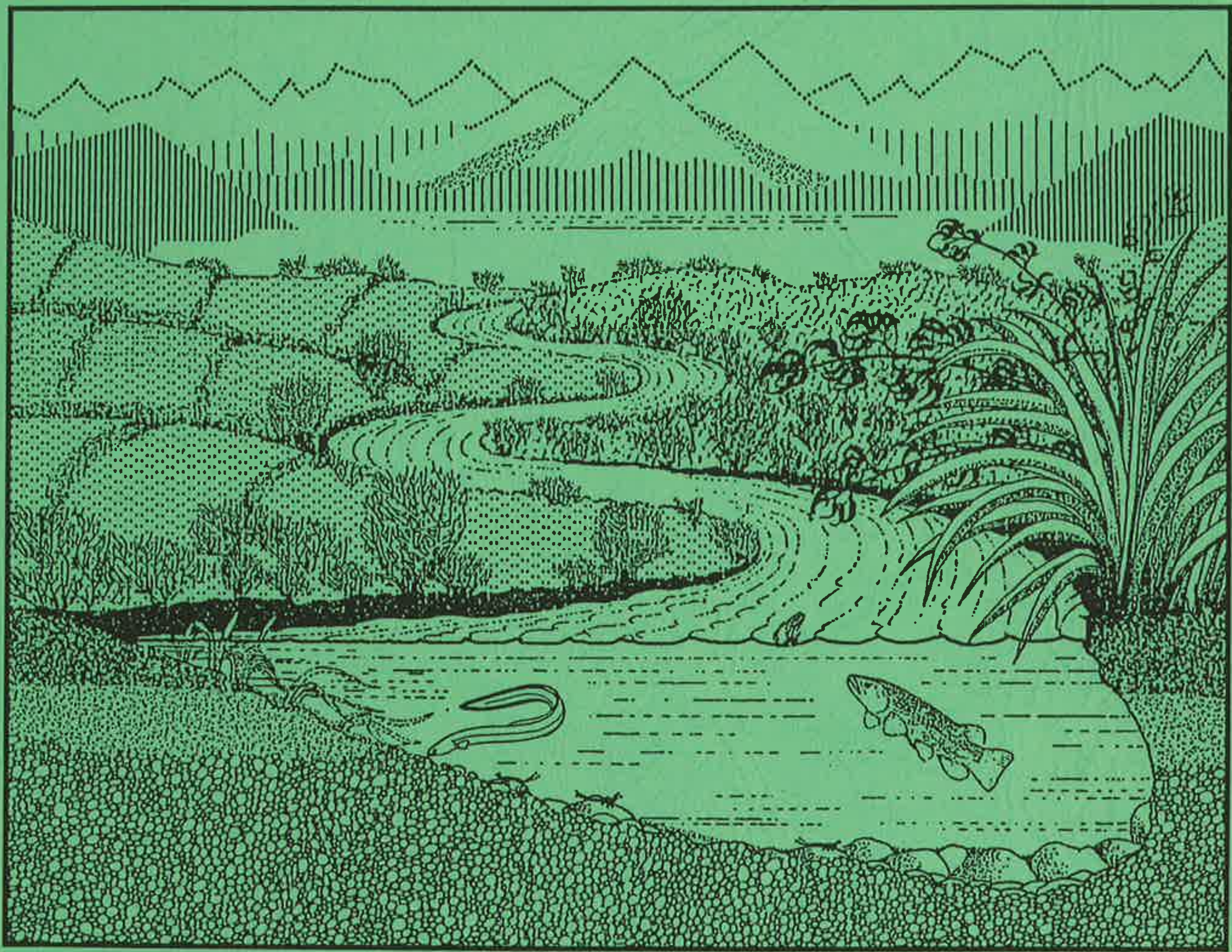
ISSN 0113-2504

New Zealand Freshwater Fisheries Report No. 94

Fisheries investigations of the Ashers - Waituna, Benhar, and Hawkdun lignite deposit areas



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New Zealand freshwater fisheries report no. 94 (1988)

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Fisheries investigations of the Ashers-Waituna, Benhar, and Hawkdun lignite deposit areas

by

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Report to: Liquid Fuels Trust Board

Freshwater Fisheries Centre

MAFFish

Christchurch

February

1988

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SUMMARY

The Liquid Fuels Trust Board is investigating the suitability of 3 lignite deposits in Otago and Southland to support a coal-to-liquid-synthetic-fuel conversion plant. As part of these investigations, biological surveys of the waterbodies associated with each deposit area were undertaken during 1985 by fisheries staff, under contract to the Board. The study areas were Ashers-Waituna near Invercargill in Southland, Benhar near Balclutha in south Otago, and Hawkdun near St. Bathans in central Otago. The objectives of the study were to evaluate the significance of the aquatic habitats at each site, and to rank the 3 areas for the severity of the biological impact which would follow the development of a lignite mine and associated processing plant.

The study areas were found to contain differing types of aquatic habitat. The Ashers-Waituna lignite deposit lies next to Waituna Lagoon, an unmodified estuary with several tributary streams which provide extensive, high quality spawning habitat for a large number of migratory brown trout. These streams also support stocks of giant kokopu *(Galaxias argenteus)*. The nearby lower Mataura River and its outlet, Toetoes Harbour, could be affected by the abstraction of water for use in a synfuels processing plant, and by the discharge of effluent. The Mataura supports a nationally important recreational brown trout fishery, which is currently the subject of a National Water Conservation Order application. It also supports regionally important recreational and commercial whitebait fisheries, and a diverse number of other estuarine and freshwater fish species.

Of the 3 sites investigated, Ashers-Waituna has the highest biological values. Lignite development here would have severe effects, especially if salt water should intrude into the ground water as a result of mine dewatering, or if the Waituna Creek catchment was disturbed by mining.

The Benhar lignite deposit lies beneath Lake Tuakitoto, which is a significant freshwater lake and wetland complex of a size which is becoming increasingly rare in New Zealand. The lake contains a sizeable stock of short- and long-finned eels, which sustain a commercial fishery. Giant kokopu have been recorded from 2 of the

tributary streams. The lake is currently the subject of a National Water Conservation Order application on the basis of its outstanding importance as a wildlife habitat. Of the 3 sites investigated, the aquatic biological values here were ranked as medium. However, this site would suffer the greatest on-site impact if lignite mining were to proceed. The lake would be drained completely, and the lower reaches of inflowing tributary streams would be destroyed.

The Hawkdun lignite deposit is situated within the upper Manuherikia catchment, above the Falls Dam reservoir. Only 4 fish species are to be found in the study area, because access for migratory species is blocked by the dam. All fish species are common throughout the region, although the co-existence of mixed populations of brown trout and brook char in tributary streams is unusual in New Zealand. Hawkdun is considered to be the least environmentally sensitive site for lignite development. Its aquatic biological values were the lowest of the 3 sites investigated, and development there would have considerably less effect than it would at Ashers-Waituna or Benhar.

If a lignite mine and synfuels facility were to be developed in the South Island, the Hawkdun site should be selected, because its aquatic environments and values would be the least affected.

1. INTRODUCTION

1.1 Background

This study was part of the Liquid Fuels Trust Board (LFTB) Phase II site-specific studies of 3 Otago/Southland lignite deposits, and was commissioned by the LFTB in January 1985.

Aquatic biology studies were part of the LFTB's Category 5 studies, and were undertaken jointly by staff from the Freshwater Fisheries Centre (FFC), the Otago Acclimatisation Society (OAS), and the Southland Acclimatisation Society (SAS), from January to August 1985.

1.2 Study Areas

Of the 10 lignite deposits identified in the Otago/Southland region, the LFTB selected 3 for Phase II site-specific investigatory work. These deposits comprised Ashers-Waituna in Southland, Benhar in South Otago, and Hawkdun in Central Otago (Fig. 1). The study areas defined at each deposit site by the LFTB are shown in Figures 2, 3, and 4, and have 3 components: the boundary delineating the extent of the lignite deposit, the boundary of the proposed mine site within the deposit area, and the dump site. However, for the purposes of this investigation, the study area at each site was extended beyond these boundaries, so that whole catchments were included in the field surveys. Further, at each locality, the sites proposed for water abstraction to supply a potential synfuels processing plant, together with their downstream catchments, were included in the broader study area, although aquatic biological surveys of these areas were conducted at a fairly superficial level. The wider study areas are described in Section 2.

1.3 Objectives

The purpose of this study was to increase the data base for each of the 3 lignite deposit sites to an approximately equivalent, but minimal, level. Information from this and other baseline studies, together with selection of the conversion technology preferred for development of a commercial-sized synfuel facility, will enable a decision to be made as to which deposit should be investigated in more detail.

The overall objective was to rank each of the 3 deposits with respect to the potential impact of a lignite synfuel development on the aquatic environment.

The study tasks defined by the LFTB were to:

1. Compile an annotated bibliography of all published references available and relevant to the aquatic biology of the 3 study areas. Document the findings of the literature search.

2. Informally interview local people with relevant local knowledge of the 3 areas.

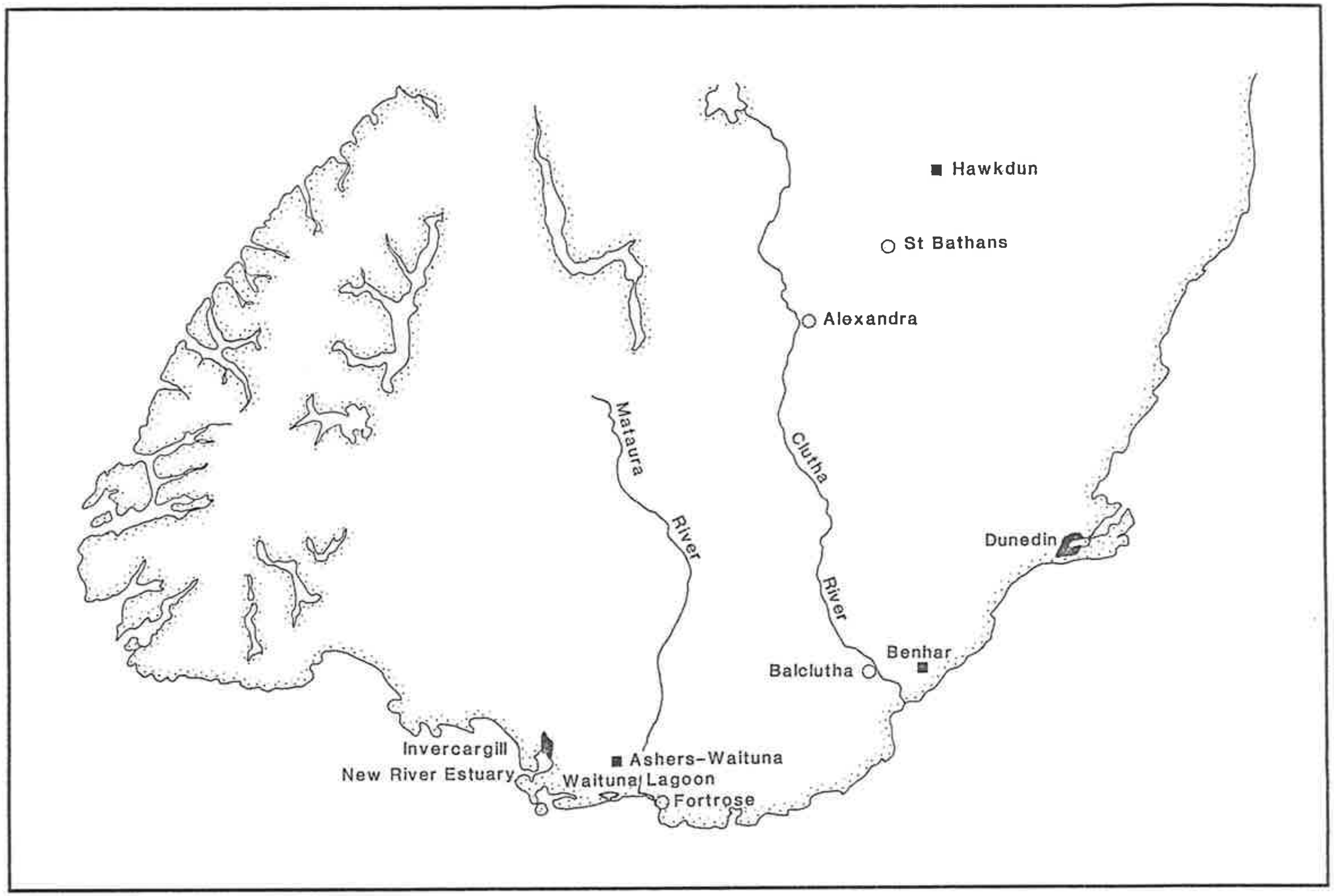

FIGURE 1. Location of lignite deposit areas.

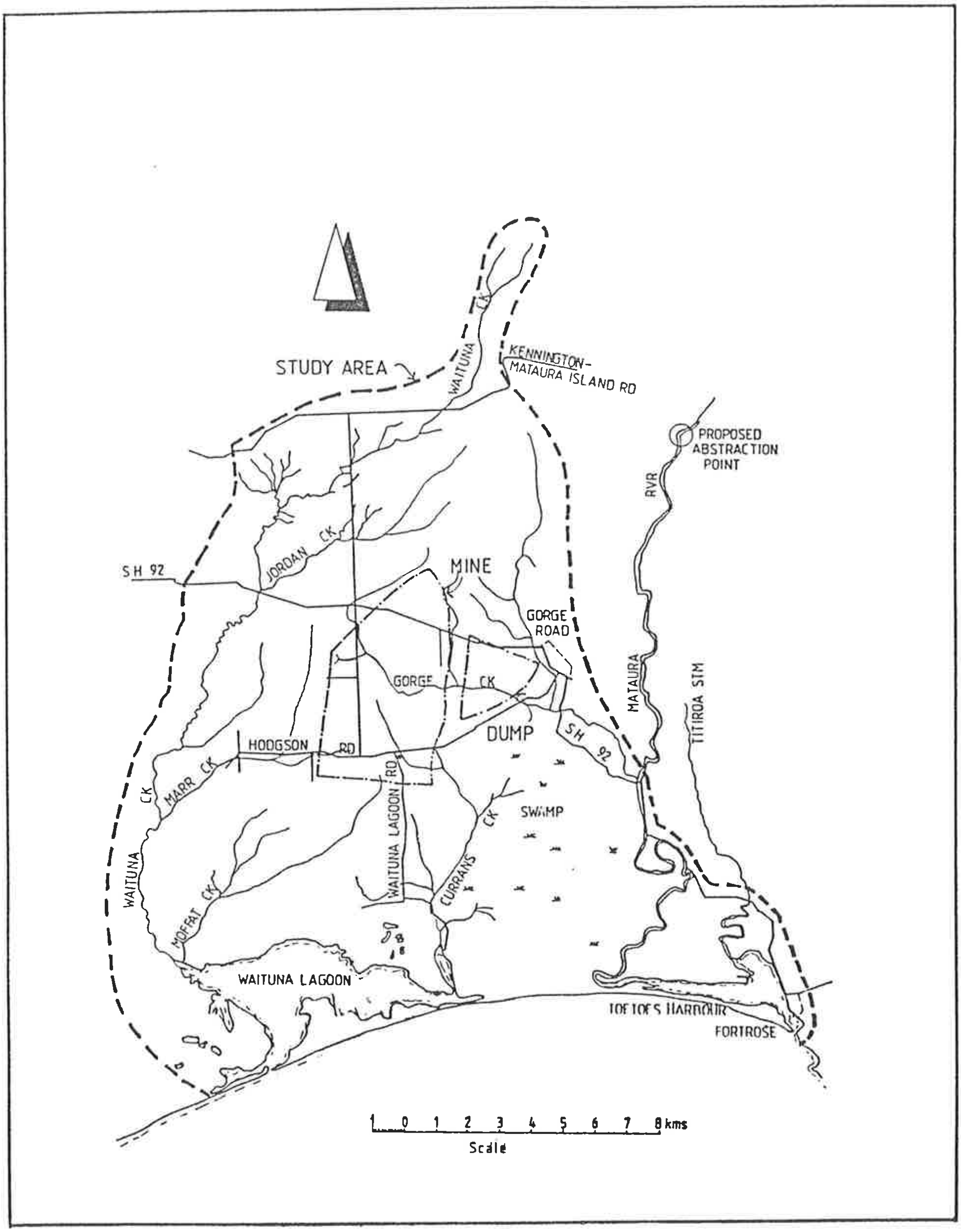

FIGURE 2. Ashers-Waituna lignite deposit area, and proposed mine and dump sites.

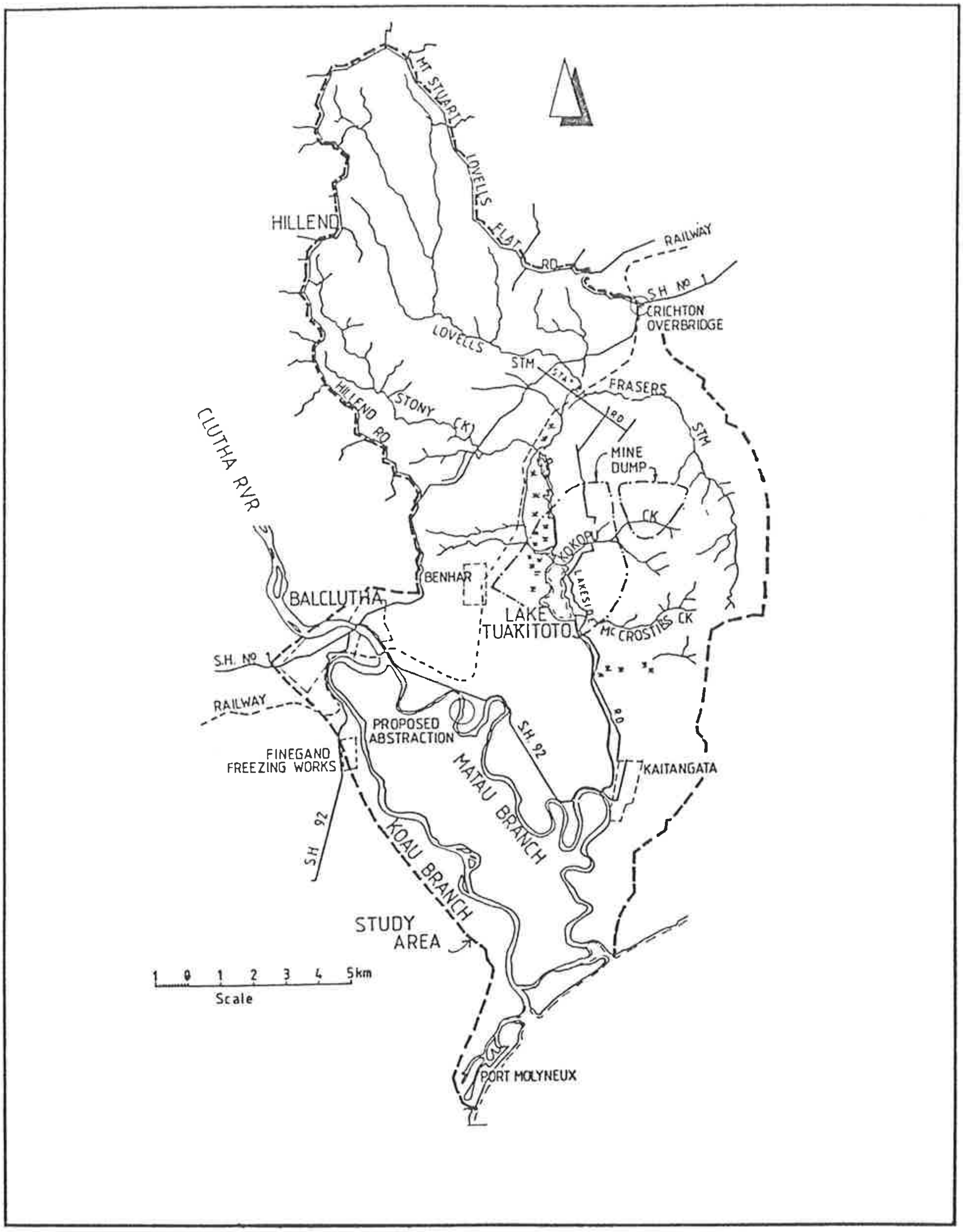

FIGURE 3. Benhar lignite deposit area, and proposed mine and dump sites.

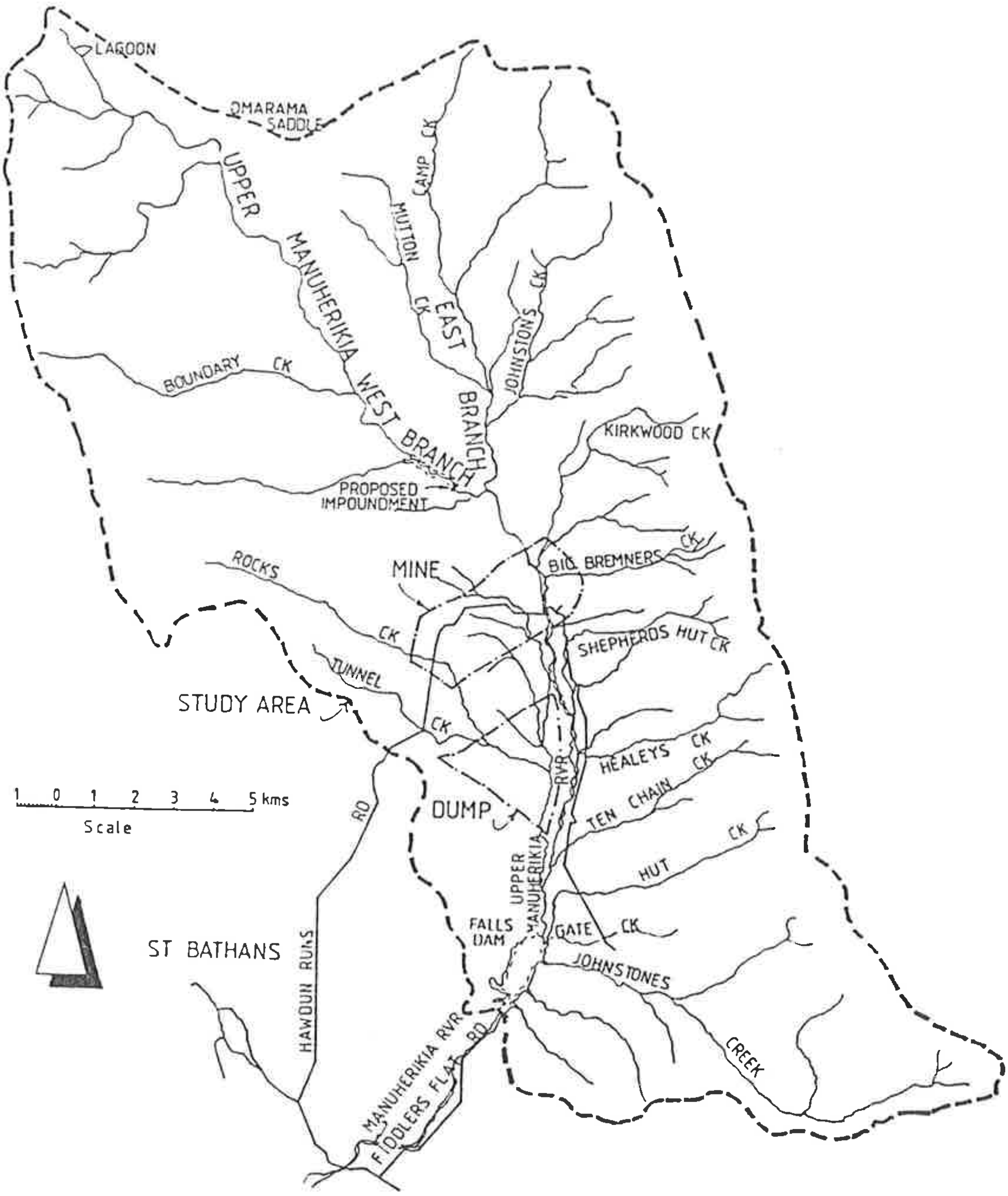

FIGURE 4. Hawkdun lignite deposit area, and proposed mine and dump sites.

3. Describe the aquatic habitats of each site.

4. Compile an inventory of principal and significant species found in the habitat types described.

5. Comment on the rare or endangered species found, or suspected to exist, within the 3 study areas.

6. Derive an 'importance index' for each habitat type. Compare each type with similar types in the area, and consider the local, regional, and national importance of each habitat. Derive a subjective importance rating for each type.

7. Comment on the possible consequences of water extraction from the Mataura and Clutha Rivers, in the cases of Ashers-Waituna and Benhar, and on water impoundment in the case of Hawkdun.

8. Derive comparative indices for each site to rank the 3 areas in terms of aquatic biological significance and the severity of impact following possible development. Develop an aquatic biology/habitat alteration matrix.

9. Outline suggested mitigative measures which could help to lessen the environmental impact on aquatic communities.

2. HABITAT DESCRIPTION

2.1 Ashers-Waituna

2.1.1 Study Area

Figure 5 shows the location of the Ashers-Waituna lignite deposit, the proposed mine site, and the associated dump area. The deposit lies under the headwaters of Waituna, Moffat, and Currans Creeks (which drain into the tidal Waituna Lagoon), and Gorge Creek, a tributary of the lower Mataura River. The boundaries of catchments that would be affected by lignite development are also shown. The wider study area, then, includes Waituna Lagoon, the lower Mataura River (the tidal zone below the confluence with Gorge Creek), and bog ponds scattered to the west and north of Waituna Lagoon.

FIGURE 5. Ashers-Waituna study area.

Geologically, the area is part of an Ice Age to Post-Ice Age outwash plain of quartz-rich river gravels which overlie a sequence of Mid-Tertiary gravels, sand, mudstone, and lignite (Department of Lands and Survey 1984a). Towards the coast, the surface cover is peat, and inland, lowland yellow-brown earths form the surface mantle. Bog ponds (tarns) are associated with the peat-covered areas.

The study area, like the whole coastal zone extending from Invercargill's Riverton Estuary to the mouth of the Mataura River, is low-lying and, until last century, was largely swamp. In the headwaters of the Waituna catchment grew podocarp-rimu forest stands, and remnants of these still exist. The advent of the dragline in the 1930s saw extensive drainage of the catchment, including stream channelisation and straightening for agricultural development. Hobbs (1940) surveyed 4 miles (6.4 km) of Waituna Creek in 1936 and stated that most of the stream was channelised. Today, the surrounding area is intensively farmed.

In 1971, in response to local concern about the diminishing number of wetlands throughout New Zealand, Waituna Lagoon, and the large area of swampland to the west of the lagoon, was designated a Reserve for Wetland Management purposes by the Department of Lands and Survey. In 1983 it was reclassified as a Scientific Reserve (Department of Lands and Survey 1984b). The Reserve is 1 of only 2 areas in New Zealand which have been listed as a "Wetland of International Importance" by the International Union for the Conservation of Nature and Natural Resources (the other being Farewell Spit at the northern extremity of the South Island). The biological features of importance identified in the Reserve include the vegetation, the waterfowl and wading bird habitat, and the eel habitat.

2.1.2 Aquatic Habitats

The Ashers-Waituna study area comprises 4 different aquatic habitat types.

2.1.2.1 Small Streams

Waituna, Moffat, Currans, and Gorge Creeks are all sluggish, single-channel, lowland streams. Where the channels have not been altered by channelisation works, they tend to meander. Present-day stream gradients range from 1:300 for Currans Creek (Fig. 6) to 1:550 for the Waituna mainstem.

The streams are typically deeply incised, with steep banks of up to 3 m in places, and stable beds. Stream sediments are predominantly white quartz gravels. Individual stones vary in size from 10 mm to 60 mm. As land development has proceeded, a deterioration in composition of stream sediments has been observed, with the beds becoming silty and even muddy in places. This has resulted primarily from agricultural use of adjacent land and from bank collapse due to stock grazing to the stream edges.

The streams themselves have a typical pool and riffle system, with pools constituting 20-50% of any given reach. The water varies in width, from 2 m in the headwaters to 7 m in the lower reaches of Waituna Creek. Water depths range from a few centimetres over riffles to 1 m in pools at normal flows.

Table 1 summarises physical characteristics and instream habitat for selected stream reaches in the study area.

FIGURE 6. Currans Creek, illustrating overhanging vegetation and stable banks.

TABLE 1. Physical characteristics of streams surveyed in the Ashers-Waituna area.

Section	Sampling date	Distance surveyed (m)	Water colour	Temp (°C)	pH	Stream width (m)	Depth range (cm)	Pools (%)	Riffles (%)	Runs (%)	Sediment (%) gravel	Sediment (%) mud	Cover	Comments
Waituna Ck S177:589018	9/4/85	30	Amber	-	-	1.0	10-30	70	30	-	60 (20-sand)	20	Good, long grass, aquatic plants	Channelised section, some bank collapse
Waituna Ck S177:553988	29/12/84	85	Clear/ brown	17.0	7.0	2.0	10-100	20	80	-	80	20	Overhanging tussock, grass, aquatic plants	Lowland stream, some bank collapse
Jordan Ck S182:589987	11/12/84	65	Murky	23.0	7.0	1.8	10-40	60	40	-	60	40	Short grass, aquatic plants	Lowland stream, channelised
Waituna Ck S182:551963	11/12/84	170	Amber	19.0	7.5	4.0	10-50	80	20	-	70 (15-sand)	15	Grass cover, aquatic plants	Lowland stream, channelised
Marr Ck S182:539707	5/12/84	100	Peaty	-	-	1.5	5-50	50	50	-	100	-	Clumps of grass, undercut banks	Lowland stream flowing from peat bog, modified by channelisation
Waituna Ck S182:513864	5/12/84	150	Blackish peat	18.5	7.3	7.0	10-40	90	10	-	95	5	Short grass	Lowland stream, modified by channelisation
Moffat Ck S182:544874	29/12/84	85	Brown	15.5	6.0	2.0	5-50	20	80	-	95	5	Overhanging grass, tussock, aquatic plants	Lowland swamp stream, stable, recently developed for agriculture
Currans Ck S182:624889	26/2/85	60	Brown	-	-	2.0	20-60	25	75	-	30	70	Good cover, flaxes, aquatic plants	Slow moving, swampy stream
Gorge Ck S182:613937	9/4/85	30	Amber	-	-	1.0	5-50	50	50	-	100	-	Short grass, aquatic plants	Low banks, channelised
Gorge Ck S182:640933	26/2/85	40	Murky	-	-	1.5	10-40	60	-	40	-	100	Short grass	Open drain, channelised, some bank collapse

None of the streams has permanent water level recorders, but, on the basis of their catchment areas and flow data from the neighbouring Waihopai catchment, mean annual flows have been estimated as 1605 l/s for Waituna Creek, 285 l/s for Moffat Creek, and 506 l/s for Currans Creek. Gorge Creek flows have not been estimated. Staff of the Southland Catchment Board (SCB) conducted low flow gaugings in these streams during the drought of March 1981, and measured flows of 2 l/s in Currans Creek (at map reference S182:610866), 9 l/s in Moffat Creek (at S182:540865), and 78 l/s in Waituna Creek (at S182:515856).

All 4 streams are classified D pursuant to the Water and Soil Conservation Act (1967) (see Appendix I), and these classifications were notified publicly in 1969. Water quality sampling of the lower reaches of Waituna Creek by the SCB in November 1980 measured a pH of 7.2, salinity of <1 $^{0}/_{0}$, a suspended solids concentration of 4.0 mg/l, turbidity of 4.0 NTU, dissolved oxygen content of 10 mg/l, and a median faecal coliform count of 480/100 ml.

The water quality of streams in the Ashers-Waituna area was sampled for the LFTB in April 1985. Some of the data are summarised in Table 2. Overall, water quality in these streams is not very high, as indicated by the values for conductivity, turbidity, BOD_5, and ammoniacal nitrogen; all streams have a naturally low pH. The quality of water in these streams reflects the intensive agriculture practised in the catchment, and in some cases does not appear to meet the standards of a Class D classification.

2.1.2.2 Waituna Lagoon

The lagoon, into which 3 of the small creeks flow (Waituna, Moffat, and Currans), is a tidal water body with a total water area of 12.82 km^2. It is elongated in shape, and shallow (less than 2 m deep at high tide, when the lagoon is open to the sea), except in the vicinity of the outlet, where the depth probably exceeds 10 m.

The lagoon bottom sediments comprise a mixture of quartz gravels, sand, peaty silts, and clays. Peaty sediments predominate at the east end (known locally as "Little Waituna"), while sand predominates in the middle ("shallows") area. Silt is deposited on the intertidal flats

TABLE 2. Water quality parameters measured in Waituna, Moffat, and Currans Creeks, April 1985.

Parameter	Waituna Creek	Moffat Creek	Currans Creek
pH	6.1	5.4	5.5
Conductivity (μS/cm)	324	210	137
Turbidity (NTU)	8.8	3.4	8.0
Suspended solids (g/m^3)	15	3	6
Dissolved oxygen (g/m^3)	9.3	7.5-9.7	8.2
BOD_5 (g/m^3)	0.4	0.5	1.0
Fe (g/m^3)	-	-	2.3
Mn (g/m^3)	-	-	0.1
Ammoniacal nitrogen (mg/m^3)	88	19-24	75

along the northern shoreline. It appears that the lagoon sediments were once predominantly quartz gravels, but with progressive land development and drainage, clays, silts, and sands have come to prevail.

The lagoon is normally open to the sea, but it closes regularly during the winter months. The water level varies by some 1.6 m between low tide, when the lagoon is open to the sea, and high tide, when the outlet is blocked. For about 50 years, local authorities and land-owners have been opening the lagoon to the sea artificially, to assist drainage, and to enable fish to move to and from the lagoon and creek system.

The waters of Waituna Lagoon were classified as SC pursuant to the Water Pollution Regulations 1963. However this classification was revised to SB in February 1982, with the exception of the small area known as "Little Waituna", into which Currans Creek drains, which remained SC. (The water quality standards set by these classifications are presented in Appendix I.)

SCB water quality sampling in Waituna Lagoon during September and October 1980 revealed very low faecal coliform counts. LFTB data collected in April 1985, when the lagoon was open to the sea, gave pH values of 6.6-7.6, conductivity of 6920 to 20 200 μS/cm, turbidity of 3.7-7.1 NTU, suspended solids of 3-5 g/m^3, dissolved oxygen of 8.8-10.3 g/m^3, a BOD_5 level of 0.5-1.1 g/m^3, an Fe level of 0.27-1.78 g/m^3, ammoniacal nitrogen of 11-74 mg/m^3, phenols of 1-7 mg/m^3, and low levels of other inorganic substances. Overall, water quality in the lagoon is good, because of regular sea water flushing.

2.1.2.3 Lower Mataura River

The 21-km reach of the lower Mataura River downstream from its confluence with Gorge Creek is tidal. The river flows into estuarine Toetoes Harbour, and enters the sea at Fortrose. At the Seaward Downs water level recorder site, the river has a mean annual flow of 98.6 m^3/s (Riddell 1984). The flow is lowest in January, February, and March, with the lowest recorded flow being 10.8 m^3/s on 19 March 1978.

The low-lying landscape and tidal influence result in the lower Mataura having a sluggish, meandering flow. It is a single-channel river, with an average surface water width of 60 m and an average depth of 6 m. The bed sediments are predominantly silts and clays, and water clarity is poor.

Toetoes Harbour has a well-defined main channel, and a surface water area of 3.45 km^2. One other tributary, Titiroa Stream, enters the estuary to the north-east. Estuarine sediments are predominantly clean gravels and sands, with some finer sediments in the inter-tidal zone. The water in the estuary is much clearer than that in the lower river.

Generally, water quality in the Mataura River above the Mataura township is good, but it deteriorates markedly downstream from the town because of effluent discharged at Mataura from a freezing works, a paper mill, a tannery, and sewage from Mataura Borough. These discharges increase water conductivity, nitrate nitrogen, ammoniacal nitrogen, BOD_5, total phosphorus, faecal coliform bacteria, turbidity, and suspended solids, and they decrease the dissolved oxygen level (McKenzie 1982, Riddell 1984). By the time the river reaches Gorge Road, the water quality has improved, but it is still much poorer than that above the Mataura township.

The lower Mataura River is classified D under the Water and Soil Conservation Act (1967), whereas Toetoes Harbour has an SC classification (see Appendix I for water quality standards). Water quality in the lower Mataura River has been a concern for the OAS and the SAS for many years. Both societies have spent considerable effort and money to quantify the biological impact of the discharges, and to improve the standard of the effluents through the imposition of more stringent legal conditions on water rights held by the dischargers.

