MAF Fisheries Research

Distribution and biology of freshwater fishes in the Cook River to Paringa River area, South Westland

Fisheries Environmental Report No. 60

Fisheries Research Division
N.Z. Ministry of Agriculture and Fisheries

ISSN 0111-4794

Fisheries Environmental Report No. 60

Distribution and biology of freshwater fishes in the Cook River to Paringa River area, South Westland

by

M.R. Main

G.J. Nicoll

G.A. Eldon

Report to: New Zealand Forest Service
South Westland Management
Evaluation Programme

Fisheries Research Division

N.Z. Ministry of Agriculture and Fisheries

Christchurch

October

1985

FISHERIES ENVIRONMENTAL REPORTS

This report is one of a series of reports issued by Fisheries Research Division on important issues related to environmental matters. They are issued under the following criteria:

(1) They are informal and should not be cited without the author's permission.

(2) They are for limited circulation, so that persons and organisations normally receiving Fisheries Research Division publications should not expect to receive copies automatically.

(3) Copies will be issued initially to organisations to which the report is directly relevant.

(4) Copies will be issued to other appropriate organisations on request to Fisheries Research Division, Ministry of Agriculture and Fisheries, P.O. Box 8324, Riccarton, Christchurch.

(5) These reports will be issued where a substantial report is required with a time constraint, e.g., a submission for a tribunal hearing.

(6) They will also be issued as interim reports of on-going environmental studies for which year by year or intermittent reporting is advantageous. These interim reports will not preclude formal scientific publication.

CONTENTS

Page

TABLES

FIGURES

1. SUMMARY

The composition and distribution of the freshwater fish faunas of the Karangarua, Hunts Beach, Makawhio, Bruce Bay, and Ohinemaka State Forests and adjoining land were studied during 1984. These areas encompass most of the Ohinetamatea, Karangarua, Manakaiaua, and Ohinemaka River catchments and parts of the Cook, Makawhio, and Mahitahi River catchments.

Fourteen species of native freshwater fish were found. In addition, the ubiquitous introduced brown trout, a solitary juvenile quinnat salmon, and two species of estuary-frequenting marine fish were recorded.

Habitat data such as instream and riparian cover, flow type, substrate, altitude, and distance from the sea were measured at all sampling sites, and pH and temperature were recorded at some. These parameters were related to fish distribution. In particular, four species of fish, two of which are rare, occurred only where there was forest cover.

The discovery of an apparently large population of ***Galaxias postvectis*** (short-jawed kokopu) in Black Creek (Ohinetamatea catchment) is considered of major scientific importance, and this water is recommended for conservation.

The implications of fishery data for land management are discussed, and recommendations are made.

2. INTRODUCTION

Westland contains the largest remaining area of virgin forest in New Zealand. Although much of the lowland forest has been logged, there are still large areas, especially those which are less accessible, that remain relatively untouched. However, there has been concern about the rate of loss of New Zealand's indigenous forests.

The region of South Westland between the Cook River in the north and Haast River in the south is one such area of largely virgin forest, though in low-lying areas some of the forest, having been logged in the past, is secondary growth. Roughly half of the forested land in this area is state forest and most of the other half is unoccupied crown land (u.c.l.). In the north-east, some of the forest lies within the Westland National Park. There are several scenic reserves scattered along State Highway 6 (S.H.6) and some forest is on leasehold and freehold land.

In 1983, Government imposed a 10-year moratorium on logging in this region, pending scientific investigation of the area. This led to the instigation of the South Westland Management Evaluation Programme (SWMEP), co-ordinated by the New Zealand Forest Service (NZFS) and involving a number of other agencies such as the Wildlife Service of the Department of Internal Affairs, Department of Lands and Survey, Ministry of Works and Development, Westland Catchment Board, Department of Scientific and Industrial Research, and Ministry of Agriculture and Fisheries (MAF). The aim of the SWMEP, to be completed by mid-1986, is to obtain a broad data base on the biota of the area and to use these data in the formulation of a management plan.

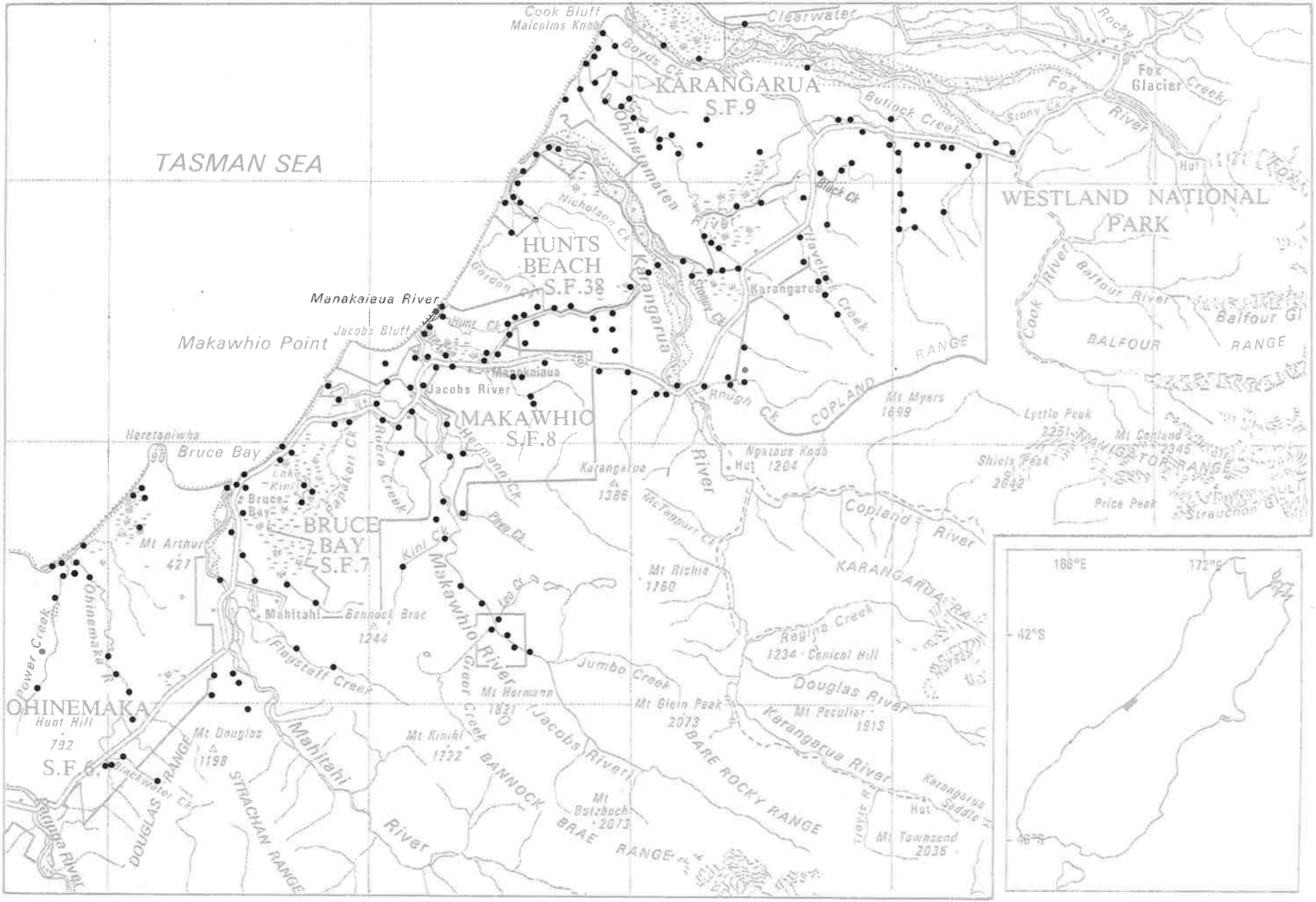

FIGURE 1. Study area showing sampling sites.

Fisheries Research Division (FRD) of MAF was invited to participate in the programme. Between late January and early August 1984, two field workers were employed to obtain data on the distribution of freshwater fishes in the area between the Cook River and Ohinemaka River in the north and south respectively, and between Westland National Park to the east and the sea to the west. NZFS supplied support, which included helicopter and jetboat access to remote areas.

Objectives of FRD in participating in this work were to determine the distribution of native freshwater fishes, their relative abundance, and their habitat requirements, and to predict the probable effect on fisheries of various forest management regimes. Data also were to be stored on computer file as part of FRD's national freshwater fish survey (McDowall and Richardson 1983).

3. STUDY AREA

The area covered by this study extends from the Cook River in the north to Ohinemaka River in the south, and from the sea in the west to the western boundary of the Westland National Park in the east, an area of about 570 km^2 (Fig.1). It is bisected by S.H.6, which follows the base of the hills at an elevation of about 30 m above sea level (a.s.l.) north of the Makawhio River. The Paringa River, which is the southern limit of the SWMEP subregion Cook River-Paringa River, is not covered in this report.

Geologically the low-lying regions of the area are of very recent origin. They consist of river gravel, glacial outwash gravel, and moraine which date back only as far as the Otira glaciation (22 000 to 14 000 years ago.) (Warren 1967, Gair 1967). The elevated areas lie within the alpine fault, are composed of garnet and schist, and are much older than the lowland areas; they date back to the Permian and Triassic periods (280-190 million years ago).

In lowland regions, the soils which have formed are predominantly lowland podzolised yellow-brown earths and gley recent soils, and in elevated forested regions the soils are mainly lowland yellow-brown earths and lowland and upland yellow-brown earths and podzols (Soil Bureau 1968).

The weather is characterised by high rainfall with frequent rain of high intensity, which gives rise to frequent and sudden floods of short duration. Data recorded at Fox Glacier, 5 km north of the Cook River, show an average of 174 rain days per year, with a mean annual rainfall of 4540 mm (New Zealand Meteorological Service 1983). Average humidity throughout the year is also high; the monthly average at 9 a.m. never falls below 89%.

No hydrological data for rivers of the region are available, but it is assumed that there are spring floods due to snow thaw in most of the main rivers, as found by McDowall and Eldon (1980) for the Haast and Waiatoto Rivers to the south.

Most of the land is covered by temperate rain forest. Tenure includes u.c.l., land in private ownership, and some scenic reserves, but most land lies in the Karangarua, Hunts Beach, Makawhio, and Bruce Bay State Forests.

There are seven main river catchments; the Cook, Ohinetamatea (Saltwater), Karangarua, Manakaiaua, Makawhio (Jacobs), Mahitahi, and Ohinemaka. These all rise on the western slopes of the Southern Alps, which have a maximum elevation of 3764 m a.s.l. (Mt Cook).

The local human population is very sparse; there are fewer than 80 permanent residents, concentrated mainly at Karangarua, Manakaiaua, Jacobs River, Mahitahi, and Bruce Bay. Farming is the principal local occupation; about 37 km^2 of the survey area is farmland. In the past, logging has been an important occupation, and there are several old, disused sawmills in the area.

3.1 The Forests

Numbers after state forest (S.F.) names refer to NZFS numbering on Westland Conservancy maps. Fishes present in each state forest are listed in Table 1.

3.1.1 Karangarua State Forest 9

Karangarua State Forest is the major forest in the study area, and covers about 110 km^2. S.H.6 divides the forest into two roughly distinct zones, both topographically and vegetatively.

To the east of the highway the terrain is elevated, and rises up to the Copland Range which has a maximum elevation of about 1970 m a.s.l. The dominant canopy species of this, the larger zone, are kamahi (*Weinmannia racemosa*), rimu (*Dacrydium cupressinum*), and southern rata (*Metrosideros umbellata*); the subcanopy is composed of pigeonwood (*Hedycarya arborea*) and whiteywood (*Melicytus ramiflorus*).

The other zone, west of S.H.6, is largely low-lying (below 30 m a.s.l.) except for spurs bordering the Cook and Ohinetamatea Rivers. In this part of the forest kahikatea (*Dacrycarpus dacrydioides*) and rimu are the dominant forest canopy species.

TABLE 1. Distribution of fishes in each state forest (S.F.). Fish recorded from waters forming the boundary of a state forest are listed as within the forest. (Subjective abundance: * rarely recorded; ** sometimes recorded; *** frequently recorded; 1 = a single record on the boundary of these two forests.)

Species	Common name	Karangarua S.F.	Hunts Beach S.F.	Makawhio S.F.	Bruce Bay S.F.	Ohinemaka S.F.	Other areas
Geotria australis	lamprey	*		*			
Anguilla australis	short-finned eel	**	**	*			**
Anguilla dieffenbachii	long-finned eel	***	***	**	***	**	***
Retropinna retropinna	common smelt	*	*	*	*		*
Galaxias maculatus	inanga	***	**	*	*		***
Galaxias brevipinnis	koaro adults	**		*		*	**
Galaxias fasciatus	banded kokopu	*	*	**		*	
Galaxias argenteus	giant kokopu	*	**	*	**	**	*
Galaxias postvectis	short-jawed kokopu	*		*			
Cheimarrichthys fosteri	torrentfish	**	*	*	*	*	*
Gobiomorphus hubbsi	blue-gilled bully	*		*	*		*
Gobiomorphus cotidianus	common bully	*	***	*	**	*	*
Gobiomorphus huttoni	red-finned bully	***	*	***	**	**	***
Rhombosolea retiaria	black flounder	*	*		*	*	*
Arripis trutta	kahawai		*		*1	*1	
Aldrichetta forsteri	yellow-eyed mullet	*	*	*	*	*	*
Salmo trutta	brown trout	**	*	**	*	***	**
Oncorhynchus tshawytscha	quinnat salmon						*

Almost the whole catchment of the Ohinetamatea River lies within this forest. Some tributaries of the Karangarua River and one of the Cook River are also within its boundaries; in places the mainstems of the two rivers form the southern and northern boundaries respectively of the forest.

3.1.2 Hunts Beach State Forest 38

Hunts Beach State Forest is a small, roughly triangular forest of about 36 km^2. It is low-lying, with a maximum elevation of 30 m a.s.l. It is bounded by the sea to the north-west, Karangarua River to the north-east, and privately owned land to the south. Most of the ground in the forest is boggy, and kahikatea is the dominant canopy tree.

Hunts Beach State Forest is drained for the most part by two sluggishly flowing, tannin-stained streams, Gordon and Nicholson Creeks, which flow into a common estuary shared with the Karangarua River.

3.1.3 Makawhio State Forest 8

Makawhio State Forest, covering about 33 km^2, is the smallest state forest in the study area. The whole forest is raised in elevation. It begins at S.H.6 to the north and rises to a line lying east-west and in line with Karangarua Peak. To the west it is bounded by the Makawhio River and leasehold land, and to the east by a line running north-south. The maximum elevation in the forest is about 1080 m a.s.l. Rimu and southern rata are the dominant canopy trees; the subcanopy is composed largely of kamahi, pigeonwood, and whiteywood.

A large section of the Manakaiaua River flows through the Makawhio State Forest and this is the main river catchment in the forest.

3.1.4 Bruce Bay State Forest 7

Bruce Bay State Forest is about 40 km^2 in area, and has a maximum elevation of about 920 m a.s.l. It is bounded by S.H.6 to the north and privately owned land to the east and west, with u.c.l. to the south.

The forest comprises roughly equal proportions of low-lying and elevated land. Most of the low-lying land consists of a large pakihi swamp (known locally as Lake Kini Pakihi) and three smaller areas of pakihi. All have been formed by logging (A. Brown, NZFS, pers. comm.). The remaining lowland forest is dominated by rimu, kahikatea, and other podocarps. In the elevated region the forest is mainly kamahi and rimu.

Drainage of this forest is by Papakeri and Ruera Creeks (Makawhio system) and by a dragline channel from Lake Kini.

3.1.5 Ohinemaka State Forest 6

Ohinemaka State Forest is about 118 km^2 in area. Roughly half is low-lying (less than 30 m a.s.l.), whereas the rest is elevated, and rises to about 1230 m a.s.l. It extends from the sea to the Douglas Range, to the north and south-east respectively, and from the Mahitahi River in the east to Paringa River in the south-west.

The vegetation of this forest is diverse (J. Mead, NZFS, pers. comm.). The canopy is composed predominantly of kahikatea and rimu, but there are patches of other podocarps and there is one patch of pakihi vegetation. On the elevated areas north-west of S.H.6, silver beech (*Nothofagus menziesii*) is present.

Ohinemaka State Forest is drained by the Ohinemaka River and its tributaries.

3.1.6 Other Areas

There are also some areas of forested u.c.l, and some leasehold and freehold land, both forested and pastured, in the study area.

3.2 The Catchments

Physical features of each catchment studied are summarised in Table 2.

TABLE 2. Physical features of catchments in the study area.

River	Catchment area (km^2)	River length (km)	Origin	Water colour
Cook	340	32	glacial	grey
Ohinetamatea	100	29	rain	clear-tannin
Karangarua	350	47	glacial/rain	blue-grey
Manakaiaua	60	18	rain	clear-tannin
Makawhio	175	31	rain/snow	clear
Mahitahi	225	33	rain/snow	clear
Ohinemaka	72	15	rain	clear

3.2.1 Cook River

The Cook River is largely glacially fed. It derives most of its flow from the Fox River, which in turn gains most of its flow from Fox Glacier. The Cook flows for about 32 km and has a catchment of about 340 km^2, mostly within Westland National Park.

Because of its glacial origin it is a cold river. A spot-sampled February temperature of only 6°C was recorded at S.H.6 bridge (compared with February temperatures of 12-14°C for most other rivers of the region), though the temperature increased to 11°C 12 km downstream. The glacier contributes a high sediment load to the river which gives it a greyish colour.

Above S.H.6 bridge the Cook River has a narrow, gorge-like valley rising steeply to the Balfour Range. Below the junction of the Cook and Fox Rivers is a broad flood plain, across which several spring-fed streams flow. Throughout its length the Cook is a torrentially flowing river.

The mainstem of the river has changed course from that shown on the NZMS1 S78 topographical map (2nd edition 1977), and the lower reaches now follow the course of the Clearwater River north-west of the original course. In its lower reaches the flood plain and old course of the river skirt the northern-most edge of Karangarua State Forest.

Only the mainstem and part of the catchment on the south side of the river were included in the study area.

3.2.2 Ohinetamatea River

This rain-fed river rises in the Copland Range at a maximum elevation of about 1230 m a.s.l. and flows through Karangarua State Forest for its entire length. It has a twisting course, which is about 29 km long, and a catchment of about 100 km^2.

In its upper reaches, the Ohinetamatea River is clear, very swiftly flowing, and bouldery, with many small falls. Its physiography gradually changes with a reduction in gradient, until the river becomes a wide, tannin-stained, sluggishly flowing, tidal reach shortly before it enters the sea. The upper reaches flow through a gorge, which widens to become a very narrow flood plain in the middle section and this gradually diminishes so that in the lower reaches the river flows in a confined, entrenched channel.

3.2.3 Karangarua River

The Karangarua River rises in the Hooker Range at an elevation of about 1540 m a.s.l. and is in part glacially fed. It flows for about 47 km and has a catchment of more than 350 km^2, most of which lies in Westland National Park, but some of which also includes parts of the Karangarua and Hunts Beach State Forests. Although it flows through forested areas for most of its length, there are several kilometres of its course below S.H.6 where forest has been cleared and replaced by rough pasture.

The Karangarua is swiftly flowing and blue-grey in colour, and it is the largest river in the study area. Below S.H.6 it has a moderately wide flood plain and is slightly braided.

At its mouth the Karangarua River and Gordon and Nicholson Creeks share a common estuary. These two creeks are much branched and drain Hunts Beach State Forest. Both creeks are deeply entrenched, sluggish, tannin-stained, have a mud and gravel bed, and are tidal for several kilometres upstream from their common mouth.

3.2.4 Manakaiaua River

The Manakaiaua is a small, rain-fed river, about 18 km long, which rises in the Bare Rocky Range at an altitude of about 1230 m a.s.l. Its catchment of about 60 km^2 lies in Makawhio State Forest, u.c.l, and private land. Most of the catchment is forested, but in the lower reaches, on private land, some of the forest has been cleared and replaced with rough pasture.

In its upper reaches the Manakaiaua River is clear and flows very swiftly through a narrow, gorge-like valley. About 3 km above S.H.6 its bed widens to form a narrow flood plain, and the river velocity decreases. In the lower 2 km it is more or less entrenched, slightly tannin-stained, sluggish, and tidal.

3.2.5 Makawhio River

The Makawhio rises in the Bare Rocky and Bannock Brae Ranges at an altitude of about 1230-1380 m a.s.l. It is a snow- and rain-fed river, and has a catchment of about 175 km^2. For most of its length of 31 km it flows through u.c.l and leasehold land, though some of the lowest reaches are bordered on the true right bank by Makawhio State Forest. The lower part of the leasehold land has been cleared of forest to become rough pasture.

This is a clear river with a slight blue tinge. In the upper reaches it has a bouldery bed and is very swiftly flowing. Where it emerges from the forest into rough pasture the bed widens into a narrow flood plain, the substrate becomes less coarse, and water velocity is reduced. From here to its mouth the river continues to widen, and the flow continues to decrease.

The Makawhio catchment formerly included Lake Kini and its surrounding pakihi. This area is being drained by a dragline running directly to the sea and is now largely isolated from the Makawhio catchment.

3.2.6 Mahitahi River

The Mahitahi rises in the Bannock Brae and Strachan Ranges at altitudes of up to about 1850 m a.s.l. and has a catchment of about 225 km^2. It is fed by snow and rain. The river rises in u.c.l.

and flows for 33 km. In the lower reaches, the true left bank is bordered by Ohinemaka State Forest, and the true right bank is bordered by land of diverse, but mainly private, tenure. Only the lower reaches and lower tributaries of this river were sampled.

The Mahitahi is a fast-flowing river with a stoney substrate. In the lower reaches it has a narrow flood plain and is slightly braided.

3.2.7 Ohinemaka River

The Ohinemaka is a small, rain-fed river which rises in the Douglas Range at an altitude of about 1080 m a.s.l. It has a catchment of about 72 km^2 and flows for 15 km. The whole of its catchment lies within Ohinemaka State Forest.

Most of the streams which form the Ohinemaka River rise in hills, and are swiftly flowing and bouldery. As the gradient decreases water velocity decreases and substrate particle size gradually becomes reduced to fine gravel and sand near the river mouth.

4. MATERIALS

The most frequently used items of sampling gear were G40 minnow traps and minifyke nets. These were effective in sampling most fish species and were fairly light and portable, which enabled them to be readily carried long distances.

The G40 minnow trap is a Canadian, commercially produced, wire basket-type trap. It is formed of two identical halves 15 cm in length and width. Each half has a coned entrance and the halves are joined by a quick-release spring clip. For transportation, the halves of many traps can be nested. Minnow traps were baited with commercially produced salmon-feed pellets contained in perforated plastic vials.

The minifyke, made by FRD, is a scaled-down version of the commercial eel-fishing fyke net. It is a 1-m-long trap with a wing of about the same length. The netting has a stretched-mesh diameter of 10 mm and the net has only one non-return valve (Figs. 2 and 3).

Commercial single- and double-ended fyke nets with a stretched-mesh diameter of 25 mm and two non-return valves, often were used in conjunction with the previous equipment, and sometimes on their own where the depth and flow were too great for minifykes (Fig. 4). A V-wing fyke net also was used on occasions.

In some situations, notably estuaries, a 50 x 3 m, four-panelled, bottom-fishing gill net was used. The net panels had stretched-mesh diameters of 10 mm, 25 mm, 55 mm, and 85 mm.

A hand-held push-seine net, comprising a 1-m-wide apron of mosquito netting slung between two poles and weighted at the lower edge, was a useful spot-sampling tool in some shallow waters.

A 15-m-long beach-seine net, with a stretched-mesh diameter of 10 mm, was used where sufficient snag-free, slack water was available.

Towards the end of the sampling period an electric fishing team, operating a battery-powered packset machine, fished selected waters in the study area to verify trapping results.

Standard thermometers were used to measure water temperature and a Metrohm E444 meter was used to measure pH.

FIGURE 2. Minifyke set in a tributary of the Makawhio River.

FIGURE 3. Emptying the contents of a minifyke into the boat at the inlet to Lake Kini.

FIGURE 4. A single-wing fyke net set in a tributary of Power Creek (Ohinemaka catchment).

A small fibreglass dinghy with a 4 h.p. outboard engine was sometimes used on large bodies of water for setting nets and for transportation. Helicopter and jetboat access to some isolated places was provided by NZFS, but a great deal of country was covered on foot.

5. METHODS

Baited minnow traps were most effective and were used extensively where there was little or no current, but could also be used in moderate flows. They were tied to the bank and left to fish overnight. They could be used at any depth in water over a few centimetres deep and caught fish with body diameters between about 5 and 35 mm (the upper limit was determined by size of the trap entrance). It was assumed that fish caught by minnow trap were resident in the area, though some may have been attracted from outside the area by the bait.

Fyke nets work on the principle that on encountering a barrier (the wing), fish swim along it and thus into the trap. Fyke nets were not baited, but caught all except the smallest and most slender of fishes moving in shallow water or near the bottom in deeper water. A disadvantage of this was that when large eels were caught, it was necessary to examine their stomach contents to find the rest of the catch, which the eels often had eaten.

In still or slowly flowing water single-winged fyke nets were set at right angles to the bank, with the leader attached to some suitable object - a branch or rock. In faster currents the nets were angled slightly downstream to deflect the force of water. The V-wing fyke net was set in large channels, parallel with the flow, with its wings spread to cover as large an area as possible.

In large bodies of still or placid water the gill net was used to catch pelagic fishes. It was advantageous in such circumstances because it sampled species that might avoid the directing effect of trap nets (for example, species not dependent on cover).

In quiet water the push net could be used by one person pushing the net in front and trapping fish within it. However, it was most frequently used as a stop net in swiftly flowing water, where one person held the net downstream while another disturbed the substrate upstream and worked towards the net, driving fish into it.

The beach-seine net was also used as a stop net in large streams with a rapid current. It was stretched across the channel between two boulders and two people worked fish into it. This net was more conventionally used as a beach seine in suitable conditions, such as quieter stretches of the main rivers. In these instances 30 m ropes were tied to either end of the net, which was set from the dinghy and then hauled on to a gently shelving bank.

Electric fishing was undertaken primarily to test the effectiveness of the other sampling methods. At two of five stations, electric fishing caught a species which had not been recorded during previous sampling. However, because in both instances only a single individual was involved and we were primarily interested in qualitative rather than quantitative data, the other methods were deemed to be effective.

When pH and temperature data were recorded they were collected on one day so that a series of stations could be sampled under similar flow conditions.

When there was any doubt about the identity of fish, as sometimes there was in the early stages of the field work, specimens were preserved in 8% formalin and sent to the FRD Christchurch laboratory for examination.

