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Distribution and biology of freshwater fish in the Clutha River

Fisheries Research Division
Ministry of Agriculture and Fisheries
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by

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FISHERIES ENVIRONMENTAL REPORTS

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1. INTRODUCTION

New Zealand is widely regarded as being well endowed with freshwater resources. A small population and a relative lack of widespread urbanisation and industrialisation have meant an associated lack of large scale pollution problems. Despite this, there are increasing and often conflicting demands for water. In response to both consumptive and non-consumptive demands, a broad national policy and management framework has been embodied in the Water and Soil Conservation Act 1967 and its numerous amendments. Regional water boards have local responsibility for managing and allocating water resources. The first stage in the preparation of a water management or allocation plan is usually the compilation of a resource report documenting the water resources of a catchment and their existing and potential uses. For the Clutha catchment, a preliminary land and water resource inventory was published by the Otago Regional Water Board in 1976 and was followed by the Clutha Catchment Water Allocation Plan (Otago Regional Water Board 1980). The Board is currently preparing a draft management plan for the mainstem of the Clutha River and part of this exercise involves reviewing and updating the 1980 plan. This report is provided in response to a request from the Board for information on freshwater fish stocks and their habitats in the Clutha catchment.

Under the Fisheries Act 1983, the Ministry of Agriculture and Fisheries (MAF) has overall responsibility for the management of freshwater fisheries. However, the management of recreational fisheries has been delegated regionally to 22 acclimatisation societies and 2 wildlife conservancies of the Department of Internal Affairs. The

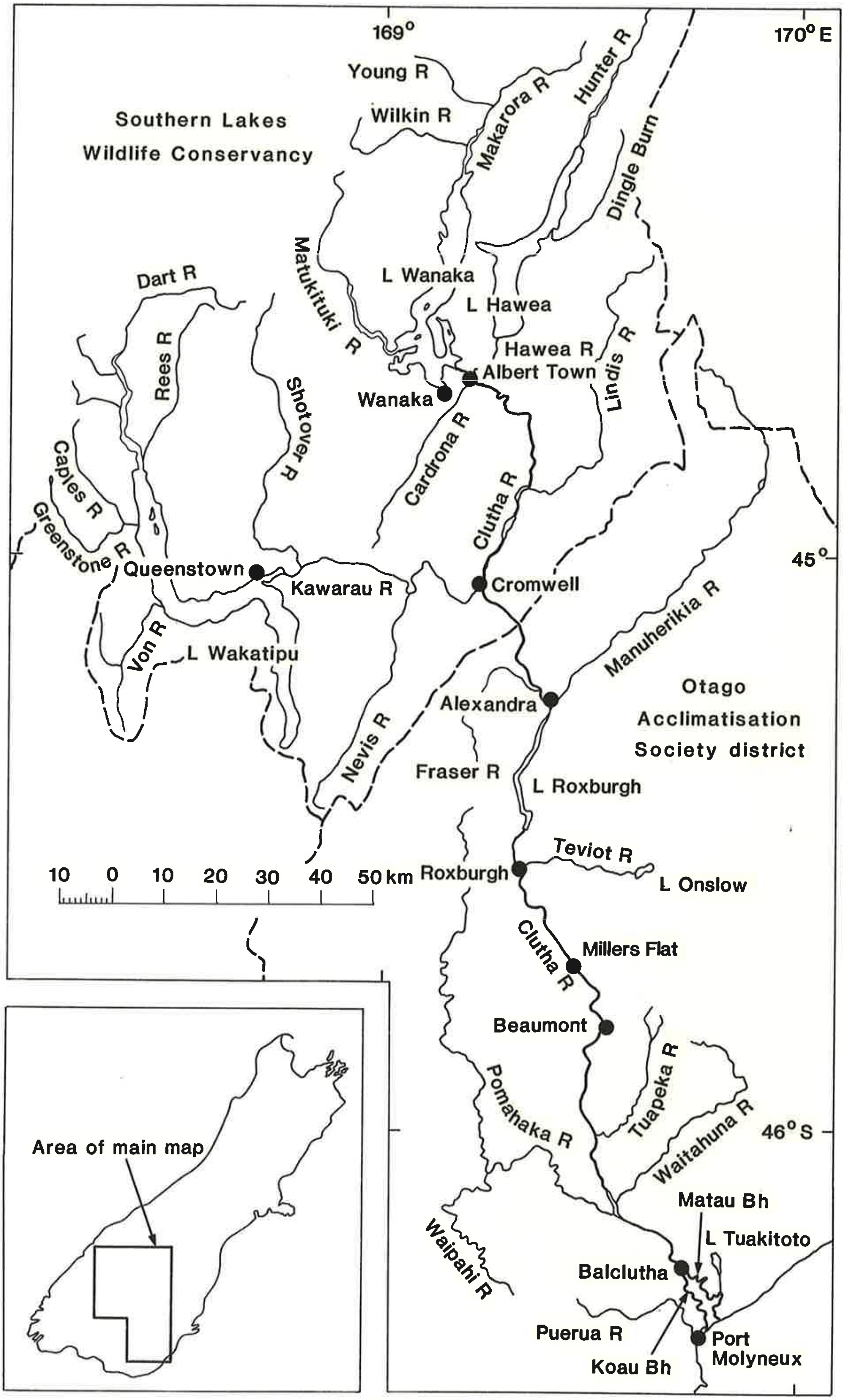

FIGURE 1. The Clutha River catchment.

Clutha catchment is jointly administered by two agencies - the Otago Acclimatisation Society and the Department of Internal Affairs (Southern Lakes Wildlife Conservancy). The geographic boundary between these agencies is approximately midway between Alexandra and Cromwell (Fig. 1).

2. CATCHMENT DESCRIPTION

The Clutha River has the largest catchment (21 390 km^2) and the largest mean annual discharge (533 m^3/s) of all New Zealand rivers. Its catchment arises on the eastern side of the Southern Alps (maximum elevation 3207 m) and the river flows for 322 km in a south-east direction to enter the sea below Balclutha. There are three distinct regions within the catchment: an alpine-subalpine region west and north of the three source lakes, a central area of block mountains of moderate altitude (maximum height 1200-2000 m) with arid valleys and gorges and limited areas of fertile terraces and fans, and a coastal zone of rolling and flat country which includes the delta area east of Balclutha. About 43% of the catchment is higher than 1000 m and this area provides most of the seasonal snowmelt during spring and early summer (Murray 1975).

The hydrology of the catchment is dominated by the contribution of three large alpine lakes, Wakatipu (293 km^2), Wanaka (192 km^2), and Hawea (119 km^2), which have mean annual discharges of 156 m^3/s, 190 m^3/s, and 63 m^3/s respectively (Jowett and Thompson 1977). Collectively these flows account for 75% of the river's flow at Balclutha (Murray 1975). Mean annual flows from other significant tributaries are: Shotover River 38 m^3/s, Nevis River 10.1 m^3/s, Lindis River 6.2 m^3/s, Manuherikia River 12.7 m^3/s, and Pomahaka River (at Burkes Ford) 23.2 m^3/s (Jowett and Thompson 1977). The Clutha River has a mean annual flow of 492 m^3/s at Roxburgh; thus downstream tributaries contribute only a further 41 m^3/s, more than half of which comes from the Pomahaka.

Despite the buffering effect of the three high country lakes, warm north-west winds in spring can cause rapid snowmelt and flooding. In 1878 such conditions caused the Clutha's largest recorded flood, which peaked at 5700 m^3/s, lasted for three weeks, and caused the Matau and Koau branches (below Balclutha) to discharge through separate mouths where formerly they shared a single outlet (Poole 1983). A flood of 2000 m^3/s at Roxburgh has a return period of 15 years, and the probable maximum flood at this site is estimated at 7836 m^3/s (Jowett and Thompson 1977).

The quality of water at the outlets of the three source lakes is very high. Although early observers recorded the Clutha as running clear (Ministry of Works and Development 1977), today water clarity below the confluence with the Kawarau River is reduced by high levels of suspended solids carried by the Shotover River. The Shotover drains through soft schist country which has been extensively modified by gold mining operations. At present an estimated 2.9 million tonnes of sediment is transported annually into Lake Roxburgh, and 62% of this is deposited in the lake (Ministry of Works and Development 1977). This has resulted in a loss of 35% of the lake volume in 20 years (Commission for the Environment 1980). Substantial amounts of fine sediment do not settle out in either Lake Roxburgh or in areas downstream from it (Otago Regional Water Board 1980) and, even with the construction of Clyde Dam upstream, it is still predicted that "the finer fraction ... should substantially pass through Roxburgh with little settlement" (Ministry of Works and Development 1977). Accordingly, it seems likely that little improvement in the clarity of water downstream of Roxburgh can be expected in future.

Present patterns of land use in the Clutha catchment have evolved over 125 years, mainly by trial and error (Otago Regional Water Board 1980). Initially, settlement took place in the fertile lower reaches, but during the 1850s large sheep stations were established in the upper and middle reaches. Periodic burning of tussock country to control scrub and weeds, and overgrazing by sheep and rabbits, has led to severe soil erosion in some areas of the middle catchment. Mining for alluvial gold by sluicing and dredging has resulted in deposits of unconsolidated overburden, though sediment from most of these deposits does not have access to water courses (Otago Regional Water Board 1980). Pastoral use is still the predominant land use in the catchment, with most intensive farming being done on the productive river flat soils of the lower reaches of the catchment. The central catchment is important for fruit growing, but irrigation is required to compensate for low rainfall. Exotic forest is established near Beaumont.

The catchment is extensively used for a variety of recreational pursuits. Mount Aspiring National Park, in the headwaters of Lakes Wakatipu and Wanaka, provides sightseeing, climbing, tramping, shooting, and fishing, and sightseeing, fishing, and water skiing are popular on all the lakes. Queenstown is the main tourist resort in the South Island, servicing water-based recreational activities in summer and skiing in winter. The main river is extensively used for angling, especially the reach from the Lake Wanaka outlet to Albert Town (Department of Internal Affairs 1981) and below Balclutha (Fisheries Research Division (FRD) unpublished data). Other water-based recreation includes swimming, canoeing, jet boating, rafting, and waterfowl shooting. Apart from recreation, the other major non-consumptive use of water is for hydro-electric power generation. Consumptive use of water is mainly for irrigation, with smaller quantities being used in frost-fighting, mining, and rural and industrial supply.

3. DATA SOURCES

The main source of information on fish distribution for this report, was FRD's Freshwater Fish Survey (McDowall and Richardson 1983). This is a computer based system for the storage and retrieval of field data on freshwater fish. Various fisheries field workers, including staff from FRD, acclimatisation societies, Wildlife Service, catchment authorities, and universities, and interested individuals, have been issued with books of field cards. The observer fills in a card and sends a carbon copy to FRD for storage. By May 1983, the scheme contained over 4000 entries. Retrieval of data for the Clutha catchment has provided 731 entries (an entry being a record of an individual species at an individual location). The location of sampling sites is shown in Figure 2.

It should be noted that the location maps where individual fish species have been recorded (Figs. 3-7) have been compiled from only the Freshwater Fish Survey data. Some additional information on fish distribution is contained in the text. For acclimatised fish, much of this additional information has come from Graynoth (1974) and Turner (1983).

