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# Distribution of freshwater fishes in the Whakapohai River to Waita River area, South Westland

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# Distribution of freshwater fishes in the Whakapohai River to Waita River area, South Westland

by

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South Westland Management
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# SUMMARY

The distribution and composition of the freshwater fish fauna within the Whakapohai, Ship Creek, and Waita River catchments was studied from November 1984 to mid February 1985.

The methods and objectives of this survey were similar to those described by Main, Nicoll, and Eldon (1985). Habitat data were recorded at all sampling sites and the ecology of the fish fauna is discussed in relation to these.

Twelve native fishes and one introduced species, the brown trout, were recorded from the study area. Among the native fishes, the giant kokopu was widely distributed; it was recorded from each of the three studied catchments, though it is rare or absent in more developed regions of New Zealand. Ship Creek, in particular, contains a rich native fish fauna, including the scarce short-jawed kokopu, and the Waita River contains commercially utilised eel and whitebait fisheries. Both of these waters are recommended for conservation.

Implications for freshwater fisheries in the study area are discussed and recommendations about future land use are made.

# 1. INTRODUCTION

In late 1984 the New Zealand Forest Service (NZFS) granted further financial support for Fisheries Research Division (FRD) of the Ministry of Agriculture and Fisheries (MAF) to participate in the South Westland Management Evaluation Programme (SWMEP).

In response to the extended financial support, further field work was undertaken in South Westland similar to that described in the first stage of the SWEMP fish survey (Main, Nicoll, and Eldon 1985). Two employees, under the direction of FRD, conducted field work in the area from the Whakapohai River in the north to the Waita River in the south. Duration of the field work was from 4 November to 21 December 1984 and from 13 January to 16 February 1985. Ecological data relevant to the distribution of native freshwater fish were obtained within the study area.

The objectives of FRD, outlined by Main, Nicoll, and Eldon (1985), remained unchanged for the second stage of the survey. These were to determine the distribution, relative abundance, and habitat requirements of native freshwater fishes and the probable impact of various forest management regimes upon fishery values.

Within the study area three catchments, Whakapohai, Ship Creek, and Waita, were identified as priority areas. The first catchment was selected for its potentially high value for native fish, owing to its reportedly low trout population (Coker and Imboden n.d.). This catchment was also chosen because of its elevated terrain compared with the other two systems.

The Ship Creek catchment was selected because analysis of whitebait samples indicated that koaro were more common than expected from a "brown-water stream", and that banded kokopu were particularly common in the system (McDowall and Eldon 1980).

The Waita catchment was surveyed because it has an important whitebait fishery (McDowall and Eldon 1980). Also, an expanse of low-lying pakihi swamp forms a significant part of the catchment, which was considered to hold high potential as a giant kokopu habitat.

All three catchments, having a combined area of 242 $km^2$, are contained within the Mataketake State Forest (Fig. 1).

## 2. STUDY AREA

The Mataketake State Forest encompassed the study area, though some sections of the area are under leasehold or freehold tenure. Private land on the north side of the Whakapohai River mouth is largely unmodified, with some residential sections next to the lagoon. A large block of leasehold land within the Forest is utilised for deer trapping.

The rock formations surrounding the Whakapohai catchment are mainly undifferentiated greywacke (Match and McKellar 1964). This is covered with upland and high-country podzolised yellow-brown earths which form the soil type over the remainder of the study area above 60 m a.s.l. (Cutler 1964). The southern faces of Law and Bald Hills, the watershed for the northern tributaries of Ship Creek, consist of morainic deposits and greywacke rock containing thin seams of limestone and sulphurous coal. Above the Alpine Fault at about 60 m a.s.l, in the area south of Ship Creek to the Haast River, the Mataketake Range is predominantly gneiss and schist, but below the fault recent alluvium and beach deposits are prevalent. Soil types below 60 m a.s.l. consist mainly of lowland podzolised earths, but organic soils underly the expanse of pakihi surrounding Bayou Hill.

Weather records were kept at the old Haast township, 4 km south of the Mataketake State Forest, from 1941 to 1976 (N.Z. Meteorological Service 1983). The average annual rainfall is 3458 mm, with the highest precipitation in spring and the lowest in winter. On average Haast receives 178 rain days a year, but because rainfall increases

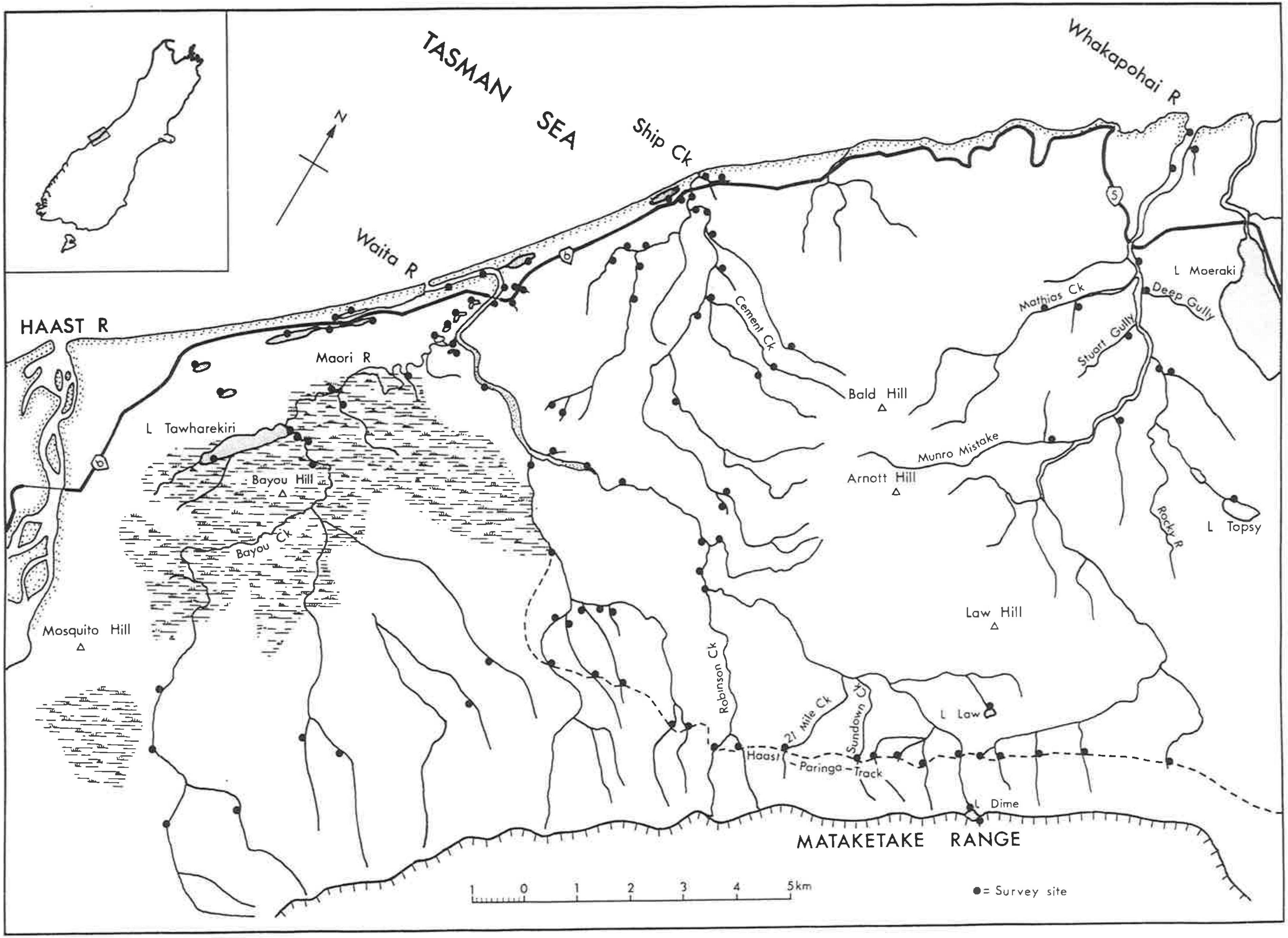


FIGURE 1. Study area, showing sampling sites, rivers, and localities mentioned in the text.

dramatically with altitude (Wards 1976), the Mataketake Range is probably wetter than the coast.

The humidity of the region is always high with a mean annual relative humidity of 83%. Average monthly figures for the period between 1949 and 1970 show that humidity peaks in late summer at 86% and drops to 79% in mid winter.

The human population of the region is sparse, with only 14 people residing permanently within the study area. Seasonal influxes of temporary residents occur during the whitebait season (1 September to 15 November), when about 100 people may inhabit the region, with as many as 65 people occupying huts on the south bank of the Waita River, west of the bridge (T. O'Regan pers. comm.).

## 2.1 Mataketake State Forest

The Mataketake State Forest is an extensive region of about 532 $km^2$ which encompasses five major river catchments. State Highway 6 (S.H.6) runs adjacent to the forest's western boundary which is the coastline between the Moeraki and Haast Rivers, and these rivers form the northern and southern borders (Fig. 1). The forest extends east to unoccupied crown land (u.c.l.) and a line running north-south along to the Macfarlane River. Paringa State Forest lies beyond the northern boundary and Okuru State Forest and Mount Aspiring National Park lie to the south.

An extensive low-lying area of about 21 $km^2$ lies in the south western corner of the State Forest. This region has the characteristics of "pakihi" in terms of land form, vegetation, and soils as described by Mew (1983). Due east of the pakihi and running parallel to the coastline, the Mataketake Range rises to an altitude of 1307 m.

Silver beech (*Nothofagus menziesii*) and kamahi (*Weinmannia racemosa*) are prevalent canopy species throughout the State Forest except at low elevations where totara (*Podocarpus totara*), rimu (*Dacrydium cupressinum*), and kahikatea (*Dacrycarpus dacrydioides*) are more common. Whitey wood (*Melicytus ramiflorus*) is predominant in the subcanopy, particularly in the Whakapohai River catchment. Tutu (*Coriaria arborea*), fuchsia (*Fuchsia excorticata*), and mako-mako (*Aristotelia serrata*) are common regenerative species along the beds and banks of the rivers. On either side of S.H.6 between the Haast and Waita Rivers, lies a series of dune lakes which are encircled with emergent vegetation, mostly *Juncus* spp., *Eleocharis spacelata*, nigger heads (*Carex secta*), stunted manuka (*Leptospermum scoparium*), and flax (*Phormium tenax*). All of these, except *Eleocharis*, are also common in the lowland pakihi.

## 2.2 Catchments

### 2.2.1 Whakapohai River

The Whakapohai is a small rain-fed river which rises in the Mataketake Range at an altitude of about 1230 m a.s.l. It flows for about 16 km and has a catchment of about 61 km$^2$. In the upper reaches, the flow is swift, with occasional falls, tumbling over very rocky substrata.

The mainstem river bed is composed mainly of cobbles and gravel. Large deep backwaters and pools 3-4 m deep, as well as shallow riffles, occur frequently. The backwaters and pools contain very clear water and have a sand and gravel bottom, offering little cover for fish. The flood plain widens steadily to be about 300 m wide at the mouth. The mouth was partially closed at the time of the survey, with only a narrow, shallow, and swift channel permitting egress to the sea. The condition of the mouth was probably atypical; alluvium would not build up during periods of higher, more normal river flow (McDowall and Eldon 1980).

2.2.2 Ship Creek

Ship Creek is a small, shaded, rain-fed river which rises on Bald Hill at an altitude of about 700 m a.s.l, though some tributaries drain an expanse of lowland bush north of the Waita River. The creek flows for 11 km and the catchment has an area of about 28 $km^2$. The drainage pattern of the Ship Creek catchment is more dendritic (i.e., it branches more frequently) than those of the Whakapohai and Waita Rivers.

At elevations over 160 m a.s.l. the tributaries rising from Bald Hill often contain very large boulders, 2-3 m across, and gravelly pools usually less than 1 m deep form at their bases. The pools are linked by cataracts and small falls flowing through clefts between adjacent boulders. At lower altitudes boulders are absent, with pools forming to a depth of about 2 m. Submerged logs become prevalent below 20 m a.s.l. and, together with deeply undercut banks, provide ample instream cover. Macrophytes are abundant only in shallow feeder streams in clearings, probably because here there is little light attenuation to limit photosynthesis, unlike in deeper waters (Kirk 1976). Before the tributaries join the mainstem, the flow becomes sluggish and more uniform, and the water becomes increasingly tannin-stained at lower elevations, where it flows over a bed of sand, gravel, and cobbles.

The tributaries draining the forest in the south of the catchment are deeply entrenched, slow moving streams with sand and gravel bottoms.

A small tributary, previously investigated by McDowall and Eldon (1980), rises from podocarp forest north of the S.H.6 bridge. This stream is of a different character from the rest of the catchment. The water is both more tannin-stained and acidic (pH 4.9) than the mainstem, and, after passing through a culvert under S.H.6, the stream widens and flows over a gravelly bed about 5 m wide. After flowing through a short series of riffles, runs, and small pools, the stream discharges into the mainstem about 500 m from the mouth.

A narrower tannin-stained tributary enters the mainstem on the opposite bank and drains a small area of swamp.

McDowall and Eldon (1980) reported a close correlation between water colour and pH, and they noted that brown, tannin-stained water is significantly more acidic than that from clear-water sites. However, headwaters of the Ship Creek catchment, though tannin-stained, have a surprisingly high pH. It appears that limestone deposits in the faulted regions of Bald Hill may increase the hardness and pH of the runoff water (see section 6.1.5).

The mouth of Ship Creek is frequently closed by heavy westerly seas (McDowall and Eldon 1980) and was almost closed at the time of the survey.

### 2.2.3 Waita River

The rain-fed Waita River rises from the Mataketake Range at about 1220 m a.s.l. and flows for about 18 km. The catchment of about 152 $km^2$ comprises the western face of the Mataketake Range, its lowlands, an expanse of pakihi, and the south-western faces of Law and Arnott Hills.

The tributaries rising from the Mataketake Range are all swift, tumbling, clear-water streams with numerous boulders in the higher reaches. Above 150 m a.s.l. the headwaters are deeply gorged, often incorporating small falls with occasional pools. Downstream, the torrential flow abates with decreasing gradient, and riffle and run sequences become more frequent.

In the higher reaches, the mainstem of the Waita River follows the base of Law and Arnott Hills, and it receives tributaries from both these and, in the northern half, from the Mataketake Range. Initially confined in a narrow steep-sided valley, the river alternates between deep pools and torrents.

At about 50 m a.s.l. the river flows out of the valley to become broad and shallow, with extensive areas of riffles. A wide flood bed develops with pastured sections grazed by cattle. Braiding develops in the 5 km of the mainstem above its confluence with the Maori River. The braids are shallow, with depths between 5 and 30 cm, which renders the river prone to moderate diurnal temperature fluctuations (McDowall and Eldon 1980).

Headwaters draining the southern half of the Mataketake Range meander through a large expanse of lowland pakihi before joining to become the Maori River, the Waita's major tributary. At its head the Maori River broadens into a shallow (0.8 m) fairly warm lake (Lake Tawharekiri). However, further downstream, below the confluence of pakihi-derived tributaries, the tannin-stained river deepens, entrenches, and cools considerably.

Below the junction with the tannin-stained Maori River, the Waita River, formerly clear and braided, becomes light-tea coloured and channelised, with riffles flowing over gravel bars. Although river flats are pastured and grazed, forest often encroaches and overhangs the river. Undermined trees produce deep, current-scoured pools in the gravel and cobble bed.

A series of dune lakes, formed in the gullies of forested sand dunes, runs parallel and adjacent to the coastline. Interspersed between the Haast River in the south and the Waita River in the north, these characteristically long narrow lakes have terminally placed, often diffuse, outlets which feed into the Waita River near its mouth and possibly at points along the Maori River (Figs. 2 and 3).

Within the tidal reaches downstream of S.H.6 the river is fast flowing, and wide, with little instream cover, though placid backwaters are also present on the eastern bank near the mouth.

The location of the river mouth along the coast is variable owing to the influence of prevailing winds. At the time of the survey, the mouth was 1 km south of the location depicted on the NZMS1 Topographical Map series map S87 (1970 edition). It appears that the mouth has breached the southern end of the lagoon shown on the map.

## 3. MATERIALS

Sampling equipment was described in the earlier study by Main, Nicoll, and Eldon (1985). In this study gill nets were particularly useful for fishing the dune lakes in the Waita River catchment. Single and double-wing fyke nets were used in the lake shallows, large pools, and ponds. Minifykes were frequently set in shallow, placid water less than 0.6 m deep.

FIGURE 2. A coastal dune lake near the mouth of the Waita River. (Photo. M. Main)

FIGURE 3. A forested dune lake in the Waita catchment. (Photo. M. Taylor)

Access to habitats was facilitated by a long-wheelbase, four-wheel-drive vehicle, which was especially useful on wide river beds. Trail motorcycles were effective in negotiating very muddy regions. A helicopter was used in some remote areas, but the absence of landing sites meant access by foot was usually necessary.

## 4. METHODS

Methods were comprehensively described by Main, Nicoll, and Eldon (1985). Therefore the following description is only a supplement.

The old Haast-Paringa cattle track traverses the northern half of the Mataketake Range at about 690 m a.s.l., and it crosses tributaries of the Waita and Whakapohai Rivers (Fig. 1). This track was used as access to sample tributaries in these two catchments, during both the study period, and on 30 March 1985 when the streams from Waterfall Creek to 21 Mile Creek were resampled.

## 5. HABITAT, ECOLOGY, AND DISTRIBUTION OF THE FISHES

This section follows the format of Main, Nicoll, and Eldon (1985) in discussing habitats and distributions of fishes found within the study area. Our results, derived from ecological data collected in this study, are compared with the literature on life cycles and habitats of the species recorded. Descriptions of all freshwater fishes caught in this study have previously been outlined by Main, Nicoll, and Eldon (1985). Consequently, in this report only the distribution and ecology of fish species in the study area will be discussed. In each catchment the percentage that each species contributed to the total catch, and the percentage of sites where a species was recorded, are presented in

Table 1. For each species, (excluding the short-jawed kokopu, blue-gilled bully, brown trout, and black flounder for which there were insufficient data), a habitat profile figure has been compiled (see Figs. 6, 7, 9, 11, 12, 13, 15, 17, and 18).

