Shortjaw kokopu (*Galaxias postvectis*) in the northern Tararua Ranges

Distribution and habitat selection

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ABSTRACT

Freshwater fish communities were surveyed at 50 sites in the Mangatainoka, Makakahi, and Ruamahanga catchments of the northern Tararua Ranges. At each site, habitat variables were recorded and fish identified and counted by spotlighting over a 100 m reach. Shortjaw kokopu occurred at nine of 37 sites in the Mangatainoka and Makakahi catchments, but none in the Ruamahanga catchment. Stepwise discriminant analysis, and logistic regression analysis, showed high channel stability and low gradient were the best predictors of shortjaw kokopu occurrence, based on the Mangatainoka and Makakahi data. Brown trout did not seem to exclude shortjaw kokopu from these streams, as both species co-existed at three sites. Forty-one shortjaw kokopu were recorded during the study, of which six were classified as sub-adults; sub-adults preferred habitats with steep gradient and smaller-sized rock substrate. In a separate survey to evaluate methods of surveying shortjaw kokopu, spotlighting was the most efficient technique; 11 shortjaw kokopu were recorded from six sites compared with three by electrofishing, and zero using gee-minnow traps. Discriminant analysis of catchment and habitat variables predicted the presence of shortjaw kokopu at three sites in the Ruamahanga catchment. As other migratory galaxiid species were present there, the absence of shortjaw kokopu suggests a lack of recruitment for this species in this catchment.

Keywords: Shortjaw kokopu, *Galaxias postvectis*, whitebait, endemic fish, habitat analysis, distribution survey, Mangatainoka River, Tararua Ranges, New Zealand.

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1. Introduction

The shortjaw kokopu (*Galaxias postvectis* Clarke, 1899) is one of five diadromous species of the family Galaxiidae native to New Zealand. A diadromous lifestyle implies a life history stage that makes a journey between marine and freshwater, in this case the juveniles (whitebait). Shortjaw kokopu exhibit a particular form of diadromy called amphidromy. Spawning takes place in the headwater streams where adults live permanently, the young on hatching are washed down to sea, before beginning the whitebait journey back up river to the adult habitat (McDowall 1988). A diadromous lifecycle is beneficial for many fish as it allows them to distribute themselves more easily around the coastline of New Zealand, colonising many rivers. However, this life history can be disrupted if there are barriers to upstream migration.

An amphidromous lifecycle may also place constraints on habitat selection. McDowall (1998) concluded from an analysis of the records of native fish on the West Coast (from the New Zealand Freshwater Fish Database, NZFFD), that most of New Zealand's diadromous fish are found at low altitudes and short distances inland. In contrast, the non-diadromous species tend to be further inland and at higher altitudes. While some diadromous fish, including shortjaw kokopu, are capable of moving significant distances upstream, McDowall found that this was generally not happening, as most individuals colonised suitable habitat at downstream sites. He reasoned that, particularly for shortjaw kokopu, this was because of ample habitat near the coast. Jowett et al. (1996) reached similar conclusions from their study of gradients of native fish with respect to land use practices around the Grey River of the West Coast. Shortjaw kokopu were not common in their study, but other diadromous species showed a gradient consistent with McDowall's (1996; 1998) results.

At present, the Department of Conservation (DOC) rates the shortjaw kokopu as a category A endangered species (Molloy & Davis 1994). This is the same endangered species rating as applies to several New Zealand icons such as kiwi (*Apteryx* spp.), black robin (*Petroica traversi*) and kakapo (*Strigops habroptilus*). This status was bestowed because, although shortjaw kokopu are known to have a wide-ranging distribution (Puysegur Point on the South Island's south coast to Kaitaia in the north and the Bay of Plenty in the east), at any given location they are generally found in very small numbers.

Several factors may explain their rarity in database records. Shortjaw kokopu may be confined to particular microhabitats that are rare (such as particular stream size and substrate), their activity patterns may not complement most survey methods (i.e. they are hard to find), and they may be rare through over-harvesting of juveniles, artificial barriers to migration, or competition/predation by introduced trout.

Habitat quality has been identified as an essential issue associated with the presence of shortjaw kokopu (Williams & Given 1981; McDowall 1984; Swales 1991; McDowall et al. 1996). Many studies have suggested that forest canopy cover of the stream is an important component of its habitat (McDowall et al. 1977; Eldon 1983, 1984; Nicoll 1984; Main 1987; McDowall 1990, 1996, 1997;

McDowall et al. 1996). However, shortjaw kokopu avoid catchments dominated by beech, *Nothofagus* spp. (McDowall et al. 1977, 1996; McDowall 1997, 2000).

Substrate type, in particular the presence of boulders and cobbles has also been reported to be a vital component for shortjaw kokopu (McDowall 1990, 2000; McDowall et al. 1996). Presence of fine sediments may also be a problem through its impact on preferred prey (Main 1987; McDowall 1996; McDowall et al. 1996).

Access to and from the sea is an important aspect for diadromous fish. Barriers such as culverts, dams and weirs can prevent or reduce shortjaw kokopu dispersal (McDowall 1984; McDowall et al. 1996). Movement by adults during spawning time could also be reduced. McDowall (1984) concluded that the presence of such barriers would undermine any conservation efforts applied to shortjaw kokopu.

Other factors suggested as causes of declining populations of shortjaw kokopu have been interactions with trout and exploitation by humans (McDowall 1984; McDowall et al. 1996). Introduced trout are often cited as limiting factors on native fish distribution, including shortjaw kokopu. McDowall et al. (1996) maintain that, although holding the competitive advantage, trout are not excluding adult shortjaw kokopu, although they do prey on juveniles. Trout and shortjaw kokopu can share the same habitat, although population sizes of shortjaw kokopu are often smaller in the presence of trout. Similar findings were described by Swales (1990) from tributaries of the Waikato River. The apparent selection of small bouldery streams by shortjaw kokopu could be a consequence of exclusion from other habitats by trout.