2.2.1.2.4 Bog Ponds

Scattered over some 6 km^2 to the north-east and 9 km^2 to the west of Waituna Lagoon are numerous bog ponds or tarns. These form where the underlying peat has not been drained artificially, and the surrounding landscape has remained largely unaltered.

The tarns vary in size from 5 m^2 to 500 m^2, and are rarely more than 2-3 m in depth. Typically, they have no obvious surface inflows or outlets, and are often found perched on peat domes (Fig. 7).

2.2 Benhar

2.2.1 Study Area

Figure 8 shows the location of the proposed Benhar lignite mine and associated mine dump. The deposit lies beneath Lake Tuakitoto and the lower reaches of its tributaries, including Lovells Stream. The boundaries of the catchment affected by lignite mining are also shown on Figure 8, and this wider study area includes the whole of Lovells Stream catchment, the catchments of smaller tributaries flowing into Lake Tuakitoto, the Kaitangata contour channel, and the lower Clutha River.

Geologically, the Tuakitoto Basin and lower Clutha area are formed of glacial till, alluvial gravels, and glacial outwash gravels, with areas of peat in swampy locations (Otago Regional Water Board 1980). Schist outcrops are to be found in the headwaters of Lovells Stream, whereas greywacke and argillites form the rest of the catchments on the

FIGURE 7. Gee minnow trapping and fyke netting a bog pond at Ashers-Waituna.

western side of the basin. The coastal hills to the east are composed of conglomerates of quartz, greywacke, and schist, with sandstones, siltstones, and mudstones containing seams of lignite.

The soils of the basin are gley, gley-recent, and organic soils, whereas those on Inch Clutha (see Section 2.2.2.3) are predominantly recent soils. Yellow-grey earths mantle the downlands to the north and west, and yellow-brown earths cover the coastal hills (Otago Regional Water Board 1980).

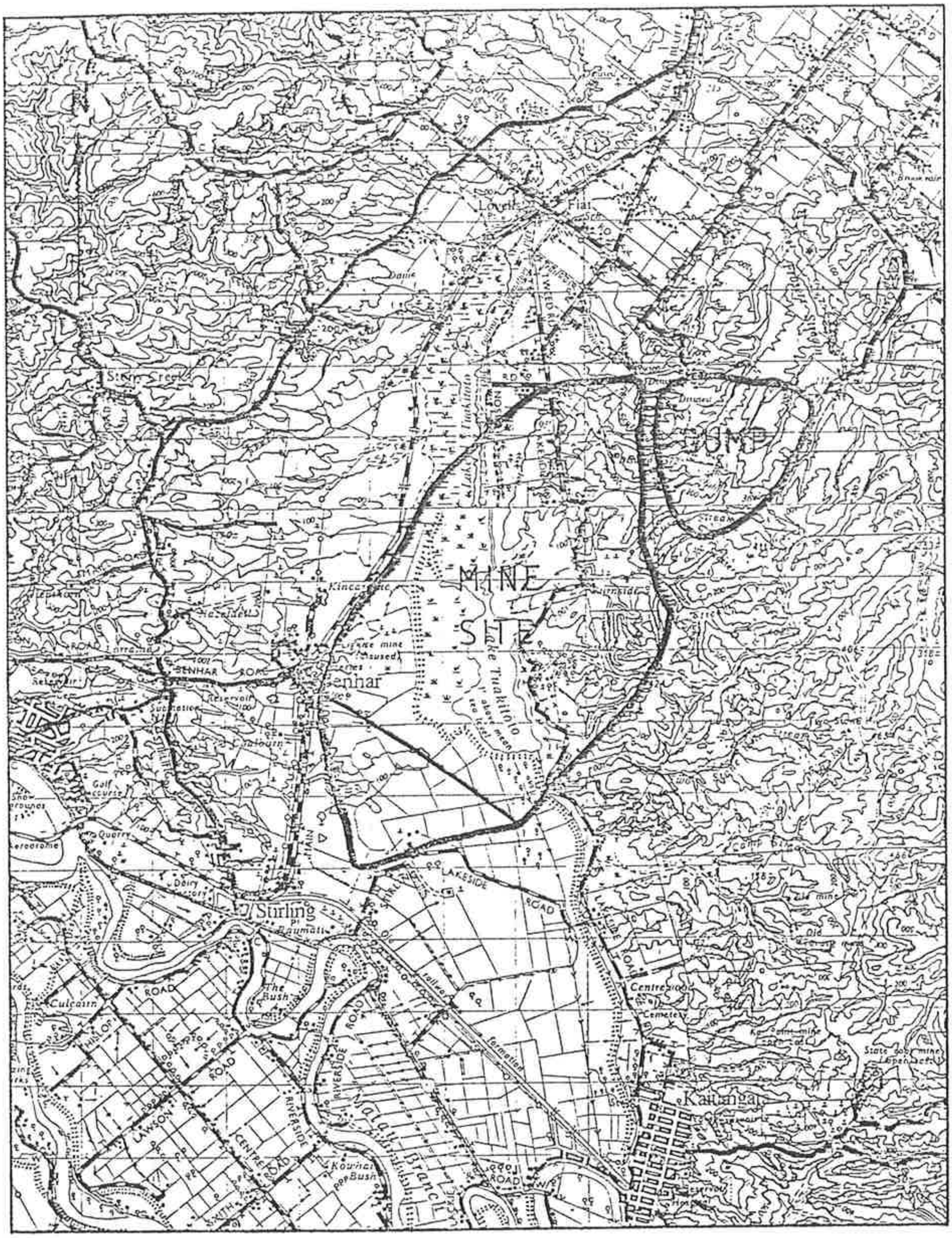

FIGURE 8. Benhar study area.

Present land use is predominantly pastoral, with dairying on the Inch Clutha and sheep farming in the rest of the catchment. Limited vegetable growing is carried out in the vicinity of the Clutha River.

The swampy, low-lying nature of the Tuakitoto basin suggests that originally this area was predominantly swamp. Land development for agriculture has led to extensive drainage, and early attempts date from late last century (Otago Catchment Board and Regional Water Board 1985). In the 1960s, the Otago Catchment Board prepared an extensive flood control and drainage scheme for Lake Tuakitoto and the lower Clutha River. The underlying philosophy of the lake drainage works was to have as much of the run-off as possible from the Tuakitoto catchment being gravity-fed to the Matau Branch of the lower Clutha River.

The principal features of this scheme were construction of the 5.5-km Kaitangata contour channel in 1967, re-routing the lake outlet stream along the eastern margin of the basin, and construction of a closure bank across the southern end of Lake Tuakitoto in 1968. This was designed to protect the low-lying land at the southern end of the lake from inundation, and led to the complete drainage of Lake Kaitangata (150 ha), as well as drainage of 223 ha at the southern end of Lake Tuakitoto. In the early 1970s, a 3-km contour channel was constructed along the western margin of the basin, to re-route Lovells Stream into Lake Tuakitoto, midway along the western margin, rather than draining into the northern end.

A set of gravity flood gates was installed in the contour channel near Kaitangata, upstream from its confluence with the Matau Branch of the Clutha River. During high water levels (at times of flood and twice every day at high tide), these gates close and prevent water from flowing back up the channel. A low-level sill was installed at the outlet to the lake (Fig. 9) to prevent the lake level from falling too low during summer, particularly for wildlife management purposes. Both structures partially restrict the passage of fish to and from the lake and upper catchment.

2.2.2 Aquatic Habitats

The Benhar study area comprises 3 different aquatic habitat types: small streams, a lake, and the Clutha River.

FIGURE 9. Control sill at the outlet of Lake Tuakitoto.

2.2.2.1 Small Streams

The many streams flowing into Lake Tuakitoto, including Lovells Stream and its main tributary, Frasers Stream, plus Saddle and Two Stone Hill Streams, Stony Creek, and other minor unnamed tributaries, are all single-channel downland or lowland-type streams, as is the lake's artificial outlet channel.

Lovells Stream, the main tributary, flows from the western catchment downlands, where it is stable, deeply incised in gullies, with a steep gradient, a rocky bed, and numerous small ephemeral inflows. Typically, the stream has a width of 3 m, a depth of 0.8 m, and a 100% boulder bed with a pool:riffle:run ratio of 40:30:30. Where it flows across the lowland plain, the character of Lovells Stream changes, because its bed has been extensively modified through channelisation works. In this reach, the stream is typically 2-3 m wide, and up to 1 m in depth (Fig. 10). Substrates are much finer, with up to 70% mud in most reaches, and gravels make up only about 20% of bed material. The flow is more sluggish, and up to 80% of the reaches are pools.

Frasers Stream, the tributary entering Lovells Stream from the east, is smaller and is channelised in its lower reaches, with ephemeral inflows towards the headwaters. The middle reaches are stable, with gravel substrates and a pool:riffle:run ratio of 30:40:30.

Stony Creek, the other major tributary of Lake Tuakitoto, which enters from the west, is similar in nature to the upper reaches of Lovells Stream.

Other tributaries entering the lake from the east are all small ephemeral streams on the downlands, but they have permanent watercourses where they flow across the low-lying swampland to the lake. They are all channelised, typically 1-2 m wide, and are sluggish in flow. Many have muddy substrates.

The Lake Tuakitoto outlet channel is a rectangular artificial channel about 11 m wide and 2 m deep. It has a sluggish flow and a mud bottom.

All Tuakitoto tributary streams are grazed by stock to their edges, which has resulted in serious bank collapse in places. Table 3 summarises the physical characteristics of selected stream reaches.

LFTB water quality data collected for Lovells Stream in 1985 indicate that agriculture in the catchment has diminished the water quality. The ranges were conductivity 127-152 μS/cm, turbidity 3-12 NTU, suspended solids 5-12 g/m^3, dissolved oxygen level 7.75-11.55 g/m^3, and BOD_5 level 0.8-2.2 g/m^3. Fe was 1.91 g/m^3, Mn was 0.32 g/m^3, ammoniacal nitrogen was 19-122 g/m^3, phenols were 1-8 g/m^3, and all other organic substances measured were present at a low level. Turbidity and BOD_5 levels are a concern in that they are approaching values detrimental to fisheries (Alabaster and Lloyd 1982).

FIGURE 10. Lower reaches of Lovells Stream.

2.2.2.2 Lake Tuakitoto

Lake Tuakitoto is a freshwater lowland lake and associated swamp, lying only 0.3 m above mean sea level. It has 4 main open-water areas: 3 small lagoons, which are connected by narrow channels, and the main lower lake, into which Lovells Stream now flows. At normal lake levels, the available habitat now totals 500 ha, compared with the original 900 ha (Watson 1984). The lake level varies by about 2.36 m between lowest and highest recorded levels (Fig. 11), and the normal level is about 1 m. Lake bottom sediments are predominantly muds and silts along the western margin, and sand along the eastern margin.

Water quality in Lake Tuakitoto is generally high, with the exception of Robsons Lagoon, the area of open water at the northern end of the lake, which no longer has any major inflows, and therefore is not flushed. Robsons Lagoon has quite a high BOD_5 level (2.8 g/m3),

TABLE 3. Physical characteristics of streams surveyed in the Benhar area

Section	Sampling date	Distance surveyed (m)	Water colour	Temp (°C)	Stream width (m)	Depth range (cm)	Pools (%)	Riffles (%)	Runs (%)	Sediment (%) boulders	gravel	sand	mud	Cover	Comments
Lovells Stream S171:568360	22/5/85	200	Clear	6.5	3.0	80	40	30	30	70	20	10	-	Overhanging banks, boulders	Gorge-like, headwater stream
Drainage Ditch S171:598348	22/5/85	200	-	7.5	1.0	70	100 (sluggish)	-	-	-	-	-	-	Choked with water cress	Drainage ditch
Lovells Stream S171:593344	18/12/84	185	Clear	-	2.0	60	70 (sluggish)	10	20	-	10	30	60	Overhanging grass bank	Channelised, lowland stream
Lovells Stream S121:594343	22/5/85	222	Clear	6.0	2.5	50	80	20	-	-	20	10	70	Aquatic plants	Channelised, lowland stream
Lovells Stream S171:591340	22/5/85	100	Clear	7.0	1.5	70	20	60	20	-	-	-	-	Aquatic plants, grasses	Channelised, lowland stream
Lovells Stream S171:592338	22/5/85	200	Clear	-	3.0	100	90	10	-	-	-	30	70	Some aquatic plants	Channelised, lowland stream
Frasers Stream S171:599341	22/5/85	70	Clear	7.0	1.0	70	30	40	30	-	50	50	-	Good, over-hanging grasses	Stable, lowland stream
Frasers Stream S171:594338	22/5/85	100	Clear	7.0	1.5	80	80 (sluggish)	-	20	-	-	10	90	Overhanging grasses, aquatic plants	Channelised stream
Drainage Ditch - Robson Rd S171:589318	17/7/84	50	Brown	-	2.0	50	100 (sluggish)	-	-	-	-	-	-	-	Channel
Saddle Stream S179:599292	17/7/84	45	Amber	-	1.0	50	40	20	40	-	40	40	20	Good, over-hanging grasses	Drainage ditch
Saddle Stream S179:591282	17/7/84	30	Brown	-	1.5	100	-	-	-	-	-	10	90	Aquatic plants	Sluggish, small stream, draining to L. Tuakitoto
Two Stone Hill Stream S179:594268	23/5/85	200	Murky	-	-	-	100 (sluggish)	-	-	-	-	-	100	Overhanging vegetation	Channelised stream

FIGURE 11. Lake Tuakitoto in winter.

a high Fe content (5.5 g/m^3), a high Zn level (6 g/m^3), and a Mn level of 1.48 g/m^3. The main body of Lake Tuakitoto sampled for the LFTB in April 1985 had a pH of 7.3-7.6, a dissolved oxygen level of 9 g/m^3, high conductivity of 200 μS/cm, a BOD_5 level of less than 1 g/m^3, and ammoniacal nitrogen of 70 mg/m^3. All other inorganic substances sampled were present at low levels.

2.2.2.3 Lower Clutha River

Downstream from Balclutha, the Clutha River divides into 2 branches, northern (Matau) and southern (Koau), which flow each side of an island known as Inch Clutha. Both have their own outlets (mouths) to the sea, but are connected by a channel behind a coastal sand spit, known as the Puerua estuary. This section of the lower Clutha offers a total length of 44.7 km of large river habitat, with at least an additional 6.3 km of backwaters and ponded areas to the south of the Koau Branch where the river mouth was located before 1878 (Otago Catchment Board and Regional Water Board 1985). Tidal influence extends up-river to about 0.5 km above Kaitangata on the Matau Branch, and to an equivalent distance upstream on the Koau Branch. The Lake Tuakitoto contour channel enters the Matau Branch approximately 7 km upstream from its mouth.

The Koau Branch channel is typically more than 150 m wide, and 2 m deep. The Matau Branch channel is typically 130 m wide and 3.5 m deep. Bottom sediments of both branches range from coarse gravels upstream to fine silts and sands at the mouth. Sands and silts predominate from about Stirling downstream.

Generally, the Clutha River upstream from Balclutha has high quality water. Below Balclutha, 3 main discharges (effluent from the Finegard Freezing Works discharged into the Koau Branch, effluent from the Stirling dairy factory discharged into the Matau Branch, and sewage from Balclutha Borough, which is discharged at 2 sites upstream from where the river splits into 2 branches), have lowered the water quality (Otago Catchment Board and Regional Water Board 1985).

Water quality sampling in the Matau Branch for the LFTB in 1985, downstream from Kaitangata, measured a pH of 7.1, conductivity of 68.5 $\mu S/cm$, turbidity of 10-13 NTU, a suspended solid level of 33-34 g/m^3, a dissolved oxygen level of 10 g/m^3, a BOD_5 level of 0.5-0.8 g/m^3, Fe at 0.91 g/m^3, phenols of 3 mg/m^3, and an ammoniacal nitrogen level of 16-18 mg/m^3. All other inorganic substances measured were present at low levels.

This one-off sample suggests that water quality is lower than it should be, although it appears to be sufficent for the fishery to thrive.

2.3 Hawkdun

2.3.1 Study Area

The Hawkdun lignite deposit, proposed mine, and dump are shown in Figure 12. The deposit underlies and straddles the mainstem of the upper Manuherikia River, one of its major tributaries (Rocks Creek), and several minor tributaries. The boundaries of the wider study area are also shown, and these encompass the whole of the upper Manuherikia River system and the Falls Dam reservoir.

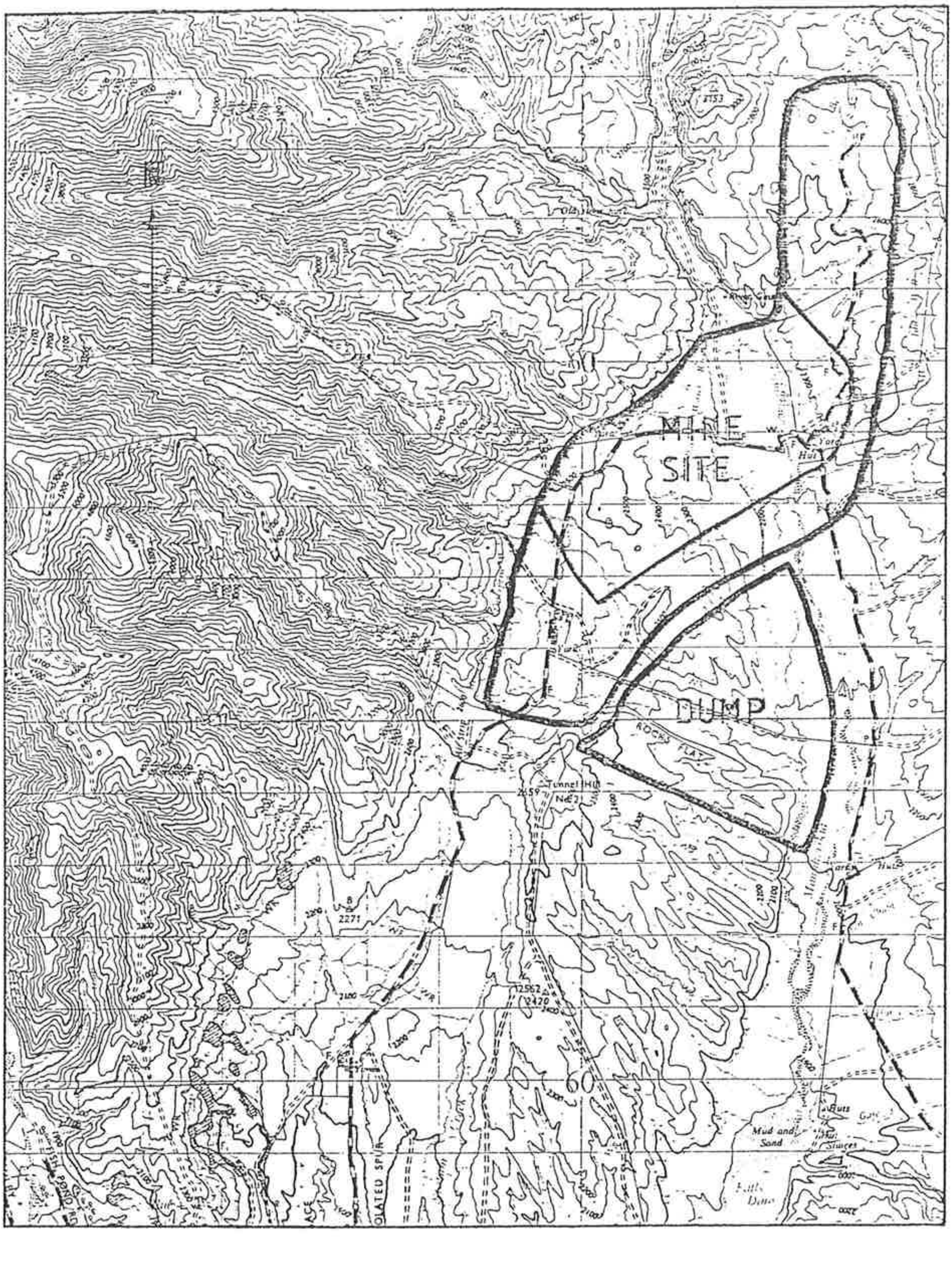

FIGURE 12. Hawkdun study area.

Geologically, the upper Manuherikia catchment is a sequence of Mesozoic greywacke and argillite, overlain in the valley floor by a Mid-Tertiary non-marine sequence of sands, silts, clays, gravels, and lignite. The soils range from yellow-grey earths in the semi-arid zone to high country steepland yellow-brown earths in the humid zone, with recent shallow and stony soils on the flood plain (Centre for Resource Management 1982).

Historically, the streams of the area have provided water for goldmining, and to the present day they provide water for irrigation in the lower Manuherikia and Ida Valleys, and in the Maniototo district. The NZMS1 map series St. Bathans sheet (S125) shows 4 main water race systems in the upper Manuherikia. On the west side of the valley, there are 3 races (Otago, Scandinavian, and the Mountain and Enterprise), none of which is operating. On the east side of the valley, the Mt. Ida water race draws water from a series of tributaries and provides irrigation for the Ida Valley and Maniototo districts.

The Falls Dam reservoir supplies water for the Omakau and Manuherikia irrigation schemes. Completed in 1935, the dam stands 33.5 m above the stream bed. The structure has a "glory hole" spillway, which prevents upstream movement of fish, but not downstream movement. The reservoir level is governed by irrigation requirements and associated mining privileges. During the irrigation season, water is used only if necessary to meet scheme requirements. In some years, this has meant that the reservoir has been emptied completely, although the Manuherikia River continues to flow through the reservoir in its original channel. Outside the irrigation season, residual flows to the Manuherikia are provided for, but there are no defined operating rules.

Recently, the Ministry of Works and Development (MWD) in the Dunedin district has investigated the possibility of raising Falls Dam to increase the reservoir storage capacity and the volume of water available for irrigation (OAS file note 1981). This proposal would raise the dam by 24.4 m, which would increase the reservoir area substantially, and the water would be backed up to Ten Chain Creek (see Fig. 12). An increase in the residual flow of 1 m^3/s below Falls Dam has also been considered.

Traditionally, the study area has been grazed extensively, mostly by sheep, but also by a small number of cattle (Centre for Resource Management 1982). The natural tussock vegetation has been oversown with introduced grasses and clover in parts of the study area to increase agricultural production.

The extensive (as opposed to intensive) land use practices of the past have left the upper Manuherikia River and tributaries largely in their natural state. They are mostly stable, unmodified streams, and this, together with their relative isolation, gives the upper Manuherikia Valley an unspoilt, wilderness quality (Fig. 13).

FIGURE 13. Upper Manuherikia Valley and Falls Dam reservoir.

2.3.2 Aquatic Habitats

The Hawkdun study area comprises 3 dominant habitat types: small tributary streams, a large river, and an impoundment.

2.3.2.1 Upper Manuherikia River Mainstem

Below the confluence of the East and West Branches, the upper Manuherikia mainstem is slightly braided. It has a stable boulder and gravel bed, and low banks (Fig. 14). Mean annual flow at the MWD water level recording site (S125: 620059) is 12 m^3/s. Snow melt from the surrounding ranges makes the mean flow highest between September and November, and the lowest flows are recorded from February to April. The lowest daily flow recorded was 0.7 m^3/s on 6 April 1976. Under normal flow conditions, the river is swift and clear.

FIGURE 14. Upper Manuherikia River.

Below the confluence of the East and West Branches, the river is typically 2 m wide and 0.1-0.6 m deep, with a bed of 80% gravel and 20% boulders. It has overhanging banks, but few pools. Further downstream, in the vicinity of Hawkdun Runs Road bridge (S125: 628039), the stream bed composition is similar, and the flow is turbulent. Riffles and runs predominate, with water up to 0.8 m deep. Towards the Falls Dam reservoir, the river varies in width from 4 m across riffles to 15 m across runs. There are few pools along the whole mainstem. Table 4 summarises the physical characteristics and habitat features of reaches surveyed in 1985.

The waters of the upper Manuherikia can best be described as pristine. Samples taken for the LFTB in April 1985 showed a naturally low pH of about 6.3, and low conductivity, suspended solids, turbidity, BOD_5, ammoniacal nitrogen, phenols, and all other inorganic substances sampled. Dissolved oxygen levels exceeded 10.5 g/m^3. The lower Manuherikia River, downstream from Falls Dam, was also sampled. Although the water quality was poorer than that above the reservoir, it was still very good.

2.3.2.2 Tributary Streams

The upper Manuherikia mainstem is fed by a series of small tributary streams which have their headwaters in the Hawkdun and St. Bathans Ranges. Several of these tributaries are fed in their lower reaches by springs arising on the valley floor. Each has unique characteristics, providing a variety of habitat types (Fig. 15). Physical characteristics and habitat features of reaches surveyed in 1985 are summarised in Table 4.

Above Falls Dam, Johnstones Creek is the first true left-bank tributary, and it enters the upper reaches of the Falls Dam reservoir. It meanders in its upper reaches, and it then flows through a gorge to the reservoir. It has a well-developed pool and riffle system, with stable banks and overhanging vegetation.

Moving upstream from the Falls Dam reservoir, Gate Creek is the first stream to enter the Manuherikia River. This stream is shallow, and is spring-fed from a marshy area in the upper reaches. It has a constant flow and an even temperature.

TABLE 4. Physical characteristics of streams surveyed in the Hawkdun area

Section	Sampling date	Distance surveyed	Water colour	Temp (°C)	Stream width (m)	Depth range (cm)	Pools (%)	Riffles (%)	Runs (%)	Sediment (%) boulders	gravel	sand	other	Cover	Comments
Unnamed Trib S116:612101	12/6/85	80	Clear	-	0.6	50	10	30	60	30	20	10	40 (Cobbles)	Overhanging tussock and banks	-
East Branch S116:612100	12/6/85	80	Clear	6.5	-	-	-	-	-	-	-	-	-	-	-
Johnstons Ck S125:612092	6/3/85	35	Clear	15.0	3.5	25	-	-	-	15	85	-	-	Boulders	Alpine stream
Manuherikia mainstem S125:620059	6/3/85	40	Clear	14.5	-	50	-	-	100	20	80	-	-	Boulders, some overhanging banks	Upland river
Kirkwoods Ck S125:632070	5/3/85	33	Clear	13.0	2.5	35	5	5	90	5	90	-	5 (Bedrock)	Overhanging banks, some boulders	-
Little Bremner Ck S125:639065	12/6/85	100	Clear	-	1.0	50	10	10 (and 20% torrent)	60	20	60	-	20 (Cobbles)	Overhanging banks	Snow and spring-fed high country stream
Big Bremner Ck S125:635049	5/3/85	42	Clear	19.0	1.0	25	65	-	35	60	35	5	-	Overhanging banks, boulders, aquatic plants	-
Manuherikia mainstem S125:628034	5/3/85	35	Clear	17.0	-	70	-	50	50	10	90	-	-	Overhanging banks, boulders	Upland river
Rocks Ck Trib S125:626013	13/6/85	80	Clear	8.0	1.5	100	10	10	80	10	50	-	40 (Cobbles)	Overhanging vegetation	Spring-fed high country stream
Rocks Ck Trib S125:630996	6/3/85	31	Clear	17.0	5.0	70	-	30	70	60	40	-	-	Overhanging banks, boulders, aquatic plants	Spring-fed stream
Rocks Ck S125:613003	5/3/85	45	Clear	14.5	1.3	50	10	25	65	20	80	-	-	Overhanging banks, boulders	High country stream
Tunnel Ck S125:596003	6/3/85	15	Brown, dirty	14.0	1.0	30	25	10	65	-	100	-	-	Overhanging banks, boulders	Small stream
Rocks Ck S125:632973	6/3/85	44	Clear	17.0	7.0	50	20	20	60	10	90	-	-	Overhanging banks	-
Ten Chain Ck S126:661985	12/6/85	80	Clear	-	2.0	50	20	60	20	20	50	10	20 (Cobbles)	Limited	Snow and spring-fed high country stream
Gate Ck S125:634946	12/6/85	110	Clear	5.6	1.0	90	-	-	-	5	95	-	-	Abundant bank and aquatic vegetation	Snow and spring-fed stream

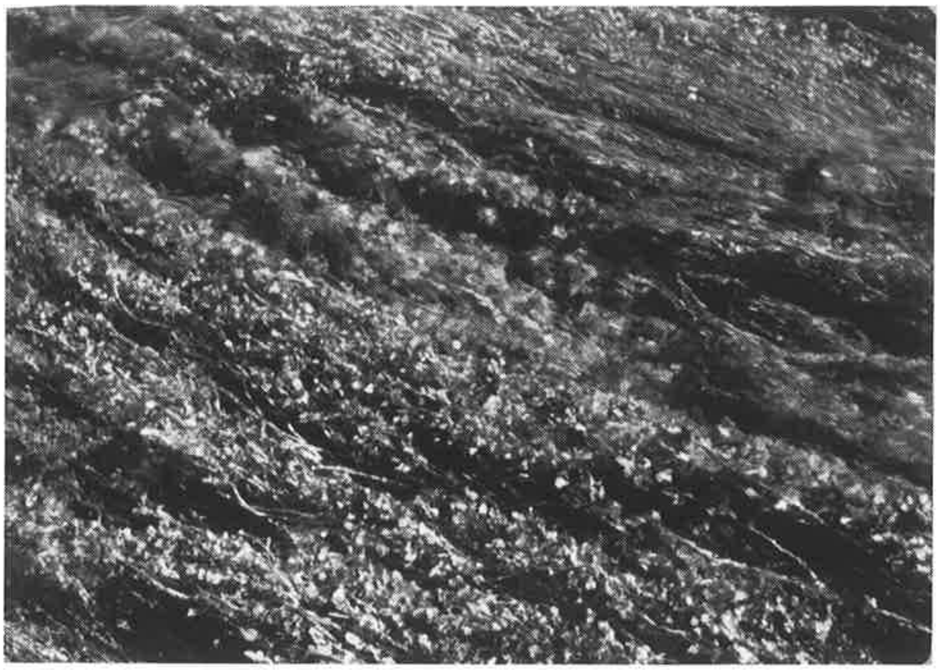

FIGURE 15. Spring-fed creeks on the valley floor support diverse aquatic macrophytes.

Hut and Ten Chain Creeks are similarly small, partly spring-fed, streams. Ten Chain Creek is known to dry up in its lower reaches, whereas Hut Creek, although it has good bank cover, tends to dry up in the middle and lower reaches in summer.

Healeys Creek is a significant left-bank tributary (Fig. 16). This small, turbulent, rocky stream is fed by snow melt, except for its lower reaches, where a series of spring-fed streams enter it. The stream bed, largely boulders, is a series of riffles and runs, with few pools. It averages 1.5 m in width and 0.4 m in depth. The lower reaches have good bank cover, and the stream bed there is predominantly gravel.

Trinity Creek offers little habitat for fish, because it frequently runs dry.

Shepherds Hut Creek also dries up in its lower reaches. However, it has a well-developed pool and riffle system downstream, and water remains in the pools during dry spells. In its lower reaches, the stream is typically 1 m wide and 1 m deep.

FIGURE 16. Stable stream margins of red tussock on Healeys Creek.

Little and Big Bremner Creeks have all their water abstracted in the upper reaches by the Mt. Ida water race, and so offer little in the way of fish habitat, although the lower reaches of Big Bremner Creek do carry water throughout the year. They are, on average, 1 m wide and up to 0.25 m deep. Stream bed sediments are 60% boulders, 35% gravel, and 5% sand.

Kirkwoods Creek also feeds the Mt. Ida water race, but it flows most of the year because of the springs in its lower reaches. It has a well-developed system of pools and riffles, and averages 2.5 m in width. Its depth is up to 0.4 m, and 90% of its bed material is gravel.

The East Branch of the Manuherikia is typically wide (up to 9 m), and shallow. It has a gravel and boulder bed, with some good pools. Camp and Johnstons Creeks are its major tributaries. Both are typical high country streams, with Johnstons Creek having a gravel and boulder bed, and good bank cover.

The West Branch has numerous minor tributaries. The mainstem is typically 6 m wide, with a well-developed pool and riffle system (Fig. 17). Its deepest pools reach 2.5 m, and its runs are usually about 1 m deep. It flows fast over a gravel bed, with some overhanging banks.

FIGURE 17. Confluence of East and West Branches of the Manuherikia River.

Rocks Creek lies further downstream along the true right bank of the Manuherikia mainstem. This stream is the largest tributary in the upper reaches, and it flows into the Manuherikia River above the Falls Dam reservoir. Rocks Creek arises in the St. Bathans Range, where it is turbulent and rocky, and it then flows across the valley floor for some 10 km. In this region, it varies in width from 1.5 m to 4 m, and its depth exceeds 0.5 m. The stream has a well-developed pool, riffle, and run system, with a bed of 80% gravel and 20% boulders, and overhanging banks. A spring-fed tributary of Rocks Creek originates along an old river terrace to the north. This stream has a constant flow, an average width of 4 m in the lower reaches, and water depths ranging up to 1 m. It consists of riffles and runs, with a bed of 60% boulders and 40% gravel. Tunnel Creek is the other major tributary of Rocks Creek. This stream also has a well-developed profile of pools, riffles, and runs, with a predominantly gravel bed and overhanging banks.

Like the upper Manuherikia mainstem, water quality in tributary streams sampled for the LFTB in April 1985 was very high. The dissolved oxygen level exceeded 10.5 g/m^3, whereas conductivity, BOD_5, suspended solids, turbidity, and inorganic substances were all measured at low levels.

2.3.2.3 Falls Dam Reservoir

The lake environment created by the Falls Dam reservoir has a surface area of 150 ha when full, and a maximum water depth of 33.5 m at the dam wall. Its storage capacity is 10.3 million million m^3 (G.N. Martin pers. comm.). Reservoir bed sediments consist of mud and silts overlying coarse gravels. The reservoir has been emptied completely during 3 of the last 5 summers (1981, 1982, and 1985) by irrigation demands and repairs to the dam wall.

2.3.2.4 Lower Manuherikia River Mainstem

Below Falls Dam, the Manuherikia River runs through a gorge for 5 km to Fiddlers Flat, where it opens out and flows over an open gravel bed, with dense stands of willow lining the banks in many areas. In this 33-km reach, the river is slightly braided and commonly suffers from extremely low flows during summer, because of water abstraction for irrigation. Jellyman (1984) noted that the monthly mean flow of the river from December to March has been reduced from 11.8 m^3/s to 3.7 m^3/s by water abstraction. Below Ophir, the river flows through another gorge for 11 km, before opening out and flowing over a wider gravel channel for the remaining 15 km to its confluence with the Clutha River at Alexandra.

3. SAMPLING METHODS

Aquatic biology studies of the lignite sites nominated by the LFTB for investigation required the use of a range of sampling methods, both to sample the flora and fauna at each site adequately, and to allow for a variety of aquatic habitats to be sampled. Sampling methods used by the OAS and the SAS to collect data from these areas before this survey are also described below.

3.1 Electric Fishing

Electric fishing surveys were carried out using both a generator-powered, pulsed-DC, electric fishing machine (Burnet 1959), and a battery-powered, back-pack electric fishing machine (Bonnett 1986). These surveys aimed to develop an inventory of fish species, to determine their distribution, and to assess their relative abundance.

The catch from each survey site was placed in a bucket containing a benzocaine solution, and, once anaesthetised, the fish were measured, identified by species, and released. Where identification could not be completed in the field, specimens were preserved in 10% formalin for later laboratory identification.

Specific sampling procedures at each study area varied, depending on site conditions.

3.1.1 Ashers-Waituna

The deep, sluggish streams of the Ashers-Waituna site were surveyed by making 2 passes with an electrode in a downstream direction into a stop net. Stunned fish were collected in dip nets and from the downstream stop net (Fig. 18).

3.1.2 Benhar

Electric fishing of tributary streams was carried out following the procedures outlined in Section 3.1.1 above. Only the generator-powered electric fishing machine was used, as the back-pack machine was

FIGURE 18. Electric fishing the lower reaches of the Waituna Creek.

found to be ineffective in the more conductive waters of this lowland coastal site (Fig. 19).

Lake margins and other lake and swamp survey sites were electric fished by mounting the generator machine on high ground, adjacent to the survey site, and by using dip nets to collect the fish.