Major tributaries and lakes are given in Figure 1. Several smaller lakes and impoundments are referred to in the text and map references

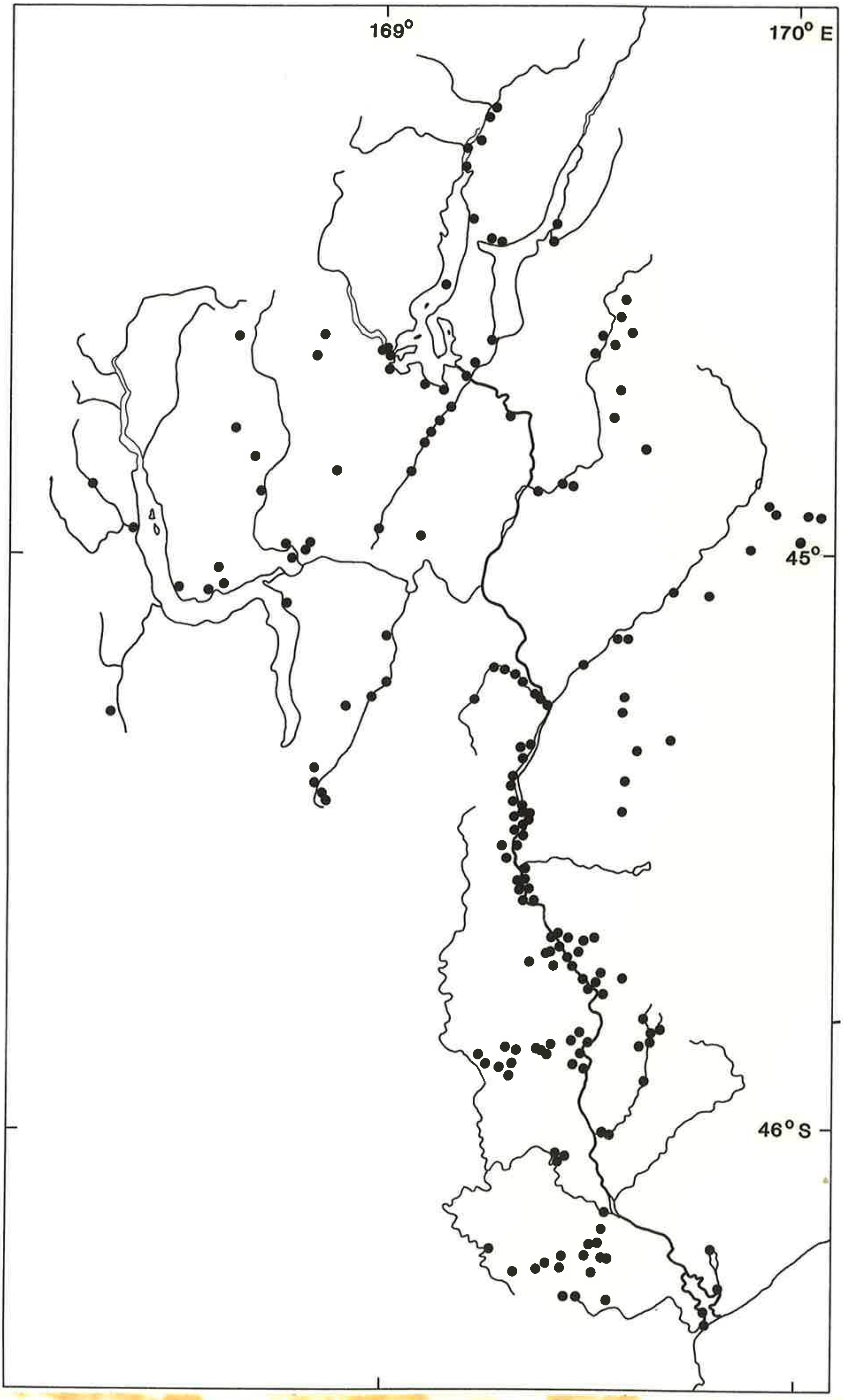

FIGURE 2. **Locations of sampling sites in the Clutha catchment recorded on FRD's Freshwater Fish Survey.**

for these are given in Appendix 1. Similarly map references for rivers and streams mentioned in the text are given in Appendix II. The co-ordinates given refer to the NZMS 1 Topographical Map series and are prefixed by the sheet number of the appropriate map.

4. FISH STOCKS: DISTRIBUTION AND BIOLOGY

4.1 Native Species

Thirteen native species have been recorded in the Clutha River catchment (Table 1). Only two species (common river galaxias and upland bully) carry out their entire life history in fresh water, though the koaro and common bully have both migratory and non-migratory (lake resident) stocks. The remaining nine species undergo migrations, either into or out of fresh water, at some stage during their life histories.

4.1.1 Lamprey (*Geotria australis*)

Two adult lampreys have been recorded in the catchment, both from Canadian Stream (Fig. 3). Presumably spawning takes place in this and other similar tributaries below Roxburgh. In addition, juvenile lampreys (ammocoetes) have been found in a muddy backwater near Millers Flat. Adults parasitise large marine fish, but enter fresh water during winter and spring to spawn. At this stage they measure 450-500 mm in length. Juveniles remain in fresh water for 3-4 years, but are seldom seen because they stay buried in the substrate in silty backwaters.

TABLE 1: Fish species recorded from the Clutha River catchment.

	Migratory			
	Freshwater to spawn (anadromous)	Saltwater to spawn	Juveniles to saltwater	Non-migratory
Native Species				
Lamprey	✓			
Short-finned eel		✓		
Long-finned eel		✓		
Common smelt*	✓			✓
Giant kokopu			✓	
Koaro*			✓	✓
Common river galaxias				✓
Inanga			✓	
Torrentfish			✓	
Blue-gilled bully			✓	
Common bully*			✓	✓
Upland bully				✓
Black flounder	✓			
Introduced Species				
Brown trout*				✓
Rainbow trout				✓
Brook char				✓
Splake				✓
Quinnat salmon*	✓			✓
Perch				✓

*These species have both migratory and non-migratory forms.

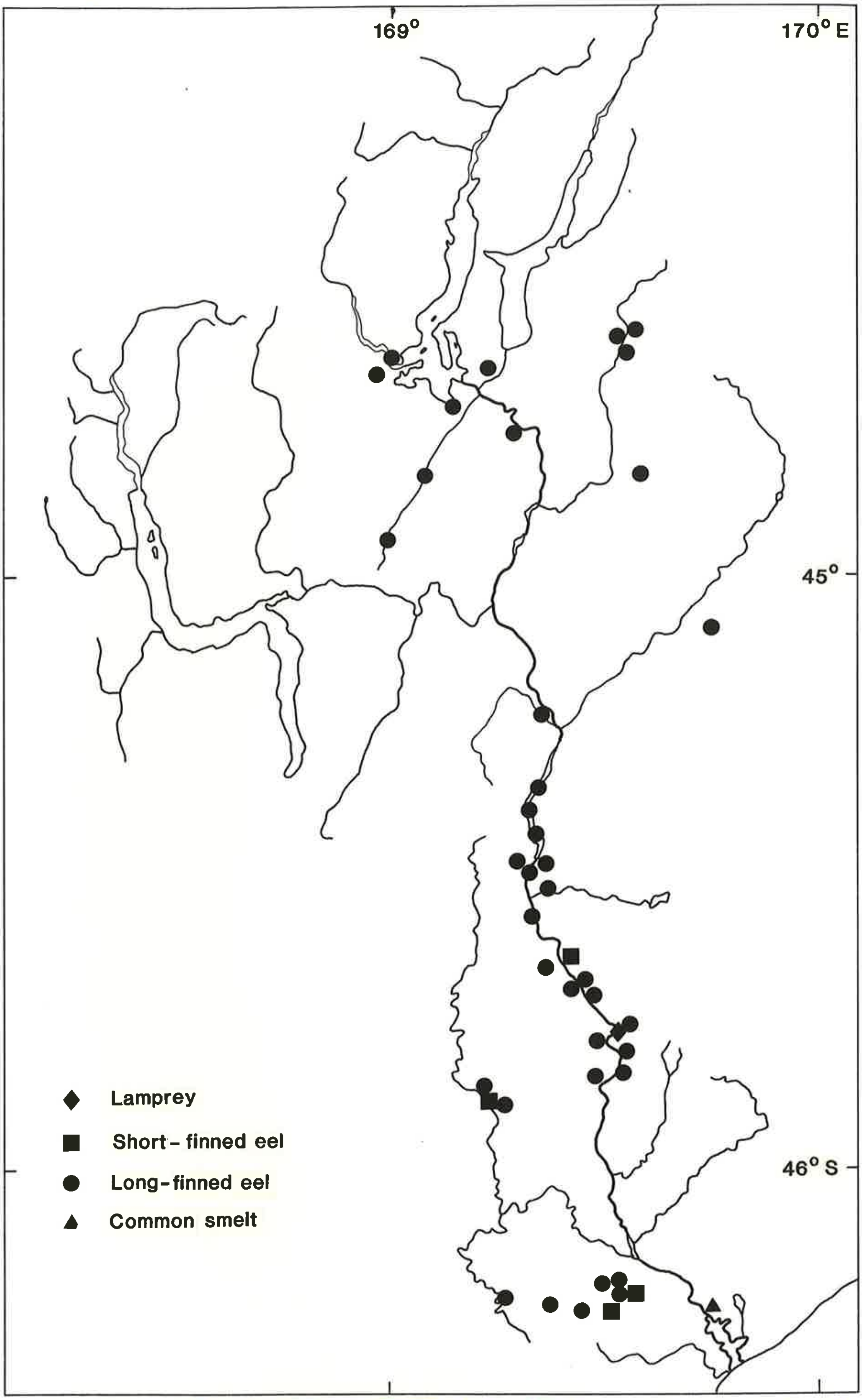

FIGURE 3. Sampling sites from which lamprey (*Geotria australis*), short-finned eel (*Anguilla australis*), long-finned eel (*Anguilla dieffenbachii*), and common smelt (*Retropinna retropinna*) have been recorded.

4.1.2 Short-finned Eel (*Anguilla australis*)

The short-finned eel has been recorded from the Kaihiku Stream and Tima Burn (Fig. 3). No doubt this species is fairly common in the lower reaches of the main river because it has a preference for sluggish, muddy waters. It also inhabits coastal swamps and lagoons, is known from Lake Tuakitoto, and is probably also found in the wetlands associated with the lower Puerua River. Short-finned eels do not penetrate far inland, though Jellyman (1977) reported two individuals among a sample of elvers collected from Roxburgh Dam. Exceptional specimens may exceed 1 m in length and, as with long-finned eels, females grow to a larger size than males.

Both species of eel have similar life histories. Adults migrate to sea during late summer and early autumn, but the spawning grounds are unknown. They are thought to be in the south-west Pacific Ocean, probably east of Fiji (Jellyman and Todd 1982). Larval eels which arrive off the coast of New Zealand metamorphose into "glass eels" before they ascend rivers in early spring. Each summer large numbers of juvenile eels (elvers) migrate further upstream in search of suitable habitat. These migrations are best known from areas where natural obstacles (for example, waterfalls) or man-made structures (for example, hydro dams) impede upstream movement.

4.1.3 Long-finned Eel (*Anguilla dieffenbachii*)

The long-finned eel is widespread throughout the Clutha system (Fig. 3). It occurs in the main river, tributaries, and source lakes. This species prefers clear-flowing, stoney waterways and has the ability to penetrate well inland. Hence it is the eel species found in South Island high country lakes, where it is frequently fished for commercially (Jellyman and Todd 1980). It has been estimated that the annual catch from Lakes Wakatipu, Hawea, and Wanaka is 40 t (Department of Internal Affairs 1981). A smaller fishery exists in Lake Roxburgh and from Roxburgh Dam to the sea. Annual catches for this part of the river are thought to be 4-5 t (FRD unpublished data).

4.1.4 Common Smelt (*Retropinna retropinna*)

There is only one record of common smelt from the Clutha catchment, from near Balclutha (Fig. 3), but smelt are known to occur in Lakes Tuakitoto, Wanaka, and Hawea. This species is seasonally abundant in the lower river; McDowall (1978) mentioned that "great shoals [of juvenile smelt] swim into rivers, like the Waikato, Manawatu, Clutha ...".