Trout are known predators of migrating whitebait. McDowall et al. (1996) describes brown trout feeding on migrating whitebait shoals, and large quantities of whitebait in the stomachs of trout during this time. While there is no direct evidence of trout predating shortjaw kokopu whitebait in particular, Eldon (1983) surmised that in rivers such as the Buller River that support large numbers of shortjaw kokopu whitebait, trout predation on shortjaw kokopu is highly probable. McDowall (1984) concluded that trout are one of the key factors associated with native fish decline, but they are practically impossible to control, especially for native diadromous species that need access to the sea.

1.1 OBJECTIVES

The main objective of this study was to determine habitat preference of shortjaw kokopu in the north-eastern Tararua Ranges, specifically to determine: the habitat factors (principally macro-habitat features) that are suitable for predicting the presence of shortjaw kokopu; the habitat characteristics that are potentially limiting the distribution of shortjaw kokopu; and whether sub-adult shortjaw kokopu have different habitat preferences from adults.

The secondary objective was to compare methods of sampling to determine the most appropriate survey method to locate shortjaw kokopu populations.

2. Study area

Three main catchments drain the study area in the north-eastern Tararua Ranges (Fig. 1). The most northerly, the Mangatainoka River, flows northwards, joining the Manawatu River near the Manawatu Gorge. The Makakahi River also flows north, joining the Mangatainoka River near Pahiatua. Adjacent to these two catchments is the Ruamahanga River, which flows south to Cook Strait.

Within the Tararua Forest Park, these three catchments are generally forested, with beech (*Nothofagus* spp.) dominant. In the Mangatainoka and Makakahi catchments, it is primarily red beech (*N. fusca*) at lower altitudes replaced by kamahi (*Weinmannia racemosa*) and leatherwood (*Olearia colensoi*) shrubs at higher altitudes. In the Ruamahanga catchment, red beech is replaced by silver beech (*N. menziesii*) at higher altitudes. To the north of the main Mangatainoka catchment, there are no beech species.

The Manawatu catchment incorporates a number of tributaries draining both the Ruahine and Tararua Ranges, and non-forested hill country to the east. Tributaries pass through farmland, mostly dairy, sheep or beef, before flowing past Palmerston North and out to the west coast at Foxton. It has several potential point sources of pollution other than general urban or farm-related output. Of particular note are the Dominion Brewery at Mangatainoka, Kiwi Lumber Sawmill in Dannevirke, and the Richmond freezing works at Oringi. Several major townships occur along the various tributaries, including Eketahuna, Pahiatua, Dannevirke, Palmerston North, and Foxton. Much of the lower Manawatu catchment runs through modified river channels, including the Flood gate at Moutoa, bank reinforcing at several sites, stop banks in Palmerston North, a hydro power station on the Mangahao River, town supply reservoirs on the Turitea Stream and Tamaki River, and barrage dams at several sites upstream of the Manawatu Gorge.

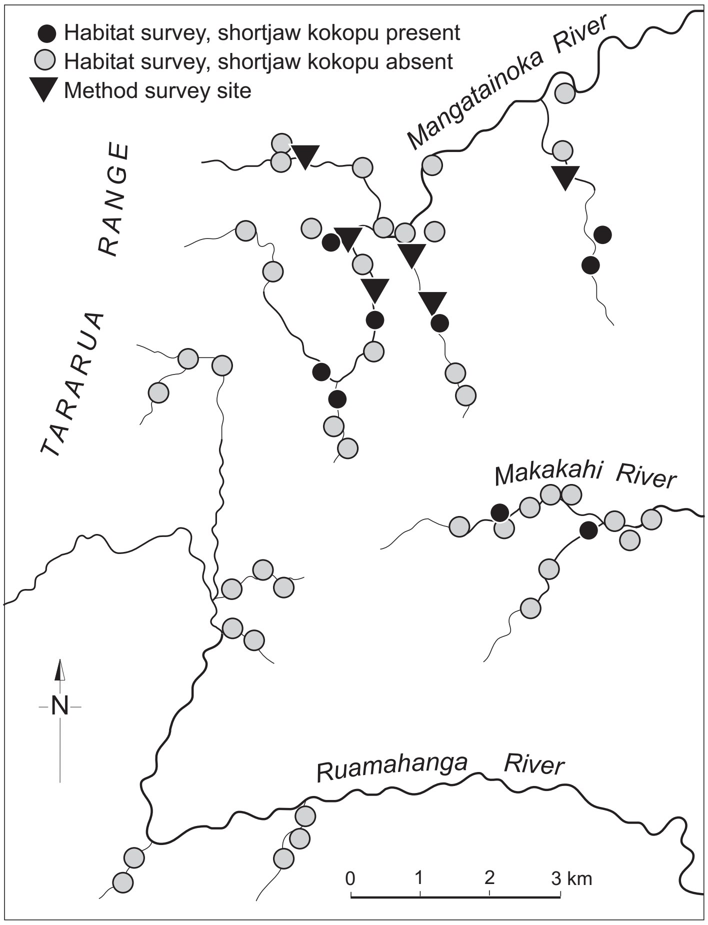


Figure 1. Approximate positions of sites surveyed, north-eastern Tararua Ranges. For simplicity and clarity of presentation, details of the 2nd- to 5th-order streams sampled have not been shown, but their exact position and characteristics are given in Table 1.

The Ruamahanga catchment, similarly, drains the Tararua Ranges, but most of its headwater tributaries are associated with farms, mainly sheep and beef. Point sources of pollution include the urban settlements of Masterton, Carterton, Greytown, and Martinborough; and in particular, the Waingawa freezing works in Masterton, the International Timber Processors Ltd sawmill in Masterton, and the wine industry associated with Martinborough. The

Ruamahanga catch-ment also has many river control methods. These include a barrage control gate at Lake Wairarapa, bank reinforcement along several reaches, and a grade control weir at Te Ore Ore. Both the Mangatainoka and Ruamahanga Rivers originate at similar altitudes (between 1100 and 1300 m a.m.s.l.), but the Makakahi River originates much lower (approx. 800 m a.m.s.l.). All of the rivers leave the Tararua Forest Park at similar altitudes (between 380 and 450 m a.m.s.l.). The Makakahi River, unlike the other two study rivers, flows through an exotic tree plantation (*Pinus radiata*) at the park boundary.