3.1.3 Hawkdun

In shallow tributary streams suited to electric fishing, survey sections were chosen and stop nets placed at both the upstream and downstream ends (Fig. 19). One pass was then made with the electrode in an upstream direction, and stunned fish were collected in hand-held dip nets. In larger streams, such as the mainstem Manuherikia River, the shallow margins were electric fished in an upstream direction without the use of stop nets, whereas deeper, swifter waters were electric fished in a downstream direction, either into a stop net fastened to the bank at either end, or into a hand-held stop net of 0.8 m x 0.8 m.

FIGURE 19. Electric fishing in Lovells Stream, Benhar, and Rocks Creek, Hawkdun.

This site was surveyed further in June 1985 using the back-pack machine. In this case, stop nets were not used, and stunned fish were captured in hand-held dip nets.

Earlier electric fishing survey work by the OAS during 1979-84 was carried out either as described above, or by making 2 passes with the electrode in an upstream direction through sections which were secured at the upstream and downstream ends by stop nets.

3.2 Netting

Netting was the preferred method for sampling fish species in the standing water bodies associated with each lignite site: Waituna Lagoon, Lake Tuakitoto, and the Falls Dam reservoir. In addition, some netting was done in Toetoes Harbour. Captured fish were handled as described in Section 3.1.

3.2.1 Seine Netting

Seine netting at Waituna Lagoon and in Toetoes Harbour was carried out at 3 sites, using a 30 m x 3 m beach seine with 13-mm stretch mesh. The net was fitted with 2 10-m-long bridles and 24-m-long hauling ropes. Sample sites were chosen for their freedom from snags, and for the availability of a suitable shore on which to land the net. The net was set in a semicircle from the back of an aluminium dinghy and then pulled ashore. One set was made at each sampling site.

At the Falls Dam reservoir, a 40.0 m x 4.5 m beach seine net of 12-cm stretch mesh was used. The net had a central 13.0 m x 3.2 m panel of 10-mm stretch mesh attached over the larger mesh, and was fitted with 2 2-m-long bridles and 100 m-long hauling ropes. Because the reservoir level was very low, the dinghy could not be launched and the net had to be set by a survey party member wearing chest waders (Fig. 20). Three sets were made along the reservoir shore near the mouth of the Manuherikia River.

Seine netting was not suitable for Lake Tuakitoto because of the muddy bed and the presence of many snags, as well as the lack of a suitable shore onto which a seine could be hauled.

FIGURE 20. Seine netting at the Falls Dam reservoir.

3.2.2 Fyke Netting

Fyke netting was the principal method used to sample fish at Lake Tuakitoto and was used also in Waituna Lagoon.

At Waituna Lagoon, single-winged commercial fyke nets were set overnight for a minimum of 12 hours. This choice was governed solely by the availability of equipment. At Lake Tuakitoto, double- and single-winged commercial fyke nets were set overnight at a variety of sites. Times of setting and lifting varied, but the nets were always set for a minimum of 12 hours (Fig. 21). At both sites, eels were counted and identified by species, but not measured. Other fish species were anaesthetised and measured as described in Section 3.1.

3.3 Trapping

Gee minnow traps were used to sample fish species at 2 of the 3 lignite sites - Ashers-Waituna and Benhar. The traps were made of 5-mm

FIGURE 21. Lifting a fyke net from Lake Tuakitoto.

galvanised-wire mesh and consisted of 2 cylindrical baskets, 15 cm in length, tapering from 20 cm in diameter at one end to 15 cm at the other (see Fig. 7).

The larger ends butted and locked together, and there was a cone-shaped entry port at either end of the trap when it was assembled (Davis *et al.* 1983). The traps were usually baited with a small quantity of commercial fish food in pellet form, placed in a perforated plastic vial attached within the trap.

3.4 Benthic Invertebrates

Benthic invertebrates are an important component of the aquatic fauna. Sampling was carried out in each study area to determine the species present, their distribution, and their relative abundance.

3.4.1 Surber Sampling

Benthic invertebrate samples were taken using a standard 0.0625 m^2 Surber sampler in riffles adjacent to the electric fishing survey sections. At Ashers-Waituna, replica samples were taken, but at the Benhar and Hawkdun sites, only 1 sample was taken at each survey section. Samples were preserved in 10% formalin for laboratory sorting and identification using a binocular microscope.

3.4.2 Dredge Sampling

A stainless steel 195 mm x 195 mm Ekman dredge was used to sample benthic invertebrates from standing waters at each lignite site. An aluminium dinghy was used to sample a range of water depths and substrate types. The sediments were sieved through a 1.0-mm sieve, and the organisms were stored in 10% formalin for laboratory sorting and identification using a binocular microscope.

3.5 Aquatic Plants

In the course of other survey work, aquatic plants and those terrestrial or emergent plants which contributed significantly to aquatic habitats were noted and identified. Samples of plants which could not be identified in the field were taken back to the laboratory.

3.6 Zooplankton

Plankton samples were taken in the standing waters of Waituna Lagoon and Lake Tuakitoto, using twin nets of 203-micron mesh with 29.5-mm diameter openings, mounted on each side of a small boat, as described by Eldon and Greager (1983). Each site was sampled only once, to give an indication of the species present and their relative abundance. After the tow, the nets were washed and their contents preserved in 10% formalin for laboratory analysis and identification. One of the purposes of plankton sampling was to determine the presence of larval stages of freshwater, estuarine, or marine fish species.

3.7 Spawning Surveys

Spawning surveys were conducted from late April to July. Survey teams walked along the banks of streams or representative sections of streams in each study area, counting trout redds and noting the extent of gravels with water depths and velocities considered to be suitable for salmonid spawning. Only 1 survey was carried out at Ashers-Waituna and Hawkdun during the study period, but at Benhar 2 were conducted, a month apart. Data from earlier spawning surveys caried out by the OAS and the SAS have also been included in this report.

3.8 Creel Surveys

To assess angler use and catch on rivers in the study areas (Mataura, Clutha, and Manuherikia), representative sections were chosen and surveyed on 1 weekday and 1 weekend day per month during the open angling season (October to April inclusive). The lower Clutha River, which has a winter fishing season, was sampled with a similar frequency from May to September inclusive.

Creel surveys have also been carried out on Waituna Lagoon and the Falls Dam reservoir. At Waituna Lagoon, the SAS conducted a creel survey during the 1963/64 angling season. The lake was divided into 3 zones, and was surveyed on weekends and weekdays from 1 October 1963 to 2 February 1964. At the Falls Dam reservoir, surveys were conducted during several fishing seasons by the OAS on 1 weekend day per month throughout the open fishing season. Surveys covered the whole reservoir whenever possible. In most instances, all anglers present at the time of the survey were interviewed, but in some isolated cases, only up to 80% of anglers were covered. Thus, the results probably underestimated catch and effort.

Creel surveys of both standing and flowing waters involved interviewing anglers present, and determining duration of fishing, angling methods, category of licence, and district of issue. Anglers' catches were checked and all fish taken and kept were measured. Data were also collected on fish taken and released, but this information was not used for the calculation of catch rates.

3.9 Expert Interviews

Local residents and people known to have special knowledge of the study sites were interviewed. They were also asked to identify other people with expert knowledge of the area, especially about local history and any commercial, recreational, or traditional fisheries. These people in turn were interviewed, and were also asked to identify others with expert knowledge. Information was also sought from government departments, local bodies, and angling clubs.

4. FISH STOCKS

4.1 Ashers-Waituna

4.1.1 Background

The Maori word "Waituna" translates into "water of eels", and the lagoon and its tributary streams were thought to be favourite fishing areas of the Maori. Traditionally, whitebait have been fished for to a limited extent at the mouth of Waituna Creek during spring, and flounders are sought within the lagoon itself.

The lower Mataura River and Toetoes Harbour are renowned for their whitebait fishery, which has been exploited since early this century. At that time, phenomenal catches were reported there, measured by the 5-gallon bucketful (L. Lobb pers. comm.). Pressure on the resource has increased, with about 350 stands being in place during the 1984 season. Whitebaiting is done on both an amateur and a commercial basis, and although catch data are not available, SAS considers that the area supports by far the most important whitebait fishery in Southland.

The earliest official records of the SAS (undated) indicate that 1500 brown trout fry *(Salmo trutta)* were liberated into the Waituna system in 1900. Earlier liberations may have occurred and the possibility of sea-run trout from another source becoming established cannot be discounted. Nevertheless, it appears that the species was well established and self-sustaining by 1918, when very successful trout angling was reported there (R.R. Sutton pers. comm.). Other releases of brown trout fry were known to have occurred in 1953 and 1954 (25 000 in each year) and in 1956 and 1961 (20 000).

Although many early records of fish stocking have been lost, 25 000 rainbow trout fry *(Salmo gairdnerii)* are known to have been liberated in the Waituna catchment in 1922. However, this species did not become established.

As early as 1940, Hobbs highlighted the importance of the Waituna system for brown trout spawning and rearing. He described a brown trout trapping programme on Waituna Creek from April to July 1936, when 1904 brown trout were trapped, 1177 of which were females averaging 2.8 kg in weight. His original field notes indicated that fish up to 4.3 kg were trapped, and he described Waituna Creek as being "both remarkable for the size of the spawning run which enters it and also because being essentially a nursery stream it offers no angling. Angling is limited to the rip-tide at the outlet of the lagoon" (Hobbs 1940).

In 1961, the SAS successfully trapped spawning brown trout in Waituna Creek to procure ova for hatchery purposes; 250 000 eggs were obtained and hatched at Te Anau. From 1966 to 1970, the then N.Z. Marine Department investigated brown trout spawning in Waituna Lagoon and its 3 tributaries. The trapping exercise led to the conclusion that spawning brown trout were mostly 4- and 6-year-old females and 4-year-old males. In addition, the SAS conducted spawning surveys of Waituna Lagoon tributaries in 1964, 1966, 1970, 1978, 1979, and 1984. (This information is presented in Section 4.1.3.2.)

Brown trout fry were released into the Mataura system as early as 1871, and Witherow and Scott (1984) considered that brown trout were well established throughout the Mataura River by 1890. By 1927, more than 2 million brown trout fry had been released into the Mataura River and tributaries. The SAS has no records of trout releases into Gorge Creek.

The Waituna and Mataura brown trout populations are self-sustaining, and have been for many years, so that artificial stocking is no longer necessary. In fact, the SAS no longer artificially stocks any of the rivers under its statutory control; natural recruitment is considered to be sufficient to maintain populations where the habitat is suitable.

4.1.2 Species Composition, Distribution, Life Histories, and Habitat Requirements

Information on fish species present in Waituna Creek was obtained from electric fishing surveys carried out by the SAS in January 1979

(Table 5), and during the study period. Electric fishing was also carried out in Moffat, Currans, and Gorge Creeks. Gee minnow traps and fyke nets were used at less accessible sites in these tributary streams, and seine nets were used in Waituna Lagoon and Toetoes Harbour. The sampling sites are shown in Figure 22, and the results are presented in Appendix II.

Table 6 summarises the relative abundance of fish species recorded in each ecosystem surveyed. Within the study area were found 11 native and 2 introduced freshwater species, and 7 marine or estuarine species. The life history and migratory habits of each species are described briefly in Tables 7 and 8.

Freshwater fish species which migrate between fresh and salt water at some stage of their life cycle are termed diadromous. Those which migrate upstream to spawn are termed anadromous, whereas those which migrate downstream to do so are termed catadromous (McDowall 1976). Of the 18 truly freshwater species recorded during this study, 14 are diadromous and must reach the sea to complete their life cycles, and 4 reside in fresh water throughout their life histories (brook char, perch, common river galaxias, and upland bully). Two species (brown trout and quinnat salmon) can be separated into sea-run and freshwater-resident stocks. Both sea-run and freshwater trout are caught by anglers in Waituna Lagoon and the lower Mataura River. Freshwater quinnat salmon do not reside in any of the 3 study areas.

4.1.2.1 Brown Trout *(Salmo trutta)*

This species was caught in Waituna Lagoon and in all of the small streams sampled except Moffat Creek. It is known to be abundant in the lower Mataura River and Toetoes Harbour. Of the 10 sites electric fished (Section 10.2), trout were the dominant species at the 2 upper Waituna Creek sites. Generally, brown trout were abundant in Waituna Creek, but fewer were recorded from both Currans and Gorge Creeks.

The value of the small streams as nursery areas for brown trout is highlighted by the electric fishing data. Assuming that trout shorter than 100 mm hatched in spring 1984, catches show that the streams hold predominantly 0+ fish, and only a small number of older fish. The 2

TABLE 5. Waituna electric fishing survey results, 1979

Creek	Map reference	Species present
Waituna	S177:628069	Brown trout (fingerlings), long-finned eel, inanga, bully spp.
Waituna	S177:614032	Brown trout (fingerlings), long-finned eel, giant kokopu
Waituna	S177:589017	Brown trout (fingerlings), long-finned eel, inanga, giant kokopu, bully spp.
Waituna	S177:576007	Brown trout (fingerlings), inanga, bully spp.
Waituna	S177:576006	Brown trout (fingerlings), inanga, bully spp.
Waituna	S177:553988	Brown trout (fingerlings), long-finned eel, inanga, bully spp., black flounder
Waituna	S182:553963	Brown trout (fingerlings), inanga
Marr	S182:543913	Brown trout (fingerlings), long-finned eel, bully spp.
Marr	S182:518892	Brown trout (fingerlings), long-finned eel, inanga, bully spp.

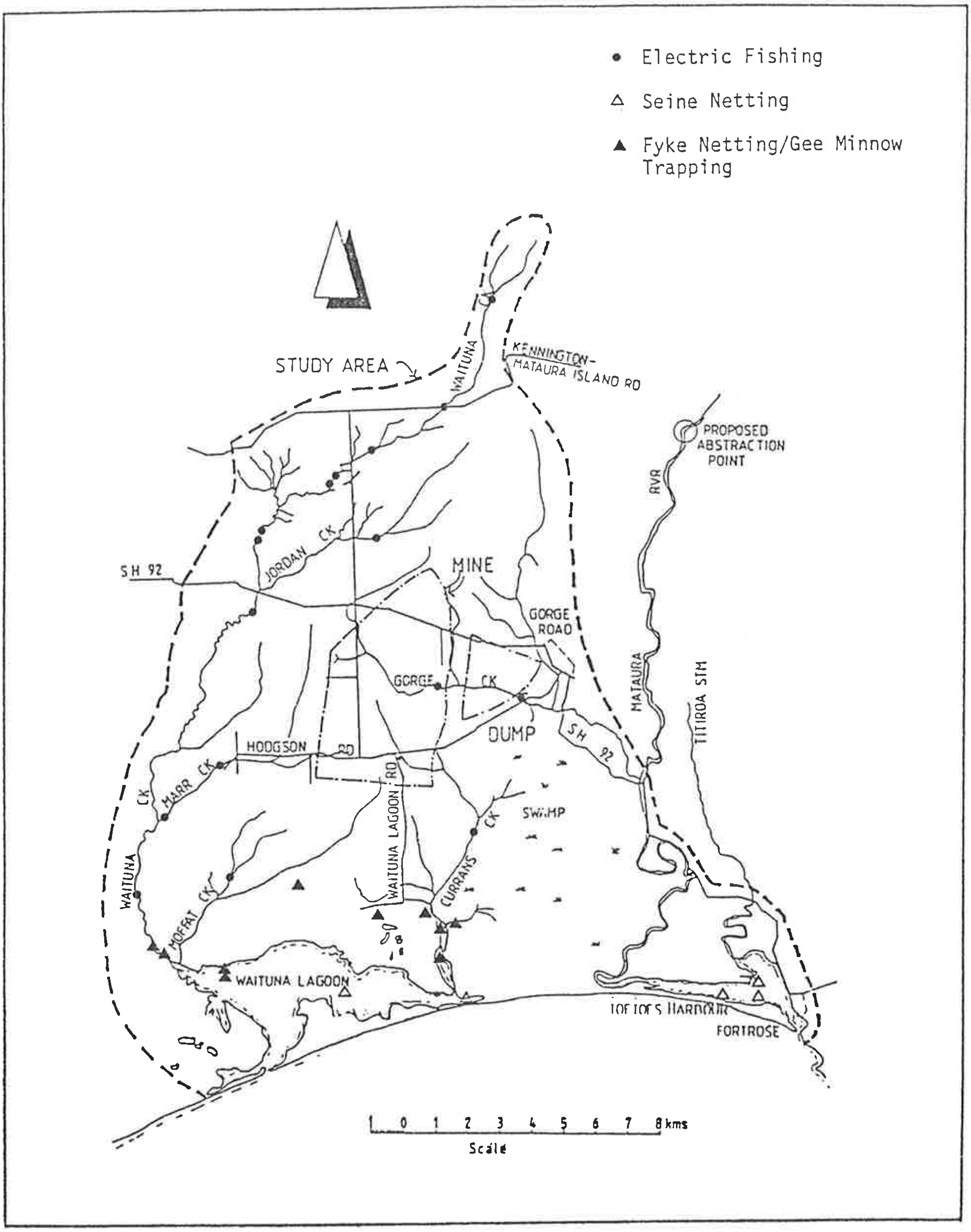

FIGURE 22. Ashers-Waituna sampling sites.

TABLE 6. Relative abundance of fish species in the Ashers-Waituna study area

Species	Waituna Creek	Moffat Creek	Currans Creek	Waituna Lagoon	Bog Ponds	Gorge Creek	Mataura River and Toetoes Harbour
Brown trout	****	-	**	****	-	***	*****
Perch	-	-	-	-	-	-	****
Long-finned eel	*****	****	****	**	-	*****	*****
Sbort-finned eel	-	-	-	***	-	-	***
Lamprey	*	-	-	-	-	-	**
Common bully	*****	****	****	*****	-	***	***
Upland bully	-	-	-	-	-	**	-
Red-finned bully	**	*	-	-	-	-	-
Inanga	*****	*****	***	****	-	**	*****
Giant kokopu	*	**	**	-	-	-	*
Banded kokopu	*	-	-	-	-	-	*
Common smelt	*	-	-	*****	-	-	***
Black flounder	**	-	-	*****	-	-	***
Yellowbelly flounder	-	-	-	****	-	-	****
Sand flounder	-	-	-	***	-	-	**
Cockabully	-	-	-	**	-	-	**
Yellow-eyed mullet	-	-	-	-	-	-	**
Kahawai	-	-	-	*	-	-	**
Stargazer	-	-	-	-	-	-	**
Parrotfish	-	-	-	-	-	-	*
Freshwater crayfish	**	-	-	-	*****	**	-

***** Abundant.
**** Common.
*** Frequent.
** Occasional.
* Rare.
- Not recorded.

TABLE 7. Generalised life histories of fish species recorded from the 3 study areas

Fish species	Adult habitat	Adult migration and reproduction	Juvenile habitat and migration	Occurrence
INTRODUCED FISH				
Brown trout (*Salmo trutta*)	Streams, rivers, lakes.	Some populations resident. Adults migrate upstream to spawn in gravel beds, April to July.	Some populations resident. Fry or 1+ fish migrate downstream Sept. to Dec. or as fingerlings in autumn.	* # †
Brook char (*Salvelinus fontinalis*)	Headwater streams.	Resident, do not migrate. Spawn autumn and early winter.	Resident, do not migrate.	#
Perch (*Perca fluviatilis*)	Slow flowing rivers and lakes.	Resident, do not migrate. Spawn on aquatic weeds or debris, Sept. and Oct.	Resident, do not migrate.	* †
Quinnat salmon (*Oncorhynchus tshawytscha*)	Marine. East and West coasts of South Island and some South Island lakes.	Enter fresh water Nov. to June. Migrate upstream to spawn in tributary streams.	Migrate downstream for most of the year. Juveniles may remain in fresh water up to a year, before going to sea.	†
NATIVE FISH				
Long-finned eel (*Anguilla dieffenbachii*)	NZ wide in all waters.	Resident populations. Mature adults migrate to sea in autumn for breeding.	Glass eels enter fresh water in late winter or spring. Elvers migrate upstream in summer.	* †
Short-finned eel (*Anguilla australis*)	NZ wide, coastal waters.			
Lamprey (*Geotria australis*)	Streams, rivers, lakes. Adults parasitic on marine fish.	Adults enter fresh water during winter and spring to spawn in stream gravels.	Resident in silty backwaters before migrating to sea in late autumn and winter.	* †

TABLE 7. (ctd.)

Fish species	Adult habitat	Adult migration and reproduction	Juvenile habitat and migration	Occurrence
NATIVE FISH (ctd.)				
Common smelt (*Retropinna retropinna*)	Found in the sea, lower river reaches, and in some lakes.	Migrate upstream to spawn, probably on sandy/ silty stream and estuary beds in spring and summer.	Newly-hatched larvae washed to sea to return the following spring.	* †
Common river galaxias (*Galaxias vulgaris*)	Found in streams and rivers in Otago, Southland, and Canterbury.	Resident, do not migrate. Spawn in spring.	Resident in same habitat as adults.	#
Banded kokopu (*Galaxias fasciatus*)	Found in coastal streams and lakes.	Probably do not migrate far to spawn. Spawn in fresh water in autumn.	Newly-hatched larvae washed to sea. Return to rivers as whitebait in spring.	*
Koaro (*Galaxias brevipinnis*)	NZ wide, usually in small, rapidly flowing, forested streams.	Do not migrate, spawn in fresh water in autumn and early winter.	Larvae migrate downstream to sea in autumn/winter. Return as whitebait in spring.	†
Giant kokopu (*Galaxias argenteus*)	Coastal streams, lowland swamp streams, coastal lakes.	Probably do not migrate far to spawn. Spawn in fresh water in autumn/early winter.	Newly-hatched larvae washed to sea. Return to rivers as whitebait in spring.	* †
Inanga (*Galaxias maculatus*)	Abundant in slow-flowing lowland streams, swamps, and lagoons.	Mature adults migrate downstream to estuaries in late summer/autumn. Spawn at spring tides on terrestrial plants.	Newly-hatched larvae washed to sea. Return to rivers as whitebait in spring.	* †

TABLE 7. (ctd.)

Fish species	Adult habitat	Adult migration and reproduction	Juvenile habitat and migration	Occurrence
NATIVE FISH (ctd.)				
Red-finned bully (*Gobiomorphus huttoni*)	Found mainly in rocky streams near the coast.	Resident, do not migrate. Spawn in winter/early spring. Eggs attached to underside of rocks.	Larvae washed to sea. Juveniles migrate upstream during spring and summer.	*
Common bully (*Gobiomorphus cotidianus*)	Found in lowland rivers, lakes, and streams, and inland lakes.	Resident, do not migrate. Spawn spring/early summer; eggs laid in gravel nests.	Larvae washed to sea or lakes. Juveniles migrate upstream late spring/summer.	* †
Upland bully (*Gobiomorphus breviceps*)	Found in SI, and southern NI, in all waters.	Resident, do not migrate. Spawn spring/early summer. Eggs attached to underside of boulders/debris.	Larvae and juveniles live and develop in fresh water near where spawned, or in still or slow flowing waters.	* #
Giant bully (*Gobiomorphus gobioides*)	NZ wide, in coastal streams, rivers, and estuaries.	Do not migrate. Spawning behaviour uncertain.	Not known. Probable that larvae washed to sea and juveniles enter fresh water in spring/summer.	†
Black flounder (*Rhombosolea retiaria*)	NZ wide in coastal rivers and lakes.	Migrate to sea to spawn in winter.	Juveniles return to fresh water in spring.	* †
Yellowbelly flounder (*Rhombosolea leporina*)	Marine fish, but found in estuaries and lowland reaches of rivers.	Spawn in spring in shallow marine waters, including estuaries.	Juveniles inhabit shallow waters and move to deeper waters as they mature.	*
Sand flounder (*Rhombosolea plebeia*)	NZ wide. Marine fish, but occurs in estuaries.	Marine.	Marine.	*

TABLE 7. (ctd.)

Fish species	Adult habitat	Adult migration and reproduction	Juvenile habitat and migration	Occurrence
NATIVE FISH (ctd.)				
Cockabully (*Tripterygion nigripenne*)	Common along rocky seashores and river estuaries. A marine species.	Resident; time of spawning varies according to location but occurs during spring and summer.	Little is known about the larval or juvenile stages of this species.	*
Yellow-eyed mullet (*Aldrichetta forsteri*	Marine fish, but common in tidal river estuaries in shoals on the rising tide.	Spawning occurs at sea, probably in early summer and autumn.	Juveniles reside in similar habitat to adults.	* †
Kahawai (*Arripis trutta*)	Marine/estuarine species. NZ wide, coastal seas and estuaries.	Spawn at sea in late spring/summer. Common in estuaries in summer months.	Resident at sea.	* †
Stargazer (*Leptoscopus macropygus*)	NZ wide, in coastal seas, river estuaries, and lowland reaches of rivers.	Probably spawn at sea.	Habitat as for adult fish.	*
Parrotfish (*Pseudolabrus celidotus*)	Marine species, occasional estuarine visitor.	Marine.	Marine.	*

* Ashers-Waituna
† Benhar
\# Hawkdun

TABLE 8. Seasonality of freshwater fish spawning and migrations

Season	Adult upstream migration	Adult downstream migration	Adult spawning	Juvenile downstream migration	Juvenile upstream migration
Spring	Common smelt Lamprey	Brown trout	Perch Common smelt Lamprey Common bully Upland bully Common river galaxias Red-finned bully Yellowbelly flounder	Brown trout (fry) Common smelt (larvae) Common bully (larvae) Quinnat salmon (fry)	Eel (glass eels) Giant kokopu Inanga Red-finned bully Common bully Black flounder Banded kokopu Koaro Giant bully
Summer	Quinnat salmon		Common bully Upland bully Cockabully Yellow-eyed mullet Common smelt	Quinnat salmon (fingerlings)	Eel (elvers) Red-finned bully Common bully Giant bully
Autumn	Brown trout Quinnat salmon	Eels Giant kokopu Inanga Banded kokopu	Brook char Giant kokopu Inanga Yellow-eyed mullet Banded kokopu Koaro Quinnat salmon	Brown trout (fingerlings) Inanga (larvae) Lamprey Quinnat salmon (fingerlings)	
Winter	Brown trout	Black flounder Brown trout	Red-finned bully Brown trout Black flounder Brook char Lamprey Koaro	Giant kokopu (larvae) Banded kokopu (larvae) Quinnat salmon (fingerlings)	

largest fish (510 mm and 470 mm) were caught in Waituna Creek. At all other sites (with the exception of Jordan and Currans Creeks), at least 1 fish between 100 mm and 225 mm in length was caught. However, electric fishing is not an efficient technique for catching larger trout, and sub-adult fish may be more abundant than these data suggest. During the spawning season (May to July), large numbers of adult brown trout are present throughout these small streams. Trout were caught in both pools and riffles, but were most common around gravel bars and riffles.

Only 2 trout were caught by seine netting in the lagoon, 1 juvenile and 1 larger fish. Little can be concluded from this sampling, but angling records verify that the lagoon is an important adult brown trout habitat (see Section 4.1.4.1).

4.1.2.2 Perch *(Perca fluviatilis)*

Perch are found in the lower Mataura River, and they are considered to be common there. The sluggish waters of the Mataura offer an ideal habitat and adequate spawning areas. These fish reach takeable size, and are fished for to a limited extent. Perch are wholly freshwater fish, and do not enter the sea or estuaries where the salinity is high (McDowall 1978). None have been reported in Toetoes Harbour, nor in Waituna Lagoon or its tributaries (A. Russell pers. comm.).

4.1.2.3 Long-finned Eel *(Anguilla dieffenbachii)*

This species was abundant in all of the small streams in the study area, and was recorded from Waituna Lagoon. Little is known of the number present in the lower Mataura River, although they are known to be present there and in Toetoes Harbour. None were captured in the bog ponds sampled.

At all of the electric fishing sites, eels varied in size from very small elvers (100 mm) to large adults (750 mm). Gee trapping and fyke netting produced fish from 385 mm to 547 mm. The wide variation in size and abundance suggests that the area supports a stable eel population.

Eels were caught primarily in pools, where they used overhanging banks and aquatic vegetation for cover. Those caught in the black, peaty waters of Currans Creek were very dark in colour. All of the small streams of the Waituna system provide good habitat for juvenile and adult long-finned eels.

4.1.2.4 Short-finned Eel *(Anguilla australis)*

Short-finned eels were caught only in Waituna Lagoon, where the 5 adults that were taken ranged in size from 380 mm to 920 mm. They are also known to be present in the lower Mataura River, and probably in Toetoes Harbour. They are usually found in lowland coastal waters, and although they were not recorded from the lower reaches of the Waituna creeks, they are probably present there.

This species was less common than the long-finned eel. Although it was found in Waituna Lagoon in only small numbers, the habitat that the lagoon offers for adults and probably for juveniles is valuable for maintaining eel stocks.

4.1.2.5 Lamprey *(Geotria australis)*

Only 1 lamprey was caught, in Marr Creek (Fig. 23), a mature female 400 mm long. Adult lampreys migrate upstream from the sea in spring and early summer to breed, and a greater number would probably have been caught if that period had been sampled. They are thought to die after spawning (McDowall 1978).

Adult lampreys are known to be present seasonally in the lower Mataura River, where large upstream runs take place during the spring. Their spawning migration is the basis for a traditional Maori fishery at Mataura Falls (Todd 1979), although this resource is rarely exploited today (G. Te Au pers. comm.).

4.1.2.6 Common Bully *(Gobiomorphus cotidianus)*

As their name suggests, common bullies were widespread and abundant in the Waituna system at all of the sites electric fished, with the exception of Jordan Creek and Gorge Creek at Ashers Road, and in

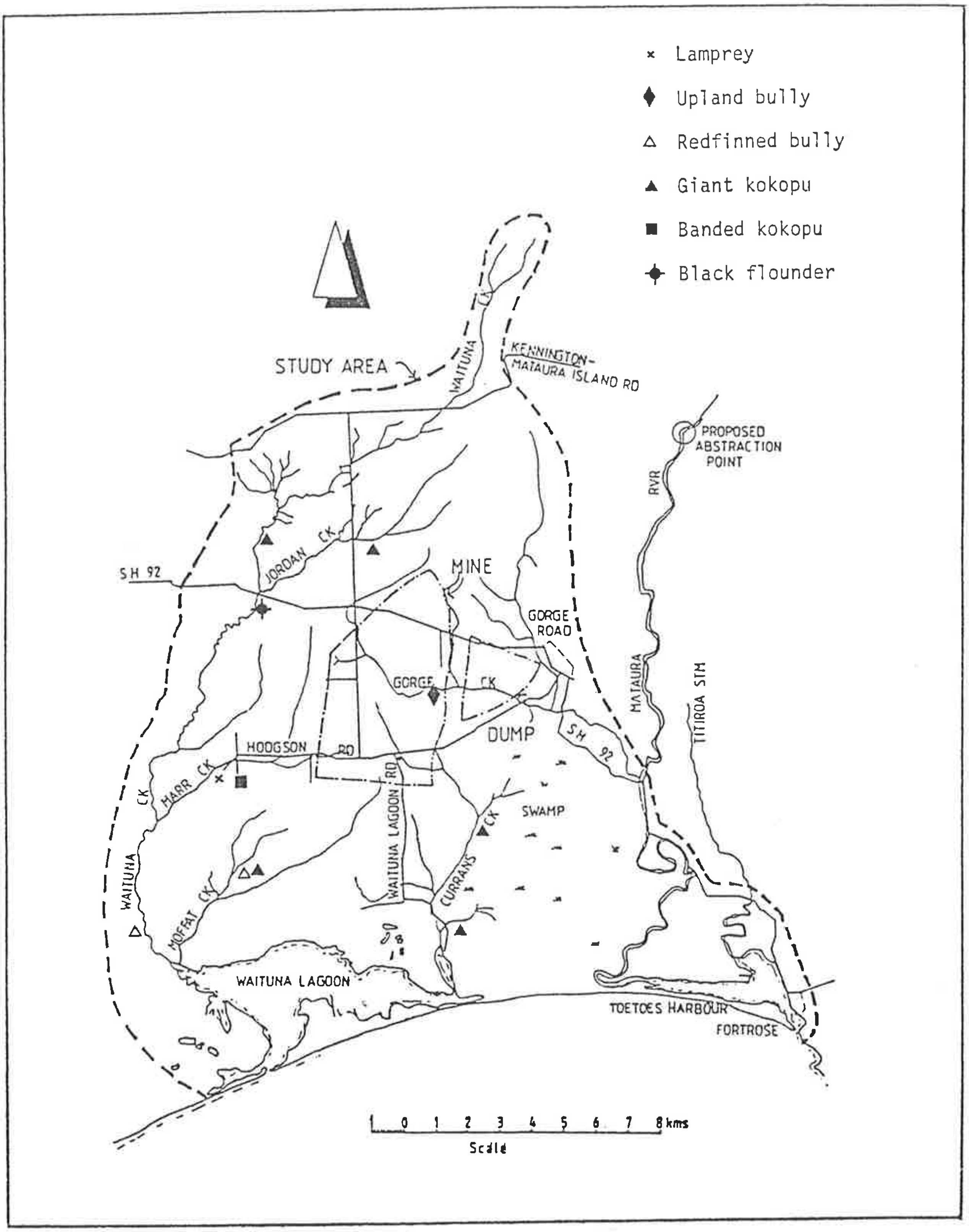

FIGURE 23. Distribution of uncommon fish species in Ashers-Waituna streams.

Waituna Lagoon. They were particularly common in Marr and Currans Creeks, and in lower Waituna Creek at map reference S182:513864. The species is undoubtedly present in the lower Mataura River, and probably in Toetoes Harbour.

Fish sizes ranged from 30 mm to 108 mm, including juveniles and mature adults. A full range of sizes was found, both in the streams and in the lagoon. The very large fish caught in lower Waituna Creek were particularly noteworthy. In the streams, they were caught in the shallow margins of pools, amid aquatic vegetation which they use for cover, but they appeared to be equally well-adapted to the shallow, open water of Waituna Lagoon.

4.1.2.7 Upland Bully *(Gobiomorphus breviceps)*

Two adult specimens (50 mm and 60 mm) were caught from a riffle in Gorge Creek at Ashers Road (S182:613937) (Fig. 23), but the species was absent from all other sampling sites.

4.1.2.8 Red-finned Bully *(Gobiomorphus huttoni)*

Eleven adult fish were caught (Fig. 23), 1 in Moffat Creek, and the rest in Waituna Creek at the section furthest downstream that was electric fished (S182:513864). None were caught in Waituna Lagoon, Currans, or Gorge Creeks. Thus, they appear to be restricted to the most coastal sections of the Waituna tributaries.

This species favours rapidly flowing, bouldery streams which provide good cover, but small populations are to be found in gravelly, weedy streams (McDowall 1978). Fish caught during this study were generally found in pools.

4.1.2.9 Giant Kokopu *(Galaxias argenteus)*

Giant kokopu were caught at 4 of the electric fishing sites: Jordan, Moffat, and Currans Creeks, and the middle reaches of Waituna Creek (Fig. 23). They were also netted in a small tributary of Currans Creek at map reference S182:615857, but were absent from Gorge Creek and Waituna Lagoon. Seventeen fish were caught in total, ranging in size from 103 mm to 490 mm, and all were adults (Fig. 24). Although

FIGURE 24. Giant kokopu caught by fyke net from a tributary of Currans Creek.

the lower Mataura River was not sampled during this study, giant kokopu are also known to reside there, and are occasionally caught by anglers (L. Lobb pers. comm.).

Giant kokopu are usually found in coastal lowland creeks, and they favour streams with good cover such as debris in the water or overhanging banks (McDowall 1978). In the Waituna system, this was certainly the case, as all were caught in pools with plenty of cover. McDowall (1978) suggested that giant kokopu are not compatible with brown trout and are usually found only where trout are rare or absent. The electric fishing data support this hypothesis, as the largest numbers of kokopu were caught in Moffat Creek and a tributary of Currans Creek, where there were no trout. McDowall (1978) stated that "The Giant Kokopu now seems rare....Decline of the Giant Kokopu in developed areas can be attributed largely to loss of cover..." This has arisen with the development of adjacent land for agriculture and is almost certainly true in the Waituna system, where kokopu were reportedly once very common (R. McNaughton pers. comm.). McDowall believes that the giant kokopu should be regarded and treated as a threatened species. As well as habitat, their survival depends on freedom for the juveniles to return from the sea to fresh water during spring, as part of the whitebait run.