Species and numbers of fishes, as well as fish habitat data, were recorded on Freshwater Fish Survey sheets (Appendix I). Habitat data included details on whether sites were tidal, their distance from the sea, their altitude, details of cover present, the colour of the water, and a broad categorisation of bank vegetation type. Subjective flow and substrate data also were recorded. Data were analysed later to determine factors affecting the distribution of species and the habitat requirements of native fishes. Data were recorded on a computer file as part of the New Zealand Freshwater Fish Survey (McDowall and Richardson 1983).

Sampling was carried out as systematically as practicable. It was started at Cook River and continued progressively southwards. Every waterbody was sampled if possible, though some areas were excluded, mainly because of inaccessibility or lack of time. Such areas included the upper reaches of the Manakaiaua, Makawhio, and Mahitahi Rivers.

6. HABITAT, ECOLOGY, AND DISTRIBUTION OF THE FISHES

In this section each species recorded during the study is discussed separately, and its life cycle, habitat requirements, general distribution, and specific distribution in the study area are outlined. Unless otherwise acknowledged, the life cycle and general distribution data are from McDowall (1978). Details of habitat requirements and distribution of species in the study area are results from this survey.

Table 1 lists fishes recorded during the study, and their relative abundance in each state forest. Appendix II shows the distribution of fishes by catchment.

6.1 Habitat Features

Table 3 summarises physical habitat data for species present at six or more sites of the 202 sampled.

6.1.1 Water Temperature

Spot-recorded river and stream temperatures for January to March (when temperatures are most likely to be critical for fishes) ranged from 6°C (Cook River, at 120 m a.s.l.) to 22°C (a minor tributary of the Manakaiaua River). The mean for 29 records was 13.7°C (standard deviation 2.45), and 23 of the records fell within the range 12-15°C.

Standing water temperatures in ponds, ditches, and bogs etc. were higher, and ranged from 12°C to 26°C (mean = 17.7°C, s.d. = 3.6, n = 13).

Maximum water temperatures at which the different species of fish were recorded are shown in Table 4. These data are sparse and need to be supplemented in the next stage of the South Westland programme.

6.1.2 pH

Spot-recorded pH levels for 24 rivers and major tributaries in this study ranged from 5.8 to an exceptional 7.8 (mean = 6.6, s.d. = 0.50) (Table 5). The levels for 31 small streams and other waters found to contain fish, ranged from 3.8 to 6.7 (mean = 5.7, s.d. = 0.87).

The range, mean, and standard deviation of pH levels recorded from the habitats of 13 species of fish are listed in Table 6. Means and 95% confidence limits for each species are shown in Figure 5.

TABLE 3. Presence of fish species and habitat features at 202 sampling sites. (Only those species found at six or more sites have been included.) Each group of categories may not sum to the total number of sites at which the species was present, because more than one catebory may be present in any data record.

			Distance from sea (km)					Altitude (m)					Flow type								Substrate type						Instream and riparian cover					Bank vegetation				Water colour					Presence/absence brown trout	
	No. of individuals	No. of sites at which species present	< 1	1-5	5-10	10-20	> 20	< 30	30-60	60-90	90-120	> 120	Still	Sluggish	Pool	Run	Riffle	Torrent	Fall	Pond, lake, swamp	Boulders	Cobbles	Gravel	Sand	Mud	Detritus	Weed and/or emergent veg.	Overhanging banks	Overhanging vegetation	Logs	Nil	Forest	Forest and grass	Grass/scrub	Swamp	Clear	Light tea	Dark tea	Grey	Other	Juveniles	Adults
Long-finned eel	504	82	11	23	23	20	6	66	7	4	2	3	5	30	39	33	22	5	4	13	12	37	49	51	31	9	28	43	8	27	2	48	11	18	9	26	22	25	0	8	8	8
Short-finned eel	75	17	1	6	4	6	0	16	0	0	1	0	4	2	1	4	1	1	0	10	0	3	2	3	15	14	10	9	1	3	0	9	1	6	1	1	3	8	0	5	1	2
Common smelt	30	6	3	1	2	0	0	6	0	0	0	0	0	3	1	3	0	0	0	0	0	4	5	6	0	0	0	1	0	2	1	5	1	1	0	1	2	0	1	3	0	3
Inanga	355	42	5	19	9	8	2	39	2	0	1	0	5	20	14	17	12	3	1	5	2	17	21	23	22	5	22	23	2	15	2	18	6	14	8	11	9	13	1	6	3	4
Koaro adults	76	21	0	0	4	11	6	0	2	6	3	12	0	0	20	15	7	5	10	0	20	16	15	17	0	0	0	3	2	1	0	21	0	0	0	18	3	0	0	0	4	0
Banded kokopu	75	17	3	5	4	4	1	11	3	2	0	0	1	7	12	8	7	0	2	1	2	14	10	7	7	1	4	11	4	11	0	12	5	0	1	0	7	8	0	2	3	0
Giant kokopu	39	22	1	11	3	6	1	18	3	0	0	0	3	9	13	7	4	0	2	1	3	9	11	9	15	2	10	15	3	10	0	16	5	0	2	2	7	11	0	1	2	0
Short-jawed kokopu	15	6	0	0	2	1	3	2	2	1	0	1	0	2	6	5	2	1	0	0	3	6	6	5	0	0	0	3	0	2	0	6	0	0	0	1	5	1	0	0	1	0
Torrentfish	257	19	4	3	9	2	1	16	3	0	0	0	1	5	4	12	10	4	0	0	2	16	16	16	1	0	4	3	0	3	0	8	4	6	1	11	2	1	3	2	8	2
Red-finned bully	279	46	4	11	18	7	8	35	7	3	1	0	3	15	27	31	23	4	1	1	5	24	36	31	11	3	11	26	4	18	0	23	9	12	4	17	12	13	1	6	2	12
Common bully	157	24	10	11	1	1	1	23	1	0	0	0	0	15	12	7	4	0	0	0	0	11	15	20	6	1	6	11	1	10	2	17	5	4	2	8	4	9	3	0	1	4
Blue-gilled bully	72	6	0	1	4	0	1	4	2	0	0	0	0	0	2	5	5	2	0	0	0	6	6	5	0	0	0	0	0	0	0	2	0	4	0	4	0	0	0	2	5	0
Black flounder	32	9	4	2	3	0	0	9	0	0	0	0	0	5	1	2	1	0	0	1	0	7	6	7	2	0	3	1	1	2	1	4	2	3	0	3	2	3	1	0	2	4
Yellow-eyed mullet	224	7	6	1	0	0	0	7	0	0	0	0	0	5	1	1	0	0	0	0	0	3	6	6	0	0	0	1	0	3	3	6	0	3	0	1	2	2	2	1	0	5
Brown trout	86	40	5	8	10	14	4	27	2	4	5	4	1	1	21	26	15	6	2	1	8	24	35	32	4	0	7	18	4	14	2	27	3	11	0	23	5	4	3	6	-	-

TABLE 4. Maximum summer water temperatures (°C) at which fishes were recorded.

Species	Maximum temperature (°C)	*n*
Long-finned eel	26	16
Short-finned eel	26	9
Inanga	26	18
Koaro (adults)	15	2
Banded kokopu	14	6
Giant kokopu	18	5
Short-jawed kokopu	14	3
Torrentfish	15	2
Common bully	16	3
Red-finned bully	22	14
Blue-gilled bully	15	1
Black flounder	16	2
Brown trout	16	6

TABLE 5. Values of pH's of rivers and major tributaries.

River	pH
Cook River	7.1
Large stream on the Cook River flood plain	7.8
Small stream on the Cook River flood plain	6.7
Bullock Creek	6.8
Ohinetamatea River	6.6-6.9
Black Creek	5.9
Havelock Creek	7.2
Hobson Creek	5.8
Stoney Creek	6.6-6.8
Rough Creek	7.0
Karangarua River	6.7-7.1
Maimai Creek	6.5
Hunt Creek	6.6
Manakaiaua River	7.1
Pita Creek	6.3
Break Creek	6.3
Makawhio River	6.3
Kini Creek	6.8
Hermann Creek	6.5
Leo Creek	7.1
Papakeri Creek	7.1
Lake Kini outlet	5.8
Mahitahi River	6.2-7.0
Blackwater Creek	5.9

TABLE 6. Values of pH's of habitats from which fishes were recorded.

Species	Range	Mean	s.d.	*n*
Long-finned eel	4.3 - 7.1	6.3	0.63	36
Short-finned eel	4.5 - 6.7	6.1	0.82	6
Inanga	3.8 - 7.0	6.0	0.83	23
Koaro (adults)	6.5 - 7.1	6.8	0.22	10
Banded kokopu	5.0 - 6.6	5.9	0.48	9
Giant kokopu	4.2 - 7.1	5.8	0.82	12
Short-jawed kokopu	5.7 - 6.6	6.1	0.47	3
Torrentfish	5.8 - 7.8	6.7	0.45	15
Common bully	4.3 - 7.1	6.3	0.93	7
Red-finned bully	4.7 - 7.1	6.2	0.53	33
Blue-gilled bully	6.3 - 7.8	6.9	0.56	6
Brown trout	5.0 - 7.8	6.5	0.56	20
Black flounder	6.8	6.8	-	3

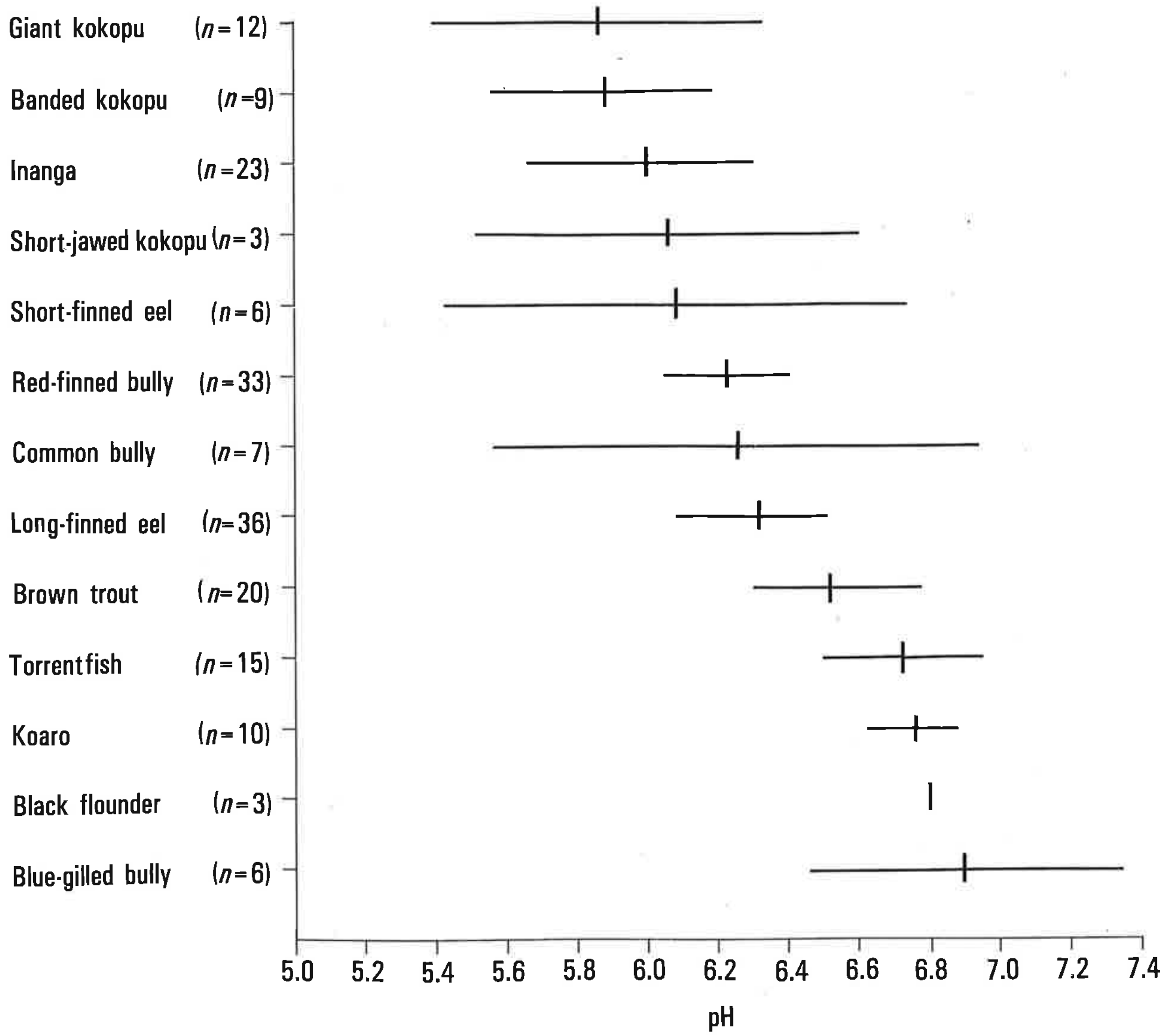

FIGURE 5. Mean and 95% confidence limits of pH from habitats of 13 fish species in South Westland, 1984.

6.2 Native Fishes

Of the 27 known native freshwater fishes, 14 were recorded in the survey area. All 14 species are diadromous (that is, they migrate between fresh and salt water), and most fishes are endemic (that is, they are present only in New Zealand). However the lamprey, short-finned eel, inanga, and koaro are also present in other Southern Hemisphere countries. Table 1 lists fishes recorded during the study and their relative abundance in each state forest.

6.2.1 Lamprey (*Geotria australis*)

To the untrained eye the adult lamprey resembles a slender eel, but it swims with a sinuous motion. On first entering fresh water it is silver with steel blue stripes, but later it changes colour to brown. At this stage it is commonly 450-550 mm long.

Adults enter fresh water during winter to spawn. Spawning sites in New Zealand are unknown, but as adults are fairly adept at climbing low falls and swift rapids, spawning sites may be far upstream. Larval life takes place entirely in fresh water. The first stage (ammocoete) burrows into the silt bottom of quiet waters and sieves the water to obtain microscopic food organisms. Ammocoetes metamorphose into the second stage (macrophthalmia), probably in late summer or autumn, and this stage makes its way to sea.

Lampreys are highly cryptic, with habits that do not make them easy to trap or observe. However, an ammocoete was taken from a tributary of the Ohinetamatea River and a macrophthalmia from Pita Creek (Manakaiaua system) (Fig.6). It is reasonable to assume that lampreys may be widespread in South Westland.

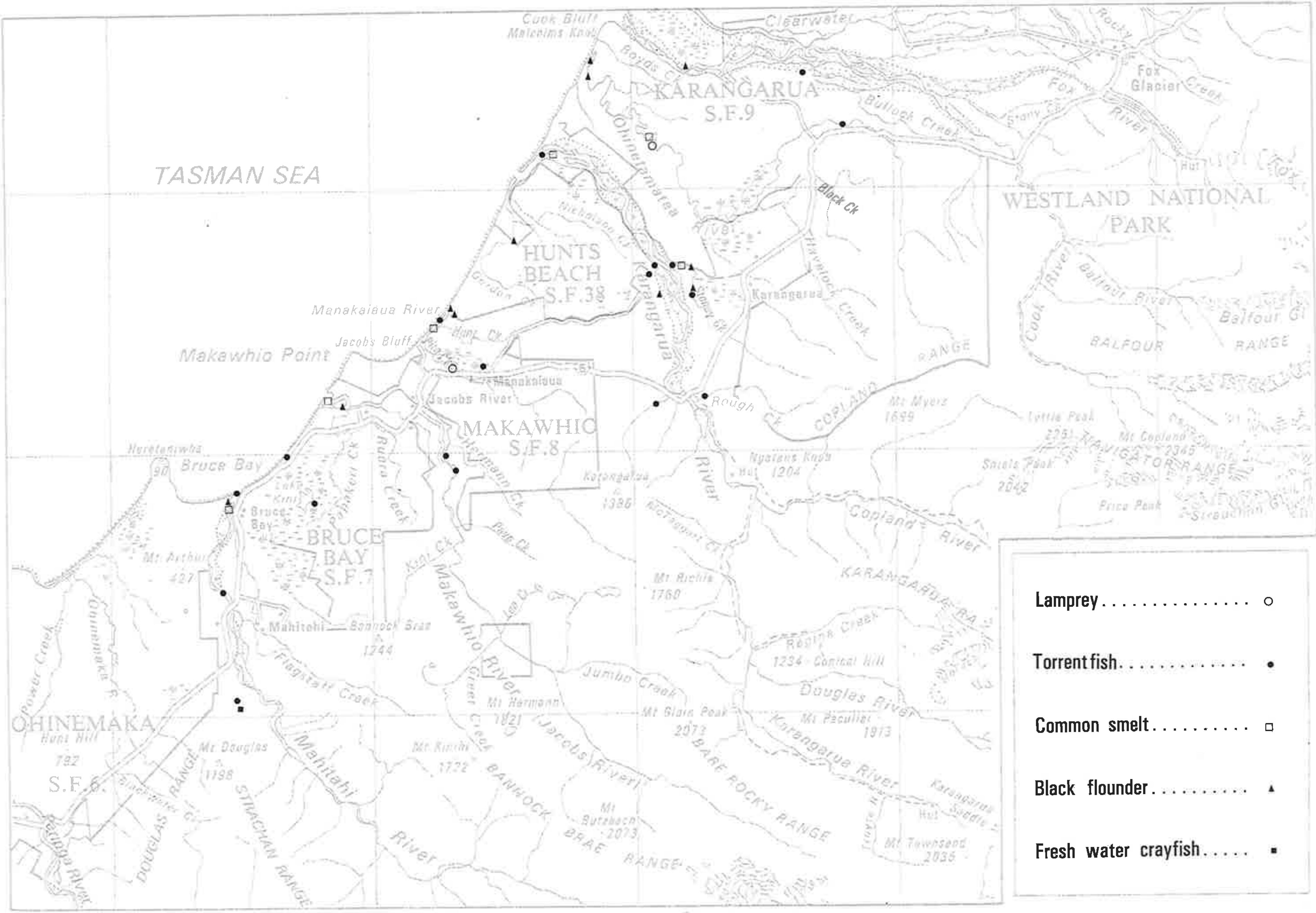

FIGURE 6. Sites from which lamprey (*Geotria australis*), common smelt (*Retropinna retropinna*), torrentfish (*Cheimarrichthys fosteri*), black flounder (*Rhombosolea retiaria*), and freshwater crayfish (*Paranephrops planifrons*) were recorded.

6.2.2 Long-finned Eel (*Anguilla dieffenbachii*)

Long-finned eels begin their life as leaf-shaped leptocephalus larvae in the sea. They metamorphose into small "glass" eels and in spring they enter streams and rivers, where they spend several months in the lower reaches. During this time they lose their transparency and slowly migrate upstream. Adult eels migrate to sea and spawn somewhere in sub-tropical seas. Females usually migrate when a little over 1 m long, males when about 650 mm. Very large eels may be older than 60 years of age (Jellyman and Todd 1982) and are females which have been slow to reach sexual maturity. Long-finned eels are the most widespread fish in New Zealand streams and rivers, partly because they are able to penetrate the furthest reaches of river systems.

During this study long-finned eels were almost invariably present in any habitat which contained fish. They were the most widely distributed and numerous species of fish in the study area (Fig.7), because of their ability to extensively penetrate river systems and their broad habitat tolerances.

From rapid water such as riffles and torrents, only juvenile long-finned eels (elvers) were collected. Not many long-finned eel sites (19.3%) were above 30 m a.s.l., though some (3.6%) were at altitudes greater than 120 m a.s.l. Otherwise this species occupied a very wide range of habitats, and was abundant if cover was available (Fig.8).

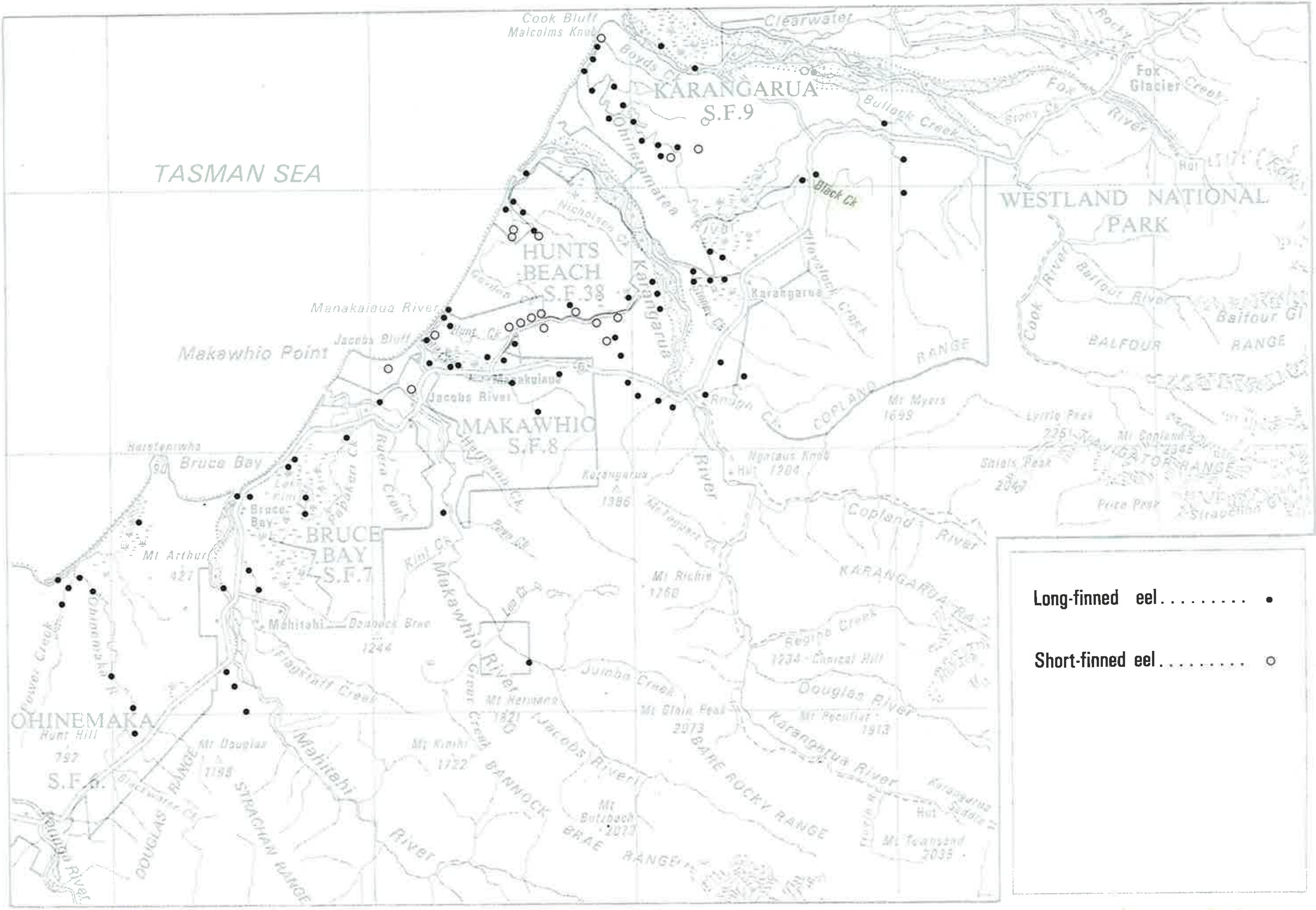

FIGURE 7. Sites from which long-finned (*Anguilla dieffenbachii*) and short-finned eels (*A. australis*) were recorded.

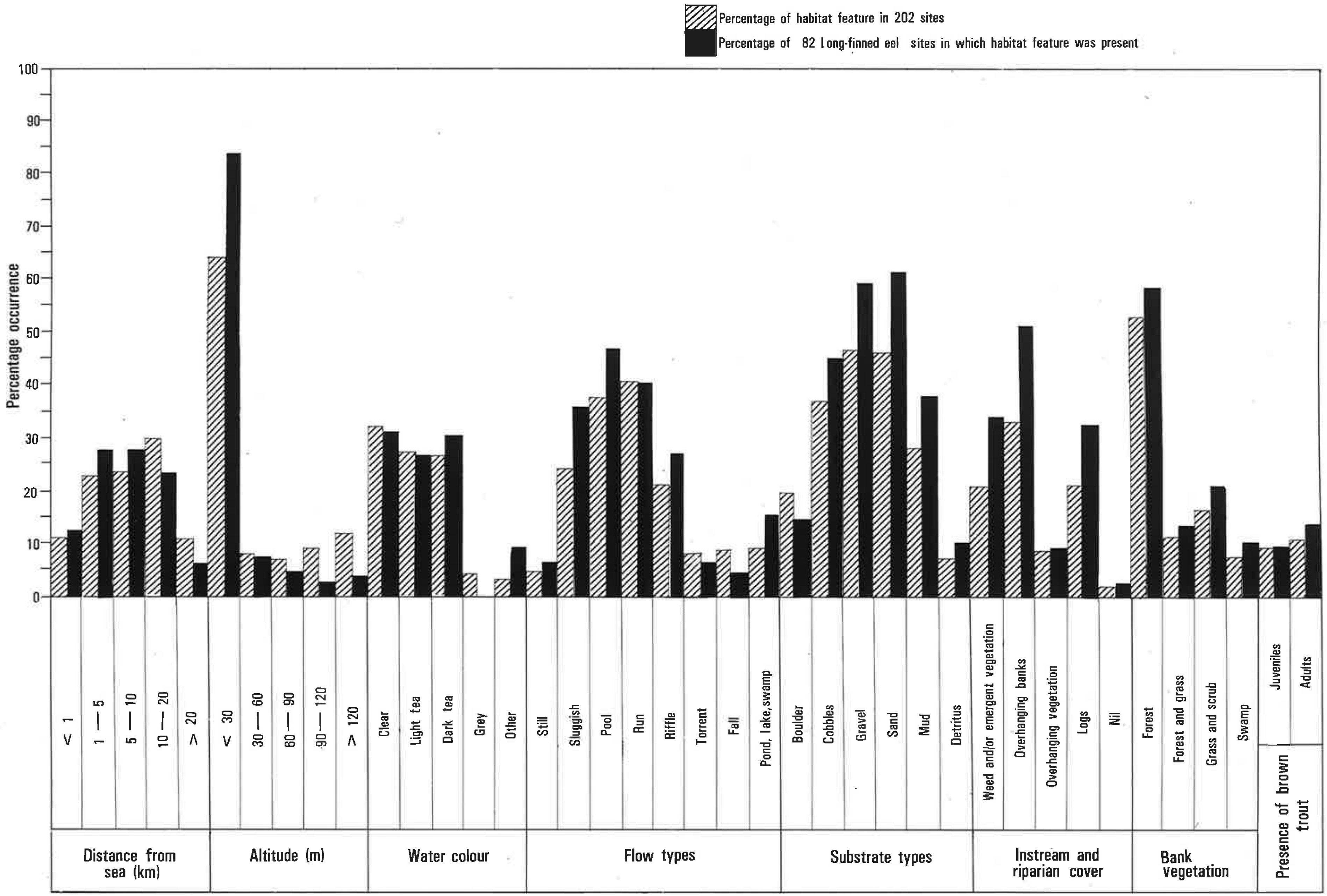

FIGURE 8. Features of long-finned eel habitats.