The data from sites where a particular species was recorded were examined to determine the percentage frequency with which certain habitat features occurred. These data are shown as the first set of histograms (a) on the habitat profile figures. Habitat features for all sites from which fish were recorded have also been expressed as percentages of their incidence. These percentages are shown in the second set of histograms (b) on the habitat profile figures for each species. These indicate how frequently habitat features were recorded from sampling sites throughout the study area.

The third set of histograms (c) on the habitat profile figures are derived by dividing the percentages in the first set (a) by the percentages in the second set (b) for each respective habitat feature. These histograms reflect how habitat features associated with a fish species, differ from the extent that the same features appear in the general study area. Appendix I shows the distribution of the fishes by catchment.

TABLE 1. Number of each species of fish recorded in each catchment, percentage of the catchment sites from which each species was recorded, and percentage of the total fish recorded in each catchment

| Species | Whakapohai River catchment | | | Ship Creek catchment | | | Waita River catchment | | |
|---|---|---|---|---|---|---|---|---|---|
| | Number recorded | % of catchment sites | % of catchment total | Number recorded | % of catchment sites | % of catchment total | Number recorded | % of catchment sites | % of catchment total |
| Common bully | 6 | 4.3 | 3.4 | 32 | 6.7 | 12.2 | 24 | 7.6 | 5.2 |
| Blue-gilled bully | 3 | 4.3 | 1.7 | 3 | 1.4 | 1.1 | 0 | 0 | 0 |
| Red-finned bully | 33 | 13.0 | 18.9 | 37 | 14.8 | 14.1 | 65 | 10.2 | 13.9 |
| Inanga | 22 | 8.7 | 12.6 | 47 | 14.8 | 17.9 | 66 | 12.7 | 14.2 |
| Banded kokopu | 2 | 2.2 | 1.1 | 37 | 12.2 | 14.1 | 1 | 0.8 | 0.2 |
| Giant kokopu | 4 | 2.2 | 2.3 | 12 | 8.1 | 4.6 | 21 | 8.5 | 4.5 |
| Short-jawed kokopu | 0 | 0 | 0 | 1 | 1.4 | 0.4 | 0 | 0 | 0 |
| Koaro (adults) | 58 | 23.9 | 33.3 | 37 | 9.5 | 14.1 | 18 | 5.9 | 3.9 |
| Koaro (juveniles) | 2 | 4.3 | 0.6 | 15 | 4.1 | 5.7 | 4 | 2.5 | 0.9 |
| Short-finned eel | 0 | 0 | 0 | 4 | 2.7 | 1.5 | 80 | 13.5 | 17.2 |
| Long-finned eel | 19 | 21.7 | 10.9 | 28 | 17.5 | 10.6 | 132 | 21.2 | 28.3 |
| Brown trout (adults) | 1 | 2.2 | 0.6 | 5 | 1.4 | 1.9 | 11 | 5 | 2.4 |
| Brown trout (parr) | 1 | 2.2 | 0.6 | 2 | 2.7 | 0.7 | 18 | 6.8 | 3.9 |
| Black flounder | 2 | 4.3 | 1.1 | 1 | 1.4 | 0.4 | 0 | 0 | 0 |
| Torrentfish | 21 | 8.7 | 12.0 | 1 | 1.4 | 0.4 | 26 | 4.2 | 5.6 |
| Total | 174 | | | 262 | | | 466 | | |

## 5.1 Habitat Features

### 5.1.1 Water Temperature

Despite the limitations of temperature data based on spot recordings, general conclusions can be reached about temperature and fish habitats.

Swampy ponds and dune lakes reached the highest temperatures with an average recorded temperature of 16.6°C from 16 readings (s.d. = 2.76°C, c.v. = 17.3%). A fairly high reading of 23°C was recorded at Lake Tawharekiri where the water is very shallow and exposed to the sun. However, free-flowing streams and rivers were much cooler, particularly at high altitudes, with an average temperature of 12.2°C based on 73 spot recordings (s.d. = 2.5°C, c.v. = 20.4%).

Average water temperatures of habitats for the various fish species caught are listed in Table 2.

### 5.1.2 pH

With the exception of three sites, pH recordings were taken at all sampling localities. Table 3 shows the means and ranges of pH for the habitats from which each species was collected, based on data from this stage of the fish survey. The pH means and 95% confidence intervals for each fish is shown in Figure 4.

Although the average pH, based on 105 samples, was 6.4, values ranged from 4.1 in a pakihi-derived pond, to 7.3 in a northern tributary of Ship Creek. Both of these habitats contained fish. Acidity was high in swampy ponds, dune lakes, and tributaries draining regions of pakihi,

TABLE 2. Temperature data for habitats from which fishes were recorded (between 4 December 1984 and 17 February 1985)

| Species | Mean (°C) | Standard deviation | Sample size | Range |
|---|---|---|---|---|
| Common bully | 14.1 | 2.90 | 12 | 10.3-19.5 |
| Blue-gilled bully | 14.0 | - | 1 | - |
| Red-finned bully | 13.4 | 1.12 | 21 | 11.0-15.8 |
| Inanga | 14.9 | 2.73 | 21 | 11.0-23.0 |
| Banded kokopu | 13.2 | 1.04 | 9 | 11.0-14.0 |
| Giant kokopu | 14.3 | 1.63 | 15 | 12.5-18.0 |
| Short-jawed kokopu | 14.0 | - | 1 | - |
| Koaro (adults) | 11.4 | 2.74 | 19 | 7.3-17.5 |
| Koaro (juveniles) | 12.8 | 1.36 | 5 | 10.5-14.0 |
| Short-finned eel | 15.8 | 2.99 | 18 | 11.5-23.0 |
| Long-finned eel | 14.7 | 2.62 | 29 | 11.0-23.0 |
| Brown trout (adults) | 14.8 | 3.86 | 8 | 11.0-23.0 |
| Brown trout (parr) | 12.8 | 0.92 | 8 | 11.0-14.0 |
| Black flounder | 13.0 | - | 1 | - |
| Torrentfish | 12.8 | 1.60 | 6 | 10.5-14.0 |

TABLE 3. pH data for habitats from which fish species were recorded

| | pH data for the Whakapohai, Ship Creek, and Waita catchments | | | | |
|---|---|---|---|---|---|
| Species | Mean | Standard deviation | No. of sites | Range | 95% confidence interval |
| Common bully | 6.3 | 0.58 | 14 | 4.9-7.2 | 6.0-6.6 |
| Blue-gilled bully | 6.9 | 0.27 | 3 | 6.6-7.1 | 6.6-7.2 |
| Red-finned bully | 6.7 | 0.54 | 28 | 4.9-7.2 | 6.5-6.9 |
| Inanga | 6.1 | 0.77 | 24 | 4.1-7.2 | 5.8-6.4 |
| Banded kokopu | 5.8 | 0.80 | 9 | 4.9-7.2 | 5.3-6.3 |
| Giant kokopu | 5.8 | 0.88 | 16 | 4.1-7.2 | 5.4-6.2 |
| Short-jawed kokopu | 7.1 | - | 1 | - | 0 |
| Koaro (adults) | 6.9 | 0.28 | 24 | 6.2-7.3 | 6.8-7.0 |
| Koaro (juveniles) | 6.8 | 0.67 | 11 | 4.9-7.4 | 6.4-7.2 |
| Short-finned eel | 5.5 | 0.90 | 18 | 4.1-6.6 | 5.1-5.9 |
| Long-finned eel | 6.3 | 0.67 | 37 | 4.7-7.2 | 6.1-6.5 |
| Brown trout (adults) | 6.5 | 0.38 | 8 | 6.0-7.3 | 6.2-6.8 |
| Brown trout (parr) | 6.9 | 0.22 | 10 | 6.5-7.2 | 6.8-7.0 |
| Black flounder | 6.6 | 0 | 2 | 6.6-6.6 | 0 |
| Torrentfish | 7.0 | 0.29 | 9 | 6.6-7.3 | 6.8-7.2 |

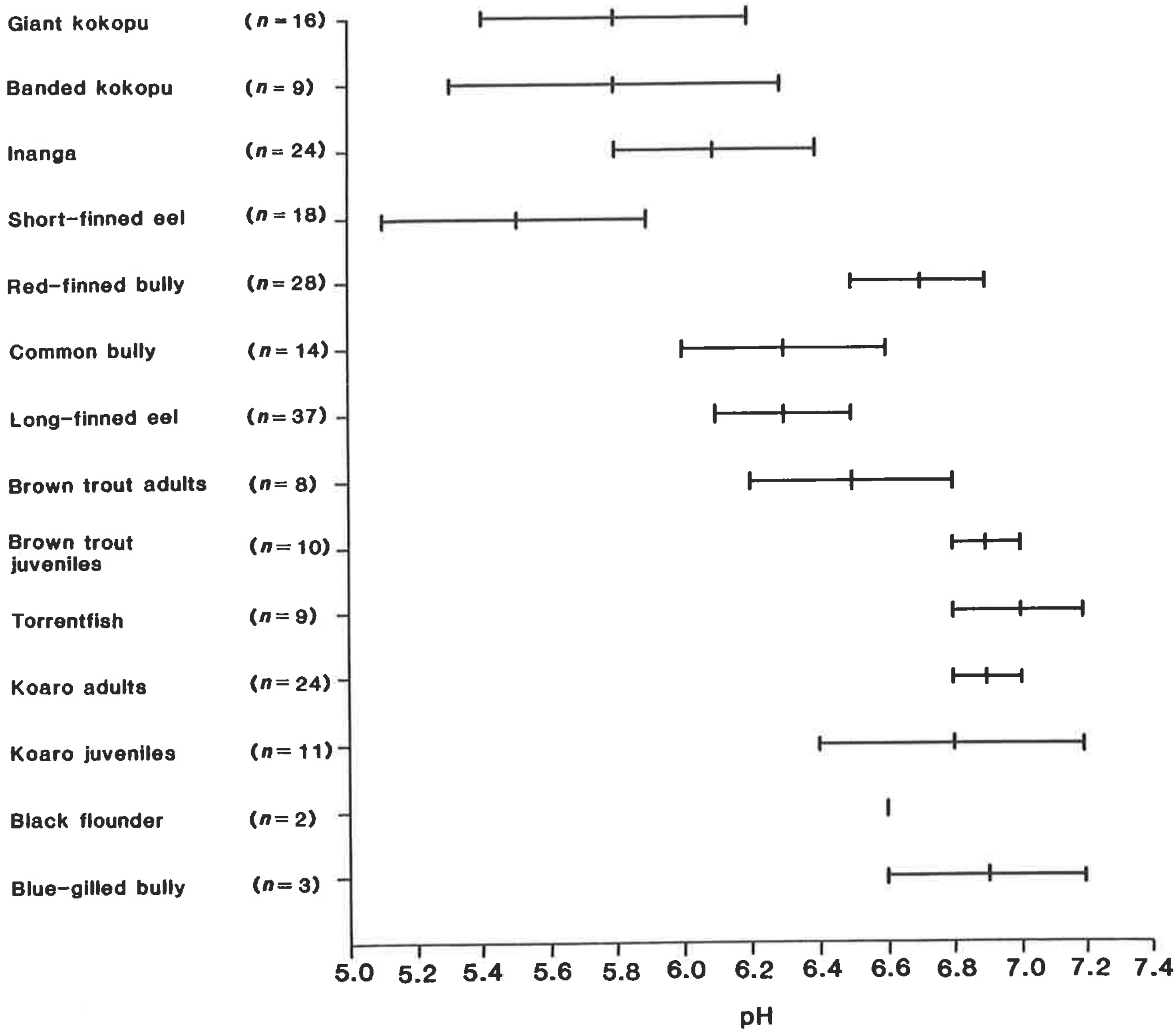


FIGURE 4. Mean and 95% confidence limits of pH from habitats of 12 fish species in South Westland, November 1984 - February 1985.

where the water is strongly influenced by the acidic nature of compounds released from decomposing vegetation (McDowall and Eldon 1980). A total of 20 pH recordings was taken from dune lakes, ponds, and swamps; the average pH was 5.5 (s.d. = 0.82, c.v. = 15%). Free-flowing rivers and streams were less acidic, particularly in steep terrain where runoff was faster, thus reducing the influence of decomposing plant material. An average pH of 6.7 was obtained from 81 sample site records along rivers and streams (s.d. = 0.47, c.v. = 7%).

## 5.2 Native Fishes

Of the 27 native freshwater fish species, 12 species, all diadromous, were recorded from the study area. With the exception of two species of the whitebait family and the short-finned eel, all native fish caught during the survey were endemic (i.e., found exclusively in New Zealand). The three non-endemic species are found in eastern Australia, and inanga, the predominant whitebait species, is also found in South America.

### 5.2.1 Long-finned Eel (*Anguilla dieffenbachii*)

The long-finned eel was the most ubiquitous fish species in the study area and was noted from 49.4% of survey sites where fish were recorded. It was often found with the short-finned eel, but the longfin occupied a more diverse range of habitats and penetrated further inland (Fig. 5).

Adult long-finned eels were found in pools and lakes, but they were also common in sluggishly flowing water courses. The migrating elvers, present in runs and riffles, penetrate further upstream than shortfin juveniles.

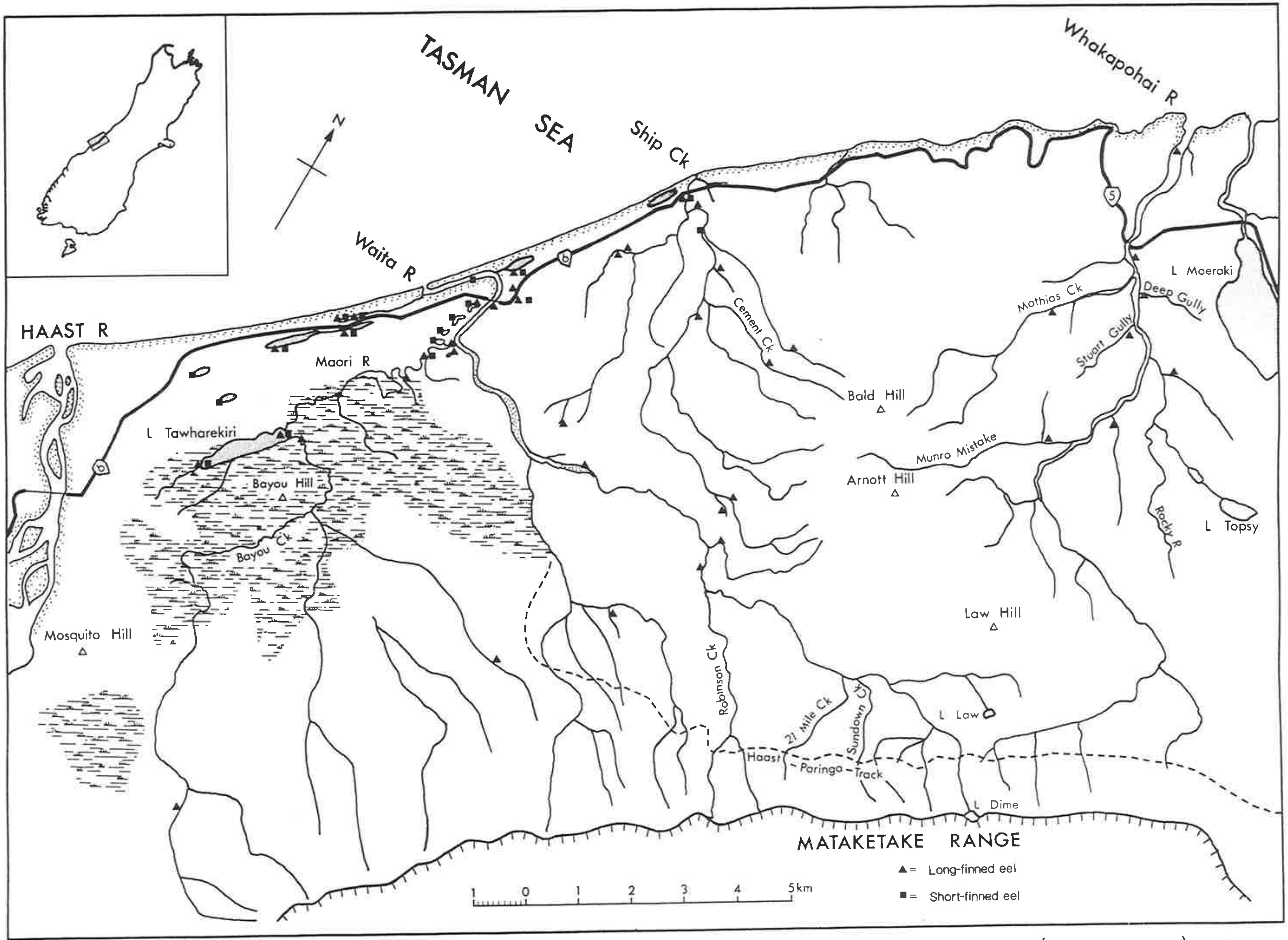




FIGURE 5. Sites from which long-finned eels (*Anguilla dieffenbachii*) and short-finned eels (*A. australis*) were recorded.

The habitat utilisation profile for the longfin (Fig. 6), is more uniform than that of the shortfin (Fig. 7). This indicates that the longfin was recorded from a wider range of habitat types than the shortfin.

The long-finned eel was found in mildly acidic to slightly alkaline waters, but it was less common in water of very low pH. The average pH of habitats where the longfin occurred (6.3) was higher than that of habitats where the shortfin was found (5.5), with a lower coefficient of variation (11%). The utilisation profiles for water colour parallel those for pH, because these factors are correlated (section 6.1.5).

In the higher reaches of the three catchments the long-finned eel utilised boulders and submerged logs as cover. Feeding normally occurs after dark, though individuals are often observed foraging during the day. At lower altitudes, long-finned eels utilised macrophytes, undercut banks, logs, and on occasions old root holes in the stream bed for cover.

Subjective observation of stomach contents showed that smaller eels feed on insects of aquatic and terrestrial origin. During the summer many large adult cicadas and dragonflies became trapped on the water surface, and these were often taken by long-finned eels. Other insects ingested were ground beetles (Carabidae), ground wetas, (Stenopelmatidae) and cave wetas (Raphidophoridae). Many of these insects are seasonal and so are available as food only at certain times of year. This suggests, as noted by Cairns (1942), that long-finned eels are opportunistic feeders, ingesting insects available at the time, rather than feeding selectively on a few species.