3. Methods

3.1 HABITAT SELECTION

Fifty sites were selected (Fig. 1) from within the upper forested catchments of the Mangatainoka (25 sites), Makakahi (12 sites) and Ruamahanga Rivers (13 sites). Stream orders ranged from 2 to 6 (see Table 1 for site details). Between January and May 2001 the sites were surveyed for freshwater fish, using spotlighting technique (30 W spotlight with 12 V (7 A hour) battery).

At each site, during the day before the spotlight survey, catchment and habitat characteristics were assessed over a 100 m stretch of river. The catchment variables were obtained from a topography map (NZMS 260 S25: Levin 1995): stream order, based on Strahlers classifications (1952); altitude; gradient; grid references.

Habitat variables recorded were:

- Average width: from 5 transects
- Average depth: from 5 depths evenly spaced across each transect
- Conductivity: corrected to 25°C, Orion (model 122)
- Velocity: timing fluorescent dye flow over the 100 m
- Flow type %: backwater, pool, deep pool, riffle, run, falls
- Overhead cover %: estimate along length of site
- Undercut bank %
- Debris jams %
- Vegetation types %: podocarp/hardwoods, beech, shrubs, exotic, pasture, tussock, low grass/leatherwood/bare rock
- Pfankuch stability scores: bottom section of a Pfankuch table (Pfankuch 1975)
- Moss and periphyton: subjective scale (1–10)
- Substrate size %: using Wolman (1954) walk procedure. Substrate was categorised into 10 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 and silt (S&S) < 1 mm. These frequencies were subsequently used to calculate a rock size index:
  (B*8 + LC*7 + C*6 + LP*5 + P*4 + LG*3 + G*2 + SG*1 + S&S*0)/no. of rocks

TABLE 1. CHARACTERISTICS OF SITES SURVEYED FOR SHORTJAW KOKOPU.

TFP indicates sites within the Tararua Forest Park boundary.

SITE	GRID REFERENCE	STREAM ORDER	ALT. m a.s.l.	GRAD-IENT	AVERAGE WIDTH	OVERHEAD COVER (%)
Mg1 TFP	S25:249533	4	420	10	366	65
Mg2 TFP	S25:250526	2	480	40	198	85
Mg3 TFP	S25:249530	3	435	15	233	70
Mg4 TFP	S25:254539	2	380	25	212	85
Mg5 TFP	S25:247536	4	400	15	506	30
Mg6	S25:253554	5	330	5	1052	30
Mg7 TFP	S25:255545	5	360	5	656	60
Mg8	S25:256557	5	320	5	482	5
Mg9	S25:254563	5	350	5	464	5
Mg10	S25:244568	2	400	20	219	60
Mg11	S25:242568	3	405	10	193	40
Mg12	S25:263543	4	420	10	312	40
Mg13	S25:268531	2	530	20	350	40
Mg14	S25:267534	2	510	15	330	60
Mg15	S25:282568	4	310	5	624	10
Mg16	S25:286556	2	360	15	156	90
Mg17	S25:286549	3	360	5	300	75
Mg18	S25:262557	2	340	25	135	80
Mg19	S25:259555	5	330	5	1273	30
Mg20	S25:247555	2	360	20	150	75
Mg21	S25:250555	3	340	5	156	50
Mg22 TFP	S25:240552	3	530	5	430	15
Mg23 TFP	S25:237557	3	555	15	362	75
Mg24	S25:284576	6	280	5	1580	15
Mg25	S25:263568	6	310	5	1646	5
Mk1 TFP	S25:282516	2	380	25	205	40
Mk2 TFP	S25:280517	2	400	25	208	70
Mk3 TFP	S25:277515	3	410	10	213	55
Mk4 TFP	S25:272515	4	430	5	336	40
Mk5 TFP	S25:267512	3	490	10	248	40
Mk6 TFP	S25:273515	2	430	25	255	30
Mk7	S25:293514	4	350	5	341	30
Mk8	S25:292513	2	355	15	102	85
Mk9	S25:288513	4	360	5	363	40
Mk10 TFP	S25:286514	3	370	10	282	55
Mk11 TFP	S25:280508	3	420	15	211	60
Mk12 TFP	S25:277502	3	490	15	266	50
Rua1 TFP	S25:233537	4	565	5	319	20
Rua2 TFP	S25:228538	3	600	20	281	25
Rua3 TFP	S25:224535	3	660	25	223	35
Rua4 TFP	S25:243472	4	350	5	551	50
Rua5 TFP	S25:243469	3	360	20	146	85
Rua6 TFP	S25:241465	4	380	10	511	50
Rua7 TFP	S25:218467	4	400	10	370	70
Rua8 TFP	S25:217463	4	420	10	332	30
Rua9 TFP	S25:233499	3	440	10	201	80
Rua10 TFP	S25:237497	3	500	20	229	85
Rua11 TFP	S25:233505	4	450	5	358	70
Rua12 TFP	S25:238507	3	470	5	154	80
Rua13 TFP	S25:240506	3	500	10	211	85

Starting approximately 30 minutes after dark, two people using 30 W spotlights traversed the 100 m reach twice, recording all fish seen. Fish length was measured (for those that could be captured with a hand net) or estimated to ± 2 cm. Shortjaw kokopu were classified into broad age classes using the definition of Studholme et al. (unpubl. report 1999): juveniles < 90 mm, subadult 90–120 mm, adult > 120 mm.

3.2 STATISTICAL ANALYSIS

Predictive models of shortjaw kokopu presence/absence in relation to habitat variables were developed using discriminant and logistic regression analysis (SAS 1995). Discriminant analysis assumes multivariate-normal distribution of predictor variables and linear relationships between predictors and group membership. Logistic regression specifies a non-linear ('s' shaped) relationship between probability of group membership and predictor variables (which can be continuous or categorical).

Since there were a large number of predictor variables (some highly correlated) and few cases where shortjaw kokopu were present, we used stepwise addition of variables to find simple, robust models for predicting presence and absence of shortjaw kokopu.

