Critical habitats for the conservation of giant kokopu, *Galaxias argenteus* (Gmelin, 1789)

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M.L. Bonnett, R.M. McDowall, J.R.E. Sykes

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A B S T R A C T

Giant kokopu (*Galaxias argenteus*) is the largest of the galaxiid fishes, and is only found in New Zealand. Some landlocked (non-migratory) populations exist, but giant kokopu are normally diadromous, and juveniles make up part of the annual whitebait run. In order to manage and conserve the species, the critical features of giant kokopu habitat must be determined.

Analysis of information from the New Zealand Freshwater Fish Database (NZFFD), and from field surveys in Southland and along the western coast of the South Island, indicate that five habitat features are critical for both juvenile and adult fish: low water velocity, water depth, proximity to the sea, and the presence of instream and riparian cover. An experiment utilising artificially constructed habitat emphasised the importance of instream cover and low water velocity.

All measurements of habitat occupied by giant kokopu were made during daylight, and thus may not accurately reflect the full range of habitats (e.g. feeding and/or night-time habitats) they use or require.

Seeing or catching giant kokopu is often difficult, as they are mostly cryptic and commonly occupy habitats that are hard to sample and/or see into. Overall, it seems likely that their abundance is underestimated.

The association of giant kokopu with other freshwater fish, the impact of whitebaiting and eel fishing, and the importance of identified critical habitat features for the conservation and management of the species is discussed.

Keywords: giant kokopu; *Galaxias argenteus*; New Zealand; habitat; habitat preference; freshwater fish.

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1. Introduction

Information from this study has already been presented in an MSc thesis (Bonnett 2000), and two scientific papers (Bonnett & Sykes 2002; Bonnett & Lambert 2002). This report has been written ‘in parallel’ with the above publications, with the aim of presenting the information in a more ‘usable’ form and with broader appeal to both the general public and the staff of the Department of Conservation (DOC).

The giant kokopu (*Galaxias argenteus*) is the largest species of the galaxiid fishes and is widely distributed throughout New Zealand, where it is endemic. It is diadromous, normally migrating between the sea and freshwater as part of its life cycle, although landlocked (non-migratory) populations exist in some lakes and ponds. Giant kokopu juveniles migrate into rivers in mixed-species whitebait shoals during the spring (McDowall & Eldon 1980). Although widespread, this species is uncommon, and is mostly associated with unmodified coastal areas such as South Westland. It is regarded as a threatened species (Williams & Given 1981; Tisdall 1994) and its rarity led to DOC instituting whitebait fishing regulations aimed at reducing exploitation of giant kokopu whitebait in the fishery; this proved controversial (New Zealand House of Representatives, 1994).

Before this study was commissioned, information on the biology and distribution of giant kokopu was limited and fragmented. Since 1979 there has been some information published on their diet, life-expectancy and growth (Jellyman 1979; Main 1988) and, more recently, on the date of and age at migration of giant kokopu whitebait (McDowall & Kelly 1999). In many parts of New Zealand the giant kokopu is perceived as being rare, especially in eastern areas and particularly where there are large human populations or where agriculture is well-developed. It seems likely that its decline can be attributed largely to loss of suitable habitat, and McDowall (1990) suggests that as pastoral development continues, it is likely that the decline of the species will continue.

DOC has concerns about the conservation status of giant kokopu, and is seeking ways of ensuring its long-term protection. Without knowledge of its habitat requirements, it would be difficult to protect the species and make rational decisions about impending land use or the establishment of reserves. One of the most effective contributions to ensuring its protection is to obtain an understanding of the critical features of habitats favoured by the species, and for this reason DOC seeks better definition of its habitat. This information can form a basis for the development and application of viable strategies for managing populations and habitats, and for ensuring the protection of the species. This report is the outcome of a study commissioned by DOC to obtain and review information about the habitat features critical for giant kokopu.

1.1 HISTORICAL AND BIOLOGICAL BACKGROUND

The giant kokopu was the first galaxiid to be described, being collected by naturalists visiting New Zealand with Captain James Cook in 1773. It was initially considered to be an ‘esox’ or pike (Gmelin, 1789; Forster 1844), probably owing to superficial similarities to this northern hemisphere fish, such as the large, well-toothed mouth and the dorsal fin set well back on the trunk. As a result of some confusion it was formally described in 1789 as *Esox argenteus*—the *argenteus* meaning 'silvery'—a strange description of giant kokopu, which is a dark olive to brown fish with distinctive gold spots. George Cuvier, a French biologist, was the first to recognise that the fish was not a pike, and named it *Galaxias* because its spotted colour pattern resembled a galaxy of stars. Therefore it became *Galaxias argenteus,* the scientific name we know giant kokopu by today. Other names include Maori trout, bull trout and native trout.

The giant kokopu is widely mentioned in both Maori and early colonial literature. The fish was certainly encountered by gold miners working in the streams and swamps of Westland during the 1860s, and was also quite widely known to early explorers and settlers, such as Charles Heaphy and Charles Douglas (Heaphy 1842; McDowall 1980). Given that such individuals had a continuing need for readily available protein, it is easy to imagine that giant kokopu often found their way into their frying pans, along with the ubiquitous eels, and other larger native fish.

It comes as a surprise to many people that the giant kokopu is one of the whitebait species, because the adult bears so little resemblance to the slim, transparent juvenile. Adults may exceed 400 mm in length and weigh more than a kilogram, but generally a 'large' giant kokopu would be anything over 300 mm and/or 500 g. Larger fish are more likely to be females (Rasmussen 1990), as is the case for *G. fasciatus* (Hopkins 1979), *G. maculatus* (McDowall 1968), *G. eldoni* and *G. anomalus* (Allibone & Townsend 1997).

Previous studies of giant kokopu have been few, and little is known about it. Taylor (1988) summarised information on habitat preferences derived from a broad survey of fish populations in rivers of South Westland (Taylor & Main 1987). Some studies suggest that giant kokopu feed predominantly on terrestrial insects (Jellyman 1979; Main et al. 1985), although Main & Lyon (1988) noted giant kokopu feeding on insects in stream drift, and Main (1988) found that aquatic prey formed 87.9% of prey items by abundance. The diet of landlocked adult fish included a wide range of prey items, including juvenile giant kokopu (Rasmussen 1990). The shape and position of its fins adapt it for behaviour as a 'skulking predator' (McDowall 1990), and it would appear that giant kokopu are opportunistic feeders.

Giant kokopu probably take three years to reach maturity (Rasmussen, 1990), and may live for many years; a large adult fish (400 mm long and weighing 1.05 kg) was estimated from otolith growth rings to be between 21 and 27 years old (McDowall 1990). After the first two or three years, growth is slow, varying from 1.9 to 13.4 mm per year at lengths between 234 and 330 mm (Jellyman 1979). Giant kokopu whitebait are 45–50 mm long and almost totally unpigmented. After returning to freshwater from the sea they gradually develop a dull greenish-grey coloration with a silvery-olive belly. Then up to six or eight pale vertical bands or blotches develop on the sides, and the fish becomes quite stocky. Because of the bands, young giant kokopu are hard to distinguish from banded kokopu (*G. fasciatus*). As the fish grows, the banding and blotching fade beneath the distinctive adult colour markings (Appendix 1).

Spawning habitat has not been described, although there have been several observations of downstream movements of significant numbers of ripe adult male giant kokopu during late autumn and early winter (McDowall 1990). In a landlocked population in Southland, spawning appeared to be mostly complete by the end of June, although the wide size range of juveniles caught in December suggests that spawning may take place over a considerable length of time (Rasmussen 1990). Recent research on the date and age at migration of giant kokopu whitebait indicates that spawning occurs between early June and early August (McDowall & Kelly 1999). Eggs in ripe females are relatively small, about 2 mm in diameter, and a female 336 mm long contained 25 000 eggs (Jellyman 1979).

Giant kokopu whitebait are a component of the annual whitebait catch, although their contribution is insignificant (McDowall 1990, McDowall & Kelly 1999). They appear in very small numbers in whitebait catches towards the end of spring. Presently, the whitebait fishing season terminates on 14 November whereas giant kokopu whitebait mostly appear in the catches from early November onwards (McDowall & Eldon 1980; McDowall & Kelly 1999); thus, the longer the season the greater the potential risks to giant kokopu stocks. This means that a shortening of the fishing season would offer protection of giant kokopu from exploitation in the fishery. Moves by DOC to change the season and offer such protection created controversy, culminating in a review of proposed regulatory changes by the Regulations Review Committee of Parliament.

2. Methods

Three approaches were used to determine the habitat requirements of giant kokopu. These are outlined briefly in this section, and more detail is presented with the results.

2.1 DATA FROM THE NEW ZEALAND FRESHWATER FISH DATABASE (NZFFD)

This database is an archive of information on the distribution of New Zealand freshwater fishes, containing data principally from the last 30–40 years. NIWA manages the database, and has responsibility for data entry, quality control, storage, and retrieval. Data have been contributed by a diverse range of individuals and organisations, including government departments, crown research institutes, research agencies, fish and game councils, universities, and recreational and commercial fishers. Many records contain only basic data (date, location and map reference, presence of fish species), whereas some records have more detailed information on the abundance of fish species and the habitats where they were found. The methods and objectives of the various contributors have varied widely, but the data provide a heterogeneous and valuable collection of information on our freshwater fauna. Not only does the

NZFFD serve as a basis for our knowledge of fish distribution, but it also provides useful information on the habitat characteristics of each species. Further information on the NZFFD is available in McDowall & Richardson (1983) and Richardson (1989).

We initially used the database to identify areas where giant kokopu were most common and which would be suitable for more intensive study. Database information was also used to construct a distribution map and to examine giant kokopu occurrence and habitat selection with respect to broad habitat features such as elevation, distance inland, and water type. Information in many of the database records also provided some indication of abundance, length frequency and co-occurrence with other native and introduced fish species.

2.2 HABITAT SURVEYS

More intensive field studies were required to gain explicit and quantitative data on the habitat of giant kokopu. Surveys were undertaken in Westland and Southland, using electrofishing, unbaited fyke nets, and spotlight observations. (For convenience, in this report, we refer to the entire West Coast of the South Island, including Fiordland, as Westland). In areas where giant kokopu were found, a range of habitat parameters was measured; these included water depth and velocity, water chemistry, substrate composition, physical characteristics of the stream and its banks, and both riparian and instream cover.

In addition to measurements taken where fish were caught or seen, habitat measurements were taken from adjacent areas where giant kokopu were not found. This provided comparisons and some basis for determining habitat selection, although absence of giant kokopu did not necessarily mean that the habitat was unsuitable.

This detailed information was analysed to determine which features (if any) of giant kokopu habitat are critical—i.e. which features of the habitat were usually selected by giant kokopu. This type of analysis was limited to a narrow range of habitat types, as detailed information was only available for giant kokopu that were found in water where researchers could readily catch or observe the fish, and identify specifically which features of the habitat were probably associated with presence of fish. In other words, 'good' data were readily obtained from electrofishing surveys of small streams and drains, because the location of giant kokopu could be 'pinpointed' and features measured. In other areas, such as lagoons and larger streams/rivers, the water was too deep for effective electrofishing and/or spotlight observations, and sampling was undertaken using fyke nets. Data from these areas were more general (and so less precise), as the habitat used by any fish could not be accurately determined or measured. In most cases where fyke nets were used, the habitat was quite uniform in terms of water depth, velocity, substrate and cover—which also made it difficult to distinguish any differences between areas where giant kokopu were and were not caught.

2.3 SITE SELECTION TRIALS

The information from surveys in small Westland streams suggested that giant kokopu frequently selected specific types of habitat, particularly any relatively deep areas of low water velocity with dense overhead cover such as logs and debris. As a simple test of this hypothesis, some ‘artificial’ habitat structures were placed in a small Westland stream. The stream was accessible to giant kokopu, and already contained a good number of mainly adult fish. The habitat structures were placed in areas where giant kokopu had not been previously encountered, and the structures were surveyed on two later occasions.

Anecdotal information suggested that giant kokopu in lakes were associated mostly with vegetated shores, rather than open beaches. To test this, vegetated and open shores of Lake Kaniere, Westland, were surveyed using baited standard fyke nets.

3. Analysis of the NZFFD

There were 14 343 records on the NZFFD when this analysis was undertaken (June 1999). Of these, 665 were ‘null’ records (i.e. records from locations where no fish were caught) and 561 were records for giant kokopu—so that giant kokopu had been found in approximately 4% of the sites sampled around New Zealand. These fish were recorded from 154 distinct catchments (as defined in ‘Catchments of New Zealand’, Soil Conservation and Rivers Control Council 1956). The map references of 61 giant kokopu records matched those of previous records, but there was no way to determine how many of these sites were actually ‘repeats’ or from localities in very close proximity, as sites > 50 m apart may have been assigned identical map references. Thus, comparisons made in this study were based on the assumption that site duplication was unlikely to seriously distort the analyses.

It was immediately obvious from the distribution map (Fig. 1) that giant kokopu were more frequently encountered in Westland than anywhere else; of the 561 records, 312 (56%) were from this region. As they had also been recorded in a wide variety of water types, this region was selected for more detailed research on habitat selection. There were also 67 records from Southland (12% of the national total), many of which were from modified streams and drains in a pastoral/agricultural environment, so that habitat surveys from this region provided a useful comparison with forested and undisturbed waters in Westland.