6.2.3 Short-finned Eel (*Anguilla australis*)

The lifecycle of the short-finned eel is very similar to that of the longfin. However, at the time of migration to the sea, short-finned eels are smaller than longfins, generally 50-100 cm for females and 38-55 cm for males (Jellyman and Todd 1982).

In New Zealand this eel is less widely distributed than the longfin, but in addition to New Zealand it is present in Australia, Tasmania, New Caledonia, Norfolk Island, and other islands to the north.

In the study area, the short-finned eel was the more prevalent of the two eel species only between Hunts Beach State Forest and S.H.6, where there are many ponds among rough pasture. Otherwise it was not abundant, though it was recorded from a spring-fed stream on the Cook River flood plain, Boyds Creek, ponds and swamps in the Ohinetamatea catchment, Gordon and Nicholson Creeks, Boiler Creek (Manakaiaua system), a pond in the Manakaiaua system, and a small lake in Makawhio State Forest (Fig. 7).

The short-finned eel seems to be more specific in its habitat requirements than the longfin. It was usually at low altitudes (below 30 m a.s.l.) and always less than 20 km from the sea. However, there was one population in a small unnamed lake on a plateau (map reference S78/379510), where the altitude was greater than 100 m a.s.l. (Fig. 9). Although juveniles often were present in riffles, almost all adults were recorded from standing or slack water. More than 50% of the sites were ponds, lakes, or swamps (compared with less than 20% of long-finned eel sites). The substrate of these habitats was usually mud. Cover in the form of aquatic or emergent vegetation, detritus, and overhanging banks was almost always present. Only 5.9% of sites from

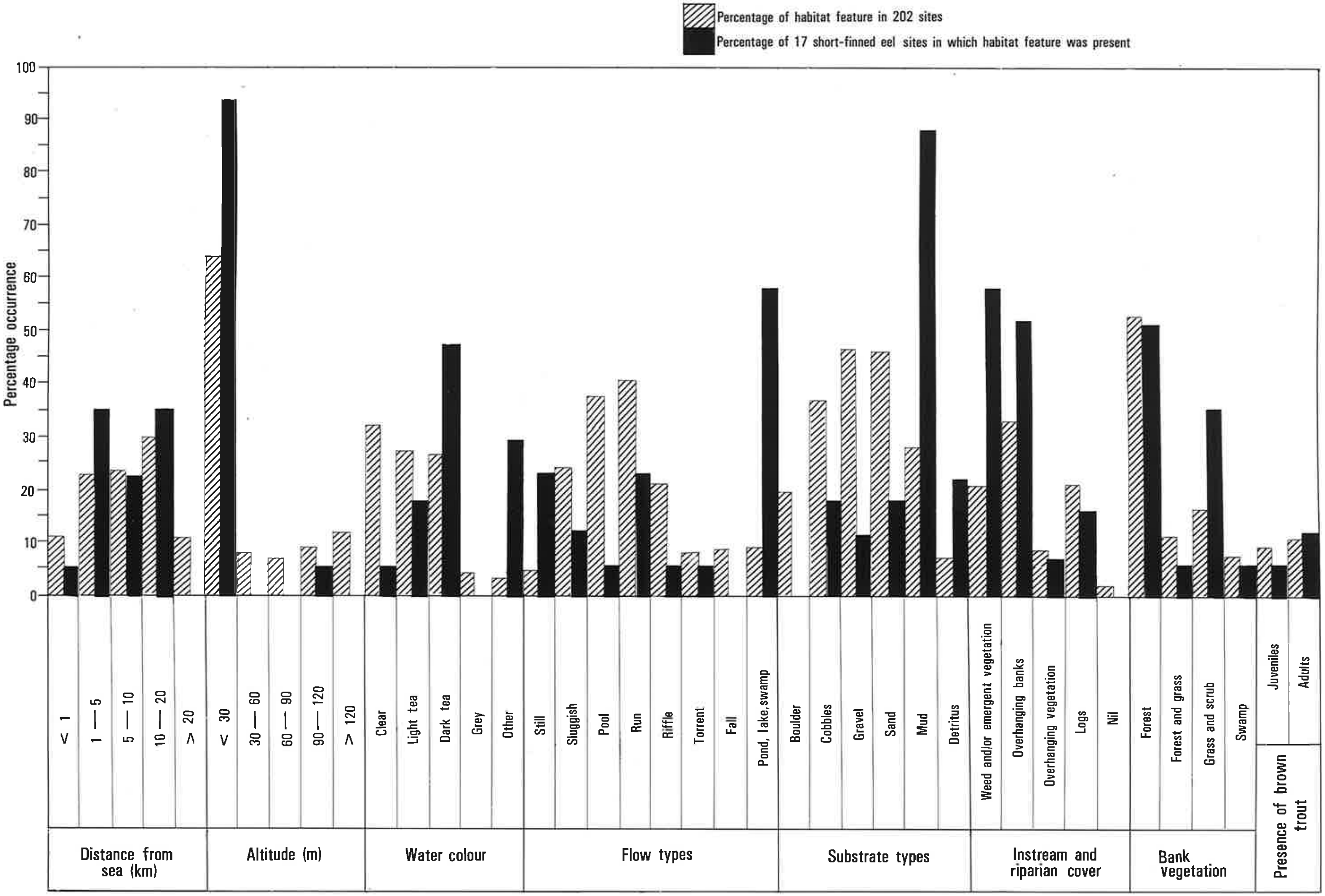

FIGURE 9. Features of short-finned eel habitats.

which short-finned eels were recorded were clear (compared with 32.1% of all sites sampled), the majority (64.6%) being tannin-stained.

6.2.4 Common Smelt (*Retropinna retropinna*)

The common smelt is a slender, streamlined fish and is easily identified by its peculiar cucumber-like smell, a characteristic which gives rise to the alternative name of "cucumber fish". Adult smelt are 100-140 mm long.

Smelt move into lowland rivers in large shoals during spring (as almost mature adults) and spend the summer there, where they reach full maturity (McDowall 1981). They are usually found close to the sea, though if a river has only a gentle gradient they may penetrate far inland. Smelt spawn in sandy pools, the adults dying after spawning and the larvae going to sea upon hatching (McDowall 1981). Smelt are present in rivers throughout the country and there are also lacustrine (lake-dwelling) populations.

Common smelt were taken infrequently during this study. The most inland site at which they occurred was the confluence of the Karangarua River with Stoney Creek, about 9 km from the sea. They were also taken from a tributary of Ohinetamatea River and from the mouths of the Karangarua, Manakaiaua, Makawhio, and Mahitahi Rivers (see Fig.6).

The common smelt is a non-cryptic, pelagic fish, less dependent on physical cover than other species. Consequently the sites from which it was taken often had little cover available. It was found in slack water at low altitude (below 30 m a.s.l.) and most of its habitats were tidal.

6.2.5 Whitebait Species

Whitebait are the juveniles of five species of the family Galaxiidae: inanga (*Galaxias maculatus*) , koaro (*G. brevipinnis*), banded kokopu (*G. fasciatus*), giant kokopu (*G. argenteus*), and short-jawed kokopu (*G. postvectis*).

The most important of these, the inanga, spawns in the estuarine reaches of streams and rivers during autumn. It spawns among vegetation which is normally only covered by water at high spring tides, and the eggs hatch on a later spring tide. Fry are about 7 mm long when they hatch and get washed to sea. They return to fresh water in spring (McDowall 1968a).

Banded kokopu spawn in winter (Ots and Eldon 1975, Mitchell and Penlington 1982), upstream, and close to adult habitat. The fry, which hatch during floods, are about 10 mm long and are carried downstream to sea. The details of spawning in the remaining three species are unknown, but are probably similar to those of banded kokopu.

There is no evidence that whitebait return to their natal stream, but populations are probably localised, with particular stocks returning to the rivers of a certain area (McDowall and Eldon 1980).

6.2.5.1 Inanga (*Galaxias maculatus*)

Inanga are the most slender and smallest of the whitebait species, and usually reach only 100-110 mm in length. They are shoaling, pelagic fish, widely distributed throughout low-lying areas of the country and are also present in Australia, South America, and some South Pacific islands.

In the study area they were taken from almost all low-lying sites that were still or slowly flowing, and were taken often from backwaters (Fig.10). They were the third most commonly collected species, after the long-finned eel and red-finned bully. Like these species they seemed to have broad habitat tolerances (Fig.11). Because of their shoaling, pelagic nature they were largely independent of cover, and so were often found where cover was scarce. However, in rapidly flowing streams and rivers they were almost always present only in the backwaters. They often occurred in ponds which were connected with streams only at times of surface flooding and so must have entered the ponds at such times.

6.2.5.2 Koaro (*Galaxias brevipinnis*)

Koaro are larger than inanga (up to about 200 mm) and stouter in build (but not as stout as kokopu). They have irregular blotching on the back and sides, and are the second most important species in the whitebait catch.

Koaro are present throughout the country, wherever suitable habitat exists, as well as on the Chatham and sub-Antarctic Islands, in Tasmania, and in mainland Australia. There are numerous lacustrine populations in New Zealand, mostly in alpine lakes.

Adults were taken from most of the tumbling, rocky, torrential streams east of S.H.6, provided conditions were suitable, and also were taken from the upper reaches of Power Creek (Ohinemaka system) (Fig.12). However, inexplicably, koaro were not collected from some streams which appeared to provide suitable habitat. Notable among these was Havelock Creek where no koaro were found despite intensive sampling.

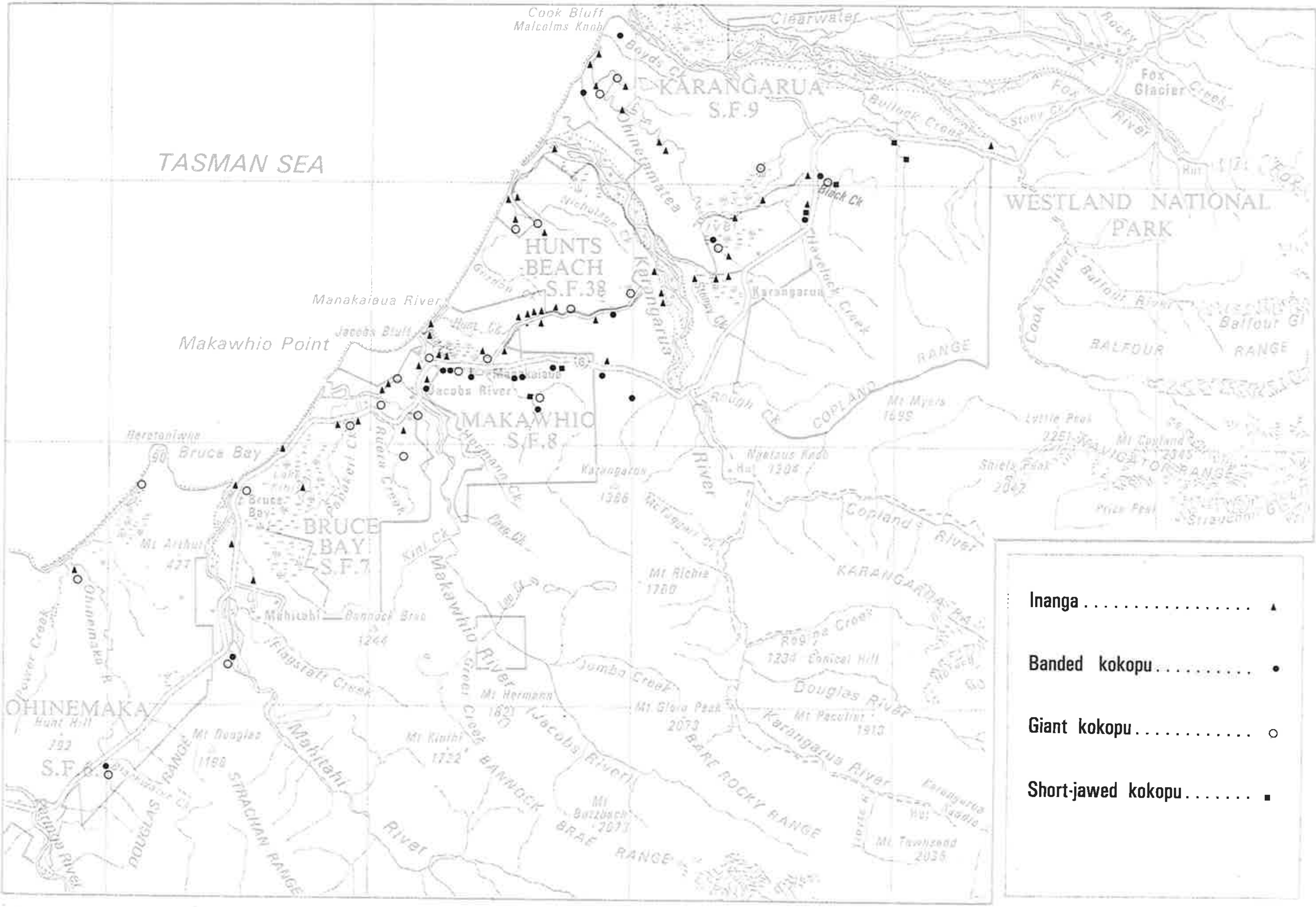

FIGURE 10. Sites from which inanga (*Galaxias maculatus*), banded kokopu (*G. fasciatus*), giant kokopu (*G. argenteus*), and short-jawed kokopu (*G. postvectis*) were recorded.

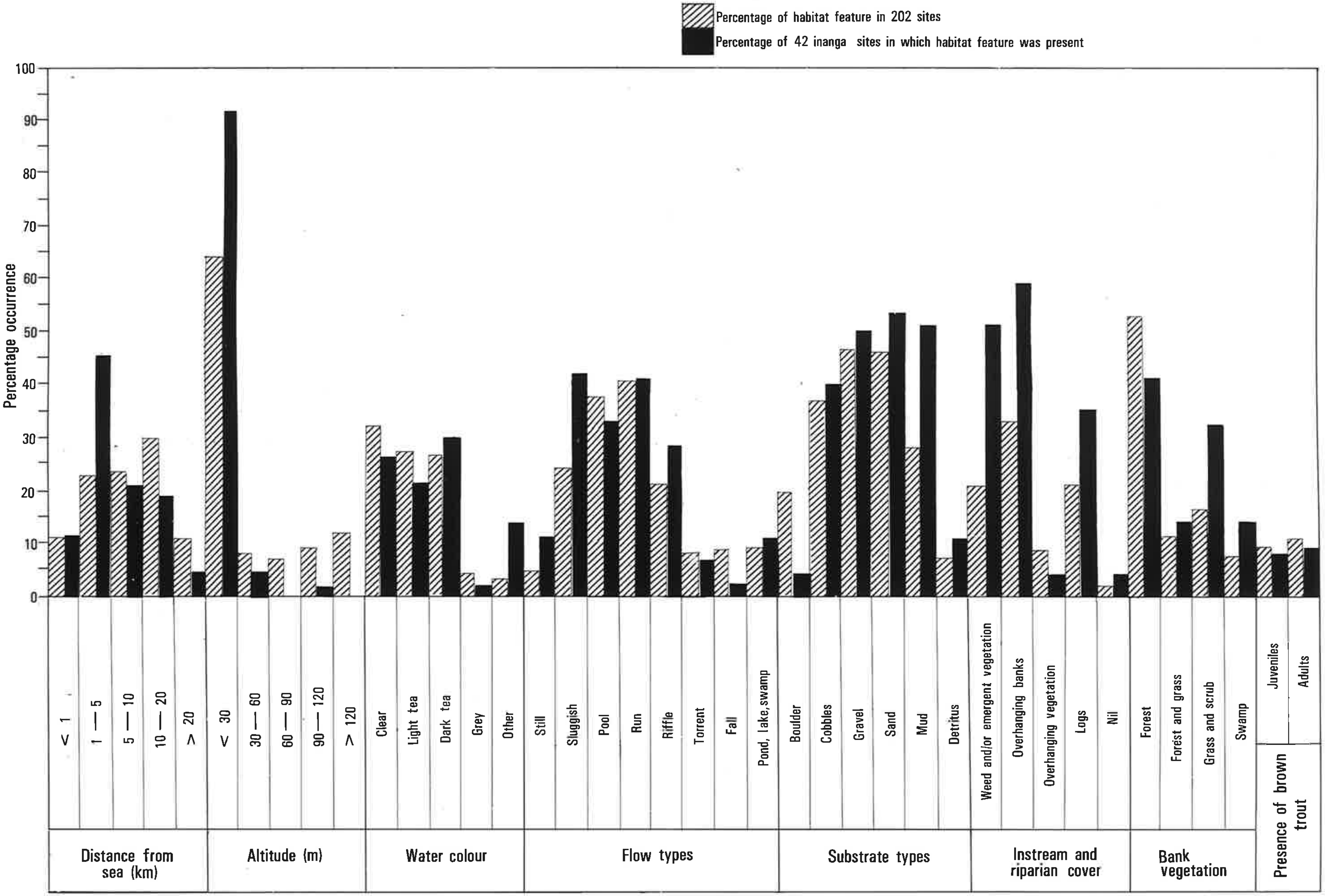

FIGURE 11. Features of inanga habitats.

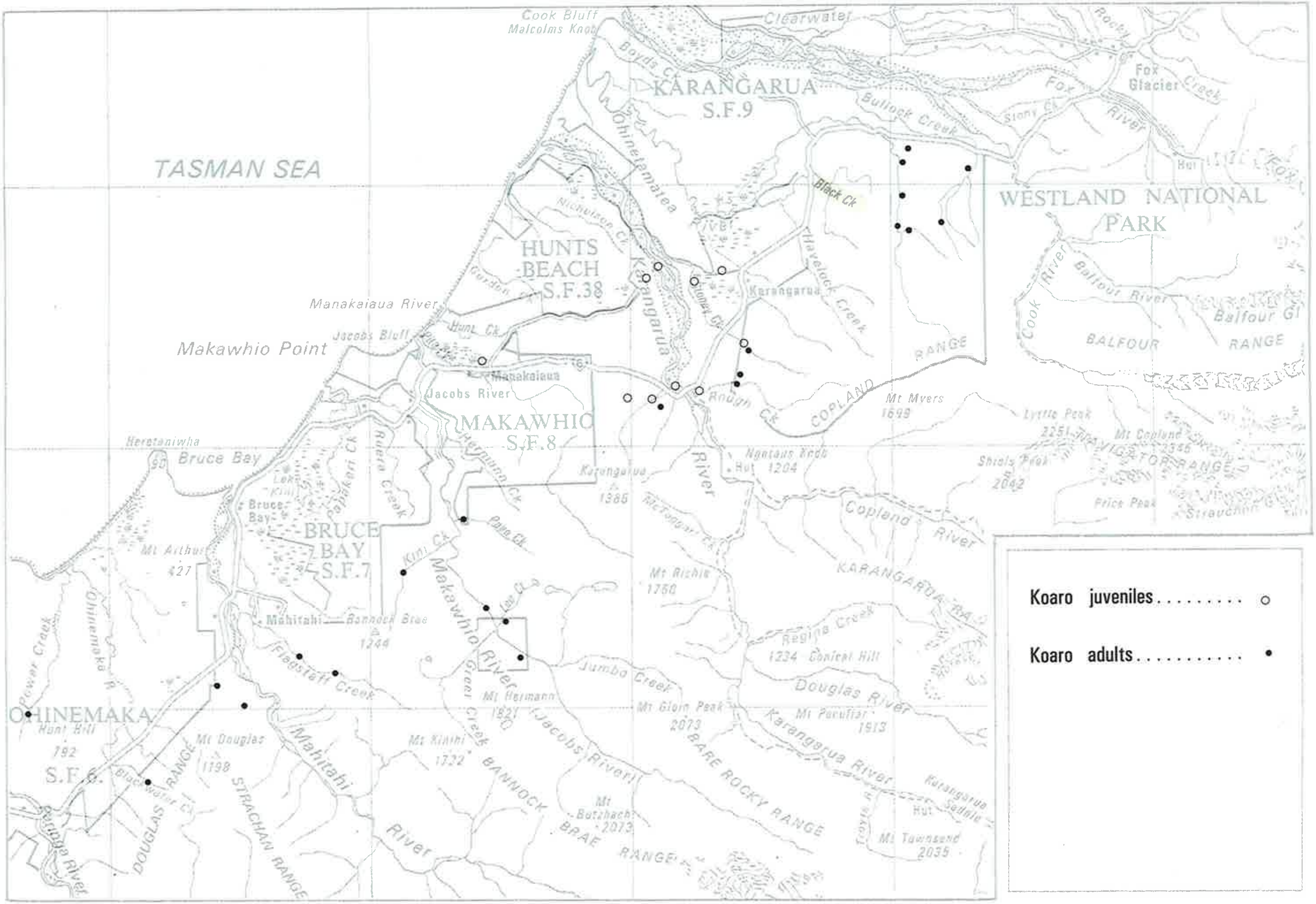

FIGURE 12. Sites from which koaro (*Galaxias brevipinnis*) were recorded.

Late-immature stage (post-whitebait) koaro, were present in the lower and middle reaches of most rivers during February, March, and April. These were fish migrating from the sea to adult habitats. For this reason habitat data for koaro in Figure 13 (and Table 3) exclude these records.

Adult koaro were quite specific in their habitat requirements. They were collected where the water was clear or only slightly tannin-stained and never where it was deeply tannin-stained. All adult koaro were collected from pools, runs, and riffles of usually unstable, flood prone, tumbling forest streams. There was always plentiful cover present in the form of cobbles and boulders. Koaro were the most commonly collected fish at the more inland sites and at the highest elevations. No adults were collected less than 5 km from the sea or at under 30 m a.s.l. Most sites were further than 10 km from the sea (81.0%) and higher than 120 m a.s.l. (57.1%)(Fig. 13). Koaro are known to be adept at climbing (McDowall 1978) and are the best climbers of the whitebait species. Koaro and adult brown trout were not collected together.

6.2.5.3 Banded Kokopu (*Galaxias fasciatus*)

Banded kokopu are much stouter than inanga and koaro and have a series of pale bands across the sides of the body, which is dark in colour. They are also larger, commonly reaching 150-200 mm in length. This species is third in importance in the whitebait catch (McDowall and Eldon 1980). Banded kokopu whitebait appear in quite large numbers in some rivers in October and are known as "golden bait" because of an amber pigmentation.

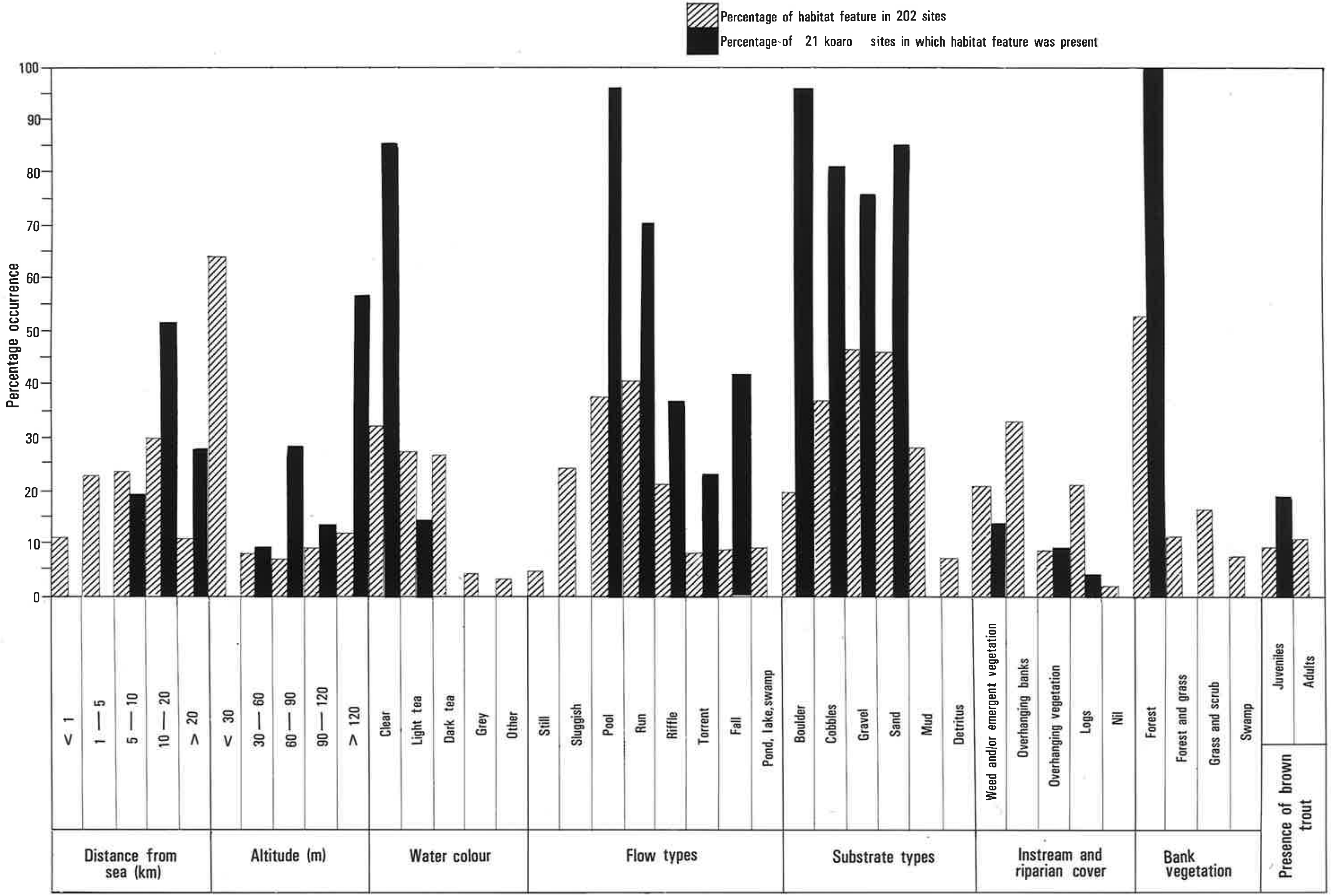

FIGURE 13. Features of adult koaro habitats.

Banded kokopu are found throughout New Zealand and on some offshore islands. McDowall (1978) stated that they are the least rare of the three kokopu species, and are fairly common in some areas. During this study they were recorded from fewer sites than the giant kokopu, but were often collected in larger numbers, even though their habitats usually were less extensive.