3.3 COMPARISON OF METHODS

During the first week in June 2001, six sites in the Mangatainoka River were sampled using three methods: spotlighting, electrofishing, and trapping. These sites were different from those surveyed in the previous section, but located close to where shortjaw kokopu were known to be present. Habitat characteristics were recorded and an initial spotlight survey carried out, as described above, 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, a second spotlight survey was carried out and 10 gee-minnow traps were placed in pools through 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.

4. Results

4.1 HABITAT SELECTION

The distribution survey found shortjaw kokopu to be sparsely distributed. Of the 50 sites surveyed, only nine (18%) were found to contain shortjaw kokopu (Figs 2, 3). The Mangatainoka River had a slightly higher percentage with seven

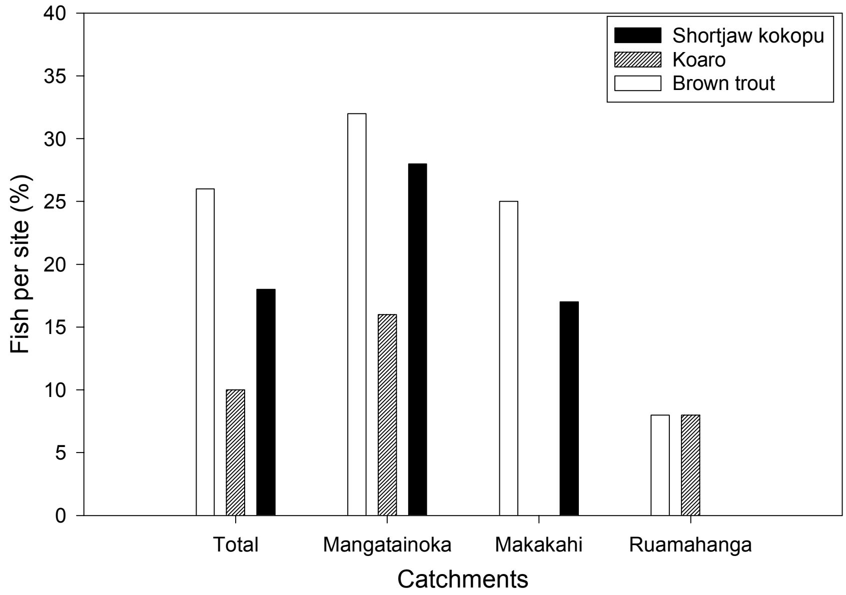


Figure 2. Percentage of shortjaw kokopu, koaro, and brown trout by catchment.

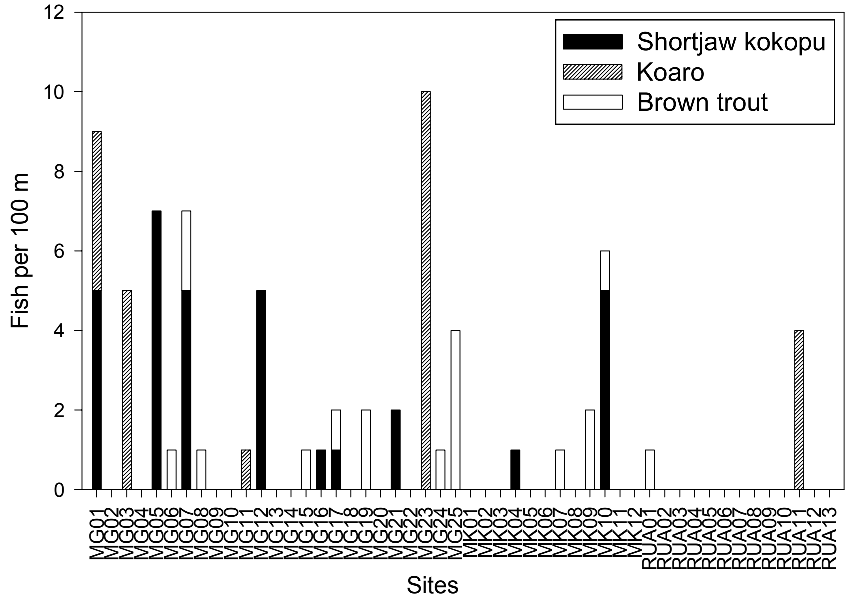


Figure 3. Numbers of shortjaw kokopu, koaro, and brown trout at each site.

of 25 sites (28%) containing shortjaw kokopu. In contrast, the Makakahi River had two of 12 sites (16%) with shortjaw kokopu, and no shortjaw kokopu were found in the Ruamahanga River. Five of 17 sites inside the Tararua Forest Park contained shortjaw kokopu, compared with four of 20 outside the park, not a significant difference ($\chi^2 = 0.0903$, $p = 0.7638$).

Densities of shortjaw kokopu at the nine sites were 1–7 fish per 100 m, with a total of 32 shortjaw kokopu being counted in this survey. Nine were found outside the forest park boundary in the Mangatainoka Catchment, 17 were found inside the park boundary in the Mangatainoka catchment, and six in the Makakahi catchment.

Koaro (*Galaxias brevipinnis*) were found at five sites (10%), four in the Mangatainoka catchment (16%), and one in the Ruamahanga catchment (8%). Densities ranged from 1 to 10 fish per site and one koaro was found outside the park boundary. Koaro and shortjaw kokopu shared only one site, a 4th-order stream in the Mangatainoka catchment.

Brown trout (*Salmo trutta*), the only exotic fish species present in the survey, were found at 13 sites (26%), only two of which were inside the park boundary. Trout were found in all of the catchments, and densities were 1–4 fish. Brown trout and shortjaw kokopu were found together at three sites, but koaro and brown trout were never present together. A chi-squared test showed no significant association (positive or negative) between trout presence and shortjaw kokopu presence ($\chi^2 = 0.7831$, $p = 0.3762$).

Longfin eels (*Anguilla dieffenbachii*) were found at 43 sites (86%), 23 in the Mangatainoka catchment (92%), 11 in the Makakahi catchment (92%), and nine in the Ruamahanga catchment (69%).

Cran's bully (*Gobiomorphus basalis*) were found at 12 sites (24%), eight in the Mangatainoka catchment (32%), three in the Makakahi catchment (25%), and one in the Ruamahanga catchment (8%).

Banded kokopu (*Galaxias fasciatus*) were found at only one site (2%), which occurred in the Ruamahanga catchment (8%).