4.1.2.10 Banded Kokopu *(Galaxias fasciatus)*

This species was caught at 1 locality only, Marr Creek (S182:539907), where 3 adults were caught in pools (Fig. 23). These fish mainly favour forested (but some swampy) streams with good cover, so it is somewhat unusual that they should be found in the Waituna system. Nevertheless, Allen (1951) noted that banded kokopu "appears to have found a secondary habitat in very small streams flowing through grassland, which are deeply entrenched and have relatively good pools ... [where] its shade requirements are probably provided by long grass overhanging and often almost completely hiding the streams." Juveniles of this species are also part of the whitebait run, so freedom for them to return from the sea is essential. Populations are known to exist in small tributary streams of the lower Mataura River (A. Russell pers. comm.).

4.1.2.11 Inanga *(Galaxias maculatus)*

Inanga were found at all of the sites electric fished, with the exception of Waituna Creek at map reference S177:589018, as well as in Waituna Lagoon. However, their absence from the Waituna Creek site is probably due to the fact that this site was sampled later than the others (April), after the downstream spawning migration.

Inanga were common, particularly in Moffat and Waituna Creeks, where large numbers were recorded in the lower reaches (sites S182:513864 and S182:551963). At these 3 sites, inanga were the dominant species. Fish caught by all sampling methods varied in size from 55 mm to 115 mm, and all were adults.

Inanga are usually found in shoals in open, gently flowing or still waters (McDowall 1978). They inhabit a diversity of habitats - clear waters, swamps, and estuaries. In the Waituna system they were found in all water types, and were most common within pools in the streams surveyed. They were abundant in Toetoes Harbour and the lower reaches of the Mataura River.

Inanga are the most important species in the whitebait catch, and freedom to move to and from the sea is essential for them to complete their life cycle.

4.1.2.12 Common Smelt *(Retropinna retropinna)*

Only 1 common smelt was caught in a stream (lower Waituna Creek, site S182:513864), but the species was abundant in Waituna Lagoon. Two seine netting hauls in the lagoon caught 382 specimens, making this the dominant species caught. The fish ranged in size from 67 mm to 110 mm. McDowall (1978) noted that in sea-going populations such as this one, the adults are usually longer than 70 mm.

Waituna Lagoon obviously offers an ideal habitat for common smelt. Their absence from the streams is probably due to the time of year when the electric fishing was carried out. Had the streams been surveyed in spring or early summer, larger numbers could have been expected as the fish moved upstream in shoals to spawn.

4.1.2.13 Black Flounder *(Rhombosolea retiaria)*

Black flounders were found at 1 site in Waituna Creek (middle reaches at S181:551963) and in Waituna Lagoon (Fig. 23). In Waituna Creek, 6 fish were caught in quiet pools, and these ranged in size from 110 mm to 190 mm. At the 2 sites seine netted in the lake, 28 fish were caught and positively identified, ranging in size from 32 mm to 380 mm (Fig. 25). In addition, 176 juveniles were caught, but these could not be positively identified as any 1 of the 3 species of flounder living in the lake: black, yellowbelly, and sand flounders. Waituna Lagoon and Toetoes Harbour both provide good adult and nursery habitat for flounders. Flounders do not spawn in fresh water, but juveniles migrate into rivers and estuaries from the sea while they are still small. Black flounders can penetrate inland for a considerable distance (McDowall 1978).

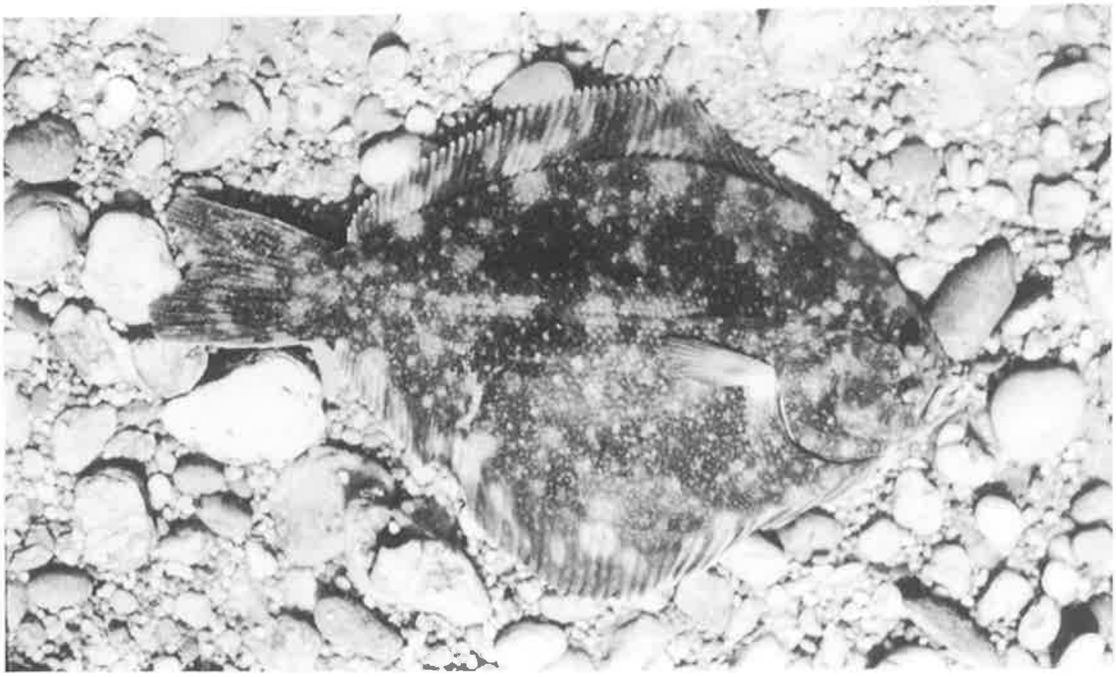

FIGURE 25. Adult black flounder caught by seine net in Waituna streams.

4.1.2.14 Yellowbelly Flounder *(Rhombosolea leporina)*

This marine species is commonly found in estuaries and coastal lakes, such as Waituna Lagoon. They were less common than black flounders, as only 3 were caught (135 mm, 147 mm, and 380 mm in length).

4.1.2.15 Sand Flounder *(Rhombosolea plebeia)*

Adults and juveniles of this marine species were found in Waituna Lagoon, suggesting that it provides suitable habitat for both.

4.1.2.16 Cockabully *(Tripterygion nigripenne)*

Cockabullies were found in Waituna Lagoon and probably live also in the lower reaches of the Mataura River and in Toetoes Harbour. They are essentially a marine species, but are common in estuaries. Six adult specimens were caught in the lagoon. These fish prefer a habitat with good rocky cover (McDowall 1978), which is rare in Waituna. All of the fish were caught in shallow, open water.

4.1.2.17 Yellow-eyed Mullet *(Aldrichetta forsteri)*

Three specimens were caught in Waituna Lagoon (92 mm, 105 mm, and 120 mm) and the species also inhabits the lower Mataura River and Toetoes Harbour. It is essentially a marine species, usually found in shoals in coastal waters, but it is commonly found in tidal river estuaries and may penetrate into fresh water (McDowall 1978). Galloway *et al.* (1971) reported netting mullet from Waituna Lagoon in 1967 and 1970.

4.1.2.18 Stargazer *(Leptoscopus macropygus)*

This marine species is found in the lower Mataura River and Toetoes Harbour, and has been reported from Waituna Lagoon (Galloway *et al.* 1971). The sandy substrate of Toetoes Harbour obviously suits its burrowing habits. The specimens found were generally small (about 100 mm).

4.1.2.19 Parrotfish *(Pseudolabrus celidotus)*

This marine species is a rare visitor to Toetoes Harbour and was recorded on only 1 occasion.

4.1.2.20 Kahawai *(Arripis trutta)*

This marine fish is occasionally taken by anglers when Waituna Lagoon is open to the sea (R. McNaughton pers. comm.), and is also a regular visitor to Toetoes Harbour (A. Russell pers. comm.).

4.1.2.21 Freshwater Crayfish *(Paranephrops zealandicus)*

Only a few freshwater crayfish, or koura, were found in Marr Creek, but they were abundant in the 2 bog ponds netted. All size classes were present in the ponds, ranging in length from 35 mm to 135 mm (Fig. 26). Some of the larger specimens were mature females with eggs.

In streams, koura are generally found in shallow water at the margins, hiding under banks. The shallow, well-vegetated bog ponds (see Fig. 7) provide this species with suitable habitat for all phases of their life cycle, and the populations found there were large.

FIGURE 26. Freshwater crayfish caught in bog ponds at Ashers-Waituna.

4.1.3 Spawning

To ensure the survival of fish species, adequate spawning habitat is essential.

4.1.3.1 Native Fish

New Zealand's native freshwater fish fauna retains strong links with the sea. Of the 27 native species which can be regarded as true residents of fresh water, 16 need access to the sea at some stage of their life history. Some species spawn in fresh water and their eggs or larvae are washed to sea, whereas others spawn at sea and their juveniles migrate into fresh water. Little is known about the spawning of native fish within the study area, except that documented life histories suggest that several of the species present probably spawn there and require adequate habitat. The spawning requirements of native fish recorded in the study area are summarised in Table 9.

TABLE 9. Spawning requirements of native fish

Species	Spawning requirements
Lamprey	Use stream gravels to create a nest for their eggs in spring
Common bully	Use stream gravels to create a nest for their eggs in spring/summer
Upland bully	Use instream rocks, logs, debris for attaching their eggs to in spring/summer
Red-finned bully	Use instream rocks, debris for attaching eggs to from July to November
Inanga	Spawn in estuaries, deposit eggs on marginal vegetation during full tides in summer/autumn
Giant kokopu	Spawn in lower reaches of streams in autumn/early winter
Banded kokopu	Spawn in lower reaches of streams in autumn/early winter
Common smelt	Spawn in estuaries, eggs sink to mud or sand in spring/summer
Flounder spp.	Probably use estuarine waters for spawning

4.1.3.2 Introduced Fish

Perch, which are found in the lower Mataura, spawn in fresh water during spring. No spawning surveys have been done in the study area, but perch are known to be prolific egg producers, and will use a variety of habitats, including aquatic macrophytes, submerged logs, and tree roots, to which they attach long ribbons of eggs.

The SAS has carried out detailed surveys of brown trout spawning in Waituna, Moffat, and Currans Creeks, and historical data are available for 1964 (July), 1966 (July), 1970 (June), 1978 (June), 1979 (June), and 1984 (June). In June 1985, as part of these studies, another spawning survey was completed, which included part of Gorge Creek.

Brown trout spawning in Waituna Creek can best be described as spectacular, in terms of the number of redds constructed. The creek has an adequate supply of well-oxygenated water, which is needed within the gravels where the redds are situated (Fig. 27).

FIGURE 27. Brown trout spawning gravels in Waituna Creek.

Trout spawning areas at Ashers-Waituna are shown in Figure 28, and results of the spawning surveys are presented in Section 10.3. Figure 29 shows total redd counts for Jordan, Moffat, and Currans Creeks and for the small Waituna Creek tributaries, for the years surveyed. Total spawning increased dramatically from 1964 to 1985, particularly in Jordan Creek.

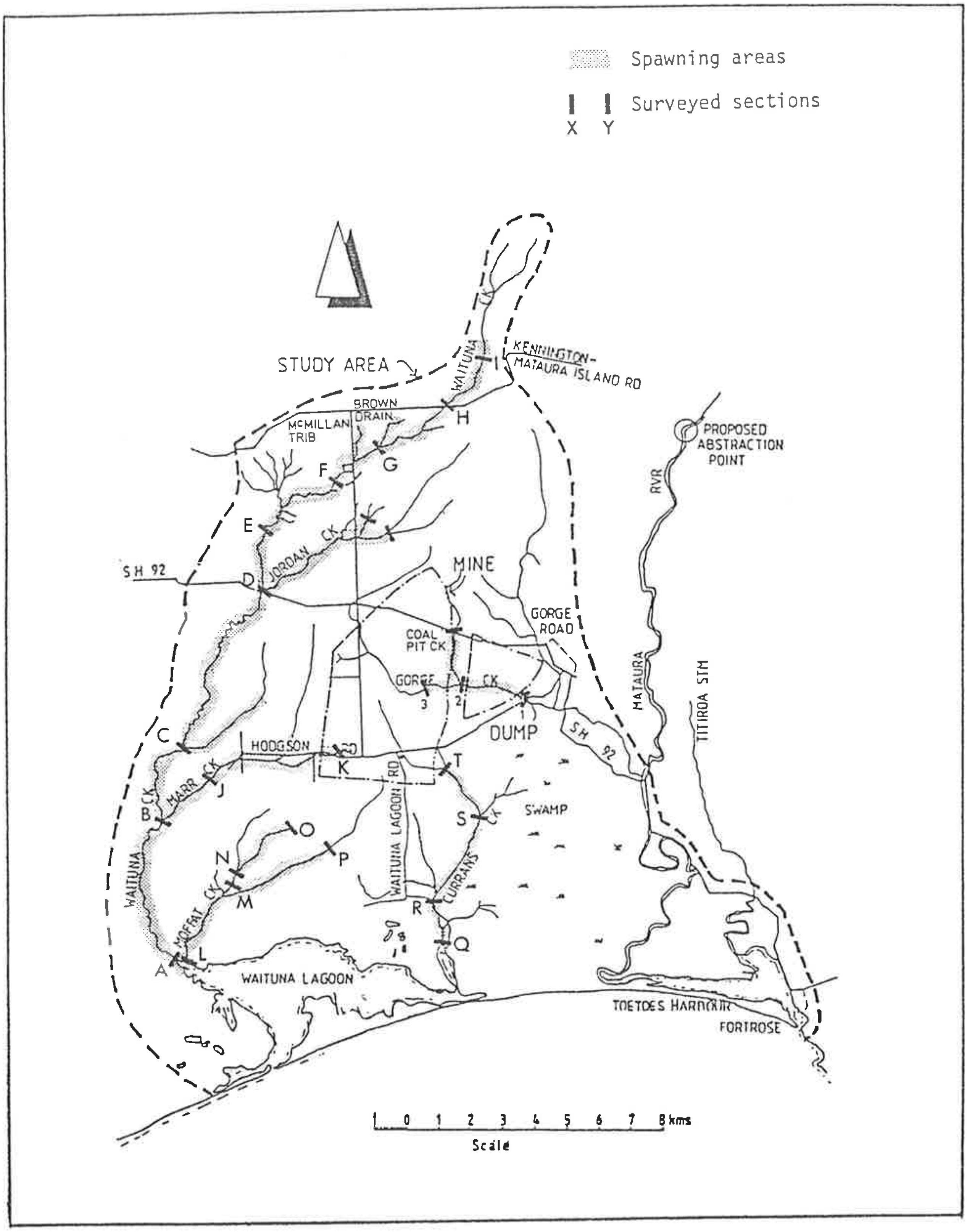

FIGURE 28. Trout spawning areas at Ashers-Waituna.

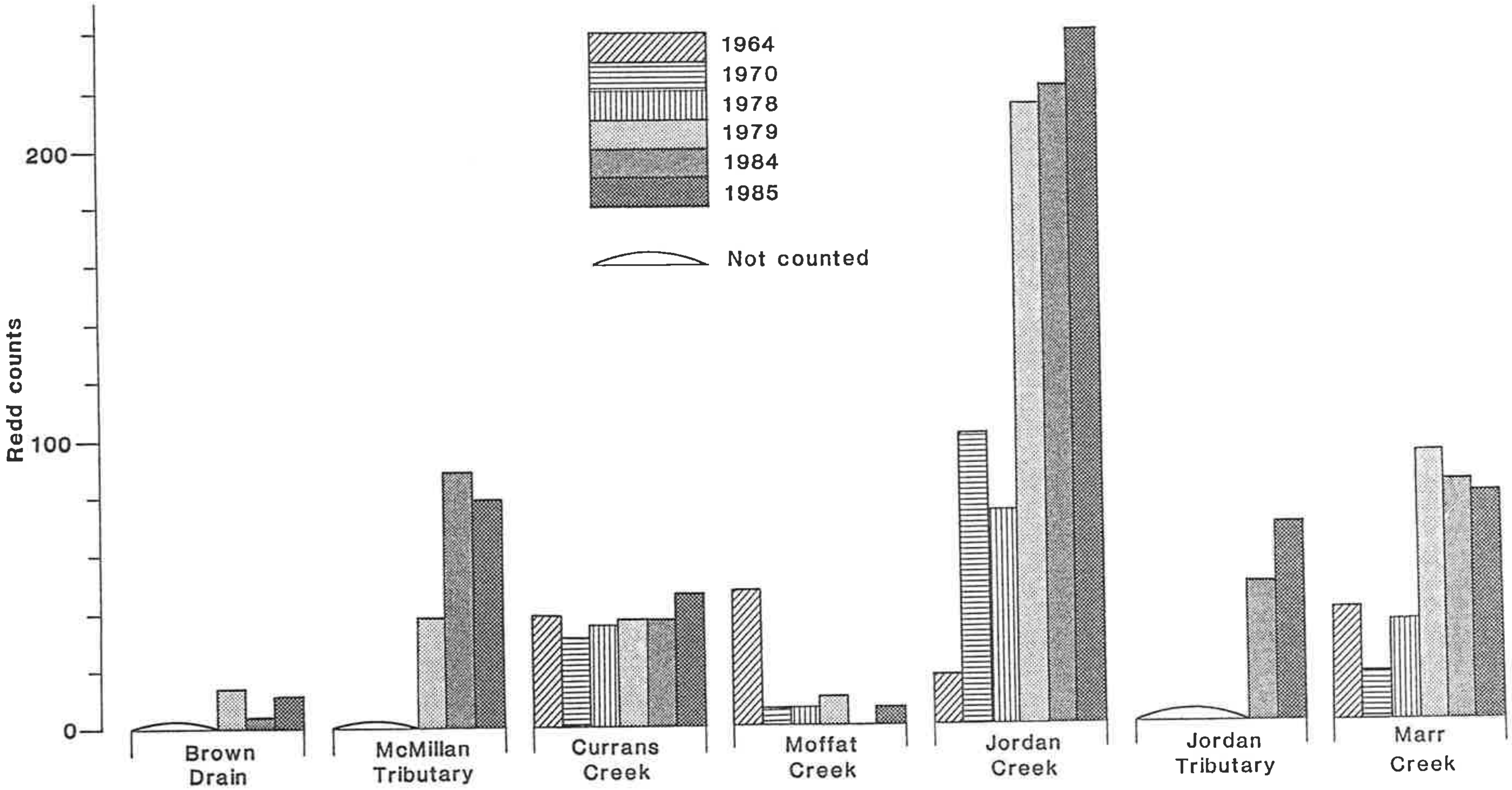

FIGURE 29. Trout redd counts in Waituna streams, 1964-85.

Spawning in Currans Creek has been reasonably static since 1964. Redd density is low here compared to other Waituna streams, probably because this sluggish, peaty stream has limited spawning gravels, confined to a short reach (ST) in the upper section (see Appendix III). Recently, land development, including channel and drainage works, has proceeded rapidly in the vicinity of the spawning reach of this stream. The SAS are concerned that the limited spawning area available to trout may deteriorate or may be destroyed completely.

Moffat Creek is the only stream where the number of redds counted has dropped (Fig. 29), and this decline in spawning activity cannot be readily explained. Channel clearing works may have contributed to it, particularly in the late 1960s, but the stream still contains suitable gravels. Macrophyte growth can inhibit fish passage, and this can be a problem at times in this stream.

Gorge Creek was surveyed for the first time in 1985. Previously, it was considered unlikely to be important for spawning. However, the data collected during 1985 suggest that its importance may have been underestimated. Redds were found wherever gravels were available, although, where it has been channelised, the stream bed is lignite, because the gravels have been removed by a mechanical excavator.

Since 1964, specific sections of Waituna Creek have been surveyed (Fig. 30); map references are given in Appendix III. Compared to other trout spawning streams, Waituna Creek has a high redd count. The highest density was recorded in 1985 in Section GH, where almost 140 redds were observed per kilometre of stream, which is equivalent to 1 redd every 7 m.

Since the surveys began in 1964, spawning activity has increased substantially in Waituna Creek and its tributaries (Fig. 31). From 1964 to 1970, redd counts were static, but by 1978, they began to increase, and this trend has continued to the present day. Increased spawning can be attributed primarily to a decrease in channel straightening and maintenance works within the stream from about 1975 onwards. In other words, there has been less stream and gravel disturbance than in the past. Unfortunately, stream maintenance, including gravel removal, still continues, despite attempts to keep it to a minimum during the spawning period.

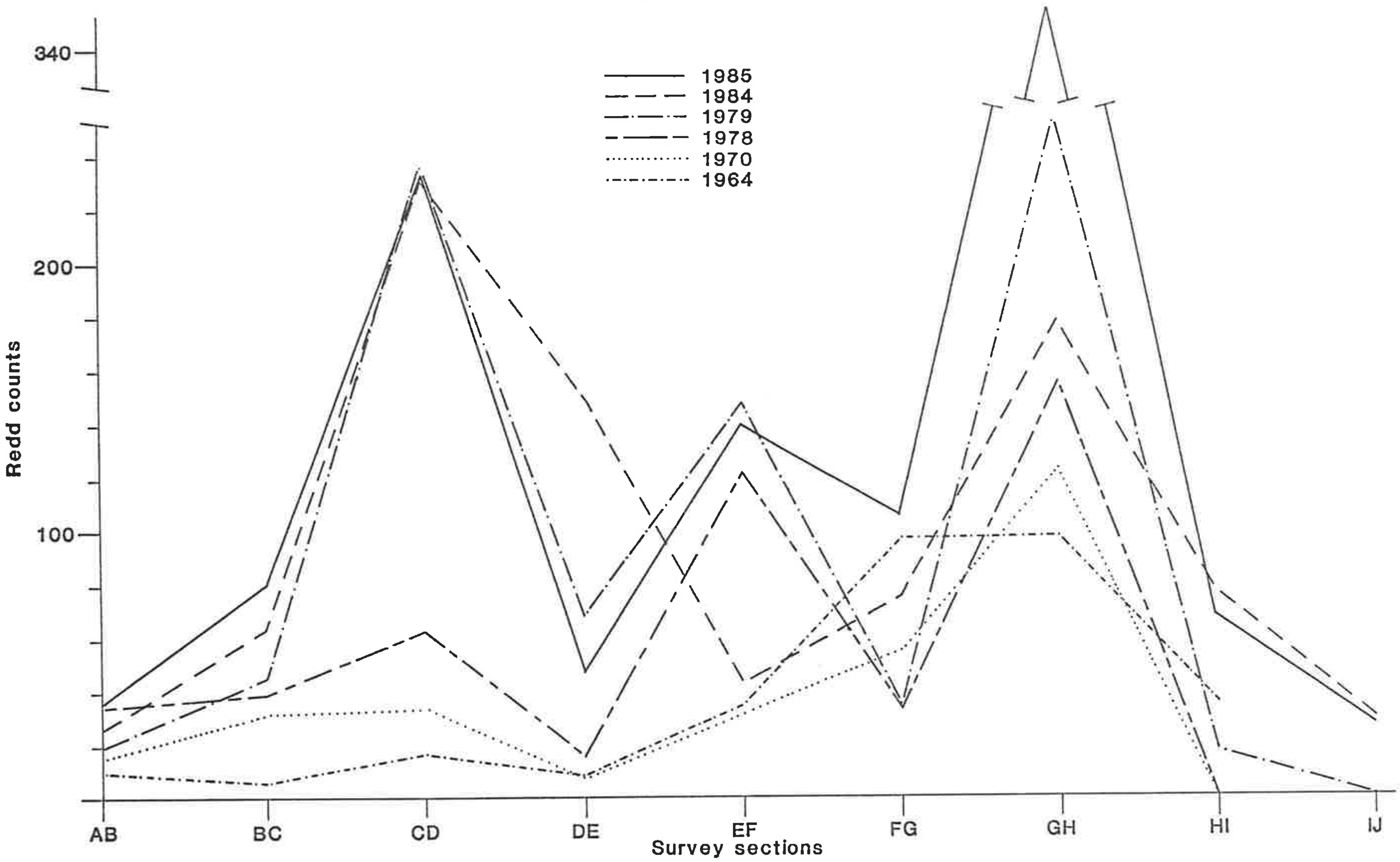

FIGURE 30. Trout redd counts in surveyed sections of Waituna Creek.

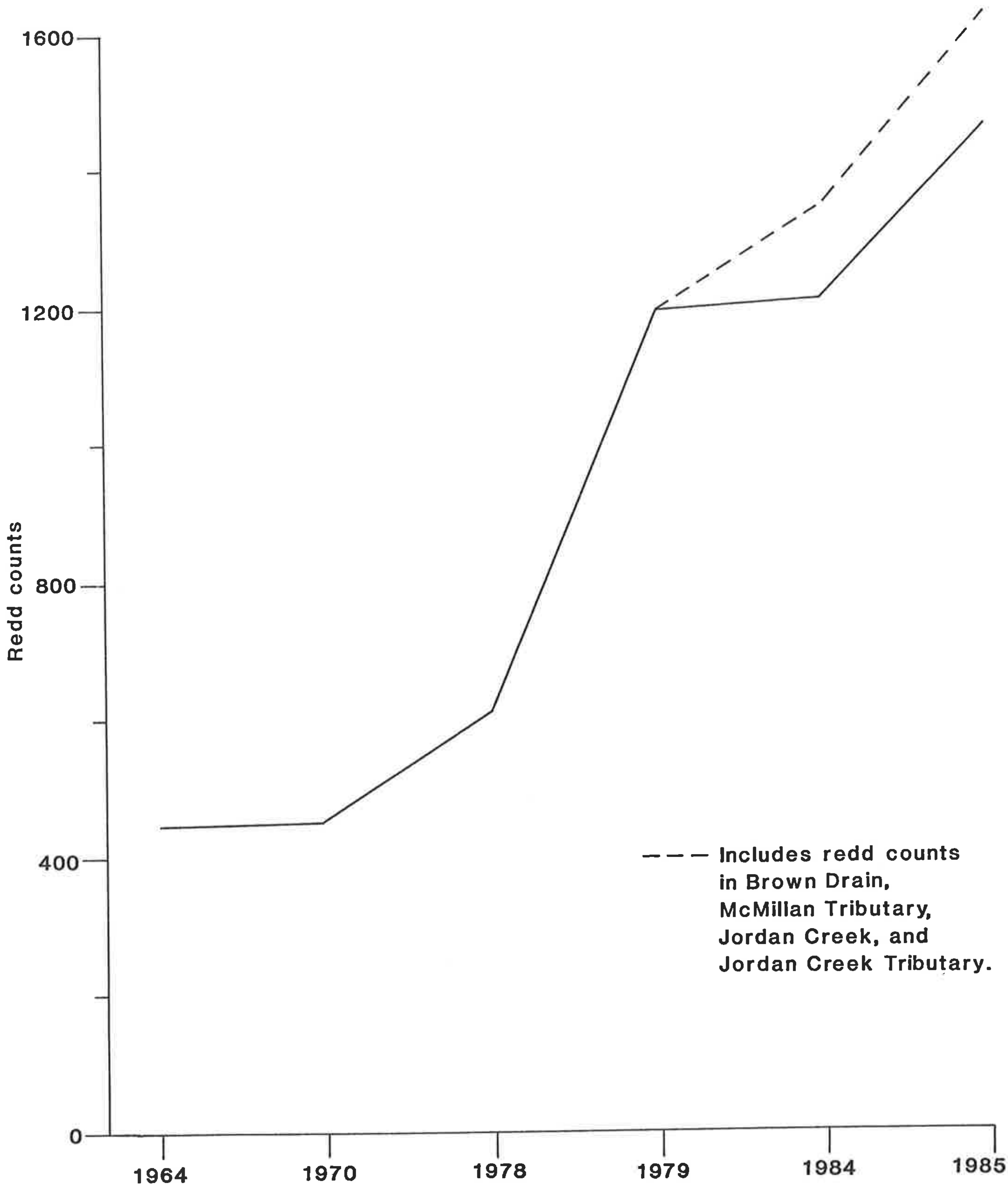

FIGURE 31. Trout redd counts in Waituna Creek and tributaries.

On the whole, Waituna Creek seems to have been recovering for about 10 years. Figure 30 shows that the redd counts within surveyed sections have varied between years. One factor that may affect the number of spawning fish in the Waituna system is whether the lagoon outlet is open or closed during the spawning run. The SAS has no records of lagoon openings for earlier spawning surveys, but it is likely that if the outlet was closed to sea-run trout, the redd count could be expected to be lower. In 1985, the outlet closed early in May, restricting access for trout. The main spawning run usually begins late in May or early in June, so for 1985, spawning activity must have been exclusive to fish residing in the lagoon at that time. Bearing in mind that the 1985 redd counts were higher than any previously recorded, it appears that closure of the outlet had little effect on spawning activity, or that most sea-run fish had entered the system by early May. It cannot be discounted, however, that the redd count could have been even higher if the outlet had remained open. The total count of 1625 redds for the 3 Waituna tributary streams suggests that at least 3250 sexually mature brown trout were present in the Waituna system in 1985. However, a sex ratio of more than 1 male per female is not uncommon, and adult trout do not spawn every year, so the population may be even larger than that indicated by redd counts.

The lower Mataura River has not been surveyed for spawning, because water clarity and visibility have made it impossible. Spawning in this zone is thought to be negligible, due to unsuitable water depths, unavailability of suitable spawning gravels, and the fact that the reach is tidal. However, above the tidal zone, the Mataura River mainstem is thought to be used a great deal by brown trout for spawning, because suitable gravels exist throughout its length (Witherow and Scott 1984). Brown trout usually migrate upstream to spawn, so adequate passage through the tidal zone and lower reaches is essential.

In summary, brown trout spawning is extensive within the study area, particularly in Waituna Creek. The level of spawning appears to be greater than that required to sustain the Waituna lagoon trout population, and it is likely that Waituna spawning and nursery habitats may be regionally important for recruitment of sea-run fish to other rivers in the area. However, there is insufficient evidence to support this theory at present. Nevertheless, both the neighbouring Mataura and Oreti rivers have large populations of sea-run trout.

4.1.4 Recreational Fisheries

4.1.4.1 Waituna Lagoon

Brown trout angling in Waituna Lagoon is reported to have been well established by the first decade of this century (R.R. Sutton pers. comm.). Angling is limited to the lagoon itself, and the waters near the outlet to the sea are the most popular. The catch comprises trout living in the lagoon and many sea-run trout, which are easily distinguished by their silvery colouring. Angling is considered to be best when the lagoon is open to the sea and sea-run trout have free access.

Large fish are caught regularly in these waters. For example, SAS files record 2 of the largest as an 8 kg (864 mm) fish caught near the outlet during the 1948/49 season and a 7.3 kg (838 mm) fish caught in March 1967.

Bad weather often makes fishing conditions at the lagoon difficult, and only experienced anglers can fish there successfully. Natural bait and spin fishing are the most popular and successful fishing methods.

Graynoth and Skrzynski (1974) summarised the results of the National Angling Diary Schemes for Southland rivers. Data for Waituna Lagoon are available for 5 angling seasons from 1947 to 1952, and for 1957, 1962, and 1967. Using only the 1962 and 1967 data, an average catch rate of 0.13 fish per hour was calculated for Waituna. The average length of brown trout caught in 1947 was 560 mm and in 1967, 580 mm. In 1962 and 1967, only 5% of the fish caught were undersized. Comparing these data to those from other rivers in Southland, Waituna Lagoon had the lowest catch rate in the district, but the largest average size and one of the lowest percentages of undersized fish caught. Graynoth and Skrzynski (1974) also estimated the annual crop of fish taken from Waituna Lagoon to range from 100 in 1948, 1949, and 1962, to 2410 in 1950.

During the 1963/64 angling season, the SAS carried out a creel survey of Waituna Lagoon (SAS Annual Report 1964). In the 3 zones surveyed, no anglers were observed in Zone B (western Waituna Lagoon), but Table 10 presents the results from Zones A (the outlet region) and C (the eastern lagoon). The data confirm that large size is a characteristic of the fish taken by anglers from Waituna Lagoon, which puts the lake into a "trophy fishery" category, together with the upper Pomahaka River in Otago, where sea-run brown trout average 525 mm in length (Scott and Watson 1980). Lake Tarawera is also rated as a trophy fishery for rainbow trout, and fish taken by anglers there during the 1973/74 season averaged 552 mm in length (Burstall 1975). The headwaters of the Rangitikei River also contain very large rainbow trout which anglers regard as trophy fish. The average size of a sample of 45 fish caught in the headwaters between 1970 and 1981 was 599 mm (Hicks and Watson 1985).

TABLE 10. Creel census data from Waituna Lagoon, 1963/64

	Zone A	Zone C
Total hours fished	85.0	123.5
No. of fish caught	8	9
Average fish length (mm)	650	594
Average fish weight (kg)	2.8	2.2
No. of days	11	13
No. of anglers	21	34
Catch rate (fish/hour)	0.09	0.07

The results of the Waituna creel census largely agreed with data obtained from Graynoth and Skrzynski's (1974) angler diaries, in that they showed a low catch rate but large fish. Further angler diary, creel census, and angler interview data have been collected from Waituna Lagoon by the SAS from time to time, and this information is summarised in Table 11.

TABLE 11. Angling data from Waituna Lagoon

Sampling method	1964/65 Creel census	1970/71 Angler diaries	1972/73 Angler diaries	1973/74 Angler diaries	1974/75 Angler diaries	1976/77 Angler diaries	1977/78 Angler diaries	1980/81 Questionnaire
Total hours fished	-	281	114	148	180.5	95	86	3 076
No. of fish caught	71	30	9	14	45	16	19	690
Total weight of catch (kg)	191	72	20.3	38.4	98.0	41.8	55.2	-
Average fish weight (kg)	2.7	2.4	2.3	2.8	2.2	2.6	2.9	-
Average fish length (mm)	658	610	-	-	-	-	-	-
Catch rate (fish/hour)	-	0.11	0.08	0.09	0.25	0.17	0.22	0.22
No. of anglers	-	9	3	4	7	-	-	47

The relative merits of various methods for collecting angling data have been discussed by Witherow and Scott (1984). Alhtough angler diaries are known to overestimate catch per effort statistics, the catch rate (fish per hour) and average size of fish from Waituna Lagoon from all of the data sources are remarkably consistent.

The 1980/81 Waituna questionnaire (SAS Annual Report 1983) tried to quantify anglers' and shooters' appreciation of the Waituna area. The questionnaire was sent to all licence holders known to use the area. Waituna Lagoon is fished by a group of keen local anglers, many of whom have a long family tradition of angling at Waituna. Some families have been fishing there for 4 generations and have strong ties with the area. The vagaries of the weather at Waituna mean that huts are essential for the safety of anglers and shooters, and many of these have been in place for more than half a century. In the 1981 questionnaire, users ranked the tranquility and wilderness values of Waituna, together with the camp life associated with the area, ahead of the quality of fish and game caught. Catch rates derived from this questionnaire generally agree with those calculated from previous creel census and angler diary returns (Table 11).

In summary, Waituna Lagoon is important locally, and perhaps regionally, for angling, offering trophy-sized fish, but a fairly low catch rate. Traditionally the lagoon has been fished by a group of keen, hardy, local anglers. In addition to trout angling, the lagoon sustains a minor flounder fishery, and some whitebaiting is carried out in Waituna Creek (R.R. Sutton pers. comm.).

4.1.4.2 Lower Mataura River

In contrast to Waituna Lagoon, the Mataura River is an internationally renowned brown trout fishery. Witherow and Scott (1984) documented the results of creel surveys carried out on specific reaches of the Mataura River during the 1976/77 to 1980/81 fishing seasons. The lower Mataura, below Gorge Road Bridge (S182:682906), was part of their furthest downstream sampling reach (Zone A). They found that this zone (the lower and tidal reaches) was fished less heavily than the middle reaches, around Mataura and Gore, and it tended to be fished mostly by local people living within the Mataura Valley or in nearby Invercargill, rather than by visitors. Natural bait was the most popular fishing method in these turbid waters.

The mean catch rate from Witherow and Scott's creel census data for the whole Mataura River was 0.22 fish per hour. Although Zone A had the lowest catch rate of all zones surveyed (0.19 fish per hour), this was still higher than the overall catch rate reported for all rivers in the OAS district (Scott and Watson 1980). It also compares very favourably with summer catch rates reported for the lower Clutha River (see Section 4.2.4.1).

Graynoth (1974a) estimated a catch rate of 0.65 fish per hour for the whole Mataura River from angling diary results for the 1962 and 1967 fishing seasons, and described the river as "probably the best brown trout fishery in the country and maybe in the world". From the results of FFC's National River Angling survey, Teirney *et al.* (1984) established that the Mataura River supports a locally, regionally, and nationally important brown trout fishery.