Our observations support the view of Cairns (1942) that as eels get larger they supplement their insect diet with increasing quantities of

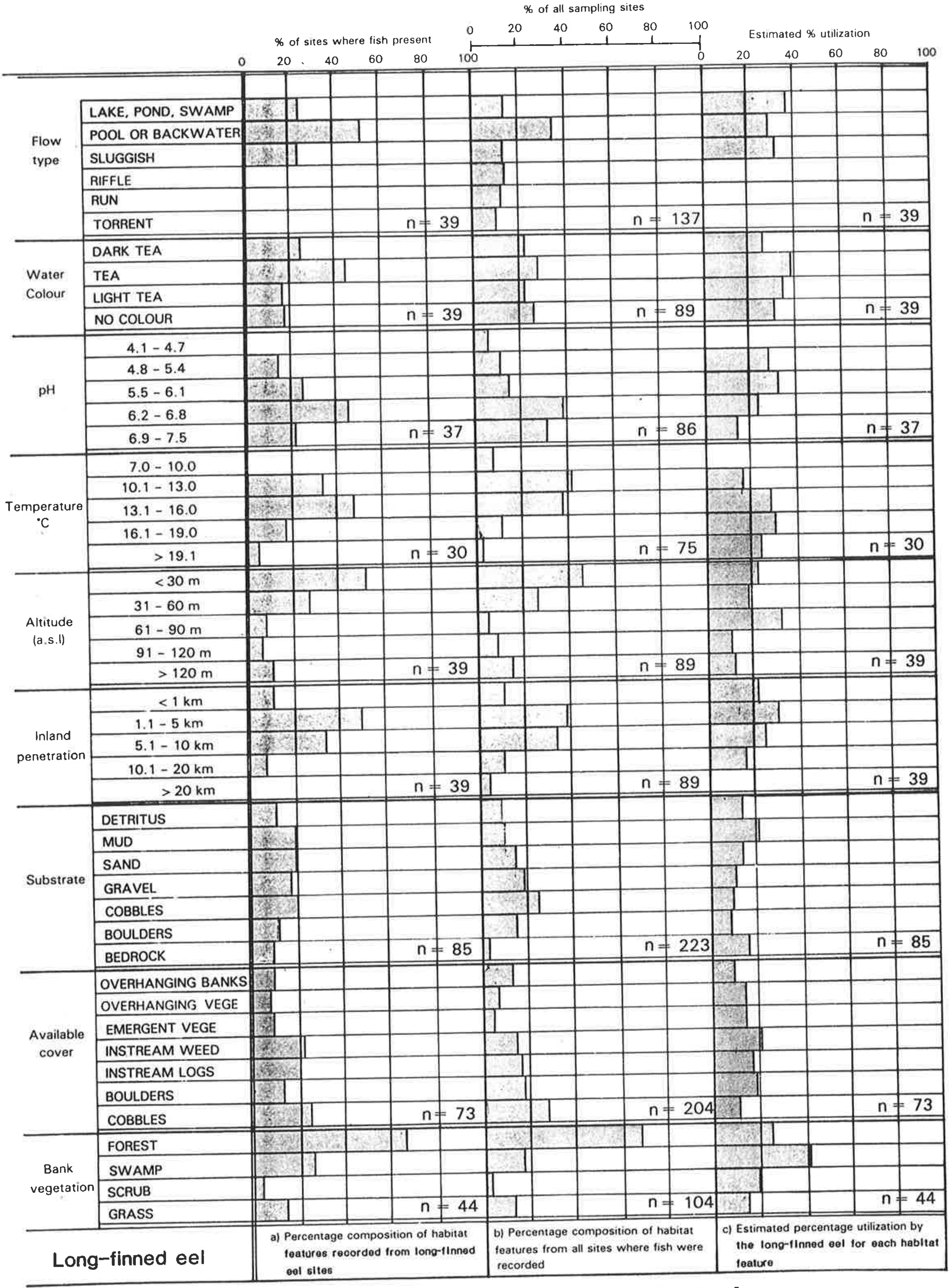


FIGURE 6. Habitat profile for the long-finned eel.

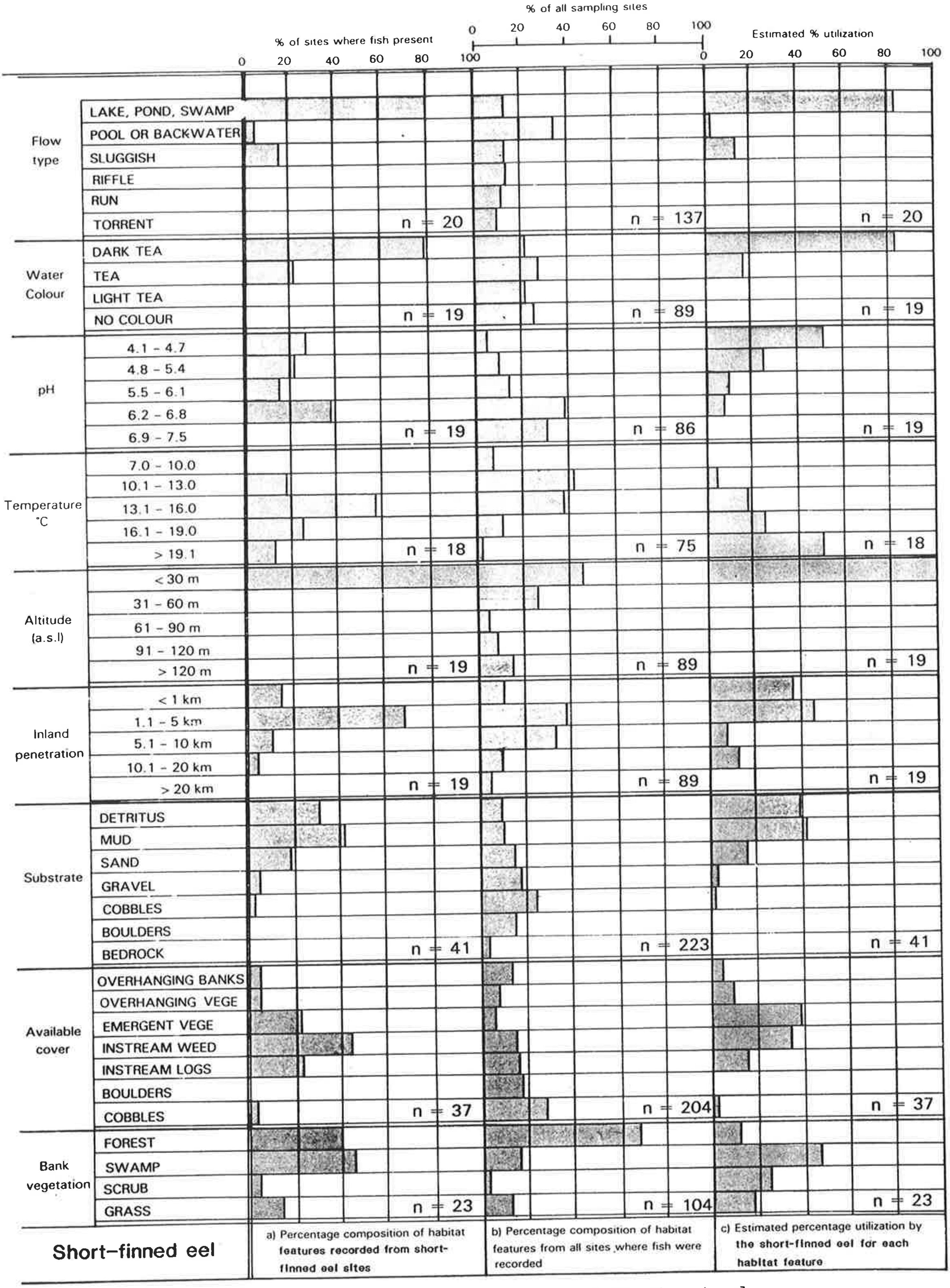


FIGURE 7. Habitat profile for the short-finned eel.

fish. Eight fishes were identified from gut contents; they were inanga, koaro, giant kokopu, common bully, red-finned bully, black flounder, short-finned eel, and brown trout parr. The larger fish (giant kokopu, short-finned eel, black flounder, and brown trout parr) were probably ingested while eels were in the nets and traps, whereas smaller fish species, capable of passing through the net meshes, were possibly ingested before the eel's capture, as part of its normal diet.

### 5.2.2 Short-finned Eel (*Anguilla australis*)

The short-finned eel was most frequently found in the lowland regions of the Waita catchment (Fig. 5). Most of the dune lakes support populations of shortfins, and so does the tannin-stained Maori River. Bush ponds separated from the main stream also appear to provide suitable habitat. Almost all fish caught occupied tannin-stained water, but two dune lakes were quite turbid with high levels of suspended solids and organic material.

The average pH of the short-finned eel habitats calculated from 18 readings was low (5.5, s.d. = 0.90), whereas the range of pH values for adult habitats was 4.1-6.6.

The average temperature from adult short-finned eel habitats was 15.8°C (s.d. = 3.0°C). The lowest temperature of 11.5°C was recorded from a shaded bush pond and the highest reading of 23°C was obtained from Lake Tawharekiri (Fig. 1). It appears that short-finned eels have a wide tolerance to both elevated temperatures and presumably low oxygen tensions in the water. Short-finned eel habitats were typically still or slow-flowing waters, whereas migrating elvers were found in runs and riffles near the Waita River mouth. Macrophytes provided cover in the water (84% of sites), and the substrate was often composed of mud, detritus, or both (89% of sites).

The habitat profile for the short-finned eel (Fig. 7) indicates that the species predominates in standing waters (lakes, ponds, and swamps), whereas the long-finned eel was found in slow-moving streams and rivers (Fig. 6).

Inland penetration by this species is less than that of the long-finned eel. In 84% of the sites where the short-finned eel was present the distance to the river mouth was less than 5 km. Eels were recorded from Lake Tawharekiri, 11 km upstream from the Waita River mouth, and they are probably common throughout the area of pakihi, which, because of difficulties with boat access, was not sampled. There were no recordings of shortfins climbing to over 30 m a.s.l.

#### 5.2.3 Whitebait Species

Whitebait are the juveniles of five species of the family Galaxiidae. All five species were recorded from the study area, with a total of 305 adult fish caught. Of these fish 38% were inanga, 37% koaro, 14% banded kokopu, 10% giant kokopu, and 0.3% (1 specimen) the short-jawed kokopu.

##### 5.2.3.1 Inanga (*Galaxias maculatus*)

Juvenile inanga form the largest component of whitebait catches in New Zealand (McDowall and Eldon 1980).

Within the study area, all inanga were confined to low altitude habitats and appeared to be abundant in the lower reaches of all three catchments (Table 1, Fig. 8). Seventy percent of sites where inanga were recorded were below 30 m a.s.l. and no sites were above 60 m a.s.l. Most (85%) of the inanga sites were less than 5 km from the river mouths.

Many of the habitats were exposed to the sun and had fairly high water temperatures. The highest temperature was recorded from Lake Tawharekiri (23°C (Table 2)); a stream draining a shallow pond into the Maori River was measured at 19.5°C. The coolest habitat in which inanga were present was a shaded, sluggish bush stream of only 11.0°C. The average temperature taken from 23 sites where adult and post whitebait inanga were recorded was 14.9°C (s.d. = 2.73°C). Many of the habitats in which inanga were present are probably subject to wide diurnal temperature variations because they lacked shading vegetation.

Access to the sea was not always obvious in habitats containing inanga. Ponds separated from the mainstem of Ship Creek, which contained high numbers of individuals, were presumably flooded by the mainstream in spring, and this allowed their colonisation by the migrating whitebait swimming upstream.

Sampling localities differed widely in pH. An inanga was caught in a swampy pond with a pH of 4.1, whereas other specimens were recorded from a backwater of the Whakapohai River with a pH of 7.2. The average pH from 24 adult inanga habitats was 6.1 (s.d. = 0.77, c.v. = 12%). Inanga do not appear to be affected adversely by pH, though they were less common in habitats with alkaline waters (Fig. 9). This is probably because, in the study area, these habitats are generally further inland and inaccessible to inanga or are too swiftly flowing.

As reported by Main, Nicoll, and Eldon (1985), riparian or instream

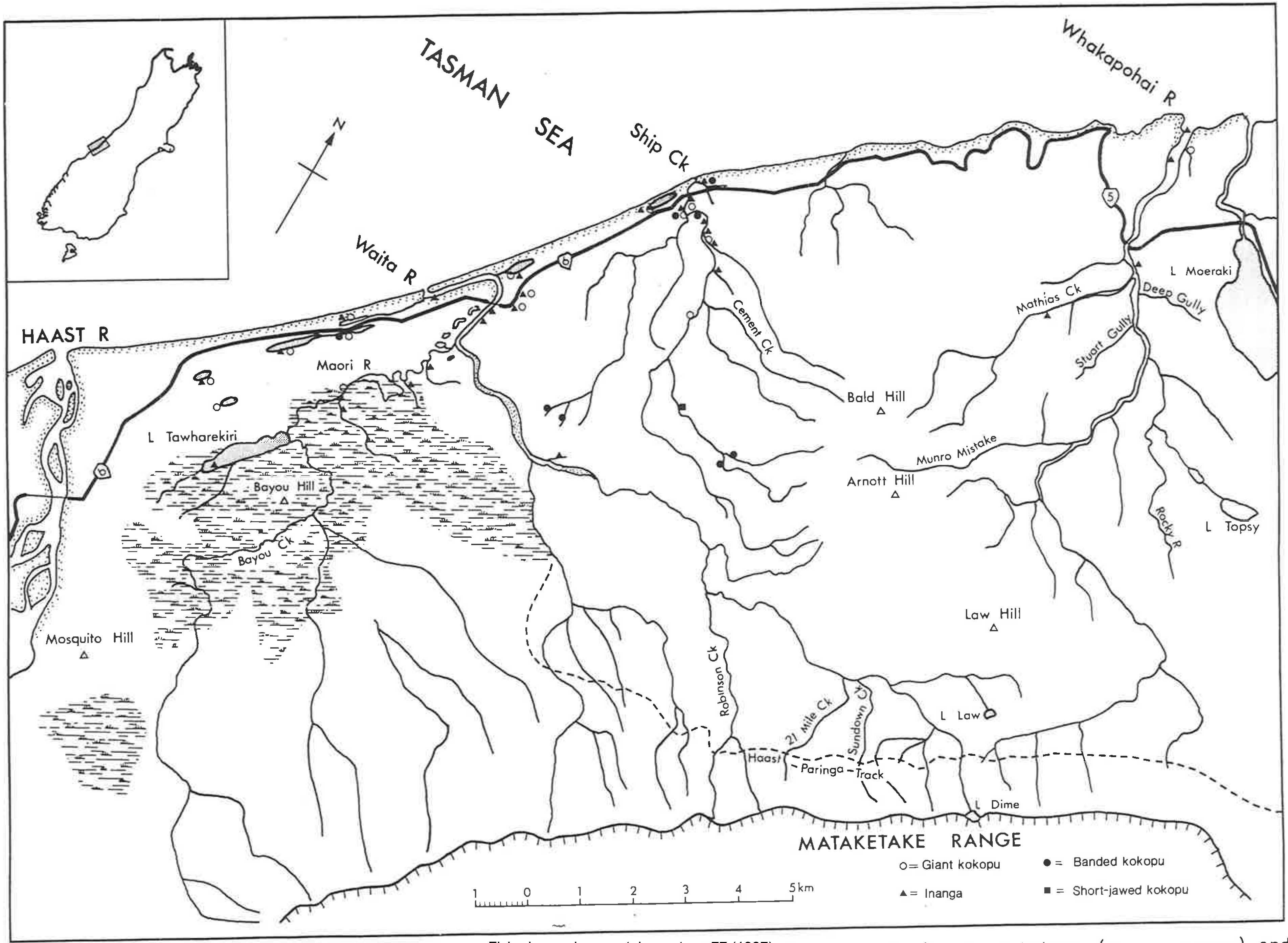




FIGURE 8. Sites from which inanga (*Galaxias maculatus*), banded kokopu (*G. fasciatus*), giant kokopu (*G. argenteus*) and short-jawed kokopu (*G. postvectis*) were recorded.

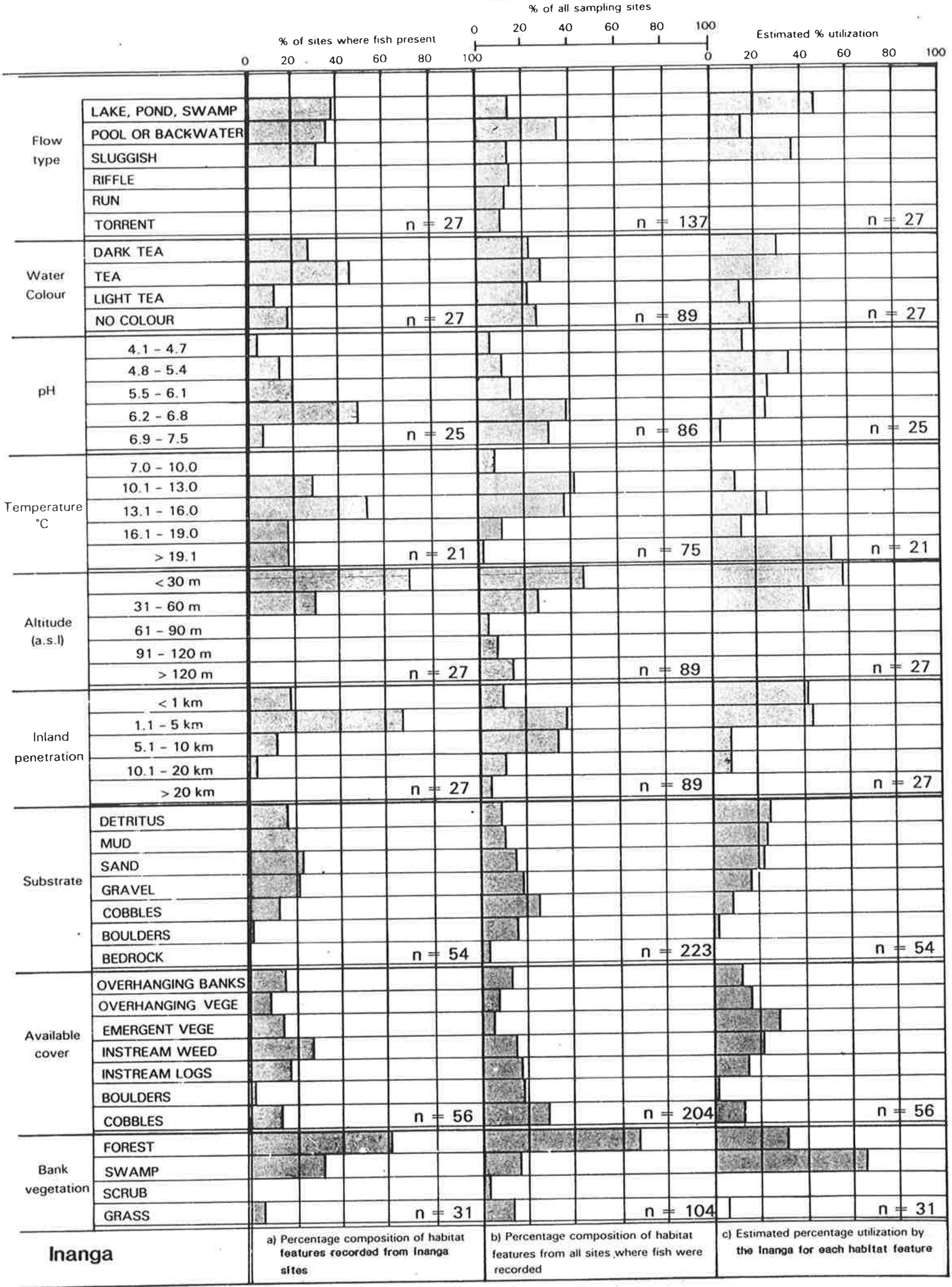


FIGURE 9. Habitat profile for inanga.

cover does not seem to be important to this pelagic species. River-dwelling populations were often seen shoaling in quiet water almost devoid of cover, and inanga did not appear to utilise cover even when it was present, except perhaps at times of flooding when they used it to shelter from the increased water velocity. Adult inanga and fresh-run whitebait were found in quiet backwaters of the Waita River when the mainstream was in full flood, in late January 1985. This is late for whitebait to be running, but small runs are known to occur throughout the year (McDowall and Eldon 1980). Whitebait fishermen have observed the movement of whitebait away from the mainstream into quieter waters when the current was unfavourably high (McDowall and Eldon 1980).