3.1 DISTRIBUTION

Giant kokopu are widely distributed throughout much of New Zealand, and are known to occur on the three main islands, on Great and Little Barrier Islands, and in the Chatham Islands (Skrzynski 1967; Rutledge 1992). However, they are

Figure 1. Distribution of giant kokopu, *Galaxias argenteus*.

far from being evenly distributed. They are uncommon along the east coast from East Cape to Otago, and absent from most of Northland (Fig. 1). Nearly all the records (87%) on the NZFFD are from only four regions: Westland, Wellington, Southland, and Waikato. All the other records, from areas such as Taranaki, Bay of Plenty, and Auckland, make up only 13% of the total. To some extent the uneven distribution of giant kokopu is exaggerated by sampling effort, and it must be noted that areas such as Westland, Wellington, and Waikato have been extensively studied. However, in other heavily sampled areas such as Taranaki and Canterbury, giant kokopu were not often recorded.

The sparseness of giant kokopu in eastern areas parallels that of three other diadromous galaxiid species: banded kokopu, shortjaw kokopu (*G. postvectis*) and koaro (*G. brevipinnis*). In fact, of all the whitebait species, only inanga (*G. maculatus*) comes close to being uniformly distributed around the country.

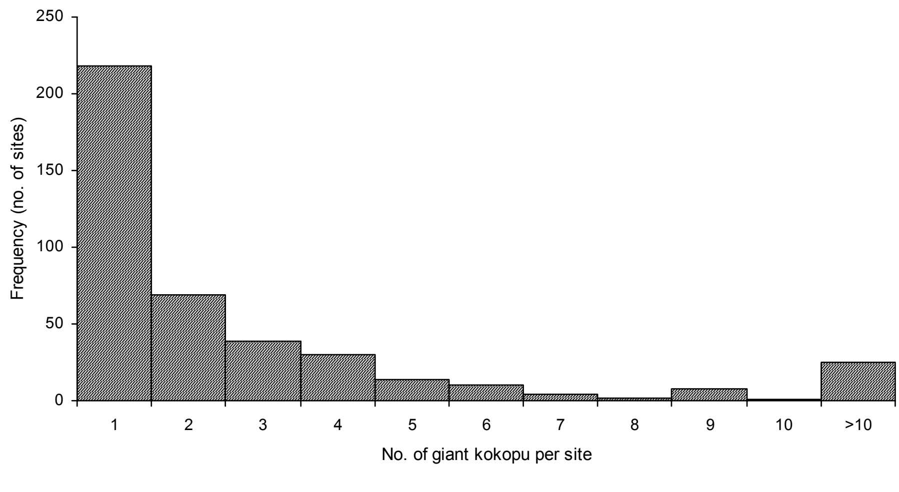
It seems likely that the sparseness of giant kokopu in some areas can be attributed largely to a lack of suitable or available habitat, rather than some other, more general, factor that excludes the fish. Much of this habitat shortage can be attributed to wetland drainage, stream realignment and draglining, and land development. Probably less than 10% of New Zealand's wetlands remain (Anon. 1983). In Canterbury, for instance, vast areas of wetland have been drained around Lake Ellesmere, and along the coastal strip from the Ashburton River to the Waitaki River (McDowall, 1998). Wetlands in Canterbury are now very sparse, and apart from a landlocked population of giant kokopu known to occur in a small lagoon near Temuka (Horseshoe Lagoon), there has been only one definite record of giant kokopu from Canterbury in the past 50 years. Yet in the mid 1800s, the fish was well-known from at least some of the South Canterbury wetlands and associated streams (Studholme 1940); and it was certainly recorded from the vicinity of Lake Ellesmere (Stokell 1949). The Waikato had lost 50 000 ha of wetland by the late 1970s (Thompson 1979), and although giant kokopu remain relatively widespread in the Waikato catchment (Fig. 1), there can be little doubt that numbers are greatly diminished there. Similar commentary could be made for the Manawatu and Wairarapa Plains, where there has been extensive deforestation, wetland drainage, stream realignment, and intensive land development.

3.2 ABUNDANCE

At each of 561 sites where giant kokopu were recorded, some measure of their abundance was also noted. In some instances this was a relative measure (terms such as 'rare', 'common' etc.), but in most cases actual numbers of fish caught were recorded. Of these, just over half (51%) specified a single specimen, and 6% specified more than 10 specimens (Fig. 2).

It is interesting to note the relatively high proportion of records with > 10 specimens. This figure is partly influenced by the inclusion of records for juvenile giant kokopu caught in whitebait nets. However, records for catches of 10 or more adults are not uncommon, and in one instance 174 adult giant kokopu were recorded. Many of these records were contributed by commercial eel fishers using fyke nets, in which giant kokopu are readily caught, but there are also some records for electrofishing. Of the 561 records, 196 (35%) were for electrofishing, 162 (29%) for fyke netting, 116 (21%) for other nets and traps,

Figure 2. Numbers of giant kokopu recorded at NZFFD sites.



and 87 (15%) for other, unknown or unspecified methods. The last category included six records where angling was used, one using diving (a giant kokopu was found dead on the streambed), and 38 instances of fish being recorded by observation.

Despite 51% of the records being of single specimens, abundance data from the NZFFD imply that, where giant kokopu occur, they are often present in significant numbers, i.e. as a population.

3.3 SIZE

The giant kokopu has historically been recorded up to 580 mm (weight 2.7 kg—Clarke 1899), but modern data suggest that this was an exceptionally large specimen. NZFFD data include 114 records of giant kokopu length, for which a length/frequency plot is presented in Fig. 3a. Length data were also collected during the field surveys for the present study in Westland and Southland, and these are presented for comparison (Fig 3b). The proportion of 'large' fish in the samples is notable—for most species it would be expected that juvenile fish would dominate. There are several possible reasons for this:

- Juvenile fish may be less frequently encountered because they are small and cryptic.
- Small fish are more difficult to see and catch either by electrofishing or in fyke nets.
- Juveniles may be most common in other habitat types, either by choice, or because they are excluded from adult habitats by competition or predation.
- It is likely that some juvenile giant kokopu are not recorded as such, because they have been mistaken for banded kokopu. At lengths less than about 130 mm, and especially when about 60–100 mm, giant kokopu may have pale bands across the sides, and careful examination is needed to distinguish between the two species.

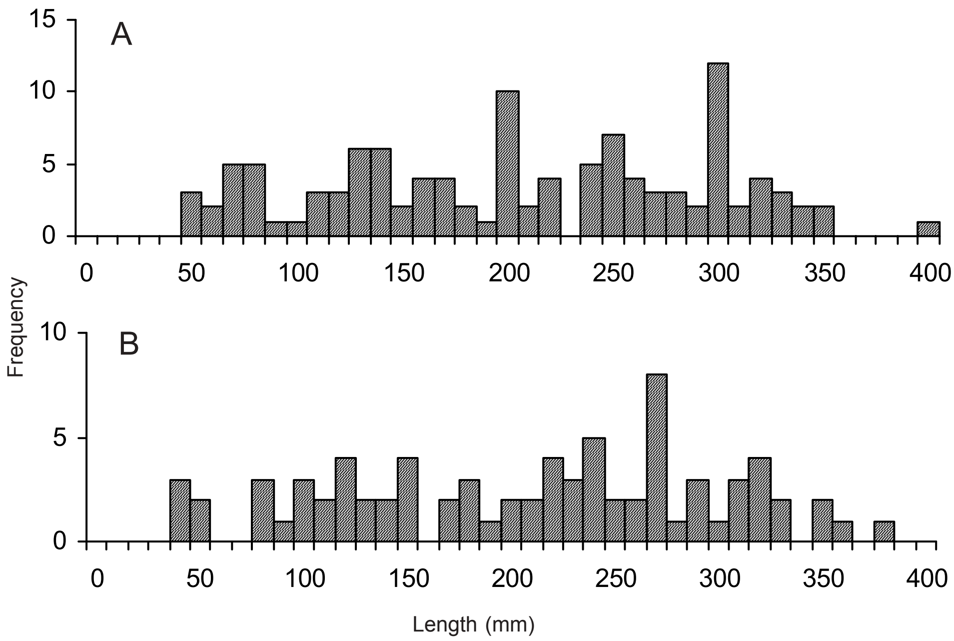


Figure 3. Length frequency of giant kokopu from (a) the NZFFD, and (b) from surveys in Westland and Southland.

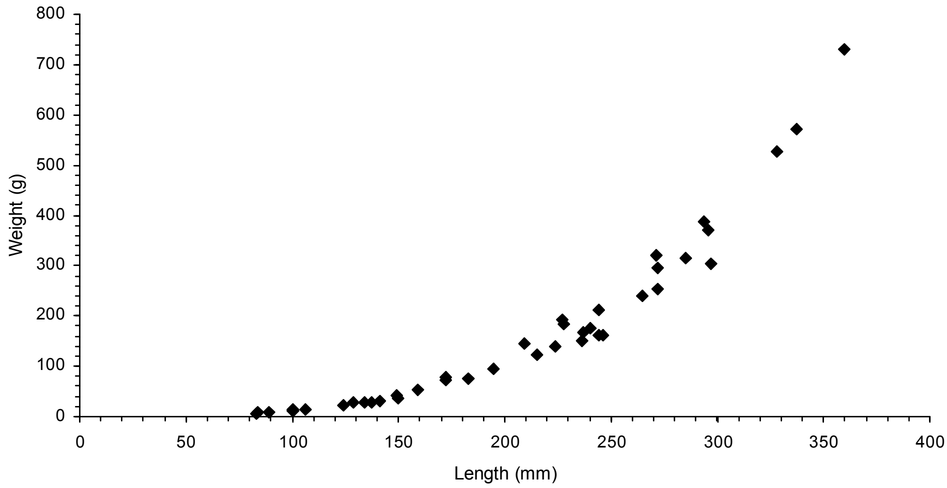


Figure 4. The length-weight relationship of giant kokopu caught in Westland and Southland.

Length records from the NZFFD have 'peaks' at 200, 250 and 300 mm (Fig. 4a), but these almost certainly are artifacts corresponding to estimated rather than measured length. We do not consider that they are indicative of age classes. Length and weight measurements for 40 fish from field surveys in Westland and Southland in autumn 1999 are plotted in Fig. 4. These data were also used to calculate a length/weight relationship for fish from 44 to 380 mm in length:

Weight (in grams) = $5.0912 \times 10^{-6} L^{3.1774}$ ($n = 40$, $r^2 = 0.992$).

3.4 HABITAT

Habitat features recorded on the NZFFD do not necessarily refer to the microhabitat occupied by giant kokopu—i.e. the information tends to be 'averaged' for the whole site sampled. Thus the habitat information contained in the database is mostly limited to 'broad-scale' features.

3.4.1 Water type

Giant kokopu are found in a wide range of water types, including estuaries, lagoons, swamps, streams, drains, rivers, ponds and lakes (Appendix 2). There is really no water type that is 'typical' for the species. Usually they are associated with coastal habitats with direct access to the sea, but they are also known in 'landlocked' populations at low to considerable elevations—e.g. in Lake Luxmore, near Lake Te Anau, at over 380 m elevation.

The NZFFD records habitat type, and entries are categorised on the basis of six features:

- Whether the water is flowing or still
- Whether it is connected to the sea
- Its source—whether it is fed by rain, snow or springs
- Its channel type (single or braided) or its outlet type
- Its size (small, medium or large)
- Whether it is natural or man made

Examination of habitat types for giant kokopu records on the NZFFD reveals that 483 (86%) came from flowing water. More specifically, 212 (38%) were recorded in small, natural, rain-fed, single channel streams. This appears to be significant, until it is measured against all records on the database; 91% of these are from flowing water and 41% from small, natural, rain-fed, single channel streams. Thus, these data do not show that giant kokopu are expressly choosing such habitats, though they do show that the species is not avoiding them.

One feature does appear to be significant—of the 561 records for giant kokopu, only 3 (0.5%) are from braided streams, compared with 5% for all fish records on the database. This is consistent with the fact that giant kokopu have never been recorded in any of the braided rivers along the east coast of either the North or South Islands. With this exception, giant kokopu are not apparently associated with any one type of macro-habitat.

3.4.2 Stream size

Despite their relatively large size, adult giant kokopu are regularly encountered in very small streams and drains. Stream sizes on the NZFFD are classified by width as small (< 10 m), medium (10–20 m), and large (> 20 m), and for many of the entries stream width has also been recorded in metres. Of the giant kokopu recorded in flowing water, 250 (52%) were from small streams, and where stream width was recorded it averaged 7.1 m. Sampling effort, however, is biased in favour of small streams, because these are more readily sampled than larger bodies of water.

During our field surveys, adult giant kokopu were sometimes captured in shallow streams and drains which were less than 1 m wide. It is perhaps surprising to see fish, some of which exceeded 300 mm in length and 0.5 kg in weight, in such confined habitat, although this phenomenon was also reported by Haast (1873), who commented that 'often the waterway is so narrow that a large fish like a [kokopu] can scarcely turn around'. Nevertheless, there is little evidence to support the suggestion that giant kokopu is a 'small stream' fish. They do also occur in large rivers, but are probably less likely to be encountered in these situations using commonly applied sampling techniques.

3.4.3 Forest type and absence/presence

Our data provide little evidence for an association between giant kokopu occurrence and the presence/absence of forest, or with forest type. Significant populations occur in both forested streams and pastoral drains, as well as in a diversity of other open and forested habitats. This is in strong contrast to shortjaw kokopu, which occurs almost exclusively in streams flowing through podocarp/hardwood forests (McDowall et al. 1996).

3.4.4 Water temperature and acidity

Of the sites where giant kokopu were recorded on the NZFFD, 26% also recorded water temperature and 19% recorded pH, compared with 34% and 17% respectively for all fish sites on the database. There is little difference in the distribution of water temperature frequencies between giant kokopu sites and all NZFFD sites (Fig. 5), although it appears that giant kokopu are not common in warmer waters. The comparison for pH is more marked, and Fig. 6 indicates that giant kokopu are mostly found in low pH (acidic) water; 75% of giant kokopu records are from water with a pH of less than 7. This certainly fits with

Figure 5. Water temperature at sites where giant kokopu were recorded, compared with temperature at all sites.