Witherow and Scott (1984) estimated that almost 20% of Mataura anglers come from beyond the Mataura Valley and Invercargill, and obviously travel some distance to fish the river. It was also found that nearly 5% of all anglers were from overseas, which confirms the river's international reputation.

As well as brown trout angling, the lower Mataura River supports a regionally important whitebait fishery, which is exploited by commercial and recreational users. Perch are also caught in the river, and kahawai and flounders are fished for in Toetoes Harbour.

4.2 Benhar

4.2.1 Background

There is little historical information on native fisheries in the Benhar area. Giant kokopu were common in Lake Tuakitoto in the 1940s, and eels and lampreys both formed the basis of traditional Maori fisheries in the past (M. Wylie pers. comm.). Records in FFC's national freshwater fish data base (McDowall and Richardson 1983) indicate from observations made in 1973 that the giant kokopu was present in Lake Kaitangata, which is now drained, but which used to lie south of Lake Tuakitoto, as well as in Lake Tuakitoto itself.

The lower Clutha River supports a whitebait fishery of at least regional importance, and 56 permanent stands were in place on the Matau Branch in August 1984. However, recreational whitebaiters were much more numerous, and whitebaiting is carried out on both branches of the Clutha.

Official OAS records indicate that brown trout were first released into Lovells Stream in 1874. In 1875, "about 40 large fish" were released directly into Lake Tuakitoto. Brown trout liberations into Lovells and Frasers Streams continued from then until 1941, with a recorded total of 720 000 brown trout having been released into the Tuakitoto subcatchment. The present brown trout population is self-sustaining by natural spawning, and artificial stocking is not necessary.

Brown trout were liberated into the lower Clutha River during the late 1860s and early 1870s, and the fish apparently became established readily, and spread widely (Jellyman 1984). Sea-run trout are common in the lower Clutha, as well as a large resident population.

Brook char were recorded as being released into Lovells and Fraser Streams in 1870 and again from 1914 to 1916. Although 19 000 releases were recorded, this species has not become established, and it is doubtful if a self-sustaining population has ever existed.

From 1905 or 1906, 10 000 rainbow trout have been released into Lovells Stream. No other liberations have been documented, and there is no record of a population ever becoming established.

Perch inhabit both the lower Clutha River and the Tuakitoto subcatchment, but no records of release dates or numbers have been found. However, the 1891 OAS Annual Report stated, referring to perch, that "these fish are becoming very numerous; Kaitangata Lake and Lovells Stream are simply swarming with them". Self-sustaining populations of this species obviously became established very quickly.

Quinnat salmon were liberated into the Clutha system in 1877, but this release was unsuccessful. Subsequent releases and natural dispersal of the species from the Waitaki River resulted in a population becoming established by the 1920s. Construction of Roxburgh Dam in 1956 led to a deterioration in the salmon fishery, because no fish pass was installed to allow the salmon to reach their traditional spawning grounds in the headwaters.

In 1976, ICI/Wattie established an experimental salmon ocean ranching project on the Matau Branch at Kaitangata. Up to 1985, roughly 1 200 000 fish had been released to the river. This has enhanced the recreational fishery considerably; about 800 returning adult fish were reported to be caught by anglers in 1983, and over 1400 in 1984 (Gillard 1985).

4.2.2 Species Composition, Distribution, Life Histories, and Habitat Requirements

Information on fish species in the Tuakitoto subcatchment was obtained from electric fishing surveys conducted by the OAS in February 1982 and from June 1984 to May 1985. Gee minnow traps and fyke nets were used at the less accessible sites in Lake Tuakitoto. The sampling sites are shown in Figure 32. The lower Clutha River was not sampled, but information on the fishery was obtained from Jellyman (1984) and from unpublished OAS records. Some fyke netting was carried out in the Puerua Estuary. Sampling results are presented in Appendix IV.

Table 12 summarises the relative abundance of fish species recorded in each ecosystem surveyed. The study area is inhabited by 15 species in total: 10 native, 3 introduced, 2 marine or estuarine, plus the freshwater crayfish. The life history and migratory habits of each are described briefly in Tables 7 and 8. Of the 13 freshwater fish species found, 11 are diadromous, 1 is resident (perch), and 1 (brown trout) can be diadromous or resident. Sea-run brown trout are found in the lower Clutha River during their spawning migrations to the upper Pomahaka River.

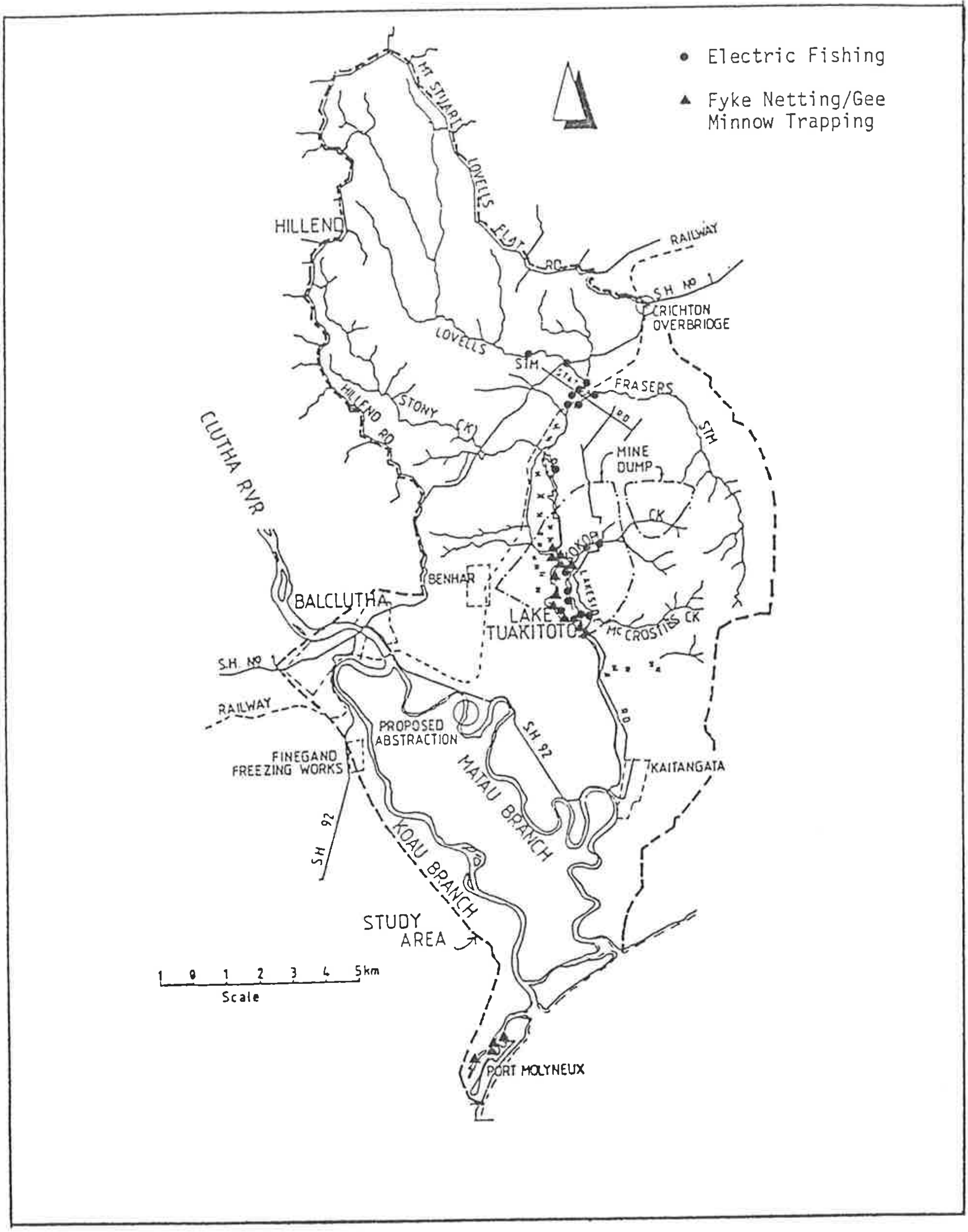

FIGURE 32. Benhar sampling sites.

TABLE 12. Relative abundance of fish species in the Benhar study area

Species	Lovells Stream	Frasers Stream	Kokopu Creek	McCrosties Creek	Lake Tuakitoto	Puerua Estuary and Lower Clutha River†
Brown trout	****	****	*****	***	**	*****
Perch	***	****	-	*****	*****	***
Quinnat salmon	-	-	-	-	-	***
Long-finned eel	***	***	**	**	**	****
Short-finned eel	-	-	-	-	****	****
Lamprey	-	-	-	-	-	*
Common bully	-	-	***	-	**	*****
Giant bully	-	-	-	-	-	*
Inanga	*	*	-	*	*	*****
Giant kokopu	-	-	***	**	**#	**
Koaro	-	-	-	-	-	****
Common smelt	*	-	-	*	-	*
Black flounder	-	-	-	-	-	****
Yellow-eyed mullet	-	-	-	-	-	****
Kahawai	-	-	-	-	-	*
Freshwater crayfish	**	-	-	-	-	-

***** Abundant.
**** Common.
*** Frequent.
** Occasional.
* Rare.
- Not recorded.
† Based on Jellyman (1984).
# Reported to be present.

4.2.2.1 Brown Trout *(Salmo trutta)*

This species was caught in all tributary streams and in Lake Tuakitoto, and is known to be abundant in the lower Clutha River (Jellyman 1984). Juvenile brown trout were common in Lovells Stream, whereas adults were relatively few in number, although more were present during the spawning season (May-July). The largest fish caught was 555 mm, but most were in the 100-250 mm range. In Frasers Stream most were juvenile (0+) fish, with a few larger fish. The Stony Creek population was similar.

Small numbers of juvenile brown trout were caught in Saddle and Two Stone Hill Streams. Lovells and Frasers Streams, and Stony Creek are important trout rearing areas, but provide limited habitat for adult fish.

Only a small number of brown trout were caught in Lake Tuakitoto. This may reflect a low population density, and Lake Tuakitoto may have limited value as a habitat for adult brown trout because of low summer lake levels and high summer water temperatures (R. Dungey pers. comm.). Fish caught were mostly adults, and the largest was 580 mm.

Netting of the Puerua Estuary also produced brown trout, ranging in size from 300 mm to 555 mm.

4.2.2.2 Perch *(Perca fluviatilis)*

Perch were found in all of the areas sampled, including the Puerua Estuary, and are thought to be present also in moderate numbers in the lower Clutha River. They were abundant in the still waters of Lake Tuakitoto, and common in the lower and middle reaches of all tributary streams. The smallest number was caught at the Lovells Stream site furthest upstream, and the greatest number in Frasers Stream. Large numbers of perch were caught in Two Stone Hill Stream (551 fish over a 30-m stretch of stream), and in Saddle Stream. Most fish caught in the tributary streams were juveniles (less than 100 mm in length), and were probably young-of-the-year (0+) fish (Jellyman 1980). It appears, then, that these slow-flowing, sluggish streams offer ideal rearing habitat for perch.

All size classes of perch (50-425 mm) were caught in Lake Tuakitoto, indicating that the lake provides good adult and juvenile rearing habitat.

Perch are a totally freshwater species, and they spawn in the lake and tributary streams. They attach strings of eggs to aquatic vegetation, so the aquatic plants in the streams and lake, and the lake's marginal vegetation, provide ideal spawning habitat. At Benhar, perch were most abundant where aquatic plant growth was prolific.

4.2.2.3 Quinnat Salmon *(Oncorhynchus tshawytscha)*

A moderate number of quinnat salmon live in the lower Clutha River. The adults migrate upstream from the sea from January to May to spawn in tributary streams below Roxburgh Dam. Jellyman (1984) considered that juvenile fish may remain in the Clutha River system for up to 3 years before going to sea to complete the marine phase of their life cycle. Thus, the lower Clutha River is important in providing juvenile salmon rearing habitat. Although the increasing size of the adult salmon run into the Clutha River is due largely to hatchery releases, natural spawning in tributaries below Roxburgh has also increased in recent years.

4.2.2.4 Long-finned Eel *(Anguilla dieffenbachii)*

Long-finned eels were found in moderate numbers in all of the Lake Tuakitoto tributaries. They were also caught in the lake itself, although in much smaller numbers than their short-finned relative. They are considered to be common in the lower Clutha River, but were not found in the Puerua Estuary during netting, although they are probably present there.

Eels in the tributary streams ranged in size from 230 mm to 1150 mm. The long-finned eels caught in Lake Tuakitoto were not measured, but both juveniles and mature adults were caught. Within the streams, they were usually found in pools, whereas in the lake they were generally found near the marginal vegetation. Both the tributary streams and the lake provide suitable rearing and adult habitat for this species.

4.2.2.5 Short-finned Eel *(Anguilla australis)*

Short-finned eels were caught in Lake Tuakitoto, but were notably absent from the tributary streams. They are thought to be common in the lower Clutha River (Jellyman 1984) and were also present in the sluggish waters of the Puerua Estuary. The eels caught were not measured, but juveniles and large adult fish were both present. This species was more numerous in the lake than long-fins, and the marginal vegetation again provided good cover.

Lake Tuakitoto appears to provide suitable habitat for short-finned eels of all sizes. With the drainage of many large, swampy, open-water areas in this region, the habitat of this lowland and coastal-dwelling species has diminished, thereby increasing the importance of the remaining habitat (Fig. 33).

FIGURE 33. The shallow margins of the eastern shore of Lake Tuakitoto are important for several species of native fish.

4.2.2.6 Lamprey *(Geotria australis)*

Adult lampreys migrate upstream from the sea to spawn. Although they were not caught in the study area, they have been observed in tributaries of the Clutha as far upstream as Roxburgh Dam.

4.2.2.7 Common Bully *(Gobiomorphus cotidianus)*

Common bullies were caught in Lake Tuakitoto and in Saddle Stream, but were not recorded from other tributary streams. They are known to be present in the lower Clutha River. Although only a few fish were caught, both juveniles and adults were present in the samples. The fish were found in the shallow margins of the lake, although cover is not essential to their survival, and they are often found in open waters.

This species undoubtedly is a food source for the large number of adult eels in Lake Tuakitoto. The lack of success in netting and trapping them may be due, in part, to the presence of eels, which could have discouraged bullies from entering trapping devices, or the eels may have consumed those already in the traps. However, it is more likely that the density of this species in the lake is low compared to that of other fish species.

4.2.2.8 Giant Bully *(Gobiomorphus gobioides)*

Six adult giant bullies were caught in fyke nets in the Puerua Estuary. The species had not been reported from the area previously. These are estuary-dwelling fish, preferring sluggish waters, but little is known of their life history.

4.2.2.9 Giant Kokopu *(Galaxias argenteus)*

Few giant kokopu were present in the area, because suitable habitat is limited. Every effort was made to net and trap them in Lake Tuakitoto, but without success, although they are present because eel fishermen report them in their fyke nets from time to time. However, some were caught in 2 of the Lake Tuakitoto tributaries: 20 in Saddle Stream, ranging in size from 60 mm to 240 mm, and 1 in Two Stone Hill

Stream, measuring 310 mm. One specimen was caught in the Puerua River deviation channel (335 mm), and they are reported to be present in the lower Clutha River.

All of the fish were found in habitat considered to be typical for giant kokopu: pools within slow-flowing streams where there was plenty of cover. It was reported that 9 giant kokopu were removed from Two Stone Hill Stream during a mechanical ditching operation in April 1985, but only 1 survived (R. Dungey pers. comm.). The small number of fish caught, despite considerable sampling effort, suggests that the area has only a small population with a very limited distribution, and that their continued presence is under threat.

Little is known about giant kokopu spawning in the area, but they are thought to spawn close to areas of adult habitat (McDowall 1978).

4.2.2.10 Inanga *(Galaxias maculatus)*

Inanga (Fig. 34) were found in small numbers in Lovells, Two Stone Hill, and Frasers Streams, and in Lake Tuakitoto. They are very common in the lower Clutha River, where they reportedly make up 89.5% of the Clutha whitebait run (McDowall 1965).

The small number of inanga in the Tuakitoto basin may be attributable to the time of year of the sampling (May); at this time, most of the adult fish would have moved downstream to the tidal reaches to spawn. However, it is also likely that flood gates on the contour channel and the lake outlet weir may restrict their movement, as they are unable to climb. Nevertheless, some fish do negotiate the channel, because electric fishing of Lovells Stream in December 1984 produced 8 adults, and they may be more common in the summer months. As at Waituna, the fish caught were found in pools or in sluggish reaches of streams.

4.2.2.11 Koaro *(Galaxias brevipinnis)*

Although koaro were not caught during sampling, they are reported to be present in the lower Clutha River (Jellyman 1984). McDowall (1978) noted that they are rare in eastern streams of the South Island of New Zealand, as they prefer forested habitats.

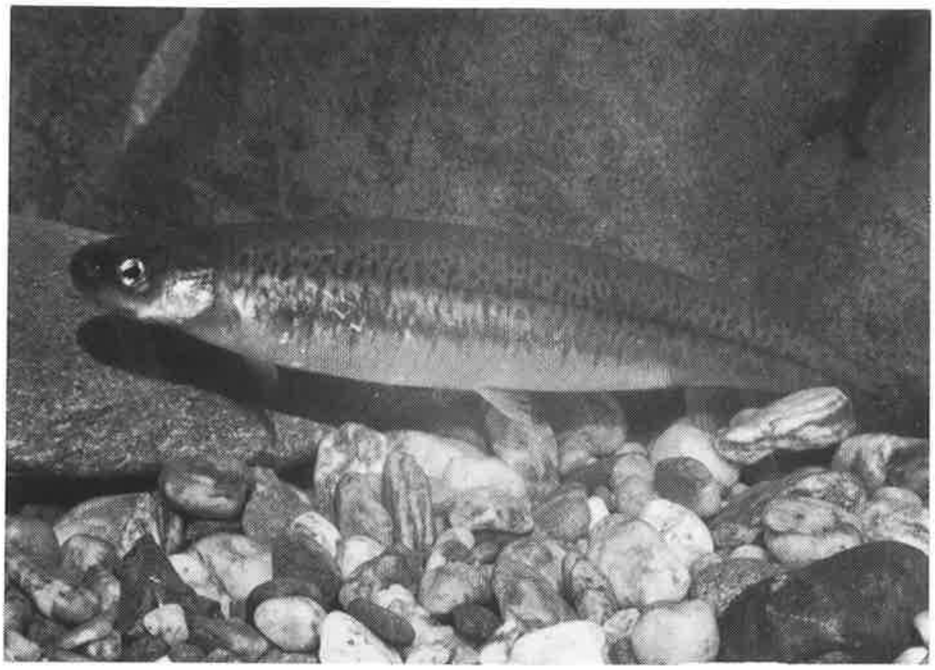

FIGURE 34. Inanga from Lake Tuakitoto.

4.2.2.12 Common Smelt *(Retropinna retropinna)*

Common smelt were caught in small numbers in Lovells and Two Stone Hill Streams. Large shoals have been reported in the lower Clutha River (McDowall 1978), and the fish must migrate up the contour channel and through Lake Tuakitoto from time to time. All specimens caught were adults.

4.2.2.13 Black Flounder *(Rhombosolea retiaria)*

Fish of this species were not caught in Lake Tuakitoto or its tributaries, which was rather surprising, as the habitat appears to be suitable. It is likely that the Kaitangata flood gates and the lake outlet weir, which create a partial restriction for fish, may explain their absence. Black flounders were abundant in the Puerua Estuary, with specimens ranging in size from 86 mm to 410 mm. The sampling methods were not suited to catching juveniles, but the estuary obviously provides ideal habitat for this species. Jellyman (1984) noted that black flounders are common in the lower Clutha River, and a very large specimen (474 mm) was caught during survey work in 1984 (R.R. Dungey pers. comm.).

4.2.2.14 Yellow-eyed Mullet *(Aldrichetta forsteri)*

Unpublished OAS records indicate that this marine species is common in shoals in the tidal waters of the lower Clutha River, particularly during the winter months. No specimens were caught during this study.

4.2.2.15 Kahawai *(Arripis trutta)*

This marine species is common in and around the mouth of the Clutha River, particularly from December to March. No specimens were caught during netting of the Puerua Estuary, but kahawai are excellent swimmers, and are hard to catch using the sampling methods employed during this study.

4.2.2.16 Freshwater Crayfish *(Paranephrops zealandicus)*

Freshwater crayfish were found only in Lovells Stream, where they were present in small numbers. They are probably distributed more widely than this, but their numbers appear to be limited.

4.2.3 Spawning

4.2.3.1 Native Fish

Given what is known of their life histories (Table 7) and spawning requirements (Table 9), 6 of the 10 native fish species recorded in the study area probably spawn wherever conditions are suitable. Inanga and smelt are likely to spawn in the tidal reaches of the lower Clutha River. Lampreys migrate into fresh water to spawn on gravel substrates, and the tributary streams of Lake Tuakitoto appear to provide suitable habitat. Common and red-finned bullies spawn near their adult habitat, and so bully spawning is likely to be widespread. Giant kokopu probably do not migrate far to spawn, and as they have been found in both Two Stone Hill and Saddle Streams, it is likely that they spawn in these waters and in Lake Tuakitoto.

Long- and short-finned eels, black flounders, and yellow-eyed mullet all spawn at sea.

4.2.3.2 Introduced Fish

During May and June 1985, trout spawning surveys were conducted on 8 reaches of 7 streams in the study area. These surveys complemented earlier work by the OAS, and the results are presented in Appendix V and Figure 35.

Brown trout spawning is widespread throughout Lovells and Fraser Streams, and also occurs in the lower reaches of Stony Creek. Spawning activity peaks in May and June. In 1968, the culvert on Stony Creek at State Highway (S.H.) 1 had to be modified to allow trout to migrate upstream to spawn (D. Betts pers. comm.). However, access from Lake Tuakitoto through the lower reaches of this stream is now restricted by channelisation works and a dam downstream from S.H.1, and the number of fish which reach the spawning area has declined.

In 1983, there was an unconfirmed report of a salmon leaping the lake outlet weir from the contour channel, but there have been no observations of salmon spawning within the channel or in tributary streams of Lake Tuakitoto.

Perch spawn in Lake Tuakitoto, and in suitable reaches of tributary streams. Their spawning is prolific, and eggs are commonly observed during spring, attached to the bases of emergent vegetation in the lake and its wetlands, as well as in the lower reaches of Saddle and Two Stone Hill Streams and other tributaries.

4.2.4 Recreational Fisheries

Brown trout were reported to be present both in the lower Clutha River and in Lake Kaitangata, which is now drained (Hamilton 1904). While no reference was made to trout in Lake Tuakitoto or in Lovells Stream at that time, it is probable that they were established throughout the whole subcatchment.

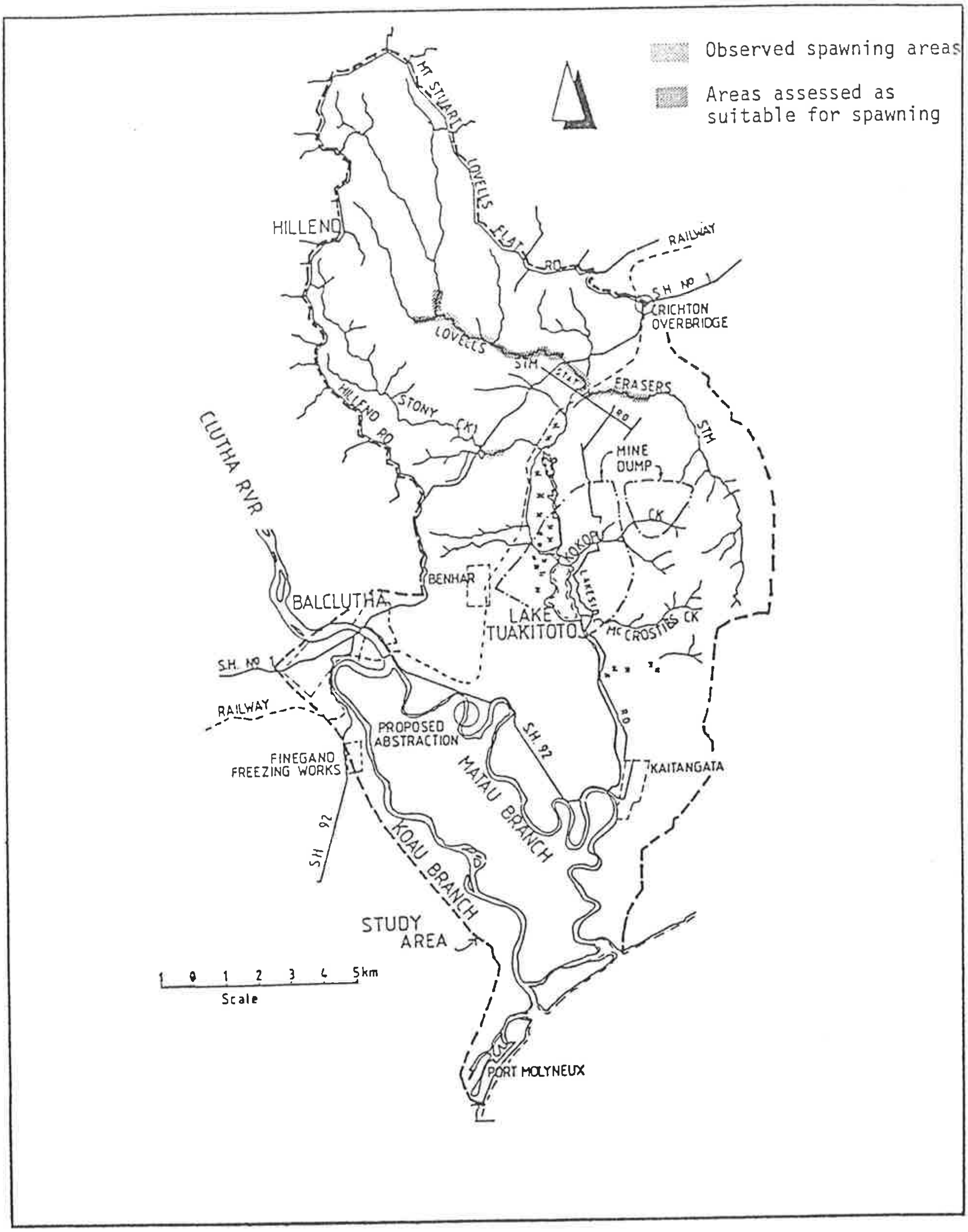

FIGURE 35. Trout spawning areas at Benhar.

4.2.4.1 Lower Clutha River

Creel surveys have been carried out by the OAS on representative reaches of the lower Clutha River during 7 open seasons (October-April inclusive) from 1971 to 1977, and in 1980/81 (Table 13). In addition, a winter fishing season (May to September inclusive) was introduced in 1973, and creel surveys have also been conducted over 4 winter seasons from 1973 to 1976.

TABLE 13. Lower Clutha River creel survey results, 1971-81

Fishing season	No. of anglers surveyed	Hours fished	Catch rate (fish/hour)	Average size (cm)	Empty bags (%)	Anglers km/day
1971-77, 1980/81 (summer)	638	1603.5	0.17	39.2	78	0.8
1973-76 (winter)	201	549.0	0.32	41.2	65	0.8

Angling pressure here is the highest recorded within the OAS district, with 0.8 anglers/km/day recorded for summer and winter seasons combined. The summer catch rate and size of fish taken by anglers are about average for the district, but both are considerably greater in winter. This appears to be due to the presence of large migratory trout in the lower river during July, August, and September.

During the last 2 angling seasons, the number of sea-run salmon in the Clutha has increased substantially as a result of the ICI/Wattie salmon ranching operation. In 1984, the number of salmon taken by anglers was estimated to be 1400, 7 times the estimated catch for 1982 (Gillard 1985). Creel census survey data in Table 13 pertain only to trout. These surveys did not detect any salmon angling, which indicates that it attracted little interest in the lower Clutha River before 1981.

A postal survey of OAS licence holders for the 1982/83 fishing season, undertaken to assess anglers' catch and effort on the lower

Clutha River from Alexandra to the mouth (Whiting 1986), identified the reach downstream from Balclutha to the mouth as the most popular zone for angling.

Results of FFC's National River Angling Survey for the Clutha River from Roxburgh Dam to the sea indicated that the river in that reach was accessible, with an abundance of fishable water, and an average to good catch rate. On the basis of these data, Richardson *et al*. (1984) ranked the lower Clutha fishery as at least regionally important.

Perch, yellow-eyed mullet, kahawai, and black flounders are also taken by anglers in the Clutha River below Balclutha. Whereas kahawai and mullet do not move far into the river from the sea, black flounders have been recorded as far upstream as Clydevale, and perch are found throughout the lower river.

Although there have been no quantitative assessments of whitebaiting on the lower Clutha River, it is known to be an extremely popular recreational (and often commercial) activity during the season from August to November. It is concentrated mostly in the reach below Balclutha.

4.2.4.2 Lake Tuakitoto

The angling value of Lake Tuakitoto was not mentioned in any of the literature reviewed for this study. Therefore, assessment of angler use and success for the lake has been based solely on interviews with 25 local residents, Balclutha being the most distant place of residence. Of those interviewed, 19 fished Lake Tuakitoto or the channels regularly, and 2 others had fished in the lake but no longer did so.

Both trout and perch were taken regularly by anglers, with trout ranging in size from 0.7-5.4 kg (1½-12 lbs), and perch from 0.7-1.4 kg (1½-3 lbs). Experienced fly anglers reported catching large trout (exceeding 1.8 kg), and cited fish size as one of the attractions of the angling provided by the lake and channels. Several of the interviewees valued the lake highly for the type of angling it provided. Other features which anglers claimed as reasons for fishing there included the presence of wildlife and proximity to home.

4.2.4.3 Lovells Stream

None of the people interviewed fished in Lovells Stream, except in the channelised reach where it enters the lake. However, a Dunedin resident known to fish the stream considers that it provides an attractive small stream fishery, which suits artificial fly angling and produces trout up to 1.8 kg (4 lb). Nevertheless, the stream appears to receive very little use by anglers, despite its acceptable trout stocks.

4.2.5 Commercial Fisheries

The lower Clutha catchment (including the Tuakitoto subcatchment) supports an important commercial eel fishery, but catch return data collected by the Fisheries Management Division of the Ministry of Agriculture and Fisheries do not allow the annual catch for specific river systems to be determined. However, in 1983, a questionnaire survey of commercial eelers who fished in the Clutha catchment below Roxburgh Dam indicated a catch of more than 20 tonnes per year (D.J. Jellyman pers. comm.).

Lake Tuakitoto supports an eel fishery of mostly short-finned eels (Fig. 36). Commercial eeling in the lake began in the mid 1960s, and in the first year of operation, 92 tons (imperial) were taken (B. Smith pers. comm.). However, stocks were depleted rapidly, and the current average annual catch is estimated to be 4 tonnes (B. Smith pers. comm.).

Whitebaiting, which is both a recreational and a commercial activity, is discussed in Sections 4.2.1 and 4.2.4.1.

4.2.6 Traditional Fisheries

Although there are no known traditional fisheries within the study area at present, the fish stocks of Lake Tuakitoto are known to have been utilised by the Maori people in the past. One local resident has confirmed that Lake Tuakitoto and its tributaries were fished for both eels and lampreys by Maori until the turn of the century (M. Wylie pers. comm.), and they probably also fished for giant kokopu, which were common in the lake up to the 1940s (K. Robson pers. comm.).

FIGURE 36. Commercial eelers catch large numbers of eels from Lake Tuakitoto.

4.3 Hawkdun

4.3.1 Background

The first recorded liberation of brown trout into the Manuherikia River system was in 1874, when 680 fish were released (OAS Annual Reports). In 1875, 242 brown trout were liberated into the upper reaches "above the Falls", presumably a reference to the present site of Falls Dam. Liberations continued until 1949, by which time 730 000 fish had been released (OAS Annual Reports). The size of fish at time of release was rarely noted in the historical records. It is generally thought that brown trout were well established in Otago rivers by 1900 (Graynoth 1974a), and this generalisation probably applies to the Manuherikia River.

The only recorded liberation of brook char into the Manuherikia catchment occurred in 1888, when 400 fish were released into Dunstan Creek. However, it is apparent from OAS Annual Reports that brook char were released widely throughout Otago, although specific liberation points were not often mentioned.

From 1958 to 1960, a total of 300 000 rainbow trout was liberated into the Manuherikia River above and below Falls Dam, in an unsuccessful attempt to establish a self-sustaining population.

Today, brown trout and brook char are well established in the Manuherikia system, although the latter are confined to a number of discrete populations in the upper tributaries. Brook char seldom reach more than 200 mm in length, and have little angling potential.

Limited angling is reported to have taken place in the upper Manuherikia River during the 1930s, before Falls Dam was completed in 1935 (Scott 1979), and fish in the 12-14 inch size range were most common.

Little is known about the effect of the Manuherikia Falls on fish passage, but construction of the dam effectively created 2 separate fisheries, upstream and downstream, and prevented all upstream movement of fish. Downstream movement is possible through the spillway at certain flows. After the dam was built and the reservoir filled, the area became more popular for angling, and fishing in the reservoir was reported to be good. Severe droughts in 1948 and 1956 emptied the Falls Dam reservoir, but within 2 years, fishing was again reported to be good, which suggests that the reservoir had been restocked naturally from the upper Manuherikia River.

The OAS has not stocked any of the streams in the upper Manuherikia catchment since 1949, apart from the rainbow trout liberations mentioned above, because brook char and brown trout populations in the system are maintained adequately by natural reproduction. Brown trout populations in the upper Manuherikia catchment appear to fall into 2 groups: a population of large fish in the reservoir, and a population of small fish in the river. The mainstem and tributaries provide important spawning and rearing habitat for all stocks.

4.3.2 Species Composition, Distribution, Life Histories, and Habitat Requirements

The first detailed fisheries surveys to be carried out in the upper Manuherikia catchment were conducted by the OAS in February 1981 and January 1982 to establish which fish species were present and how they were distributed. Further electric fishing of the streams was done as part of this study, as well as seine netting in the Falls Dam reservoir.

The sampling sites are shown in Figure 37, and the results are presented in Appendix VI. Table 14 summarises the data on the relative abundance of fish species present in each of the areas surveyed.

Four fish species were found in the upper Manuherikia River system: 2 introduced (brown trout and brook char) and 2 native (common river galaxias and upland bully). Their life histories and migratory habits are described briefly in Tables 7 and 8. It is worth noting that none are diadromous, i.e., they do not need to migrate to sea to complete their life cycle. The limited species composition of the area is partly a consequence of the presence of the Falls Dam barrier, as well as that of Roxburgh Dam on the Clutha River, and is partly related to altitude.

4.3.2.1 Brown Trout *(Salmo trutta)*

Brown trout were found at all of the sites surveyed and in all habitats. They were the most abundant and dominant species at every site, apart from Big Bremner and Johnstons Creeks and the East Branch, where brook char dominated. The smaller tributary streams contained a large number of juveniles, as well as stocks of adult fish which reach sexual maturity at a small size. The upper Manuherikia mainstem, West Branch, and lower reaches of Rocks Creek (Fig. 38) contained large fish, but at a low density.

The Falls Dam reservoir supports a population of adult brown trout (Fig. 39), and fish up to 570 mm were caught by anglers. Numerous juvenile brown trout were caught by seine netting in the reservoir, which indicates a high level of downstream recruitment.