Typical inanga habitats had substrates with a high composition of detritus and finer sediment particles (Fig. 9). Detritus may be indirectly important to the fish in providing a food source for invertebrates.

#### 5.2.3.2 Koaro (*Galaxias brevipinnis*)

Koaro was a commonly recorded species in the Ship Creek and Whakapohai catchments particularly at higher elevations (Table 1), but it was relatively uncommon in the Waita River catchment (Fig. 10). Of the sites where adult koaro were recorded, 71% had elevations over 60 m a.s.l. Adult koaro were present at only two sites below 30 m a.s.l. Most adults (92% of recorded sites) had penetrated more than 5 km inland.

The koaro's habitat appeared to be tumbling streams with cover in the form of boulders and large cobbles. The fish were caught in pools, riffles, runs, and even torrents, but they were never recorded from

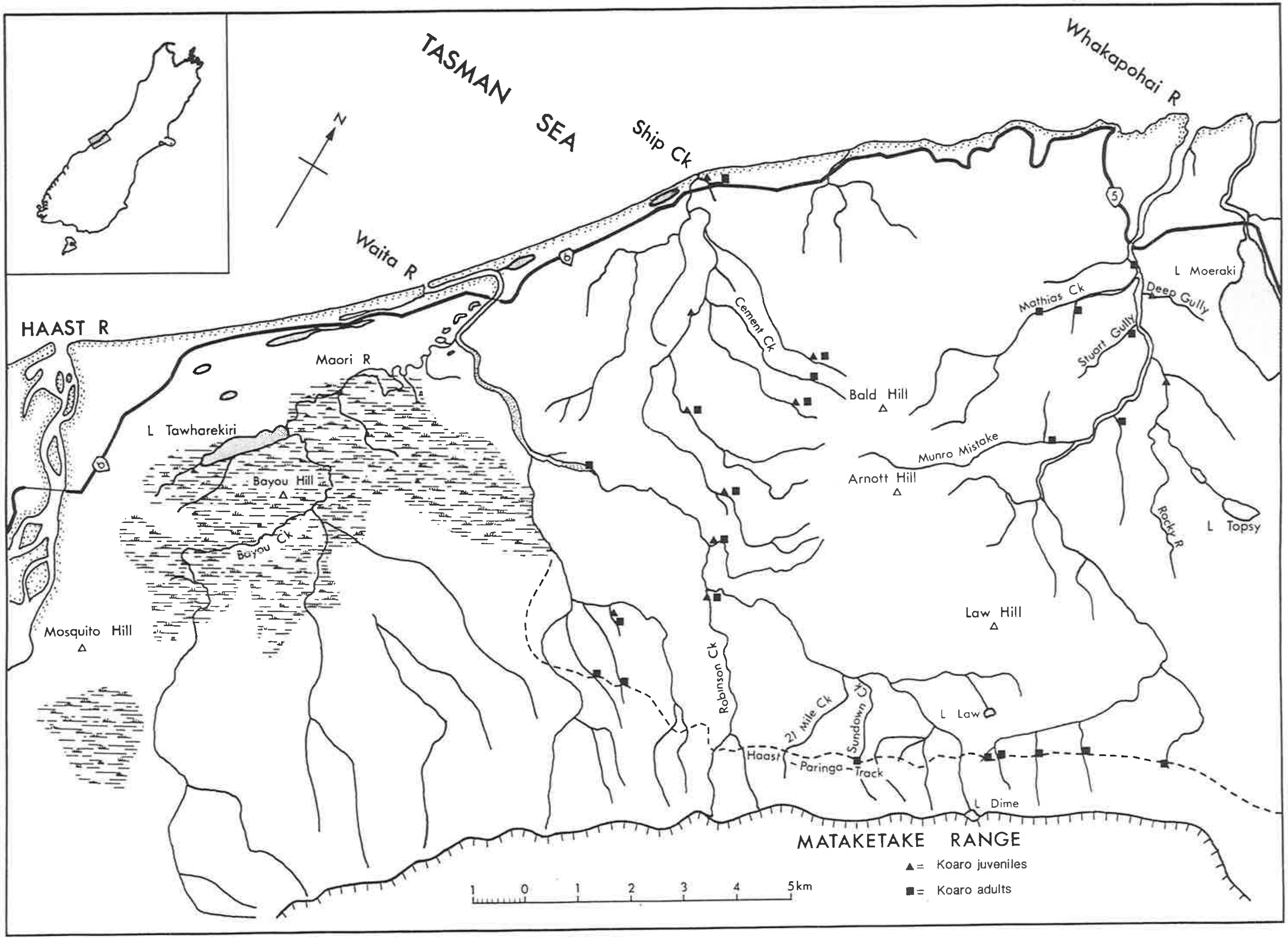


FIGURE 10. Sites from which koaro (*Galaxias brevipinnis*) was recorded.

backwaters, rivers with only a sluggish flow, or sites where there was a significant amount of detritus, mud, or sand (Fig. 11). The water was either without colour or slightly tannin-stained and the pH was usually close to 7. The average pH for the 24 sites where adults were taken was 6.9 (s.d. = 0.28, c.v. = 4%)

Water temperatures were usually cool in the higher altitude streams, but a small, shallow, drainage ditch running alongside S.H.6 had a temperature of 17.5°C. This habitat is atypical for koaro because the water depth varied between 2 cm and 10 cm, and the ditch may dry up completely in periods of low rainfall. Presumably under these conditions the fish would enter the tannin-stained tributary of Ship Creek which the ditch feeds. This tributary had a recorded pH of 4.9, and both post-whitebait and adult koaro have been recorded from it. It is possible that migrating koaro whitebait enter this acidic tributary of Ship Creek in spring when rainwater raises the pH of the stream and the tumbling neutral water may appear as a more favourable habitat.

Post-whitebait juveniles were recorded at 11 other sites, but because the fish were probably still migrating upstream, their presence did not necessarily reflect a suitable habitat for adult koaro. Habitat data for these and other juveniles have therefore been excluded from the derivation of all adult habitat profile figures.

Despite the koaro's reputation for reaching high altitudes (McDowall 1978), it was absent from many apparently suitable environments in the Waita headwaters. However, streams of a similar gradient and altitude that feed the Whakapohai River did contain these fish. Some of the Waita River tributaries from Waterfall Creek to 21 Mile Creek were resampled on 30 March 1985, but no fish were caught or observed. Of the

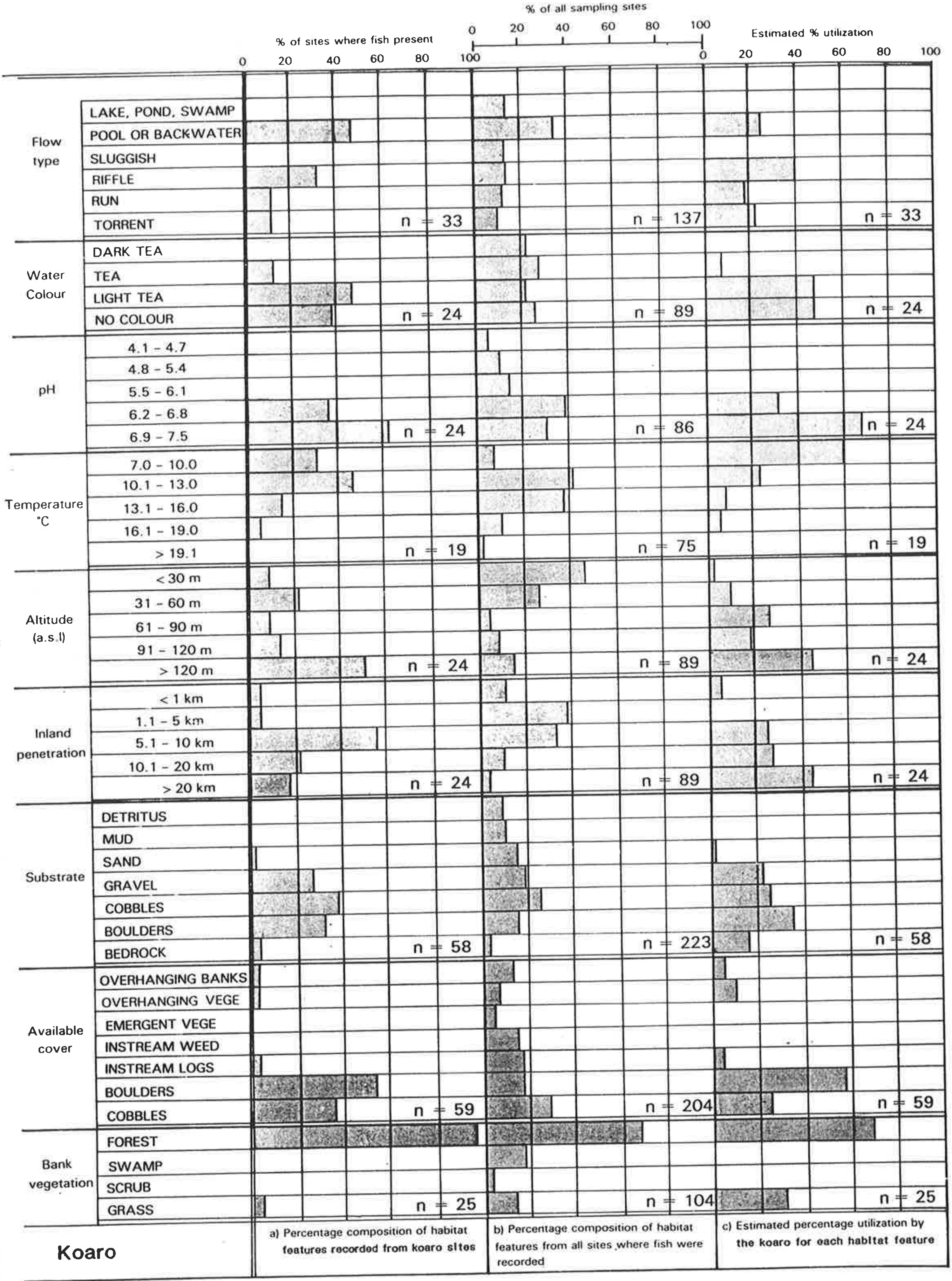


FIGURE 11. Habitat profile for koaro.

13 Waita River tributaries sampled, which cross the Haast-Paringa Track, only 3 contained koaro. In contrast, the species was taken from all five tributaries of the Whakapohai River which flow across the Track (Fig. 10). Fishing methods were similar for both catchments; they involved setting G40 minnow traps in available pools and the extensive use of the stop net in faster water flows. The anomaly in fish distribution between Waita and Whakapohai tributaries is discussed in section 6.2.2.

5.2.3.3 Banded Kokopu (*Galaxias fasciatus*)

The banded kokopu was recorded from 10 sites within the study area, 8 within the Ship Creek catchment (Fig. 8). It was the third most abundant galaxiid species. Some sites had high population densities, particularly shallow ponds in the Ship Creek catchment; the density of banded kokopu was at least $0.9/m^2$ at one of these locations.

All banded kokopu habitats were shaded by vegetation, and consequently the waters were slightly cool; the average of nine readings was 13°C (s.d. = 1.0, c.v. = 8%). The water was invariably tannin-stained, usually heavily, and it often had a low pH (mean = 5.8, s.d. = 0.8). The fish appear to reside in the pools or sluggishly flowing regions of narrow forested streams (see Fig. 20), but they were also recorded in shaded bush ponds and swamps (Fig. 12). Banded kokopu have also been recorded from Lake Topsy, a lake at about 150 m a.s.l. in the Whakapohai River catchment (FRD unpublished data). It is possible that these fish comprise a lake dwelling, non-migratory population. This is the only record of banded kokopu in the Whakapohai catchment. All other records of banded kokopu in this study, with one exception, were from Ship Creek and its tributaries.

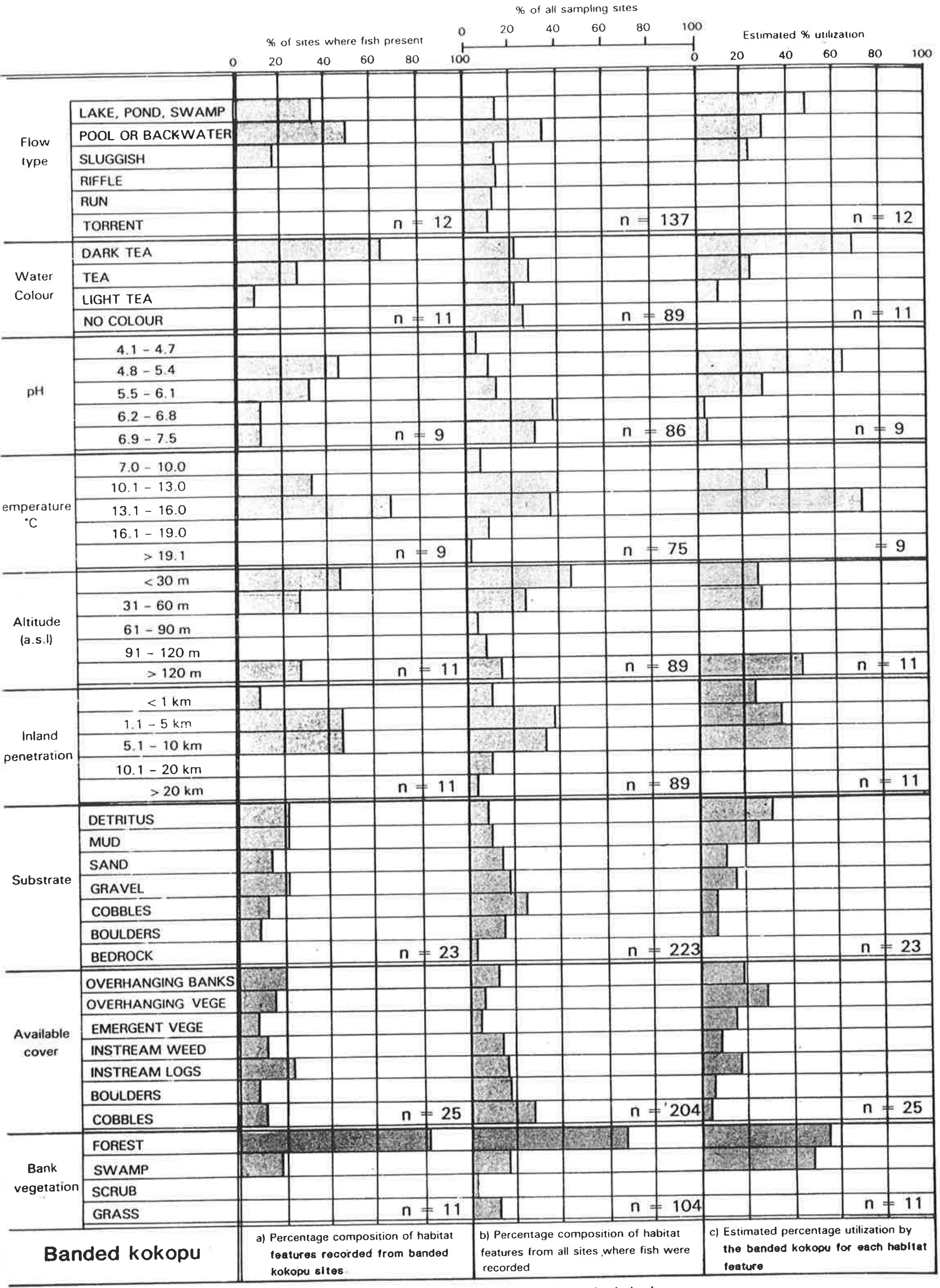


FIGURE 12. Habitat profile for banded kokopu.

Main, Nicoll, and Eldon (1985) reported that most of the banded kokopu sites in their study area were at low elevations and close to the sea; we found the same in this study. However, the Lake Topsy record and two stream sites in the Ship Creek catchment were over 140 m a.s.l.

It has been suggested in the literature (McDowall 1978) that the banded kokopu is nocturnal, but can be seen foraging in daytime in dimly-lit forest streams. In this study banded kokopu were observed during the day in a heavily shaded brook in the Ship Creek catchment and at other sites. The fish did not appear to be timid, and were easily approached and caught with nets.