Smelt have been introduced into a large number of inland lakes, especially in the North Island, but there is no known record of their introduction to the Clutha lakes. Although not regarded as strong upstream migrants, adult smelt are occasionally found considerable distances from the sea. Therefore, it is likely that smelt in Lakes Hawea and Wanaka (Hutchinson 1974) are self-introduced; these populations are entirely lake-dwelling and do not require access to the sea.

Adult smelt (also known as cucumber fish because of their characteristic odour) between 80 and 100 mm long, migrate from the sea into fresh water to spawn from early spring until autumn. Although the spawning site is unknown it is thought to be in or near estuaries, where eggs are released and sink into the substrate (McDowall 1978). On hatching the larvae are swept out to sea and return about a year later as small fish 45-60 mm long. At this stage they form large shoals and are frequently taken by whitebaiters in the lower reaches of large rivers like the Clutha. Apparently most of these fish move back into the sea before returning to fresh water to spawn.

4.1.5 Giant Kokopu (*Galaxias argenteus*)

The giant kokopu commonly grows to 400 mm and is the largest of the galaxiid (whitebait) species. Its preferred habitat is slow flowing waters in swamps, lowland creeks, and lakes, but always where there is abundant cover (McDowall 1978). In the Clutha system these fish have been recorded from Lake Kaitangata (since drained), Lake Tuakitoto, and the lower Pomahaka River (Fig. 4). As they frequent similar habitats to the short-finned eel, they are sometimes encountered by eel fishermen. However, they are now regarded as one of our rare native species, largely because of a loss of habitat resulting from swamp drainage and pastoral development.

Juveniles of the giant kokopu occur in the whitebait catch. McDowall (1965) recorded that the "kokopu species" (*Galaxias argenteus*, *G. fasciatus*, and *G. postvectis*) made up 2% of the whitebait in Clutha River samples - the highest percentage found for South Island east coast rivers. On average the kokopu species comprised 0.4% of the whitebait in these rivers.

4.1.6 Koaro (*Galaxias brevipinnis*)

The koaro has a very widespread distribution in the Clutha catchment, having been recorded from Balclutha, in tributaries from Ettrick Stream to Beaumont River, and in the three source lakes and their tributaries (Fig. 4). In the upper Clutha area this species has

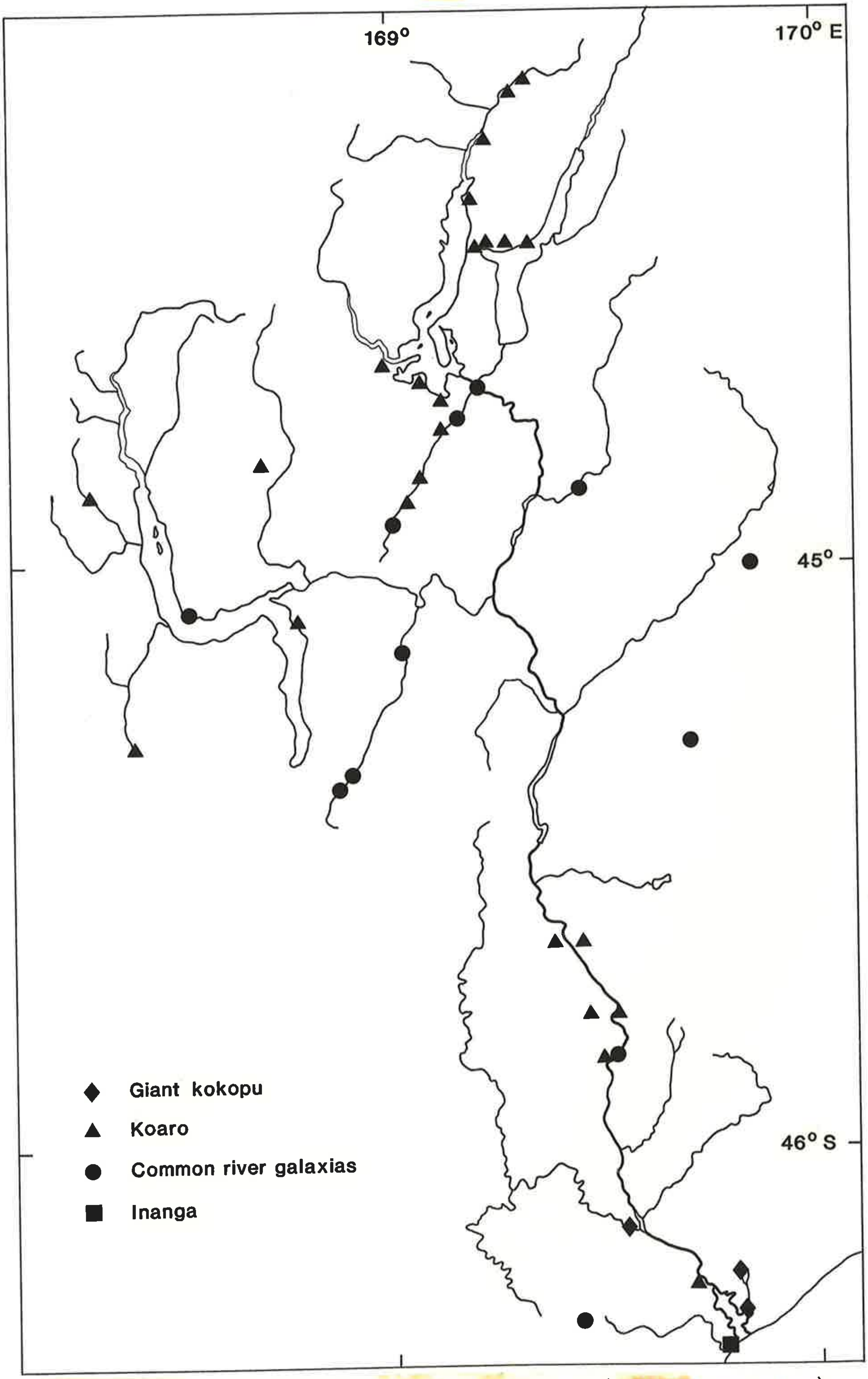

FIGURE 4. Sampling sites at which giant kokopu (*Galaxias argenteus*), koaro (*Galaxias brevipinnis*), common river galaxias (*Galaxias vulgaris*), and inanga (*Galaxias maculatus*) have been recorded.

been described as "relatively common" (Department of Internal Affairs 1981), but downstream of Roxburgh koaro are uncommon (FRD unpublished data).

Adults of diadromous populations breed in autumn or early winter, probably in their adult habitat. It is presumed that the larvae are swept out to sea and return as whitebait during early spring (McDowall 1978). In a sample of Clutha River whitebait, McDowall (1965) found 8.5% were koaro. Juveniles have considerable climbing ability and are able to wriggle their way up damp, vertical, rock faces and populate areas above waterfalls.

Lake-dwelling populations have a similar life history pattern. Adults live in tributary streams and rivers, probably spawning there, and the larvae are washed into the lake. Larvae use the lake water in a manner similar to which anadromous stocks use the sea; shoals of whitebait migrate into river mouths in spring. McDowall (1978) recorded that large migrations of whitebait used to occur from Lake Wanaka into the Matukituki River, where they were caught by traditional whitebaiting methods. However, this fishery is no longer permitted.

4.1.7 Common River Galaxias (*Galaxias vulgaris*)

This species is the most common and widespread galaxiid in Otago and Canterbury rivers (McDowall 1978). In the Clutha catchment it is principally an upstream species, being recorded from the major tributary rivers below the source lakes (Fig. 4). Schools of juveniles have been recorded in sheltered backwaters in the main river upstream of Alexandra, which indicates that the species is reasonably common in this area (Department of Internal Affairs 1981).

Unlike the koaro, the common river galaxias does not migrate to sea. Adults reach 150 mm and live in moderately swift rivers, where they spawn in late winter and spring. The larvae are usually swept downstream and seek out quiet backwaters and shallows. Here they grow to about 30 mm before moving back into the faster-flowing adult habitat (McDowall 1978).

4.1.8 Inanga (*Galaxias maculatus*)

Juveniles of this species are the principal component of the whitebait catch in almost all New Zealand rivers (McDowall 1978). In the Clutha catchment they have been recorded only from the vicinity of Port Molyneux and Lake Tuakitoto (Fig. 4), but they undoubtedly exist in large numbers in tidal areas below Balclutha. Data from McDowall (1965) indicate that *G. maculatus* (formerly *G. attenuatus*) juveniles comprised 89.5% of Clutha River whitebait - this is somewhat less than the average figure of 98.5% for all Canterbury and Otago rivers sampled because of the relatively high proportions of koaro and kokopu species in the Clutha samples.

The inanga has a life history precisely adapted to tidal cycles. Spawning is mainly in autumn and adult fish (up to 150 mm) migrate downstream from lower river areas (beyond sea water influence) into estuarine areas. These migrations occur on full and new moon phases and enable the inanga to take advantage of high spring tides to deposit eggs among grasses and rushes on the river bank. The eggs, though exposed to the air, are kept from drying out by the moisture of the grass and substrate. They hatch 2 weeks later, on the next spring tide. The larvae are washed out to sea where they remain for about 6 months before returning, during late winter and spring, as the familiar whitebait. After a year in fresh water most inanga mature and spawn, though some may delay spawning for a further year.

4.1.9 Torrentfish (*Cheimarrichthys fosteri*)

Torrentfish have been recorded from Blackleugh Burn, Carsons Stream, and Tima Burn (Fig. 5). Their habit of living in the tumbling, broken water of streams and rivers means that they are seldom seen. As this species requires access to the sea for part of its life history, there will be no populations above Roxburgh Dam, though it would be possible for individuals to reach Roxburgh since this species has penetrated over 70 km up the Rakaia River (Davis *et al.* 1983). However, the specialised habitat requirements of torrentfish are not found in the main river channel of the Clutha (partly because of the incised nature of the river channel and also the fluctuating flows from Roxburgh Dam), and so populations will be confined to fast tumbling sections of the lower tributary streams.

Adults seldom exceed 150 mm. Although the biology is not completely known, it is assumed that the larvae go to sea. Juveniles, 23-30 mm long, have been recorded entering fresh water during spring and autumn (Eldon and Greager 1983).

4.1.10 Blue-gilled Bully (*Gobiomorphus hubbsi*)

This bully is the smallest of the six New Zealand species and rarely exceeds 80 mm in length. In the Clutha catchment it has been recorded only from Tima and Benger Burns (Fig. 5). It lives among rocks and boulders of fast flowing streams, in very similar habitat to the torrentfish. Like the torrentfish, the larvae go to sea and juveniles return to fresh water in spring and autumn (Eldon and Greager 1983).