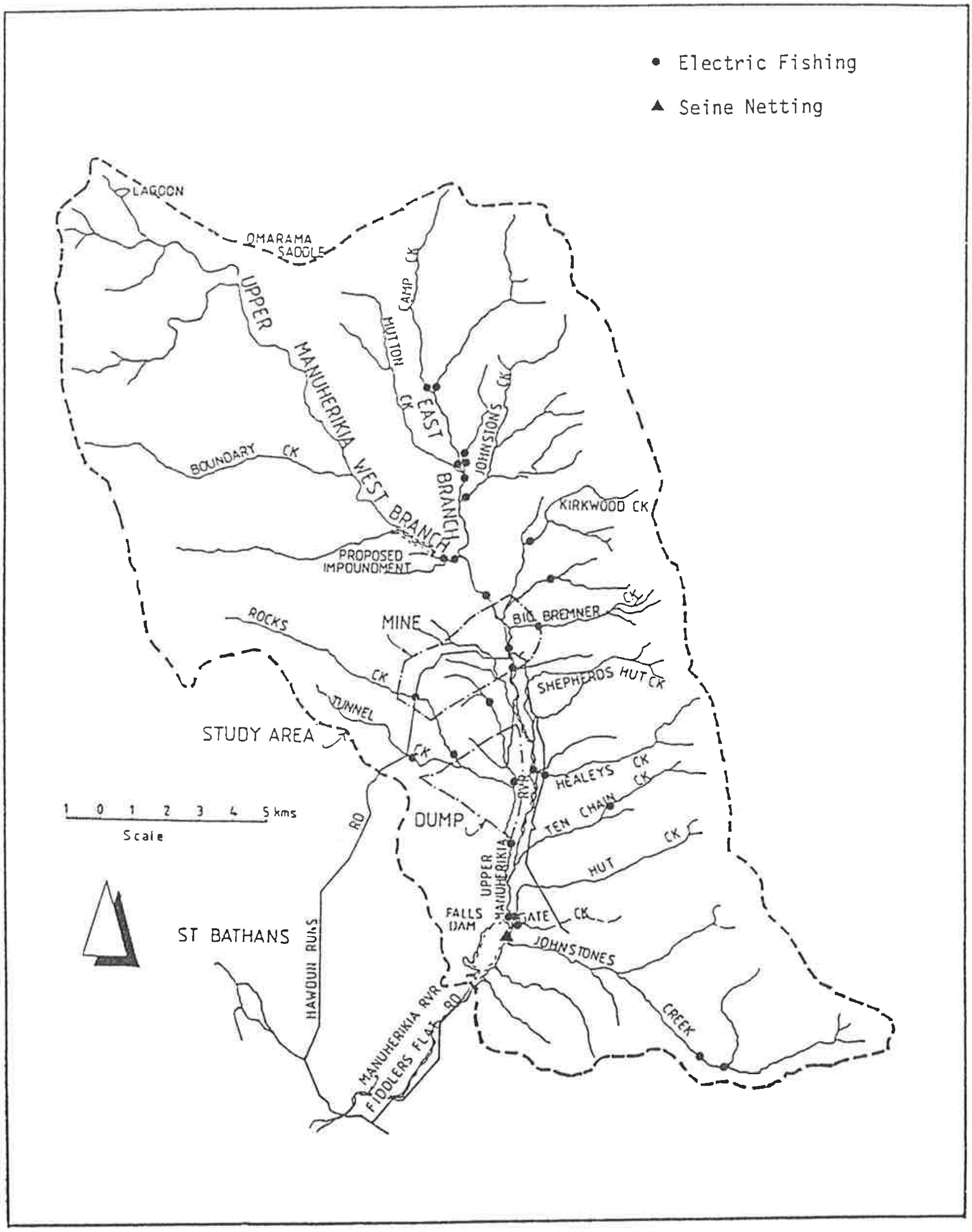

FIGURE 37. Hawkdun sampling sites.

TABLE 14. Relative abundance of fish species in the Hawkdun study area

Sampling area	Brown trout	Brook char	Common river galaxias	Upland bully
Camp Creek	***	****	-	-
East Branch	***	***	-	-
Johnstons Creek	***	****	**	*
West Branch	***	**	*	*
Kirkwoods Creek	***	**	-	-
Little Bremner Creek	****	***	-	-
Big Bremner Creek	**	****	-	-
Healeys Creek	*****	***	-	***
Ten Chain Creek	***	-	-	-
Hut Creek	*****	-	-	**
Gate Creek	*****	-	-	**
Johnstones Creek	***	****	-	-
Rocks Creek and tributaries	*****	-	-	**
Upper Manuherikia mainstem	****	**	-	**
Falls Dam reservoir	****	-	-	***

***** Abundant.
**** Common.
*** Frequent.
** Occasional.
* Rare.
- Not recorded.

In tributary streams, juvenile trout were most commonly caught in shallow runs and riffles, whereas larger fish were generally taken in deeper pools or in areas of suitable cover, such as undercut banks. The low density of large fish in the upper Manuherikia mainstem is probably related to channel form, and in particular to the small number of pools.

Although the upstream limit for brown trout in the Manuherikia catchment was not determined during this study, they were common in Camp Creek, the survey site furthest upstream.

FIGURE 38. Rocks Creek, the largest upper Manuherikia tributary, supports a brown trout population but no brook char.

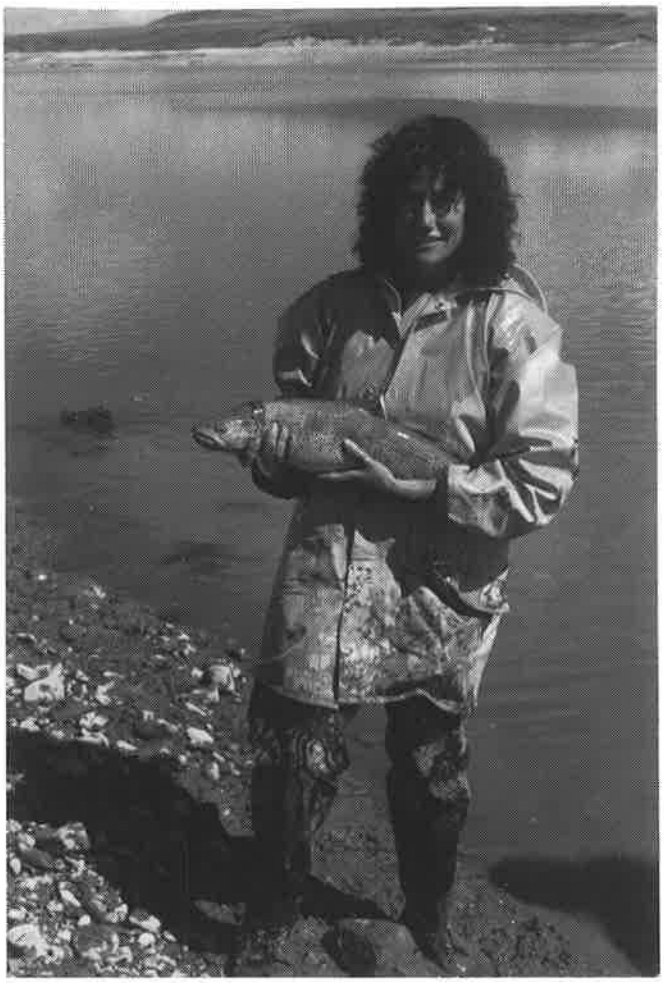

FIGURE 39. Adult brown trout caught by seine netting in Falls Dam reservoir.

4.3.2.2 Brook Char *(Salvelinus fontinalis)*

During this study, brook char were found in all of the tributary streams surveyed except Rocks Creek, and have been recorded previously from Johnstons, Camp, Kirkwoods, Big Bremner, Healeys, and Johnstones Creeks, and from the East and West Branches of the Manuherikia (Fig. 40).

A few brook char have been recorded from the Manuherikia mainstem, but their absence from the Falls Dam reservoir suggests that they do not recruit downstream into this still water environment. This hypothesis is supported by angler catch data, which record only brown trout being taken in the reservoir.

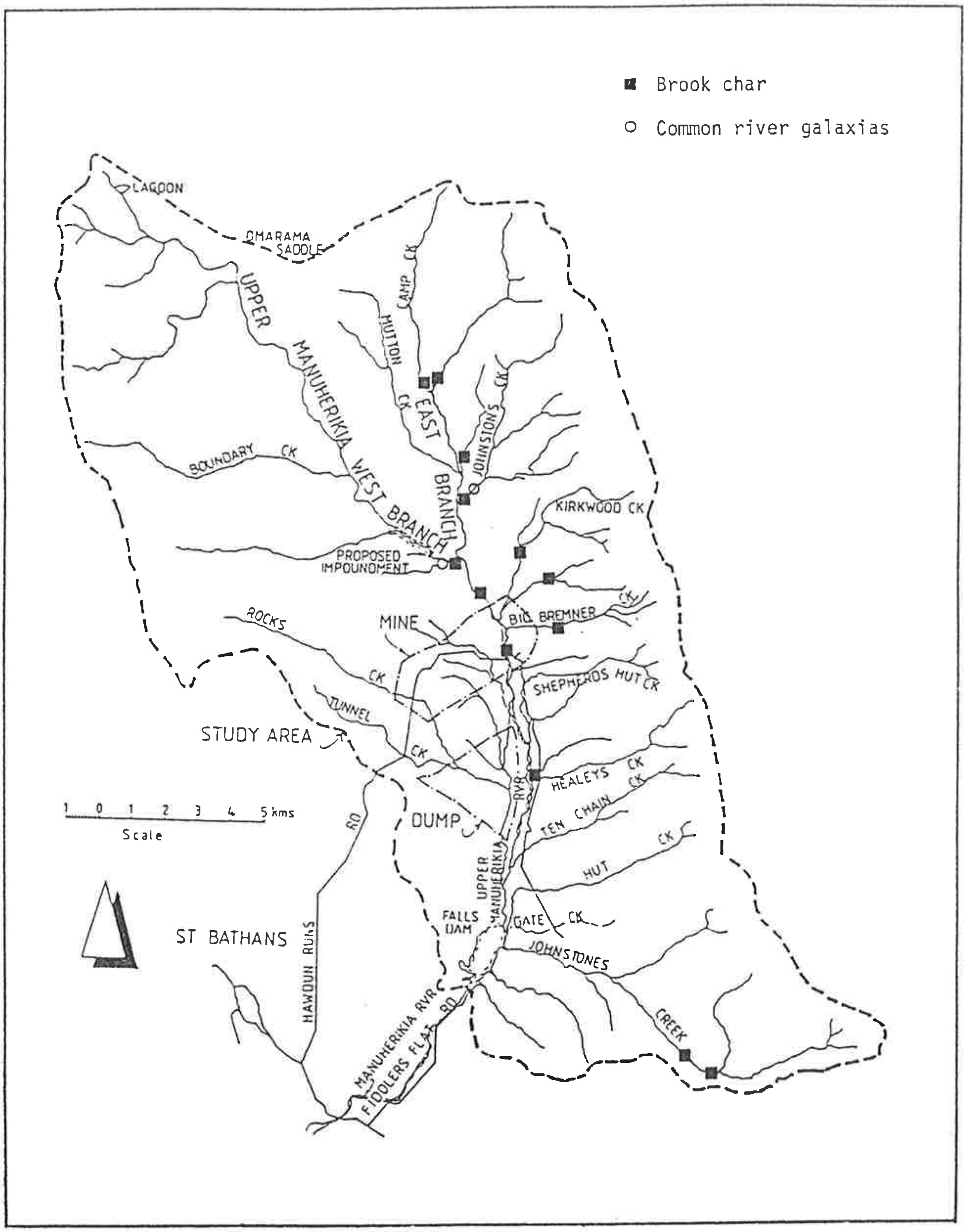

FIGURE 40. Distribution of brook char and common river galaxias at Hawkdun.

McDowall (1978) commented that brook char do not seem to coexist with brown trout, and are usually found upstream from trout populations. This is not so in the upper Manuherikia, where brook char and brown trout can be considered as co-dominant species in all of the tributary streams surveyed, with the exceptions of Rocks, Hut, Spring, Ten Chain, and Gate Creeks. Although brown trout were usually present in greater numbers, brook char were more common in Big Bremner and Johnstons Creeks.

Although brook char can grow to several kilograms in weight, the Hawkdun population, like those in adjacent subcatchments (Dunstan Creek and the Ida Burn) and most other populations in New Zealand, comprises only small fish (Fig. 41). The largest specimen recorded during this study was 165 mm long, but these fish can reach maturity at about 150 mm (McDowall 1978). The well-stocked tributaries of the Manuherikia are used by the OAS to obtain juvenile brook char for release into other waters in their district which have insufficient natural spawning to maintain stocks for anglers.

Brook char showed no detectable habitat preference at any of the sites surveyed, and occupied the same habitat as juvenile and yearling brown trout.

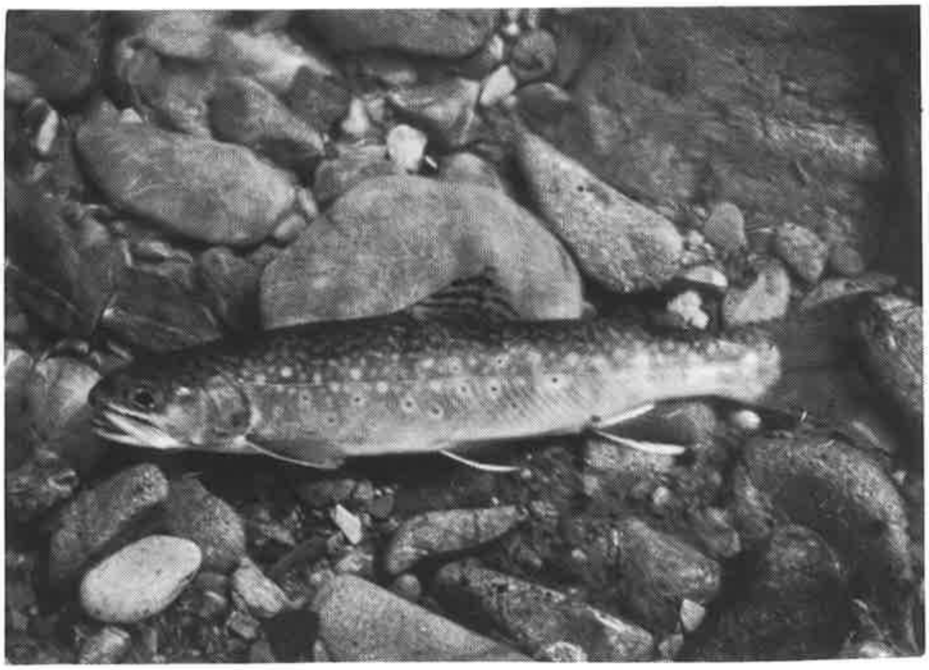

FIGURE 41. Large numbers of brook char are present in the upper Manuherikia catchment.

4.3.2.3 Common River Galaxias *(Galaxias vulgaris)*

During this study, fish of this species were found in only 1 of the streams surveyed, Johnstons Creek (a tributary of the East Branch), but they are known to be present also in the West Branch of the Manuherikia. The 5 fish caught at the survey site were adults, and ranged in size from 73 mm to 107 mm. During the 1981 survey of Johnstons Creek by the OAS, specimens of this species were also present. Johnstons Creek is a bouldery stream dominated by riffles and runs, which is the habitat described as typical for common river galaxias by McDowall (1978).

4.3.2.4 Upland Bully *(Gobiomorphus breviceps)*

Upland bullies were found in the Falls Dam reservoir, the Manuherikia mainstem, and Healeys, Hut, Rocks, and Gate Creeks. They are known to be present also in the East and West Branches, but were not caught in Big Bremner, Little Bremner, Kirkwoods, Ten Chain, or Johnstons Creeks.

Specimens of all sizes were captured, from very small juveniles to well-grown adults of up to 90 mm, although the actual number of fish caught was small (Fig. 42). Upland bullies were generally caught in the shallow margins of streams, where the water flows slowly.

FIGURE 42. Small numbers of upland bully are widespread in the upper Manuherikia catchment.

4.3.3 Spawning

4.3.3.1 Native Fish

Both of the native fish species found in the study area (common river galaxias and upland bully) are residents and typically spawn in their adult habitat.

Common river galaxias spawn in winter and spring, and build primitive nests in rapidly flowing water (McDowall 1978). Johnstons Creek, where they were common, is a shallow, swift, bouldery stream, typical of their described adult habitat. No juveniles of the species were observed during sampling.

Upland bullies spawn in spring and summer, and lay their eggs in a nest on some firm object, usually a rock. The young rear in fresh water near where they hatch (McDowall 1978). Schools of juvenile bullies were observed in the shallow margins of Rocks Creek, just below a survey section from which adults were recorded. Juveniles were also found in the Falls Dam reservoir.

4.3.3.2 Introduced Fish

Salmonid spawning within the study area was assessed by counting redds on representative sections of streams, and by reviewing earlier spawning survey data collected by OAS staff between 1979 and 1981.

During mid June 1985, 26 reaches of 13 streams (including the upper Manuherikia mainstem) were inspected. This complemented earlier surveys of 19 reaches of 9 streams and the mainstem. The results are presented in Appendix VII, and Figure 43 shows the distribution of reaches where redds were observed, as well as that of areas assessed as suitable for spawning. Although this study did not include spawning surveys of the West Branch above Boundary Creek, an aerial assessment in 1982 indicated that suitable trout spawning areas were common (M. Wright pers. comm.).

Brown trout spawn between April and July in Otago, with a peak in activity in May and June. The smallest sexually ripe male trout measured was 132 mm. Brown trout spawning is widespread within the

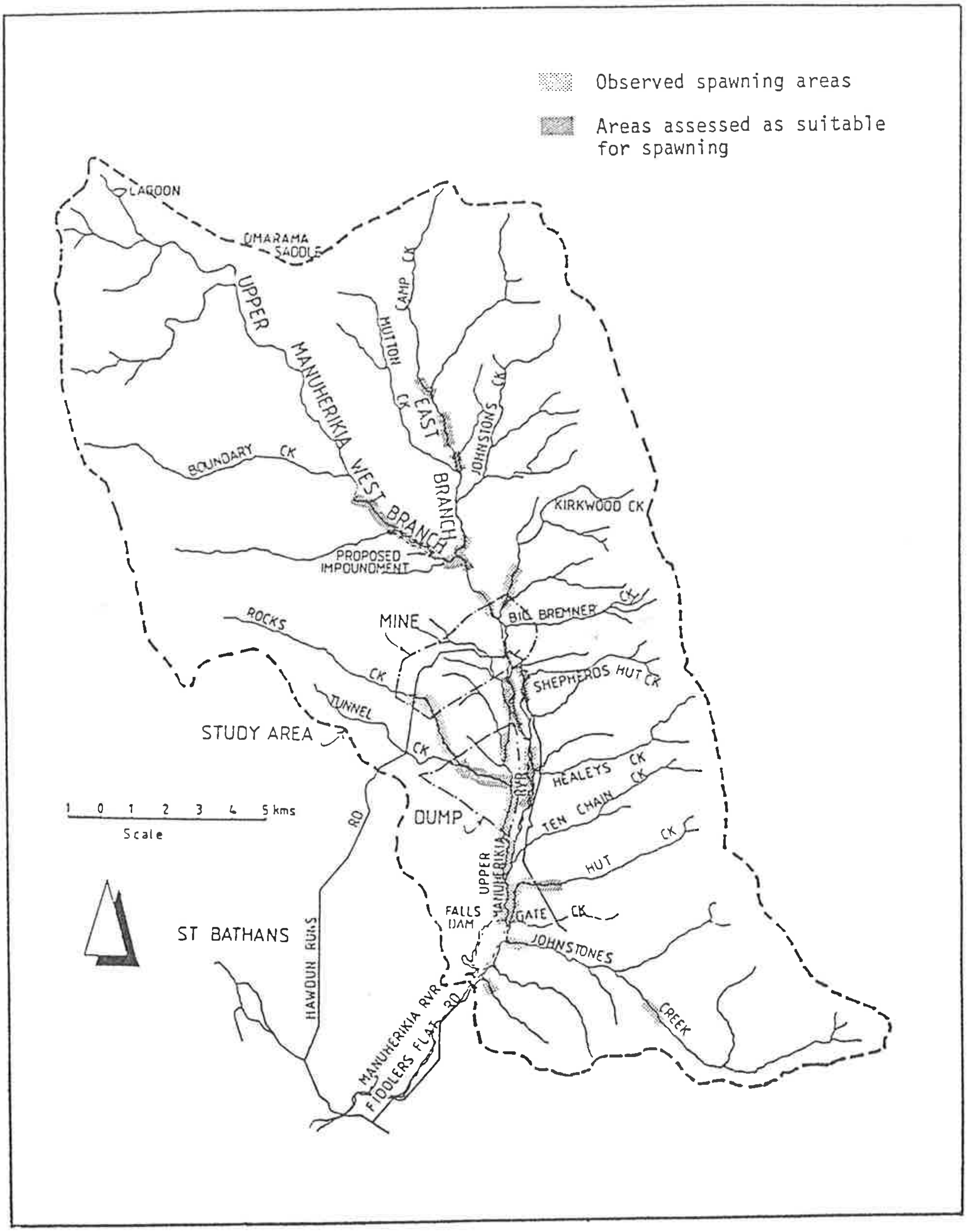

FIGURE 43. Trout spawning areas at Hawkdun.

upper catchment, and recruitment, both into the river-resident population and downstream into the standing waters of the Falls Dam reservoir, is far greater than that required to maintain trout stocks. Overall, trout spawning areas are common and widespread in the upper catchment.

In Otago, brook char appear to spawn earlier than brown trout, with a peak in March and April (D. Scott pers. comm.). Characteristically, populations of this species in the headwaters of several catchments throughout Otago are stunted. One sexually ripe male of 120 mm fork length was noted in Little Bremner Creek, and 2 others, also males, of 245 and 251 mm were recorded from the mainstem of the river late in April of 1981. Redds observed during this study could not be ascribed specifically to either brown trout or brook char, but the widespread distribution of char within the upper catchment suggests strongly that they will spawn wherever conditions are suitable.

4.3.4 Recreational Fisheries

Brown trout were established in the Manuherikia River system around the turn of the century, and an early guide to New Zealand angling (Hamilton 1904) indicated that an exploitable population existed shortly after that time. The waters of the Manuherikia catchment continue to support self-sustaining brown trout fisheries both above and below Falls Dam, and within the Falls Dam reservoir. Angler use of fish stocks within the study area, and in the catchment downstream, was assessed by reviewing historical data and by contacting and interviewing anglers known to fish in the area. Angler use, success, and opinion have been assessed previously by the National Angling Diary Scheme (Graynoth 1974b), by an investigation of the Otago Acclimatisation district trout fishery (Graynoth 1974a), by FFC's National River Angler Survey of Otago (Richardson *et al.* 1984), and by the creel surveys carried out by the OAS between 1975 and 1981.

Twenty-two anglers were interviewed as part of this study, and they were asked to specify which areas within the catchment they fished, the average number of visits they made each year, aspects of the environment which enhanced their recreational angling, the average size of fish taken, their assessment of the catch rate, the importance of the waters to them, and any aspects which adversely affected their sport.

4.3.4.1 Manuherikia River below Falls Dam

A recent angling guide produced by the OAS (Turner 1983) described the Manuherikia River as supporting "a population of brown trout which is self-sustaining and generally constant ... the average size increases towards the headwaters with some trophy class fish in the gorge at St. Bathans". An earlier guide book (Benfield 1948) described the trout as being "plentiful" and as "averaging about a pound".

Graynoth (1974a) noted that weed growth and water abstraction for irrigation made angling difficult in summer, and reported an average size of 38 cm for brown trout. He noted also that perch, rainbow trout, and quinnat salmon are taken occasionally in the Manuherikia River, probably below Falls Dam, and in the lower reaches near Alexandra.

Creel surveys of several reaches of the river below Falls Dam have shown that they support little angling activity. Surveys on 2 sections in the middle reaches during the 1975/76 and 1977/78 fishing seasons recorded no anglers, and those on 3 representative sections of the river below Falls Dam during the 1981/82 and 1984/85 seasons indicated that angling pressure was low.

However, the results of FFC's national survey of river anglers (Richardson et al. 1984) contradicted the results of the creel surveys, in that the Manuherikia River attracted more than 10% of the Otago respondents to the survey. The respondents commented on the accessibility, high degree of solitude, pleasant scenic qualities, low catch rate, and small trout of the river as a whole, and rated it above average for importance. They also reported that they had combined picnicking, swimming, and camping with angling.

Eight of the interviewed anglers reported fishing the river below Falls Dam, and described a variable catch rate of fish ranging in size from 30 cm to 60 cm. The importance of the water to these anglers also varied, but the peace and solitude and the scenery were constantly quoted as being important aspects of the angling experience. All of the anglers interviewed complained about low summer flows due to abstraction. The interviewees averaged 5 visits per season.

4.3.4.2 Falls Dam Reservoir

The Falls Dam reservoir, which is also known as Manuherikia Dam, was described by Benfield (1948) as providing easy fishing and as "being well stocked with rainbow trout ... with the occasional brown trout being landed". This reference to rainbow trout stocks appears to be an error, because the only recorded liberations of this species occurred between 1958 and 1960, and there is no record of rainbow trout being taken from the lake by diarists in the National Angling Diary Scheme (Graynoth 1974b).

Turner (1983) described the reservoir as holding ... "a good stock of brown trout which vary in average size depending on the season. At times there are a large number of fish around the 500 g mark with larger fish being harder to find". Graynoth's (1974a) assessment of catch rate and average size of fish recorded by anglers between 1947 and 1968 showed that brown trout taken from the reservoir averaged 36.9 cm, and were caught at a rate of 0.56-2.0 fish per hour. However, the tendency of diary schemes to overestimate catch rate has been documented clearly in a survey of the Mataura fishery (Scott 1979). It is generally agreed that a more realistic figure can be obtained from creel surveys.

Creel surveys have been carried out on the Falls Dam reservoir by the OAS over 6 angling seasons since 1975. The results (Table 15) show that the average fish size varies little between seasons, and the average for the whole period was 34.3 cm. The fish taken and kept by anglers (Fig. 44) ranged between 25 cm and 56 cm in length. The overall catch rate was 0.18 fish per hour for trout taken and kept, and this varied seasonally from 0.07 fish per hour in 1976/77 to 0.25 fish per hour in 1978/79.

The dominant angling method used in the reservoir was natural bait, which was used by 75% of the anglers interviewed and accounted for 82% of the total angling effort. The rest of the anglers fished with threadline.

All of the anglers interviewed during the creel surveys came from within the OAS district, and many lived locally. Thirty-two percent of anglers held junior licences, and were thus under 16 years of age.

TABLE 15. Creel survey data for the Falls Dam reservoir, 1975/76-1981/82

Fishing season	No. of anglers surveyed	Hours Fished	No. of fish kept	No. of fish returned	Average length (cm)	Catch rate (fish/hour)
1975/76	18	83.5	9	12	35.9	0.11
1976/77	8	13.5	1	1	32.5	0.07
1978/79	13	31.5	8	2	38.0	0.25
1979/80	24	57.0	12	19	31.6	0.21
1980/81	23	95.0	21	4	33.5	0.22
1981/82	6	7.0	1	0	42.5	0.14
Total	92	287.5	52	38		
Average					34.3	0.18

Of the 22 anglers interviewed during this study, 9 reported fishing in the Falls Dam reservoir. They described a variable catch rate of trout which ranged from 30 cm to 50 cm in size. All considered the lake to be of average or better importance for angling, and they regarded peace and solitude, and scenery as important aspects of the angling experience. The most common complaint was the effect of abstraction on the lake water levels after the beginning of the new year (Fig. 45).

Of these 9 anglers, who reported an average of 15 visits (total 132) to the reservoir each year, 3 were hut owners, and these accounted for 88% (116) of the total number of visits reported. With the exception of 1 angler, all of those interviewed lived in the area between Alexandra and Ranfurly.

In a regional context, the Falls Dam reservoir is locally important for angling. There are several other irrigation reservoirs supporting trout fisheries near Falls Dam, 2 of which (Pool Burn and Upper Manor Burn reservoirs) also lie within the Manuherikia catchment, and offer angling opportunities similar to those of the Falls Dam reservoir. The Pool Burn reservoir contains stocks of brown trout, and the Upper Manor Burn reservoir supports a rainbow trout fishery.

4.3.4.3 Manuherikia River above Falls Dam Reservoir

There have been no creel surveys in the Manuherika River above the Falls Dam reservoir, and none of the literature reviewed pertains

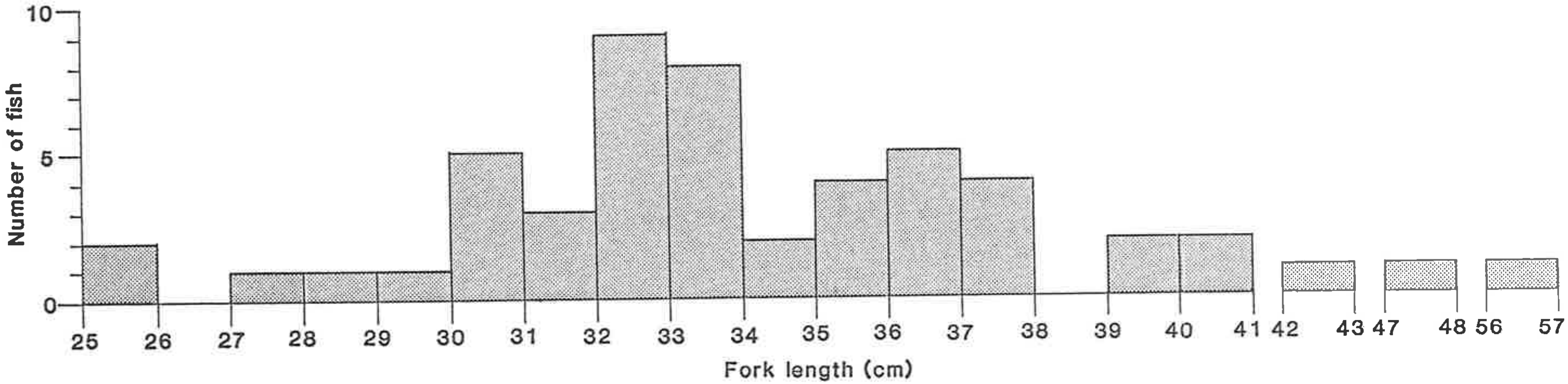

FIGURE 44. Length frequency of Falls Dam trout, 1975-82.

FIGURE 45. Falls Dam reservoir, March 1985.

specifically to that reach of the river. However, 6 of the 22 anglers interviewed as part of this study fished above the reservoir and described as typical a low catch of brown trout up to 60 cm in size, particularly in the mainstem above Boundary Creek, and in the West Branch. Scenery, and peace and solititude were considered to be positive attributes of the area. The average number of visits per season for the 6 anglers was 16.5, but 2 who lived in the immediate vicinity made 92% of the visits.

Angling effort was concentrated almost exclusively in the mainstem above its confluence with Kirkwoods Creek, and in the West Branch, with few takable fish being reported elsewhere in the upper catchment.

The upper Manuherikia is subjected to a very low angling pressure, but offers anglers the opportunity to catch large fish at a low catch rate in a predominantly natural landscape. Because other fisheries in the region have similar characteristics, the fishery is considered to be of local importance only.

5. BENTHIC INVERTEBRATES AND ZOOPLANKTON

5.1 Ecological Importance of Benthos

Numerous New Zealand studies have demonstrated the importance of some components of the benthic fauna in the diet of both juvenile and adult fish. Allen (1951) described the food of trout in streams as being derived generally from 3 sources - benthic invertebrates, small terrestrial animals, and small fish - and considered the benthic fauna to be the most important. In the Mataura River, Witherow and Scott (1984) showed that mayflies and midges were an important food source for juvenile brown trout. McDowall (1984) considered caddisflies, mayflies, stoneflies, chironomids, and snails to contribute significantly to the diet of both adult and juvenile trout throughout New Zealand. Similarly, in a dietary analysis of fish inhabiting the lower Rakaia River, Sagar and Eldon (1983) found that the diets of common and upland bullies, long-finned eels, and juvenile brown trout were dominated by *Deleatidium* spp. (mayflies) and chironomids, with caddisflies also contributing.

The benthic invertebrate community is an important component of freshwater ecosystems, and its productivity and diversity provide a good indicator of environmental conditions (Davis *et al.* 1983), particularly for running waters rather than for lakes. The benthic fauna of New Zealand lakes is not rich in species compared to other zoogeographical regions, and Forsyth (1975) expressed reservation about the use of some species as trophic indicators. This was confirmed by Timms (1982), who concluded that it was impractical to type New Zealand lakes by the characteristics of their benthos. However, in the Mataura River in Southland, Witherow and Scott (1984) successfully used the ratio of oligochaetes to Ephemeroptera as an indicator of organic pollution for different reaches.

The diversity of aquatic habitats sampled in this programme - from the high country streams of the upper Manuherikia catchment to the sluggish, tidally-influenced waters of Waituna Lagoon - produced some marked differences between sites in the relative abundance and species composition of invertebrates.

The only reported studies of the benthic fauna within, or adjacent to, the 3 study areas are those on the lower Mataura River (Witherow and Scott 1984). However, a study of the benthic fauna of Hut Creek, a tributary of the upper Manuherikia, is in progress, and its results correlate well with the groupings of species found at survey sites elsewhere in the upper Manuherikia catchment (G. Ryder pers. comm.).

5.2 Ashers-Waituna

The aquatic environments within the Ashers-Waituna study area are of 2 kinds: the predominantly still water habitat of Waituna Lagoon, and the running water habitats of tributary streams. The sampling sites are shown in Figure 46. (Bog ponds were not sampled for benthic invertebrates.)

5.2.1 Waituna Lagoon

A total of 9 taxa was identified from 3 sites within Waituna Lagoon. These sites included a variety of substrate types, from fine gravels to silt. Although this limited sampling gives only an indication of the species present and their relative abundance within the lagoon, it was considered to be appropriate for this study.

At all sites, amphipods (Crustacea) were by far the dominant taxa, comprising 56.8-90.5% of animals sampled (Table 16). The gastropod (snail), *Potamopyrgus* sp., was the next most common taxon, at 6.8-22.8%. Annelids (worms) formed 2.7-15.7% of the samples. Species composition and relative abundance was similar between sites, except for a reduced number of amphipods at the deeper eastern sampling site. This site had more snails, and 2 other taxa which were not present at any other site: flatworms (Platyhelminthes) and the isopod *Austridotea annectans* (Crustacea). A few caddisflies were recorded at the Waituna Creek confluence site.

The benthic fauna at Waituna Lagoon was low in species diversity, and, with the exception of 1 site, low in numerical abundance. This

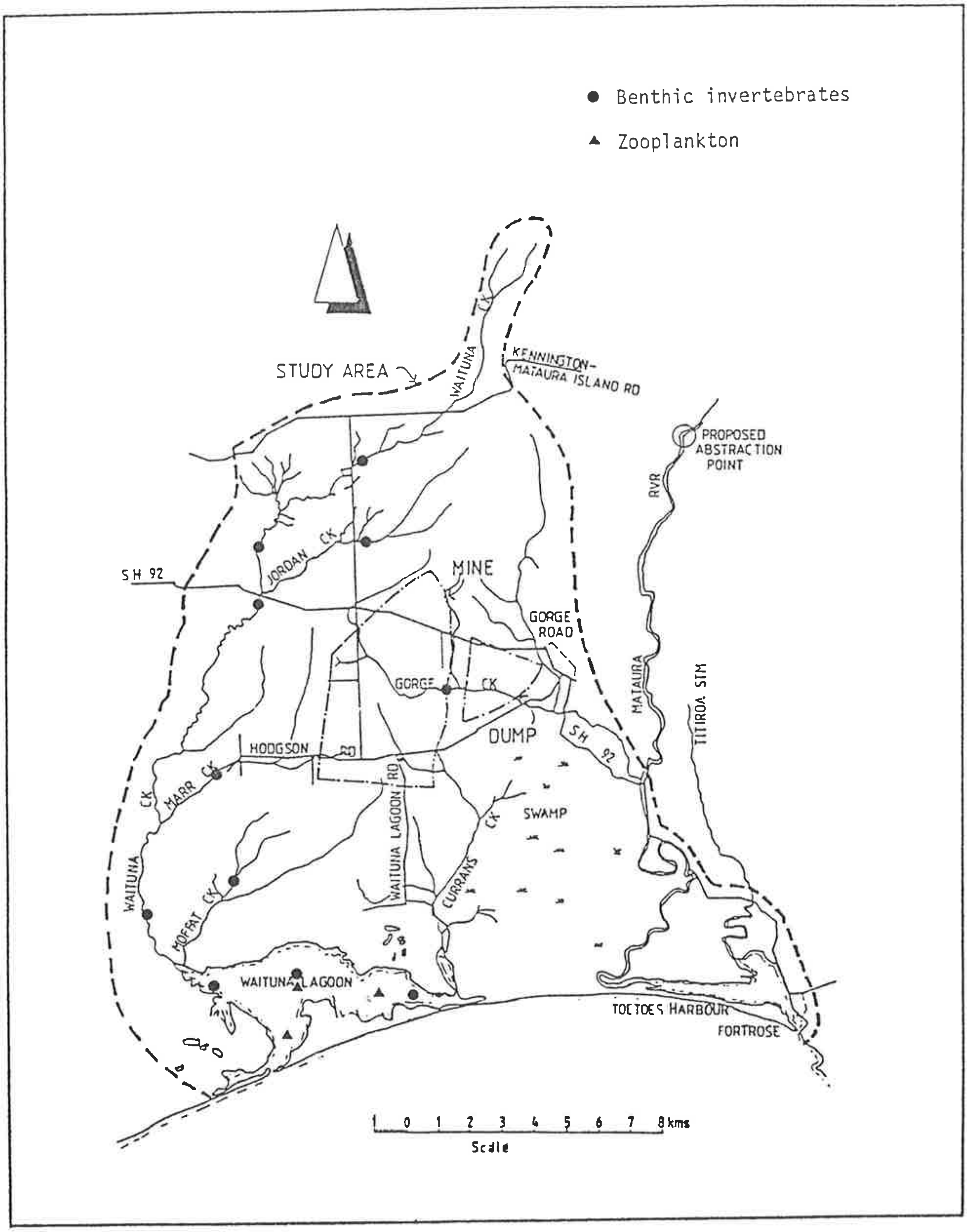

FIGURE 46. Ashers-Waituna benthos and zooplankton sampling sites.

