxiid nest.

Allibone & Caskey (2000) describe a koaro nest found adjacent to a riffle, with eggs laid amongst the cobble substrate. Similar sites for koaro nests are described by O'Connor & Koehn (1998). Banded kokopu are described as laying eggs among debris collected at the tail of pools and in rapids (Hopkins 1979), or on the stream margins during flood conditions (Mitchell & Penlington 1982). Shortjaw kokopu nests resemble banded kokopu nests, but generally had less vegetation and debris present (Charteris 2002).

Although the nest could not be identified to species with certainty, based on the characteristics of the nest and fish species normally resident in the adjacent pool, it is very likely that this was a shortjaw kokopu nest.

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