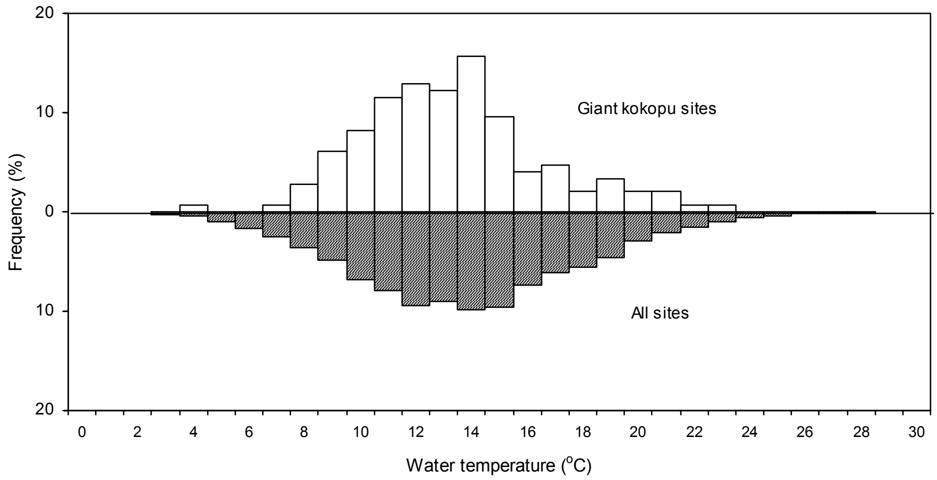
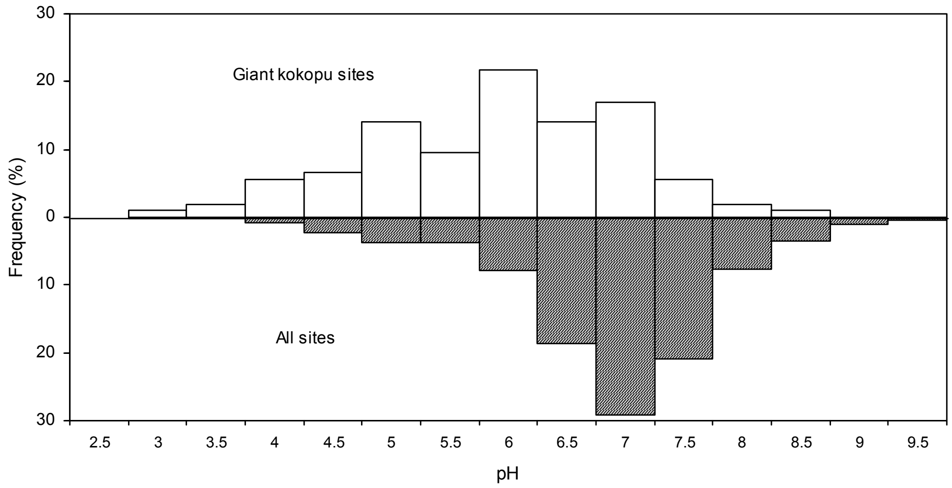


Figure 6. Water pH at sites where giant kokopu were recorded, compared with pH at all sites.



our perception that giant kokopu are associated with tannin-stained and acidic waters, but it should be noted that:

- Measuring pH in the field is difficult and frequently inaccurate, especially as some waters are naturally buffered.
- The pH was measured at only a small proportion of sites, and may have been more likely to be measured in tannin-stained waters when observers thought pH may be a factor affecting fish distribution, etc.
- The values of pH, and also temperature, may simply reflect the distribution of giant kokopu and the relative abundance in Westland and Southland, where waters are generally cooler and quite frequently acidic/tannin stained.

3.4.5 Inland penetration and elevation

The giant kokopu is often regarded as a 'lowland' or 'coastal' species with little climbing ability, especially when compared with some other galaxiids. The NZFFD was used to compare giant kokopu with 'all fish' records with respect to both inland penetration and elevation; these comparisons are presented in Figs. 7 and 8 respectively.

The description of giant kokopu distribution as 'coastal and lowland' appears to be well founded: 55.6% of giant kokopu records were from elevations of 10 m

Figure 7. Distance inland at sites where giant kokopu were recorded, compared with all sites.

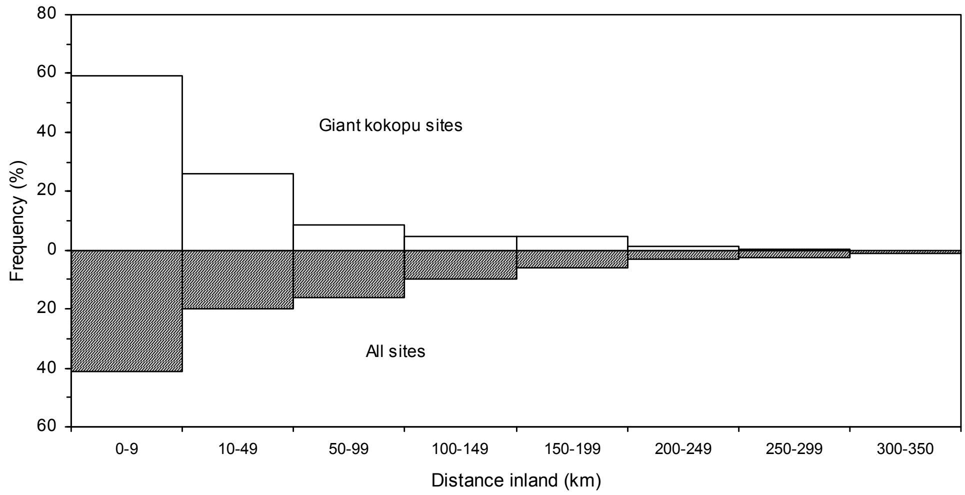


Figure 8. Elevation at sites where giant kokopu were recorded, compared with elevation at all sites.

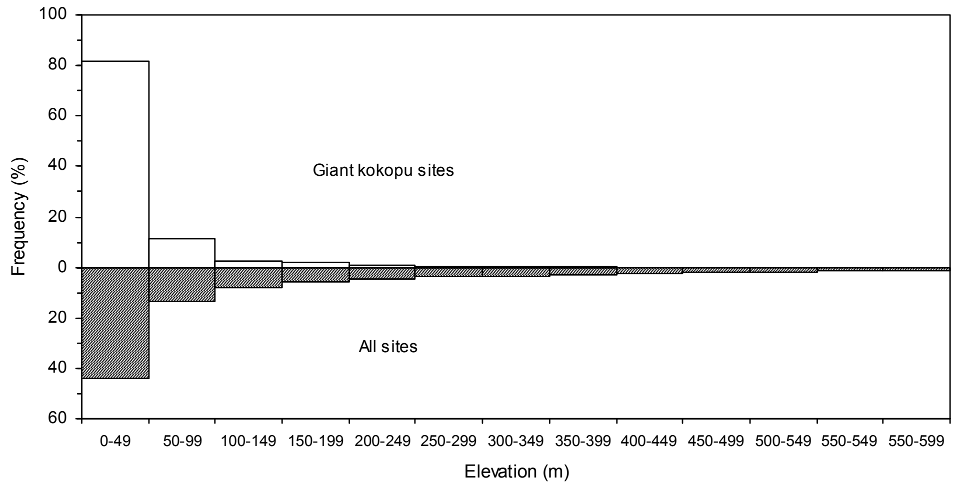
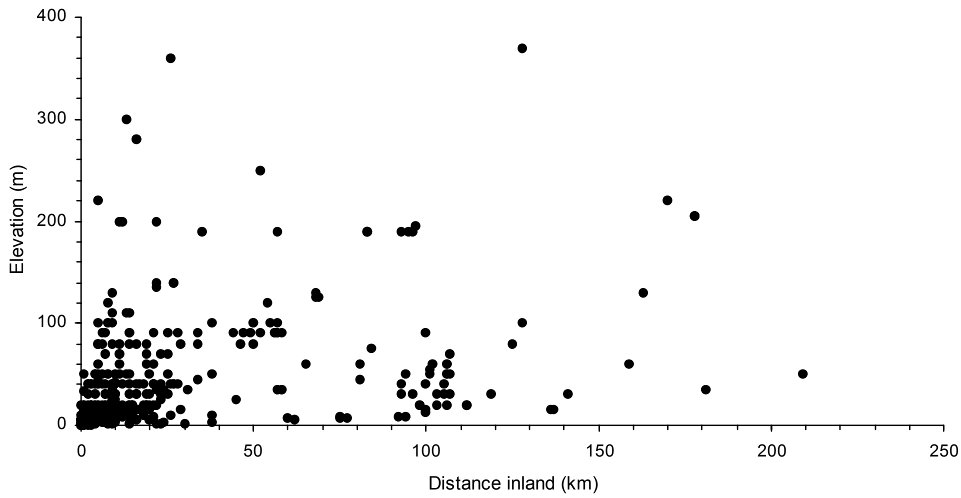


Figure 9. Distance inland versus Elevation at sites where giant kokopu were recorded.



asl or less, and 59% were from 10 km inland or less. Of course, river gradients vary significantly, so that a giant kokopu caught at low elevation does not necessarily mean that it was close to the sea, and vice-versa. However, 58.1% of giant kokopu records are from sites of elevation 10 m or less and 10 km inland or less (Fig. 9). The distribution of points in this figure may partially reflect sampling effort, which is known to be much more intensive at lower elevations and in areas with easy access.

The number of records from higher elevation and distances inland suggests that some giant kokopu are capable of significant upstream migration. Furthermore, records at 200 m elevation or more, but within 20 km of the sea, suggest that this species is able to penetrate rivers of relatively steep gradient; 200 m elevation at 20 km inland equates to a gradient or slope of 10 m/km or 1%. (By contrast, many of the major rivers in New Zealand, such as the Grey, Manawatu, Waikato, Wanganui, and Whakatane, have gradients of less than 2 m/km or 0.2%). It must be noted that records of giant kokopu at extremes of elevation and inland penetration do not necessarily represent sea-migratory fish. Land-locked populations (i.e. with no marine phase) of giant kokopu are known to occur (Lakes Brunner, Mistletoe, Luxmore, George, Horseshoe Lagoon, and others) and, in fact, may be reasonably common in some lakes (notably hydro lakes such as Lake Monowai) and isolated ponds. Overall, however, it appears that although giant kokopu are capable of penetrating well inland and ascending significant gradients, they are mostly a low elevation/coastal species.

3.5 SPECIES ASSOCIATED WITH GIANT KOKOPU

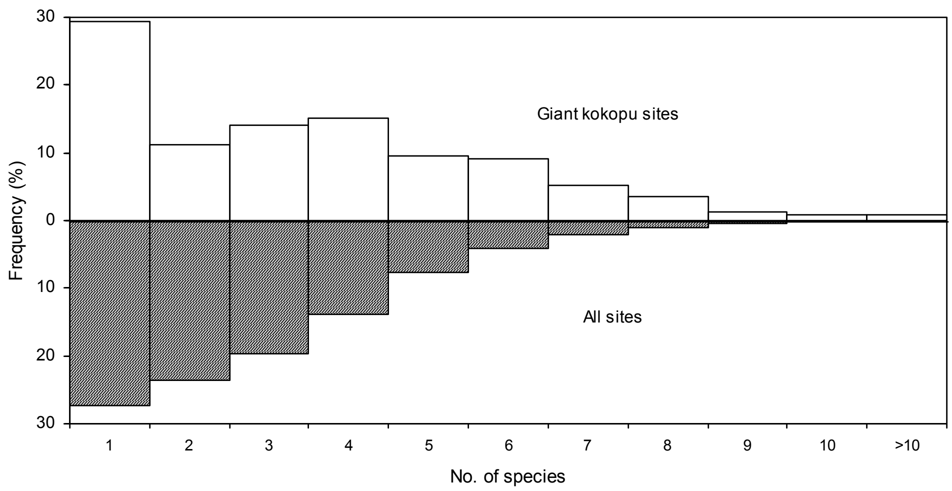
3.5.1 Species richness at giant kokopu sites

A wide variety of indigenous and exotic fish species shares the habitats occupied by giant kokopu. The frequency distribution of species richness (the number of species) at sites with giant kokopu is presented in Fig. 10, and is compared with species richness in all sites where one or more species of fish were recorded in the NZFFD. It is clear that giant kokopu sites encompass the full range of species richness—in 29% of sites it was the only species recorded, but there are also sites where 10 or more species are present. At some sites giant kokopu has been recorded with up to 17 other species. This can be interpreted as indicating that giant kokopu occupy a wide range of water types, and is not clearly associated with any one particular type.

3.5.2 Species associations

The giant kokopu has been found with a total of 33 other species, which further reflects both its wide distribution and broad range of habitat. For those species

Figure 10. Number of species at sites where giant kokopu were recorded, compared with all sites.



that are reasonably common and widespread, co-occurence with giant kokopu is summarised in Table 1, which lists the species, the total number of times each occurs on the NZFFD, the total number of co-occurrences with giant kokopu, and the percentages of the respective totals. The ratios of percentage co-occurrence to percentage of total records have been calculated for each species, and provide a 'weighted' measure of the significance of the associations. A high ratio implies the species is closely associated with giant kokopu sites, and vice-versa.

Some species occur frequently with giant kokopu, but are also extremely common; for instance, longfin eels (*Anguilla dieffenbachii*) occur in 44% of giant kokopu sites, but they also occur in 45% of all NZFFD records. Thus, although longfin eels are the most commonly co-occuring species with giant kokopu, their co-occurrence is much as would be expected given that eels are widespread and relatively common.