TABLE 16. Relative abundance (%) of benthic invertebrates at 3 sites in Waituna Lagoon, 5 August 1985

Survey site	Eastern end	Centre lake	Waituna Ck confluence
Substrate	fine gravel	sand/fine gravel	silt/coarse sand
Depth (m)	2.75	0.45	0.45
Platyhelminthes			
Dugesiidae	11.4	-	-
Annelida			
Oligochaeta species A	6.8	1.7	9.4
Oligochaeta species B	-	1.0	-
Tubificidae	-	-	6.3
Mollusca			
Potamopyrgus sp.	22.8	6.8	7.7
Crustacea			
Austridotea annectans	2.2	-	-
Paracorophium excavatum	56.8	90.5	73.4
Trichoptera			
Oxyethira albiceps	-	-	1.6
Pycnocentrodes spp.	-	-	1.6
No. of taxa	5	4	6
No. of animals/m^2	44	361	64

feature was common to all of the 3 standing waterbodies surveyed. At the time of sampling (August 1985), few aquatic weeds were present in the lagoon, and they are not known to be abundant at any time of year. Freshwater crayfish *(Paranephrops zealandicus)* are common in tributary streams of Waituna Lagoon, but were not detected in the lagoon samples. Nevertheless, they probably do live in the lagoon. Marine crabs were taken during seine netting in the lagoon, which suggests a salt water influence.

The species composition of Waituna Lagoon was found to be similar to that recorded in comparable waterbodies such as Lake Ellesmere, where *Potamopyrgus*, tubificid worms, isopods, chironomids, and caddisfly larvae have been recorded (Forsyth 1975). A major difference was the presence of a significant proportion of amphipods in the Waituna samples.

5.2.2 Waituna Streams

A total of 16 taxa was identified from 8 sampling sites in streams within the Ashers-Waituna study area (Table 17). The number of taxa at each site ranged from 5 to 10, with an average of 7.

The benthic fauna of all sites was dominated by 3 groups: gastropods of the genus *Potamopyrgus*, being 3.2-81% of the animals sampled; chironomid larvae, at 0.1-87.4% ; and annelid worms, at 9.1-59%. The remaining 0.3-7.6% of the sample included mayflies (found at 2 sites only), caddisflies (found at 6 of the 8 sites), and dipteran taxa other than chironomids.

The benthic invertebrates of streams in the Ashers-Waituna area were quite different from those found at Hawkdun and Benhar, where mayflies and caddisflies dominated. The high density of snails and chironomids in the Ashers-Waituna Streams probably reflects a low water velocity, which is preferred by species of these groups. Although the fauna of the lower Mataura River is similar to that of the Ashers-Waituna streams, in that chironomids are dominant (Witherow and Scott 1984), this similarity should be treated with caution, because of the influence of organic pollution on the Mataura River below the Mataura township.

TABLE 17. Relative abundance (%) of benthic invertebrates in streams of the Ashers-Waituna study area

Survey site	1	2	3	4	5	6	7	8
Map reference	S177: 589018	S182: 553988	S182: 589987	S182: 557963	S182: 539907	S182: 513864	S182: 544874	S182: 613937
Sampling date	9/4/85	29/12/84	15/1/85	11/12/84	5/12/84	5/12/84	29/12/84	9/4/85
Platyhelminthes								
Dugesiidae sp.	-	-	-	-	-	-	-	0.6
Annelida								
Oligochaeta	0.2	-	-	0.4	0.1	-	-	0.8
Other annelids	18.0	59.0	42.0	57.0	9.0	33.0	21.0	39.0
Mollusca								
Potamopyrgus antipodarum	81.0	18.0	20.0	38.0	3.2	22.0	65.0	45.0
Sphaerium sp.	0.1	0.2	-	-	-	0.1	-	5.5
Crustacea								
Amphipoda	0.2	-	-	-	-	-	3.8	-
Ephemeroptera								
Deleatidium sp.	0.4	-	0.5	-	-	-	-	-
Trichoptera								
Oxyethira albiceps	-	0.7	-	-	-	0.4	3.8	4.0
Rhyacophilidae	-	-	3.0	0.3	-	-	-	-
Hydrobiosus spp.	-	-	-	-	-	-	-	0.1
Pycnocentrodes spp.	-	-	-	-	-	0.3	-	1.6
Hudsonema sp.	-	-	-	-	-	-	-	0.6
Diptera								
Austrosimulium	-	3.5	3.4	-	0.3	0.6	3.6	-
Chironomidae	0.1	18.4	31.1	3.5	87.4	43.1	2.6	2.8
Tipulidae	-	0.2	-	0.8	-	0.4	0.1	-
Muscidae	-	-	-	-	-	0.1	0.1	-
No. of taxa	7	7	6	6	5	9	8	10
No. of animals/m^2	25 350	8 160	6 225	15 255	13 230	20 974	14 640	7 608

Both the quantity and quality of food available to fish in the Waituna streams may be lower than in other streams of the region. Generally, chironomids and annelids are found within, rather than upon, the substrate, and therefore they are not readily available to the fish. Gastropods live on the surface of the substrate, but studies in Lake Benmore have shown that trout are unable to digest gastropods completely, so these have little food value (N. McCarter pers. comm.).

5.3 Benhar

The aquatic environments of the Benhar study site also comprise still water and running water habitats. The sites sampled are shown in Figure 47.

5.3.1 Lake Tuakitoto

A total of 14 taxa was identified from samples taken from the open waters of Lake Tuakitoto (2 sites) and the adjacent swamp (1 site). The sites differed markedly in species composition and abundance (Table 18). The number of taxa present in the samples ranged from 4 to 12, with the swamp and lake edge sites both having low species diversity and few animals. Annelids, chironomids, and amphipods were dominant at both sites. By comparison, the lake centre site had a rich fauna, dominated by the gastrod *Potamopyrgus antipodarum*, the bivalve *Sphaerium*, the larvae of caddisflies, and chironomids.

As at Waituna Lagoon, few weeds were present at the time of sampling. However, beds of *Elodea* are common during summer and these provide another habitat for aquatic invertebrates. Water boatman (Hemiptera) are commonly observed in the lake, often in association with weed beds. Although freshwater crayfish *(Paranephrops zealandicus)* were not detected during this survey, they are known to be present in tributary streams, and probably also in the lake. The large freshwater mussel *Hyridella menziesi* is also found quite commonly in the lake (R. Dungey pers. comm.), although it was not present in these samples.

Lake Tuakitoto and Lake Wairarapa are both shallow coastal lakes, and the limited data available in the literature suggest that they support similar animal communities. Forsyth (1975) reported freshwater

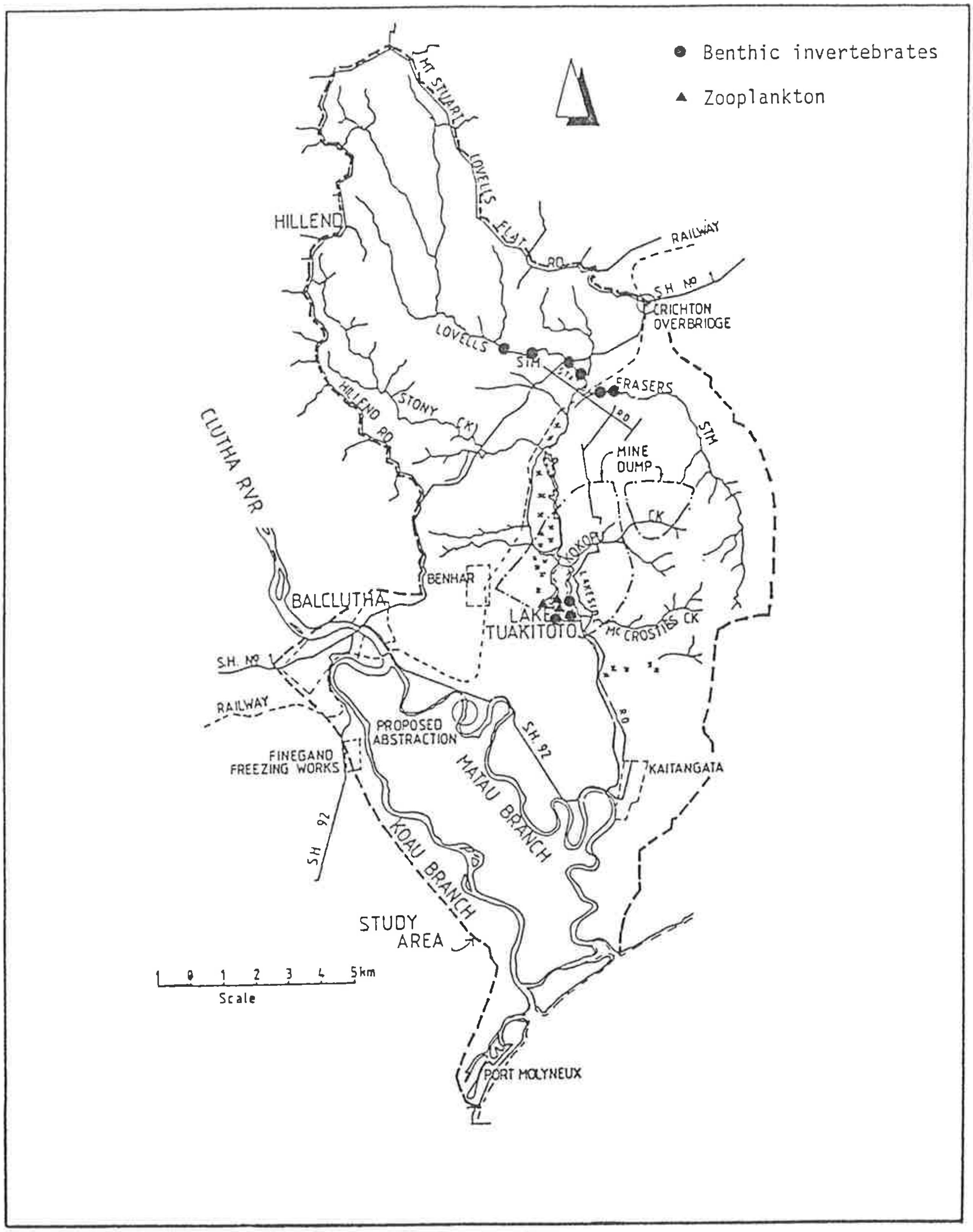

FIGURE 47. Benhar benthos and zooplankton sampling sites.

TABLE 18. Relative abundance (%) of benthic invertebrates at 3 sites in Lake Tuakitoto, 8 August 1985

Survey site	Swamp	Lake edge	Lake centre
Substrate	mud	mud	mud
Depth (m)	0.25	0.5	0.6
Distance from shore (m)	0	1	200
Nematoda	-	-	1.5
Platyhelminthes	-	-	9.6
Annelida	57.3	20.0	-
Mollusca			
Potamopyrgus antipodarum	-	-	14.8
Sphaerium sp.	-	-	24.1
Lymnaea sp.	-	-	0.4
Physa sp.	-	-	0.4
Crustacea			
Paracalliope fluviatilis	7.1	40.0	1.9
Ostracoda	7.1	-	-
Trichoptera			
Caddis sp.	-	-	38.1
Diptera			
Chironomidae	21.4	30.0	9.3
Other dipterans	7.1	-	3.0
Lepidoptera	-	-	0.4
Odonata	-	10.0	1.5
No. of taxa	5	4	12
No. of animals/m^2	14	10	270

mussels as being fairly common in all parts of Lake Wairarapa. More recently, Moore *et al.* (1984) observed shrimps in the shallows along the lake margin, and copepods, shrimps, water fleas, water boatmen, ostracods, damselfly nymphs, water beetles, and mosquito larvae in nearby swamps.

5.3.2 Tributary Streams

A total of 22 taxa was identified from 6 sampling sites in Lovells and Frasers Streams (Table 19). The number of taxa at each site ranged from 4 to 15, with an average of 9.

At all sites, the fauna was dominated by 3 groups: caddisflies, being 14.8-72% of the samples; mayflies, at 5.8-36.1%; and *Potamopyrgus antipodarum*, at 13.5-29.4% (Table 19). The remaining 5% or less included dipterans, beetles, ostracods, amphipods, neuropterans, and the megalopteran *Archichauliodes diversus*, although not each of these groups was represented at every site. One site (6) had a high proportion of freshwater crayfish (38%), but otherwise the relative abundance of the dominant taxa was similar at every site.

Benthic fauna in streams of the Benhar area was similar in species composition and distribution to that in streams of the Hawkdun area. In both, mayflies and caddisflies dominated the fauna; *Potamopyrgus antipodarum* were also present, although they were more common at Benhar. The fauna was similar also to that in other Otago and Southland rivers. Witherow and Scott (1984) found that the Mataura River above Gore was dominated by mayflies, whereas in the Silverstream (a tributary of the Taieri River) chironomids, mayflies, caddisflies, elmid larvae, and *Potamopyrgus* dominated the benthos (Scott 1966).

5.4 Hawkdun

As with the other 2 study sites, the benthic invertebrates of the Hawkdun area have been considered in 2 parts, those inhabiting the still water of the Falls Dam reservoir, and those inhabiting the tributary streams and mainstem of the upper Manuherikia River. The sampling sites are shown in Figure 48.

TABLE 19. Relative abundance (%) of benthic invertebrates in streams of the Benhar study area

Survey site	1	2	3	4	5	6
Map reference (s171)	565360	566359	596346	597348	600341	605343
Date	22.5.85	22.5.85	22.5.85	22.5.85	22.5.85	22.5.85
Mollusca						
Potamopyrgus antipodarum	25.5	29.4	13.5	21.4	13.9	19.9
Lymnaea sp.	-	-	2.5	-	-	-
Crustacea						
Ostracoda	-	-	2.7	-	-	-
Amphipoda	-	-	0.5	0.5	-	-
Paranephrops zealandicus	-	-	-	-	-	38.8
Coleoptera						
Elmidae	-	-	-	0.3	2.7	-
Ephemeroptera						
Deleatidium sp.	6.7	31.7	14.5	5.8	36.1	26.5
Coloburiscus humeralis	-	1.3	-	-	-	-
Megaloptera						
Archichauliodes diversus	-	-	0.5	-	-	-
Neuroptera	2.1	1.0	0.5	-	-	-
Trichoptera						
Aoteapsyche spp.	6.2	24.3	-	3.9	-	-
Hydrobiosella spp.	-	0.8	0.2	-	-	-
Hydrobiosis spp.	1.0	2.9	0.2	0.9	-	-
Oxyethira albiceps	-	-	-	-	44.6	14.8
Pycnocentrodes spp.	0.5	-	3.0	1.4	2.7	-
Pycnocentrella spp.	-	0.8	-	61.4	-	-
Helicopsyche sp.	54.5	2.6	1.0	4.4	-	-
Hudsonema sp.	-	-	59.0	-	-	-
Diptera						
Simulidae	-	-	0.2	-	-	-
Tipulidae	3.1	5.0	1.5	-	-	-
Chironomidae	0.5	0.2	-	-	-	-
Muscidae	-	-	0.2	-	-	-
No. of taxa	9	11	15	9	5	4
No. of animals/m^2	3 104	6 048	13 072	8 000	576	3 376

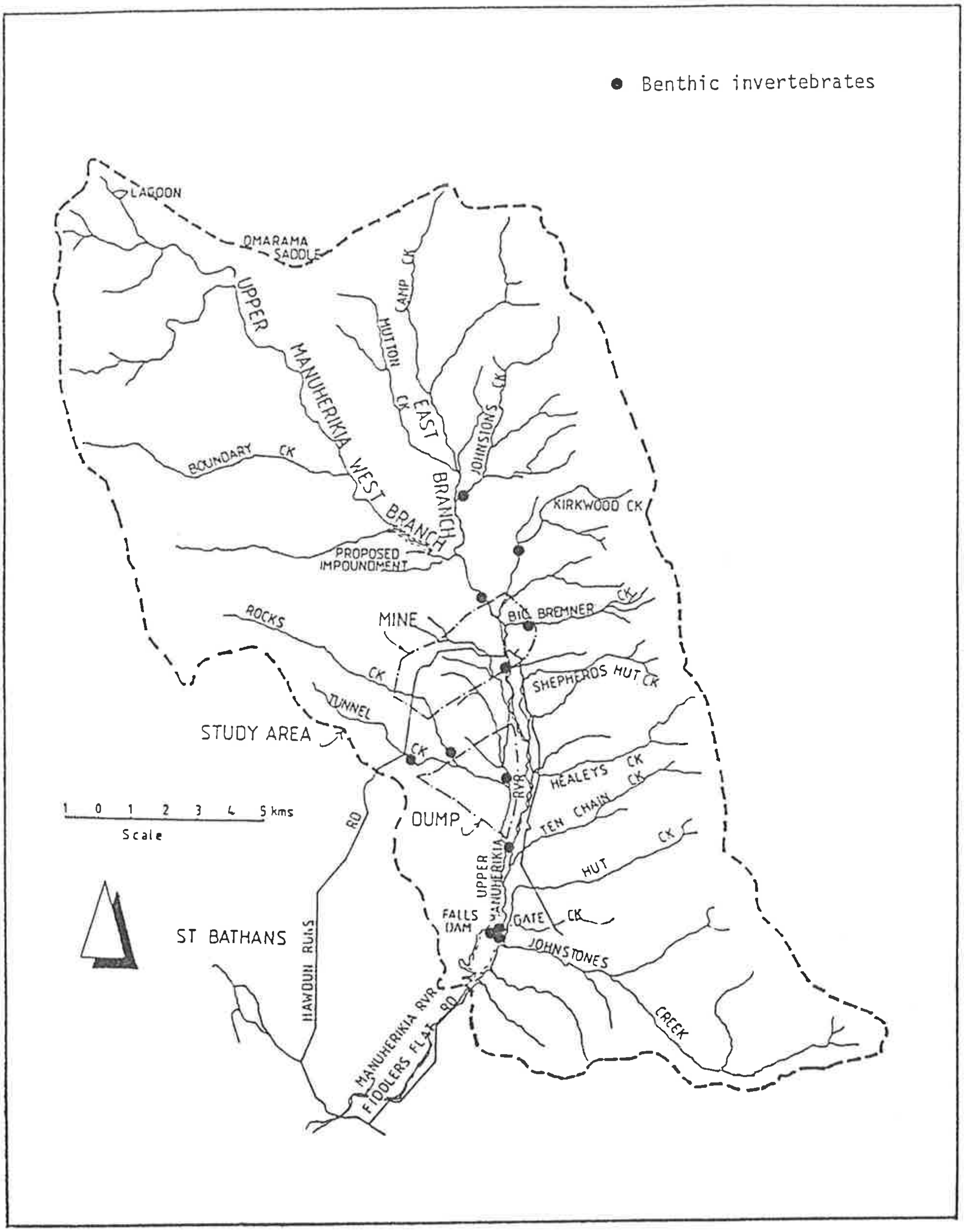

FIGURE 48. Hawkdun benthic invertebrate sampling sites.

5.4.1 Falls Dam Reservoir

The bed sediments of the Falls Dam reservoir are largely riverine silts and mud, with some areas of fine gravel. The representativeness of the benthic samples from the reservoir should be considered with caution because of the water level regime over the previous summer; the reservoir was empty for several months from late March 1985 because of a drought in Otago (see Fig. 45). Consequently, the littoral and benthic invertebrate populations would have had to recolonise the substrate as the reservoir filled.

A total of 9 taxa was identified from the 3 sample sites. The number of taxa at each site ranged from 3 and 7, with an average of 5 (Table 20). Species numbers and diversity declined towards the shore, possibly reflecting the length of time since recolonisation.

TABLE 20. Relative abundance (%) of benthic invertebrates at 3 sites in the Falls Dam reservoir, 9 August 1985

Survey site	1	2	3
Substrate	mud	mud	mud
Depth (m)	0.26	0.35	1.17
Distance from shore (m)	1	25	45
Nematoda	75.0	35.8	84.7
Mollusca			
Potamopyrgus antipodarum	8.3	-	2.5
Melanopsis trifasciata	-	-	4.2
Crustacea			
Ostracoda	-	-	1.0
Coleoptera			
Hydrophilidae	16.7	-	-
Trichoptera			
Oxyethira albiceps	-	-	1.0
Pycnocentrodes spp.	-	50.0	4.2
Olinga feredayi	-	7.1	2.5
Diptera			
Muscidae	-	7.1	-
No. of taxa	3	4	7
No. of animals/m^2	12	14	118

At Site 1, in shallow water next to the shoreline, the fauna was dominated by nematode worms (75%), with coleopterans and gastropods of the genus *Potamopyrgus* being the only other taxa recorded. Site 2, 25 m offshore, was dominated by caddisflies (57%), with nematode worms contributing 35.8%, and the only other taxon present being a dipteran. Site 3 had the greatest species diversity, although its fauna was also dominated by nematode worms (84.7%). Snails, caddisflies, and ostracods were minor components of the fauna at this site.

Aquatic weeds are not a significant feature of the aquatic environment in the Falls Dam reservoir, probably because the fluctuating water level does not permit macrophyte beds to become established.

The results of sampling are not easily interpreted because of the paucity of work on benthic fauna in similar water bodies, and the complicating effect of the reservoir being empty throughout late summer and autumn. While *Potamopyrgus* and caddisflies are reported to be constituents of lake faunas elsewhere in New Zealand (Forsyth 1975), nematode worms are not usually dominant in lakes. Timms (1982) sampled the benthic communities of 20 lakes in the South Island, and reported an average of only 12.4 taxa per lake (range 1-26). Therefore, the total of 9 taxa recorded here is not unusual, particuarly when the effect of the drought is taken into account. In Timms' study, the majority of animals collected were tubificid worms, chironomids, and *Potamopyrgus antipodarum* .

5.4.2 Tributary Streams

A total of 24 taxa was identified from 9 survey sites within the upper Manuherikia catchment. The number of taxa per site ranged from 6 to 14, with an average of 9.

Generally, there was a strong similarity between streams in the dominant groups present; these were mayflies (3.5-75%) and caddisflies (6-80%) (Table 21). Commonly, where one of these was strongly represented, the other was less abundant. Chironomids were abundant at only 2 sites. Minor components of the fauna included molluscs (except at Site 8, where they comprised almost half of the animals present), stoneflies, dobsonflies (Fig. 49), beetles, and dipterans other than chironomids.

TABLE 21. Relative abundance (%) of benthic invertebrates in streams of the Hawkdun study area, 5-7 March 1985

Survey site	1	2	3	4	5	6	7	8	9
Map reference (S125)	613003	628034	635049	632070	596003	602059	612092	630996	632973
Nematoda	-	-	-	-	-	-	-	1.2	-
Mollusca									
Potamopyrgus antipodarum	-	-	4.0	-	10.0	-	-	45.7	-
Ephemeroptera									
Coloburiscus humeralis	-	-	14.0	-	-	2.4	-	-	-
Deleatidium sp.	14.3	68.2	13.3	57.9	-	10.8	75.0	3.5	39.6
Plecoptera									
Zelandoperla sp.	4.0	2.3	-	-	5.0	-	-	-	-
Stenoperla sp.	-	2.3	1.3	-	-	1.2	-	1.2	2.3
Megaloptera									
Archichauliodes diversus	-	-	0.7	-	-	-	-	-	-
Coleoptera									
Elmidae	12.1	11.4	-	5.5	5.0	-	3.6	-	4.7
Trichoptera									
Aoteapsyche spp.	19.2	4.5	8.6	-	-	4.8	-	10.6	25.6
Hydrobiosis spp.	-	-	-	5.2	-	-	1.2	1.8	-
Oxyethira albiceps	3 0	-	10.6	-	25.0	-	1.2	1.2	-
Pycnocentrodes spp.	-	2.3	-	5.2	-	9.6	-	-	-
Confluens sp.	-	-	32.7	-	-	-	-	-	4.6
Zelolessica sp.	-	-	2.6	-	-	-	-	-	-
Pycnocentrella sp.	-	-	1.3	-	-	-	-	27.0	18.6
Rhyacophilidae	-	-	7.3	-	-	-	-	-	-
Polycentropodidae	1.0	-	-	-	-	-	-	-	-
Olinga feredayi	3.0	4.5	1.0	-	45.0	41.0	3.6	5.8	-
Caddis pupae	-	-	-	-	10.0	-	-	-	-
Diptera									
Chironomidae	42.4	-	-	15.8	-	-	4.8	-	2.3
Simulidae	-	-	1.3	5.2	-	-	1.2	-	-
Tipulidae	1.0	4.5	1.3	5.2	-	30.2	9.5	-	2.3
Ceratopogonidae	-	-	-	-	-	-	-	1.0	-
Muscidae	-	-	-	-	-	-	-	1.0	-
No. of taxa	9	8	14	7	6	7	8	11	8
No. of animals/m^2	1 584	704	2 400	304	320	1 328	1 344	2 720	688

FIGURE 49. Dobsonfly *(Archichauliodes diversus)* are present only in streams at Benhar and Hawkdun.

The benthic fauna of Hawkdun streams, like that of Benhar streams, was typical for streams in Otago and Southland.

5.5 Zooplankton

Plankton sampling was carried out only at Waituna Lagoon and Lake Tuakitoto. The sampling sites are shown in Figures 46 and 47 respectively.

5.5.1 Ecological Importance

New Zealand has fairly few species of lake-dwelling zooplankton. Although species diversity may reflect both the complexity and the status of a particular lake ecosystem overseas, this is not so in New Zealand because of the lack of diversity and also because of a lack of basic biological information (Chapman *et al.* 1975). Data on the relative abundance of zooplankton species are also limited.

Zooplankton are an important component of the diet of some fish species, which may depend on them either throughout their life cycle or at a particular stage. Smelt, some galaxiid species, perch, and juvenile trout are known to feed on zooplankton, and adult trout may prey on larger zooplankters such as *Daphnia* if they are abundant. Occasionally, bullies may also be partly planktivorous (Chapman *et al.* 1975).

Eldon and Greager (1983) reported that cladocerans featured in the diets of inanga and juvenile salmon sampled during their study of Rakaia Lagoon, and that this indicated mid-water feeding. Moore *et al.* (1984) noted that, in Lake Wairarapa, invertebrates, including zooplankton, are part of the food chains that lead to frogs, fish, and birds.

5.5.2 Sampling Results

A total of 9 taxa was identified from 4 sampling sites in Waituna Lagoon. Two copepod species dominated the fauna, and mysid shrimps were also common. The amphipod *Paracalliope fluviatilis* was present (Table 22); this species is often associated with bankside vegetation (Winterbourn 1981), such as that around the lagoon.

A total of 10 taxa was identified from 3 sampling sites in Lake Tuakitoto. The fauna there was dominated by 3 cladoceran species (Table 22). Copepods were common, and *Paracalliope fluviatilis* was again present.

The only similarity in the plankton taxa at the 2 sites was the presence of copepods and amphipods. The finding of 5 species of cladocerans at Lake Tuakitoto can be regarded as atypical, because Chapman *et al.* (1975) noted that the presence of 3 cladoceran species at 1 site is unusual.

Comparison of the plankton fauna of the 2 water bodies with similar waters is made difficult by a lack of published data. However, a species of calanoid copepod has been reported in Lake Wairarapa by Chapman *et al.* (1975), and Eldon and Greager (1983) reported finding cladocerans in the diet of fish in Rakaia Lagoon. Despite the lack of detailed information on plankton in New Zealand lakes, and the limitations of the data collected in this survey, the relative abundance and species diversity of the plankton in both waterbodies appears to be similar to that in others of their type.

TABLE 22. Results of plankton sampling in Waituna Lagoon and Lake Tuakitoto, August 1985

Sampling site	Waituna Lagoon	Lake Tuakitoto
Date	1/8/85	8/8/85
Annelida	*	*
Mollusca	*	-
Copepoda - Species A and B	***	-
Calanoida - *Boeckella* sp.	-	**
Cyclopoida - *Acanthocyclops* sp.	-	**
Cladocera		
Daphnia carinata	-	***
Daphnia obtusa	-	**
Ceriodaphnia dubia	-	***
Simocephalus sp.	-	***
Chydarus sp	-	*
Mysidacea		
Zoea larvae	*	-
Tenagomysis sp.	**	-
Amphipoda		
Paracalliope fluviatilis	*	*
Diptera		
Chironomid larvae	*	*
Larval fish	*	-
No. of taxa	9	10

- Not recorded.
* Present.
** Common.
*** Abundant.

5.6 Summary

The low species diversity and low numerical abundance of benthic invertebrates in the still water habitats of the 3 study areas appear to be typical for habitats of this type in New Zealand. Specific differences between localities can be attributed to the particular environmental conditions of each locality, such as the marine influence on Waituna Lagoon. The situation is similar for the benthic fauna of the running water habitats, where the species composition was like that reported from comparable habitats within the Otago/Southland area. Therefore, the relatively low species diversity and the dominance of gastropods, annelids, and chironomids in the Waituna streams are typical of low velocity habitats, whereas the higher species diversity and the dominance of mayflies and caddisflies at Hawkdun are more typical of unpolluted fast-flowing waters.

6. AQUATIC PLANTS AND MARGINAL VEGETATION

6.1 Ecological Importance

Instream aquatic plants and stream bank vegetation are often neglected in considerations of stream ecology. In many cases, particularly where streams flow through agricultural land, such plants are considered a nuisance, and are classified as weeds which inhibit drainage. They are often removed chemically (by spraying) or mechanically (by digger).

6.1.1 Aquatic Plants

Plants in this category include algae and aquatic macrophytes. Although macrophytes are not present in many streams, algae are present in most. Both play an important role in providing a diversity of instream habitat (Hynes 1970).

Macrophytes are generally most common in streams and rivers which have low water velocity, which enables the plants to become established, and they are typically found in lowland reaches. Such plants provide cover for many fish species, and some are used for spawning and attachment of eggs (e.g., by perch and inanga).

Algae and aquatic plants are also valuable as substrates and food sources for benthic invertebrates. Many of these animals (e.g., snails, mayflies, and some species of caddis) are grazers, consuming diatoms, algae, and macrophyte leaves. Some caddis species are detritivores, feeding on decaying and dying plants, and others, such as damselflies, dragonflies, and beetles, lay their eggs on aquatic macrophytes.

Macrophytes also have a role in stabilising streams, by slowing the water velocity and enhancing stream-bed stability, which in turn enhances stream habitat for benthic invertebrates and fish. Table 23 describes the growth habits of aquatic plants recorded from the 3 study areas.

6.1.2 Marginal Vegetation

Marginal vegetation is primarily important for the role it plays in maintaining stable banks and stream channels. Vegetation overhanging streams provides good cover for some fish species, and is also important for terrestrial phases in the life cycles of some invertebrates. For instance, caddis and stonefly adults use overhanging vegetation for resting.

6.2 Ashers-Waituna

Table 24 describes the relative abundance of the variety of macrophytes and algae found in the small creeks at Ashers-Waituna. Macrophytes were sparse in stream sections that had been recently cleared by digger (Jordan and lower Waituna Creeks), and where cattle or sheep had had access to streams (Marr Creek). Conversely, in streams that had not been modified (Moffat and Currans Creeks), they were abundant. *Gluycerias fluitans* and *Agrostis stolonifera* were the dominant species, being found in all streams, and filamentous green algae were also present in all streams. Overall, Ashers-Waituna streams can best be described as supporting an abundant macrophytic flora. Many of the fish species present in the streams use macrophytes for cover, so they are important in providing a diversity of fish habitat.

TABLE 23. Growth habits of aquatic plants found in streams in the 3 study areas

Species	Common name	Growth habits
Lemna minor	Duckweed	Quiet shallow water at streams edge
Callitriche stagnalis	Starwort	Quiet shallow water at streams edge
Callitriche hamulata	Starwort	Faster flowing water, toward middle of stream
Potamogeton ochreatus	Pondweed	At stream edge, also mid stream in deeper faster water
Potamogeton cheesemanii	Pondweed	Slow quiet waters
Agrostis stolonifera	Fiorin	Shallow water at stream edge, tends to encroach on stream from the banks
Elodea canadensis	Canadian pondweed	Quieter waters at edge in shallow and deep water
Nitella hookeri	Stonewort	Shallow flowing waters, toward middle of stream
Nasturtium officinale	Watercress	In quiet waters at stream edge
Mimulus guttalus	Monkey musk	In quiet waters at stream edge, not always growing in water
Glyceria fluitans	Floating sweet grass	In most stream localities, shallow and deep water, slow and faster waters
Juncus articulatus	Jointed rush	In shallow, slower waters
Polygonum spp.	Willow weed	At stream edge, sometimes in water
Juncus bulbosus	Bulbous rush	In shallow slower waters
Scirpus sulcatus	Rush	In slow flowing deep waters at stream edge
Pratia angulata	Pratia	In slow deep waters
Myosotis caespitosa	Tufted forget-me-not	At stream edge, not always growing in water
Azolla rubra	Azolla	In still waters
Ranunculus sp.	Buttercup	In still quiet waters at stream edge
Myriophyllum sp.	Water-milfoil	In still lake waters

TABLE 24. Relative abundance of aquatic plants observed in streams in the Ashers-Waituna area

Species	Waituna Creek	Moffat Creek	Currans Creek	Gorge Creek
Lemna minor	-	***	-	-
Callitriche stagnalis	*	**	*	*
Callitriche hamulata	*	*	-	*
Potamogeton ochreatus	**	-	***	*
Elodea canadensis	*	-	-	*
Nitella hookeri	*	*	-	*
Nasturtium officinale	*	-	-	-
Mimulus guttalus	*	-	-	*
Glyceria fluitans	***	**	**	**
Juncus articulatus	*	*	-	-
Juncus bulbosus	*	-	-	-
Polygonum spp.	*	-	-	-
Agrostis stolonifera	***	***	-	***
Scirpus sulcatus	-	-	-	*
Pratia angulata	-	-	-	*
Filamentous green algae	**	**	*	**

- Not recorded.
* Sparse.
** Common.
*** Abundant.

The marginal vegetation recorded from Ashers-Waituna streams is listed in Table 25. Pasture grasses dominated the plant communities, particularly where land has been developed for agriculture, and were long where the stream margins were not accessible to stock. Other species, such as flaxes and red tussock, had a chance to become established, and the vegetation provided good overhanging cover for the stream (see Fig. 6). Native species such as red tussock were dominant in the lower reaches of Waituna, Moffat, and Currans Creeks. Such areas provide good cover for fish, particularly giant kokopu, large eels, and trout. Most streams, however, had short, grazed grasses, and bank collapse was widespread and significant in some places.

The vegetation of Waituna Lagoon has been surveyed extensively in the past (Crosby-Smith 1927, Kelly 1967, Kelly 1968, Hubbard 1974). The dominant species around the margin of the lagoon is the jointed rush (*Leptocarpus similis*), and *Eleocharis gracilis* and *Scirpus* sp. are found in less saline areas. Small herbs are common in areas that are

TABLE 25. Relative abundance of marginal vegetation of streams in the Ashers-Waituna area

Species	Common name	Waituna Creek	Moffat Creek	Currans Creek	Gorge Creek
Ulex europaeus	Gorse	*	-	**	*
Carex coriacea	Cutty grass	*	**	-	*
Phormium tenax	Flax	*	*	**	-
Rubus idaeus	Blackberry	*	-	-	-
Juncus sp.	Rushes	*	-	*	**
Blechnum sp.	Ferns	*	-	*	-
-	Pasture grasses	***	***	***	***
Trifolium sp.	Clover	*	-	-	-
Cirsium sp.	Thistles	*	-	-	*
Senecio sp.	Ragwort	*	-	*	*
Ranunculus sp.	Buttercup	*	-	-	-
Rumex sp.	Dock	*	-	-	-
Bromus mollis	Broom	*	-	-	*
Chinochloa rubra	Red tussock	*	*	***	-
Coprosma sp.	Coprosma	*	-	*	-
Carex sp.	Sedge	*	*	-	-
Cortaderia richardii	Toetoe	-	-	-	*
Leptospermum scoparium	Manuka	-	-	-	**

- Not recorded.
* Sparse.
** Common.
*** Abundant.

inundated from time to time. The rush plant community is considered to be important for inanga spawning.