Habitats included a tributary of Boyds Creek, Scotchmans Creek, Black Creek (Ohinetamatea system), a small unnamed tributary of the Ohinetamatea River, Hunt Creek and its tributaries (Manakaiaua system), Pita Creek and tributaries, two unnamed tributaries of the Manakaiaua River, a tributary of the Mahitahi River, a tributary of Blackwater Creek (Ohinemaka system), and a lower tributary of Power Creek (see Fig.10).

Banded kokopu preferred tannin-stained water where there was some forest present and ample cover in the form of cobbles, overhanging banks, overhanging vegetation, detritus, and/or logs. Usually they were taken from the pools, and occasionally the riffles, of small, gently tumbling, stable bush streams. Most banded kokopu sites were fairly close to the sea (1-5 km inland) and at low altitude (less than 30 m a.s.l.) (Fig.14); normally there was a gentle gradient at the sites. Nowhere was banded kokopu found far inland or at higher elevations, despite the fact that its whitebait stage is known to be able to negotiate substantial waterfalls (McDowall 1978). It has been recorded at over 200 m a.s.l. in North Westland (Eldon 1968) and at 150 m a.s.l. in Lake Topsy, south of our study area (FRD unpublished data). Banded kokopu were not recorded from any site at which adult trout were present.

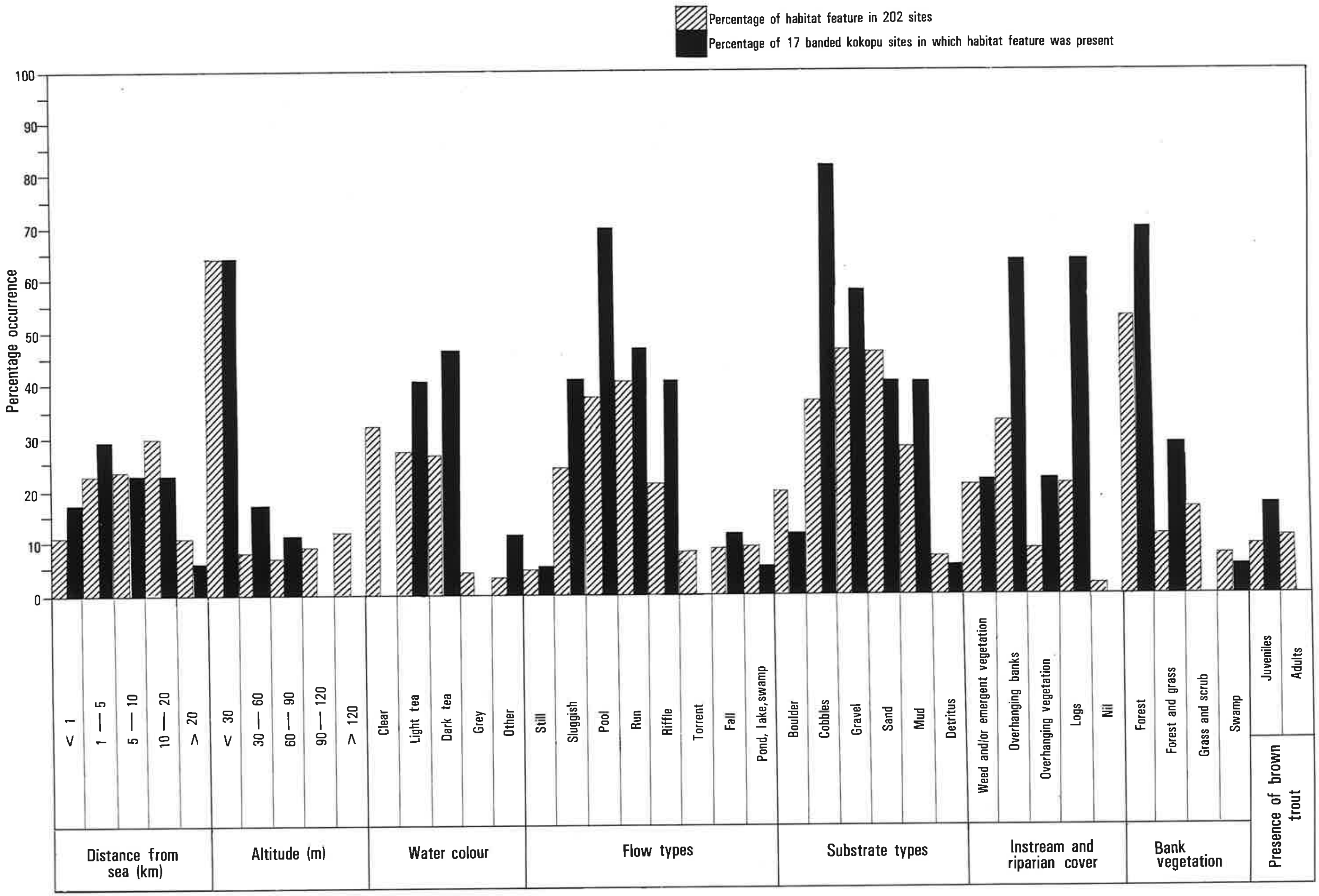

FIGURE 14. Features of banded kokopu habitats.

6.2.5.4 Giant Kokopu (*Galaxias argenteus*)

The giant kokopu is a large, stocky fish with a mosaic of golden crescents, bars, and other shapes covering its body, which is otherwise generally dark in colour. It is not very significant in the whitebait catch (McDowall and Eldon 1980). Adult giant kokopu have been recorded up to almost 600 mm long, but more commonly are half that size. Whitebait of this species enter rivers during November (McDowall and Eldon 1980).

Giant kokopu are secretive fish which normally emerge to feed at night and therefore are not often seen. They are considered by McDowall (1978) to be a threatened species. They are distributed throughout low-lying coastal areas of New Zealand and some of its islands, but in many regions, such as Canterbury, they are very rare, possibly absent.

During our study giant kokopu were recorded from most of the apparently suitable sites. However, nowhere were they taken in large numbers, the largest sample (four individuals) being from Break Creek (Manakaiaua system). They also were recorded from some other lower tributaries of the Manakaiaua River, lower tributaries of Ohinetamatea River, Gordon and Nicholson Creeks, roadside ditches, Papakeri Creek (Makawhio system) and other lower tributaries of the Makawhio River, a tributary of Blackwater Creek, a small coastal lake, and a lower tributary of Power Creek (see Fig.10). Although they were expected to be present at Lake Kini they were not recorded there.

Giant kokopu were taken mainly at low altitudes close to the sea (Fig.15), Most of their habitats were in still, or only gently flowing, tannin-stained waters. Many of the habitats had a mud substrate and

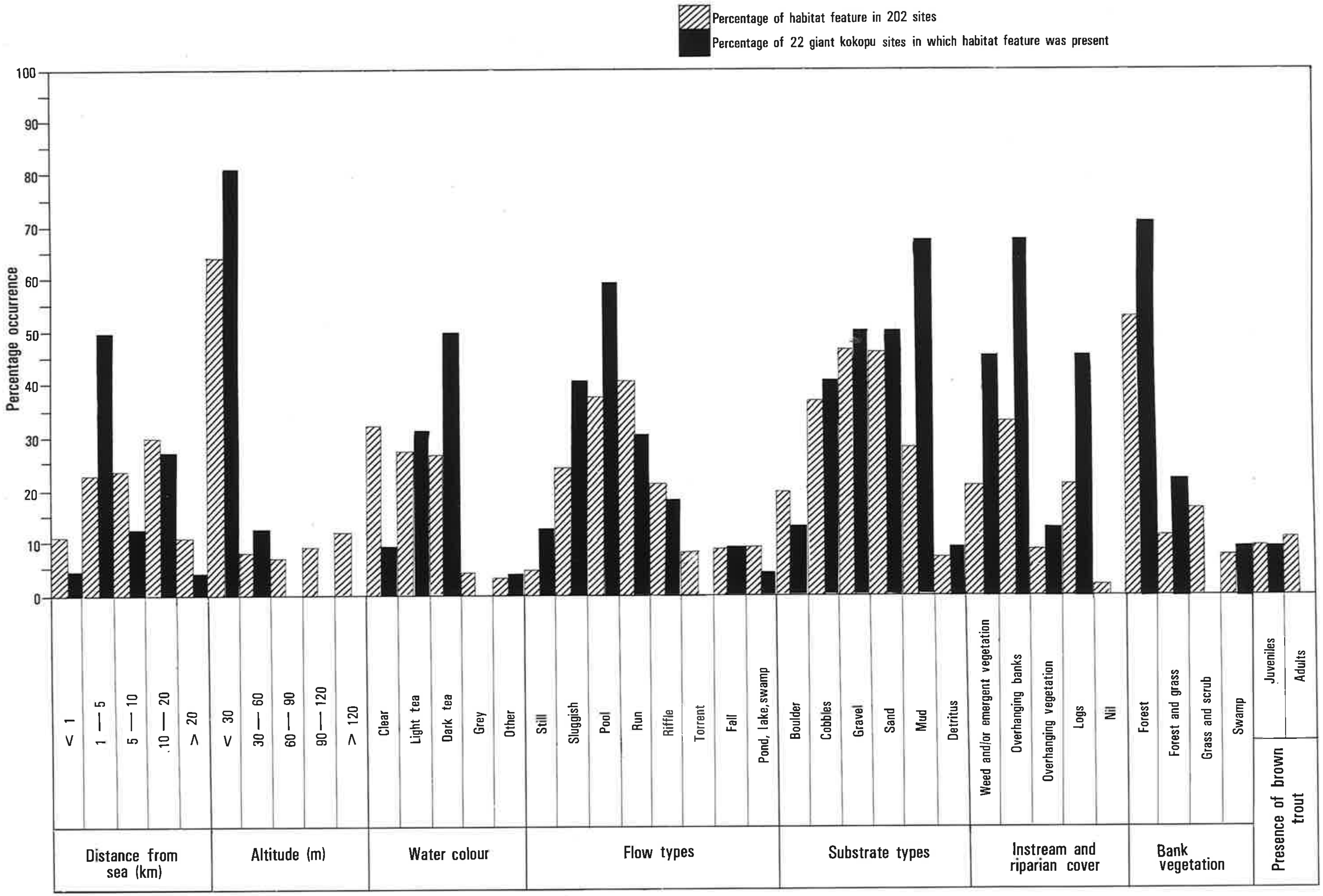

FIGURE 15. Features of giant kokopu habitats.

cover available in the form of aquatic or emergent vegetation, overhanging banks, overhanging vegetation, and logs. At all sites from which they were collected forest was present to some, if only a limited, extent, (for example, part of Pita Creek, where only one bank was forested). Adult trout were not collected at any site from which giant kokopu were recorded.

6.2.5.5 Short-jawed Kokopu (*Galaxias postvectis*)

Short-jawed kokopu (Fig.16) are similar in size and shape to banded kokopu, but have an undershot lower jaw and they lack the pale bands of the banded kokopu. However, they are highly variable with respect to this character. Dark bands on a pale background are present in some fish, (mostly smaller ones) whereas other fish are speckled or spotted. Although a whitebait species, its contribution to the whitebait catch is insignificant (McDowall and Eldon 1980).

The short-jawed kokopu is a rare fish. At February 1984 it was known from only 55 streams and rivers throughout New Zealand (FRD's N.Z. Freshwater Fish Survey). Before this study it was unrecorded from South Westland, though its presence was suspected. During our work it was taken from Black Creek and three other tributaries of the Ohinetamatea River, and two tributaries of the Manakaiaua River (see Fig.10). Of these, Black Creek appeared to have by far the largest population, six specimens being taken there and many others observed. The species was recorded only above waterfalls upstream from S.H.6, and a single long-finned eel was the only other fish recorded there. This is surprising because banded kokopu were recorded a short distance downstream and should have been capable of climbing the falls. At two other sites both these kokopu species were recorded together.

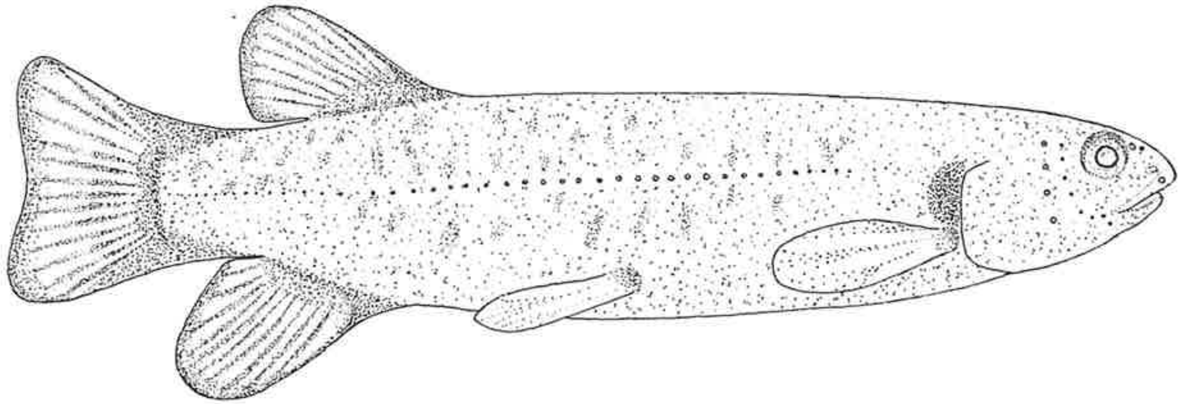

FIGURE 16. Short-jawed kokopu (*Galaxias postvectis*), life-size. (Illustration by M.R. Main.)

Short-jawed kokopu were recorded only at sites where there were no adult brown trout. All sites were in stable bush streams with gravel and cobble substrates and tannin-stained water.

6.2.6 Torrentfish (*Cheimarrichthys fosteri*)

Torrentfish have a broad, shovel-shaped head, an undershot jaw, and often have an orange, golden, or pink colouration on the fins. They often reach about 100 mm in length. Little is known of their life history, but their larval life is marine (McDowall 1973) and the juveniles migrate upstream in spring when they are about 25 mm long (Eldon and Greager 1983).

In the study area torrentfish were recorded from suitable habitats in all rivers and some tributaries. An exception was the mainstem of the Cook River, where no fish were collected. However, the species was present in streams on the flood plain of that river. Other rivers and streams from which it was taken were Ohinetamatea River, Karangarua River and several tributaries including Rough, Stoney, and Maimai Creeks, Manakaiaua River, Makawhio River, and the inlet to and outlet from Lake Kini (see Fig.6).

The common name torrentfish refers to what is generally considered to be their preferred habitat, that is, the riffles and torrents of rivers and streams, where the water often is only a few centimetres deep (McDowall 1978). However, though torrentfish usually were recorded from such areas during this study, they also were taken from two slack-water sites - quiet sections of a stream on the Cook River flood plain, and the sluggish stream that is the inlet to Lake Kini. Torrentfish were always at low elevations (less than 60 m a.s.l.) and most were less than

10 km from the sea (Fig. 17). Adults were cryptic and sought cobbles for cover during the day, but during February and March juveniles often were collected from river mouths where the substrate was sand or gravel and where little cover was available. These fish probably had arrived recently from the sea. In most cases (55.6%), water from which torrentfish were collected was clear.

6.2.7 Red-finned Bully (*Gobiomorphus huttoni*)

The male red-finned bully is brightly coloured, with red colouration on the fins and red stripes on the head and body. The female is less colourful. They are stocky fish, commonly less than 100 mm in length.

Red-finned bully eggs are deposited on the underside of rocks during late winter and spring. Fry are about 3 mm long on hatching, at which time they go to sea. After growing to about 15-20 mm at sea, juveniles migrate upstream to adult habitats.

Red-finned bullies are found throughout most of New Zealand and on the Chatham Islands. In this study, they were normally present at low altitudes and at times penetrated fairly well inland, if the gradient was not excessively steep (Fig.18). However, an exception was one site on a tributary of Maimai Creek (Karangarua system), where the gradient was quite pronounced. Otherwise it was present almost everywhere that there was cover and occupied a fairly wide range of habitats (Fig.19). It was the second most commonly collected species, after the long-finned eel.

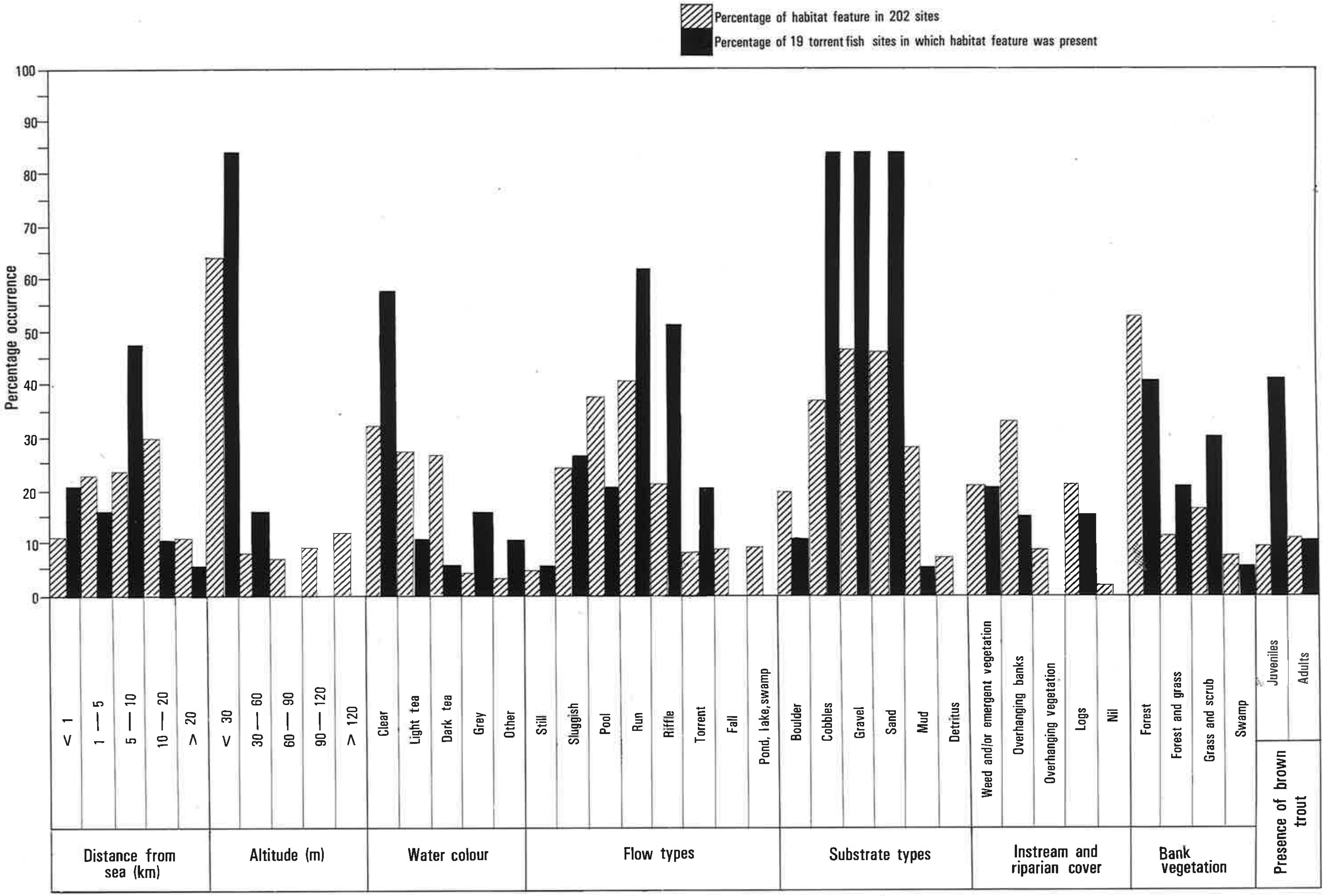

FIGURE 17. Features of torrentfish habitats.

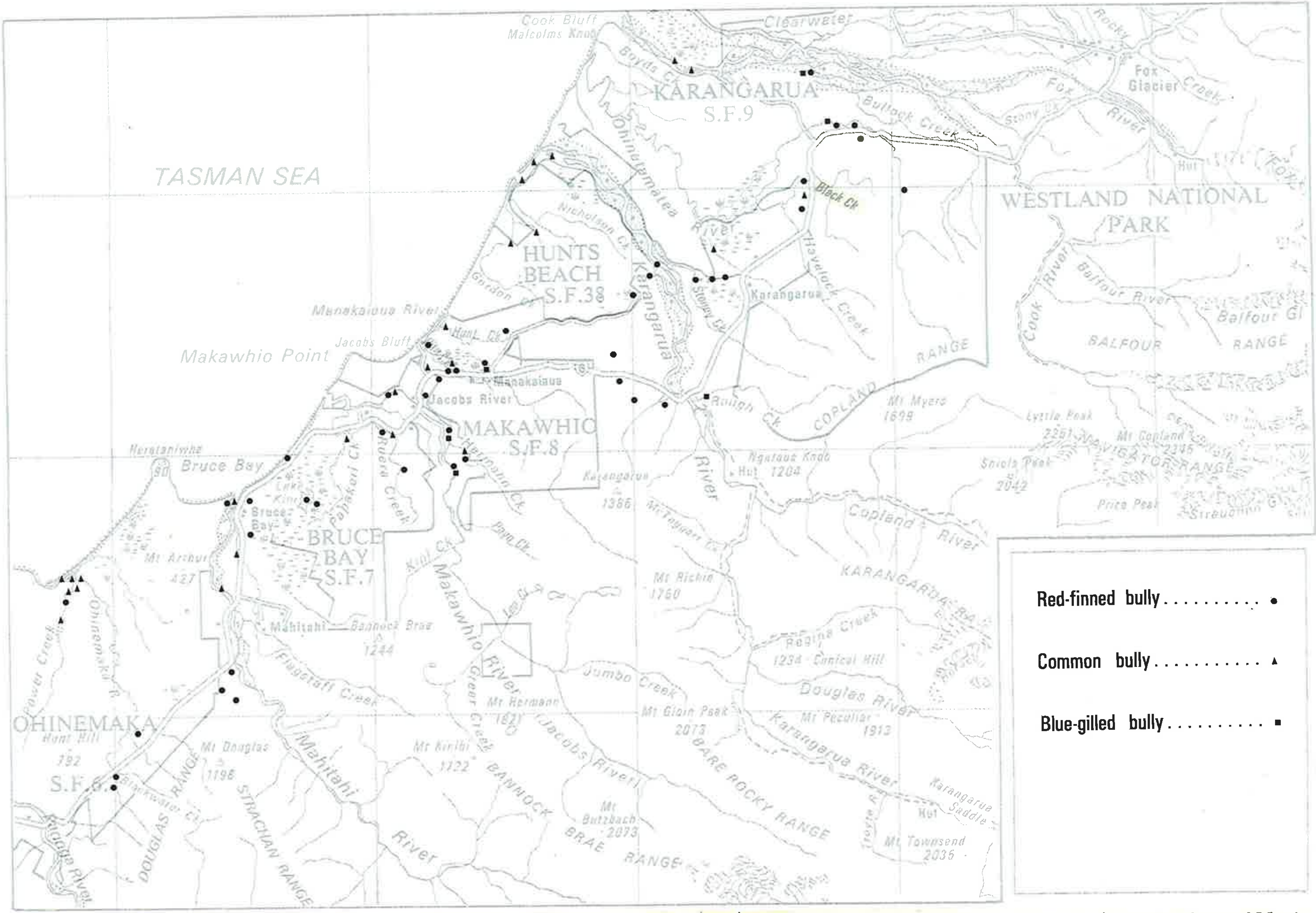

FIGURE 18. Sites from which red-finned bully (*Gobiomorphus huttoni*), common bully (*G. cotidianus*), and blue-gilled bully (*G. hubbsi*) were recorded.

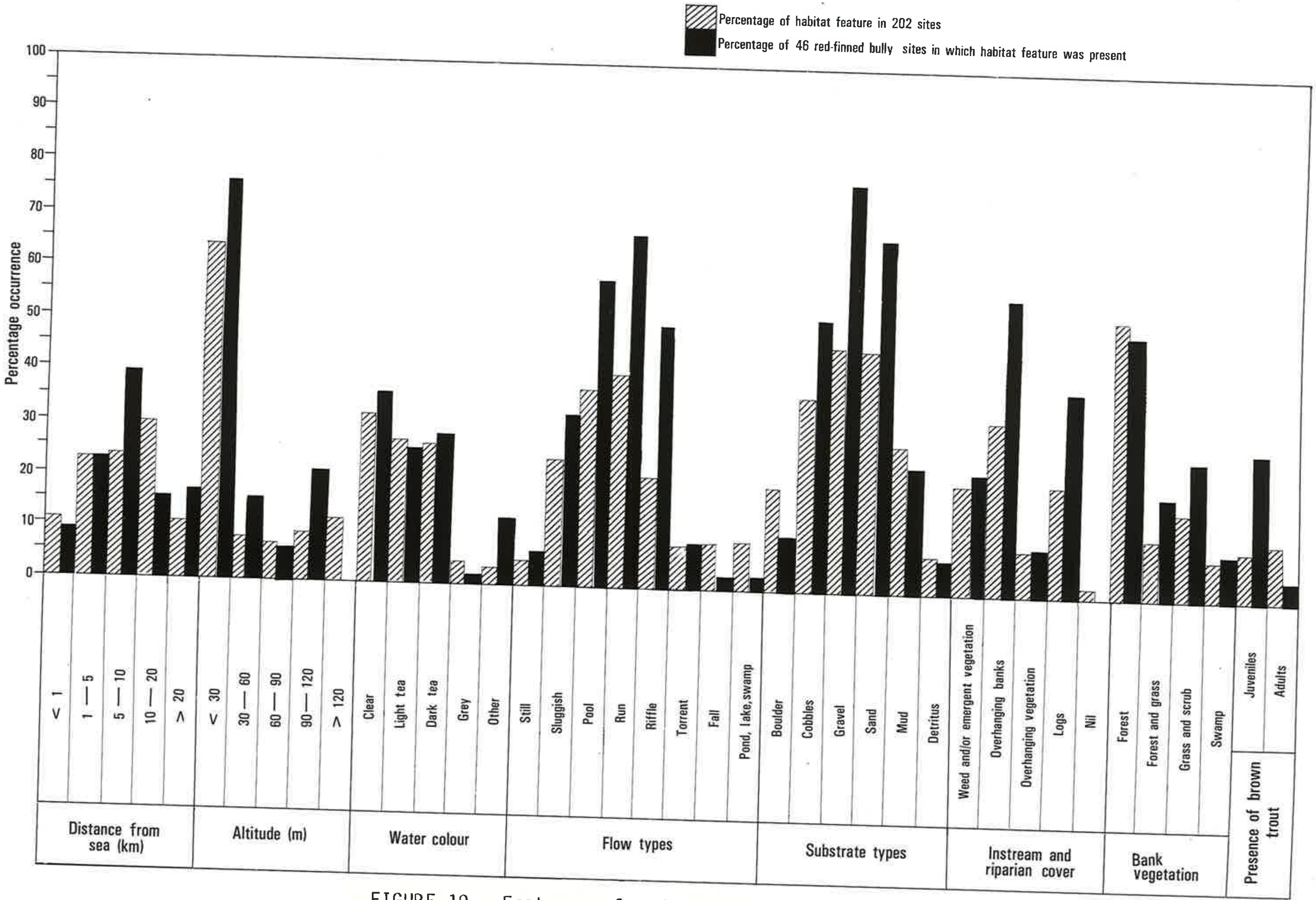

FIGURE 19. Features of red-finned bully habitats.