The species which appear to have high affinity for giant kokopu sites are the other two kokopu species, shortjaw and banded. There are several other species with weighted ratios of 1 or more, and when this is considered along with the relatively high species richness at many giant kokopu sites, it implies that giant kokopu is involved in a wide variety of species associations. Any matrix of species associations derived from the NZFFD data would probably be complex and inconclusive.

TABLE 1. SPECIES OF FISH CO-OCCURRING WITH GIANT KOKOPU (gk) ON THE NZFFD (EXCLUDES SPECIES FOR WHICH THERE ARE LESS THAN 200 RECORDS).

SPECIES	NO. OF CO-OCCURRENCES WITH GIANT KOKOPU	NO. OF RECORDS ON NZFFD	PERCENT OF gk RECORDS	PERCENT OF NZFFD RECORDS	RATIO gk/NZFFD
Shortjaw kokopu	30	288	5.35	2.11	2.54
Banded kokopu	150	1565	26.74	11.44	2.34
Inanga	125	1607	22.28	11.75	1.90
Lamprey	33	430	5.88	3.14	1.87
Giant bully	19	264	3.39	1.93	1.75
Redfin bully	161	2265	28.70	16.56	1.73
Shortfin eel	125	2524	22.28	18.45	1.21
Longfin eel	249	6007	44.39	43.92	1.01
Common bully	99	2570	17.65	18.79	0.94
Koaro	56	1562	9.98	11.42	0.87
Goldfish	8	286	1.43	2.09	0.68
Mosquitofish	8	288	1.43	2.11	0.68
Bluegill bully	19	704	3.39	5.15	0.66
Common smelt	22	913	3.92	6.67	0.59
Torrentfish	31	1338	5.53	9.78	0.56
Brown trout	94	4299	16.76	31.43	0.53
Crans bully	8	543	1.43	3.97	0.36
Rainbow trout	8	1183	1.43	8.65	0.16
Dwarf galaxias	1	318	0.18	2.32	0.08
Upland bully	4	1537	0.71	11.24	0.06

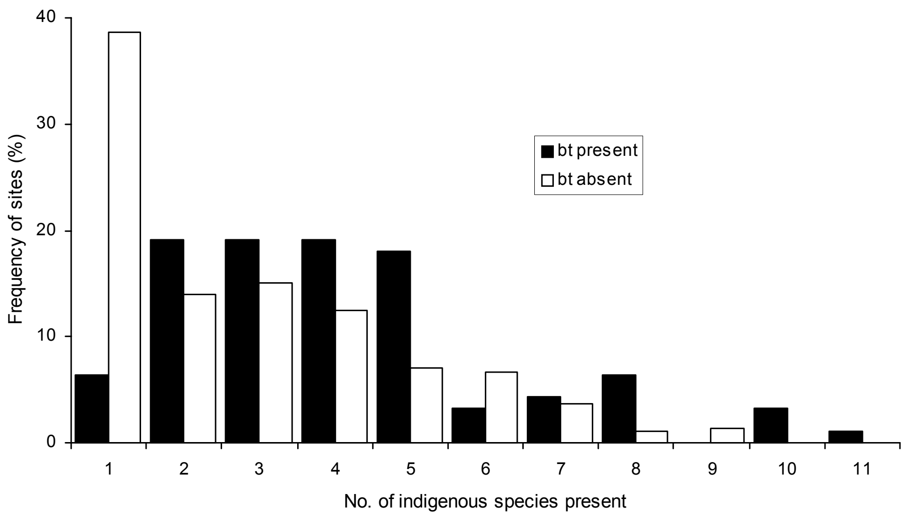
3.5.3 Impact of introduced fish

Of the 21 introduced fish species in New Zealand freshwaters (McDowall 1990), brown trout (*Salmo trutta*) are particularly pervasive, and may be found throughout most of New Zealand. They occur in 94 of the sites where giant kokopu have been recorded (Table 1). However, it would appear that giant kokopu may be much more likely to occur in habitat where brown trout are absent. Brown trout occur in over 31% of NZFFD records, although only in 16.8% of all giant kokopu sites (conversely brown trout are absent from over 83% of giant kokopu sites).

There was little difference in indigenous species richness at sites where trout were present or absent, as can be seen in Fig. 11. Overall, there appears to be little affinity between giant kokopu and brown trout, although the two species cannot be said to be mutually exclusive.

Note that Table 1 is derived from NZFFD records that may be biased—at any one site some species may have a vastly different probability of capture, and may therefore be misrepresented on the database. Moreover, the database may be dominated by records from accessible sites that are easy to sample, which may present a skewed picture of fish abundance and distribution.

Figure 11. Species richness of giant kokopu sites at which brown trout (bt) are absent or present.



4. Habitat surveys and analysis

Habitat surveys were undertaken in Westland during April 1998 and in Southland (including parts of the Catlins region) during April 1999. Surveys were designed to gain explicit and quantitative data on the habitats occupied by giant kokopu and, for comparison, on adjacent habitat (in the same stream or pond etc.) that was not occupied. At each site, the habitat parameters measured included:

- Water depth and velocity, measured using standard flow gauging equipment. Measurements of water depth and velocity were averaged from a minimum of three spot measurements close to where fish were caught. Measuring the velocity at 60% of the depth below the water surface approximates mean velocities in the water column.
- Substrate composition was measured using the Wolman walk method (Mosley 1982), with a minimum of 50 stones measured at each site; substrate size was expressed as D^{50}, the cumulative size frequency incorporating 50% of the substrate particles measured.
- Stream width.
- Water quality; temperature, pH, conductivity, turbidity, and dissolved oxygen, as measured using a Horiba U-10 multi-parameter water quality checker.

Assessments were also made of:

- Riparian cover; estimates were made of the proportion (%) of the bank that was uncovered (open) or covered by native vegetation, exotic vegetation, scrub, raupo/flax, or grass. We used a separate category for raupo and flax, simply because anecdotal evidence suggested this type of cover was important.
- Instream cover available to fish; an estimate was made of the proportion (%) of the streambed covered by each type. The categories of cover used were: filamentous algae, substrate, debris (mainly sticks and leaves), logs, instream vegetation, and culvert/bridge structures.
- Substrate embeddedness and compaction, both of which were subjectively rated on a scale of 1–5; where 1 corresponded to little or no embeddedness/compaction, and 5 very embedded/compacted. In reality, both these assessments were difficult to perform in a consistent manner in field surveys. Consequently, we cannot be sure how important or useful the assessments were, and analyses of their importance to giant kokopu are dubious.
- The proportion (%) of the bank that could be classed as vertical, sloped, undercut, or slumped.

All measurements were taken as close as possible to where giant kokopu were caught, usually within 1 m. Additional measurements were taken from adjacent areas which had been fished, but where giant kokopu did not occur. To avoid bias, these measurements were taken at random distances along the stream or in random locations in ponds, lagoons etc.

Habitats in some waters where giant kokopu were absent may have been suitable, but not occupied because the habitat was inaccessible. Thus we confined our measurements of habitat to water bodies in which we actually observed giant kokopu, and attempted to distinguish suitable from unsuitable within these.

All the habitat measurements made where fish were encountered corresponded to habitat occupied by the fish during daylight, thus the conclusions may not accurately reflect the full range of habitats used or required by giant kokopu.

4.1 OBSERVATIONS

There was a distinct benefit in undertaking an intensive habitat survey for giant kokopu—with experience in the field it became possible to predict subjectively, but accurately, where giant kokopu might be found. This applied particularly to electrofishing surveys in streams and drains, although subjective predictions were also reasonably accurate for fyke netting and spotlighting operations. While such knowledge proved to be very useful in the field, it has limited use for detailed analysis, and also had the potential to be distracting—we had to be careful not to concentrate on 'likely' spots, but to sample as wide a range of habitats as possible.

The features that were regularly observed and associated with the presence of giant kokopu in streams were:

- Areas of low water velocity
- Relatively deep water, especially in small streams
- Dense 'log-jams' or debris at and below the water surface
- Bank shelter such as undercut banks, very large boulders, bridge foundations, or culverts

Three of these features make seeing or catching giant kokopu difficult—so perhaps it is not surprising that the casual observer infrequently encounters this species. It also became obvious that giant kokopu were not easy to catch using electric fishing equipment, as it took considerable effort to catch fish amongst dense log-jams and/or under banks. Giant kokopu exhibited normal, but unspectacular, reactions to electrical currents, so that stunned fish were not easily seen and usually did not splash around. Giant kokopu that inhabit lagoons, lakes, ponds, swamps and larger rivers may be even less likely to be encountered, except by people angling or using fyke nets and/or traps. Thus, overall, giant kokopu abundance may be considerably underestimated.

Surveying streams at night using a hand-held spotlight was not always successful. This technique was used several times in small Westland streams, using a lightweight one million candlepower light. Generally this was used with a red filter, which reduced glare on the water surface. In most streams a variety of fish species were observed, and some species, notably banded kokopu, were easily spotted and scooped up in a dip net. Giant kokopu were seen occasionally, but more often than not they were in or close to dense instream cover or overhanging banks. There was nothing to suggest that giant kokopu in streams occupy radically different habitats during the night, although they might well be more active during the hours of darkness.

We did not make any scientifically based comparisons between the effectiveness of electrofishing and observation by spotlight, but on several occasions streams were spotlighted at night before electrofishing next day, and electrofishing was shown to be far more effective. Spotlighting is a simple, cheap and safe technique, but it is limited to clear and/or shallow water. It does not work well in areas with dense instream cover and is ineffective in tannin-stained ponds, lagoons and swamps where giant kokopu might be present. Nevertheless, it may be a useful technique for quick assessments of some waters, provided the users are prepared to be patient and careful. Overall, no single method will be effective in all types of water at all times, and we would encourage the use of as wide a range of methods as possible.

4.2 HABITAT VARIABLES

Comparisons were made between giant kokopu sites and other sites on the basis of mean values of habitat variables; these are summarised in Table 2. Westland and Southland values are given separately, although only data

TABLE 2. MEAN, MEDIAN (IN PARENTHESES) AND RANGE OF VALUES OF HABITAT FEATURES MEASURED OR ASSESSED IN WESTLAND AND SOUTHLAND SITES.

	WESTLAND		SOUTHLAND		RANGE	
GIANT KOKOPU	ABSENT	PRESENT	ABSENT	PRESENT	MIN.	MAX.
Site Location						
Distance inland (km)	7.53 (2.12)	3.61 (2.01)	14.4 (8.0)	9.8 (6.0)	0.05	58
Elevation a.s.l. (m)	21.5 (11.5)	17.1 (10.5)	7.9 (5.0)	5.6 (5.0)	0	140
Physical features						
Water depth (m)	0.43 (0.24)	0.63 (0.40)	0.33 (0.20)	0.32 (.30)	0.06	1.5
Water velocity (m/s)	0.10 (0.05)	0.03 (0.02)	0.17 (0.15)	0.07 (0.06)	0	0.54
Channel width (m)	3.66 (3.45)	3.6 (3.60)	2.01 (2.0)	1.81 (1.30)	0.7	100
Mean substrate size (mm)	30.6 (30.6)	30.3 (28.6)	28.5 (0.1)	1.05 (0.01)	0	341.3
Substrate (1–5)						
Compactness	2.2 (2)	1.8 (2)	2.1 (2)	2.5 (2)	1	5
Embededness	2.8 (3)	3.8 (4)	4.8 (5)	4.6 (5)	1	5
Bank composition (%)						
Flat	15 (0)	13 (0)	0 (0)	0 (0)	0	90
Sloped	56 (50)	49 (50)	85 (100)	89 (100)	0	100
Vertical	17 (5)	16 (0)	11 (0)	5 (0)	0	100
Undercut	9 (0)	21 (0)	0 (0)	0 (0)	0	100
Slumped	3 (0)	1 (0)	4 (0)	6 (0)	0	50
Riparian cover (%)						
Native vegetation	43 (10)	55 (90)	0 (0)	0 (0)	0	100
Exotic vegetation	2 (0)	0 (0)	0 (0)	0 (0)	0	40
Scrub	15 (10)	10 (0)	39 (30)	40 (30)	0	100
Raupo/flax	0 (0)	20 (0)	4 (0)	13 (0)	0	80
Open—no vegetation	14 (0)	2 (0)	8 (0)	0 (0)	0	95
Grass	26 (0)	13 (0)	49 (60)	47 (30)	0	100
Overhead shade	34 (15)	49 (60)	20 (10)	17 (10)	0	100
Instream cover (%)						
Filamentous algae	0 (0)	2 (0)	0 (0)	0 (0)	0	50
Substrate	3 (0)	6 (0)	0 (0)	0 (0)	0	30
Debris	4 (1)	16 (10)	19 (10)	18 (10)	0	80
Log	3 (0)	14 (10)	0 (0)	2 (0)	0	45
Vegetation	7 (0)	6 (0)	17 (5)	35 (50)	0	80
Culvert/bridge	0 (0)	0 (0)	0 (0)	1 (0)	0	10

collected in flowing water sites are presented; some habitat features could not be accurately determined where fyke nets were used and the exact location of fish could not be determined.

Water velocity stands out as being important for giant kokopu in both Westland and Southland flowing water. Mean water velocity where giant kokopu occurred was less than half that of other sites. It appears that giant kokopu also prefer sites closer to the sea, although this may be a reflection of their preference for the habitats in lowland areas rather than the fish's ability to move upstream.

Several other habitat variables in Table 2 appear to be important for giant kokopu occurrence, but not consistently so for both Westland and Southland sites. These include:

Riparian vegetation. In both regions it appears that giant kokopu are mostly absent in sites where there is no riparian vegetation (i.e. where riparian vegetation = 'open'). In Westland, native riparian vegetation seems most important, whereas in Southland raupo/flax (which is also a type of native vegetation) appears to be important. The Southland streams surveyed were essentially pastoral drains, which contained virtually no native vegetation apart from raupo/flax.