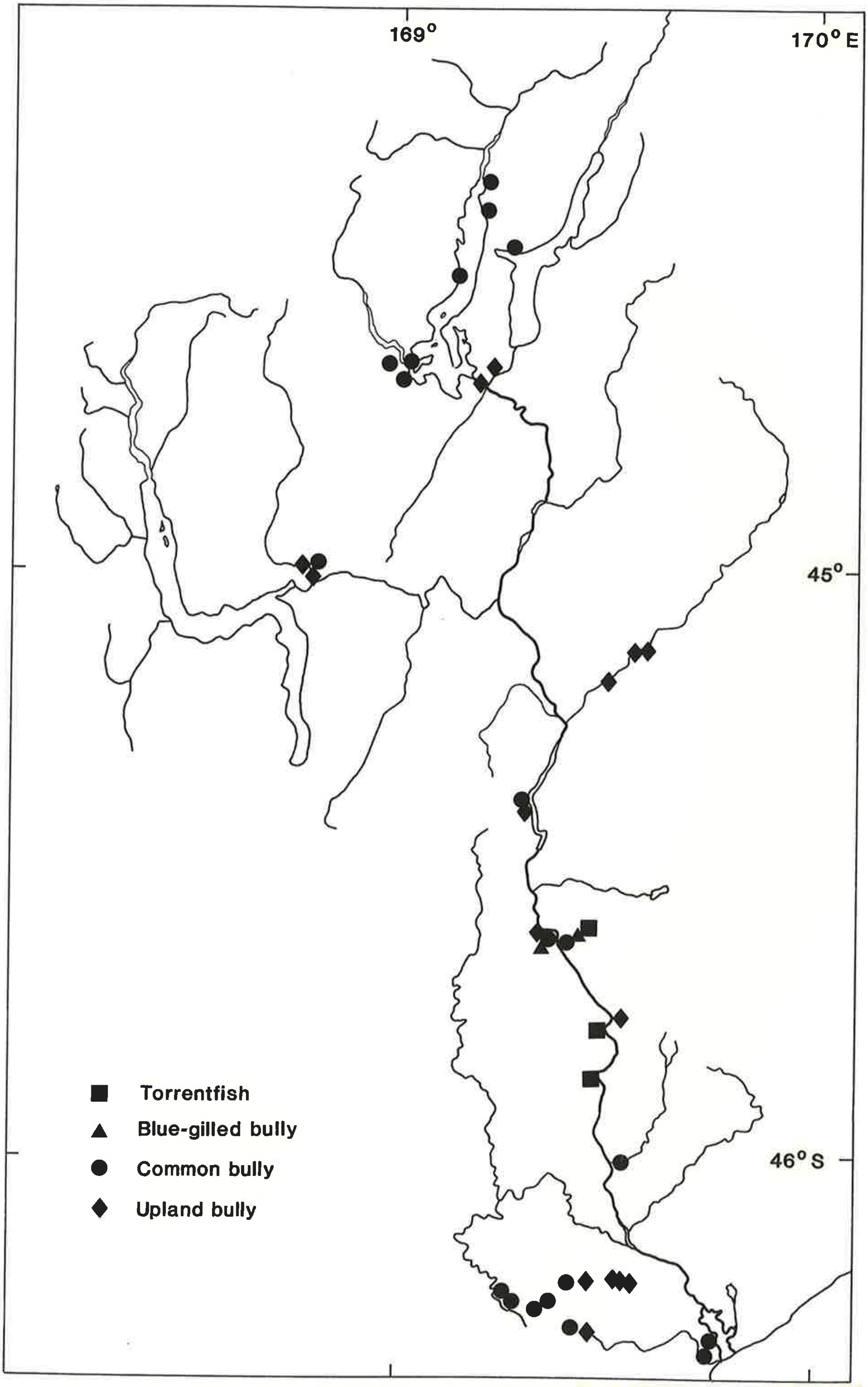

FIGURE 5. Sampling sites at which torrentfish (*Cheimarrichthys fosteri*), blue-gilled bully (*Gobiomorphus hubbsi*), common bully (*Gobiomorphus cotidianus*), and upland bully (*Gobiomorphus breviceps*) have been recorded.

McDowall (1978) stated that this species does not penetrate far upstream, mostly less than 10-15 km. In the Rakaia River it has been found 70 km inland, but is described as rare beyond 50 km (Davis *et al.* 1983). The Clutha locations represent the most inland records to date. Like the torrentfish, the blue-gilled bully is unlikely to be a common species in the Clutha catchment, because of the lack of suitable habitat in downstream tributaries.

4.1.11 Common Bully (*Gobiomorphus cotidianus*)

This is the most widespread bully in New Zealand, and, because it is the least secretive of the bullies, it is also the most widely seen. The species forms both sea-going and lake-dwelling populations, and both population types are represented in the Clutha system. Sea-going populations occur in the main river tributaries downstream of Roxburgh Dam (Fig. 5), and there are lake-dwelling populations in the Manorburn and Greenland Reservoirs, Lake Onslow, Lake Roxburgh, Lake Hayes, Diamond Lake (Wanaka), Lake Hawea, Lake Wanaka, and probably Lake Wakatipu and associated smaller lakes. Above Roxburgh Dam the common bully is closely associated with the large lakes and the lower reaches of lake tributaries. It would not be expected in the tributary rivers between those lakes and Lake Roxburgh.

In rivers, the common bully normally hides among marginal cover, but in lakes it is frequently seen in large numbers on open shorelines. Spawning occurs in rivers in spring and summer and the newly hatched larvae go to sea where they grow to 15-20 mm in length before returning later in spring and summer (McDowall 1978). In lakes, the larvae frequently move well offshore to the mid and surface waters. At a length of about 10 mm they become bottom dwelling and move to inshore shallows. Larger adults, up to 80 mm, tend to be found in deeper water.

4.1.12 Upland Bully (*Gobiomorphus breviceps*)

Principally a South Island species, the upland bully is probably the most common and widespread bully in the South Island. The common name is misleading because the fish is frequently found at low altitudes (McDowall 1978). This is so in the Clutha catchment, where it has been recorded from downstream tributaries of the Pomahaka River (Fig. 5). It has also been found in Low Burn, Benger Burn, Elbow Creek (Lake Roxburgh), the lower Manuherikia River and tributaries, the lower Lindis and Shotover Rivers, and tributaries of the upper Clutha River.

Adults grow to 100 mm and live in a variety of habitats. Although mainly a species of gently flowing rivers, it also occurs in swift streams and upland lakes. So far it has not been recorded from any of the Clutha high country lakes, though it is very likely to be in some of these. The species does not require access to the sea, the life history being carried out entirely in the adult habitat. Juveniles initially dwell in surface and mid waters before they adopt the bottom-living mode of life of adults.

4.1.13 Black Flounder (*Rhombosolea retiaria*)

This flounder is regarded as a true freshwater species, even though its entire life cycle is not spent in fresh water (McDowall 1978). It is common in inshore marine areas and river estuaries throughout New Zealand. In rivers it penetrates at least 60-70 km inland, even negotiating quite swift rapids. In the Clutha it is known from the lower Pomahaka River (Turner 1983), the Tuapeka River (C. Hardy, FRD, pers. comm.), and it is no doubt common below Balclutha.

Nothing is known about the breeding of black flounder, but it probably takes place at sea. The larvae initially swim in a normal upright position before the left eye migrates across the snout to the right side. At this stage the juvenile fish take up life on the bottom. Juveniles enter river mouths in spring and many probably continue to move freely between estuarine and inshore sea areas as they grow.

4.1.14 Other Possible Species

It is probable that the now extinct grayling (*Prototroctes oxyrhynchus*) once occurred in the lower Clutha river. Although previously abundant in the lower reaches of rivers throughout the country, this species is thought to have become extinct in the 1930s, probably through the combined impacts of habitat disruption and the introduction of trout (McDowall 1978).

Although Stokell's smelt (*Stockellia anisodon*) has not been recorded from the lower Clutha, it almost certainly occurs there, as it has been found from the Waimakariri River in Canterbury to the Waiua River in Southland (McDowall 1978).

Graham (1953) recorded the banded kokopu (*Galaxias fasciatus*) from "around Lake Wakatipu". However, as this is a sea-going species and currently there are no confirmed populations further than about 40 km inland, it is more likely that Graham was mistakenly referring to koaro.

The alpine galaxias (*Galaxias paucispondylus*) is known from alpine streams in Canterbury and the upper Oreti River in Southland. McDowall (1978) suggested that further populations would be found in the alpine streams of central South Island areas. Accordingly, it is possible that this species will occur in the alpine tributaries of the three source lakes of the Clutha.

Although not recorded so far, it is also probable that small numbers of the giant bully (*Gobiomorphus gobioides*) and the red-finned bully (*G.*

huttoni) occur in the lower river. Both species are widespread throughout New Zealand, but the giant bully is confined to estuaries, whereas the red-finned bully penetrates further upstream.

A variety of marine species also periodically venture into the lower reaches of rivers. For instance, Eldon and Greager (1983) gave a list of 50 fish species recorded from Canterbury estuaries (Rakaia Lagoon, Lake Ellesmere, Avon-Heathcote Estuary). Species that could be expected to occur in the lower reaches of the Clutha include yellow-eyed mullet (*Aldrichetta forsteri*), kahawai (*Arripis trutta*), various flounders (*Rhombosolea* spp.), stargazers (*Leptoscopus macropygus*, *Crapatalus novaezelandiae*), red cod (*Pseudophycis bachus*), sprat (*Sprattus antipodum*), and cockabully (*Tripterygion nigripenne*).

4.2 Introduced Species

Early European settlers regarded the New Zealand freshwater fish fauna as sparse and lacking the species they were used to catching. Accordingly, acclimatisation societies were organised to introduce various exotic animal species, including fish, into New Zealand. Six introduced fish species (including one hybrid) have been established in the Clutha catchment, and a further two species were introduced, but did not become established. In addition, the Department of Internal Affairs hatchery at Wanaka has brood stocks of another introduced species (lake char).

4.2.1 Brown Trout (*Salmo trutta*)

Liberations of brown trout were made into the lower Clutha River during the late 1860s and early 1870s (Hutchinson 1980). The fish apparently established readily and spread widely, to become firmly established in Lake Wanaka by 1885. Today brown trout are the most commonly encountered fish in the Clutha catchment. Of the 731 Clutha catchment entries in the Freshwater Fish Survey computer file, 311 (43%) are for brown trout. This species occurs throughout the main river, tributary rivers and streams, and lakes. Probably the only waters where it does not occur are those where natural obstacles have prevented its upstream passage. Brown trout have proved to be an extremely adaptable species capable of growing rapidly to a large size when food and space are abundant - as was the situation when they initially colonised new areas. For instance, Spackman (1892) recorded that a 28 lb (12.7 kg) brown trout was poached from Butel Creek, Lake Hayes, in 1882. Since fish were stocked there in only 1874, this represented an average annual growth rate of 3½ lbs (1.6 kg). He also recorded a 28-lb fish from Lake Wakatipu and stated that trout there "are exceedingly fat and lazy, and, on account of the clearness of the water and abundance of food, are difficult to catch with rod and line". Less plausible reports are contained in Thomson (1922) who quoted from the 1883 annual report of the Otago Acclimatisation Society: "One taken in Lake Hayes, said to have been 60 lbs in weight; two seen in the Clutha River, below the mouth of the Lindis, estimated at 80 lbs each .... As no *Salmo fario* [brown trout] over 30 lbs seems ever to have been taken in English waters, the above weights must be received with caution".

More recently, the increase in area of Lake Onslow from 367 to 834 ha (resulting from the installation of a new dam at the outlet) has meant a substantially increased food supply for trout in that lake. As a consequence the average size of fish has increased from 35 to 46 cm (Tonkin 1983), though this can be expected to decrease in future years as the fishery stabilises. In small waterways trout grow more slowly and reach maturity at a much smaller size. For instance, the average size of 102 angler-caught trout in the Teviot River which drains Lake Onslow was 18.3 cm (Boud and Cunningham n.d. (a)).

In New Zealand, brown trout are primarily river-dwelling, though substantial populations also occur in lakes (McDowall 1978). With rainbow trout (*S. gairdnerii*) they form the basis of a very important recreational fishery. Brown trout predominate over rainbow trout both in the upper Clutha River (Graynoth 1971, Department of Internal Affairs 1981), and in the lower Clutha River (where Graynoth (1974) estimated they constituted 98% of anglers' catches). They also predominate in Lakes Wakatipu and Wanaka (Graynoth 1971). In the smaller lakes, for example, Lake Onslow, Lake Rere, Lake Hayes, Moke Lake, Lake McKellar and Lake Sylvan brown trout only are found, but they occur with other salmonids in Butchers Dam, Diamond Lake, and Lake Roxburgh. Several smaller dam impoundments contain only brown trout; for example, Malones Dam, Phoenix Dam, Gabriels Gully Dam, Fraser Dam, Conroys Dam, Lanes Dam, Poolburn Reservoir, and Falls Dam. Brown trout have been liberated in the past in a number of small unnamed irrigation ponds in the central catchment region.