6.2.8 Common Bully (*Gobiomorphus cotidianus*)

The common bully is a stocky, drab looking, grey-coloured fish of up to about 120 mm in length. Its life cycle is similar to that of the red-finned bully. It is the most widespread of the bullies and is found throughout New Zealand, both as sea-run and lacustrine populations.

In the study area the common bully was less widespread than the red-finned bully. However, where it was present it was often numerous. It was recorded from the lower reaches of all the main rivers except the Cook River, though it was present in a stream on the old course of that river. In addition it was recorded from lower tributaries of the Ohinetamatea and Mahitahi Rivers, and from Gordon, Nicholson, Sam, Pita, Break, Hermann, Ruera, and Papakeri Creeks (Fig.18).

Common bullies were almost always found less than 5 km from the sea (87.4%), though one site was about 21 km inland. Often the sites were tidal. Sites were always less than 60 m a.s.l. and all sites but one (95.8%) were below 30 m a.s.l. (Fig. 20). Common bullies usually were taken from sluggish waters and they never occurred where the water flow was rapid. They were fairly non-cryptic fish and often were present where the substrate was sand and where cover was scarce.

6.2.9 Blue-gilled Bully (*Gobiomorphus hubbsi*)

The blue-gilled bully is the most slender of the bullies, being narrow and tubular in shape with an iridescent blue colour on the gill membranes. It is one of the smallest New Zealand fish, and commonly reaches only 50-60 mm in length. The life cycle may be similar to that of the red-finned bully. Although rarely seen, the blue-gilled bully is present throughout New Zealand in suitable habitats. In the study

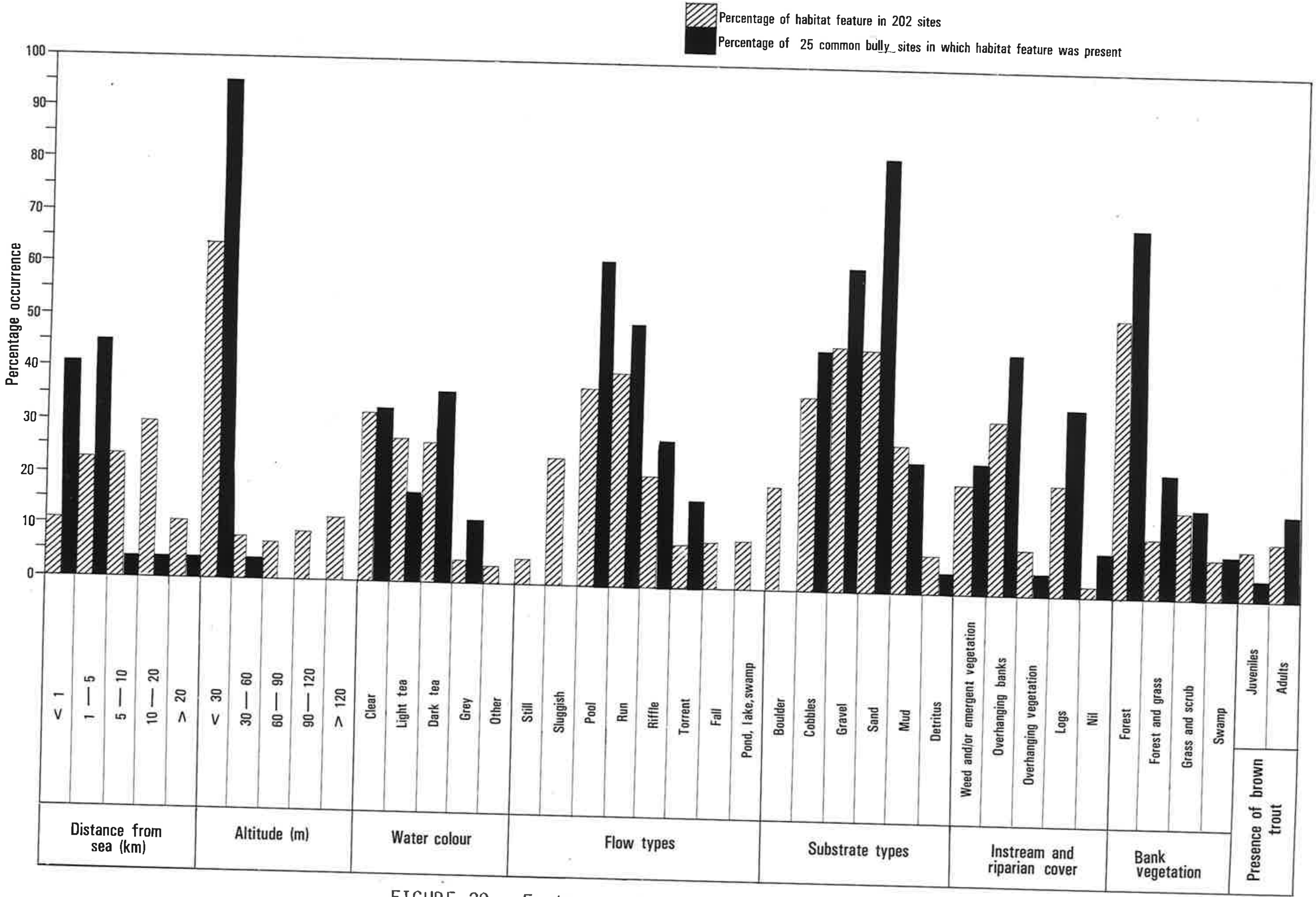

FIGURE 20. Features of common bully habitats.

area it was collected from a spring stream on the Cook River flood plain, Rough Creek, and Ohinetamatea, Manakaiaua, and Makawhio Rivers (Fig.18).

Blue-gilled bullies were found at low elevations (less than 60 m a.s.l.) and at moderate distances from the sea (mostly less than 10 km). They utilised only cobbles for cover in the most swiftly flowing, often shallow, sections of clear streams and rivers. Torrentfish invariably were collected with them, but blue-gilled bullies were often absent from sites at which torrentfish were present, such as Karangarua River, possibly because of the slightly sedimented nature of that river.

6.2.10 Black Flounder (***Rhombosolea retiaria***)

Black (or river) flounders have brick-red mottling on their upper surface and a grey-white to grey undersurface, and commonly grow to 200-250 mm long. They are a true freshwater flounder and have been reported as far as 70 km up the Rangitikei River (McDowall 1978), though they are more common closer to the sea. It is probable that adult black flounders migrate to sea in winter to spawn. Larval flounders are pelagic, upright swimmers, with an eye on either side of the head. Before entering fresh water the larvae undergo a metamorphosis whereby the left eye migrates to the right side and the fish become bottom dwellers.

Black flounders are present in coastal areas around New Zealand. During this study they were recorded 9 km up the Karangarua River, from the lower reaches of a stream on the Cook River flood plain, and from the lower reaches of Ohinetamatea River, Gordon Creek, Hunt Creek, Manakaiaua River, Papakeri Creek, and Mahitahi River (see Fig.6).

They were found most often in the quiet backwaters and slack reaches of rivers, usually where the substrate was sand, but also where it was cobbles and gravel (for example, in the Karangarua River and Cook River flood plain). They have no special need for cover because of an ability to merge with their background. At most sites the water was clear, but Gordon Creek for example was deeply tannin-stained.

6.3 Estuarine Fishes

These are species which are principally marine fishes, but which spend some time in fresh water, usually in estuarine reaches though they may penetrate further inland.

6.3.1 Kahawai (*Arripis trutta*)

Kahawai are streamlined fish, reaching 500-550 mm in length. They are found in roving shoals, feeding on small pelagic fishes and are favoured as a sporting fish by estuary anglers. They move into the estuarine reaches of rivers as the tide rises and sometimes move further upstream; the species has been recorded 50-65 km up the Waikato River. They are found in coastal seas around New Zealand and Australia.

Young kahawai were recorded from the estuary of Karangarua River and an adult from the estuary of Mahitahi River (Fig. 21). However kahawai undoubtedly move into the mouths of other rivers.

6.3.2 Yellow-eyed Mullet (*Aldrichetta forsteri*)

Yellow-eyed mullet are familiar to many people, usually under the misnomer of herring. They are streamlined, silvery fish with yellow eyes and commonly grow to about 300 mm. Like kahawai, shoals of this fish frequently enter fresh water on a rising tide and may move well beyond the tidal influence.

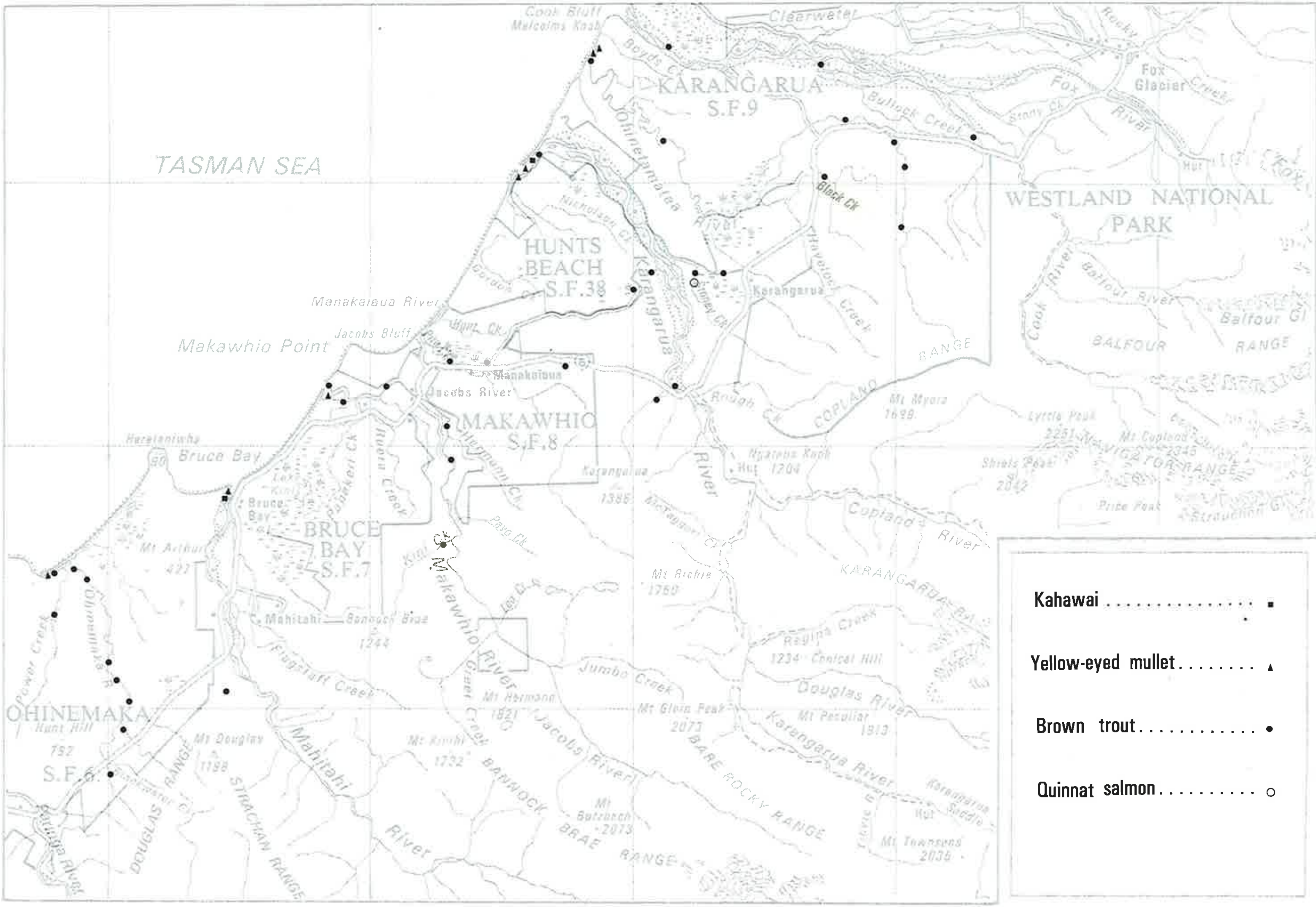

FIGURE 21. Sites from which estuarine and introduced species were recorded.

Yellow-eyed mullet are found in coastal seas, harbours, estuaries and in the lower reaches of rivers of New Zealand and Australia. During this study they were recorded from the mouths of all rivers except the Cook, though they may also be present there (Fig. 21).

Being a shoaling, pelagic fish they do not require cover, nor do they seem to have any specific habitat requirements in fresh water.

6.4 Introduced Fishes

Since the arrival of Europeans in New Zealand there have been numerous attempts to acclimatise a variety of exotic fishes for various reasons, primarily to establish sport fisheries. Fourteen species have been successfully established and two of the most widespread, brown trout and quinnat salmon, were collected during this study.

6.4.1 Brown Trout (*Salmo trutta*)

Brown trout are a well known and important sporting fish throughout the world; there are lacustrine, river-dwelling, and sea-run populations. Brown trout spawn in the gravel of streams and rivers in May and June. Small trout feed largely on stream and river-bottom invertebrates, but larger fish tend to be piscivorous and feed extensively on small fishes.

Brown trout occur naturally throughout Europe and have been introduced into many countries. In New Zealand they are widespread from about Coromandel southwards. If they have access to the sea, brown trout may spread extensively from the point of a single liberation.

In the study area fingerlings (probably first year fish) were widespread and were especially common in the middle and upper reaches of rivers and streams. Adults often were found in the lower reaches of the main rivers and also in the middle and upper reaches of the Makawhio (Fig. 21).

Brown trout prefer fast-flowing waters with little sediment, a high oxygen concentration, and plentiful instream cover. However, they are adaptable fish and adults often were present where such conditions did not occur. For example, the lagoon at Karangarua River mouth, where brown trout were present, has no current, a high sediment concentration, and may have a fairly low oxygen tension. However, trout were not recorded where the substrate was composed of mud, where the water was deeply tannin-stained, or where there was a steep gradient with significant cataracts (Fig. 22).

6.4.2 Quinnat Salmon (*Oncorhynchus tshawytscha*)

Quinnat (chinook) salmon are a popular sporting fish on the east coast of the South Island and are rapidly gaining commercial importance. They spend most of their life at sea and migrate upstream to the stream of their birth, most commonly when they are three years old, but sometimes at two or four years of age. They require moderately swiftly flowing, stable, cobbled or gravel-bottomed, silt-free streams for spawning. Adults do not feed while in fresh water and die after spawning.

The natural distribution of quinnat salmon is along the western coasts of North America and North-east Asia. Despite attempts to induce sea-run populations in several other countries, the South Island

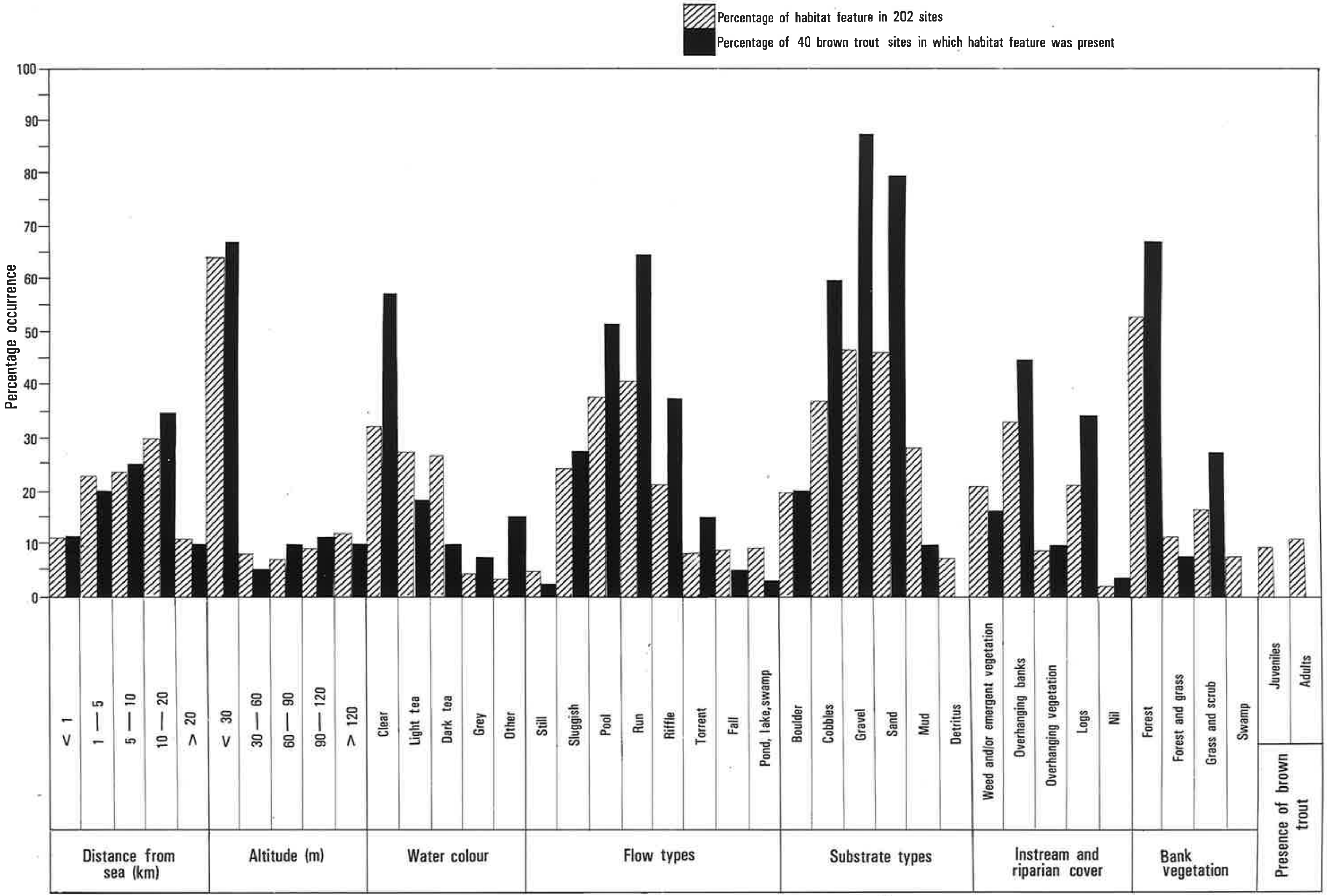

FIGURE 22. Features of brown trout habitats.

of New Zealand is the only place in the Southern Hemisphere in which self-sustaining, induced sea-run populations have been established. In Westland, minor runs of salmon are known to occur in the Taramakau, Whataroa, Paringa, and Moeraki Rivers. Recently, a run was established in the Hokitika River for commercial purposes. Some lacustrine populations are present in Westland, in Lakes Paringa, Moeraki, and Mapourika, as well as in Okarito Lagoon.

A single juvenile quinnat salmon was taken from Stoney Creek (Fig. 21). This may indicate the presence of a hitherto unexpected minor run in the Karangarua River. Being diadromous, the quinnat has a ready ability to disperse. Runs in rivers on the east coast are derived largely from fish liberated in the Waitaki River (McDowall 1978). In Westland, fry are currently being released into the Hokitika River and Windbag Stream (Paringa River). Like the Rakaia River, which supports the largest salmon stock in New Zealand (Davis, Eldon, Glova, and Sagar 1983), the Karangarua River is a slightly silted, braided river with an unstable gravel and cobble substrate.

6.5 Crustacea

6.5.1 Freshwater Crayfish (*Paranephrops planifrons*)

Paranephrops planifrons is one of two freshwater crayfish in New Zealand and grows to about 70 mm carapace length (Chapman and Lewis 1976). Crayfish live in a wide range of habitats, from lakes and ponds to streams and swamps, where the substrate is gravel or mud. During the day they shelter under a rock or in a burrow and emerge to feed at night. Crayfish eggs are attached to the female and after hatching the young are carried until their third moult (Chapman and Lewis 1976).

Paranephrops planifrons is distributed throughout the North Island and in Nelson, Marlborough, and Westland (Chapman and Lewis 1976). Eldon (1981) drew attention to the diminishing numbers of crayfish. A single crayfish was collected from a forested tributary of the Mahitahi River (see Fig. 6). This is FRD's first contemporary record of freshwater crayfish in Westland south of Okarito River.

7. DISCUSSION

7.1 Factors Affecting Fish Distributions

7.1.1 Distance from the Sea and Altitude

These two factors are largely interrelated because, in general, altitude increases with distance from the sea, and the higher the altitude the greater the cumulative barriers to upstream movement of fishes. Consequently, those species which are unable to climb occur only close to the sea and at low altitudes.

Yellow-eyed mullet and kahawai are estuarine fishes and so were recorded only very close to the sea. Inanga, blue-gilled bullies, common bullies, common smelt, giant kokopu, and torrentfish occurred further inland, but only if there was a gentle gradient because they are unable to negotiate obstacles such as boulders.

Short-finned eels, red-finned bullies, and brown trout often were present even further inland and at greater altitude, provided that cataracts were not too great. None of these species appeared able to climb falls. However, at one site, short-finned eels were present above 100 m a.s.l.

Long-finned eels, banded kokopu, short-jawed kokopu, and koaro were commonly recorded at the greatest distances inland and at the highest altitudes. These fish are all able to climb. Adult koaro were not recorded less than 5 km from the sea or below 30 m a.s.l.

7.1.2 Flow Type

All fishes (other than the red-finned bully) seemed to have preference for certain water flows (Fig. 23).

Elvers of both eel species were recorded only from the faster-flowing sections of streams and rivers (riffles and torrents). Conversely, adults were recorded only from more gently flowing or still reaches, and from ponds, lakes, and swamps.

Inanga, common smelt, common bullies, black flounders, and yellow-eyed mullet were recorded most frequently from sluggish waters. Giant, banded, and short-jawed kokopu, koaro, and adult brown trout seemed to prefer pools, though giant kokopu also were recorded from sluggish waters, and adult trout from runs. Koaro probably were present also in faster water, but were not captured. Juvenile brown trout were recorded from riffles.

Blue-gilled bullies were recorded only from more swiftly flowing waters, riffles, and torrents. Torrentfish most frequently were recorded where these flow types were present, though they were found in all other flow types as well; they occurred in a larger range of flow types than was expected.

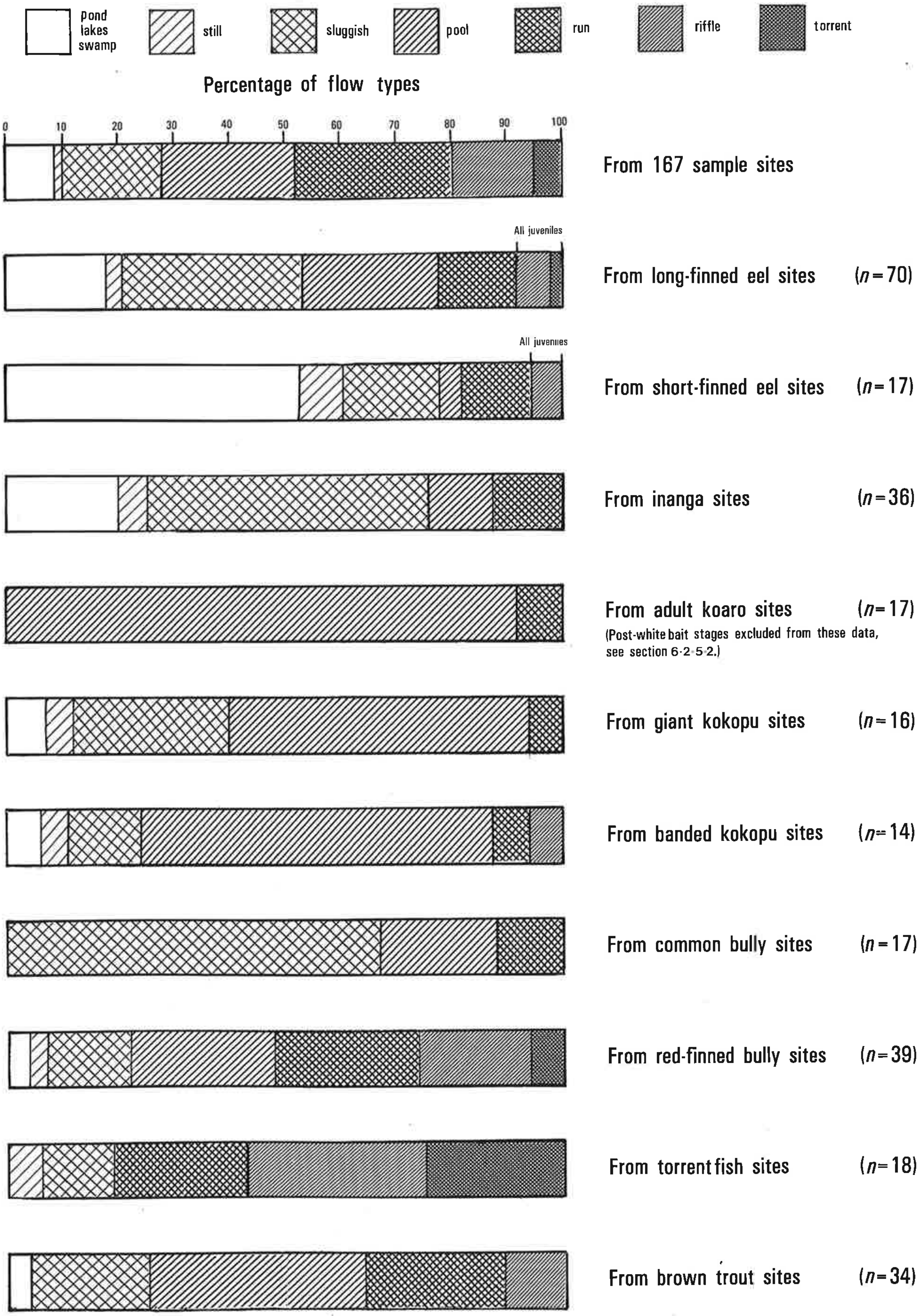

FIGURE 23. Percentage of various flow types occupied by fish. (Only those species with greater than 10 records included.)