Instream cover. In Westland, logs and debris appear to be closely associated with the presence of giant kokopu, whereas in Southland, instream vegetation and debris were important. Note that Westland streams contained comparatively little instream vegetation, and that streams in Southland were essentially pastoral drains, all having been regularly straightened, channelised and cleared—logs were virtually non-existent but debris and instream vegetation (mostly grasses) were common (see appendix 2).

Substrate size. It appears that giant kokopu may prefer smaller substrates, although the association with smaller substrate size may simply reflect a preference for water of low velocity (where smaller substrate may be expected to occur).

Undercut banks. In Westland it appears that giant kokopu select undercut banks, which supports our subjective observations. In Southland, however, undercut banks were not a feature of the streams/drains surveyed, although in these waterways giant kokopu were often present in and around culverts and bridges. These structures make up a very small proportion of the total available instream cover, so that their utilisation may be significant.

Shade. This appears to be significant in Westland, but not Southland. This may partly reflect fish's preference for riparian cover, rather than a preference for shade. In Westland streams, areas with riparian cover (usually bush) were generally well shaded, whereas Southland streams and drains often had abundant riparian cover in the form of grass and scrub which provided little overhead shade.

Overall, the basic analysis suggests that giant kokopu occur mostly in low-velocity water, and in areas with significant riparian vegetation. Instream cover is also important, be it logs, vegetation or debris, or the cover provided by structures such as bridges and culverts.

The water quality data at giant kokopu sites (Table 3) were not suitable for detailed analysis for two reasons. Firstly, as may be expected in flowing waters, values of temperature, pH, etc. were identical for adjacent sites where giant kokopu were and were not present, so that these features could not be used to discriminate between sites. In this respect measurements of pH, temperature, conductivity, dissolved oxygen, and turbidity are not strictly 'habitat variables' and may have an abnormal distribution. Secondly, the accuracy of these data (particularly for pH and dissolved oxygen) is questionable; in most cases physical features were measured with a multi-function water analyser, which, despite being frequently and carefully calibrated, gave inconsistent results.

4.3 DISCRIMINANT FUNCTION ANALYSIS

The field surveys were designed to provide data suitable for multivariate analysis, particularly discriminant function analysis (DFA). This technique was identified as being the most suitable for identifying which of the variables measured in the field was critical, and the technique was used to create a statistical model associating habitat variables with the presence of giant kokopu.

Analysis was performed on a pc using the SYSAT 8.0 statistical software package (Wilkinson 1998). Separate analyses were performed on seven datasets in relation to geographical location (Westland or Southland), fish size (juvenile $\leq$ 120 mm, or adult > 120 mm), and whether or not the water was flowing. A further analysis was performed using all datasets combined. Data for still water (lentic) sites such as lagoons, ponds and lakes, were generally less accurate, as these areas were sampled with fyke nets, and a full analysis using only lentic sites was not possible.

In all analyses there were two types of sites: those where giant kokopu were found, and those where they were not. Discriminant functions analysis (DFA) was used to find the combination of habitat variables that best classified (or discriminated between) the two groups. Analyses were carried out in a backwards stepwise manner; initially all the variables were used in the model, then variables that had the least influence on the presence of giant kokopu were successively removed from the model. Results are presented in Table 4. For each analysis, separate F statistic values are listed for the variables (habitat features) which remain in the model after backward stepping. Also listed are jack-knifed classification matrix values, which are measures of the success of 'self testing' in the model. These are calculated by leaving out single cases to

TABLE 3. PHYSICAL (WATER QUALITY) FEATURES OF GIANT KOKOPU HABITAT MEASURED DURING FIELD SURVEYS IN WESTLAND AND SOUTHLAND.

FEATURE	MEAN	MINIMUM	MAXIMUM
Temperature (^oC)	11.7	9.1	15.1
pH	6.1	4.1	8
Conductivity (mS/cm)	0.157	0.028	0.386
Dissolved oxygen (mg/L)	8.9	4.2	12.8
Turbidity (ntu)	13.8	1	95

TABLE 4. SUMMARY OF DISCRIMINANT FUNCTIONS ANALYSES OF GIANT KOKOPU HABITAT FEATURES. F VALUES ARE PRESENTED FOR FEATURES THAT DISCRIMINATED BETWEEN UTILISED AND NON-UTILISED FEATURES. REFER TO TABLE 2 FOR UNITS OF HABITAT MEASUREMENTS.

REGION	WESTLAND				SOUTHLAND			ALL
WATER TYPE	ALL	FLOWING	ALL	ALL	ALL	ALL	ALL	ALL
FISH SIZE	ALL	ALL	≥ 120 mm	< 120 mm	ALL	≥ 120 mm	< 120 mm	ALL
Geographical features								
Inland penetration	4.54		3.16		9.58	62.89	8.44	9.08
Elevation						75.29	63.36	
Hydrological features								
Water depth					36.95		53.3	12.6
Water velocity	4.28	2.94	4.83		9.62			10.7
Stream width	6.93		9.07		40.73			4.37
Substrate features								
Substrate size (median)								4.83
Substrate compaction						18.37	7.14	20.2
Substrate embeddedness			2.69		12.97		67.58	
Bank composition								
Flat	5.08		5.21	10.79				
Sloped	3.4		3.75	16.57		40.4	9.21	
Vertical	2.8		3.18			38.96	17.33	2.92
Undercut	4.72		4.9					
Slumped								
Riparian cover								
Native vegetation	7.17		5.32	21.4				42.5
Scrub	3.23		2.51		36.07	42.37	3.24	49.9
Exotic vegetation								4
Raupo/flax	14.15		9.25			49.69	13.23	
Open	2.41			4.7	48.83	25.63	4.95	52.9
Grass					58.66		15.43	56.7
Shade	7.3	14.04	8.39	15.18	14.09	27.22	23.77	5.34
Instream cover								
Filamentous algae	3.66		5.29	2.24				
Substrate	24.74	23.34	22.77	30.92				23.9
Debris					37.32	33.54	27.28	
Log	48.99	59.53	43.05	54.54	9.93			56.9
Instream vegetation					30.83	7.08	19.24	61.7
Culvert/bridge					32.23	48.33		9.19
No. of sites fish present	31	21	29	2	25	14	11	56
No. of sites fish absent	30	30	30	30	42	42	42	72
Jack-knifed predictions								
% correct absent	97	93	97	100	99	100	98	90
% correct present	87	95	93	0	95	93	100	80
% overall correct	92	94	95	94	98	98	98	86

classify the remainder. Thus if there were 100 cases in the model, case x is removed and the remaining 99 cases used to predict if giant kokopu were present for case x or not. All cases are cross-validated in this manner, and the jack-knifed values summarise the success of predicting the presence or absence of giant kokopu for all cases in each dataset.

Those habitat variables with consistently higher F-values in all analyses do not necessarily correlate positively with giant kokopu occurrence; they may indicate a correlation with giant kokopu absence. For example, ‘open’ riparian cover has high values in six of the eight analyses, but from Table 2 it can be seen that giant kokopu mostly avoid sites where riparian cover was ‘open’.

For most dataset models outlined in Table 4 there are numerous habitat features which appear to be significant. The exception is for the Westland flowing water sites with all fish sizes, for which the DFA model identifies four features as being important: water velocity, overhead shade, substrate cover, and log cover.

Habitat variables pertaining to both riparian and instream cover appear to be significant, but not consistently so for each of the datasets. We interpret this as meaning that the presence of some form of riparian and instream cover is important, but that its composition may not be. Furthermore, the lack of consistency possibly reflects differences in habitat features between Southland and Westland sites. Use of variables such as the proportion of native vegetation to predict the occurrence of giant kokopu in Southland is not logical, as the sites surveyed in Southland were virtually all pastoral streams and drains, with riparian vegetation that consisted mainly of introduced grasses and low scrub. Similarly, streams in Westland mostly lacked instream vegetation, and this variable could not be expected to be a good predictor of giant kokopu occurrence for the region.

The utility of the DFA model may also be reduced by the complexity of some variables and the overlap between them. For instance, during field surveys, bank composition was assessed as five separate variables that essentially described a single feature, bank slope. To clarify which features were important, the discriminant functions analyses were repeated using simplified habitat variables. The five variables used to describe the stream bank composition were reduced to one variable, bank slope (% of the banks sloped). Similarly, the six variables describing riparian vegetation were combined into a single variable, riparian vegetation (% of the riparian area covered in vegetation), and the six variables describing instream cover were reduced to one variable, instream cover (% of the bed covered by instream features).

The results of the DFA analyses using simplified variables are presented in Table 5. Simplification of the variables has resulted in a slight loss of ‘predictability’ in the model, as can be seen from the slightly lower jack-knifed predictions. However, use of the simplified variables has resulted in a much clearer and consistent model that allows better identification of critical features. From the analyses, using both original and simplified data variables, it is apparent that several habitat features are most frequently and consistently associated with giant kokopu occurrence.

Instream cover is the habitat feature most consistently associated with giant kokopu occurrence. It appears that the composition of the instream cover may not be important. In Westland, logs in the water were the cover that seemed most important, whereas in Southland, giant kokopu were consistently associated with instream vegetation, debris and bridge/culvert structures. Generally these factors strongly support the intuitive contention that giant kokopu are a ‘cover loving’ species.

TABLE 5. SUMMARY OF DISCRIMINANT FUNCTIONS ANALYSES OF GIANT KOKOPU HABITAT FEATURES USING SIMPLIFIED VARIABLES. F VALUES ARE PRESENTED FOR FEATURES THAT DISCRIMINATED BETWEEN UTILISED AND NON-UTILISED FEATURES. REFER TO TABLE 2 FOR UNITS OF HABITAT MEASUREMENTS.

REGION	WESTLAND				SOUTHLAND			ALL
WATER TYPE	ALL	FLOWING	ALL	ALL	ALL	ALL	ALL	ALL
FISH SIZE	ALL	ALL	≥120 mm	<120 mm	ALL	≥120 mm	<120 mm	ALL
Geographical features								
Inland penetration						2.65		15.47
Elevation					11.49	6.13	19.7	
Hydrological features								
Water depth	5.1		4.65					7.42
Water velocity	7.04	8.9	7.25		22.4	13.54	15.07	20.29
Stream width	2.22							
Substrate features								
Size (median)								
Compaction				2.28	2.29		6.3	
Embeddedness	2.28		5.15		12.66	13.5	9.75	
Bank composition								
Sloped	3.04							
Riparian cover								
Riparian			3.61					
Shade	32.24	36.42	32.36					11.52
Instream cover								
Instream cover	29.01	46.49	30.76	8.59	20.45	11.31	25.2	54.04
No. of sites fish present	31	21	29	2	25	14	11	56
No. of sites fish absent	30	30	30	30	42	42	42	72
Jack-knifed predictions								
% correct absent	87	90	87	93	81	81	88	86
% correct present	94	90	90	50	80	64	73	77
% overall correct	90	90	88	91	81	77	85	82

Water velocity was also strongly associated with giant kokopu presence, and fish were almost always found in areas of low velocity. Possibly, water velocity may not be so critical for juvenile fish (< 120 mm in length), and smaller specimens may be more tolerant of faster flowing water.

Shade is also often associated with giant kokopu presence, particularly in Westland, and appears to be, overall, a good predictor of giant kokopu presence. It is logical to regard shade and **riparian cover** together as a habitat feature; areas with dense riparian cover would normally be shaded, and vice-versa. The consistency of the shade variable supports the hypothesis that it is the presence of some form of riparian cover, rather than its composition, which is important. Variables measuring different types of riparian cover were often, but not consistently, associated with giant kokopu presence during the initial DFA, and a lack of riparian cover ('open') was associated with fish absence in both Southland and Westland (Table 2).

Inland penetration; the occurrence of giant kokopu was associated with proximity to the sea, especially in Southland waters. Low elevation was also a feature in Southland, and it is fair to say that giant kokopu is predominantly a 'coastal' species. That this variable was not so strongly associated with giant kokopu in Westland may be a function of the more restricted range of distances inland and elevations sampled in that region. This may be compounded by the fact that several of the higher/inland areas surveyed contained populations that were probably 'landlocked' or non-diadromous. There is a strong implication that inclusion of more habitat data from sites that were much further inland would emphasise the importance of proximity to the sea for giant kokopu occurrence.

Water depth is also an important feature, although it is probably the least consistent of the parameters that show strong association with giant kokopu presence. Unfortunately, only a limited range of depths could be effectively sampled during field surveys, so that discrimination based on the water depth variable may have been limited. Our subjective observations of giant kokopu in the field indicate water depth as being both important for, and a good predictor of, giant kokopu presence.

Substrate embededness and compaction were variously associated with giant kokopu presence for several datasets, but did not appear to be very important overall. In fact, from Table 2 it is apparent that these two features are unlikely to be good 'predictors' of giant kokopu presence, as there is little difference in variable mean values between sites containing giant kokopu and those that do not. It can also be seen that such differences are inconsistent between Westland and Southland cases. Thus it would be difficult to ascertain whether a significant F-value in the DFA model was associated with giant kokopu presence or absence.

The objective of the analysis was always to identify which of the habitat features are important for giant kokopu, rather than construct a more quantitative model for predicting the abundance of giant kokopu. Such a model would have to be based on more quantitative data, e.g. biomass per unit area, rather than presence/absence information. This, in turn, would probably require considerably more fieldwork to collect sufficient data.