In addition to freshwater resident stocks, there are also sea-going stocks of brown trout in the river below Roxburgh Dam. The Pomahaka River is well known to anglers for the sea-run trout which migrate upstream during December-March to spawn in the upper reaches. Large sea-run trout also migrate up the Clutha to as far as Roxburgh Dam, where many are caught by anglers. Many trout live in the lower reaches of the river and probably move freely between river and sea to take advantage of seasonal migrations of juvenile smelt, whitebait, bullies, etc. for food.

Regardless of where they live, brown trout spawn in fresh water. Upstream spawning migrations take place in autumn, and spawning occurs in tributary streams during May and June. Eggs are laid in shallow "nests" (redds) in clean gravel. Newly hatched juveniles (fry) remain in the redd for several weeks - at this stage both fry and eggs are vulnerable to suffocation by silt deposition or dislodgement by floods. On emerging from the redd, juvenile trout take up residence in the shallow waters of streams or river margins. As they grow they seek progressively larger pools, where a social hierarchy is established in which the largest fish dominate.

4.2.2 Rainbow Trout (*Salmo gairdnerii*)

The first rainbow trout were liberated into the Clutha River in 1895 when 1500 fish were released into the Waipahi River (Thomson 1922). Regular stocking of various waters has continued since.

The Pembroke Hatchery was established at Lake Wanaka in the early 1900s, and large numbers of rainbow trout were released into Wanaka and other lakes. For instance, Hutchinson (1980) recorded that 1.25 million rainbow fry were liberated during 1935 alone, and from 1954 to 1970, 5.3 million rainbow fry were liberated into Lake Wanaka. As with brown trout, the rainbow trout initially grew rapidly and attained a large size. Thomson (1922) recorded a 2-year-old fish of 10 lbs (4.5 kg) from Lake Hawea.

In the Clutha catchment rainbow trout are not as widespread as brown trout (Fig. 6). A few rainbows are caught below Roxburgh dam and in Lake Roxburgh itself, but mostly they are confined to the source lakes and their tributaries. Graynoth (1971) recorded rainbows as the dominant salmonid in Lake Hawea, and both its major tributaries, the Hunter River and Dingle Burn, are noted rainbow fisheries. Rainbows comprise about one-third of the fish caught in Lake Wakatipu (Graynoth 1971) and both the Greenstone and Caples Rivers are important angling

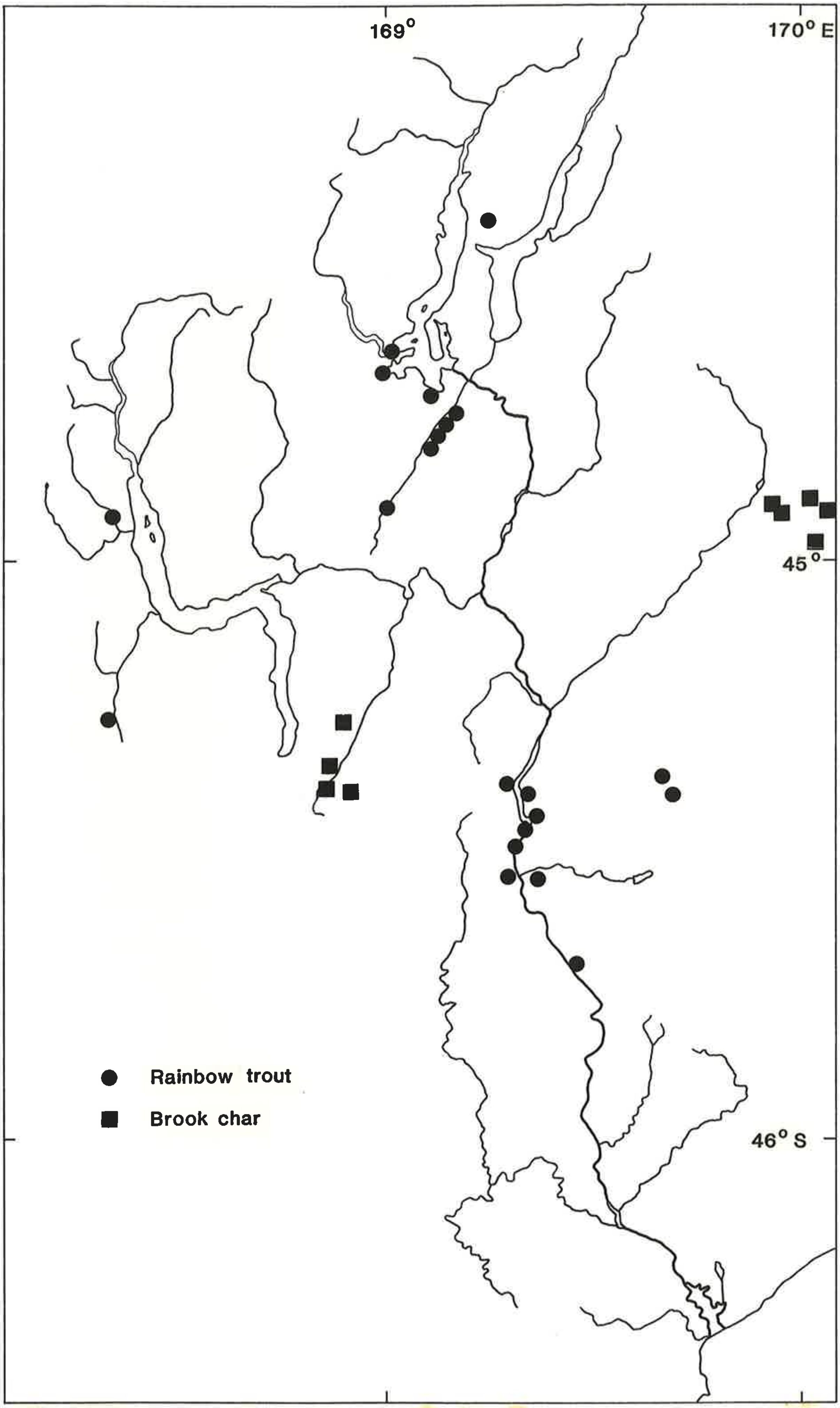

FIGURE 6. Sampling sites from which rainbow trout (*Salmo gairdnerii*), and brook char (*Salvelinus fontinalis*) have been recorded.

and spawning rivers. Similarly the main tributaries of Lake Wanaka (Makarora, Wilkin, Young, and Matukituki Rivers) hold significant rainbow stocks, especially in the upper reaches. Some of the smaller lakes contain rainbows; for example, Diamond Lake, Lake Von, and Butchers Dam, and the upper Manorburn Reservoir contains rainbows only. In recent years Lake Johnson was managed as an experimental rainbow fishery, but the fish are now no longer stocked there. Although they were liberated in Lake Onslow (Thomson 1922), and some releases were made in Pinders Pond, rainbows have since disappeared from these lakes. Similarly, a population in a small impoundment on Minzion Burn is thought to have escaped when the dam was washed out in 1978 (C. Tonkin, Otago Acclimatisation Society, pers. comm.).

Rainbow trout are not known to form sea-going populations in New Zealand. Apart from this, their life history is similar to brown trout, except that the main spawning period is June and July, somewhat later than that of brown trout. This later spawning means that their redds are more vulnerable to spring floods than are those of the earlier spawning brown trout. Hence, the annual recruitment of juvenile rainbows can fluctuate markedly from year to year.

4.2.3 Brook Char (*Salvelinus fontinalis*)

Brook char, or brook trout, were introduced into New Zealand from North America in 1877. The Otago Acclimatisation Society obtained two batches of fry in 1885 and probably started liberations in the district in 1886 (Thomson 1922). In the Clutha, wild stocks of brook char have been recorded from the upper reaches of the Manuherikia, Mototapu (a Matukituki tributary), and Nevis Rivers (Fig. 6). This confined distribution is typical of this species in other catchments. Brook char are not able to co-exist readily with other salmonids, especially brown trout, and consequently become confined to small headwater streams. In such waters they seldom exceed 200 mm in length (McDowall 1978). Spawning takes place during autumn and winter.

In lakes where other species of trout are absent, brook char reach a larger size. Lake Dispute and Dingle Lagoon are currently being managed as brook char fisheries. Previously, liberations were made into Lake Johnson, but these have since been discontinued and in the absence of further introductions it is anticipated that this population will die out (R. Hutchinson, Department of Internal Affairs, pers. comm.). The Otago Acclimatisation Society is investigating the possibility of liberations into suitable small impoundments in their district.

4.2.4 Splake (hybrid of *Salvelinus fontinalis x S. namaycush*)

Splake, a hybrid produced by fertilising mackinaw (lake char) eggs with brook char sperm, have been produced at the Department of Internal Affairs Hatchery at Wanaka and were liberated into Lake Dispute in 1983. These fish are a "by-product" of the programme to rear mackinaw in the hatchery. When male mackinaw failed to mature in two successive years, the available eggs were fertilised with brook char sperm.

Splake are a fertile hybrid which grow faster than either parent and may reach 7 kg in size (Scott and Crossman 1973). In North America they have been introduced into the Great Lakes and other waters and are reputed to be a popular sports fish.

4.2.5 Quinnat Salmon (*Oncorhynchus tshawytscha*)

Another North American species, quinnat salmon was first introduced into New Zealand in 1875 and first liberated into the Clutha system

(Waipahi River) in 1877. These liberations did not succeed and quinnat salmon did not become established in New Zealand waters until the early 1900s. From 1919 to 1927, quinnat salmon were raised at the Pembroke Hatchery, Wanaka (Flain 1973) and fry were released into Lake Wanaka. An anadromous stock was established, and reports in the 1920s recorded large numbers of returning fish (Anon. 1977). Salmon were regularly caught in Lakes Hawea and Wanaka, but apparently less frequently in Lake Wakatipu, though they were known to spawn in Diamond Creek (R. Hutchinson, Department of Internal Affairs, pers. comm.). Voluntarily landlocked stocks of quinnat developed in all three lakes. After the installation of Roxburgh Dam in 1956, the anadromous stocks were denied access beyond this point.

Anadromous quinnat salmon are caught from the river mouth to below Roxburgh Dam, the latter area being the most popular site for anglers. Since 1977, ICI/Watties have been releasing salmon fry and fingerlings into the lower Clutha to try to produce a commercial return of adults to the hatchery. However, a considerable number of adults bypass the hatchery and continue upstream to as far as Roxburgh Dam. Although salmon of up to 11 kg are caught quite regularly at Roxburgh Dam, the average size of Clutha salmon is smaller than those from other salmon rivers. The reason for this is that juvenile fish may spend up to three years in the Clutha River before migrating to sea (Flain 1980). Since growth in fresh water is slower than in the sea, the average size of adults is correspondingly smaller than for rivers where juveniles spend a year or less in fresh water.

The peak spawning period for salmon is April and May. As with trout, salmon excavate a redd in which eggs are laid, but, unlike trout, the adults die after spawning. Spawning occurs in the main river downstream of Roxburgh Dam, especially in the vicinity of Roxburgh township. However, the contribution that such spawning makes to the returning salmon stock is uncertain because the redds are subject to variations in flow caused by variable dam discharges. Tributaries where spawning is know to occur are Teviot River, Benger Burn, Blackleugh Burn, Tuapeka River, Minzion Burn, Tima Burn, and Coal Creek. In addition, salmon were reported in 1983 from the Pomahaka River, Waipahi River, Parasol Stream, Flodden Stream, and Rankel Burn (Hansen 1983).