7.1.3 Cover

The importance of cover to cryptic fishes cannot be over-emphasised. Cover provides a place to which fishes can retreat and so reduce the threat of predation. In general, waters with little cover had few fishes. For example, the bed of Bullock Creek at S.H.6 had been so modified by bulldozing (to reduce road flooding), that no significant cover was available to fishes (Fig. 24). No fish were collected at this site, but several hundred metres upstream, where the bed remains unmodified (Fig.25), koaro (which are very demanding of cover) were present.

Common smelt and yellow-eyed mullet (which are pelagic, non-cryptic fishes) and black flounder, did not seem to have any specific requirement for cover, and often occurred where cover was unavailable.

Cover may consist of the substrate or instream or riparian cover. Boulders and cobbles, and to a limited extent gravel, are the substrate types which offer cover to fishes. Instream cover includes macrophytes, emergent vegetation, and logs, and riparian cover refers to overhanging banks and overhanging vegetation (grasses, herbaceous plants, and shrub and tree branches).

Torrentfish and blue-gilled bullies used only cobbles for cover and koaro only cobbles and boulders. Most fishes utilised the substrate as well as instream and riparian cover. However, the substrate was normally of little value as cover to some species (for example, both species of eel, inanga, giant kokopu, and common bully), because they were present most often where the substrate was composed of mud and sand. These substrate types, because they do not have large enough interstices, are unavailable as cover to most fishes. However, lamprey

FIGURE 24. Bullock Creek at S.H.6. This section of stream has been bulldozed, leaving little cover, and no fish were collected from here.

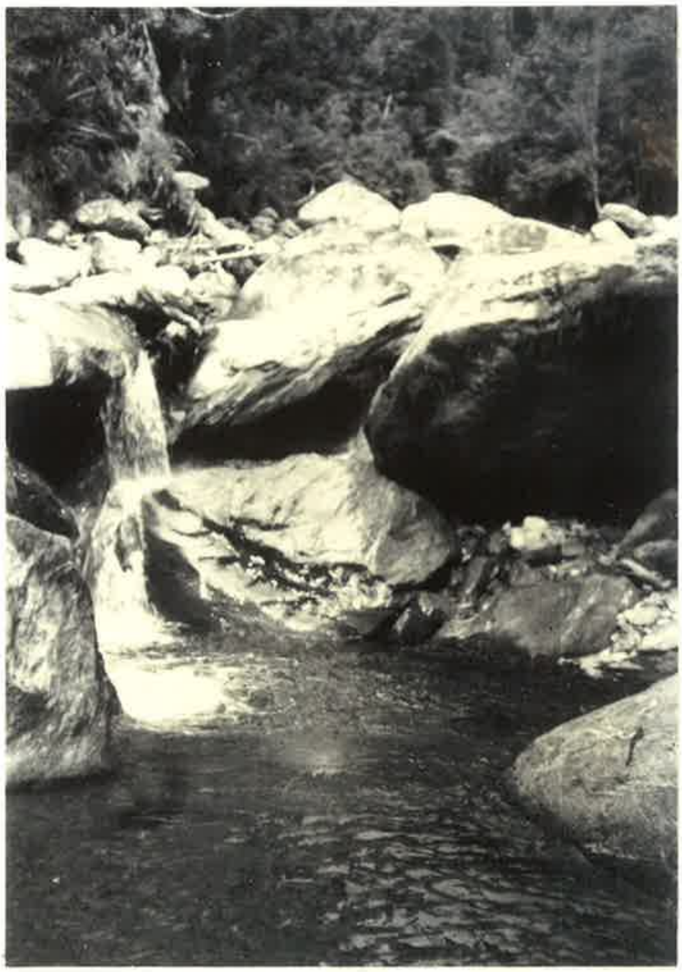

FIGURE 25. Bullock Creek upstream of S.H.6, where koaro were collected. Note plentiful cover in the form of cobbles and boulders.

ammocoetes (McDowall 1978) and small eels (less than about 300 mm) (Burnet 1952) can burrow into them. Where these substrates are present, instream and riparian cover are important, for example, Papakeri Creek (Fig. 26).

7.1.4 Bank Vegetation

McDowall (1980a) stated that koaro, banded kokopu, and short-jawed kokopu disappear when forest cover is removed. Nowhere in our study area was any of these species, or the giant kokopu, recorded where forest was not present to some extent. There may be several reasons for the dependence of these fishes on forests and these are outlined below.

Forest attracts numerous insects and arachnids (Phillips 1929) and frequently these are utilised by fishes as food. Jellyman (1979) found that in Lake Pounui in the Wairarapa, 57% of the food of giant kokopu was terrestrial in origin. During this study, the stomach of one of the few of these fish examined was crammed with terrestrial beetles. Similarly, a preliminary investigation during this study indicated that terrestrial invertebrates formed a substantial part of the diet of short-jawed kokopu. Eldon (1969) noted that banded kokopu in an aquarium readily took live insects from the water surface. In addition, Cadwallader, Eden, and Hook (1980) suggested that bankside vegetation provided an important food source, in the form of terrestrial invertebrates, for an Australian galaxiid.

The presence of forest may be necessary to maintain an adequate level of humidity among bank vegetation and thereby prevent egg desiccation. Mitchell and Penlington (1982) observed that eggs of the banded kokopu were deposited on forested stream banks above the normal water level and the same may be true of other kokopu species.

FIGURE 26. Papakeri Creek, typical habitat of the giant kokopu. Note plentiful instream and riparian cover - fallen logs and emergent and overhanging vegetation.

Removal of riparian forest vegetation and the associated shading gives rise to significant increases in summer stream temperatures (Graynoth 1979, O'Loughlin 1980). There is some evidence that koaro may be unable to withstand even slightly raised temperatures (Woods 1966). Other species also may be intolerant of increased temperature.

Forests provide cover for fishes directly in the form of overhanging vegetation, fallen logs, and detritus. Cover is provided indirectly by the stabilising effect of vegetation roots on banks, which themselves are an important source of cover for some fishes.

A striking example of the effect of loss of riparian vegetation on fishes was seen in Hunt Creek (Figs. 27 and 28). A section of stream where the banks had been cleared of forest and replaced with pasture was devoid of cover. The banks had collapsed and the substrate comprised fine material. Only a few long-finned eels were present. However, a few hundred metres upstream where the stream flowed through forest, cover (in the form of overhanging vegetation, fallen logs, overhanging banks, and cobbles) was plentiful and so too were fish. Five species were recorded here - banded kokopu, koaro, red-finned bully, long-finned eel, and brown trout.

7.1.5 Water colour and pH

South Westland waters generally have low pH, with smaller streams having the lowest values (McDowall and Eldon 1980). This trend was evident in this study (see Table 5). McDowall and Eldon (1980) showed for rivers and streams south of our study area that, under normal flow regimes, as the water became more tannin-stained (tea-coloured), pH decreased (became more acidic). A negative correlation coefficient of

FIGURE 27. Hunt Creek above S.H.6. Note fine substrate, collapsed banks, and lack of overhanging vegetation. Only a few long-finned eels were collected here.

FIGURE 28. An unmodified section of Hunt Creek a short distance upstream. Note overhanging vegetation and banks. Five species of fish were recorded here.

0.87 was calculated for 20 pairs of average light loss and mean pH values from McDowall and Eldon (1980), and so these two variables have been treated together in this discussion.

Water acidity is a well known factor affecting the distribution of some fishes. Excessively high or low pH kills fish by destroying their gill and skin epithelia and may also kill them less directly (Alabaster and Lloyd 1980). McDowall and Eldon (1980) observed differences in the composition of whitebait migrations which they linked with pH of the streams studied. They noted that koaro whitebait avoided tributaries which were tannin-stained and acidic, but that banded kokopu freely entered such waters. This study confirms their observations. Mean pH (with 95% confidence limits) for the habitats of these two species were quite different (see Fig. 5), though the ranges overlapped (see Table 6) and both species have sometimes been found in the same water.

The mean pH of giant kokopu habitats was also low, but confidence limits were wide (see Fig. 5) and range great (see Table 6). It may be that this fish is not limited by pH values, but by the presence of trout (see section 7.1.7). Trout do not generally favour acidic waters, and so such habitats remain available to the giant kokopu. While giant kokopu are now usually found in waters with low - even very low - pH values, we do not believe that acidity is essential in the fish's environment, except in so far as it excludes trout with which the giant kokopu is incompatible.

There are few data for the short-jawed kokopu, but its habitats had low pH values, and this was the only obvious parameter which differentiated them from koaro habitats. Both the short-jawed kokopu and koaro are adept climbers as whitebait, at which stage the two species are extremely difficult to tell apart, and in the past both were thought to occupy similar habitats in tumbling forest streams. The steeper section of Black Creek appeared ideal koaro habitat, but only short-jawed kokopu were recorded there. At pH 5.9 (see Table 5) the water in this stream is more acidic than the minimum (6.5) recorded in koaro habitats in this study (see Table 6). Therefore pH may be a factor which separates these two species.

Short-finned eels also were usually found in acidic waters, but this was a reflection of the sluggish nature of its habitats, lower pH's being recorded in waters with low, slow flows.

Brown trout are not usually associated with acidic water, and those found in such waters in South Westland were usually in poor condition. Alabaster and Lloyd (1980) stated that alevin (yolk-sac) stage trout will not survive in water with a pH of 4.7-5.4; pH values in and below this range were recorded frequently in the tannin-stained waters of South Westland, both by McDowall and Eldon (1980) and during this study.

Blue-gilled bullies, and to a lesser extent torrentfish, were species of colour-free water, but this may be simply a reversal of the situation with short-finned eels. Both torrentfish and blue-gilled bullies prefer rapid, usually large streams or rivers, and these have higher pH values and hence less colour.

Distributions of the remaining species seemed to be unaffected by pH.

7.1.6 Temperature

Although few temperature data were recorded, temperature tolerances are apparent for those species with the larger number of records (see Table 4). Of these, long-finned eels, inanga, and red-finned bullies were all present in waters with a wide range of temperature, which suggests they are eurythermal (have broad temperature tolerances). This is reflected by their wide geographical range and abundance; these species were the three most commonly recorded in this study. Woods (1966) stated that in the laboratory inanga readily acclimatised to temperatures up to 27°C. We recorded them in the field at temperatures up to 26°C. Red-finned bullies were recorded at temperatures up to 22°C, though McDowall (1964) found that at temperatures above 19°C premature emergence of fry occurred.

Short-finned eels were found in waters with a narrower range of temperatures (with a higher minimum temperature and a correspondingly higher mean) than waters in which long-finned eels were found. They were commonly recorded from standing waters, which usually had higher temperatures than streams and rivers and often had temperatures higher than air temperature. Jellyman (1974) reported that short-finned eel elvers could withstand temperatures of up to 30°C, a temperature about 5°C higher than that which long-finned eel elvers could survive for prolonged periods. The maximum at which each eel species was recorded during this study was 26°C.

Of the remaining species, banded kokopu are reported to be able to acclimatise to temperatures of up to 27°C (Woods 1966) and short-jawed kokopu and adult koaro to temperatures up to 23°C (Eldon 1969). However juvenile koaro apparently die at temperatures above 17°C and so are attracted to cold, snow-fed rivers (Woods 1966).

Depending on other variables such as oxygen levels, size of fish, temperature to which the fish has been acclimatised, rapidity of temperature change, and period of exposure, the upper lethal temperature limit for brown trout has been found to be between 22°C and 28°C (Morgan and Graynoth 1978). We recorded it at temperatures up to 16°C.

7.1.7 Presence of Brown Trout

The distribution of some native fishes may be limited by brown trout through competition for food and space and by predation. Adult trout are known to eat large numbers of whitebait, bullies, smelt, and other native fishes (McDowall 1978, Eldon 1979).

Brown trout are aggressive competitors and occupied most habitats available in the study area. Exceptions were those with a mud substrate, tannin-stained water, or steep gradient. Small trout (less than 200 mm long) use an invertebrate food source very similar to that of some indigenous fishes (Phillips 1929, Cadwallader 1975, Sagar and Eldon 1983). Hopkins (1965) found that eels, bullies, and trout fed on the same organisms, but avoided competition by utilising different size ranges. However, Cadwallader (1975) found that trout competed directly with the common river galaxias (*Galaxias vulgaris*) and thereby excluded it from some areas. Although *G. vulgaris* was not recorded from our study area, there are indications (McDowall 1968b, Cadwallader 1975) that the same competition exists between brown trout and other native fishes, especially other galaxiids. It appears that a similar situation occurs in Australia (for example, Jackson and Williams 1980).

Since the introduction of trout into a small Northland lake in 1957, the population of the rare dwarf inanga (*G. gracilis*) there has been eliminated (McDowall 1968b). Koaro used to be taken from Lake Taupo in large quantities by the Maori, but since the introduction of trout, koaro are no longer present in sufficient quantity to warrant harvesting (McDowall 1984). Another galaxiid, the dwarf galaxias (*G. divergens*) tends to retreat into the hills and be found above barriers to the upstream migration of trout (McDowall 1984).

In the study area adult trout were not recorded in association with giant, banded, or short-jawed kokopu or adult koaro. However, juvenile trout occasionally were recorded at sites where these galaxiids were present, though these sites were all small in extent and were presumably unsuitable habitats for adult trout.

The typical habitat of torrentfish (riffles and shallow rapids of fast-flowing streams and rivers) is infrequently used by predatory adult trout. However in streams in which adult trout were not resident there was some indication that torrentfish may utilise a wider variety of habitats. For example, in a spring stream on the Cook River flood plain from which adult trout were not recorded, torrentfish were numerous in the sluggish reaches (Fig. 29), as well as in those habitats with which they are more commonly associated.

7.2 The Fisheries

7.2.1 Rare Species

Short-jawed kokopu are rare fish, listed by the International Union for the Conservation of Nature and Natural Resources in the "Red Data Book", Volume 4 (Fishes) (Miller 1977), as a species whose present status is indeterminate. In other words, it is apparently rare and if

FIGURE 29. (a) A slowly flowing section of a stream on the Cook River flood plain where torrentfish were plentiful. This is an atypical torrentfish habitat.

FIGURE 29. (b) A wider view of the same stream (the section shown in 29(a) is in the bottom left corner).

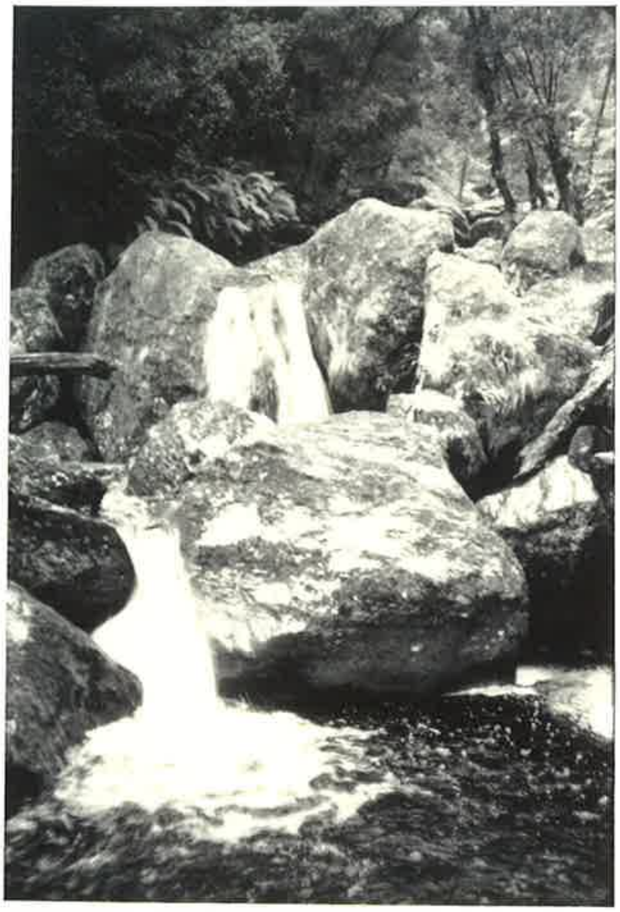

FIGURE 30. A fairly large population of short-jawed kokopu is present in pools above these falls on Black Creek.

more was known about its distribution and population size it may be found to be in danger of extinction. A recent increase in fisheries survey work by a variety of agencies (for example, catchment boards, acclimatisation societies, private consultants) has more than doubled the number of known habitats of this species recorded by McDowall (1978). However, there are still very few sites throughout New Zealand where more than two or three specimens have been recorded. Black Creek (Fig.30) was found to have a fairly large population of short-jawed kokopu and must rank among the most important habitats known for the fish. Under criteria outlined by Teirney, Unwin, Rowe, McDowall, and Graynoth (1982), Ohinetamatea River, the parent system of Black Creek, should be considered a river with biological fishery values of national importance. Specifically, Black Creek is:

1. a water containing an endangered indigenous species,

2. a water containing an indigenous species of extremely local distribution,

3. a water of exceptional value for an indigenous fish.

Mortimer, Nathan, Dawson, and Eggers (1984) reported that the Westland Catchment Board wished to quarry boulders from Black Creek, but that the application was refused on scenic grounds. For ecological and scientific reasons it is extremely fortuitous that the application was refused.

Although not as rare as the short-jawed kokopu, giant kokopu are considered by McDowall (1978) to be threatened, mainly because of a reduction in suitable habitat, but also because of competition from trout. Westland is one of the strongholds of this species, which is very rare on the east coast of the South Island and is declining in numbers elsewhere (Eldon 1983). Further destruction of giant kokopu habitat may cause it to become extinct, like the New Zealand grayling (*Prototroctes oxyrhynchus*) (Jellyman 1979, Eldon 1983).

Giant kokopu make a contribution, though insignificant, to the whitebait fishery. However, in the past they may have been far more common. Charles Douglas, writing last century, stated they were "... common all over the country wherever a bog hole or dark bush creek exists." (McDowall 1980b). Their whitebait runs may then have been more significant.

7.2.2 Whitebait Fishery

Westland is the most important whitebaiting region in New Zealand, and rivers in the study area support some commercial fishing. However, the whitebait fishery in general has declined as habitats have been destroyed on a massive scale (Eldon 1983).

The most important contributor to the whitebait catch, inanga, is fairly insensitive to habitat deterioration (R.M. McDowall pers. comm.). However some effects of logging, such as excessive sedimentation, are likely to adversely affect its distribution. In addition, as discussed below (see section 7.3.2.1), stock grazing of estuarine areas may reduce inanga populations. Because whitebait are not known to "home" on their natal streams and rivers as salmon do, wide-scale destruction of adults or eggs in any stream will affect overall recruitment of whitebait in the whole area.

7.2.3 Eel Fishery

New Zealand has a significant and valuable eel fishery. In 1975 when the catch peaked at 2363 t, eels were the country's most valuable finfish export (Jellyman and Todd 1982). Since then the fishery has declined owing to over-exploitation of the resource (Todd 1982). Eldon (1983) noted that there is potential to stabilise the fishery on a continuous yield basis, provided habitats remain.

Westland has one of the least exploited eel stocks, but because all fish are potential breeding stock, any major local population decline may affect recruitment overall. Therefore, little-exploited areas such as Westland act as stock reservoirs for more heavily fished areas.

At the time of this study there was no commercial eel fishing in the study area, but it is understood that in previous years the Ohinetamatea River has been fished commercially.

7.2.4 Species Not Recorded

It was expected that the brown mudfish (***Neochanna apoda***) and giant bully (***Gobiomorphus gobioides***) might be recorded during this study. Neither was recorded from the study area, nor ever has been.

The brown mudfish and other non-diadromous fishes may be absent because the area has only recently (on a geological time scale) become available as a fish habitat, its fluvio-glacial structure being among the youngest in the country. Consequently there has been little time for non-diadromous species to evolve in the area or to reach it by dispersal from other areas. Some of the non-diadromous fishes present in other regions, such as alpine galaxias (***Galaxias paucispondylus***) and long-jawed galaxias (*G. prognathus*), are extremely limited in distribution (McDowall 1978), which indicates that they have evolved only recently or have only limited powers of dispersal. However brown mudfish are widespread in North Westland (Eldon 1968) and suitable habitat for them is plentiful in the survey area.

The giant bully is known from only a few localities throughout New Zealand, but is probably present more often than is realised (McDowall 1978). Its absence from our study area is harder to explain than that of brown mudfish, because, unlike the mudfish, it is diadromous and so its dispersal ability is far greater. Furthermore, suitable habitat is not uncommon and the fish is known to be present further south (in the Haast region) and further north (McDowall 1978).

7.3 Implications for Management

There are several management options available for the South Westland forests. They include:

1. preservation of the forests in their present state,
2. selective logging,
3. clear felling with, for example, these subsequent land uses:
    (1) agriculture,
    (2) exotic afforestation, or
    (3) goldmining.

Of these, the two forest harvesting options, especially clear felling, have considerable implications for fisheries. Some of these implications are discussed here.

7.3.1 Possible Effects of Forest Harvesting

7.3.1.1 Removal of shade

Removal of riparian vegetation exposes streams to increased light levels. Ordinarily some streams may receive less than 5% of available solar radiation (Morgan and Graynoth 1978). Increased levels of light may lead to rapid growth of filamentous green algae (Morgan and Graynoth 1978, Graynoth 1979). Such algal blooms are undesirable because microbial decomposition of the mass of algae can reduce oxygen concentrations below that required by fishes and the invertebrate fauna.

Loss of riparian vegetation also gives rise to significantly higher summer water temperatures and slightly lower winter temperatures. Graynoth (1979) studied a clear felled catchment in Nelson and found that monthly mean temperatures increased in summer by up to 6.5°C and decreased in winter by up to 2.5°C. O'Loughlin (1980) did not record winter temperatures, but found that clear felling of Nelson and Westland beech forests increased summer afternoon stream water temperatures by 3-8°C above those of streams in intact forest.

Johnson (1971) found that in an alpine area of Canterbury the presence of forest cover did not significantly affect annual mean stream temperatures, but it did reduce the magnitude of the temperature range. Although no data were given, Johnson's figures and tables show that the temperature range of a stream with only 10% forest cover (Hut Stream) was about 9°C, whereas that of a stream with 85% cover (Lyndon Stream) was only about 4°C.

High stream temperatures can kill fish directly, reduce their activity, affect reproduction, and alter the composition of the benthic fauna

(Morgan and Graynoth 1978). The oxygen solubility of water decreases and the metabolic requirement of fish increases with an increase in temperature, (Hill 1976). For example, an increase of temperature from 0°C to 24°C decreases oxygen solubility by 40%.

As noted previously, koaro may be particularly sensitive to increased temperatures (see section 7.1.6). Spot-sampled summer temperatures of many of the streams in the study area were in the range 12-15°C (see section 6.1.1). An increase of 6.5°C, such as recorded by Graynoth (1979) after forest removal, would increase the mean water temperature to above 18°C, a temperature which could be lethal to koaro juveniles.

Removal of riparian cover also may raise the pH of water by the loss of humus-forming vegetation. This may benefit koaro and brown trout, but would probably further limit distribution of kokopu species.

7.3.1.2 Sedimentation

Streams from undisturbed forest catchments are generally clear and transport negligible sediment, except during periods of high rainfall (O'Loughlin, Rowe, and Pearce 1978). Although stream sediment levels reach a peak during logging operations, levels remain high after cessation of logging because of the loss of stabilising vegetation (Brown and Krygier 1971).

Excessive sedimentation is detrimental to fisheries for various reasons, as listed by Phillips (1971). In particular, sediment can:

1. kill adult fishes directly by causing damage to gill membranes,

2. smother eggs and fry of those fishes which lay their eggs among cobbles and gravel (in the study area this includes red-finned and blue-gilled bullies, brown trout, and probably torrentfish),

3. reduce dissolved oxygen concentration because of microbial decomposition of organic material in the sediment,

4. smother the benthic invertebrate food source,

5. block substrate interstices, thereby reducing the availability of substrate for cover (in the study area species which would be affected include koaro, red-finned and blue-gilled bullies, and torrentfish),

6. reduce natural algal populations by reducing the penetration of light.

The Cook River has a naturally high sediment load derived from the Fox Glacier. Despite intensive sampling, no fish were collected from this river, which may indicate that fishes were unable to live there because of excessive sedimentation.

In addition, a tributary of the Karangarua River in an area which has been cleared of forest and is now being farmed, has become sedimented with a layer of silt covering the cobble substrate. Only small numbers of long-finned eels, inanga, and red-finned bullies were recorded there. By comparison, in one of two unsilted streams nearby, long-finned eels, short-finned eels, inanga, koaro juveniles, and brown trout were recorded, and in the other (Stoney Creek) there were long-finned eels, inanga, koaro juveniles, torrentfish, red-finned bullies, black flounder, brown trout, and juvenile quinnat salmon.

Associated road building and slash-burning activities, rather than logging itself, give the greatest increase in stream sediment levels (Lynch, Corbett, and Hoopes 1977, Graynoth 1979, O'Loughlin, Rowe, and Pearce 1980). In an area of North Westland which was harvested by log-skidders and burned, O'Loughlin, Rowe, and Pearce (1980) reported an eight-fold increase in sediment yield rate over a control area; most of the increased sediment was derived from skidder tracks. Mosley (1980) found that a forest road system in Nelson increased river sedimentation by only 25%, but that large quantities of sediment were temporarily stored in headwater streams.

However, that logging itself can be responsible for large increases in stream sediment levels was clearly shown by O'Loughlin and Pearce (1976), Graynoth (1979), and O'Loughlin, Rowe, and Pearce (1982). As already indicated, this is due largely to loss of the stabilising effect of vegetation roots. O'Loughlin, Rowe, and Pearce (1982) stated that "...loss of reinforcement from tree roots is a dominant factor in ... accelerated sediment yields in clear felled steep headwater catchments". The ways in which forest cover stabilises hillsides were described by O'Loughlin (1974) and O'Loughlin, Rowe, and Pearce (1982).

The work of O'Loughlin, Rowe, and Pearce (1980, 1982) was in North Westland, in an area (Tawhai State Forest) where the mean annual rainfall is about 2600 mm. In South Westland, where the mean annual rainfall is far higher (4540 mm at Fox Glacier), the effect of sedimentation is likely to be more pronounced, as it is aggravated by high rainfall. Areas which could be particularly badly affected include a small part of the catchment of the Ohinetamatea River above S.H.6, a plateau in the headwaters of Black Creek, almost the whole of Makawhio State Forest, most of the elevated part of Bruce Bay State Forest and some unoccupied crown land up the Mahitahi River valley. These areas have in common a soil type (Arahura Hill), which the Soil Bureau (1968) stated is prone to severe erosion if the forest cover is removed. The Soil Bureau has recommended that such areas remain in protection forestry. In addition, some areas (some of the elevated regions of Karangarua State Forest, small parts of Makawhio and Bruce Bay State Forests, and elevated regions of Ohinemaka State Forest west of S.H.6) are composed of Matiri Steepland soils. These areas also are easily eroded and the same recommendation was applied to them. To a large extent these areas coincide with those which Fitzsimmons and O'Loughlin (1984) recommended should not be logged because of slope instability and the possiblity of large-scale mass-wasting.