5. Artificially constructed habitat

In several small Westland streams giant kokopu were relatively common, but almost always only found under and amongst dense accumulations of logs and debris. Logs that had accumulated around large boulders, or on stream banks, seemed to form habitat with dense instream cover and areas of low water velocity. To test if these two features were the 'key' to giant kokopu occurrence, six artificial habitats were constructed within a 200 m reach of Viaduct Creek, a small lowland tributary of the Arahura River, Westland. The artificial habitats were constructed using metal fencing standards ('warratahs') driven into the stream-bed and banks; logs (mostly fallen branches from native bush) were attached to these with steel wire, to form a sort of platform near the water surface (Appendix 3). Some of the logs were placed close to the streambed, and created an area of 1–2 m^2 of dense instream cover which fish could occupy. In sites where water velocity was thought to be too great for giant kokopu, boulders were moved close to the structure to create zones of low water velocity.

These structures were created in December 1998, and left for about three months to accumulate natural stream debris. One of the structures was destroyed by high stream flows, and the remaining five were surveyed in March 1999 and again in May 1999. Results of both surveys are summarised in Table 6. During the May survey, a 220 m reach of Viaduct Creek including the five structures, was carefully electrofished. A total of eight giant kokopu were caught, including four utilising the artificial structures.

While this experiment lends support to the hypothesis that giant kokopu utilise habitat with dense instream cover and low water velocity, it is not definitive proof and cannot be statistically justified. It would be feasible to conduct a more detailed study using artificial structures, and to examine habitat selection and utilisation more rigorously, but such a major experiment was outside the scope of this project. It must also be stressed that, although these structures appeared to 'attract' giant kokopu, we knew from previous surveys that the stream already supported a population of these fish, and creating artificial habitat would not necessarily increase the carrying capacity of the stream. We are not trying to promote the use of habitat structures in other streams or waterways that are perceived to require habitat enhancement. The major objective of this study was to identify critical habitat features, and the successful use of artificial habitats simply supports the hypothesis that instream cover and low water velocity are critical.

During both the February and May surveys, banded kokopu and redfin bully were also observed in the artificial structures, particularly in the structures where giant kokopu were absent.

TABLE 6. ARTIFICIAL HABITAT STRUCTURES CREATED IN VIADUCT CREEK, DECEMBER 1998.

STRUCTURE	MEAN WATER DEPTH (m)	MEAN WATER VELOCITY (m/s)	GIANT KOKOPU CAUGHT	
			3/3/99	13/5/99
a	0.3	0.01	295 mm	
b	0.17	0.19	destroyed by high flows	
c	0.13	0.03	192 mm	
d	0.28	0		337 mm
e	0.24	0		240 mm
f	0.37	0	332 mm, 305 mm	183 mm, 137 mm

6. Vegetated and open shores

There is some anectodal evidence that giant kokopu in lakes are mostly associated with vegetated rather than open shores (C. Tonkin, pers. comm). Discriminant function analyses have demonstrated that riparian vegetation is very important for giant kokopu in flowing water, and that there is a strong association between 'open' banks and absence of giant kokopu. To test this in still water, fyke nets were baited with 'Marmite' (a common yeast extract) and set overnight along vegetated and open beaches of the eastern shores of Lake Kaniere, Westland, on the nights of 12–13 May and 13–14 May 1999.

A total of 13 giant kokopu were caught in the fyke nets, along with 58 eels and eight perch (Table 7). The slight differences in catch rates between vegetated and open shores were not statistically significant, and the results do not support the hypothesis that giant kokopu are associated with vegetated shores. It is possible that giant kokopu in Lake Kaniere are more common near the mouths of tributary streams and/or in areas where there is dense underwater cover. It would be difficult to distinguish these features from the effect of vegetated shores without substantial effort and a carefully designed experiment.

TABLE 7. CATCH PER FYKE NET IN OPEN AND VEGETATED SHORES, LAKE KANIERE, MAY 1999.

NET NUMBER	OPEN SHORE				VEGETATED SHORE			
	GIANT KOKOPU	LONGFIN EEL	SHORTFIN EEL	PERCH	GIANT KOKOPU	LONGFIN EEL	SHORTFIN EEL	PERCH
Night 1, 12–13 May 1999								
Big Bay and Camp Bay area								
1		3			3	2		
2		2		1		2		
3						4		1
4	1				2	1	1	
5	1	12				4		1
Night 2, 13–14 May 1999								
Christmas Bay to Rose Creek								
1		3		1				1
2					1	4	1	
3	2	4				4		1
4	1	1			1	5		2
5		4	1		1			
Total	5	29	1	2	8	26	2	6

7. Discussion

7.1 CRITICAL HABITAT FEATURES

This report has highlighted five critical features of giant kokopu habitat:

- instream cover
- riparian cover
- proximity to the sea
- water depth
- low water velocity

It must be emphasised that statistical models used to analyse these features are based mainly on information from flowing water (lotic) habitats, as data from most still water (lentic) habitats were less explicit. Nevertheless, some data for lentic habitats are included in the discriminant function analyses, and we assume that the same habitat features are critical for both (although obviously water velocity would not be a feature in lentic environs). There is also an underlying assumption that the places where giant kokopu were caught or seen represent 'normal' habitat for the species; it is possible that they use quite different habitats at different times or when undisturbed. Overall, the knowledge gained during this research, and all the incidental information in the literature, support the view that in all water types giant kokopu are very strongly associated with cover, slow or still water, and proximity to the sea.

The importance of terrestrial items in the diet of giant kokopu may be linked to their association with riparian vegetation, and their probable lifestyle as a 'skulking predator' may account for their preference for dense instream cover. However, in some situations aquatic items dominate giant kokopu diet and, perhaps, the description 'opportunistic' may be the best way to describe their feeding.

The habitat requirements of giant kokopu have previously only been described in a generalised manner, as most studies have concentrated on other aspects of the fish's ecology and biology, such as diet, age and growth. As part of a study on fish habitat and the effect of forestry practices, Taylor (1988) reported briefly on giant kokopu and their habitat attributes, from fish captured in South Westland. His results closely resemble what was found during this study, and can be summarised as follows:

- Giant kokopu were coastal, and records of their presence declined with distance inland and increased elevation
- They were found in a variety of habitats including coastal lakes, swamps, and slow-flowing rivers and streams
- They were mostly found in slow-moving water
- They were cover-dependant, and predominately associated with submerged, emergent and overhanging vegetation as well as submerged logs
- They were associated with murky, tannin-stained water with low pH and muddy substrates
- They seldom co-occurred with trout

Analysis of the chemical features we measured in the field were inconclusive, but, overall, it appears that giant kokopu are mostly found in acidic (low pH) waters, which, in the two regions where giant kokopu are most common, usually coincides with dark, tannin-stained water. Temperature preferences were not apparent, and although giant kokopu may be encountered more frequently in cooler water, this may simply be a function of their geographical distribution—there are many more giant kokopu records from Westland or Southland than from the warmer regions.

Until recently, giant kokopu were generally regarded as poor climbers, and although they are mostly found at low elevation, it has become increasingly obvious that some giant kokopu do travel considerable distances upstream and attain significant elevations. They are apparently also capable of ascending substantial waterfalls, as reported by Hanchet (1990). Landlocked populations of giant kokopu may occur both coastally and at considerable elevation and distance from the sea. Overall, however, the description 'coastal species' is quite fitting, and the probability of encountering giant kokopu appears to decrease with distance from the sea.

It may be that giant kokopu are coastal only because the type of habitat they prefer is found at low elevations. They may be more likely to occur in streams, rivers and drains if there is a direct connection to a body of fresh or estuarine water. In Westland and Southland giant kokopu were frequently encountered in relatively small streams and drains that were connected to the extensive coastal lagoons, swamps and lakes.

Initially there appeared to be some marked differences between habitat selection in Westland and Southland. Giant kokopu in Westland streams, ponds and lagoons were generally associated with instream cover consisting of logs and debris, and mostly with riparian cover consisting of native bush, scrub, flax or raupo. In Southland they were mostly found in streams and drains with instream vegetation cover and riparian cover mostly of grass. However, native bush and instream logs were certainly not a feature of the pastoral drains in Southland, and many of the areas sampled in Westland had little instream vegetation. All this implies that it is the presence of some form of instream and riparian cover that is important, rather than its composition. The presence of giant kokopu under culverts and bridges perhaps indicates that giant kokopu utilise these structures as 'cover' and further implies that lack of cover may be limiting giant kokopu populations in these areas. The success of artificial habitat structures in a small Westland stream emphasised the species' preference for logs and debris as instream cover, and for low water velocities. We would not encourage the construction of such structures in an attempt to enhance giant kokopu habitat and we do not imply that doing so would increase the standing stock of this species.

Juvenile and adult giant kokopu were sometimes caught in close proximity to one another, and there is little to indicate that juveniles occupy different habitats from adults. However, so few juvenile fish have ever been recorded on the NZFFD that we cannot rule out the possibility of their occupying some other types of habitat(s). Some smaller fish were found in faster-flowing water, perhaps because they were small enough to reside in the small gaps amongst the substrates and instream cover. Observations of giant kokopu in a pond in

Southland indicated that adults were more active at night, while post-whitebait juveniles became inactive, choosing to lie in extremely shallow water amid twigs, debris and weeds (Rasmussen 1990).

The lack of NZFFD records for juvenile giant kokopu does not necessarily mean juveniles are rare, or that they occupy habitats that have not been sampled. The lack may be attributable to one or both of the following:

- Juveniles may be much less likely to be caught using commonly applied sampling methods. Electrofishing is a size-biased technique, and large fish are more likely to be stunned and caught with an electric fishing machine (Lamarque 1990). This bias may be exaggerated in areas of dense instream cover where, even if stunned, small fish may not be seen. Juvenile fish are also unlikely to be caught in fyke nets set by commercial eel fishers, as small fish might either escape through the mesh or escapement tubes, or be eaten by larger fish (e.g. eels) caught in the net.
- Juvenile giant kokopu may not be correctly identified; they are not easily distinguished from banded kokopu until they reach about 120–150 mm in length, so that catches of juvenile giant kokopu may not be recorded.

7.2 SEASONAL PATTERNS AND SPAWNING

Virtually all the field work for this study was done in the autumns of 1998 and 1999, and there is no way of knowing if the habitat criteria described for the autumn are consistent for all seasons. It is quite possible that giant kokopu utilise quite different habitat for breeding, although the success of landlocked populations suggests that neither distinct nor separate spawning habitat, nor a marine life-stage, are obligatory. In diadromous populations the availability of spawning habitat (whatever that may be) is possibly a limiting factor. Until more is known of the spawning habits and habitats of giant kokopu, we can only speculate whether such habitat is limiting the stocks.

McDowall (1990) reported downstream migrations of significant numbers of ripe adult male giant kokopu during the late autumn and early winter, possibly coinciding with spring tides, and Jellyman (1979) found ripe males and females in April. The information presented by Rasmussen (1990) is unclear with respect to giant kokopu spawning time, as he reported that in various locations spawning had been mostly completed by late June and July, whereas ripe fish were also observed in August and September. He also reported that eggs were coated with a sticky gel, and that they sank quickly when placed in water and adhered to any material they touched in the water.

Having ‘sticky’ eggs and making downstream migrations near spring tides suggests that diadromous stocks of giant kokopu may have similar spawning habits to inanga (*G. maculatus*), which deposits sticky eggs amongst submerged marginal vegetation near peak spring high tides (McDowall 1990). The spawning of landlocked giant kokopu in ponds and lakes obviously would not be dependent on tidal cycles. Rasmussen (1990) postulated that landlocked giant kokopu did not spawn in response to changes in water level or flooding in ponds, and did not suggest any alternative.

Obviously, there is considerable need for knowledge of the spawning habits and habitats of giant kokopu if rational decisions on its management and conservation are to be made.

8. Conservation issues

8.1 ARE GIANT KOKOPU RARE, ENDANGERED OR VULNERABLE?

In recent times this species has generally been regarded as rare or uncommon, and it has been classified as a threatened species in the New Zealand Red Data Book (Williams & Given 1981). In many areas (e.g. South Canterbury) it is now very infrequently encountered, despite being common enough for early settlers to be interested in giant kokopu as a food item (Anderson 1916). The decline in numbers and distribution of giant kokopu in developed areas can probably be attributed largely to agricultural and urban development, leading to loss of suitable habitat, particularly the loss of suitable instream and riparian cover. The region where giant kokopu are now most common (Westland) is also probably the least developed. However, giant kokopu are also relatively common in Southland, where they are found predominantly in highly modified streams and drains, as well as dredge ponds and coastal lakes, amongst pastoral land that has been developed for many years. The common, and probably critical features, of habitats in both these regions are proximity and access to the sea, areas of low water velocity, riparian vegetation, and dense instream cover. Both Southland and Westland are also notable for an abundance of lagoons, estuaries, swamps, coastal lakes and ponds that may be of significance for giant kokopu populations.

Analysis of information from the NZFFD has shown that giant kokopu utilise a very broad range of water types, from small streams and drains, to rivers, ponds, swamps, and lakes. This feature, and their ability to form landlocked populations, may significantly lessen any vulnerability to extinction, though we would stress that survival of giant kokopu limited to landlocked populations should not be regarded as anything better than an extreme measure to be adopted as a last resort. Such a population would not represent the natural biological characteristics of the species, would in all probability contain only a fraction of the species' genetic diversity, and could be highly vulnerable to local extirpation. A conservation goal for giant kokopu must be retention of populations that undertake the sea-migratory life history.