4.2 PREDICTING SHORTJAW KOKOPU PRESENCE

Stepwise discriminant analysis on the whole data set identified conductivity as the strongest predictor for shortjaw kokopu presence. Seven other variables were also selected by the discriminant analysis: in order of preference, low percentages of debris jams, low periphyton, high percentage of shrubs, high stream order, high percentage of beech, low percentage of runs, and low average width. This discriminant function correctly predicted shortjaw kokopu presence or absence in all but two sites. These were in the Makakahi catchment, where shortjaw kokopu were predicted to be present with high probability (0.76, 0.98) but were not recorded.

Since no shortjaw kokopu were recorded in the Ruamahanga catchment, it is possible that factors beyond the immediate habitat are excluding the fish, in which case, models predicting occurrence from habitat are unlikely to be successful. We repeated the analysis on just the 37 sites in the Manawatu catchments where shortjaw kokopu are known to exist.

The Manawatu data set distinguished a low Pfankuch score (= high stability) as the best predictor of presence (Fig. 4). Four other variables were also selected: low gradient, small percentage of run, high percentage of beech, and a high percentage of shrubs. However, Pfankuch and run were subsequently removed by the stepwise procedure.

The discriminant function correctly predicted 89% of sites. Three sites in the Mangatainoka catchment and one in the Makakahi were incorrectly predicted to have shortjaw kokopu. Applying this discriminant function to the Ruamahanga catchment, three sites were predicted to have shortjaw kokopu present with high probability (0.70, 0.91, 0.97).

Stepwise logistic regression analysis of the whole data set found no significant predictors. With the Manawatu data set, Pfankuch score ($\chi^2 = 5.5183$, $p = 0.0188$), gradient ($\chi^2 = 5.0141$, $p = 0.0251$) and rock index ($\chi^2 = 3.8623$, $p = 0.0494$) were found to be significant predictors.

Although the stepwise models did not select stream order, 3rd- and 4th-order streams are the preferred stream size for shortjaw kokopu (Fig. 5).

4.3 SIZE DISTRIBUTION

Sizes of shortjaw kokopu surveyed ranged between 70 mm and 220 mm in length, with a median of 160 mm (Fig. 6). Adult shortjaw kokopu were found at 12 out of 13 sites (including the sites used for comparison of methods). Only six sites were found to contain sub-adult or juvenile fish. Stepwise discriminant analysis used to investigate habitat variables associated with the presence of sub-adults showed steeper gradient as the best predictor. Three other variables, low percentage of podocarp/hardwood, low periphyton, and smaller substrate size, were also selected by the analysis. The discriminant analysis correctly predicted all cases.

4.4 COMPARISON OF METHODS

Shortjaw kokopu were recorded by spotlighting at four of the six sites and by electrofishing at two sites. Longfin eels (*Anguilla dieffenbachii*) and brown trout (*Salmo trutta*) were also less likely to be surveyed by electrofishing (two sites and one site, respectively) than spotlighting (four sites and five sites, respectively). Cran's bully (*Gobiomorphus basalis*) we identified by spotlighting at five sites, electrofishing at three sites, and gee-minnow trapping at one site. Only electrofishing identified any torrentfish (*Cheimarrichthys fosteri*), found at only one site.

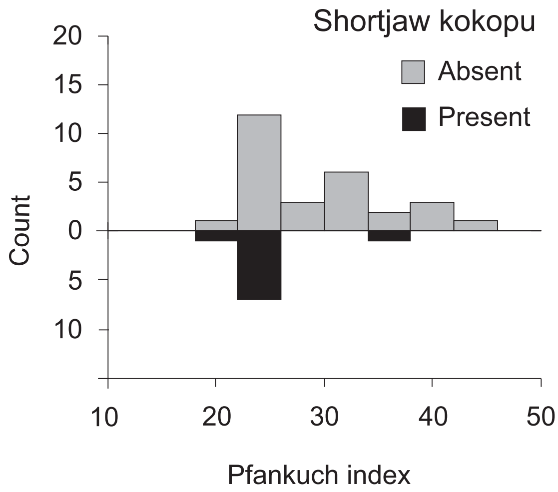


Figure 4. Comparison of stability levels and shortjaw kokopu presence.

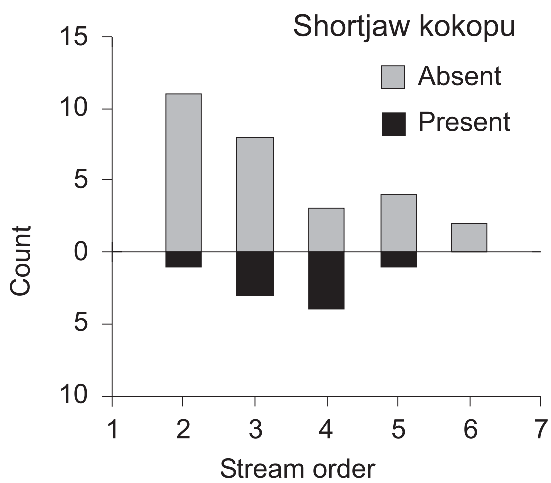
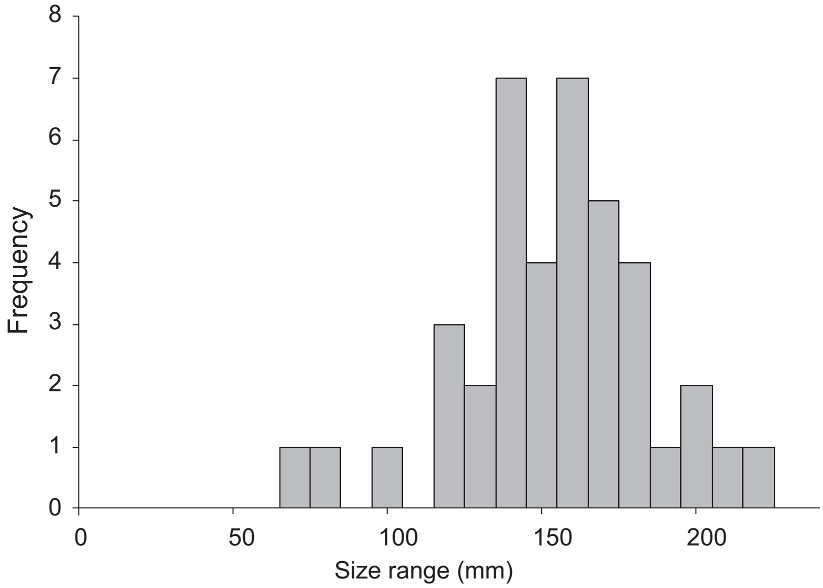


Figure 5. Comparison of shortjaw kokopu across stream orders.