5.2.3.4 Giant Kokopu (*Galaxias argenteus*)

The giant kokopu was common in parts of the survey area, but it was usually confined to coastal, low-lying regions. All fish were collected from sites less than 30 m a.s.l. and 88% were within 5 km of the sea (Fig. 8).

This species was frequently encountered in the lower reaches of the Waita Catchment, especially the dune lakes, swamps, and tributaries of these waters. The slow-flowing Maori River and Ship Creek also contained giant kokopu. However, the fish was not recorded from the Whakapohai River.

All fish were taken from acidic, tannin-stained water where an abundance of instream cover was available. Macrophytes, emergent vegetation, and logs provided sanctuary for this retiring, nocturnal fish. The average pH at sites where giant kokopu occurred was 5.8 (s.d. = 0.86, c.v. = 14.9%).

Giant kokopu normally inhabited only still or sluggishly flowing waters, and the substratum in such places consisted largely of mud, detritus, sand, or combinations of these. Many giant kokopu habitats were warm because of exposure to the sun. Notable among such habitats were the dune lakes and swamps, where there was no riparian forest (Fig. 13).

5.2.3.5 Short-jawed Kokopu (*Galaxias postvectis*)

In this survey only one specimen was collected, from a tributary of Ship Creek (Fig. 8). It was obtained from a pool where cover consisted largely of cobbles, with a small amount of overhanging vegetation. The water was slightly tannin-stained and was similar in this regard to short-jawed kokopu habitats described by Main, Nicoll, and Eldon (1985), except that the water was slightly alkaline with a pH of 7.1.

5.2.4 Torrentfish (*Cheimarrichthys fosteri*)

Forty-eight torrentfish were collected from ten sites in the study area and about half of these fish were taken from each of the Waita and Whakapohai catchments (Fig. 14). Only one specimen was recorded from Ship Creek (Table 1). Torrentfish are capable of negotiating swift shutes and torrents, but they were never caught above free falls of water. The habitat profile for the torrentfish is given in Figure 15. Torrentfish were almost always collected from torrents and riffles, but they were occasionally taken from runs below a section of broken water.

Gravel, cobbles, and boulders formed the substrate where the adult torrentfish were collected and finer particle sizes were totally absent from the habitat of adult fish. All adult fish were found either in

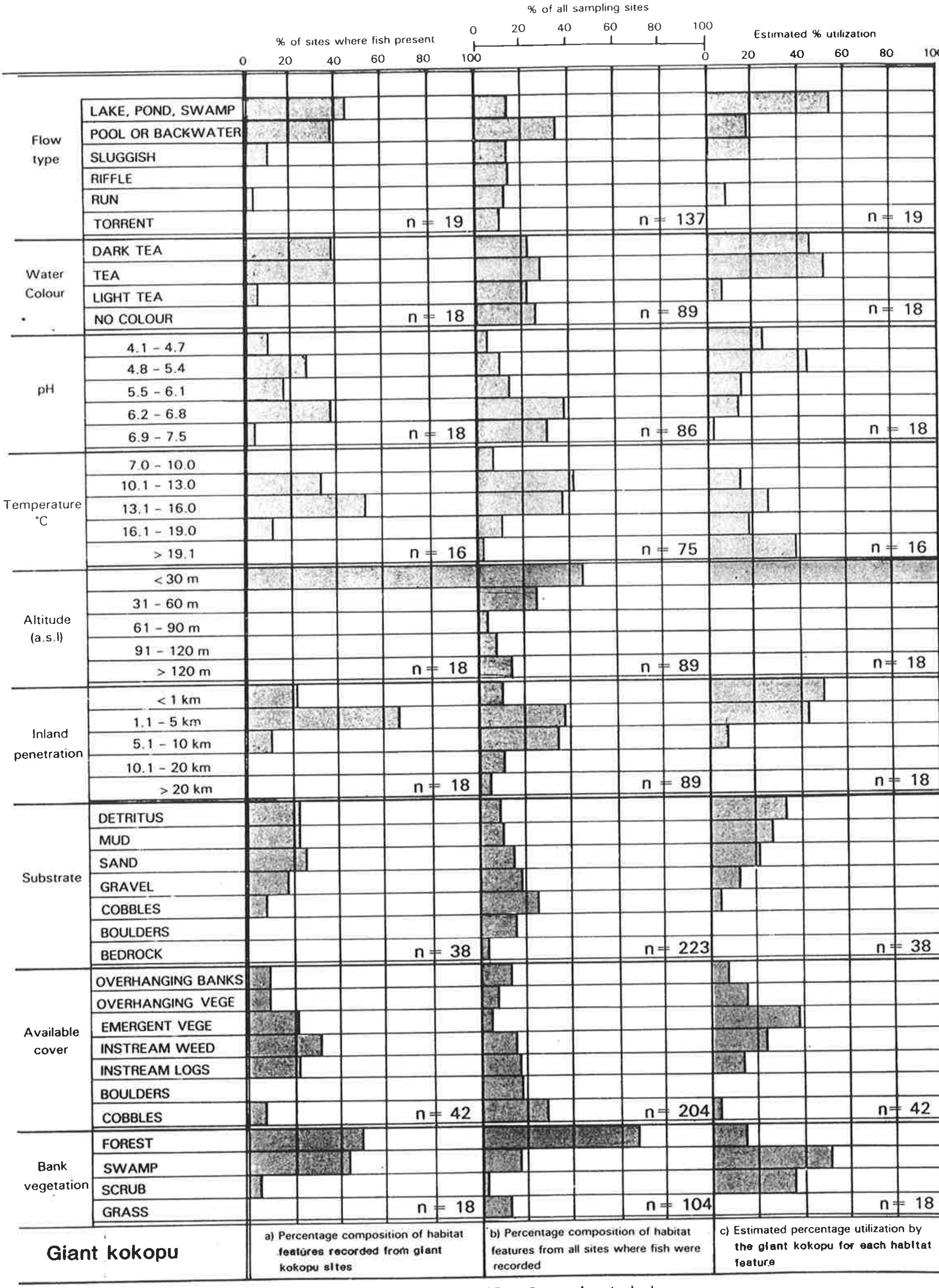


FIGURE 13. Habitat profile for giant kokopu.

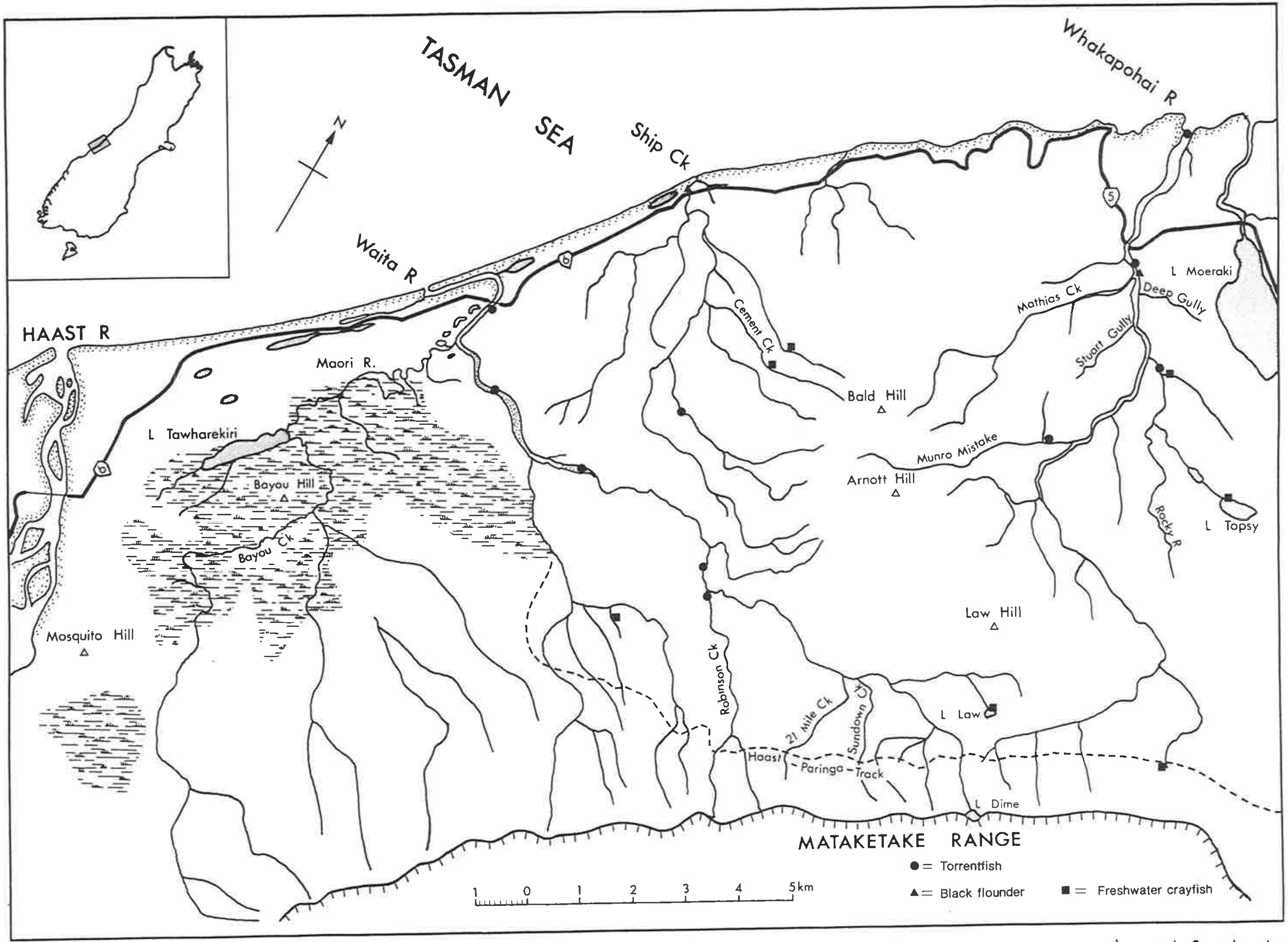




FIGURE 14. Sites from which torrentfish (*Cheimarrichthys fosteri*), black flounder (*Rhombosolea retiaria*), and freshwater crayfish (*Paranephrops planifrons*) were recorded.

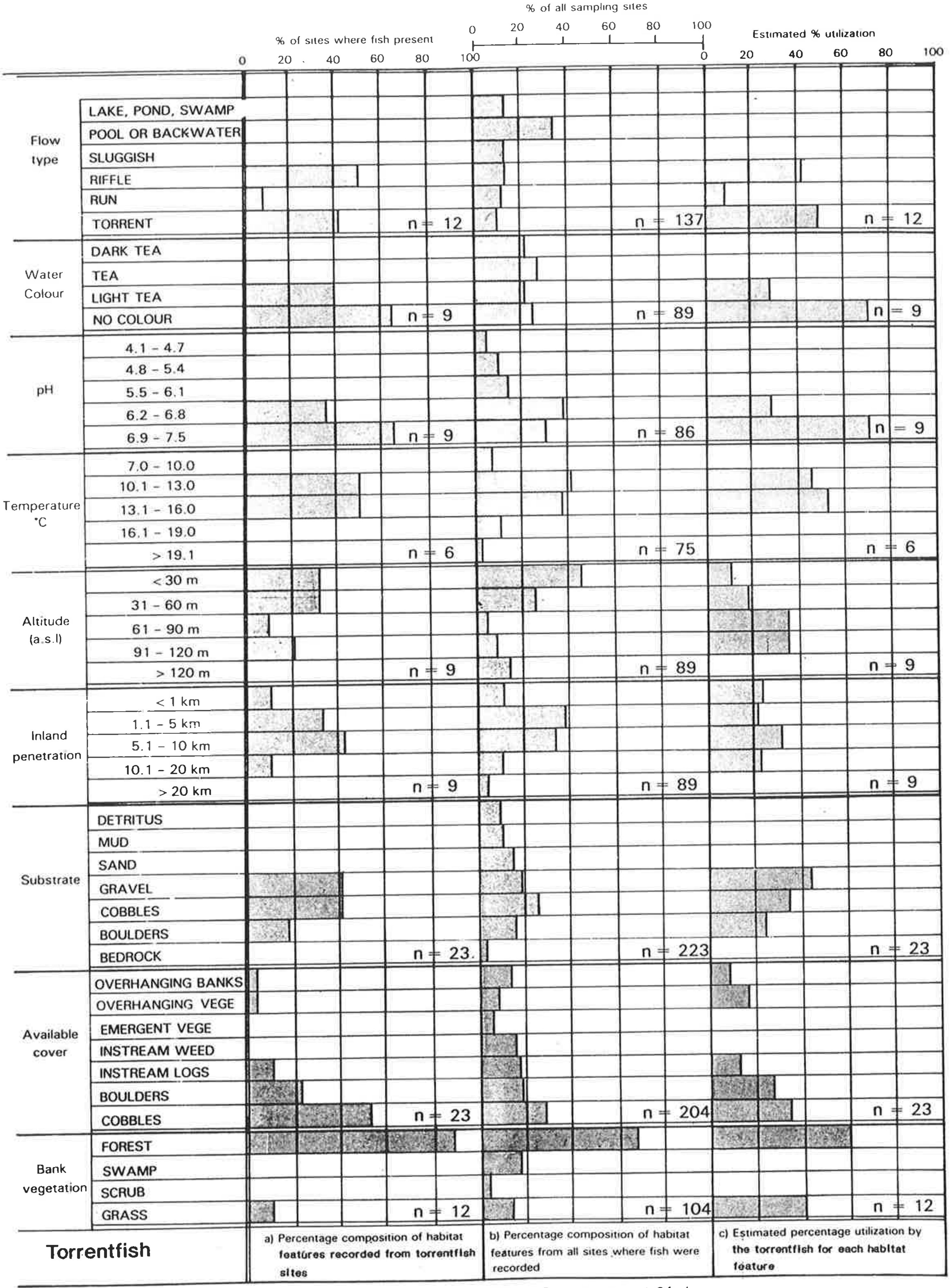


FIGURE 15. Habitat profile for torrentfish.

riffles or torrents, but juveniles migrating upstream were caught near the mouth of the Whakapohai River in sluggish water, where the substrate was predominantly fine gravel and sand.

The average pH of all sites where torrentfish were found was 7.0 (s.d. = 0.29, c.v. = 4.1%). Water temperatures varied considerably from site to site. Of the six temperature readings taken, an average of 12.8°C was obtained (s.d. = 1.6°C, c.v. = 12.5%) (Table 2).

The water usually had no colour (70% of sites), but it was slightly tannin-stained at three sampling locations.

The size of specimens increased with their distance from the sea. The smallest specimens were juveniles, about 30 mm in length, caught in the lagoon at the Whakapohai River mouth, whereas fish 1 km upstream from the Waita River mouth were about 80 mm long. Gravid specimens were collected from the most inland torrentfish sites in the Waita and Whakapohai catchments, at about 10 km from the sea. The one specimen obtained from Ship Creek (5 km inland) was also gravid. It is thought that gravid torrentfish migrate downstream to spawn in the lower reaches of rivers and that the fry are washed into the sea (G.A. Eldon pers.comm.).

### 5.2.5 Red-finned Bully (*Gobiomorphus huttoni*)

Within the study area, 135 red-finned bullies were recorded from a total of 28 sites. The species was widely distributed in all catchments, but it was not present in the Maori River (Fig. 16, Table 1).

The red-finned bully did not climb to the same altitudes or penetrate as far inland as did the long-finned eel or the koaro.

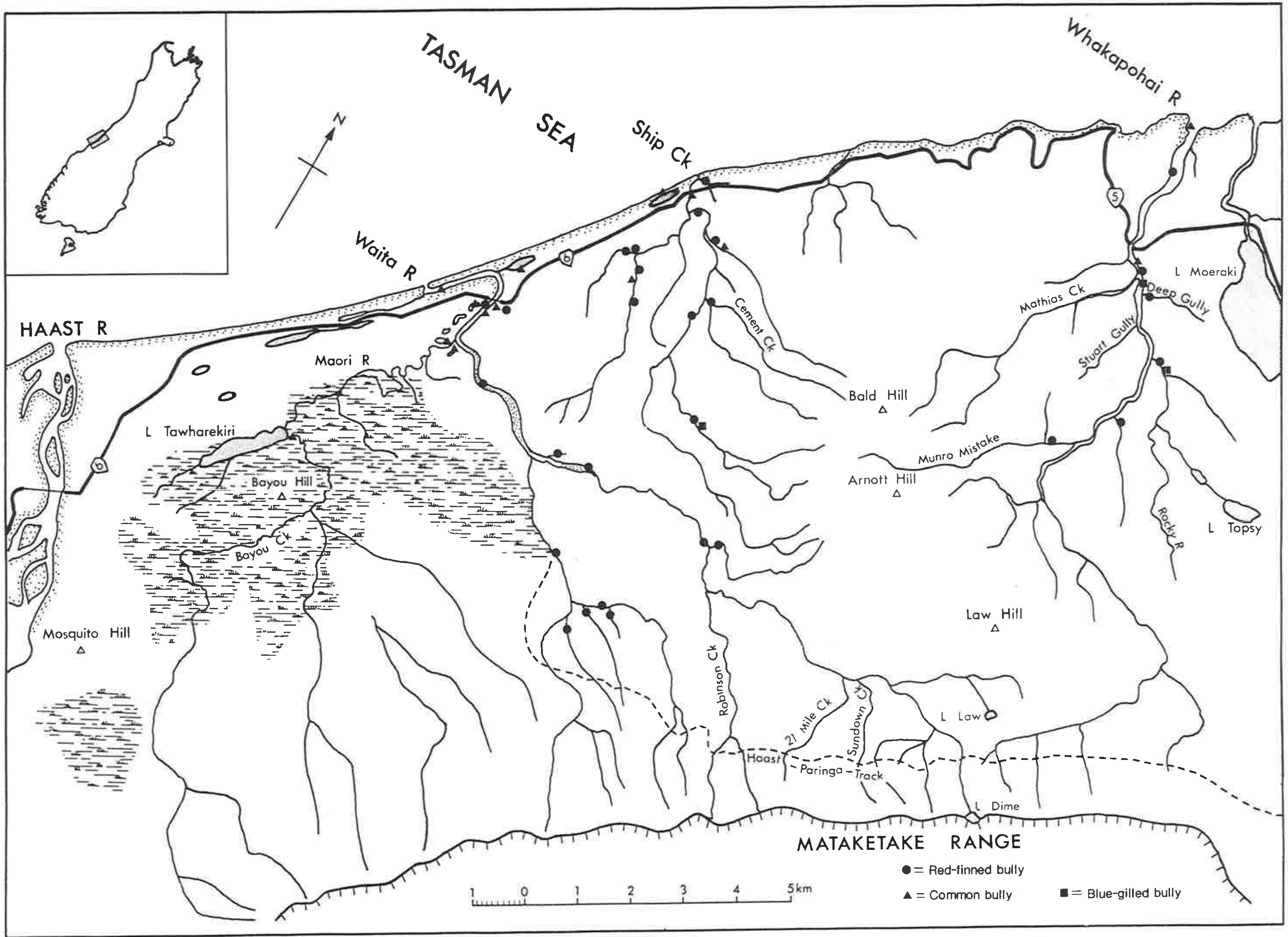


FIGURE 16. Sites from which red-finned bully (*Gobiomorphus huttoni*), common bully (*G. cotidianus*) and blue-gilled bully (*G. hubbsi*) were recorded.