8.2 IMPACT OF WHITEBAIT HARVESTING

Sampling shows that giant kokopu are taken in the whitebait fishery (McDowall & Eldon 1980; McDowall & Kelly 1999). Sampling data show that they tend to appear in the whitebait catch during early November, McDowall & Eldon (1980) suggesting about the second week. The most intensive fishing takes place in Westland, which is also where the greatest numbers of giant kokopu are found. Since the whitebait fishing season in Westland continues until 14 November (under the West Coast Whitebait Fishing Regulations), there is a period of overlap between capture of whitebait and the migration of giant kokopu. It was on the basis of this overlap, combined with concern about the conservation status of giant kokopu, that DOC proposed an earlier cessation of whitebait fishing in West Coast rivers in 1994. Data collected since that time (McDowall & Kelly 1999) suggest that migrations of giant kokopu persist through November and into December, which may be interpreted as indicating that capture of giant kokopu whitebait in the fishery need no longer be a matter of serious conservation concern. It seems to us that this question needs to be carefully considered. Data on this question are still quite sparse, and are based on rather erratic and inconsistent sampling. In particular, it is not yet known what proportion of giant kokopu migration takes place beyond the fishing season (after 14 November). Although the recent data do alleviate concerns, a precautionary approach is desirable. Obtaining further, and more reliable data on this question is a substantial and costly task. Ideally, what is required is to undertake a rigorous, quantitative sampling programme on a chosen river system in which day by day variation in the numbers of giant kokopu migrating is determined. Until that is done, we will be in a situation where all that can be stated with any assurance is that giant kokopu whitebait migrate late in the season, and continue to migrate at least into December.

8.3 IMPACT OF COMMERCIAL EEL FISHING

Eels constitute a significant fishery resource in New Zealand (Jellyman 1993), and in recent times there has been intensive commercial exploitation of eel stocks. It is possible that eel fishing has had some impact on giant kokopu populations, although any such impact would be difficult to measure. Most commercial eel fishing is done with fyke nets, in which giant kokopu also seem to be readily caught. Anectodal evidence from eel fishers, particularly in Southland and Westland, suggests that adult giant kokopu are frequently caught in some locations. While giant kokopu may be 'hardy' fish, being caught in fyke nets can only have a deleterious impact on stocks, as not all fish will survive being trapped in a fyke net, with numerous eels, for a night or more. Careless treatment of any giant kokopu in the nets may also result in significant mortalities.

There is a possibility that removal of eels by commercial fishers is of benefit to giant kokopu stocks. There certainly appear to be viable populations of giant kokopu in areas such as Southland that are heavily and regularly exploited by commercial fishers, some of whom might argue that removing large predators and competitors increases the survival and growth of other species.

Regardless of any impacts they may or may not have on native fish populations, some eel fishers do already provide important information on the distribution of giant kokopu, and other species. In fact, some eel fishers may be able to add significantly to our knowledge of the native fish fauna, in particular giant kokopu, as they probably have more interactions with the fish than anyone else.

There may be further potential for 'picking their brains' about aspects of giant kokopu life history, especially evidence of spawning migrations and habitats.

8.4 IMPACTS OF INTRODUCED SPECIES

There has been a long and active history of introducing exotic plants and animals into New Zealand (Thomson 1922), and although this has gained wide attention, there has been little explicit study of the relationships between the indigenous and introduced fish fauna (McDowall 1990). The potential impacts of introductions may include habitat disruption, competition for food or space, and predation.

Brown trout is the species thought most likely to be incompatible with giant kokopu. Analysis of the NZFFD indicates the two species are not mutually exclusive, but are less frequently found together than might be expected, given that both species are widespread and occur in a broad range of habitats throughout the country. There is little to suggest that the presence of brown trout would significantly disrupt the habitat for giant kokopu, and any impacts would most likely be from competition and/or predation.

Taylor & Main (1987) captured few giant kokopu, banded kokopu or koaro from habitats containing adult brown trout in South Westland, and Allibone (1997) observed a lack of sympatry between kokopu and salmonids in coastal Otago. Land-use changes, as well as the introduction of exotic species, may also have significant impacts on the native fish, as concluded by Minns (1990). It would be difficult to quantify these impacts or to distinguish between the causes, and Chadderton & Allibone (2000) concluded that a combination of the absence of both introduced fish and habitat destruction explained the higher abundance of large galaxiids and their use of mainstem habitats in some Stewart Island streams.

8.5 CONSERVATION AND MANAGEMENT OF GIANT KOKOPU

A frequently expressed strategy for conserving and managing fish stocks could be summarised as: 'Take care of the habitat and the fish will take care of themselves'. There is an underlying assumption that populations of giant kokopu are limited by habitat, mainly because the decline in stocks has apparently matched a decline in available habitat. Much of the decline in the abundance of New Zealand freshwater fish can be attributed to human impact, mostly by changes to the habitat. Since the time of human occupation, impacts have included: extensive deforestation, impoundment of rivers, pollution, eutrophication, wetland drainage, water abstraction and the introduction of a host of plants, pests and animals that modify the habitat. If we wish to retain stocks of indigenous fish, it is obvious that we need to identify and conserve their habitat, and even restore it where practical.

Presumably the task of locating giant kokopu habitat will continue to be based on field survey work, and involve two separate processes: an assessment of the habitat to see if it meets the identified criteria, and sampling to establish if giant kokopu already occupy it. Both processes are enhanced by knowledge of the habitat requirements of the species.

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Appendix 1

IDENTIFICATION OF GIANT KOKOPU

One of the purposes of this report is to provide DOC field managers and staff with information that helps them to identify giant kokopu habitat (and then conserve this habitat as a way of conserving the species). Critical to identifying giant kokopu habitat is being able reliably to identify the species at all life stages. In this section this issue is dealt with in some detail.

At large size, identification of giant kokopu is no problem once observers are familiar with a few diagnostic details. In particular, large giant kokopu (above about 150 mm) are distinctive and easily identified by having a profusion of small gold spots, lines, rings and crescents that cover the entire body except the belly, and spread onto the base of at least the dorsal fin. Otherwise the fish is usually a dull brown-olive, usually quite dark. These gold markings prompted Charles Douglas, noted early Westland surveyor, to refer to giant kokopu as the fish that:

> 'carries the Hebrew alphabet about with him. I don't know whether the fish has all the letters and I am not even sure if they are Hebrew characters. They may be Sanscrit; but on the cock-a-bullas black body are yellow markings like the characters seen in the handwriting on the wall in pictures of Belshazzars feast' (McDowall, 1980).

Other diagnostic characters include that: the jaws are equal; the mouth is very large, reaching well back past the eye; the origin of the anal fin is a little behind the level of the origin of the dorsal fin; and in many instances simply the large size is diagnostic; few other New Zealand galaxiids grow to more than 200–250 mm long, and those that exceed this length do so quite rarely. At this size, the colouration and thick-set build of the giant kokopu are highly distinctive (Fig A1.1).

It is not so simple with the whitebait stage through early juvenile life.

The following account of diagnostic characters for identification of whitebait is based on examination of specimens that are well preserved and, particularly, specimens that are placed in preservative (formalin or alcohol) soon after

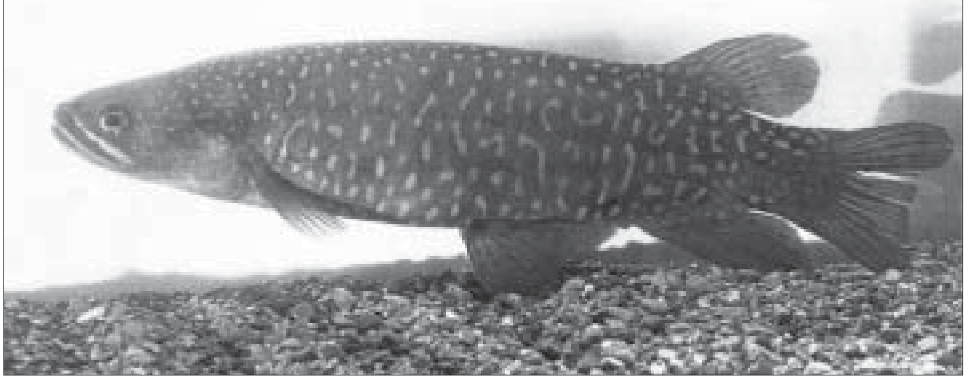


Figure A1.1 An adult giant kokopu, approx. 280 mm in length.

capture. It is important that they be preserved in plenty of liquid so that body shape is not distorted, and that fins are able to assume natural shapes and positions. Specimens that are poorly preserved, that are not preserved until well after capture, or which are preserved after being frozen, pose much more difficult identification problems.

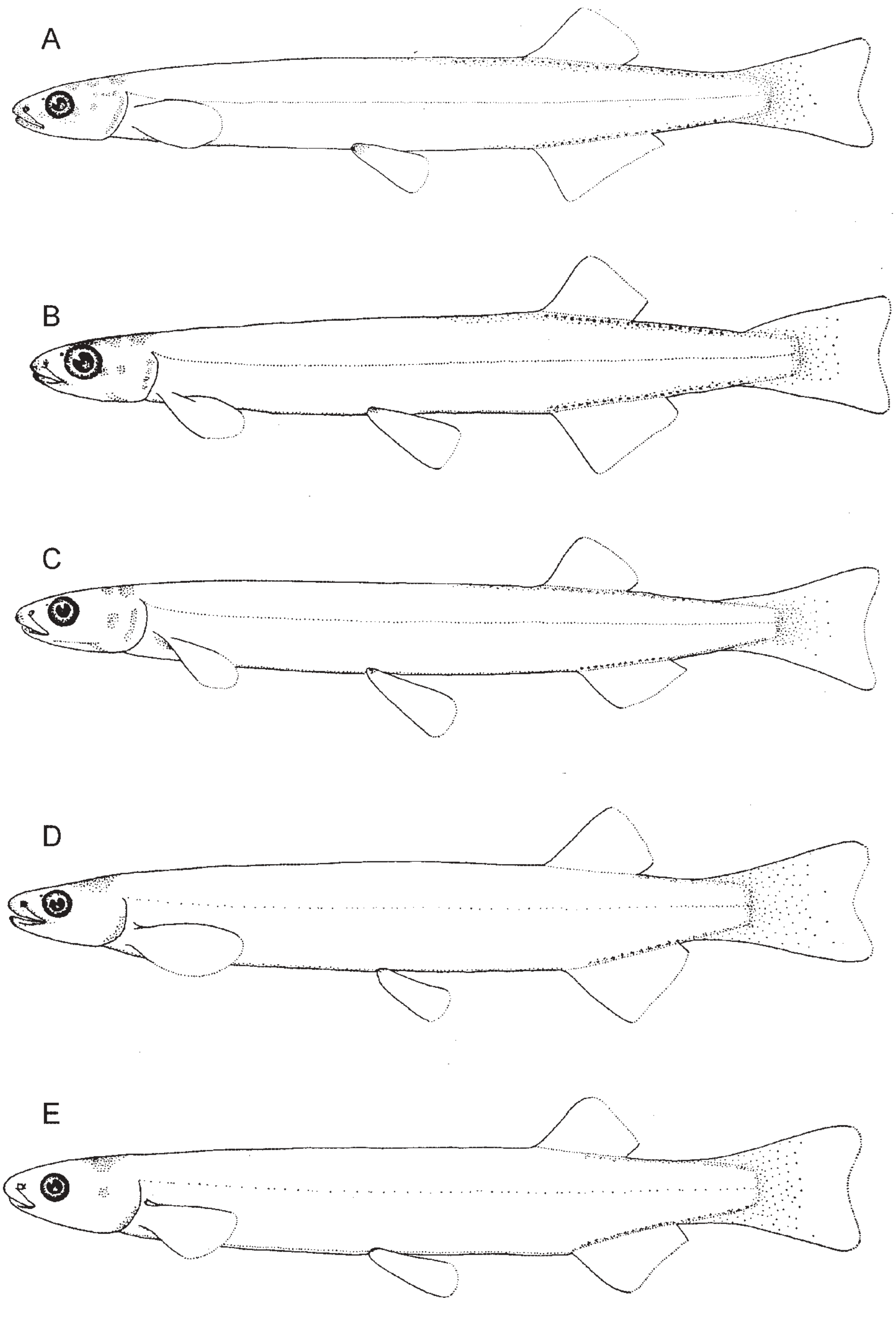
Below are presented a series of protocols for whitebait identification. The protocols are, to some extent, structured around comparative characters and, only to a limited extent, on individual species' diagnostic characters. Moreover, they are based on an assumption that the samples needing identification contain several species of whitebait. Though it is usually reasonably safe to assume that there are inanga whitebait in any whitebait sample, it cannot be assumed that there are always either or both of koaro and banded kokopu. It can normally be assumed that giant kokopu are unlikely to be present. Therefore, the identification protocols discussed below, which are difficult to apply at the best of times, create additional problems where samples do not contain several species, especially when a fundamental criterion is relative size. However, some of the criteria are not size-dependent and are therefore helpful with samples of limited species diversity. The only solution to this problem is for observers to develop experience with identifying the species from known mixed-species samples, and to apply the experience gained to those that may not be multi-species samples. If this seems imprecise and tortuous, it simply reflects the difficulties involved in identifying whitebait from catch samples.

Identification protocols

Although it is known that five species of *Galaxias* have whitebait juveniles that are taken in the fishery (Fig. A1.2), at present no diagnostic criteria have been identified that permit identification of the whitebait of the shortjaw kokopu, *Galaxias postvectis*. It is known that this species is amongst the whitebait captured from captive rearing of samples through to a stage when identification is possible. Owing to the rarity of adult shortjaw kokopu (McDowall et al. 1996) it is considered likely that its whitebait is also rare in the fishery. This means that its separation from the other species is even more difficult, but that failure to do so does not seriously distort analysis of catch. A few shortjaw kokopu whitebait are evidently being misidentified amongst the koaro whitebait. Therefore the protocols below deal with only four species.