Figure 6. Size frequency of shortjaw kokopu recorded in the Mangatainoka and Makakahi catchments.



A total of three shortjaw kokopu were caught in the six sites using electrofishing while the spotlighting runs ranged between one and three per survey night (if they were present at the site), and a total population of nine was estimated from the six sites (Fig. 7). In every case, the fish caught using electrofishing techniques were recounted in the subsequent spotlighting runs, although these were different fish from the ones recorded in the first spotlight survey.

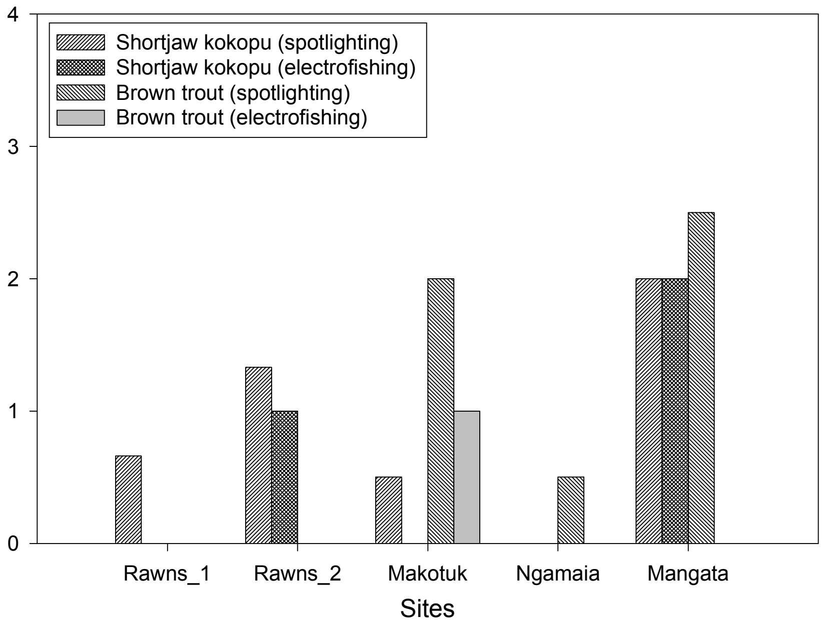


Figure 7. Average number of shortjaw kokopu and brown trout caught at each site using electrofishing and spotlighting surveys.

5. Discussion

Shortjaw kokopu were first reported from the Mangatainoka River in February 1999 (*Dominion* 20 Oct 1999), when 49 were found by spotlight along a 500 m reach of 4^{th}-order tributary. Two days earlier, eight shortjaw kokopu had been electrofished from the same reach (I.M.H., pers. obs.). Both koaro and brown trout were also found at the same site, koaro occupying the same stretch of river, and a large trout was found less than 200 m downstream.

Given the prior discovery of a large population, the sparse distribution of shortjaw kokopu around the Mangatainoka catchment found in the present study was quite unexpected. Many of the sites surveyed had characteristics that suggested suitability for shortjaw kokopu such as large substrate size and forest cover (Eldon 1983, 1984; Nicoll 1984; McDowall 1990, 1998, 2000; McDowall et al. 1996; Jowett et al. 1998; Caskey unpubl. report 1999; Studholme et al. unpubl. report 1999; Jack & Barrier unpubl. report 2000).

Koaro were also expected to be more prevalent in the survey. However, the sites where they were recorded were always at the upper limits of shortjaw kokopu distribution and above, so they could be present further up the streams than we surveyed.

Brown trout were common in the lower-altitude sections of the Mangatainoka catchment. Trout have often been considered to be a key determinant of Galaxiidae distribution (McDowall 1990; McDowall et al. 1996), but as this survey showed, they do not appear to be limiting the populations in the Mangatainoka and Makakahi Rivers.

Longfin eels were the most widely dispersed fish species in the study, as expected given its widespread upland records in the NZFFD (McDowall 1990, 2000). Cran's bully was restricted to the lower-altitude reaches, in both the Manawatu and the Ruamahanga catchments. Although they are a non-migratory species, Cran's bully does not range as far inland as some migratory galaxiids (McDowall 1990, 2000).

Previous research (McDowall et al. 1977; Eldon 1983, 1984; Nicoll 1984; McDowall 1990, 1997, 1998, 2000; McDowall et al. 1996; Jowett et al. 1998; Caskey unpubl. report 1999; Studholme et al. unpubl. report 1999; Jack & Barrier unpubl. report 2000) suggested that substrate size, stream size, forest cover (especially non-beech forest), absence of trout, altitude, and distance inland should be good predictors of shortjaw kokopu, so some combination of these factors was expected to be important in this study.

Surprisingly, conductivity was selected by discriminant analysis as the best predictor in the full set of 50 sites. Further analysis revealed that the Ruamahanga River, where no shortjaw kokopu were found, had a significantly lower conductivity than the other catchments ($T = 6.26$, $p < 0.0001$).

This is also surprising since all three catchments are adjacent and share similar geology and vegetation. The Ruamahanga sites were visited last in the survey, so it is possible that changing weather and stream flows are responsible for the difference in conductivity.

It is also possible that conductivity really is a key factor in shortjaw kokopu distribution, perhaps through solutes directing migration choices. If this was the case, we would expect conductivity to remain a good predictor in the restricted data set of Manawatu catchments, but this was not so. The complete absence of shortjaw kokopu from the Ruamahanga sites means that the predictive models, based on all data, are heavily influenced by catchment-wide characteristics (such as conductivity) and so may not be useful for predicting occurrence within a catchment where fish are known to exist.