However, it penetrated further inland than either the inanga or common bully. Most red-finned bullies (86%) were caught between 1 km and 10 km upstream from the river mouth. In only one instance was the fish recorded more than 10 km upstream. Most habitats (71%) were below 60 m a.s.l., though at two sites (about 150 m a.s.l.) fish were recorded from the bases of waterfalls.

The habitat profile for the red-finned bully (Fig. 17) illustrates the wide range of habitat types which this species occupies. Specimens were recorded from all flow types, from standing waters to torrents, but the fish appeared to utilise mainly riffles and pools. It was not taken from water of very low pH, and only rarely from deeply tannin-stained water. Neutral and slightly alkaline waters were highly utilised.

Although sometimes found in muddy and/or sandy locations, individuals were most commonly collected from streams with a gravel, cobble, or boulder substrate.

### 5.2.6 Common Bully (*Gobiomorphus cotidianus*)

The common bully was less widely distributed than the red-finned bully (Fig. 16, Table 1), but its presence was more conspicuous because of its habit of basking in sandy or gravel-bottomed shallows, where cover was scarce. This species did not seem to exploit available cover to the degree that other fish did.

The common bully had a pronounced coastal distribution. All fish were recorded within 6 km of the sea, and 40% of the sites at which it occurred were 1 km or less from river mouths. The fish was recorded from dune lakes in the Ship Creek and Waita catchments, and from tidal estuarine waters in all of the catchments surveyed. The dune lakes had

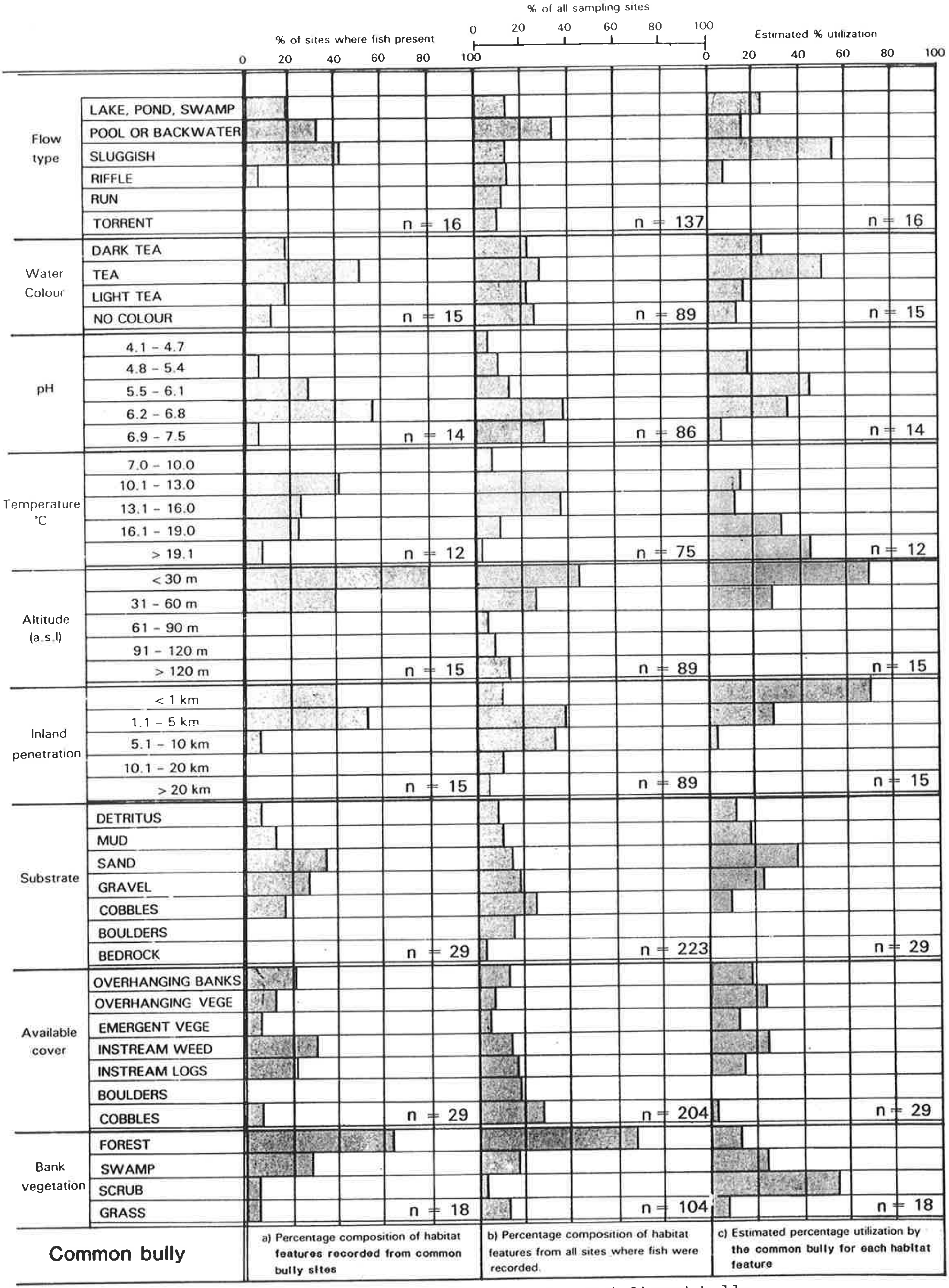


FIGURE 17. Habitat profile for the red-finned bully.

muddy bottoms, but sand and gravel were more prevalent in estuaries. None of the fish was taken from bouldery habitats.

Unlike the red-finned bully, the common bully is not found in swiftly flowing currents, but prefers sluggish or stationary water in pools, backwaters, dune lakes, or ponds accessible from the sea (Fig. 18).

Water colour of common bully habitats varied from dark tea to completely clear, with tannin-stained water being predominant. The average pH, based on 14 readings, was 6.3 (Table 3) (s.d. = 0.58, c.v. = 9.2%).

### 5.2.7 Blue-gilled Bully (*Gobiomorphus hubbsi*)

The blue-gilled bully was collected from only three locations. Three specimens were taken from Ship Creek and three more were obtained from the Whakapohai River and one of its tributaries (Fig. 16). All three sites were between 1 km and 10 km upstream of the sea and between 30 m and 60 m a.s.l. The six specimens were caught in riffles or torrents, in light tea-coloured or uncoloured water, with a pH close to neutral. McDowall (1978) points out that the torrentfish and the blue-gilled bully have very similar habitats. Within the study area torrentfish were recorded from each of the three blue-gilled bully habitats. Main, Nicoll, and Eldon (1985) reported similar results.

The blue-gilled bully, like the torrentfish, is usually small enough to exploit cobbles and small boulders for cover. The bully's very limited distribution within the study area is difficult to explain, especially as the torrentfish was so widely recorded. The blue-gilled bully was also reported to be far less abundant than the torrentfish in the first stage of the fish survey.

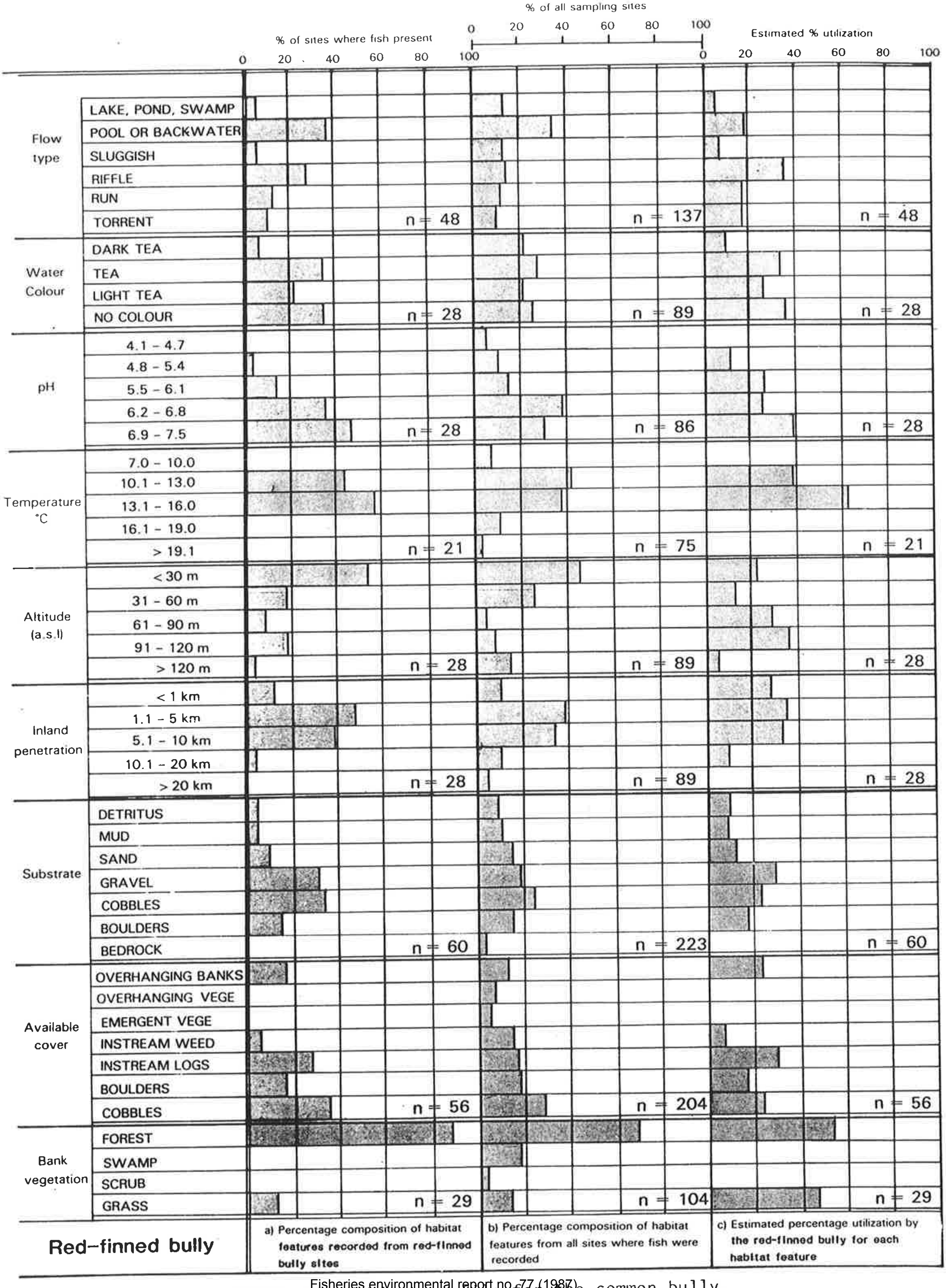


FIGURE 18. Habitat profile for the common bully.

### 5.2.8 Black Flounder (*Rhombosolea retiaria*)

The black flounder was recorded from only two locations in the study area, near the mouth of Ship Creek, and in a deep pool about 4 km upstream of the Whakapohai River mouth (Fig. 14). Both habitats were in quiet water with a sand and gravel bottom. This is consistent with the findings from the first part of the survey.

Although the pH of the water at the two sampling sites was the same (6.6), the Ship Creek habitat was tidal, tannin-stained, and probably slightly saline, whereas the Whakapohai River site consisted of clear, fresh water.

## 5.3 Introduced Fishes

Of the 14 freshwater fish successfully introduced into New Zealand, only brown trout were collected from the study area. Quinnat salmon were not found, which was expected because of the small size and tannin-stained nature of the rivers surveyed. However, they are present in rivers north of the study area.

### 5.3.1 Brown Trout (*Salmo trutta*)

The brown trout was widely distributed in the study area and was recorded from 18 sites within the three catchments (Fig. 19).

Trout juveniles or parr were caught in runs, riffles, and torrents of the higher reaches of Ship Creek and the Waita and Maori Rivers. Spawning probably occurs near these locations. Adult fish appeared particularly abundant in the Maori River and the lower reaches of Ship Creek. Occasionally trout were observed in deep pools in the Whakapohai River.

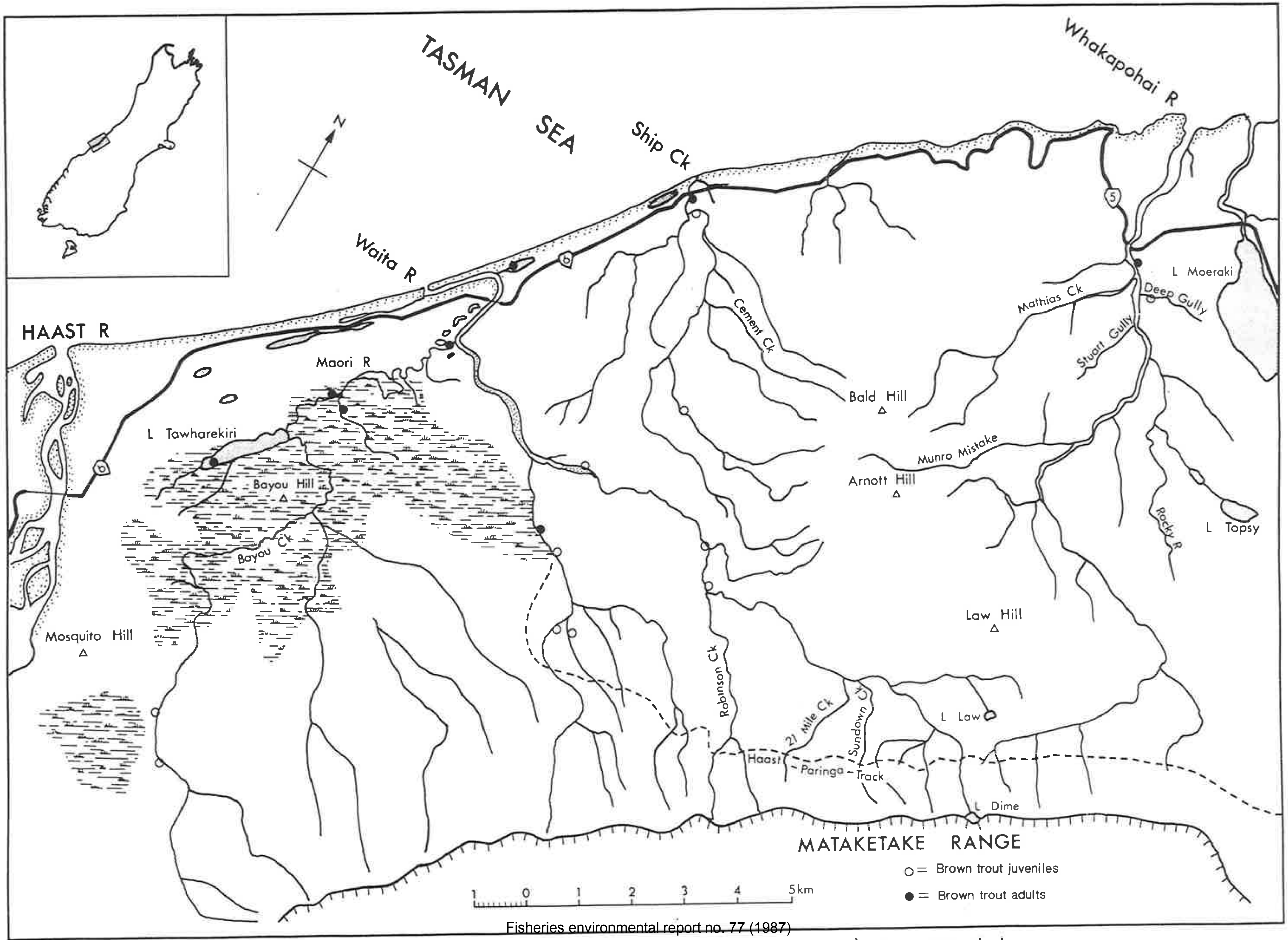




FIGURE 19. Sites from which brown trout (*Salmo trutta*) was recorded.

A dune lake about 2 km from the Waita River mouth contained adult fish and so did shallow Lake Tawharekiri, at least in times of flood. Both these sites have a muddy, detritus-covered substrate, with tannin-stained water which reaches high temperatures. A reading of 23°C was obtained from the Lake Tawharekiri.

The pH of brown trout habitats varied from 6.0, (Maori River) to 7.3 (Waita River). The average pH, based on the 18 sample sites, was 6.7 (s.d. = 0.35, c.v. = 5.2%). Nine sites from which trout parr were recorded had an average pH of 6.9, and reflected the greater abundance of parr in the neutral, higher reaches of rivers.

Main, Nicoll, and Eldon (1985) recorded no trout where the substrate was muddy or the water deeply tannin-stained. However, both Lake Tawharekiri and the Maori River had these qualities.

## 5.4 Crustacea

### 5.4.1 Freshwater Crayfish (*Paranephrops planifrons*)

The presence of freshwater crayfish was noted from seven sites, all of which were at high altitudes (Fig. 14).

A dense population of large individuals was recorded from Lake Law and its outlet at about 734 m a.s.l. Twenty-three specimens were caught from the detritus-filled lake and six from its outlet. No fish were caught from either site and it is probable that if fish were present, especially eels and trout, predation would have severely reduced crayfish numbers (Chapman and Lewis 1976).

Crayfish were also recorded from the upstream reaches of some tributaries in all three catchments surveyed, though these individuals were not of the same size or abundance as those in Lake Law.

Crayfish were found in cool, shaded streams, often in pools with a cobble substrate. Occasionally they were observed resting on the bottom, but the slightest disturbance would send them scuttling for cover under rocks.