Landlocked quinnat salmon are an important component of the anglers' catch in Lakes Wakatipu, Hawea, and Wanaka. They also occur in Diamond Lake. Data from Graynoth (1971) show that from 1947 to 1967 quinnat salmon made up 26% of anglers' catches in Lake Hawea, but more recently Hutchinson (1981) reported that they could comprise up to 60% of the catch in this lake and that they also predominate in Lake Wakatipu in some years. Their average size is smaller than that of both brown and rainbow trout (Graynoth 1971), but they are regarded as more catchable than either of the trout species. Their life history pattern is similar to anadromous stocks; adult fish migrate to headwater tributaries of the lakes to spawn. Some salmon are caught in the Hawea River and Lake Roxburgh, but it is probable that these represent fish moving from the source lakes to the sea rather than resident landlocked stocks, because surveys of potential spawning waters (Lake Roxburgh tributaries and the Manuherikia and Fraser Rivers) have not located any spawning salmon or their redds.

4.2.6 Perch (*Perca fluviatilis*)

The European perch was among the earliest of fishes introduced into New Zealand. The first successful introductions were to Otago in 1868.

In 1891 the Otago Acclimatisation Society annual report stated "These fish are becoming very numerous; Kaitangata Lake and Lovell's Creek are simply swarming with them" (Thomson 1922). In the upper Clutha they are recorded from Lakes Hayes and Johnson, Mt Nicholas Lagoon, and occasionally from Lake Wakatipu and the upper Kawarau River. Although not numerous, perch have been recorded from the Fraser and Manuherikia Rivers, Lake Roxburgh, the mouths of the Minzion and Talla Burns, the lower Pomahaka River, Lake Kaitangata, and the lower Clutha. They are probably also present in the Waipahi and Puerua Rivers. In addition, there are populations in Lanes Dam (Alexandra), Pinders Pond near Millers Flat, and in flooded dredge pits upstream of Roxburgh and downstream to Beaumont.

Perch prefer still or gently flowing water and hence they are not likely to occur in large numbers or to reach a significant size in the main river. The largest fish recorded from the main river near Roxburgh is 24 cm (FRD unpublished data). Spawning occurs in spring when long egg strands are laid over weed beds in shallow water. Juvenile perch shoal in shallow water and adults frequently also move in shoals, especially in lakes. Although they are an acclimatised fish, and anglers require a licence to fish for them, they are not extensively sought by anglers. In the absence of angling pressure and predation, large populations of small fish frequently occur in lakes (McDowall 1978).

4.2.7 Unsuccessful Introductions

Atlantic salmon (*Salmo salar*) were first introduced into New Zealand from England and Scotland in 1868. Eggs were hatched in specially constructed ponds at Kahiku on the Waiwera Stream, lower Clutha River, but it seems that the resulting 500 fish were released prematurely by the hatchery manager (whose "services ... were dispensed with by the commissioners, they having appointed a gentleman who seems to have had some influence with the Government, and on whose land the ponds were situated, but who was totally ignorant of the treatment the fish would need" (Thomson 1922)). In 1874, a 1.4-kg Atlantic salmon was reported from the Clutha. Eggs were imported throughout New Zealand over many years, and fish were reared at several locations, including the Pembroke Hatchery, Wanaka. An estimated 146 900 fry were liberated into the Clutha system from 1868 to 1900 (Thomson 1922). Although "Atlantic Salmon" were recorded from Lake Wanaka in the 1920s, it is almost certain that these were landlocked quinnat salmon. There is no evidence that either anadromous or landlocked stocks of Atlantic salmon were ever established in the Clutha catchment.

The other exotic fish released into the Clutha was the lake whitefish, *Coregonus clupeaformis* (= *C. albus*). Eggs from North America were imported into New Zealand in 1876. In 1878 the Otago Acclimatisation Society received a box of eggs and hatched 1000 fry - these were to have been released into Lake Wanaka; however, they "got as far as the Teviot, but they had nearly all died, except one or two which were liberated in a lagoon communicating with the Clutha" (Thomson 1922). A larger liberation into Lake Wakatipu was made in 1880, and another release (of 50 000 fry) was made into Lakes Wakatipu, Hawea, and Wanaka in 1887. These appear to be the last liberations into the Clutha system, though liberations into other South Island rivers continued intermittently until 1907. Nowhere in New Zealand were these liberations successful, and government finally abandoned the project.

4.2.8 Hatchery Stocks

The Wildlife Service, Department of Internal Affairs, maintains a small brood stock of mackinaw (lake char), *Salvelinus namaycush*, at their Wanaka hatchery. This species was introduced into New Zealand from North America in 1906 and liberated into Lakes Grassmere and Pearson in Canterbury. It is rather surprising that a population has established in Lake Pearson, because the species normally inhabits cold and deep lakes. Although mackinaw reach 46 kg in North America, they are not known to have grown larger than 4.5 kg in New Zealand, and the average size taken by anglers is considerably less than this.

To provide a hatchery brood stock for possible liberations of progeny in the Southern Lakes Wildlife Conservancy district, Wildlife Service staff obtained a few fish from Lake Pearson in 1978 and supplemented these with a further 11 fish in 1981. Despite the initial failure of males to mature, successful hatchery spawning occurred in 1983 and stocks are now available to be liberated back into Lake Pearson. The possibility of liberations into natural lakes and also into the proposed new hydro lakes within the conservancy district is being considered.

5. FACTORS AFFECTING FISH DISTRIBUTIONS

5.1 Natural Features

Many native fish species have specific habitat preferences, to the extent that they will actively seek out their preferred habitat and will be rarely found elsewhere. Among the native species recorded from the Clutha catchment, both eel species, the giant kokopu, koaro, common river galaxias, torrentfish, and blue-gilled bully all have distinct habitat preferences. Thus their distribution and abundance are directly related to the availability of the required habitat.

For those species which have a marine phase in their life histories, distance upstream from the sea imposes limitations on distribution. Inanga and common smelt are both essentially coastal species, and short-finned eels, torrentfish, and blue-gilled bullies do not migrate inland to any great distance. In contrast, the long-finned eel penetrates to the headwaters of catchments throughout the country.

In some tributary streams, the presence of waterfalls acts as a physical barrier to upstream migration. However, juvenile eels and koaro are adept at climbing and are frequently able to negotiate waterfalls by climbing up the splash zone or negotiating areas of reduced flow along the margins. In ephermeral streams, such as the upper Benger Burn, fish are forced to move out as flows become reduced. Quite often fish become stranded and die from starvation, predation, or as a result of elevated temperatures.

5.2 Man-made Features

In the Clutha catchment, the most dramatic changes in the distribution both of native and exotic fish species have been due to modifications that European man has made to the environment; for example, drained swamps, cleared forests, and dammed rivers. Of major significance for many native fish species was the introduction of predatory northern hemisphere fishes to a fauna which had evolved almost without predators. The extinct grayling is considered to be a casualty of both the introduction of salmonids and the modification of habitats (McDowall 1978).

The following subsections outline the main man-made physical changes which have affected fish distributions in the Clutha catchment.

5.2.1 Barriers

The Clutha River is ideally suited to development for hydro-electricity. The large flow, stablilised to some extent by the upstream lakes, and the single-thread incised channel with rocky buttresses and gorges, are all attractive features for power production. Although Roxburgh Dam (320 MW, commissioned 1956) is the only state hydro scheme operating on the Clutha at present, Clyde Dam (432 MW) is under construction, and Luggate (90 MW) and Queensberry (180 MW) Dams are due for commissioning in 1991 and 1993 respectively. Five options for hydro development of the Kawarau River have recently been proposed; these options range from one to three dams producing 100-210 MW (Ministry of Works and Development 1984). The power potential of the lower Clutha (Roxburgh to Tuapeka Mouth) has been given as 900 MW (Natusch 1982) and current investigations have identified four possible dam sites (Ministry of Works and Development 1983), though it is understood that a maximum of three dams would be built. Thus, when fully developed, the Clutha River could have as many as seven dams, with up to three on the Kawarau River. In addition, there are control structures on Lakes Wakatipu and Hawea. (Manipulation of water levels in Lake Wanaka is currently prohibited by the Lake Wanaka Preservation Act 1973.) The Lake Wakatipu control gates were installed in 1926 to control flows in the Kawarau River to enable gold mining of the river bed. The scheme failed and ownership of the gates passed to the Electricity Division of the Ministry of Energy in 1956 (Jones 1977). Today the gates are permanently open and the lake level is uncontrolled. The Hawea control structure became operative in 1959. It is designed to provide additional storage and greater control of water levels in the lake for power generation, but it also acts as a barrier to upstream migrating fish.

There are several local authority hydro stations in the catchment; namely, the Glenorchy, Wye Creek, Roaring Meg, Upper Meg, Fraser River, and Upper and Lower Teviot River stations. A recent report (Royds Sutherland & McLeay 1982) has identified a further five potential schemes in the Clutha catchment. In addition to hydro dams, there are several irrigation reservoirs which store winter run-off. These include Falls Dam (Manuherikia River), Ida Burn Dam (tributary of Manuherikia), Manorburn Reservoir and Lower Dam, and Poolburn Reservoir (Manuherikia River), Butchers Dam, and Conroys Dam.

Dams without fish passes are a barrier to upstream migrating fish. In most instances they are a complete barrier, but young eels and some galaxiids are able to negotiate some dams and weirs under certain circumstances. When Roxburgh Dam was built, fisheries managers (from Wildlife Division of the Department of Internal Affairs and Fisheries Division of the Marine Department) agreed that no fish pass was necessary. This decision resulted in the end of the anadromous quinnat salmon migration to the upper Clutha and lakes. The reason for the decision was apparently to "protect upper lake fisheries from contamination by eels or salmon" (Little 1975). Presumably the intention was to try to manage the Lake Roxburgh fishery, and the fisheries of any future upstream hydro reservoirs, as discrete and separate entities, because Wildlife Division later advocated the installation of fish screens at penstock intakes of proposed upper Clutha dams to prevent the downstream movement and loss of salmonids (Ministry of Works and Development 1975).

The barrier created by the Roxburgh Dam has substantially altered fish populations in the Clutha River. It has curtailed upstream migrations of long-finned eels, koaro, anadromous quinnat salmon, and sea-run brown trout, and common bullies and koaro immediately upstream of the dam have reverted to a lake-dwelling existence. Any upstream stocks of torrentfish and blue-gilled bullies will have disappeared. Similarly, additional downstream state hydro, local authority, and irrigation dams will all have impeded upstream fish migrations. Downstream migrations of fish are also affected, either by direct mortality when passing through turbines or over spillways, or by delays to migration caused by fish becoming disoriented on entering an area of reduced flow. (Other features of hydro dams which affect fish distributions are mentioned in Section 5.2.2.)

Specific concern has been expressed that Roxburgh Dam has led to the almost total exclusion of young eels from the upper Clutha catchment (Glova and Davis 1981, Jellyman 1982). Accordingly the upstream eel fishery is based on a residual stock which is being depleted by fishing, natural mortality, and the seaward migration of maturing eels. Eventually this will lead to the disappearance of eels from the upper catchment. A report on the annual elver migration at Roxburgh (Boud and Cunningham n.d. (b)) concluded that "few, if any, eels succeed in passing the dam". Recent studies of eels in Lake Roxburgh have confirmed this, though a small proportion of eels in the lake is less than 28 years old and so arrived in the lake after construction of the dam (FRD unpublished data).

Road culverts which incorporate a free fall of water, usually act as a complete barrier to all fish species, including eels (McDowall 1978). In the vicinity of Lake Roxburgh, Gorge Creek, Elbow Creek, Butchers

Creek, and Shingle Creek all have culverts which are impassable to fish. Low head weirs may also block fish passage. For instance, a weir constructed in the mid 1970s across the East Back Stream, an important spawning and nursery stream of the Pomahaka, prevented brown trout reaching spawning areas (Tonkin 1981).