Analysis of the data excluding the Ruamahanga selected a different set of predictor variables, mostly related to stream stability. The Pfankuch index of stability was the best single predictor of shortjaw kokopu presence in both discriminant and logistic regression models. Both models also selected low gradient. Other variables selected by one or other model related to large substrate size and components of the riparian vegetation. Surprisingly, percentage of beech forest was a positive predictor of shortjaw kokopu presence, contrary to the findings of McDowall (1997).

Variation in stability within the Mangatainoka catchment has a spatial component. The main stream and tributaries on the western side that drain the Tararua main range have steeper gradients, are less stable, and generally lack shortjaw kokopu. Western tributaries would also be more influenced by the predominantly westerly weather pattern although even in the eastern Mangatainoka and Makakahi Rivers, heavy flooding and landslides affected some of the smaller streams in late October 2000.

The statistical models predicted shortjaw kokopu presence in some sites where they were not present, particularly in the Ruamahanga catchment. This suggests there are other factors that may be hindering shortjaw kokopu access to areas with suitable habitat. Previous reports have suggested that river mouth location is an important factor (McDowall 1990, 2000; McDowall et al. 1996), especially as shortjaw kokopu are recorded mainly from western locations. However, shortjaw kokopu have been reported in streams draining to the North Island's south coast (Rebergen & Joy unpubl. report 1999). This, and the presence of other migratory galaxiidae species in the Ruamahanga River suggests that migration is not prevented at the river mouth, but between the mouth and the headwaters surveyed.

Two sites in the Makakahi River were predicted to support shortjaw kokopu but none were recorded. Both cases were above sites containing shortjaw kokopu, roughly 500 m and 900 m above the same site. Both sites contained similar habitat in almost every respect to the lower site where shortjaw kokopu were present. A recent slip blocked the stream below the uppermost site but there was no obvious barrier preventing access to the other site. McDowall (1998) suggested that the lack of upstream dispersal in West Coast populations of shortjaw kokopu was a sign of under-saturation. With ample good habitat near the coast, there was no reason to migrate further inland. This Makakahi population seems to be exhibiting a similar pattern, suggesting a lack of juvenile recruitment results in the occupation of only the lower part of the available habitat.

Two sites in the Mangatainoka catchment, incorrectly predicted to have shortjaw kokopu, contained high numbers of koaro. These sites were close to, but above, sites where shortjaw kokopu were present, further supporting under-saturation in this region.

A limitation of the statistics model used is that it relies on monotonic relationships between habitat variables and fish occurrence. If shortjaw kokopu showed a preference for intermediate levels of a habitat variable, this would not be detected. This is the case for stream order (Fig. 5). Shortjaw kokopu showed a preference for mid-sized streams (particularly 4^{th}-order) in these catchments.

5.1 HABITAT SELECTION

There are several habitat variables identified by the study for predicting the presence of shortjaw kokopu.

- High stability: Pfankuch index (bottom section: > 26)
- Low gradient: < 20 m in 100 m
- Dense riparian vegetation of either native shrubs or forest
- Substrate and bedforms dominated by pool-riffle sequences (not runs) with coarse substrate (boulders).

Streams not having this combination of habitat features are unlikely to support shortjaw kokopu. However, some streams which match these criteria perfectly may not support shortjaw kokopu if factors outside the immediate habitat prevent access. This appears to be the case in the Ruamahanga catchment, but the design of the study cannot identify the particular causes. It is possible that some river structure or pollutant is preventing migration of shortjaw kokopu in the Ruamahanga. It is also possible that 'under-saturation' in recruitment means that shortjaw kokopu do not need to venture so far up the Ruamahanga, in which case we would expect to find populations in tributaries closer to the sea.

5.2 SIZE DISTRIBUTION

Sub-adults made up 15% of the shortjaw kokopu population in this study, similar to findings of Studholme et al. (unpubl. report 1999). Both life stages co-occurred in the same sites, as also noted by Studholme et al. (unpubl. report 1999). However, sites supporting sub-adults did show differentiation from general shortjaw kokopu habitat; sub-adults preferred steeper gradients, vegetation without podocarp/hardwoods dominating, smaller substrate sizes, and less periphyton. The steeper gradients of smaller tributaries may restrict trout access to site with these characteristics, although two sites supporting sub-adult shortjaw kokopu also contained trout up to 400 mm long.

Jack & Barrier (unpubl. report 2000) also found that most juvenile shortjaw kokopu occurred in habitat described as steeper gradient, supporting more rapids. This habitat use was not only restricted to daylight hours, which made spotlight assessments of numbers difficult. They suggested that this could be avoidance behaviour, preventing predation or aggression by larger fish, including adult shortjaw kokopu.

Habitat characteristics identified by discriminant analysis as predictors of sub-adult shortjaw kokopu were:

- gradient at the steeper end of the range surveyed (10–20 m per100 m)
- less podocarp forest in the riparian vegetation
- low periphyton, implying a relatively closed canopy
- smaller general rock sizes (gravel and cobble substrate classes).

5.3 COMPARISON OF SURVEY METHODS

Electrofishing has been cited as the best means for surveying shortjaw kokopu (McDowall et al. 1996), but recent surveys have suggested spotlighting is a more efficient means if presence is unknown (Studholme et al. unpubl. report 1999; Jack & Barrier unpubl. report 2000). Gee-minnow traps have been used successfully to catch other stream galaxiids (M. Joy, pers. comm.) but we know of no other attempts to survey shortjaw kokopu with this method.

Electrofishing was found to be less efficient than spotlighting for surveying shortjaw kokopu. Although three fish were caught, all of these were also identified during spotlighting runs. Electrofishing failed to detect shortjaw kokopu in two sites where spotlighting showed them to be present. However, electrofishing did not appear to disturb the fish, as all shortjaw kokopu captured were behaving normally when re-sighted with spotlights.

Brighter spotlights have been found to be more disturbing to the fish (Studholme et al. unpubl. report 1999), and bigger bulbs use battery power faster. We recommend using small bulbs (30 W), which are less disturbing on fish communities than 75 W bulbs, and conserve power about three times as long.