# 6. DISCUSSION

## 6.1 Factors Affecting Fish Distributions

### 6.1.1 Distance From the Sea and Altitude

All of the native freshwater fish caught in the study area have life cycles where juveniles migrate upstream from the sea in spring and summer to colonise adult habitats. The introduced brown trout differs in that river-dwelling adults swim upstream into the headwaters to spawn (McDowall 1984).

In the unmodified environment, natural barriers to upstream migration, such as waterfalls and torrents, generally increase in severity with altitude and distance inland. In the study area, and in South Westland generally, the Southern Alps and their associated foothills lie close to the sea. Because of this, stream gradients and the level of difficulty for upstream migration increase more rapidly with distance inland than they do in less mountainous regions of New Zealand. Fishes clearly differ in their ability to negotiate obstructions, and within the study area the distribution of the various species reflected this.

The koaro was recorded furthest inland, often above considerable barriers such as waterfalls and near vertical shutes. Long-finned eel and banded kokopu were not as common as koaro at high altitudes, but evidently they were also capable of negotiating barriers to upstream movement. All three species have juveniles that are accomplished climbers, with the ability to move up damp vertical rock surfaces (McDowall 1978).

Meredith, Davie, and Forster (1982) showed the presence of cutaneous respiration in the Canterbury mudfish, and Meredith (1981) considered that most other New Zealand galaxiids could utilise a similar, but less complex mechanism. Berg and Steen (1965) proved that eels can use their gills while exposed to the air, and Jakubowski (1960), cited in Berg and Steen (1965), noted that vascularised sections of the fins and abdomen may also be important in respiration.

The red-finned bully, blue-gilled bully, torrentfish, and brown trout, though not recognised as able climbers, were found upstream of torrents and cataracts. Adult brown trout can negotiate steep falls of water by leaping, whereas the smaller bullies and torrentfish probably overcome the obstacle in steps, exploiting small interstices between rocks.

Inanga, short-finned eel, and giant kokopu, usually exhibited little upstream penetration, but they were found far inland if the current was placid. Inanga were caught in Lake Tawharekiri, 12 km from the sea, and giant kokopu have also been taken from the same location (D. Munro pers. comm.).

Common bullies were never found far from the sea; the furthest inland they were recorded was 6 km, in the Maori River system.

Both black flounder records within the study area were from close to the sea, though McDowall (1978) cited records of long penetrations inland by this species and mentioned its surprising ability to negotiate rapids.

6.1.2 Flow Type

Flow type appears to be an important factor affecting the distribution of fish within a watercourse. Fish differ in the type and range of water flows which they inhabit (see flow type utilisation histograms for adult fish in habitat profile figures).

Elvers of both short-finned and long-finned eels were collected from riffles and runs. However, adult eels were never recorded from swift flows; they preferred sluggishly flowing or still water (Figs. 6 and 7). The long-finned eel was most frequently found in slow-moving rivers, whereas the short-finned eel was more commonly encountered in swamps, ponds, and dune lakes at low altitudes.

Inanga were also found in a wide variety of standing waters, slow-flowing streams, ponds, lakes, and backwaters. No adults were recorded in waters with a velocity exceeding a gentle run.

The two most common kokopu species, giant kokopu and banded kokopu, were also recorded from placid waters, though no individuals of banded kokopu were found in the dune lakes. This is probably because dune lakes are too warm or open for banded kokopu which prefers cooler water in shaded streams (Fig. 20). Water flow profiles for the banded and giant kokopu are shown in Figures 12 and 13.

Adult koaro and brown trout were common pool inhabitants, with individuals being easily observed in clear water. However, koaro were also recorded from riffles and torrents (Fig. 11).

FIGURE 20. A tributary of Ship Creek where banded kokopu was particularly abundant. (Photo. G. Kelly)

Black flounder were recorded from pools, but they were probably also present in sluggish reaches and runs, as was noted by Main, Nicoll, and Eldon (1985).

Torrentfish and blue-gilled bullies occupied similar habitats within the study area; they favoured habitats composed of riffle and torrent flow types (Fig. 15).

Unlike the blue-gilled bully, the common bully preferred quiet flows and still water, though migratory juveniles were found near the Waita River mouth in quickly running water (Fig. 18).

The red-finned bully was the most common bully in the study area and was recorded from all flow types. Main, Nicoll, and Eldon (1985) reported little flow preference by this species. However, the utilisation profile for the red-finned bully (Fig. 17) indicates riffles and pools may provide the most suitable habitat.

### 6.1.3 Cover

Cover is utilised by fish for sanctuary from strong currents and predators, and, for piscivorous (fish-eating) fish, it provides concealment for the ambushing of prey. Organic cover may also serve an important role in providing a food source for invertebrate prey items (Church, Davis, and Taylor 1979).

Main, Nicoll, and Eldon (1985) described the three categories of cover available to fishes (substrate, instream, and riparian) and discussed the degree of cover dependence of various species. In this report, cover utilisation histograms for the common species are given in the habitat profile figures.

Fish species inhabiting or encountering powerful water currents use the substrate for shelter from the physical force of the water and for predator avoidance. These fish include the koaro and torrentfish (Figs. 11 and 15), and the blue-gilled bully.

In habitats where the water velocity was slower, use of instream and riparian cover was predominant. The giant kokopu, banded kokopu, and short-finned eel were recorded from sites where cover of this type was common. The giant kokopu's habitat utilisation profile (Fig. 13), illustrates its occurrence in weed- and log-filled watercourses. The banded kokopu appeared to be particularly dependent on overhanging banks and vegetation (Fig. 12) and was absent from open, unshaded habitats. Inanga and brown trout were less dependent on riparian cover. Shoaling of inanga in open water may afford some protection, and deep water provides cover for trout.

The ubiquitous long-finned eel exploited all types of cover and so its cover utilisation profile is quite uniform (Fig. 6). It was found co-habiting with the short-finned eel in rivers at low elevations where it used logs, banks, and macrophytes for cover, whereas at higher elevations large eels were observed around the bases of boulders.

The common bully had a low dependence on cover and was often seen in river shallows. Predominant cover types at sites where this bully was found included macrophytes, overhanging vegetation, and undercut banks (Fig. 18).

Main, Nicoll, and Eldon (1985) pointed out that the black flounder appeared not to require cover; it often inhabited regions where cover was scarce. McDowall (1978) noted that the black flounder obscures itself in sand and gravel, which breaks up its body outline, and that it changes its colouration to match that of the river bottom. With the exception of one site with an entirely gravel bottom, all other localities from which this fish has been taken (in both stages of the fish survey) have contained mud, sand, or composites of both. The black flounder's distribution may be limited to habitats with substrates composed of alluvium suitable for concealment. This is probably especially important for predator avoidance. The stomach contents of two long-finned eels indicated that large long-finned eels preyed on flounder; brown trout possibly prey on them also.

Quantitative studies on the effect of cover removal on fish populations have been carried out in Australia. Hortle and Lake (1983) compared fish densities between channelised and unchannelised sections of a river in Southern Victoria and noted that unchannelised sites were richer in both abundance and species diversity. However, the abundance of inanga was lower in unchannelised sites, and these authors suggested that predation pressure by the larger eels and trout (which find cover in the unmodified habitats), may account for this.

### 6.1.4 Bank vegetation

Riparian vegetation is critically important to at least some of the native fishes inhabiting unmodified bush streams. McDowall (1978) considered the removal of bank vegetation was partly instrumental in the general decline of New Zealand's native freshwater fish fauna. Church, Davis, and Taylor (1979) cite Giger (1973) who indicated that the removal of overhanging trees resulted in a decrease in abundance of large trout in North America.

Bank vegetation has far reaching effects on the general nature of a watercourse and consequently its value as a fish habitat. Church, Davis, and Taylor (1979) reported that bank vegetation can dictate the amount of allochthonous energy available to the aquatic habitat through the supply of terrestrial plant and animal matter. Animal matter may be immediately available for assimilation by the fish as noted by Main, Nicoll, and Eldon (1985), whereas plant material may provide the vast bulk of the nutritional requirements for aquatic invertebrate prey items (Church, Davis, and Taylor 1979).

A report by the Southland Acclimatisation Society (1981) mentioned that mosses close to the waterline inhibit erosion of clays and sandstones, and submerged bank vegetation, in times of high flow, prevents soil erosion. This is pertinent to conditions in South Westland where rivers can remain high for extended periods. Removal of bank vegetation can lead to gradual bank collapse, and it tends to destabilise the watercourse and lead to river bed destruction. Allen (1952) reported that bottom fauna numbers in the Horokiwi Stream dropped by over 50% as a result of floods. This led to a distinct reduction in the size of trout.

Surrounding soils and humus influence the chemical nature of runoff water entering a stream, river, or lake. McDowall and Eldon (1980) pointed out that organic acids and tannins leached from the forest floor, and decomposing plant material, lower the pH in forested streams. They also reported that chemical analyses of acidic, brown waters showed they are high in nitrates and organic nitrogen, which are mainly derived from vegetation.

Removal of riparian vegetation leads to both elevated water temperatures in summer, loss of shade, and lowered temperatures in winter in conjunction with a wider diurnal temperature range (Graynoth 1979).

### 6.1.5 Water Colour and pH

The close relationship between the intensity of colour in tannin-stained waters and its pH is well established. McDowall and Eldon (1980) linked light absorbance data to the pH of water samples taken from rivers in the Haast region. Main, Nicoll, and Eldon (1985) calculated a correlation coefficient of -0.87 between these data.

However, though tannins and organic acids from decomposing vegetation stain the water and lower the pH, there is evidence that *Sphagnum* mosses, abundant in lowlying areas of the Mataketake State Forest, are also responsible for acidifying runoff (Clymo 1963).

Conversely, the influence of limestone and other calcareous deposits may raise the pH to a level significantly higher than that indicated by the water colour. The tributaries of Ship Creek draining Bald Hill may be affected by geology of the substrate. These waters traverse limestone beds and sulphurous coal deposits (Geological Survey, pers. comm., Match and McKellar 1964). McDowall and Eldon (1980) reported that the hardness of Ship Creek water was 20 ppm, which probably reflects the higher concentration of calcium. A short tributary draining lowland podocarp forest and entering Ship Creek near the S.H.6 bridge was reported as more acidic (pH 4.7) and softer (hardness about 13 ppm) than the main stream (pH 6.2) (McDowall and Eldon 1980). Our spot recordings of pH for the tributary and the main stream were 4.9 and 6.6 respectively.

Water pH does not appear to be a factor limiting the distribution of most adult fishes in South Westland. Fishes recorded from habitats with a narrow pH range were koaro, torrentfish, blue-gilled bully, and the black flounder. Throughout the total study area (i.e., both survey stages) brown trout were not taken from waters with a pH less than 5.0, though habitats of lower pH, otherwise apparently suitable for trout, were noted.

With the blue-gilled bully and torrentfish the narrow range of pH recordings may simply reflect the uniformity of pH levels in the tumbling upper and middle reaches which these fishes inhabit.

The black flounder was recorded from only 2 locations in this study and 11 from the last study further north. The five pH readings from these locations ranged between 6.6 and 6.8. In FRD's Fish Distribution Data Base for South Island rivers (unpublished), the lowest pH recorded for the black flounder is 6.5 and the highest is 9.5. This fish may avoid acidic rivers.

Apart from koaro, all the adult galaxiids recorded during the survey were found in habitats with a wide range of pH (Table 3). Main, Nicoll, and Eldon (1985) reported that specimens of the scarce short-jawed kokopu were taken from rocky streams of low pH. However, the fish obtained from Ship Creek in this study was from slightly alkaline water (pH 7.1), and a search of FRD's Fish Distribution Data Base indicated that this species has a wide tolerance of water pH.

The pH varies with the flow regime of a river or stream. McDowall and Eldon (1980) measured the pH of Ship Creek and the Waita River at specific locations over about a month. The average range in pH within the catchments over this period was about 0.8 of a pH unit. Recordings taken within reach of the incoming tide are elevated by the influx of seawater. McDowall and Eldon (1980) recorded an elevation of 1.6 pH units above the average low-tide readings because of tidal influence.

Water pH is interrelated, directly and indirectly, with many other habitat features. For example, habitats with a low pH are generally at low altitudes, and are in slow-flowing streams with little gradient. Experiments controlling other habitat variables may clarify the importance of water acidity on freshwater fish distribution.

### 6.1.6 Temperature

Temperature recordings were taken on a routine basis from most sampling sites and the statistics are presented in Table 2. Temperature utilisation profiles have been calculated for all species except blue-gilled bully, black flounder, brown trout, and short-jawed kokopu.

The temperature extremes recorded during the study did not exceed the lethal temperature limits cited by Main, Nicoll, and Eldon (1985) for adult fish. Inanga, short-finned eels, and long-finned eels had the greatest habitat temperature ranges recorded during the survey. Temperatures ranged from a minimum of 11.0°C for inanga and the long-finned eel (11.5°C for the short-finned eel), to a maximum of 23°C for all three species (Table 2). The utilisation profiles for the short-finned eel and inanga (Figs. 7 and 9) are similar, and show the more frequent exploitation of higher water temperatures by these two species compared with other freshwater fishes. The temperature profile for the long-finned eel (Fig. 6) is more uniform and shows the utilisation of cooler waters at higher altitudes by the long-finned eel compared with the short-finned eel. No long-finned eels were caught in waters cooler than 11°C and foraging activity may be severely reduced in water lower than this temperature (G.A. Eldon pers.comm.). However, Main and Nicoll (unpublished data), collected long-finned eels during winter at temperatures as low as 8°C, though short-finned eels were not recorded from waters below 13°C.

Large adult koaro were taken from a drainage channel which had a temperature of 17.5°C. No juveniles were found here, though one was found in the cooler (13.3°C) tannin-stained main branch. Woods (1966), claimed that the upper lethal temperature for juvenile koaro is between 17 and 20°C which may explain the absence of juveniles in the channel until after further physiological development, when temperature tolerances increases. Woods (1966) claimed that the upper lethal temperature for adult koaro is 23.0°C.

Most adult koaro were found in clear, cool, tumbling streams. Utilisation histograms (Fig. 6) indicate most fish utilised waters of low temperature; the mean temperature of adult habitats was only 11.4°C (s.d. = 2.74°C) (Table 2). Excluding the atypical Ship Creek location, the average temperature of koaro habitats was 10°C (s.d. = 2.36°C).

### 6.1.7 Presence of Brown Trout

The presence of brown trout in a mixed species habitat probably affects the distribution of native freshwater fishes.

Brown trout are generalised, opportunistic predators that feed on a wide variety of prey depending on its availability and palatability. Brown trout over 2 years old are at least partially piscivorous (fish-eating) (Allen 1952). Bullies, particularly the conspicuous common bully, and whitebait are important food items for river and lake-dwelling trout (McDowall 1984).

There is evidence that trout compete with galaxiids for invertebrate food items, space, and cover (McDowall 1978). McDowall (1978) also suggested that interspecific competition for cover between the giant kokopu and the introduced brown trout may exist, and that the two species are apparently incompatible. Main, Nicoll, and Eldon (1985) pointed out that adult trout and giant kokopu were never recorded from the same site.

A commercial eel fisherman, D. Munro (pers. comm.), who fishes in the vicinity of Lake Tawharekiri, catches giant kokopu in the lake and further downstream, in the Maori River, on a regular basis. However, these fish are caught as a result of heavy fishing pressure with baited fyke nets, and a proportion of the catch may be recaptures. No giant kokopu were recorded from the Maori River system in this survey, though some brown trout were caught and many more were observed. It appears there is only a small population of giant kokopu in the Maori River.

Ship Creek also contained populations of trout and giant kokopu in the lower reaches, but they were not collected from the same sites.

The hypothesis that brown trout and giant kokopu are incompatible could not be investigated because survey methods prevented the estimation of absolute abundance of fishes and the determination of their spatial distribution within a watercourse. The abundance of instream cover in both Ship Creek and the Maori River may permit the existence of both species, albeit in different locations.

Long-finned eels may have an influence on trout distribution. Burnet (1968) recorded a high level of predation by long-finned eels on small trout. The effect of this was the establishment of a population of large trout, because of a reduction in competition for food and territory among the survivors. The same situation probably occurs in many West Coast rivers, which are noted for their large trout and abundant eel populations.

## 6.2 The Fisheries

### 6.2.1 Rare Species

The short-jawed kokopu, though by no means common, has been found from an increasing number of sites throughout New Zealand. McDowall (1978) reported that the species had been recorded from less than 20 sites nation-wide. At the time of writing this report, 97 locations had been described, 44 within the South Island, and all but 4 of these were from Westland (FRD unpublished data). The West Coast, with large areas still unmodified by man, provides a stronghold for this species. Only one specimen was collected from this study area, but populations may exist in unsurveyed headwaters.

The giant kokopu is not a rare species in South Westland, but it is very scarce in more developed regions of New Zealand (McDowall 1978). Within the study area giant kokopu was recorded from most suitable habitats, and some specimens captured were notably large. The largest caught was from the lower reaches of Ship Creek and was about 380 mm long. Giant kokopu appeared to be more common in this study area than in the area described by Main, Nicoll, and Eldon (1985). This may reflect the greater number of suitable habitats accessible to the fish in this study area.

### 6.2.2 Whitebait Fishery

Unfortunately, whitebait catches have not been recorded since 1978. However, it appears from local Fisheries Officers' reports and from figures in McDowall and Eldon (1980), that, though catches have not declined appreciably, fishing pressure has increased dramatically. The

Fisheries Officer at Haast (M. Freer, pers. comm.) considers that increased fishing pressure is reducing escapement. Reduced escapement could lead to a serious decline in the fishery.

Of the three rivers surveyed in the study area the Waita River is the only one with a commercial fishery. There are important spawning grounds in the lagoon and backwaters surrounding the Waita River mouth, and maturation occurs in the Maori River and its associated dune lakes and swamps. Preservation of the spawning grounds in their natural state would help maintain the whitebait fishery values of the Waita and other rivers in the region. McDowall and Eldon (1980) recorded an average seasonal catch of 2260 kg during the period 1969 to 1973, but the catch varied between 1202 kg in 1973 and 3584 kg in 1970. Therefore, interseasonal variation is wide, and McDowall and Eldon (loc. cit.) have shown that the catch fluctuations for rivers in the region (the Haast, Okuru, Turnbull, Waiatoto, and Arawata Rivers) vary in unison.