5.2.2 Loss of Habitat

Several developments in the Clutha catchment have led to the downgrading or loss of fish habitat; the main ones being water abstraction, lake drawdown and fluctuating downstream flows caused by hydro generation, and wetland drainage.

Water is abstracted for irrigation, frost fighting, and public water supply. Of these uses, irrigation has the greatest requirement, utilising 94% of the 15.43 m^3/s of water presently abstracted from the river (calculations based on data in Otago Regional Water Board 1980). As at May 1976, there were about 680 water rights (including mining privileges) for private irrigation and 84 Crown rights for government schemes. The irrigation season is from September to May, with the time of peak demand varying considerably according to local climate and soil type.

From a fisheries viewpoint, abstractions from tributaries are of far greater concern than abstractions from the main river (at present 65% of the catchment's abstracted water comes from tributaries, excluding the Kawarau River). Tributary streams and rivers provide important fish habitats, especially for salmonid spawning and rearing. Abstraction of water reduces the habitat available for fish (with associated reduction of cover and food) and diverts fish into water races if the intakes of these are unscreened. The flow of the Lindis River is completely diverted for long periods in summer, and most of the flow of the Cardrona River is similarly abstracted (Hutchinson 1974). The entire flow of the Fraser River has been regularly diverted each year for irrigation usage (Harker 1978), though up to 1 m^3/s of water will be available from the Clyde Dam to augment the Fraser's flow. Large-scale abstraction of the Manuherikia River has reduced its mean flow during December-March, from a monthly average of 11.83 m^3/s to 3.72 m^3/s (calculations based on data in Otago Acclimatisation Society Annual Report 1976). Other tributaries substantially affected by abstraction are the Teviot and Arrow Rivers and Benger Burn.

Frost fighting occurs from September to November, and though there may be an instant demand for up to 5 m^3/s, much of this is supplied from irrigation races. Public water supply for domestic consumption, stock water, and industry is fairly small, amounting to 0.65 m^3/s. Similarly an out-of-catchment diversion of 0.14 m^3/s from the Beaumont River into Lake Mahinerangi is of little consequence. The Hawkdun Irrigation Scheme diverts an average of 0.27 m^3/s from the upper Manuherikia River into the Taieri catchment (Otago Catchment and Regional Water Board 1983). As noted above, the Manuherikia River is already seriously abstracted for uses within its own catchment.

The seasonal variation in the level of Lake Hawea, and the daily fluctuations in the level of Lake Roxburgh, cause quantitative changes to fish habitat. Lake Hawea has a considerable operating range of 19.35 m, which can result in a drying out of the normal littoral zone (the marginal area with high light penetration which forms the most important food producing zone in lakes). The very small migration of spawning trout into Long Valley Stream (Lake Hawea) in 1977 was attributed to the extensive drawdown of the lake at this time

(Department of Internal Affairs 1978). A study of Lake Roxburgh (Winter 1964) indicated that 15-70% of the littoral area was exposed daily, which resulted in considerable reductions in the invertebrate fauna.

Associated with lake drawdowns are fluctuating flows downstream of dams. Large variations in discharge from Lake Hawea greatly limit the value of trout spawning areas at the confluence of this river and the Clutha (Hutchinson 1974). Daily variations in flow of 150-700 m^3/s from Roxburgh Dam are certainly a major factor limiting fish production in the river below the dam. Such variations result in periodic exposure and drying-up of littoral habitats, with a corresponding loss of weed growth and food production from these areas. Slumping of river banks and river mouth instability (for example, the blockage of the Matau or Koau branch mouths or the migration of the Koau mouth and the consequent risk of flooding) have also been attributed to flow fluctuations caused by Roxburgh Dam (Otago Regional Water Board 1980).

Under the "Clutha Delta (Lower Clutha) Drainage and Flood Protection Scheme" extensive drainage and stopbanking has occurred in the Clutha downstream of Balclutha. A total of 114 km of stopbanks and 230 km of drainage channels has been formed (Poole 1983). The original scheme design required drainage and reclamation of one-third of Lake Tuakitoto as well as the whole of the swamp at the top end of the lake. After representations by various environmental organisations in 1967, plans were adjusted to ensure preservation of much of the area, but "drainage and reclamation of the wetlands excluded from the 1967 proposal did occur, and this included nearly a third of Lake Tuakitoto itself, Lake Kaitangata and the wetland between these two lakes" (Neilson 1983). From a fisheries viewpoint, reduction or loss of these wetlands is of considerable significance. These areas provided the only known habitat of the giant kokopu and probably also sustained populations of short-finned eels, inanga, common bullies, black flounders, perch, and brown trout.

5.2.3 Water Quality

Water quality throughout the Clutha catchment is generally very high (Otago Regional Water Board 1980). The water of the upper river is described as "pristine", partly because Lakes Wanaka and Hawea act as nutrient sinks (Ministry of Works and Development 1982). However, there are some specific areas of concern. Lakes Hayes and Johnson are both eutrophic; their deeper waters become completely deoxygenated by late summer, and surface oxygen concentrations in Lake Johnson fall to levels at which there is danger of extermination of rainbow trout (Michell and Burns 1979). The primary cause of this problem is nutrient input from the surrounding farmland and holiday dwellings.

High sediment concentrations in the Kawarau River reduce its value as permanent fish habitat and its appeal to anglers. Some trout spawning takes place on the gravel fan at the confluence of the Kawarau and Shotover Rivers, though the success of this would be limited by silt deposition (Hutchinson 1974). In severely abstracted rivers, abnormally high water temperatures may occur during summer. For instance, Hutchinson (1974) recorded a maximum of 28 °C during December 1973 in the Cardrona River; 25 °C is usually regarded as the highest temperature trout can survive for short periods (Alabaster and Lloyd 1980).

Coal fines and washings from open cast mining at Coal Creek have periodically caused some localised downgrading of the stream (C. Tonkin, Otago Acclimatisation Society, pers. comm.), but generally the impacts of urban development and industry appear to be small. The only substantial industrial water requirment in the catchment is for the Waitaki-NZR Finegand Freezing Works near Balclutha, which draws most of its requirement from groundwater. Most effluent from the works is only partially treated and is discharged directly into the main river. The impact of this unsightly enrichment on aquatic life has not been studied. In February 1981, a major ammonia leak from the works killed all fish life in the Waitepeka Lagoon. Some remedial work has taken place to prevent another leak, but there is still concern that these measures may be inadequate (Watson 1982).

6. DISCUSSION

Major changes in the composition and distribution of fish stocks in the Clutha catchment have been brought about by man-made developments, particularly wetland drainage, hydro development, and water abstraction for irrigation. Of these, hydro development has had the greatest impact on fish populations and will have an increasing impact in the future if the proposed dams downstream of Roxburgh are constructed. Construction of Roxburgh Dam has prevented upstream migration of long-finned eels, koaro, common bullies, quinnat salmon, sea-run brown trout, and, to a lesser extent, lampreys, short-finned eels, torrentfish, blue-gilled bullies, and possibly smelt. Populations of koaro and common bullies in the vicinity of Lake Roxburgh have had to adapt to a lake-dwelling mode of life since access to the sea has been denied. Any further hydro developments between Roxburgh and the Tuapeka Mouth will decrease the variety of native species currently found in this area. A fisheries study in progress in this area is designed to ascertain the present fish stocks, to predict the impacts of any future hydro development, and to recommend appropriate measures to mitigate the effects of such development.

The Roxburgh Dam, in addition to being a barrier to fish passage, creates a flow regime which has a marked destabilising effect on downstream fish habitats. Because Roxburgh is a peak demand station, discharges from it are subject to sudden change. Although base flows do not fall below an agreed minimum of 100 m^3/s, flows may increase to a peak of 800 m^3/s within 2 hours (Otago Regional Water Board 1980). Increases in spillway discharges of 500 m^3/s per half hour have been recorded (Commission for the Environment 1982).

Future hydro development may have direct effects on fish populations. During construction, care is needed to ensure that large quantitites of silt, oil, etc. do not enter waterways. Any silt flushing of reservoirs should be carried out at high flows and be timed to avoid the salmonid spawning season. Also, the integrated operation of the various stations should ensure that lake drawdowns and downstream flow fluctuations are kept to a minimum. Residual flows adequate to maintain existing fisheries values will have to be set for any sections of the river where most of the flow is to be diverted into a power canal; for example, Dumbarton Rock investigation site on the lower Clutha (Ministry of Works and Development 1983).

At present 27 282 ha of the Clutha catchment are partially or fully irrigated, but a further 35 000 ha could be incorporated in proposed Government schemes, including Earnscleugh (1750 ha) and Manuherikia (19 700 ha). Water abstractions will increase accordingly from the present requirement of 14.5 m^3/s to 27.4 m^3/s in an average year and 36.5 m^3/s in a dry year (Otago Regional Water Board 1980). Currently, a number of tributary rivers are seriously affected by abstraction of water for irrigation; apart from water harvesting, there seems to be little potential for additional abstraction. Irrigation requirements in the upper Clutha are planned to be met from the Luggate and Queensberry impoundments and some augmentation of the low summer flows of the Lindis River may also be possible from these sources (Ministry of Works and Development 1982).

The complete drainage of Lake Kaitangata and partial drainage of adjacent wetlands has resulted in loss of habitat for a variety of native species. This habitat loss has increased the importance of the remaining wetland in the area, Lake Tuakitoko. Consequently, the fact that the Benhar lignite field beneath the lake has recently been added to the four lignite fields already identified by the Liquid Fuels Trust Board as warranting further investigation is of concern to fishery and wildlife managers alike. In drawing attention to the importance of wetlands as fish habitats, McDowall (1982) noted that of New Zealand's 27 species of native freshwater fishes, at least eight species are habitually found in wetlands of various types and a further four are occasionally found there. Lowland wetlands, in particular, are an important habitat for inanga, the most abundant of the whitebait species. The substantial reduction in whitebait migrations throughout the country is mainly attributable to loss of swamp and estuarine habitat.

Central Otago has lignite deposits at Hawkdun, Homehills, and Roxburgh East which collectively amount to about 970 million tonnes (Hooper, McKenzie, and Natusch 1983). The Liquid Fuels Trust Board recently decided that further investigation of the Hawkdun deposit is warranted, but that the other two deposits are not sufficently attractive for further investigations at this stage. As the Hawkdun deposit lies beneath the Manuherikia River, above the Falls Dam, concern has been expressed already that open cast mining and processing could detrimentally affect trout fisheries in the river and its tributaries (Watson 1981).

Despite these adverse effects, the Clutha catchment still supports several important fisheries. Kahawai fishing, whitebaiting, floundering, and trout fishing are recreational fisheries associated with the lower reaches and mouth. Commercial eel fishing occurs throughout the catchment, though the failure of significant recruitment beyond Roxburgh Dam will mean that the fishery upstream of the dam will eventually become uneconomic. Given the present high level of exploitation of eels, FRD is concerned for the maintenance of eel stocks in all waters to which eels have historically had access. In previous submissions (Glova and Davis 1981, Jellyman 1982) FRD has advocated that provision be made for eel passage in the Clutha system, either through trapping and manual transfer, or by installation of special eel passes.

A commercial fishery recently established on the lower Clutha River is the ocean ranching of quinnat salmon. Juvenile salmon are reared in a hatchery, released to the sea, and adults return to the release site 2-4 years later. Once in fresh water, and before their return to hatchery trapping sites, these salmon are "available" to anglers.