5.4 STATUS OF SHORTJAW KOKOPU IN THE MANAWATU CATCHMENT

The presence of shortjaw kokopu in tributaries of the Manawatu River has long been known, with reports of shortjaw kokopu in the NZFFD from both the Kahuterawa Stream, and the Mangahou River (McDowall et al. 1996), and since February 1999 in the Mangatainoka River. Shortjaw kokopu are also present in the Makairo Stream (Waewaepa Range) another tributary of the Manawatu (S.B., pers. obs.). Prior to the discovery of this Mangatainoka River population, the records from the Manawatu catchment of shortjaw kokopu were only of one or two individuals captured by electrofishing (Boubee et al. unpubl. report 1995), but with the discovery of 49 fish in this isolated headwater stream, it was hoped that this particular catchment could support a shortjaw kokopu population in other tributaries. This was found to be the case, although the numbers recorded were rather disappointing. The populations of shortjaw kokopu were mainly in tributaries of the eastern side of the valley, which appears to be associated with greater stability. The most striking result is the absence of shortjaw kokopu from the Ruamahanga catchment despite having comparable habitat. Therefore, conditions in the lower catchment may be the most important factor in the long-term survival of these populations of shortjaw kokopu.

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7. References

Boubee, J.; Forsyth, D.; Richardson, J.; Barrier, R.; James, M. 1995: 1995 Mangahao Dams Desilting Fish & Invertebrate Survey. ELE312-01/1, NIWA, Hamilton.

Caskey, D. 1999: Shortjawed kokopu (*Galaxias postvectis*) research and surveys June 1998 –June 1999. Department of Conservation, Stratford.

Clarke, F.E. 1899: Notes on New Zealand Galaxiidae, more especially those of the Western Slopes: with descriptions of new species, &c. *Transactions and Proceedings of the New Zealand Institute* 31: 78–91.

Eldon, G.A. 1980: The ecology of whitebait migrations (Galaxiidae: *Galaxias* spp.). Ministry of Agriculture and Fisheries, Christchurch.

Eldon, G.A. 1983: Enigma of the third kokopu. *Freshwater Catch (NZ)* 23: 17–18.

Eldon, G.A. 1984: Carnivorous kokopu in captivity. *Freshwater Catch (NZ)* 25: 9.

Jowett, I.G.; Hayes, J.W.; Deans, N.; Eldon, G.A. 1998: Comparison of fish communities and abundance in unmodified streams of Kahurangi National Park with other areas of New Zealand. *New Zealand Journal of Marine and Freshwater Research* 32: 307–322.

Jowett, I.G.; Richardson, J.; McDowall, R.M. 1996: Relative effects of in-stream habitat and land use on fish distribution and abundance in tributaries of the Grey River, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 30: 463–475.

Main, M. 1987: Feeding habits of the shortjawed kokopu. *Freshwater Catch (NZ)* 31: 13.

McDowall, R M. 1984: Designing reserves for freshwater fish in New Zealand. *Journal of the Royal Society of New Zealand* 14(1): 17–27.

McDowall, R.M. 1988: Diadromy in fishes: migrations between marine and freshwater environments. Croom Helm, London.

McDowall, R.M. 1990: New Zealand Freshwater Fishes: A natural history and guide. Heinemann Reed, Auckland.

McDowall, R.M. 1996: Volcanism and freshwater fish biogeography in the northeastern North Island of New Zealand. *Journal of Biogeography* 26: 139–148.

McDowall, R.M. 1997: Indigenous vegetation type and the distribution of the shortjawed kokopu, *Galaxias postvectis* (Teleostei: Galaxiidae), in New Zealand. *New Zealand Journal of Zoology* 24: 243–255.

McDowall, R.M. 1998: Fighting the flow: downstream-upstream linkages in the ecology of diadromous fish faunas in West Coast New Zealand Rivers. *Freshwater Biology* 40: 111–122.

McDowall, R.M. 2000: The Reed Field Guide to New Zealand Freshwater Fish. Reed Publishing (NZ) Ltd, Auckland.

McDowall, R.M.; Eldon, G.A.; Bonnett, M.L.; Sykes, J.R.E. 1996: Critical habitat for the conservation of shortjawed kokopu, *Galaxias postvectis* Clarke. Department of Conservation, Wellington.

McDowall, R.M.; Graynoth, E.; Eldon, G.A. 1977: The occurrence and distribution of fishes in streams draining the beech forests of the West Coast and Southland, South Island, New Zealand. *Journal of the Royal Society of New Zealand* 7(4): 405–424.

Molloy, J.; Davis, A. 1994: Setting priorities for the conservation of New Zealand's threatened plants and animals. Department of Conservation, Wellington.

Nicoll, G. 1984: Freshwater life surveyed in South Westland. *Freshwater Catch (NZ)* 24: 4–6.

Pfankuch, D.J. 1975: Stream reach inventory and channel stability evaluation. US Department of Agriculture Forest Service, Region 1, Missoula, Montana.

Rebergen, A.; Joy, M. 1999: Freshwater fish survey Aorangi Rangi, Wairarapa, May 1999. Department of Conservation, Masterton.

SAS. 1995: SAS User's Guide: Statistics, Version 6.12. SAS Institute Inc, Cary, North Carolina.

Strahler, A.N. 1952: Hypsometric (area-altitude) analysis of erosional topography. *Bulletin of the Geological Society of America* 63: 1117–1142.

Studholme, B.; Barrier, R.; Jack, D. 1999: Shortjawed kokopu (*Galaxias postvectis*): Conservation status in Nelson/Marlborough - Year one, Interim Report 1999. Department of Conservation, Nelson.

Swales, S. 1990: Research on the ecology of native fish and trout in tributary streams of the Waikato River. *Freshwater Catch (NZ)* 43: 3–7.

Swales, S. 1991: Threats and conservation of native fish. *Freshwater Catch (NZ)* 45: 19–21.

Williams, G.R.; Given, D.R. 1981: The red data book of New Zealand: rare and endangered species of endemic terrestrial vertebrates and vascular plants. Nature Conservation Council, Wellington.

Wolman, M.G. 1954: A method of sampling coarse river-bed material. *Transactions of the American Geophysical Union* 35: 951–956.