7.3.1.3 Obstructions to Upstream Migration

It is important to emphasise the migratory nature of the native fishes of the study area, because any impediment to upstream migration of the poorer climbing species, such as inanga and giant kokopu, will result in exclusion of these species from upstream areas. Species such as koaro, which is an excellent climber, may be less affected. The non-penetration inland by species such as inanga is due to an inability to negotiate barriers to upstream migration. With increasing gradient, natural barriers such as falls become more frequent and less easily negotiated.

Border Creek, a tributary of Karangarua River, has been so modified by bulldozing at S.H.6 that it flows underground for several hundred metres. Consequently, no fish were collected above this point. An unnamed stream which rises on Bannock Brae dissipates into the pakihi surrounding Lake Kini. It too, was devoid of fish because access was denied them by the pakihi.

During logging operations, impediments to the upstream migration of fishes may occur in the form of log-jams and improperly placed culverts.

Log-jams composed of waste timber (slash) were commonly observed in streams during logging of exotic pine forests in Nelson (Graynoth 1979), beech forests in Southland and Westland (McDowall, Graynoth, and Eldon 1977), and beech-podocarp-hardwood forests in North Westland (O'Loughlin and Pearce 1976). O'Loughlin and Pearce (1976) reported that "substantial" structures up to 8 m high were formed. Although koaro and long-finned eels may be able to negotiate such barriers, most other fishes would be excluded from colonising the stream on the upstream side of them. In addition, O'Loughlin and Pearce (1976) and Pearce and Watson (1983) noted that large volumes of sediment and debris became stored behind some log-jams and the former authors stated that, should the blockages fail during a fairly large storm, the impact on the immediate downstream channel may be "... disastrous ...".

Large-scale mass-wasting during and after logging of steep hillsides may also cause stream blockages.

Road culverts sometimes are placed so that there is a free fall of water from the culvert on the downstream side, and this prevents upstream passage of fishes. This has occurred in a tributary of Pita Creek at S.H.6 (Fig. 31), and has effectively prevented upstream movement of red-finned bullies, inanga, and brown trout, which were present on the downstream side of a culvert. Banded kokopu, which like koaro are proficient climbers, were present above the culvert.

7.3.1.4 Increased Flooding

Both the frequency and size of stream floods increase after logging and slash-burning because of an increase in run-off (Morgan and Graynoth 1978). Increased run-off is due to a reduction in quantity of

FIGURE 31. Culvert on a tributary of Pita Creek at S.H.6. Note the free fall of water. This barrier prevented upstream migration of three species of fish.

water intercepted by vegetation and evaporated from the catchment (Pearce and Rowe 1979, Pearce 1980). In Tawhai State Forest, Pearce, Rowe, and O'Loughlin (1980) noted a first increase in water yield of 50% after clear felling and during a fairly dry year. This resulted in increased run-off ranging from 15-20% during large quick-flow events, to 300% during small events. There were also large rises in peak flow volumes. Because of South Westland's characteristically high rainfall, this effect is likely to be especially pronounced should logging occur in elevated regions, and it may give rise to more frequent and larger floods.

Flooding decreases substrate stability of a stream or river. Many native fishes (for example, giant, banded, and short-jawed kokopu, and short-finned eel) require a stable substrate (Morgan and Graynoth 1978). In addition, an unstable substrate kills eggs, fry, and benthic invertebrates.

Havelock Creek (Fig.32) is prone to heavy flooding, which necessitates frequent bulldozing at S.H.6 to avoid flooding of the bridge there. Despite intensive sampling of a large section of this stream (about 3 km), no fish were collected from it.

7.3.2 Possible Effects of some Land Uses after Clear Felling

7.3.2.1 Agriculture

Removal of forest, especially in low-lying areas, allows land to be developed for agriculture. Frequently such development means drainage of swamps and channelisation of streams by draglining. Drainage of swamps represents the loss of a fish and wildlife habitat type already

FIGURE 32. Flood prone Havelock Creek, and the bulldozer used to prevent flooding of S.H.6 bridge. No fish were collected from this stream.

few and dwindling in number (see McDowall 1975, *Freshwater Catch No. 15*, 1982). Channelisation of streams causes serious deterioration in fish habitat by greatly reducing the availability of cover and, in places, by increasing stream velocity to a uniformly fast flow, thereby reducing the number of fish species and individuals present (Field-Dodgson 1981). In the study area, draglined streams contained only a few long-finned eels or inanga, the latter being less cover-dependent than most species. Often fish were not recorded at all in such streams.

However, though the distribution of inanga is affected little by the availability of cover, it may be affected by agriculture. Because the eggs of inanga are laid on vegetation which is out of water between spring tides (see section 6.2.5), grazing of the verge vegetation of estuarine areas after spawning is likely to lead to heavy egg loss through trampling, exposure of the eggs to sun by vegetation removal, and ingestion of eggs by stock.

Grazing cattle trample stream banks and accelerate the rate of crumbling of overhangs, as for example in Hobson Creek (Fig.33). The bed of this creek is of fine material which offers no cover to fishes, and cattle have collapsed the banks to leave no cover at all. Only small numbers of long-finned eels and inanga were collected here. By contrast, drains which are fenced to exclude stock, and are not cleaned, allow the build-up of instream debris and aquatic vegetation, the growth of bankside vegetation, and the retention of banks, and thus retain some fisheries value (McDowall 1975, Eldon 1983). Such a drain occurred in the Ohinetamatea River catchment and contained giant kokopu and common bullies as well as long-finned eels.

In a tributary of the Karangarua River an algal bloom (excessive growth of filamentous brown algae) was observed. This probably had a

FIGURE 33. Hobson Creek, and the effect of farming on fisheries. Note the collapsed banks on the right.

two causes: firstly, removal of forest cover increased the incidence of light to the stream, and secondly farming may have caused enrichment of the water.

7.3.2.2 Exotic Afforestation

After removal of forest on steeper slopes where agriculture is less practical, afforestation with exotics (for example, *Pinus radiata*) may be considered a land-use option. This action may restore some soil stability. However, pine forests characteristically have a sparse undergrowth, and, because of the lack of herbaceous plants and shrubs, are unlikely to provide sufficient stability to prevent erosion (Morgan and Graynoth 1978).

Pine forests also have a different and sparse insect fauna, which may reduce the availability of food to forest-dwelling fishes.

7.3.2.3 Goldmining

As far as is known to FRD there has been no alluvial gold mining in the study area, though black sand mining is currently done at Hunt Beach and there is a claim on at least part of the Lake Kini pakihi. Alluvial mining can greatly increase the sediment load of streams and rivers, the effects of which were discussed in section 7.3.1.2.

8. RECOMMENDATIONS

In formulating a management plan for South Westland, FRD recommends that NZFS takes the following matters into account.

1. That those parts of the Ohinetamatea River catchment which are unmodified should be exempted from logging of any type. They

support a sizeable population of short-jawed kokopu and FRD considers this river to have biological values of national importance. It is understood that there is consideration on other grounds to include this catchment within Westland National Park; FRD would support such a move.

2. FRD supports the recommendations of Fitzsimmons and O'Loughlin (1984) regarding maintenance of slope stabilty and water quality. In particular, if logging takes place, we emphasise the following, that:

   (1) logging should be selective and riparian strips should be left along the margins of all water bodies. Pearce and Griffiths (1980) showed that in Okarito State Forest, 25% selective logging resulted in no reduction of water quality. Numerous authors (for example, Lantz 1971, Lynch, Corbett, and Hoopes 1977, Graynoth 1979, O'Loughlin 1980, 1982) have emphasised the importance of leaving buffer strips of vegetation along stream and river banks. Such riparian strips ameliorate many of the undesirable effects of logging, both on the waterway and on its flora and fauna. They provide cover, attract terrestrial insects, and reduce run-off and flooding; they also reduce algal growth, sedimentation, log-jams, light levels, and temperatures, while retaining dissolved oxygen concentrations and slope stability and preventing the collapse of overhanging banks. Conway (1980) in his opening address to a seminar on "Land Use in Relation to Water Quantity and Quality" quoted J.R. Gooz as saying: "Riparian strips may be the most effective management technique available for maintaining good water quality..."

(2) Roads, tracks, and landings should be constructed away from water bodies and, where they cross streams, bridges (preferably) or culverts should be constructed rather than fords. Culverts should be installed in such a way that there is not a free fall of water at their downstream ends. Construction of culverts is governed by Section 42 of the Freshwater Fisheries Regulations 1983. Details of appropriate road, track, and landing construction are given in "Forest Operations Guideline" by the National Water and Conservation Organisation (1978).

(3) Slash should not be burned, or bulldozed into streams.

(4) Any afforestation which takes place should be with indigenous species rather than exotics for the reasons discussed in section 7.3.2.2.

9. ACKNOWLEDGMENTS

This project was financed largely by New Zealand Forest Service which provided field services by way of road, air, and water transport, and base-camp accommodation. In the latter stage of the project John Watson assisted with field work. Don Jellyman, Martin Unwin, and Sally Davis are thanked for their constructive comments on the manuscript. Thanks are also due to our typist, Carol Whaitiri. The draughting in this report was done by the Department of Lands and Survey, Cartographic Branch.

10. LITERATURE CITED

Alabaster, J.S., and Lloyd, R. 1980. "Water Quality Criteria for Freshwater Fish." Butterworths, London. 297 p.

Brown, G.W., and Krygier, J.T. 1971. Clear-cut logging and sediment production in the Oregon Coast Range. *Water Resources Research 7(5)*: 1189-1198.

Burnet, A.M.R. 1952. Studies on the ecology of the New Zealand long-finned eel *Anguilla dieffenbachii* Gray. *Australian Journal of Marine and Freshwater Research 3*: 32-63.

Cadwallader, P.L. 1975. Feeding relationships of galaxiids, bullies, eels and trout in a New Zealand river. *Australian Journal of Marine and Freshwater Research 26*: 299-316.

Cadwallader, P.L, Eden, A.K., and Hook, R.A. 1980. Role of streamside vegetation as a food source for *Galaxias olidus* Gunther (Pisces: Galaxiidae). *Australian Journal of Marine and Freshwater Research 31*: 257-262.

Chapman, M.A., and Lewis, M.H. 1976. "An Introduction to the Freshwater Crustacea of New Zealand." Collins, Auckland. 261 p.

Conway, M.J. 1980. Opening address. *In*: Seminar on land use in relation to water quantity and quality. Nelson Catchment Board and Regional Water Board: 1-13.

Davis, S.F., Eldon, G.A., Glova, G.J., and Sagar, P.M. 1983. Fish populations of the lower Rakaia River. *N.Z. Ministry of Agriculture and Fisheries, Fisheries Environmental Report No.33.* 109 p.

Eldon, G.A. 1968. Notes on the presence of the brown mudfish (*Neochanna apoda* Gunther) on the west coast of the South Island of New Zealand. *N.Z. Journal of Marine and Freshwater Research 2*: 37-48.

Eldon, G.A. 1969. Observations on growth and behaviour of Galaxiidae in aquariums. *Tuatara 17*: 34-46.

Eldon, G.A. 1979. Habitat and inter-specific relationships of the Canterbury mudfish, *Neochanna burrowsius* (Salmoniformes: Galaxiidae). *N.Z. Journal of Marine and Freshwater Research 13*: 111-119.

Eldon, G.A. 1981. Freshwater crayfish. *Freshwater Catch No. 13*: 10.

Eldon, G.A. 1983. Submission on the Rotokino Swamp drainage scheme. *N.Z. Ministry of Agriculture and Fisheries, Fisheries Environmental Report No.32*: 12 p.

Eldon, G.A., and Greager, A.J. 1983. Fishes of the Rakaia lagoon. *N.Z. Ministry of Agriculture and Fisheries, Fisheries Environmental Report No. 30*. 65 p.

Field-Dodgson, M.S. 1981. Channelised fishery. *Freshwater Catch No.10*: 8-9.

Fitzsimmons, S., and O'Loughlin, C.L. 1984. A classification of landform types and implications for forest management between the Cook and Paringa Rivers, South Westland. Forest Research Institute, N.Z. Forest Service, Christchurch. 26 p, and map.

Gair, H.S. 1967. Geological Map of New Zealand, Sheet 20: Mt Cook 1:250000. New Zealand Geological Survey, Department of Scientific and Industrial Research, Wellington.

Graynoth, E. 1979. Effects of logging on stream environments and faunas in Nelson. *N.Z. Journal of Marine and Freshwater Research 13*: 79-109.

Hill, R.W. 1976. "Comparative Physiology of Animals." Harper and Row, New York. 656 p.

Hobbs, D.F. 1948. Trout fisheries in New Zealand: Their development and management. *N.Z. Marine Department, Fisheries Bulletin No.9*. 175 p.

Hopkins, C.L. 1965. Feeding relationships in a mixed population of freshwater fish. *N.Z. Journal of Science 8*: 149-157.

Jackson, P.D., and Williams, W.D. 1980. Effects of brown trout, *Salmo trutta* L., on the distribution of some native fishes in three areas of southern Victoria. *Australian Journal of Marine and Freshwater Research 31*: 61-67.

Jellyman, D.J. 1974. Aspects of the biology of juvenile freshwater eels (Anguillidae) in New Zealand. Ph.D thesis lodged in Victoria University of Wellington library.

Jellyman, D.J. 1979. Observations on the biology of the giant kokopu, *Galaxias argenteus* (Gmelin, 1789). *Mauri Ora 7*: 53-61.

Jellyman, D.J., and Todd, P.R. 1982. New Zealand freshwater eels: their biology and fishery. *N.Z. Ministry of Agriculture and Fisheries, Fisheries Research Division Information Leaflet No.11*. 19 p.

Johnson, F.A. 1971. Stream temperatures in an alpine area. *Journal of Hydrology 14*: 322-336.

Lantz, R.L. 1971. Influence of water temperature on fish survival, growth and behaviour. *In:* Krygier, J.T., and Hall, J.D. (Eds.). "Forest Land Uses and Stream Environment." Oregon State University, Corvallis, Oregon. 252 p.

Lynch, J.A., Corbett, E.S., and Hoopes, R. 1977. Implications of forest management practices on the aquatic environment. *Fisheries 2(2)*: 16-22.

McDowall, R.M. 1964. Studies on the biology of the red-finned bully *Gobiomorphus huttoni* (Ogilby): Part I - Habitat and species inter-relationships. *Transactions of the Royal Society of N.Z., Zoology 4*: 175-182.

McDowall, R.M. 1968a. *Galaxias maculatus* (Jenyns), the New Zealand whitebait. *N.Z. Marine Department, Fisheries Research Bulletin No. 2.* 84 p.

McDowall, R.M. 1968b. Interactions of the native and alien faunas of New Zealand and the problem of fish introductions. *Transactions of the American Fisheries Society 97*: 1-11.

McDowall, R.M. 1970. The galaxiid fishes of New Zealand. *Bulletin of the Museum of Comparative Zoology Harvard 139(7)*: 341-431.

McDowall, R.M. 1973. Relationships and taxonomy of the New Zealand torrentfish, *Cheimarrichthys fosteri* Haast (Pisces: Mugiloididae). *Journal of the Royal Society of N.Z. 3*: 199-217.

McDowall, R.M. 1975. Reclamation and swamp drainage - their impact on fish and fisheries. *N.Z. Ministry of Agriculture and Fisheries, Fisheries Research Division Information Leaflet No.6.* 13 p.

McDowall, R.M. 1978. "New Zealand Freshwater Fishes - A Guide and Natural History." Heinemann Educational Books, Auckland. 230 p.

McDowall, R.M. 1980a. Forest cover over streams is vital to some native freshwater fishes. *Forest and Bird 13(5)*: 22-4.

McDowall, R.M. 1980b. Charles Douglas, explorer: his notes on freshwater fisheries. *Journal of the Royal Society of N.Z. 10(4)*: 311-24.

McDowall, R.M. 1981. Freshwater fish in Fiordland National Park. *N.Z. Ministry of Agriculture and Fisheries, Fisheries Environmental Report No.12*. 31 p.

McDowall, R.M. 1984. Exotic fishes - the New Zealand experience. *In*: Courtenay, W.R., and Stauffer, J. (Eds.). "Distribution, Biology and Management of Exotic Fishes." John Hopkins Press, Baltimore.

McDowall, R.M., and Eldon, G.A. 1980. The ecology of whitebait migrations (Galaxiidae: *Galaxias* spp.). *N.Z. Ministry of Agriculture and Fisheries, Fisheries Research Bulletin No. 20*. 171 p.

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

McDowall, R.M., and Richardson, J. 1983. New Zealand freshwater fish survey - a guide to input and output. *N.Z. Ministry of Agriculture and Fisheries, Fisheries Research Division Information Leaflet No. 13*. 11 p.

Miller, R.R. (Comp.) 1977. "Red Data Book. Volume 4, Fishes." International Union for the Conservation of Nature, Morges. Unpaged.

Mitchell, C.P., and Penlington, B.P. 1982. Spawning of *Galaxias fasciatus* Gray (Salmoniformes: Galaxiidae). *N.Z. Journal of Marine and Freshwater Research 16(1)*: 131-133.

Morgan, D.R., and Graynoth, E. 1978. The influence of forestry practices on the ecology of freshwater fish in New Zealand. An introduction to the literature. *N.Z. Ministry of Agriculture and Fisheries, Fisheries Research Division Occasional Publication No.14*. 36 p.

Mortimer, G., Nathan, S., Dawson, R.M., and Eggers, M.J. 1984. Geology of the lowland area between the Cook and Paringa Rivers, South Westland. *Department of Scientific and Industrial Research, N.Z. Geological Survey Report G81*. 49 p, and map.

Mosley, M.P. 1980. The impact of forest road erosion in the Dart Valley, Nelson. *N.Z. Journal of Forestry 25(2)*: 184-198.

National Water and Soil Conservation Organisation. 1978. Forest operations guideline. *Water and Soil Management Publication No. 5*. 13 p.

New Zealand Meteorological Service. 1983. Summaries of climatological observations to 1980. *N.Z. Meteorological Service Miscellaneous Publication No.177*. 172 p.

O'Loughlin, C.L. 1974. The effect of timber removal on the stability of forest soils. *Journal of Hydrology (N.Z.) 13*: 121-134.

O'Loughlin, C.L. 1980. Water quality and sediment yield consequences of forest practices in North Westland and Nelson. pp. 152-171. *In*: Seminar on land use in relation to water quantity and quality. Nelson Catchment Board and Regional Water Board.

O'Loughlin, C.L. 1982. Forest land use and its contribution to and control of erosion - examples from New Zealand and Malaysia. *In*: Miller, D.J. (Ed.). Catchment management for optimum use of land and water resources: Documents from an ESCAP seminar - Part 2 - New Zealand contributions. *Water and Soil Miscellaneous Publication No. 46*: 327-340.

O'Loughlin, C.L., and Pearce, A.J. 1976. Influence of Cenozoic geology on mass movement and sediment yield response to forest removal, North Westland, New Zealand. *Bulletin of the International Association of Engineering Geology 14*: 41-46.

O'Loughlin, C.L., Rowe, L.K., and Pearce, A.J. 1978. Sediment yields from small forested catchments, North Westland-Nelson, New Zealand. *Journal of Hydrology (N.Z.) 17*: 1-15.

O'Loughlin, C.L., Rowe, L.K., and Pearce, A.J. 1980. Sediment yield and water quality responses to clearfelling of evergreen mixed forests in western New Zealand. *In*: The influence of man on the hydrological regime with special reference to representative and experimental basins. *International Association of Scientific Hydrology Publication No. 130*: 285-92.

O'Loughlin, C.L., Rowe, L.K., and Pearce, A.J. 1982. Exceptional storm influences on slope erosion and sediment yield in small forest catchments, North Westland, New Zealand. *In*: Proceedings of

Forestry Hydrology Symposium, Melbourne, Australia. Institute of Engineers, Australia. Unpaged.

Ots, J.P., and Eldon, G.A. 1975. Downstream movement of fry of *Galaxias fasciatus* Gray (note). *N.Z. Journal of Marine and Freshwater Research 9*: 97-99.

Pearce, A.J. 1980. Streamflow from forests. *What's New in Forest Research No.92*. 4 p.

Pearce, A.J., and Griffiths, A.D. 1980. Effects of selective logging on physical water quality in small streams, Okarito Forest. *Journal of Hydrology (N.Z.) 19(1)*: 60-67.

Pearce, A.J., and Rowe, L.K. 1979. Forest management effects on interception, evaporation and water yield. *Journal of Hydrology (N.Z.) 18*: 73-87.

Pearce, A.J., Rowe, L.K., and O'Loughlin, C.L. 1980. Effects of clearfelling and slash-burning on water yield and storm hydrographs in evergreen mixed forests, western New Zealand. pp. 119-27. *In*: The influence of man on the hydrological regime with special reference to representative and experimental basins. *International Association of Scientific Hydrology Publication No. 130*:

Pearce, A.J., and Watson, A. 1983. Medium-term effects of two landsliding episodes on channel storage of sediment. *Earth Surface Processes and Landforms 8*: 29-39.

Phillips, J.S. 1929. A report on the food of trout and other conditions affecting their well-being in the Wellington district. *N.Z. Marine Department, Fisheries Bulletin No.2*. 31 p.

Phillips, R.W. 1971. Effects of sediment on the gravel environment and fish production. *In*: Krygier, J.T., and Hall, J.D. (Eds.). *Forest Land Uses and Stream Environment.* Oregon State University, Corvallis, Oregon. 252 p.

Sagar, P.M., and Eldon, G.A. 1983. Food and feeding of small fishes in the Rakaia River, New Zealand. *N.Z. Journal of Marine and Freshwater Research 17*: 213-226

Soil Bureau. 1968. General survey of the soils of South Island, New Zealand. *Department of Scientific and Industrial Research, Soil Bureau Bulletin No. 27.* 404 p, plus maps.

Teirney, L.D., Unwin, M.J., Rowe, D.K., McDowall, R.M., and Graynoth, E. 1982. Submission on the draft inventory of wild and scenic rivers of national importance. *N.Z. Ministry of Agriculture and Fisheries, Fisheries Environmental Report No.28.* 122 p.

Todd, P.R. 1982. Eel exports take dramatic downturn. *Freshwater Catch No. 16*: 17.

Warren, G. 1967. Geological Map of New Zealand, Sheet 17: Hokitika, 1:250000. N.Z. Geological Survey, Department of Scientific and Industrial Research, Wellington.

Woods, C.S. 1966. Species composition of whitebait (*Galaxias* spp.). *Records of the Canterbury Museum 8*: 177-9.

APPENDIX I. Freshwater fish survey card.

FRESHWATER FISH SURVEY — PLEASE RETURN TO: Fisheries Research Division, Ministry of Agriculture and Fisheries, P.O. Box 297, Wellington.

7701

Catalogue Number	River/Lake System —			Catchment Number —	
Date	Sampling Locality —				
Time (N.Z.S.T)	Access —				
Observer —	NZMS 1 Co-ordinates—	NZMS 1 Map No.	Lat.	Long. —	
Fishing Method —	Distance Surveyed —	Permanent Water — Yes/No		Tidal Water — Yes/no	

HABITAT DATA

WATER	Colour —		Clarity —	Conduct. —	Temp. — °C	pH —
	Estimated Flow —		Average Width —	Depth Range		O_2 —
Flow Type %	Still —	Sluggish —	Pool —	Run —	Riffle —	Torrent —
Bottom Type %	Bed Rock—	Boulder —	Gravel —	Sand —	Mud —	Other —

Cover in water — type and abundance —

Aquatic vegetation — macrophytes — algae —

Type of river/stream/lake —

Condition of river/stream/lake—
(e.g. level, pollution, modification)

Notes on valley/vegetation —

Bottom fauna —

Purpose of work—
(e.g. Hons. degree material, Acc. Soc. data base, etc.)

General Comments—

FISH OBSERVED

	SPECIES	ABUNDANCE	CONDITIONS WHERE CAUGHT	COMMENTS *	†
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					

NOTES–

* Size, Peculiarities, Spawning, Juveniles, etc.
† Specimens Retained.

These sections must be filled in; other sections optional but desirable.

APPENDIX II. Distribution of fishes by catchment.