The composition of galaxiid stocks varies distinctly between adjacent catchments. The reason why adult koaro are so scarce in the Waita catchment is probably because of low recruitment from whitebait. McDowall and Eldon (1980) examined the species composition and total catch of whitebait from five rivers in the Haast area in 1969. Their results showed that an unusually low proportion (2.1%) of the whitebait entering the Waita River was koaro. Therefore, during the 1969 whitebait season, of the 1868 kg of whitebait caught from the Waita River, possibly only 40 kg consisted of koaro juveniles. In contrast, the Haast River has a high percentage (26%) of koaro whitebait in its catch. Of the 1400 kg of whitebait taken from this river, about 364 kg were koaro. No figures for total catch were obtained from Ship Creek, but about 3.7% of the whitebait taken from this river in normal, floodless conditions consisted of koaro. McDowall and Eldon (1980) suggested that koaro whitebait may avoid the Waita River because of its fairly warm, brown water. In contrast the Whakapohai is a very clear, cool river, which may present a more favourable catchment for colonisation by koaro.

### 6.2.3 Eel Fishery

The study area contains a significant eel fishery. Maori River, the major tributary of the Waita River, has high densities of both long-finned and short-finned eels throughout its extensive catchment. Dune lakes between the Waita and Haast Rivers also contained large eel populations, composed of both species, as did the lower reaches of Ship Creek, but it was thought that densities in these systems were less than those of the Maori River catchment.

One commercial eel fisherman operates in the study area. Based near the Okuru township, he fishes the accessible regions of Ship Creek and Maori River, but he also harvests the Turnbull, Okuru, and Haast River tributaries south of the region.

Eels grow slowly and take a considerable time to reach maturity. Therefore, they are easily overexploited. Castle (1972) reports that eels do not reach an exploitable size until they are 10 years old.

As stocks nation-wide are heavily fished, and recruitment is considered random, the West Coast probably represents an important reserve breeding stock for the national fishery. The only significant safeguard to this breeding stock is to reserve areas of no, or low, exploitation. Deliberate exploitation of mature migrating eels could substantially damage the eel fishery.

In the Westland region, catch figures for 1983 and 1984 indicate a 36% increase in catch from 12.7 t to 17.3 t. However, this fairly small increase in catch was a consequence of a considerable increase in effort, from 1791 netdays in 1983, to 3660 netdays in 1984 (Town 1985).

## 6.3 Implications for Management

Main, Nicoll, and Eldon (1985) comprehensively discussed the effects that various forest management regimes would have on fisheries. These effects are also pertinent to this study area and will not be repeated here.

Few sites in the area studied have been appreciably modified by man. Those that have been modified are discussed in relation to the modifications that have been made.

### 6.3.1 Possible Effects of Forest Harvesting

The effects of forest harvesting on fisheries are reviewed by Morgan and Graynoth (1978) and Main, Nicoll, and Eldon (1985).

#### 6.3.1.1 Sedimentation

The soils of the Mataketake Range and the Bald, Arnott, and Law Hills complex are composed of podzolised yellow-brown earths (section 3). New Zealand Soil Bureau (1968) reported that this soil type has a high susceptibility to sheet erosion if its overlying humus layer is disturbed by tree removal or cultivation. They recommend that permanent protection forest and alpine vegetation be maintained on steep land.

Destruction of the humus layer can also occur through the browsing activities of deer and goats on understory vegetation. Subsequent erosion can lead to the deterioration of the watershed (Holloway, Wendelken, Morris, Wright, Wardle, and Franklin 1963).

The detrimental effects of excessive sedimentation on the fish fauna are profound and are discussed by Morgan and Graynoth (1978).

Within the study area there were few sites with excessive sedimentation, owing to the largely unmodified nature of the state forest. However, if harvesting did proceed, potential damage to the fisheries would be considerable.

#### 6.3.1.2 Obstructions to Upstream Migration

Road culverts with a free fall of water are unnegotiable by many fishes. In a tributary of Ship Creek, a culvert passing under S.H.6 prevented inanga, red-finned bullies, and common bullies from occupying habitats further upstream. Only fishes capable of climbing the 36-cm-high bank into the culvert (viz koaro, banded kokopu and long-finned eel) were found further upstream.

### 6.3.2 Effects of Land Uses

#### 6.3.2.1 Agriculture

A narrow strip of land west of S.H.6 has been converted into pasture with swampy areas being drained by draglining. Channelisation has led to a uniform environment with little value as a fish habitat. These drainage channels, where sampled, contained only the two eel species. The muddy and sandy substrate offered no interstices for the refuge of small fish, and overhanging banks provided little cover.

Cattle grazing on the river flats of the Waita River use the shallow bed of Coppermine Creek for access to pastures further upstream. This has resulted in a trampled stream bed with partial bank collapse. Further upstream where the Coppermine Creek forks, brown trout parr were common, which suggests that there were spawning grounds in the vicinity. Fortunately, a lack of pasture and the presence of dense bush prevent cattle access to the region.

## 7. RECOMMENDATIONS

In formulating a management plan for South Westland, FRD recommends that the following matters be taken into account:

1. The Waita River and its major tributary, the Maori River, should be preserved in their present, unmodified, state. These waters support important whitebait and eel fisheries respectively. In particular, we emphasise the following.

   (1) The lagoon area around the mouth of the Waita, which serves as an inanga spawning ground, should remain unaltered with no stock access.

   (2) Stream beds should not be used as a means of access for four-wheel-drive vehicles. Well defined tracks should be cut at least 9 m from the bank and riparian vegetation maintained (Haupt and Kidd 1965).

2. Ship Creek contains an abundant and diverse galaxiid fauna and, because of its ecological importance, this catchment should be preserved in its current natural condition.

3. Stock access to watercourses should be limited as far as possible by berm fencing. This is particularly important along Coppermine Creek (Waita catchment) where cattle have caused damage to the bed and banks of the waterway. A good account of the benefits of berm fencing is given by Southland Acclimatisation Society (1981).

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APPENDIX I. Distribution of fishes by catchment.

| Whakapohai River catchment | NZMS 1 map co-ordinates | Long-finned eel | Short-finned eel | Inanga | Koaro | Banded kokopu | Giant kokopu | Short-jawed kokopu | Torrent-fish | Red-finned bully | Common bully | Blue-gilled bully | Black flounder | Brown trout | Nil caught |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Whakapohai R. mouth | S77/013527 | | | X | | | | | X | | X | | | | |
| North bank trib. | S77/015325 | | | | | | X | | | | | | | | |
| Mainstem backwater | S77/013314 | X | | X | | | | | | X | | | | | |
| Mathias Ck. | S87/005280 | X | | X | X | | | | | | | | | | |
| Mathias Ck. trib. | S87/010282 | | | | X | | | | | | | | | | |
| Mainstem | S87/017297 | X | | X | X | | | | X | X | X | X | X | X | |
| Deep Gully | S87/020293 | X | | | X | | | | | X | | | | X | |
| Stuart Gully | S87/022286 | X | | | X | | | | | | | | | | |
| Rocky R. | S87/033281 | | | | X | | | | X | X | | X | | | |
| Rocky R. trib. | S87/034282 | X | | | | | | | | | | | | | |
| Access Ck. | S87/030268 | X | | | X | | | | | X | | | | | |
| Munro Mistake | S87/030268 | X | | | X | | | | X | X | | | | | |
| Wrong Creek | S87/075213 | | | | X | | | | | | | | | | |
| Thompson Ck. | S87/057206 | | | | X | | | | | | | | | | |
| Stormy Ck. | S87/050200 | | | | X | | | | | | | | | | |
| Whakapohai headwaters | S87/044196 | | | | X | | | | | | | | | | |
| Whakapohai trib. at Maori Saddle | S87/042196 | | | | X | | | | | | | | | | |

APPENDIX I. (ctd.)

| Ship Creek catchment | NZMS 1 map co-ordinates | Long-finned eel | Short-finned eel | Inanga | Koaro | Banded kokopu | Giant kokopu | Short-jawed kokopu | Torrent-fish | Red-finned bully | Common bully | Blue-gilled bully | Black flounder | Brown trout | Nil caught |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dune lake | S87/923253 | | | X | | | X | | | | X | | | | |
| Southern-most fork | S87/925245 | X | | X | | | | | | X | | | | | |
| Pond on west bank of southern-most fork | S87/926247 | | X | X | | X | | | | X | | | | | |
| Second-most southern fork | S87/928243 | | | | | | | | | X | | | | | |
| Second-most southern fork | S87/930237 | | | X | | | X | | | X | X | | | | |
| Swamp east of S.H.6 | S87/929260 | | | X | | X | X | | | | | | | | |
| Mainstem near S.H.6 | S87/930262 | X | X | X | | | | | | | X | | X | X | |
| Ship Ck. trib. | S87/928207 | | | | | X | | | | | | | | | |
| Ship Ck. trib. | S87/930210 | X | | | | X | | | | | | | | | |
| North bank trib. west of S.H.6 | S87/931264 | | | X | X | X | | | | X | | | | | |
| North bank trib. west of S.H.6 | S87/932265 | | | | X | | | | | | | | | | |
| North fork near confluence with south fork | S87/952223 | X | | X | | | X | | | X | | | | X | |
| Pond on south bank north fork | S87/934260 | | | X | | X | | | | | | | | | |
| Ship Ck. trib. | S87/937256 | X | | X | | | X | | | X | X | | | | |
| Ship Ck. trib. | S87/942251 | X | | X | | | | | | | | | | | |

APPENDIX I. (ctd.)

| Ship Creek catchment | NZMS 1 map co-ordinates | Long-finned eel | Short-finned eel | Inanga | Koaro | Banded kokopu | Giant kokopu | Short-jawed kokopu | Torrent-fish | Red-finned bully | Common bully | Blue-gilled bully | Black flounder | Brown trout | Nil caught |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| North fork Ship Ck. | S87/943243 | X | | | X | | X | | | X | | | | | |
| Cement Ck. near confluence with mainstem | S87/944245 | | | | | | | | | X | | | | | |
| North fork Ship Ck. | S87 952 223 | | | | X | | | X | X | X | | X | | X | |
| Cement Ck. headwaters | S87/963240 | X | | | X | | | | | | | | | | |
| Cement Ck. trib. | S87/962237 | | | | X | | | | | | | | | | |
| Ship Ck. trib. | S87/964246 | X | | | X | | | | | | | | | | |
| Mainstem headwaters | S87/969213 | X | | | X | X | | | | | | | | | |
| Headwater trib. | S87/969211 | X | | | | X | | | | | | | | | |

APPENDIX I. (ctd.)

| Waita River catchment | NZMS 1 map co-ordinates | Long-finned eel | Short-finned eel | Inanga | Koaro | Banded kokopu | Giant kokopu | Short-jawed kokopu | Torrent-fish | Red-finned bully | Common bully | Blue-gilled bully | Black flounder | Brown trout | Nil caught |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dune Lake east of S.H.6 | S87/884203 | X | X | | | | | | | | | | | | |
| Mainstem upstream of S.H.6 | S87/907222 | X | | X | | | | | X | X | X | | | | |
| Bush ponds near Haast-Paringa track | S87/902215 | | X | | | | | | | | | | | | |
| Kahikatea Swamp north of Waita R. | S87/910229 | | | X | X | | | | | | | | | | |
| Outlet of swamp north of Waita R. | S87/909227 | X | | X | | X | | | | | | | | | |
| Oxbow lake east bank Maori R. | S87/901207 | X | | | | | | | | | X | | | | |
| Bayou Ck. | | | | | | | | | | | | | | | X |
| Outlet of pond near Maori R. | S87/885174 | | | X | | | | | | | X | | | | |
| Bayou Ck. near Lake Tawharekiri outlet | S87/884176 | X | | | | | | | | | | | | | |
| Maori R. trib. | S87/889186 | X | | X | | | | | | | | | | X | |
| L. Tawherekiri outlet | S87/882176 | X | X | | | | | | | | | | | | |
| Maori R. | S87/886187 | | | | | | | | | | | | | X | |
| Maori R. trib. on east bank | S87/898198 | X | X | X | | | | | | | X | | | | |
| Maori R. near confluence with Waita R. | S87/903210 | X | | | | | | | | | X | | | X | |

APPENDIX I. (ctd.)

| Waita River catchment | NZMS 1 map co-ordinates | Long-finned eel | Short-finned eel | Inanga | Koaro | Banded kokopu | Giant kokopu | Short-jawed kokopu | Torrent-fish | Red-finned bully | Common bully | Blue-gilled bully | Black flounder | Brown trout | Nil caught |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dune Lake on west bank Maori R. | S87/901209 | X | | | | | | | | | | | | | |
| Kiwi Ck. | S87/945149 | | | | | | | | | | | | | | X |
| Packhorse Ck. | S87/945158 | X | | | | | | | | | | | | | |
| North bank trib. | S87/907219 | | | X | | | | | | | X | | | | |
| Dune lake west of S.H.6 | S87/883204 | X | X | X | | | X | | | | | | | | |
| Small dune lake west of S.H.6 | S87/884205 | X | X | | | | | | | | | | | | |
| Waita mainstem near mouth | S87/898222 | | X | X | | | | | | | X | | | | |
| Stream connecting two dune lakes | S87/882202 | | | | | X | X | | | | | | | | |
| Small dune lake east of S.H.6 | S87/864185 | | X | X | | | X | | | | | | | | |
| Robinson Ck. at con-fluence with Waita R. | S87/973193 | | | | X | | | | X | | | | | | |
| Waita mainstem 8.5 km from S.H.6 | S87/973196 | X | | | | | | | X | X | | | | X | |
| Waita mainstem 7.5 km upstream from S.H.6 | S87/968202 | | | | | | | | | X | | | | X | |
| Waita mainstem 5 km upstream from S.H.6 | S87/940203 | X | | | X | | | | X | X | | | | X | |

APPENDIX I. (ctd.)

| Waita River catchment | NZMS 1 map co-ordinates | Long-finned eel | Short-finned eel | Inanga | Koaro | Banded kokopu | Giant kokopu | Short-jawed kokopu | Torrent-fish | Red-finned bully | Common bully | Blue-gilled bully | Black flounder | Brown trout | Nil caught |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Waita mainstem 2 km upstream from S.H.6 | S87/916207 | | | | | | | | X | X | | | | | |
| Swamp and outlet at S.H.6, N of Waita R. | S87/909224 | X | X | X | | | X | | | X | | | | | |
| Dragline channel | S87/882203 | X | X | | | | | | | | | | | | |
| Dune lake east of S.H.6 | S87/875195 | X | X | X | | | X | | | | | | | | |
| Dune lake east of S.H.6 | S87/870181 | | X | | | | X | | | | | | | | |
| Dune lake west of S.H.6 | S87/908237 | X | X | X | | | X | | | | X | | | X | |
| Pond on west bank Waita R. | S87/905221 | X | X | | | | | | | | | | | | |
| 21-Mile Ck. | S87/006174 | | | | | | | | | | | | | | X |
| North fork, Robinson Ck. at cattle track | S87/997170 | | | | | | | | | | | | | | X |
| Simon Slew | S87/983166 | | | | | | | | | | | | | | X |
| Simon Slew trib. | S87/978168 | | | | | | | | | | | | | | X |
| Robinson Ck. (South Fork) | S87/993167 | | | | | | | | | | | | | | X |
| Waterfall Ck. | S87/969168 | | | | X | | | | | | | | | | |
| Coppermine Ck. (north fork) | S87/963167 | | | | X | | | | | | | | | | |
| Coppermine Ck. at Haast-Paringa track | S87/995164 | | | | | | | | | | | | | | X |

APPENDIX I. (ctd.)

| Waita River catchment | NZMS 1 map co-ordinates | Long-finned eel | Short-finned eel | Inanga | Koaro | Banded kokopu | Giant kokopu | Short-jawed kokopu | Torrent-fish | Red-finned bully | Common bully | Blue-gilled bully | Black flounder | Brown trout | Nil caught |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pond on west bank Waita R. | S87/903215 | | X | | | | | | | | | | | | |
| Lake Tawharekiri | S87/872164 | X | X | X | | | | | | | | | | X | |
| Stony Ck. | S87/912107 | | | | | | | | | | | | | | X |
| Bayou Ck. (upper reaches) | S87/892115 | | | | | | | | | | | | | X | |
| Bayou Ck. (upper reaches) | S87/897108 | | | | | | | | | | | | | X | |
| Mica Ck. | S87/904097 | X | | | | | | | | | | | | | |
| Brandon Ck. | S87/920124 | | | | | | | | | | | | | | X |
| Dee Ck. | S87/926127 | | | | | | | | | | | | | | X |
| North bank trib. | S87/972203 | X | | | X | | | | | X | | | | | |
| Coppermine Ck. near confluence with Waita R. | S87/930196 | | | | | | | | | | | | | | X |
| Coppermine Ck. | S87/946184 | | | | | | | | | X | | | | X | |
| Simon Slew trib. | S87/961180 | X | | | X | | | | | X | | | | | |
| Simon Slew | S87/958180 | | | | | | | | | X | | | | | |
| Waterfall Ck. | S87/955177 | | | | | | | | | X | | | | | |
| Coppermine Ck. (north fork) | S87/954174 | | | | | | | | | X | | | | X | |
| Coppermine Ck. (south fork) | S87/951172 | | | | | | | | | | | | | X | |

APPENDIX I. (ctd.)

| Waita River catchment | NZMS 1 map co-ordinates | Long-finned eel | Short-finned eel | Inanga | Koaro | Banded kokopu | Giant kokopu | Short-jawed kokopu | Torrent-fish | Red-finned bully | Common bully | Blue-gilled bully | Black flounder | Brown trout | Nil caught |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| North bank trib. | S87/933201 | | | X | | | | | | X | | | | | |
| Kettle ponds near Lake Dime | S87/047182 to 049184 | | | | | | | | | | | | | | X |
| Lake Dime and outlet | S87/046183 | | | | | | | | | | | | | | X |
| Sundown Ck. | S87/020180 | | | X | | | | | | | | | | | |
| Chasm Ck. trib. | S87/022183 | | | | | | | | | | | | | | X |
| Chasm Ck. trib. | S87/026186 | | | | | | | | | | | | | | X |
| Chasm Ck. | S87/031188 | | | | | | | | | | | | | | X |
| Lake Dime outlet at Haast-Paringa track | S87/037192 | | | | | | | | | | | | | | X |
| Lake Law and outlet | S87/ | | | | | | | | | | | | | | X |