The whitebait stage of the giant kokopu closely resembles the comparable stages in the three other whitebait species, and is typically rare amongst the catch. Because of the sparseness of giant kokopu whitebait and their similarity to the other species, finding them in a mixed-species catch is quite difficult. It depends, in the first instance, on having good familiarity with the other species in the catch. Confusion with the whitebait of inanga is unlikely, as these are distinctive in size, shape, and colour pattern, are usually by far the most abundant in the catch, and can easily be separated out by competent observers. One of the primary criteria is size—inanga whitebait are usually the largest in any sample. However, it is not possible to specify their absolute size, as there is geographical and temporal variation in the size of all whitebait species at migration. Fish from northern and eastern parts of New Zealand are typically smaller than those from western and southern locations. Moreover, size at migration at any location varies through the season with a late-season decline in

Figure A1.2 Juveniles of the migratory ('whitebait') species of *Galaxias*: A inanga (*G. maculatus*); B banded kokopu (*G. fasciatus*); C koaro (*G. brevipinnis*); D giant kokopu (*G. argenteus*); and E shortjawed kokopu (*G. postvectis*).



size being particularly noticeable. In addition to these size variations, size at migration may vary substantially from season to season (McDowall 1968; McDowall and Eldon 1980). Thus, any criteria for identification relating to size have to relate to the relative sizes of the various species. Relative size of inanga is a useful criterion with which to begin sorting samples, in part because very few whitebait samples lack inanga whitebait (it is by far the dominant species in the catch at all locations and times).

An additional complication in identification comes from the fact that often whitebait samples contain not only a mixture of species, but a mixture of fish at various developmental stages. Especially towards the end of the spring, when whitebait have been running into the rivers for several months, and also especially if samples are caught some distance upstream from the river mouth, samples tend to include some fish that have spent several weeks in fresh water. These fish will have developed additional body pigmentation. For the purposes of sorting, therefore, any fish with a general dusky covering of black pigment spots need to be set aside, as do any fish that have lines of pigment spots that tend to form along the muscle bands as V-shaped lines, very fine and difficult to see. Criteria for separation here are, once more, difficult, as there is a continuum from freshly-run, transparent whitebait to well pigmented juveniles.

This issue having been dealt with, identification of the fresh-run whitebait can, therefore, usefully begin with sorting out inanga whitebait on the basis of:

- Size—they are the largest whitebait.
- The presence of large black spots on the back in front of the dorsal fin; these may be few, just anterior to the dorsal fin, or they may extend along the back, sometimes almost as far forward as the level of the pectoral fins.
- The lateral line is usually very clearly marked with large black spots along the middle of the sides; these two sets of spots give inanga whitebait a distinctly darker appearance and they tend to stand out in a mixed species sample.
- The origin of the dorsal fin is directly above the origin of the anal fin, so that a line through the two fin origins is perpendicular to a line through the fish's body axis.
- The pectoral fins tend to lie along the sides of the body, behind the head, and do not project laterally and face downwards (this may seem an obscure character, though once the contrast with other species is seen, it is easily recognised).
- The mouth is very small, almost embryonic-looking, extends back scarcely to the front of the eyes, and is typically surrounded by black pigmentation in the lips.

Having removed inanga whitebait from samples using the above criteria, the easiest part of identification is accomplished and, typically, a large proportion of the samples has been set aside. The later timing of the migration of giant kokopu is helpful in that it enables observers to focus on catches taken primarily in November—though occasional giant kokopu whitebait have been recorded during October (McDowall & Eldon 1980).

Once inanga whitebait have been removed, samples can usually be easily divided into two size groups:

- The longer whitebait are usually very pale with little or no black pigmentation except around the head, sometimes a lightly marked lateral line and some tiny black spots along the back, though usually few of these, if any.
- The head is flattened, the lower jaw distinctly shorter than the upper jaw.
- The origin of the anal fin is distinctly set back behind the origin of the dorsal fin. An imaginary line through the two fin origins is at a distinct angle to a line through the longitudinal axis of the fish's body.
- The pectoral fins are large, stick out distinctly from the body, and face downwards.

These are whitebait of koaro. They vary greatly in how stoutly built they are—sometimes very chunky and stocky, sometimes very slender and tapered.

Other whitebait in samples may be:

- Smaller, again with little pigmentation except around the head, though sometimes a lightly marked lateral line.
- The head is rounded, the lower jaw a little shorter than upper, but not markedly so.
- The origin of the anal fin is directly below the origin of the dorsal fin, so that a line through the two origins is perpendicular to a line through the axis of the fish's body.
- Again, the pectoral fins are large, stick out distinctly from the body, and face downwards.

These are banded kokopu whitebait.

Experience is that, particularly during early November, when sorting samples from the whitebait catch, having removed inanga whitebait (as above), and when attempting to sort and identify the remainder, there are few fish that are initially thought to be banded kokopu, but are a little larger and stouter in build. They are shorter and stouter than whitebait of koaro that are likely also to be in the catches. Initial confusion about assigning these fish to either banded kokopu or koaro draws attention to them.

If they are giant kokopu they are usually rapidly identifiable by the shape of the snout and the form of the mouth.

- The snout is rather longer and a little more pointed, but in particular, the jaws are clearly equal in length and the mouth large, reaching well below the eyes.
- The body is deeper and a little stouter in build than in other whitebait.
- The anal fin origin is set back a little from the dorsal fin origin, not as far as in koaro, though a line through the two fin origins is not perpendicular to a line through the fish's longitudinal axis.

These differences are slight and picking them requires experience, but once captured they make identification of giant kokopu whitebait reasonably reliable. In practice, the essential feature—form of the mouth—can be observed by gently pressing on the sides of the head to force the mouth to open, when the longish snout, quite clearly equal jaws and large mouth, can be seen. Use of a hand lens or low-powered binocular microscope certainly helps, especially when beginning to develop skills in identification, though are not essential and are less necessary for experienced observers.

Identification of post-whitebait juveniles is a little easier, though not much. Soon after leaving the sea, the giant kokopu whitebait develops a general covering of dark melanophores, and becomes greyish-black, with the belly silvery-grey. It continues to resemble post-whitebait of banded kokopu, but can be distinguished from koaro post-whitebait by the latter having chevron-shaped markings across the sides. Separation from banded kokopu continues to depend on characters discussed for the whitebait stage.

As colouration continues to develop, a series of pale blotches develops across the body of the fish—about 8–10 pale vertical bands to squarish blotches can be observed along the trunk. In this regard, the giant kokopu juvenile still closely resembles the banded kokopu at the same stage. Both species, as they grow and develop colouration, become much stouter in build (this also distinguishing

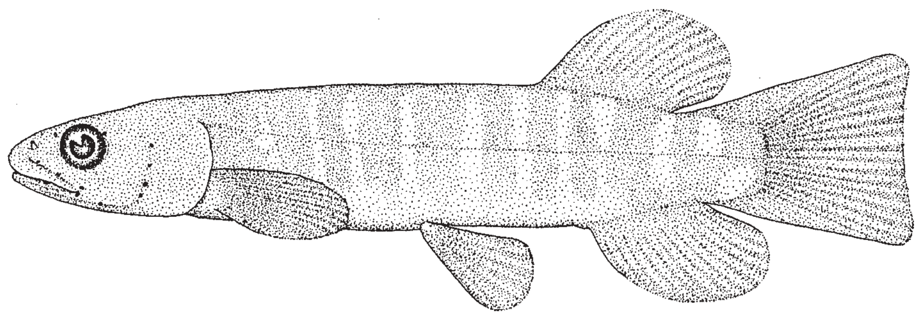


Figure A1.3 Juvenile of giant kokopu, 85 mm in length.

them easily from koaro at the post-whitebait stage, which become more slender). However, whereas in the giant kokopu these developing bands are largely confined to the sides, in the banded kokopu they tend to form a network across the back. The bands in giant kokopu tend also to be fewer and broader than in the banded kokopu. Mouth form and the relative positions of the dorsal and anal fins remain distinctive (the origin of the anal fin of the banded kokopu is directly below the origin of the dorsal).

As the young fish grow (to 60–90 mm), the colour patterns of the giant and banded kokopu become more different (Fig. A.1.3). Emphasis in the banded kokopu is towards increasing numbers of narrower bands across the sides, retention of the network of pale lines across the back that is continuous with those on the sides, and these markings tending to be grey-olive coloured; by contrast, in giant kokopu, the bands remain largely lateral, are broader, may be reduced to just a few broad, short lines or even blotches/spots, some disconnected lines may develop on the upper sides and back, and they are increasingly golden in colour.

Gradually, with further growth, these rather sparse bands in the giant kokopu are replaced by the profusion of small spots, lines, etc. characteristic of the adults. At intermediate growth stages the broad lateral botches can be seen as underlying the developing profuse spots, etc.

Throughout growth, size and form of the mouth remain distinctive in the giant kokopu.

Appendix 2

TYPES OF WATERWAY USED BY GIANT KOKOPU

Figure A2.1 A backwater/lagoon at the mouth of the Serpentine River, Westland. Several adult giant kokopu were caught amongst the logs, others were seen but not caught.

Figure A2.2 A small coastal stream/pastoral drain in the Catlins. An adult giant kokopu was caught amongst the stream vegetation opposite the net.

Figure A2.3 A coastal, swampy lagoon that drains into the Arahura river, Westland. Six giant kokopu were caught in one fyke net placed across this channel.

Figure A2.4 A small (< 3m wide) bush stream in Westland. Two giant kokopu were caught amongst the logs and debris.

Figure A2.5 A channelised stream/drain in pastoral Southland. Giant kokopu were caught amongst the dense instream vegetation.

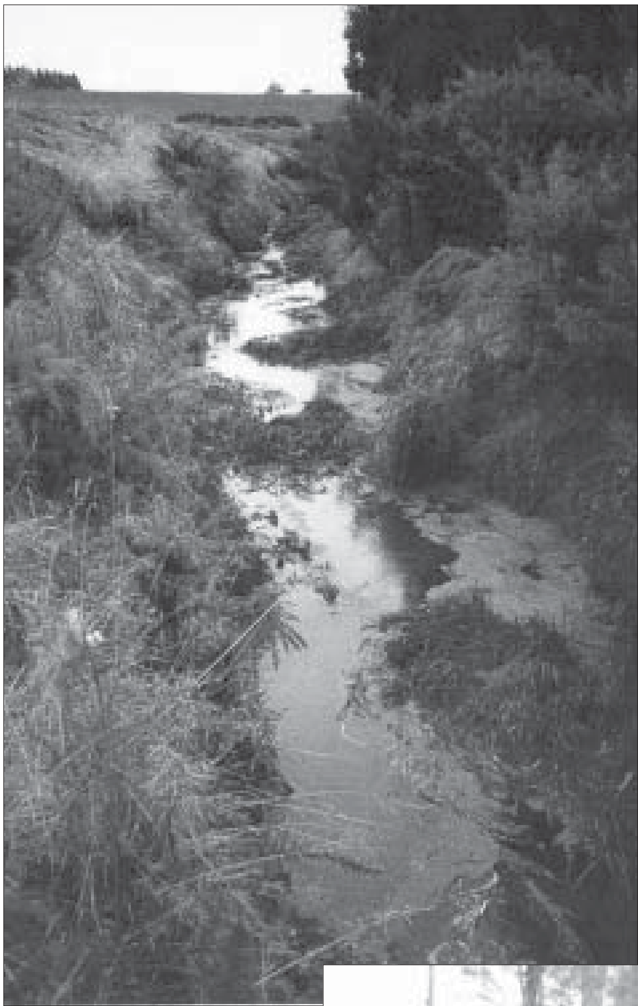
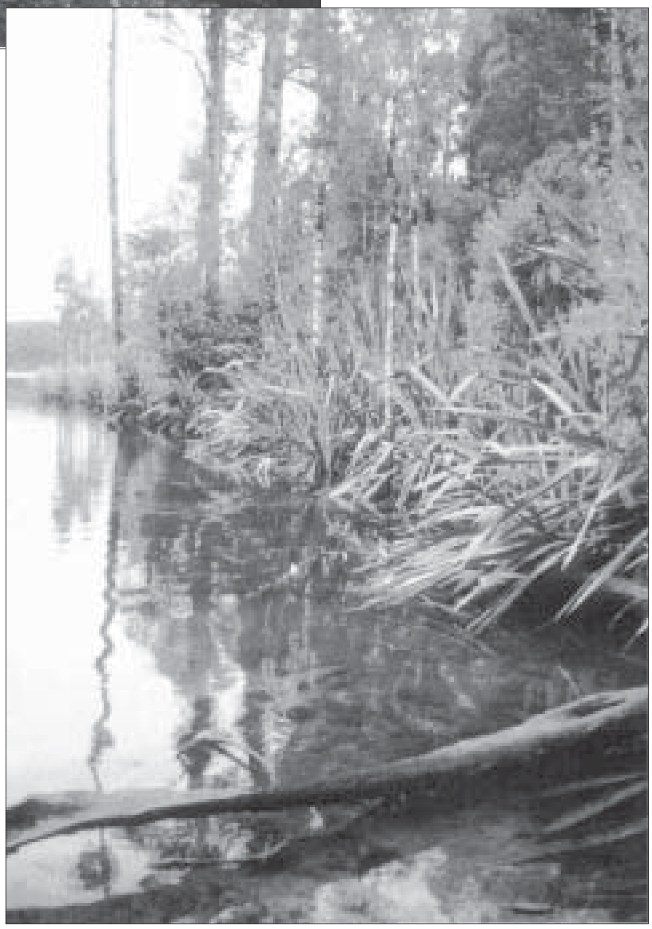


Figure A2.6 Lake Kaniere, Westland. Giant kokopu were caught in fyke nets set along the shores.



Appendix 3

CONSTRUCTION OF ARTIFICIAL HABITAT STRUCTURES

Figure A3.1 The edge of a pool in Viaduct Creek, Westland.

Figure A3.2 The same spot after construction of an 'artificial' habitat structure. Logs were attached to warratahs driven into the streambed and banks, and covered an area of approximately 3 m × 0.8 m. On each of two subsequent surveys, two giant kokopu were found under the logs.