Cook River catchment	NZMS 1 map co-ordinates	Lamprey	Long-finned eel	Short-finned eel	Common smelt	Inanga	Koaro	Banded kokopu	Giant kokopu	Short-jawed kokopu	Torrent-fish	Red-finned bully	Common bully	Blue-gilled bully	Black flounder	Kahawai	Yellow-eyed mullet	Brown trout	Quinnat salmon	Nil caught
Old bed of Cook R.	S70/494646		X										X		X			X		
Old course of Cook R. and present flood plain	From S70/540580 to S70/625640		X	X							X	X		X				X		
Cook R. at S.H.6 and about 12 km downstream	S70/530650																			X
Bullock Ck. at S.H.6	S78/628597																			X
Bullock Ck. upstream from S.H.6	S78/622585						X													
Trib. of Bullock Ck.	S78/627594																			X
Trib. of Bullock Ck.	S78/624589						X													
South Fork of Bullock Ck	S78/617583						X													

APPENDIX II. (Continued)

Cook River catchment	NZMS 1 map co-ordinates	Lamprey	Long-finned eel	Short-finned eel	Common smelt	Inanga	Koaro	Banded kokopu	Giant kokopu	Short-jawed kokopu	Torrent-fish	Red-finned bully	Common bully	Blue-gilled bully	Black flounder	Kahawai	Yellow-eyed mullet	Brown trout	Quinnat salmon	Nil caught
Small trib. of Cook R. north of Bullock Ck.	S78/632598					X												X		
west of S.H.6	S78/632598					X														
3 tribs. of Cook R. south of Bullock Ck. and east of S.H.6	S70/616601 S70/612602 S70/611601																			X

APPENDIX II. (Continued)

Boyds Creek catchment	NZMS 1 map co-ordinates	Lamprey	Long-finned eel	Short-finned eel	Common smelt	Inanga	Koaro	Banded kokopu	Giant kokopu	Short-jawed kokopu	Torrent-fish	Red-finned bully	Common bully	Blue-gilled bully	Black flounder	Kahawai	Yellow-eyed mullet	Brown trout	Quinnat salmon	Nil caught
Trib. of Boyds Ck.	S70/482648							X												
Boyds Ck.	S70/475647																			X
Boyds Ck. near mouth	S70/472648			X																

APPENDIX II. (Continued)

Ohinetamatea River catchment	NZMS 1 map co-ordinates	Lamprey	Long-finned eel	Short-finned eel	Common smelt	Inanga	Koaro	Banded kokopu	Giant kokopu	Short-jawed kokopu	Torrent-fish	Red-finned bully	Common bully	Blue-gilled bully	Black flounder	Kahawai	Yellow-eyed mullet	Brown trout	Quinnat salmon	Nil caught
Trib. of Ohinetamatea R. on north bank, west of S.H.6	S70/500603		X																	
Ohinetamatea R. midway between mouth and S.H.6	S70/497605		X	X		X						X						X		
Swamp on north bank of Ohine-tamata R.	S70/494606																			X
Trib. of Ohine-tamata R. on south bank	S70/489608	X	X		X							X								
Trib. of Ohinetamatea R. on south bank	S70/500604																			X
Swamp on south bank of Ohine-tamatea R.	S70/495602		X	X		X														

APPENDIX II. (Continued)

Ohinetamatea River catchment	NZMS 1 map co-ordinates	Lamprey	Long-finned eel	Short-finned eel	Common smelt	Inanga	Koaro	Banded kokopu	Giant kokopu	Short-jawed kokopu	Torrent-fish	Red-finned bully	Common bully	Blue-gilled bully	Black flounder	Kahawai	Yellow-eyed mullet	Brown trout	Quinnat salmon	Nil caught
Trib. of Ohinetamatea R. on north bank	S70/504600 S70/510600			X														X		
Series of bush ponds on north bank of Ohinetamatea R.	S70/510606			X														X		
Ohinetamatea R. 2 km below S.H.6 bridge	S70/575612										X	X		X				X		
Trib. of Ohinetamatea R. 1.5 km below S.H.6 bridge	S70/577610											X								
Ponds on north bank of Ohine-tamatea R.	S70/573616																			X
Trib. of Ohinetamatea R. east of S.H.6	S70/601600		X				X													

APPENDIX II. (Continued)

Ohinetamatea River catchment	NZMS 1 map co-ordinates	Lamprey	Long-finned eel	Short-finned eel	Common smelt	Inanga	Koaro	Banded kokopu	Giant kokopu	Short-jawed kokopu	Torrent-fish	Red-finned bully	Common bully	Blue-gilled bully	Black flounder	Kahawai	Yellow-eyed mullet	Brown trout	Quinnat salmon	Nil caught
Trib. of Ohinetamatea R. west of S.H.6 (same as above)	S70/587611		X																	
Small trib. of Ohine-tamatea R. at S.H.6	S78/557580					X						X	X							
Black Ck. above and below S.H.6	S78/558591		X			X		X	X	X		X						X		
Trib. of Ohinetamatea R. on south bank, 2 km east of S.H.6	S78/592601									X		X						X		
Trib. of Ohinetamataea R. at S.H.6	S78/557579								X	X		X								
Trib. of Ohinetamatea R. on north bank, 3 km east of S.H.6	S78/599594		X				X			X										

APPENDIX II. (Continued)

Ohinetamatea River catchment	NZMS 1 map co-ordinates	Lamprey	Long-finned eel	Short-finned eel	Common smelt	Inanga	Koaro	Banded kokopu	Giant kokopu	Short-jawed kokopu	Torrent-fish	Red-finned bully	Common bully	Blue-gilled bully	Black flounder	Kahawai	Yellow-eyed mullet	Brown trout	Quinnat salmon	Nil caught
4 small tribs. of Ohinetamatea R. at S.H.6	S70/584607											X								
Trib. of Ohinetamatea R. on west bank, below S.H.6	S70/537601								X											
Trib. of Ohinetamatea R. on west bank below S.H.6	S78/537584		X																	
Trib. of Ohinetamatea R. on east bank, below S.H.6	S78/535580																			X
Swamp on east bank of Ohine-tamatea R. below S.H.6	S78/535581		X			X														
Havelock Ck. at confl. with Ohine-tamatea R.	S78/534580																			X

APPENDIX II. (Continued)

Ohinetamatea River catchment	NZMS 1 map co-ordinates	Lamprey	Long-finned eel	Short-finned eel	Common smelt	Inanga	Koaro	Banded kokopu	Giant kokopu	Short-jawed kokopu	Torrent-fish	Red-finned bully	Common bully	Blue-gilled bully	Black flounder	Kahawai	Yellow-eyed mullet	Brown trout	Quinnat salmon	Nil caught
Havelock Ck. at S.H.6 and 1 km upstream	S78/552565 and S78/554554																			X
Havelock Ck. from 2 km upstream of S.H.6	S78/566535 to S78/559547																			X
Tribs. (3) of Havelock Ck. upstream of S.H.6	S78/561547 S78/561539 S78/565539																			X
Trib. 1 km upstream of mouth on south bank of Ohine-tamatea R.	S70/465639		X			X							X							
Trib. on south bank, 6 km up-stream from mouth of Ohine-tamatea R.	S70/482614		X									X								

APPENDIX II. (Continued)

Ohinetamatea River catchment	NZMS 1 map co-ordinates	Lamprey	Long-finned eel	Short-finned eel	Common smelt	Inanga	Koaro	Banded kokopu	Giant kokopu	Short-jawed kokopu	Torrent-fish	Red-finned bully	Common bully	Blue-gilled bully	Black flounder	Kahawai	Yellow-eyed mullet	Brown trout	Quinnat salmon	Nil caught
Trib. of Ohinetamatea R. on north bank, 5.5 km upstream from mouth	S70/479619		X																	
Trib. of Ohinetamatea R. on north bank 5 km upstream from mouth	S70/477616					X							X							
Trib. of Ohinetamatea R. on south bank 4.5 km upstream from mouth	S70/471619		X																	
Gordon Ck* at its confluence with Ohine-tamatea R.	S70/469642		X			X							X		X		X			
North fork of Black Ck. and a trib.	S78/567586 to S78/582589																			X
South fork of Black Ck	S78/367584 to S78/564569																			X

* One of two streams within the survey area given this name

APPENDIX II. (Continued)

Ohinetamatea River catchment	NZMS 1 map co-ordinates	Lamprey	Long-finned eel	Short-finned eel	Common smelt	Inanga	Koaro	Banded kokopu	Giant kokopu	Short-jawed kokopu	Torrent-fish	Red-finned bully	Common bully	Blue-gilled bully	Black flounder	Kahawai	Yellow-eyed mullet	Brown trout	Quinnat salmon	Nil caught
Trib. of Ohinetamatea R. on north bank, up-stream of S.H.6	S78/597582		X				X					X								
Trib. of Ohinetamatea R. on north bank, upstream of S.H.6	S78/597572 to S78/602574																			X
Channel of Ohinetamatea R., 4 km up-stream of S.H.6	S78/594566						X											X		
Trib. of Ohinetamatea R. on north bank upstream of S.H.6	S78/597565						X													
Mouth of Ohinetamatea R.	S70/468643		X										X		X		X		X	
Trib. of Ohinetamatea R. on north bank	S70/476632		X			X			X				X							

APPENDIX II. (Continued)

Ohinetamatea River catchment	NZMS 1 map co-ordinates	Lamprey	Long-finned eel	Short-finned eel	Common smelt	Inanga	Koaro	Banded kokopu	Giant kokopu	Short-jawed kokopu	Torrent-fish	Red-finned bully	Common bully	Blue-gilled bully	Black flounder	Kahawai	Yellow-eyed mullet	Brown trout	Quinnat salmon	Nil caught
Trib. of Ohinetamatea R. on south bank	S70/467627		X						X			X								
Hobson Ck. between S.H.6 and Ohinetamatea River	S78/517557		X			X														
Dragline running parallel to Hobson Ck. at base of spur, and associated stream	S78/513569		X					X	X				X							
Flax swamp adjacent to Ohinetamatea River	S78/519574					X														

APPENDIX II. (Continued)

Scotchmans Creek catchment	NZMS 1 map co-ordinates	Lamprey	Long-finned eel	Short-finned eel	Common smelt	Inanga	Koaro	Banded kokopu	Giant kokopu	Short-jawed kokopu	Torrent-fish	Red-finned bully	Common bully	Blue-gilled bully	Black flounder	Kahawai	Yellow-eyed mullet	Brown trout	Quinnat salmon	Nil caught
Scotchmans Creek	S70 460631 to S70 461628		X					X												

APPENDIX II. (Continued)

Karangarua River catchment	NZMS 1 map co-ordinates	Lamprey	Long-finned eel	Short-finned eel	Common smelt	Inanga	Koaro	Banded kokopu	Giant kokopu	Short-jawed kokopu	Torrent-fish	Red-finned bully	Common bully	Blue-gilled bully	Black flounder	Kahawai	Yellow-eyed mullet	Brown trout	Quinnat salmon	Nil caught
Lagoon between mouths of Karangarua R. and Gordon Ck.*	S78/440598												X			X	X	X		
Trib. of Gordon Ck. on north bank, 1.5 km above mouth	S78/431582		X			X														
Nicholson Ck. above its confluence with Gordon Ck.	S78/432585 to S78/435582		X																	
Mouth of Karangarua R.	S70/448601				X	X					X		X							
Below confluence of Gordon and Nicholson Cks.	S78/432587		X										X				X			
Trib. on south bank of Gordon Ck. 1.7 km above mouth	S78/430580		X			X														

* One of two streams within the survey area given this name.

APPENDIX II. (Continued)

Karangarua River catchment	NZMS 1 map co-ordinates	Lamprey	Long-finned eel	Short-finned eel	Common smelt	Inanga	Koaro	Banded kokopu	Giant kokopu	Short-jawed kokopu	Torrent-fish	Red-finned bully	Common bully	Blue-gilled bully	Black flounder	Kahawai	Yellow-eyed mullet	Brown trout	Quinnat salmon	Nil caught
1 km up each fork of Gordon Ck.	S78/432566 and S78/442572		X	X		X			X				X		X					
Edge of Karangarua R. between S.H.6 and mouth	S78/493548						X				X	X								
Trib. on south bank of Karangarua R., in rough pasture	S78/492545		X				X				X	X						X		
Same stream as above sampled within forest	S78/489537		X				X		X			X						X		
Stoney Ck. at its confluence with Karangarua R.	S78/499556				X						X				X					
Stoney Ck. above its confluence with Karang-arua R.	S78/507549		X			X	X				X	X			X			X	X	

APPENDIX II. (Continued)

Karangarua River catchment	NZMS 1 map co-ordinates	Lamprey	Long-finned eel	Short-finned eel	Common smelt	Inanga	Koaro	Banded kokopu	Giant kokopu	Short-jawed kokopu	Torrent-fish	Red-finned bully	Common bully	Blue-gilled bully	Black flounder	Kahawai	Yellow-eyed mullet	Brown trout	Quinnat salmon	Nil caught
Trib. of Karangarua R. between it and S.H.6	S78/513548		X			X						X								
Trib. of Karangarua R. between it and S.H.6	S78/520549		X	X		X	X											X		
Dragline following 4WD track between Karangarua R. and S.H.6	S78/526549																			X
Pond on east side of S.H.6	S78/514513		X																	
Pond on south bank of Karang-arua R., west of S.H.6	S78/494540		X			X														
Series of bush ponds	S78/472533 to S78/459533		X	X		X		X	X											

APPENDIX II. (Continued)

Karangarua River catchment	NZMS 1 map co-ordinates	Lamprey	Long-finned eel	Short-finned eel	Common smelt	Inanga	Koaro	Banded kokopu	Giant kokopu	Short-jawed kokopu	Torrent-fish	Red-finned bully	Common bully	Blue-gilled bully	Black flounder	Kahawai	Yellow-eyed mullet	Brown trout	Quinnat salmon	Nil caught
Karangarua R. at its confluence with Maimai Ck.	S78/495503						X											X		
Border Ck. upstream from S.H.6	S78/530539 to S78/542535																			X
Stoney Ck. upstream from S.H.6	S78/522525 to S78/525523						X													
Stoney Ck. 2 km upstream from S.H.6	S78/533515																			X
Rough Ck. 100 m above its confluence with Karangarua R.	S78/508499		X				X				X			X						
Rough Ck. 2 km above its confluence with Karangarua R.	S78/523503						X													
Trib. of Rough Ck., on north bank	S78/527506		X				X													

APPENDIX II. (Continued)

Karangarua River catchment	NZMS 1 map co-ordinates	Lamprey	Long-finned eel	Short-finned eel	Common smelt	Inanga	Koaro	Banded kokopu	Giant kokopu	Short-jawed kokopu	Torrent-fish	Red-finned bully	Common bully	Blue-gilled bully	Black flounder	Kahawai	Yellow-eyed mullet	Brown trout	Quinnat salmon	Nil caught
Maimai Ck. upstream from S.H.6	S78/496501 to S78/490497		X				X				X							X		
Trib. of Maimai Ck. on north bank, up-stream from S.H.6	S78/490497		X				X					X								

APPENDIX II. (Continued)

Manakalaua River catchment	NZMS 1 map co-ordinates	Lamprey	Long-finned eel	Short-finned eel	Common smelt	Inanga	Koaro	Banded kokopu	Giant kokopu	Short-jawed kokopu	Torrent-fish	Red-finned bully	Common bully	Blue-gilled bully	Black flounder	Kahawai	Yellow-eyed mullet	Brown trout	Quinnat salmon	Nil caught
Pita Ck. at S.H.6	S78/407512	X	X			X		X	X			X	X							
Trib. of Pita Ck. at S.H.6	S78/405512		X			X		X				X						X		
Trib. of Pita Ck. at S.H.6	S78/401512					X		X				X								
Draglines on north bank of Manakalaua R.	S78/423515 and S78/422514		X			X			X											
Ditch on east side of S.H.6	S78/392504		X			X		X	X			X								
Series of bush ponds between S.H.6 and Hunt Beach State Forest	S78/433521																			X
Break Ck. at Hunt Beach Rd.	S78/395513		X						X				X							

APPENDIX II. (Continued)

Manakalaua River catchment	NZMS 1 map co-ordinates	Lamprey	Long-finned eel	Short-finned eel	Common smelt	Inanga	Koaro	Banded kokopu	Giant kokopu	Short-jawed kokopu	Torrent-fish	Red-finned bully	Common bully	Blue-gilled bully	Black flounder	Kahawai	Yellow-eyed mullet	Brown trout	Quinnat salmon	Nil caught
Ditch beside Hunt Beach Rd. which drains into Break Ck.	S78/393513					X														
Trib. of Hunt Ck. at 4WD track	S78/430525		X	X																
Small trib. of Hunt Ck. at 4WD track	S78/431527			X		X						X								
Series of ponds in rough pasture	S78/435529		X	X		X														
Hunt Ck. below S.H.6	S78/474513		X									X								
Bush pond near logging track	S78/474518		X	X																
Series of temporary bush ponds near logging track	S78/467522 to S78/474519																			X

APPENDIX II. (Continued)

Manakaiaua River catchment	NZMS 1 map co-ordinates	Lamprey	Long-finned eel	Short-finned eel	Common smelt	Inanga	Koaro	Banded kokopu	Giant kokopu	Short-jawed kokopu	Torrent-fish	Red-finned bully	Common bully	Blue-gilled bully	Black flounder	Kahawai	Yellow-eyed mullet	Brown trout	Quinnat salmon	Nil caught
Trib. of Hunt Ck. at S.H.6	S78/471510					X		X				X								
Manakaiaua R. mouth	S78/403537		X		X						X				X		X	X		
Hunt Ck. at its confluence with Manakaiaua R.	S78/400532		X										X		X		X	X		
Series of small tribs. of Hunt Ck. at S.H.6	S78/454514 to S78/470510		X					X		X										
Sam Ck. above its confluence with Manakaiaua R.	S78/397528		X			X						X	X							
Boiler Ck. above its confluence with Manakaiaua R.	S78/398529			X		X														
Hunia Ck. at its confluence with Manakaiaua R.	S78/403534		X																	

APPENDIX II. (Continued)

Manakalaua River catchment	NZMS 1 map co-ordinates	Lamprey	Long-finned eel	Short-finned eel	Common smelt	Inanga	Koaro	Banded kokopu	Giant kokopu	Short-jawed kokopu	Torrent-fish	Red-finned bully	Common bully	Blue-gilled bully	Black flounder	Kahawai	Yellow-eyed mullet	Brown trout	Quinnat salmon	Nil caught
Manakalaua R. from S.H.6 downstream	S78/422512						X				X	X		X				X		
Hunt Ck. above S.H.6 in rough pasture	S78/478509		X																	
Hunt Ck. above S.H.6 sampled within forest	S78/479505		X				X	X				X						X		
Trib. of Manakalaua R. on north bank above S.H.6	S78/432505 to S78/435504		X					X												
Trib. of Manakalaua R. on north bank above S.H.6	S78/438498 to S78/439496		X					X	X	X										

APPENDIX II. (Continued)

Makawhio catchment	NZMS 1 map co-ordinates	Lamprey	Long-finned eel	Short-finned eel	Common smelt	Inanga	Koaro	Banded kokopu	Giant kokopu	Short-jawed kokopu	Torrent-fish	Red-finned bully	Common bully	Blue-gilled bully	Black flounder	Kahawai	Yellow-eyed mullet	Brown trout	Quinnat salmon	Nil caught
Roadside ditch south Jacobs R.	S78/385490								X											
Stream feeding roadside ditch	S78/349490					X														
Stream draining roadside ditch into Ruera Ck.	S78/362490					X						X								
Roadside ditch near Ruera Ck.	S78/371494								X											
Roadside ditch south of Jacobs R.	S78/382489					X														
Series of 4 small tribs. on south bank of Makawhio R., upstream from S.H.6	S78/413421 to S78/420409						X											X		
Trib. on south bank of Makawhio R.	S78/393438																			X

APPENDIX II. (Continued)

Makawhio catchment	NZMS 1 map co-ordinates	Lamprey	Long-finned eel	Short-finned eel	Common smelt	Inanga	Koaro	Banded kokopu	Giant kokopu	Short-jawed kokopu	Torrent-fish	Red-finned bully	Common bully	Blue-gilled bully	Black flounder	Kahawai	Yellow-eyed mullet	Brown trout	Quinnat salmon	Nil caught
Pond on south bank of Makawhio R.	S 78/404448		X																	
Kini Ck.	S78/388431						X											X		
Hermann Ck.	S78/409477 to S78/415479											X	X							
Pavo Ck.	S78/410449						X													
Ruera Ck. at S.H.6	S78/380487												X							
Trib. of Ruera Ck.	S78/384480								X											
Trib. of Ruera Ck.	S78/382480					X						X								
Trib. on north bank of Makawhio R.	S78/434394 to S78/424402																			X
Mouth of Makawhio R.	S78/353504				X												X	X		
Papakeri Ck. upstream from S.H.6	S78/357488		X						X				X							

APPENDIX II. (Continued)

Makawhio catchment	NZMS 1 map co-ordinates	Lamprey	Long-finned eel	Short-finned eel	Common smelt	Inanga	Koaro	Banded kokopu	Giant kokopu	Short-jawed kokopu	Torrent-fish	Red-finned bully	Common bully	Blue-gilled bully	Black flounder	Kahawai	Yellow-eyed mullet	Brown trout	Quinnat salmon	Nil caught
Cascade Ck.	S78/409418																			X
Leo Ck.	S78/424404						X													
Makawhio R. above Greer Ck.	S78/422401 to S78/438389																	X		
Trib. on south bank of Makawhio R.	S78/429392		X				X													
Trib. on south bank of Makawhio R.	S78/426396																			X
Trib. on south bank of Makawhio R.	S78/421399																			X
Greer Ck.	S78/421402																			X
Pond on west side of S.H.6, north of Makawhio R.	S78/391506			X																
Makawhio R. 2 km below cableway	S78/403487						X				X	X		X				X		

APPENDIX II. (Continued)

Makawhio catchment	NZMS 1 map co-ordinates	Lamprey	Long-finned eel	Short-finned eel	Common smelt	Inanga	Koaro	Banded kokopu	Giant kokopu	Short-jawed kokopu	Torrent-fish	Red-finned bully	Common bully	Blue-gilled bully	Black flounder	Kahawai	Yellow-eyed mullet	Brown trout	Quinnat salmon	Nil caught
Makawhio R. at cableway	S78/406470						X				X	X		X				X		
Makawhio R. about 4 km upstream from mouth	S78/379504		X			X						X	X					X		
Small trib. on north bank of Makawhio R.	S78/380506					X			X											
Small lake on plateau between Makewhio R.	S78/380510			X																
and sea*	S78/380510			X																

* Also <u>Galaxias</u> species observed.

APPENDIX II. (Continued)

Lake Kini catchment	NZMS 1 map co-ordinates	Lamprey	Long-finned eel	Short-finned eel	Common smelt	Inanga	Koaro	Banded kokopu	Giant kokopu	Short-jawed kokopu	Torrent-fish	Red-finned bully	Common bully	Blue-gilled bully	Black flounder	Kahawai	Yellow-eyed mullet	Brown trout	Quinnat salmon	Nil caught
Swamp drain north of Bruce Bay at S.H.6	S78/330473		X																	
Lake Kini	S78/343462		X			X						X								
Inlet of Lake Kini	S78/348460										X	X								
Dragline draining Lake Kini	S78/332475		X			X					X	X								

APPENDIX II. (Continued)

Mahitahi catchment	NZMS 1 map co-ordinates	Lamprey	Long-finned eel	Short-finned eel	Common smelt	Inanga	Koaro	Banded kokopu	Giant kokopu	Short-jawed kokopu	Torrent-fish	Red-finned bully	Common bully	Blue-gilled bully	Black flounder	Kahawai	Yellow-eyed mullet	Brown trout	Quinnat salmon	Nil caught
Small trib. of Mahitahi R. south of Bruce Bay, at S.H.6	S78/314452											X								
Flagstaff Ck.	S78/310383						X													
Trib. of Mahitahi R. 6 km north of Doughboy Ck., at S.H.6.	S78/304390		X					X	X			X								
Trib. at base of Douglas Range, east of S.H.6	S78/310383		X																	
Several small streams crossing 4WD track	S78/307389		X			X						X								
Mahitahi R. near mouth	S78/312457												X							

* Also Galaxias species juvenile.

APPENDIX II. (Continued)

Mahitahi catchment	NZMS 1 map co-ordinates	Lamprey	Long-finned eel	Short-finned eel	Common smelt	Inanga	Koaro	Banded kokopu	Giant kokopu	Short-jawed kokopu	Torrent-fish	Red-finned bully	Common bully	Blue-gilled bully	Black flounder	Kahawai	Yellow-eyed mullet	Brown trout	Quinnat salmon	Nil caught
Trib. Mahitahi R. 1 km east S.H.6*	S78/305380						X					X						X		
Trib. on west bank of Mahitahi R., 1 km east of S.H.6	S78/308387										X									
Roadside ditch south of Condon Rd.	S78/312421																			X
Lagoon draining Mahitahi R.	S78/316466		X			X							X							
Trib. of Mahitahi R. flowing into lagoon	S78/318466		X			X			X			X								
Mouth of Mahitahi R.	S78/312461				X						X				X	X	X	X		
Mahitahi R. at Buschs Rd	S78/306427		X								X		X							

* Also freshwater crayfish Paranephrops planifrons.

APPENDIX II. (Continued)

Mahitahi catchment	NZMS 1 map co-ordinates	Lamprey	Long-finned eel	Short-finned eel	Common smelt	Inanga	Koaro	Banded kokopu	Giant kokopu	Short-jawed kokopu	Torrent-fish	Red-finned bully	Common bully	Blue-gilled bully	Black flounder	Kahawai	Yellow-eyed mullet	Brown trout	Quinnat salmon	Nil caught
Creek flowing parallel to Flagstaff Ck.	S78/359408																			X
Creek flowing parallel to Flagstaff Ck.	S78/350411																			X
Makatata Ck. next to Condons Rd.	S78/323422		X			X														
Makatata Ck.	S78/322428		X																	
Makatata Ck.	S78/313445												X							

APPENDIX II. (Continued)

Ohinemaka catchment	NZMS 1 map co-ordinates	Lamprey	Long-finned eel	Short-finned eel	Common smelt	Inanga	Koaro	Banded kokopu	Giant kokopu	Short-jawed kokopu	Torrent-fish	Red-finned bully	Common bully	Blue-gilled bully	Black flounder	Kahawai	Yellow-eyed mullet	Brown trout	Quinnat salmon	Nil caught
Power Ck. 1 km up-stream of its con-fluence with Ohine-maka R.	S78/243432			X		X						X	X							
Power Ck.	S78/235321						X													
Trib. of Power Ck.	S78/243427		X										X					X		
Small trib. of Power Ck. 300 m up-stream of its con-fluence with Ohine-maka R.	S78/245429								X		X	X								
Small trib. of Power Ck.	S78/244430							X												
Lake 2 km south of Heretaniwha Point	S78/273457								X											
Ohinemaka R. near mouth	S78/237431		X										X				X	X		
Ohinemaka R. 2 km up-stream from mouth	S78/246431		X										X					X		

APPENDIX II. (Continued)

Ohinemaka catchment	NZMS 1 map co-ordinates	Lamprey	Long-finned eel	Short-finned eel	Common smelt	Inanga	Koaro	Banded kokopu	Giant kokopu	Short-jawed kokopu	Torrent-fish	Red-finned bully	Common bully	Blue-gilled bully	Black flounder	Kahawai	Yellow-eyed mullet	Brown trout	Quinnat salmon	Nil caught
Ohinemaka R. 3 km up-stream from mouth	S78/251429		X															X		
Ohinemaka R. 10 km up-stream from mouth	S78/265385		X															X		
Micmac.Ck.	S78/252439																			X
Stream draining lake and Pakahi 2 km south of Heretaniwha Point	S78/519574		X																	
Small streams near Doughboy Ck., west of S.H.6	S78/274366																			X
Small trib. of Ohinemaka R.	S78/268361		X			X						X								
Ohinemaka R. 100 m down-stream from its con-fluence with Doughboy Ck.	S78/269372		X															X		

APPENDIX II. (Continued)

Ohinemaka catchment	NZMS 1 map co-ordinates	Lamprey	Long-finned eel	Short-finned eel	Common smelt	Inanga	Koaro	Banded kokopu	Giant kokopu	Short-jawed kokopu	Torrent-fish	Red-finned bully	Common bully	Blue-gilled bully	Black flounder	Kahawai	Yellow-eyed mullet	Brown trout	Quinnat salmon	Nil caught
Trib. of Blackwater Ck. east S.H.6	S78/258347		X					X	X			X								
Blackwater Ck. from 2 km east of S.H.6	S78/268348 to S78/278336						X													
Blackwater Ck. 0.5 km east S.H.6	S78/263349											X						X		
Blackwater Ck. at S.H.6	S78/259350																	X		