From 1977 to 1982 ICI/Watties released 908 000 juvenile salmon from their Kaitangata Hatchery (Todd 1983). In some years small additional releases have been made from the Minzion Burn. A high proportion of the fish released has been tagged and fin clipped, so that it is possible to identify returning adults and ascertain the contribution hatchery fish have made to angler's catches. Although returns to the hatchery itself have been disappointing, large numbers of ex-hatchery fish have been caught by Clutha anglers, mainly at Roxburgh Dam. For the 1983 salmon season, it was estimated that of the total catch at Roxburgh (about 800 salmon) 31% were ex-hatchery fish (Gillard 1983). Rates of return from releases over recent years compare very favourably with results achieved from hatcheries on other rivers.

Most of the fish caught at Roxburgh Dam are "wild" and result from spawnings in the main river and tributaries below the dam, with a contribution from salmon emigrating from the source lakes. Hydro development downstream of Roxburgh would cause a further decline in numbers of wild fish in the Clutha system - salmon would be denied access to present spawning areas and mortality of fish emigrating from the source lakes would be substantially increased (these fish could eventually have to negotiate as many as seven dams to reach the sea). Thus, the recreational fishery would become increasingly dependent on hatchery-reared stock.

Unfortunately there are no reliable estimates of the extent of the anadromous salmon run which occurred in the Clutha River before the installation of Roxburgh Dam, though Marine Department and Otago Acclimatisation Society reports from this period suggest that runs were substantial. The following quotes are taken from the Appendices to the Journals of the House of Representatives, Wellington.

- *A good run of fish went up the Clutha branch during the last two seasons, and from reports this season it would seem that there is a good run of large fish in tributaries of Wanaka Lake at the present time.* (1922)

- *Increased numbers were also reported to be present in the waters of the upper Clutha, especially in the Matukituki tributary, and* *in the Hunter and Dingle Rivers at the head of Lake Hawea.* (1929)

- *Sea-run quinnat salmon of large size and in good condition were taken in Lake Wanaka from the middle of March which must have run the Clutha River. From Lake Wakatipu the capture of only lake-fed fish was reported.* (1933)

- *Reports from the Clutha state that an unusually large number of spawning salmon ... in that river above Cromwell, and many redds were exposed to view by the abnormally low levels to which the water fell in the winter of 1937.* (1938)

- *The run of salmon in the Clutha River also appeared to show an appreciable increase, catches having been made in larger numbers and over a great length of the river's course than has hitherto been the case. A difference between this river and the Canterbury salmon rivers, which carry a smaller volume of water, is that practically all the salmon catches are made in the upper reaches above Cromwell and not in the lower and estuarine waters.* (1939)

In recent years there has been periodic interest in the feasibility of restoring the migration of anadromous salmon beyond Roxburgh. Suggestions by Woods (1982) involved a combination of fish passes and irrigation link races to be utilised by salmon, or for salmon to be captured at the lowermost dam and trucked to release points upstream. However, Jellyman (1983) maintained that the first suggestion was not feasible on biological grounds because salmon would have no olfactory cues to guide them to the appropriate link races. (The costs of fish passes were estimated at $18-$36 million.) The trucking option could be taken up at any stage should a cost/benefit analysis indicate the procedure is feasible. Regrettably, perhaps, it seems unlikely that the re-establishment of the salmon migration is either practical or necessary. By the time anadromous fish had arrived in the source lakes, by either negotiating the various ladders and raceways, or by being impounded and trucked, they are unlikely to be in sufficiently good condition to make them attractive to anglers. The fishery for anadromous salmon below Roxburgh Dam is currently the most productive of any period since the installation of the dam (with the probable exception of the few years immediately after the commencement of Roxburgh, when the last of the adults of source-lake origin were returning). However, the good catches of recent years are due to the increasing availability of hatchery stock, and the population can always be enhanced in future by this means.

The upper Clutha River and Lakes Wakatipu, Hawea, and Wanaka, and their tributaries, are highly regarded trout fisheries. Results from the recent National Angling Survey of rivers, jointly conducted by FRD and the acclimatisation societies, have confirmed the high importance that anglers attach to rivers in this area. Of the 16 South Island rivers considered to be nationally important, 4 are in the Clutha catchment (Teirney *et al.* 1982). These rivers are the Clutha River between Lake Wanaka and Cromwell (recreational fishery), Hunter River (wilderness fishery), and Greenstone and Caples Rivers (wilderness fisheries). The Pomahaka River is considered to be regionally important. Information on the relative value of Otago rivers to anglers from throughout New Zealand is contained in Richardson, Teirney, and Unwin (In press), and equivalent information for the Southern Lakes Wildlife Conservancy district will be published in the future. The main lakes are also popular and productive fisheries (Hutchinson 1980, Turner 1983).

Although some trout spawning does occur in the main river, the continued wellbeing of both the lake and river fisheries is dependent largely on spawning and rearing in tributary streams and rivers. Hutchinson (1980) has expressed concern at continued catchment development and the absence of stock-free buffer strips along banks of spawning streams around Lake Wanaka.

The Department of Internal Affairs concluded that a fish hatchery would be required to maintain adequate fish stocks in Lake Dunstan and upstream reservoirs because existing spawning facilities were limited (Adams 1977). Also the stocking of reservoirs would enable the fisheries to be managed in favour of the more readily caught species of salmonid - quinnat salmon and rainbow trout. Provision of a suitable hatchery by Electricity Division, Ministry of Energy, was included as a condition in the Clyde Dam water rights (National Water and Soil Conservation Organisation 1979). It has since been proposed that the existing Lake Wanaka hatchery be closed and the new hatchery expanded to cater for the projected needs of the Southern Lakes Wildlife Conservancy. Several possible sites have been considered (Ministry of Works and Development 1982) and the proposal is currently being re-evaluated by Government.

With the development of Queensberry and Luggate hydro dams, the Clutha River above Cromwell will be replaced by a series of lakes (with the exception of the stretch above Albert Town). Interviews with anglers indicated that "there are river anglers and lake anglers and the former rarely deign to fish flat waters" (Cawthron Institute 1980). In recognition of the loss of this "big river" fishery, it has been agreed that the residual river downstream of Queensberry Dam should retain some characteristics of a significantly sized river, and a minimum flow of 30 m^3/s has been set (Commission for the Environment 1982).

7. CONCLUSIONS

As the largest river in New Zealand, with flow variations dampened naturally by the presence of large upstream lakes, the Clutha River could be expected to maintain large stocks of freshwater fish. The few historical records available indicate that this was so. Various catchment modifications during the past 130 years have substantially reduced both the quality and the quantity of habitat available to fish species. The impact of gold mining in the Shotover River catchment still affects water quality, and irrigation abstraction in tributary streams and rivers results, in some instances, in the complete diversion of surface waters. However, the major impact on fish distributions has been hydro development.

Despite the conclusion of a 1904 report to Parliament, which dismissed the possibility of any economic schemes on the Clutha, hydro development has proceeded. The commissioning of Roxburgh Dam in 1956 curtailed the upstream migrations of 8 of the 13 native fish species recorded from the river and 2 of the introduced species. Fluctuating lake levels and downstream flows have significantly downgraded fish habitats in both the lake and river. Additional hydro development is proceeding in the upper Clutha while the potential of the lower Clutha is being investigated.

In commenting on the supposed multiple purpose use of land and water, the current Clutha Catchment Water Allocation Plan (Otago

Regional Water Board 1980) stated "up to the present nearly all development in the Clutha catchment has been either dominant purpose or special purpose, and there has been a significant lack of adequately integrated multiple purpose development proposals. This still appears to be very much the situation, with the emphasis on dominant purpose, not multiple objective, multi-purpose development". Hydro development has already significantly altered the abundance and distribution of fish stocks in the Clutha catchment. The series of abutting hydro reservoirs which could ultimately develop from Tuapeka Mouth to Albert Town (170 km) would result in the loss of the "big-river" environment, though, with careful management, the new impoundments could develop into productive habitats for lake-dwelling fish species.

Given the considerable hydro development or planned development on the Clutha (Clyde 1640 GWh, upper Clutha 4315 GWh, lower Clutha 2000 GWh - compared with Roxburgh 1640 GWh) it is to be hoped that this will mean that other rivers throughout the country capable of being developed for hydro power can be left unmodified.

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APPENDIX 1. Co-ordinates (NZMS 1) of lakes and impoundments mentioned in the text (listed alphabetically).

Butchers Dam	S143 3147/3400
Conroys Dam	S143 3128/3415
Diamond Lake	S122 2296/4048
Dingle Lagoon	S107 3155/4440
Dispute	S132 2457/3680
Falls Dam	S125 3625/3935
Fraser Dam	S143 3034/3497
Gabriels Gully Dam	S162 3476/2713
Greenland Reservoir	S144 3393/3250
Hawea	S107 3120/4440
Hayes	S132 2678/3767
Johnson	S132 2613/3737
Kaitangata	S179 3596/2229
Lanes Dam	S143 3179/3443
Malones Dam	S162 3490/2682
Manorburn Reservoir	S144 3389/3298
Manorburn Lower Dam	S144 3237/3467
McKellar	S122 2093/3915
Mt Nicholas Lagoon	S132 2345/3600
Moke Lake	S132 2472/3735
Onslow	S153 3400/3100
Pheonix Dam	S162 3480/2694
Pinders Pond	S152 3139/3055
Poolburn Reservoir	S144 3492/3391
Rere	S131 2268/3782
Roxburgh	S143 3124/3275
Sylvan	S122 2241/4089

APPENDIX I (continued)

Tuakitoto	S179 3586/2269
Von	S141 2252/3435
Waitapeka Lagoon	S179 3517/2213
Wakatipu	S132 2500/3640
Wanaka	S115 2940/4345

APPENDIX II. Co-ordinates (NZMS 1) of rivers and streams mentioned in the text (listed alphabetically). The co-ordinates refer to the confluence of the river or stream with a larger waterway.

Arrow River	S132 2743/3738
Beaumont River	S162 3321/2775
Benger Burn	S152 3193/2977
Blackleugh Burn	S171 3284/2594
Butchers Creek	S143 3169/3408
Canadian Stream	S162 3312/2824
Caples River	S122 2260/3812
Cardrona River	S115 3005/4137
Carsons Stream	S162 3293/2717
Coal Creek	S152 3128/3168
Dart River	S122 2291/3915
Diamond Creek	S123 2305/3987
Dingle Burn	S107 3164/4465
East Back Stream	S171 3237/2552
Elbow Creek (Lake Roxburgh)	S143 3131/3127
Flodden Stream	S161 3080/2631
Fraser River	S143 3164/3458
Gorge Creek	S143 3118/3298
Greenstone River	S122 2292/3812
Hawea River	S115 3002/4143
Hunter River	S108 3216/4644
Ida Burn	S134 3457/3708
Kaihiku Stream	S171 3448/2326
Kawarau River	S133 3028/3691
Lindis River	S124 3134/3908
Long Valley Stream	S115 3038/4314

APPENDIX II (continued)

Low Burn	S162	3313/2758
Makarora River	S107	2969/4589
Manuherikia River	S143	3193/3445
Matukituki River	S115	2837/4211
Minzion Burn	S153	3249/2915
Mototapu River	S115	2780/4228
Nevis River	S133	2878/3676
Parasol Stream	S161	2976/2831
Pomahaka River	S171	3366/2365
Puerua River	S179	3553/2113
Rankle Burn	S170	3181/2495
Rees River	S123	2301/3915
Roaring Meg	S133	2749/3905
Shingle Creek	S143	3127/3245
Shotover River	S132	2648/3721
Talla Burn	S162	3306/2843
Teviot River	S152	3137/3103
Tima Burn	S153	3212/2962
Tuapeka River	S171	3315/2531
Von River	S132	2353/3629
Waipahi River	S170	3091/2442
Waitahuna River	S171	3383/2361
Waiwera Stream	S171	3277/2305
Wilkin River	S107	2977/4638
Wye Creek	S132	2637/3576
Young River	S98	3023/4727

[illegible]