Hubbard (1974) discussed the vegetation of the bog ponds and noted that the open water may contain *Sphagnum*, with *Juncus* sp., *Dracophyllum*, *Phormium*, and *Calorophus* round the margins. The vegetation of these ponds is largely in its natural state, and it provides good overhanging cover (see Fig. 7).

A survey of macrophytes and algae in the lower Mataura River lay beyond the scope of this study, and only general observations of the marginal vegetation were made. Pasture grasses predominate, particularly on the true right bank. Other species present include willows (*Salix* sp.), cutty grass (*Carex coriacea*), gorse, broom, and some manuka. Bank collapse is common, particularly where stock have access to the edge of the river.

6.3 Benhar

Aquatic plants observed in Benhar streams and Lake Tuakitoto, and their growth habits, are listed in Tables 23 and 26. Although macrophytes and algae were absent from the upper reaches of Lovells Stream, they were fairly common in all of the other streams flowing across the low-lying areas before entering Lake Tuakitoto. Saddle Stream was not surveyed. Aquatic vegetation was particularly abundant in Two Stone Hill Stream, which contained a population of giant kokopu. Filamentous green algae were recorded only in Frasers Stream, but they are seasonal, and are usually most dense during summer. Pasture species dominate the margins of streams in the study area. These are generally short, from stock grazing, and bank collapse is widespread.

TABLE 26. Relative abundance of aquatic plants observed at Benhar

Species	Lovells Stream	Frasers Stream	McCrosties Creek	Lake Tuakitoto
Lemna minor	-	-	-	**
Callitriche stagnalis	-	*	-	-
Potamogeton ochreatus	-	-	***	*
Potamogeton cheesemanii	-	-	-	*
Elodea canadensis	*	**	***	*
Nitella hookeri	-	-	***	-
Nasturtium officinale	*	*	-	-
Glyceria fluitans	*	-	-	*
Azolla rubra	-	-	***	*
Juncus sp.	-	-	-	***
Myriophyllum sp.	-	-	-	*
Ranunculus sp.	*	-	-	-
Filamentous green algae	-	*	-	*

- Not recorded.
* Sparse.
** Common.
*** Abundant.

Macrophytes were found at several locations in Lake Tuakitoto, but were most common round the margins of the lake. *Elodea* sp. is reported to be common throughout the open water of the lake during summer. The lake margin is dominated by rushes and pasture species, whereas the freshwater swamp supports a rush and sedge community, and the number of willows there is increasing (Fig. 50).

FIGURE 50. Rush and sedge community interspersed with willows in swampland associated with Lake Tuakitoto.

The fluctuating level of Lake Tuakitoto means that much of the marginal vegetation is submerged periodically (see Fig. 11). At these times, terrestrial foods (especially earthworms) are available to the fish, and eels in particular are known to exploit such food resources. The large number of perch, eels, and trout in this shallow lake suggests that the vegetation provides good cover for these species, and also spawning habitat, in the case of perch.

The vegetation of Lake Tuakitoto has been documented in detail as part of botanical studies being undertaken by Botany Division, DSIR, for the LFTB.

6.4 Hawkdun

Aquatic macrophyte growth throughout the upper Manuherikia catchment can best be described as sparse (Table 27), although the number and

TABLE 27. Relative abundance of aquatic plants observed in streams in the Hawkdun area

Species	East Branch	Johnstons Creek	West Branch	Kirkwoods Creek	Little Bremner Creek	Healeys Creek	Ten Chain Creek	Hut Creek	Gate Creek	Rocks Creek + tribs.	Upper Manuherikia mainstem
Lemna minor	-	-	-	-	-	-	-	*	-	-	-
Callitriche stagnalis	-	-	-	-	-	-	-	*	-	**	-
Potamogeton cheesemanii	-	-	-	-	-	-	-	-	-	**	-
Nasturtium officinale	*	-	-	-	-	*	-	-	*	-	-
Glyceria fluitans	-	-	-	-	-	*	-	*	-	**	-
Juncus articulatus	*	-	-	-	-	-	-	-	-	-	-
Juncus sp.	-	-	-	-	-	*	-	*	*	-	-
Myosotis caespitosa	-	-	-	-	-	*	-	*	-	**	-
Ranunculus sp.	*	-	-	-	-	-	-	-	*	-	-
Filamentous green algae	*	*	*	*	*	*	-	*	-	**	**
Filamentous brown algae	*	*	*	-	*	-	*	-	-	**	*
Diatoms	*	-	-	-	-	-	-	-	*	-	*

- Not recorded.
* Sparse.
** Common.
*** Abundant.

diversity of plants increases where tributary streams emerge from the hills to flow across the gently sloping terraces. Here, the water velocity is much slower and macrophytes can become established. This was particularly noticeable in Rocks, Hut, and Healeys Creeks and it was here that fish, particularly juvenile brown trout, were more numerous. It appears that macrophytes play an important role in enhancing fish habitat in these streams. The mainstem of the upper Manuherikia was virtually devoid of macrophytes. All streams had algal growth, with green filamentous algae being dominant and most abundant. Big Bremner and Johnstones Creeks were not surveyed.

Tussock communities dominated the marginal vegetation of streams (Table 28). Most had bankside vegetation in good condition, stable banks, and good overhanging cover for fish (see Figs. 15 and 16). In some places, however, particularly in stretches of the upper Manuherikia mainstem, the vegetation had been heavily grazed by cattle. Here, little cover was offered by overhanging vegetation, and the banks were unstable in places.

Probably because of the large variations in water level, the Falls Dam reservoir contains few, if any, aquatic plants. The reservoir margin is dominated by species of tussock and pasture grasses, but generally these do not contribute to fish habitat.

7. RELATIVE IMPORTANCE OF STUDY AREAS

7.1 Existing Habitat and Fishery Features

7.1.1 Ashers-Waituna

The study area supports an assemblage of 20 freshwater, estuarine, and marine fish species, many of which are migratory, with marine and freshwater stages in their life cycles.

Native fish species are present in all of the streams in the study area, and a variety of adult, juvenile, and spawning habitat is available. Of particular interest is the occurrence of giant kokopu (an uncommon species nationally, with a restricted distribution), banded kokopu (in limited numbers), inanga, and long-finned eels (in large

TABLE 28. Relative abundance of marginal vegetation of streams in the Hawkdun area

Species	East Branch	Johnstons Creek	West Branch	Kirkwoods Creek	Little Bremner Creek	Big Bremner Creek	Healeys Creek	Ten Chain Creek	Hut Creek	Gate Creek	Rocks Creek +tribs.	Upper Manuherikia mainstem
Chionochloa rigida	**	-	**	**	**	**	-	-	**	-	-	-
Chionochloa rubra	**	-	-	**	**	**	***	**	**	**	***	**
Poa caespitosa	***	**	**	**	**	**	-	**	**	**	**	***
Discaria toumatou	**	-	-	*	*	*	-	*	-	*	-	*
Carex sp.	-	-	-	-	-	-	*	-	*	-	-	*
Aciphylla	*	-	-	-	-	-	-	-	-	-	-	-
Olearia sp.	*	-	-	-	-	-	-	-	-	-	-	-
Coprosma sp.	*	-	-	-	-	-	-	-	-	-	-	-
Cortaderia richardii	*	-	-	-	-	-	-	-	-	-	-	-
Juncus sp.	-	-	-	-	-	-	-	-	*	-	*	-
Native broom	*	-	-	-	-	-	-	-	-	-	-	-
Willows	-	-	-	-	-	-	-	-	-	-	*	-
Pasture grasses	*	*	*	*	**	**	**	**	*	*	**	**

- Not recorded.
* Sparse.
** Common.
*** Abundant.

numbers). The bog ponds, common in the surrounding swamplands, provide ideal habitat for freshwater crayfish, which are abundant.

Waituna Creek is used extensively as a spawning ground by a large number of migratory brown trout. A feature of the stream is the abundance of suitable gravels for spawning. Gorge Creek supports some brown trout spawning in the middle reaches, and all of the small streams surveyed in the study area provide good rearing habitat for juvenile brown trout.

Waituna Lagoon is at least locally important as a recreational brown trout fishery. Although it is characterised by a low catch rate, the lagoon contains fish which are larger on average than those in any other fishery within the SAS district. It can be considered to be a trophy fishery, as the average size of fish taken there is comparable with that for other waters in New Zealand renowned for carrying large fish. The lagoon also supports minor fisheries for flounders and whitebait.

Waituna Lagoon and Toetoes Harbour support a range of estuarine and marine species, and Waituna Lagoon is particularly important for short-finned eels, common smelt, inanga, and flounder rearing and adult life phases. Inanga are also likely to spawn in these areas. The accessibility to and from the sea of Toetoes Harbour and Waituna Lagoon is vital for many migratory species to complete their life cycles.

The lower Mataura River is particularly important for adult inanga, and is probably important for spawning. Small populations of giant and banded kokopu are also present there. The lower reaches of the river are part of a nationally important and internationally renowned recreational brown trout fishery. The OAS and the SAS are currently seeking a National Water Conservation Order under the provisions of the 1981 Amendment to the Water and Soil Conservation Act (1967), to protect the outstanding recreational fisheries of the Mataura River (N.Z. Acclimatisation Societies 1983, Davis 1984). They have applied to have the present "quantity and rate of flow of natural water in the Mataura River" retained. The river also offers recreational fisheries for perch, whitebait, and eels, and in Toetoes Harbour there are flounder and kahawai fisheries. Eels and whitebait are exploited commercially as well as for recreational purposes.

7.1.2 Benhar

The Benhar area supports a moderate diversity of fish species, 3 introduced (brown trout, perch, and quinnat salmon) and 12 native, many of which are migratory.

The fresh water of Lake Tuakitoto provides very good juvenile and adult habitat for long- and short-finned eels, both of which are abundant, and supports a commercial fishery based primarily on the latter. Giant kokopu, which have a limited distribution nationally, also inhabit the lake and lower reaches of Two Stone Hill and Saddle Streams. Perch and common bullies depend on the lake for their entire life cycles. Perch are abundant, and are fished for by recreational anglers. Brown trout reside in the lake, spawning and rearing in Lovells and Frasers Streams and Stony Creek, with Lovells Stream being the most important of the 3 tributaries for spawning. The trout fishery is of local importance to anglers.

The diversity of fish species in Lake Tuakitoto and its tributary streams is limited by the contour channel flood gates at Kaitangata, and the lake outlet weir. These restrict access to the sea for fish with a marine phase in their life cycle, and this is probably aggravated in summer by low lake levels and high water temperatures. These factors are probably responsible for the absence of black flounders from the lake, and for low numbers of such species as inanga and smelt.

The lower Clutha is particularly well known for its runs of migratory (sea-run) trout, quinnat salmon, and whitebait, all of which support recreational fisheries. River-resident trout, mullet, flounders, perch, and kahawai are also fished for by recreationists. The salmon and brown trout fisheries are at least regionally important. The lower Clutha River sustains the highest angling pressure of all of the rivers surveyed by the OAS in their district. The quinnat salmon run has been enhanced significantly in recent years by releases of juvenile salmon from ICI/Wattie's ocean ranch at Kaitangata, and runs are likely to continue to increase in size.

The annual whitebait runs are exploited both recreationally and commercially from August to November, and although its use has not been quantified, the fishery is probably regionally significant. The lower

Clutha River (below Roxburgh Dam) also supports an eel fishery of at least local importance.

The lower Clutha River, from its confluence with the Pomahaka River to the sea, is included in an application for a Local Conservation Notice for the Clutha and Pomahaka Rivers lodged by the OAS in September 1984 (Otago Acclimatisation Society 1984, Davis and Watson 1985). The applicants have requested that a minimum flow be set in the Clutha River, and a decision on the application has been deferred by the Otago Regional Water Board until the outcome of the Rakaia High Court Hearing in September 1986 is known.

7.1.3 Hawkdun

The Hawkdun area provides habitat for 2 introduced and 2 native fish species. All species are non-migratory; they do not need to go to sea to complete their life cycles. For those that do, Falls and Roxburgh Dams are a barrier which restricts the diversity of species in this high country catchment.

The upper Manuherikia tributaries provide adult, juvenile, and spawning habitat for all 4 species of fish, brown trout and brook char being dominant and abundant. A feature of these tributary streams is the mixed populations of brown trout and brook char. The upper Manuherikia mainstem also supports stocks of these, with the latter being more common in the upper reaches. Juveniles of both species are abundant, and suitable spawning areas are widespread.

The Falls Dam reservoir provides juvenile and adult habitat for brown trout and upland bullies, in spite of the problems created by periodic drying-up of the lake in summer and autumn due to irrigation demands.

The upper Manuherikia River and the Falls Dam reservoir are both locally important brown trout fisheries. Brook char rarely grow large enough to have any angling potential, and have not been reported in anglers' catches.

7.2 Relative Ranking of Study Areas

7.2.1 Criteria

To assess the potential impact of lignite mining on each of the 3 study areas, a relative ranking system for the existing aquatic biological values was developed. This involved defining a set of biological variables and assigning a ranking to each study area for each variable, according to a set of predefined criteria. For all variables, a 1-5 ranking system was adopted, with 1 equating to "outstanding or exceptional value", 2 to "high value", 3 to "moderate value", 4 to "low value", and 5 to "no significant value".

Definitions of the ranking criteria for each variable were entirely subjective, being based on value judgements of which features were more or less important. It must be acknowledged that this approach involves certain assumptions. For example, it assumes that, if one area holds a greater number of fish species than another, it is necessarily more important, although it can be argued that a single-species population could make a particular area more important biologically. However, this exercise has adopted the underlying philosophy that the area with greatest species diversity, most extensive habitat, and greatest fishery use would receive the highest ranking.

The criteria used to develop the rankings are presented in Table 29, and the relative rankings for each study site are given in Table 30. Note that it is not biologically meaningful to total the rankings; to do so would assume each variable to have equal value. This is obviously not so, and it is beyond the scope of this exercise to give a weighting to each variable. For purposes of comparison, each must be considered independently and compared for each study area.

The following sections outline reasons for the allotment of rankings in Table 30, and should be read in conjunction with the table.

7.2.2 Features of Fish Stocks

7.2.2.1 Diversity

Ashers-Waituna was assigned a ranking of 1 because of the large number of species present.

TABLE 29. Criteria used to evaluate the relative importance of each study area

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1. FISH STOCKS

(A) Diversity (all species)

1. More than 15 species present
2. 11-15 species present
3. 6-10 species present
4. 2- 5 species present
5. Less than 2 species present

(B) Rarity (natives)

1. Species extremely rare or endangered
2. Species with limited distribution and declining numbers in the region
3. Species with limited distribution but moderate numbers in the region
4. Species with widespread distribution and common in the region
5. Species with widespread distribution and very common in New Zealand

(C) Rarity (introduced)

1. Species with limited distribution and rare in New Zealand
2. Species with limited distribution and small numbers in the region
3. Species with limited distribution and common in the region
4. Species with widespread distribution and common in the region
5. Species with widespread distribution and abundant in New Zealand

2. ECOSYSTEM TYPE

1. Largely unmodified ecosystem, uncommon elsewhere in New Zealand
2. Partially modified ecosystem, not common elsewhere in New Zealand
3. Partially modified ecosystem, represented elsewhere in the region
4. Modified ecosystem, common elsewhere in the region
5. Highly modified ecosystem, common elsewhere in New Zealand

3. VALUE OF HABITAT TO ALL FISH SPECIES

(A) Spawning, rearing, and adult phases of life cycle

1. Extensive or exceptionally high quality habitat
2. Widespread availability or limited areas of high quality habitat
3. Moderate availability of average quality habitat
4. Limited availability of average quality habitat
5. Limited availability of poor quality habitat

TABLE 29. (ctd.)

(B) Fish migration

1. Unrestricted passage for all fish species at all times of year
2. Partial restriction of passage for some species for some of the year, or total restriction for short durations
3. Partial restriction of passage for some fish species for most of the year
4. Severe restriction of passage for most fish species for most of the year
5. Total restriction of passage for all fish species

4. RECREATIONAL, COMMERCIAL, AND TRADITIONAL FISHERY VALUES

1. Nationally important
2. Regionally important
3. Locally important
4. Limited local use
5. No known use

Benhar received a ranking of 2, largely because of the number of species present in the lower Clutha. Lake Tuakitoto is considered to have no potential for greater species diversity, but fish movement is limited by the Kaitangata flood gates and the lake outlet weir. For instance, no black flounders were found in the lake, although it appears to offer suitable habitat.

Hawkdun received a ranking of 4, because of its relatively low species diversity. The area is considered to have no potential for greater diversity, because of the major barriers to fish migration created by Roxburgh and Falls Dams. For instance, long-finned eels can be found in the Manuherikia system downstream from Falls Dam, but not above it.

7.2.2.2 Rarity (native)

Ashers-Waituna gained a 2-ranking for its small number and limited distribution of giant kokopu and banded kokopu, both in the study area and in the region. Two other species found at Waituna were limited in distribution and number: red-finned bullies, which are common elsewhere in New Zealand, and short-finned eels.

TABLE 30. Relative rankings of existing aquatic biological values in the 3 study areas

	Variables	Ashers-Waituna	Benhar	Hawkdun
Fish stocks	Diversity (all species)	1	2	4
	Rarity (native)	2	2	4
	Rarity (introduced)	3	2	3
Ecosystem type	Lakes/estuaries/reservoirs	1	1	5
	Streams	3	4	2
	Rivers	2	2	2

Ecosystems		Waituna Lagoon	Tributary streams	Lower Mataura River	Lake Tuakitoto	Tributary streams	Lower Clutha River	Falls Dam reservoir	Tributary streams	Upper Manuherikia River
Habitat value to all fish species	Spawning	1	1	1	3	3	2	5	2	4
	Rearing	1	1	1	2	3	1	3	1	3
	Adults	1	2	1	1	4	1	3	2	3
	Fish Migration	2	1	1	3	1	1	4	2	1
Fishery value	Recreational	3	4	1	3	4	2	3	5	4
	Commercial	5	5	2	3	4	2	5	5	5
	Traditional	5	5	4	5	5	5	5	5	5

Benhar was ranked 2, entirely because of its limited distribution and small number of giant kokopu in the study area and in the region.

Hawkdun was assigned a 4-ranking, because the 2 native species present have a wide distribution and are common elsewhere both in the Manuherikia system and in the region. The common river galaxias has a restricted distribution in the study area, but it is not rare.

7.2.2.3 Rarity (introduced)

A 3-ranking was assigned for Ashers-Waituna, because, although the 2 introduced species recorded (brown trout and perch) are widespread and common in the region, the concentrations of migratory spawning trout in Waituna Creek are an unusual feature.

Benhar received a 2-ranking because the quinnat salmon in the lower Clutha River are not found elsewhere in the region.

Hawkdun received a 3-ranking because brook char have a limited regional distribution, although they are present in quite large numbers.

7.2.3 Ecosystem Type

7.2.3.1 Lakes, Estuaries, and Reservoirs

These standing waterbodies were grouped together, and those of Ashers-Waituna and Benhar were each assigned a 1-ranking. Waituna Lagoon, Toetoes Harbour, and the estuarine reach of the lower Clutha River are all largely unmodified ecosystems. Habitats of this type are limited in extent nationally, and are particularly significant for their biological productivity and species diversity. Similarly, Lake Tuakitoto is a shallow, freshwater, lowland lake and swamp ecosystem, albeit with some human modifications, and this type is now rare in New Zealand.

The Falls Dam reservoir was assigned a 5-ranking. It is a man-made waterbody, like other reservoirs in the region, such as those at Lower and Upper Manor Burn Dams, Pool Burn, Fraser Dam, and Butchers Dam.

7.2.3.2 Streams

Ashers-Waituna streams (Waituna, Moffat, Currans, and Gorge Creeks) were ranked 3, and are typical of lowland and coastal streams in Southland and some parts of Otago. Although such ecosystems are common elsewhere in the region, and these 4 have been modified, they are good examples of their type because they do not suffer from the water quality problems common in the lower reaches of Otepuni, Waikiwi, and Waihopai Streams, and Kingswell and Duck Creeks. All of these either flow through Invercargill City, or receive major discharges of effluent.

Lake Tuakitoto tributaries and Lovells Stream were assigned a 4-ranking. They are lowland streams which have been modified, in some cases extensively, and others of this type can be found elsewhere in the region.

Tributary streams in the upper Manuherikia catchment were given a 2-ranking. They are high country streams, and because they are stable and fairly unmodified, they are good examples of this type of stream ecosystem.

7.2.3.3 Rivers

The lower Mataura River was assigned a 2-ranking. Although it is a partially modified ecosystem, it is an example of a major river with an extensive tidal influence, a type uncommon elsewhere in New Zealand.

The lower Clutha River was also given a 2-ranking, because it is the largest river in the region, and one of the largest in the country.

Similarly, the upper Manuherikia River received a 2-ranking. Like its tributaries, it earned this rating for being a largely unmodified and fairly stable ecosystem of a type uncommon in New Zealand.

7.2.4 Value of Habitat to Fish

The value of habitat was considered jointly for native and introduced fish species. Because of the varied nature of the habitats in the 3 study areas, each area was subdivided into 3 ecosystem types: lakes/estuaries/reservoirs, tributary streams, and mainstem rivers.

7.2.4.1 Spawning

Waituna Lagoon, its small tributary streams, and the lower Mataura River all received 1-rankings for the value of their spawning habitat. The lagoon provides an extensive spawning area for inanga and smelt, and possibly for flounders and cockabullies. The tributary streams, particularly Waituna Creek, offer exceptional brown trout spawning habitat which is utilised by a large number of migratory trout. Three bully species, inanga, giant kokopu, banded kokopu, and lampreys probably spawn there also. The lower Mataura River provides extensive habitat for spawning of inanga, and the estuarine area is probably important for flounder rearing.

In the Benhar area, Lake Tuakitoto received a 3-ranking, because it is probably used for spawning by giant kokopu and the bully species which are present, and provides extensive spawning habitat for perch. The tributary streams also received a 3-ranking because they provide a moderate amount of spawning habitat for brown trout (Lovells Stream) and giant kokopu (Two Stone Hill and Saddle Streams). The lower Clutha was ranked 2, because it offers widespread inanga spawning habitat. Flounders probably spawn in the estuarine area and giant kokopu might do so in the lower river.

At Hawkdun, the Falls Dam reservoir does not provide spawning habitat for any of the species present, and it received a 5-ranking. However, the tributary streams were ranked 2, as they offer widespread, high quality spawning habitat, particularly for brown trout and brook char, but also for upland bullies and common river galaxias, where they are present. The upper Manuherikia mainstem provides a limited amount of spawning habitat, and received a 4-ranking.

7.2.4.2 Rearing

Waituna Lagoon, its tributary streams, and the lower Mataura River all received a 1-ranking for rearing because of their extensive areas of habitat. The lagoon offers good rearing habitat for brown trout, 3 flounder species, common bullies, long- and short-finned eels, inanga, common smelt, and cockabullies. The tributary streams provide good habitat for juvenile brown trout, long-finned eels, lampreys, giant and banded kokopu, and 3 bully species, and the lower Mataura also does so for inanga and common smelt as well as perch, eels, lampreys, bullies, and, in the estuary, flounders.

In the Benhar area, Lake Tuakitoto was ranked 2 for the extensive high quality habitat it provides for short- and long-finned eels and perch, and the potential habitat it offers for brown trout, giant kokopu, and common bullies. The lower Clutha received a 1-ranking, because of its value to juvenile inanga, eels, brown trout, and probably salmon and flounders. Lake Tuakitoto tributary streams were ranked 3 because of the moderate amount of habitat available there for brown trout juveniles, giant kokupu, long-finned eels, and common bullies.

At Hawkdun, the Falls Dam reservoir and the upper Manuherikia mainstem sustain a moderate amount of brown trout rearing, and were ranked 3. The tributary streams have extensive high quality rearing habitat for all 4 fish species present, and received a 1-ranking.

7.2.4.3 Adult Habitat

Waituna Lagoon offers extensive habitat for short-finned eels, adult brown trout, flounder species, cockabullies, common smelt, inanga, common bullies, and mullet, and thus received a 1-ranking. The tributary streams received a 2-ranking for the less extensive adult habitat available to long-finned eels, inanga, 3 species of bully, giant and banded kokopu, common smelt, and black flounders. The lower Mataura was ranked 1, particularly for its extensive inanga habitat, but also for its value as perch, eel, flounder, and brown trout habitat.

Lake Tuakitoto was assigned a 1-ranking because of the extensive habitat available to adult short- and long-finned eels and perch, and the potential habitat it offers giant kokopu, brown trout, and common bullies. Its tributary streams offer only limited, average quality habitat for giant kokopu, eels, and common bullies, and thus were ranked 4. The lower Clutha, like the lower Mataura, received a 1-ranking for the extensive area available to inanga, upstream-migrating quinnat salmon, sea-run and resident brown trout, eels, and flounders.

At Hawkdun, the Falls Dam reservoir was considered to provide a moderate amount of adult brown trout habitat, and received a 3-ranking.

In assigning this rating, the regular occurrence of low reservoir levels and occasional complete drainage in summer was taken into account. The tributary streams have extensive brook char and upland bully habitat of high quality, and were ranked 2. The upper Manuherikia mainstem has a moderate amount of habitat for brown trout, brook char, and upland bullies, and was ranked 3.

7.2.4.4 Migration

Periodically, fish passage into Waituna Lagoon is prevented briefly by the outlet to the sea closing. This appears to have little effect on the dominant migratory fish species, and for this reason a 2-ranking was assigned. Waituna tributary streams and the lower Mataura River each received a 1-ranking, as they provide free access to and from the lagoon (in the case of Waituna streams) and the sea (lower Mataura).

In Lake Tuakitoto, fish passage is partially restricted for most of the year by the flood gate at Kaitangata and the weir at the lake outlet. This is thought to have caused the absence of black flounders from the lake, and the low numbers of other fish, such as smelt and inanga. A rank of 3 was considered appropriate. The lake's tributary streams and the lower Clutha River allow fish to move freely to the lake and to the sea respectively, for all species at all times of the year, and both received a rating of 1.

At Hawkdun, Falls Dam severely restricts the movements of most fish species for most of the year. Only limited downstream movement is possible, and this ecosystem was ranked 4. The upper Manuherikia River allows unrestricted passage for all fish and received a 1-rating, but the tributary streams were ranked 2, because the movement of fish in some of these can be restricted for short periods by low flows and, particularly, by the streams drying up.

7.2.5 Fishery Value

7.2.5.1 Recreational

Waituna Lagoon is at least locally important as a brown trout fishery, and it may be regionally significant as a trophy fishery. It also supports a small flounder fishery, and received a 3-rating. Its tributary streams were ranked 4, largely because Waituna Creek's local use for whitebaiting is limited. However, the lower Mataura River received a 1-ranking, because of its national importance as a brown trout fishery. It is also regionally important as a whitebait fishery, and the flounder and kawahai fisheries in the estuary have local value.

Lake Tuakitoto supports a trout fishery of local importance, and received a 3-rating, but its tributary streams have very limited local use and were ranked 4. By contrast, the lower Clutha River has regionally important brown trout, quinnat salmon, and whitebait fisheries, and was assigned a rating of 2.

The Falls Dam reservoir is a locally important brown trout fishery and was rated 3, while the upper Manuherikia River sustains limited local use and was ranked 4. The tributary streams are not known to be fished at all; they support few, if any, takable brown trout or brook char, and were rated 5.

7.2.5.2 Commercial

Waituna Lagoon and its tributary streams were both ranked 5, because neither is known to support commercial fisheries. (It should be noted that commercial eeling is prohibited in this scientific reserve.) However, the lower Mataura River is a regionally important commercial whitebait and eel fishery, and was assigned a 2-ranking.

Lake Tuakitoto is a locally important commercial eel fishery, and was ranked 3. The lower Clutha River is a regionally important commercial fishery for both whitebait and eels, and received a 2-ranking. The tributary streams support some limited commercial eeling and were ranked 4.

At Hawkdun, there is no known commercial fishery for any species, and all ecosystems were assigned a 5-ranking.

7.2.5.3 Traditional

Only the lower Mataura River supports any traditional fisheries. It was ranked 4 for its limited local use for eeling and for its lamprey fishery.

7.3 Biological/Scientific Conservation Values

Teirney *et al.* (1982) discussed biological and scientific fishery conservation values of rivers. They stated that "there are a number of fish species populations and communities that are not harvested, but which are of considerable value to New Zealand, or the world, because of their rarity, uniqueness, and potential for expanding knowledge of fish and fisheries". They developed a set of criteria for identifying rivers with biological or scientific fishery values in a national context. These criteria applied mostly to waters containing rare indigenous or exotic species, localised distributions of indigenous or exotic species, and distinctive populations or assemblages of native species.

The International Union for Conservation of Nature (IUCN) Red Data Book (Fishes) lists New Zealand native fish species that require protection. One of these, the giant kokopu, is present in both the Ashers-Waituna and Benhar study areas. Given the criteria developed by Teirney *et al.* (1982), it could be argued from the presence of this species that habitats within these 2 study areas are nationally important, particularly Waituna, Moffat, and Currans Creeks (Ashers-Waituna), and Two Stone Hill and Saddle Streams and Lake Tuakitoto (Benhar).

The population of giant kokopu throughout New Zealand is known to have declined dramatically, primarily because habitat has been lost through agricultural development (McDowall 1978). Recent field investigations have shown that this species is distributed more widely than was previously thought, particularly on the west coast of the South Island. Nevertheless, its preferred habitat is becoming less and less common. The kokopu population in the Otago and Southland regions is limited, and those habitats which support the species should be regarded as having biological and scientific fishery values of regional importance, at least.

7.4 Overall Biological Ranking of Study Areas

Table 31 summarises the relative rankings assigned to each of the 3 study areas.

TABLE 31. Summary of rankings of aquatic biological values for the 3 study areas

Study area	Number of rankings assigned 1	2	3	4	5
Ashers-Waituna	13	5	3	2	4
Benhar	6	8	6	4	3
Hawkdun	2	5	6	5	9

On the basis of these rankings, Ashers-Waituna has the greatest biological value, followed closely by Benhar. Hawdun was ranked much lower than the other 2 areas.

8. IMPACTS OF LIGNITE MINING AND POTENTIAL MITIGATION

8.1 Introduction

This chapter discusses the impact of the proposed lignite mining on aquatic resources and habitats at each of the 3 study sites, in relation to the mine dump, the mine, proposed impoundment or abstraction of water for processing, the processing plant, and the whole study area. Measures to mitigate each of these are proposed, and a ranking system has been developed for each study area, to assess the impact according to a set of criteria.

8.2 Principal Features of the Mining Operation

The LFTB has made a preliminary assessment of the hydrological impact of mining operations at each site, with an emphasis on ground and surface water (Rosengreen 1985), and this information is summarised below. No information was available on the chemical composition of effluent from the mine or processing plant.

8.2.1 Information Relevant to all Areas

* Mining is expected to continue for 30 years, in 5-10 year blocks.

* During mining, surface drainage within the proposed mining blocks would be disrupted.

* The affected waters would be collected in holding ponds on the site, and used within the plant. None would be discharged into existing waterways.

* In the event of a flood, water would be discharged from holding ponds to stream courses.

* Water from dewatering wells adjacent to the mine pit, or ground water in the mine pit, would similarly be stored on the site, and used within the plant.

* Material in the mine dump sites would be contoured and oversown, with drainage to existing water courses.

8.2.2 Site-specific Information

8.2.2.1 Ashers-Waituna

* Surface water courses in the mine area would be destroyed.

* The level of near-surface ground water adjacent to the mine box cut would be lowered.

* In the case of 10-m-thick surficial gravel, the near-surface water table would be expected to be lowered 5 m, 2 m, and 1 m at distances of 200 m, 800 m, and 1700 m respectively, with no effect beyond 3200 m. This lowering would be less, given thinner or finer lithological units.

* Abstraction of make-up water is proposed from the Mataura River at Homestead Road (S177:695024), 10 km north-east of the northern mine boundary, at a maximum rate of 35 m^3/min (0.58 m^3/s).

8.2.2.2 Benhar

* Before mining begins, Lake Tuakitoto would be drained totally.

* Lowland, near-surface water tables adjacent to the mine box cut would be lowered.

* In the case of 18-m-thick gravel, water table draw-downs of 6 m, 4 m, and 2 m may occur at distances of 500 m, 1000 m, and 2000 m respectively from the mine face. These would be less for thinner or less permeable units, and would have no effect beyond 300-500 m.

* Southward and eastward-flowing water courses would be diverted into a channel around the western boundary of the mine.

* Westward and some southward-flowing waters would be diverted into a channel around the eastern boundary of the mine.

* The 2 diversion channels would join to flow into the existing Kaitangata channel, which discharges into the Matau Branch of the Clutha River.

* Abstraction using a surface water intake or a series of wells has been proposed from the Matau Branch of the Clutha River, south of Stirling, at a maximum rate of 35 m^3/min (0.58 m^3/s).

8.2.2.3 Hawkdun

* Surface water courses in the mine would be destroyed.

* The Manuherikia River would be diverted from its present course into a non-leaky canal round the eastern boundary of the mine and dump site, and then back into the existing river channel.

* Mining at the bottom of the river valley would drain the near-surface ground water within the mine boundary, and this would extend upstream.

* The level of ground water in the gravels of the stream bed may be lowered by about 5 m and 2 m at 200 m and 700 m respectively beyond the box cut of the mine. This would decrease to up to 1 m at a distance 1500 m upstream, if a drainage barrier is not placed upstream from the mine.

* A water storage reservoir would be constructed on the West Branch of the Manuherikia River about 700 m upstream from its confluence, and a lake 1.6 km long by 200-400 m wide would be created. This would supply water to a processing plant at a maximum rate of 35 m^3/min (0.58 m^3/s), resulting in severe fluctuations in the water level of the reservoir.

8.3 General Impacts

If lignite mining proceeds, the principal impact on the aquatic biota will result from changes in the quantity and quality of ground and surface water.

8.3.1 Water Quality

Deterioration in surface water quality or contamination of ground water can result from: increased sediment loads; accidental leaks and spills from vehicles on and around the site; on-site storage of fuels, industrial liquids, pesticides, and herbicides; pipeline breakages; holding pond failures; sewage sludge spills; leaching or seepage of trace elements and toxic materials from overburden; or polychlorinated biphenyls (PCBs) from electrical transformers (Moore and Mills 1977). Although specific potential pollutants associated with lignite mining in New Zealand have not been defined, many of these eventualities are likely, and could have a serious effect on the aquatic biota, depending on concentration. Critical water quality parameters include pH, dissolved oxygen concentration, and temperature. Once the likely contaminants have been identified, criteria can be established for the maintenance of suitable water quality for fish and aquatic organisms (Alabaster and Lloyd 1982, Church *et al.* 1978).

There is also the problem of increased sediment loads from overburden run-off, dewatering of the mine, road construction, stream crossings, and vegetation removal. Most of the sediment will be clay and silt, and could affect the aquatic plant life in 2 ways. If the solids are light or very fine and do not settle, increased water turbidity may reduce the growth of algae and aquatic plants. Secondly, if the sediment settles out, it could smother algae and kill rooted plants and mosses. Both will reduce the food supply for grazing benthic invertebrates.

Silt can also affect benthic invertebrates directly. Sedimentation on the stream bed fills the interstitial spaces between gravels and stones, depriving cryptic animals of hiding places, and rendering the habitat unsuitable for species which inhabit clean water environments. Stoneflies, mayflies, and caddisflies are particularly affected by sedimentation. Generally, bottom fauna production declines with increased silting in streams, thus diminishing the food supplies for fish. Furthermore, quite small quantities of silt can seriously affect fish spawning sites, particularly for brown trout, by blocking the gravel interstices and reducing the oxygen supply through the gravel to the eggs. Spawning of other fish species may be similarly affected.

8.3.2 Water Quantity

Stream and river flow regimes can be altered by diversions, construction of storage systems and impoundments, abstractions, water consumption, dewatering of streams, and discharges. The impact is greatest at low flows, when streams may dry up completely. This may be confined to riffles, where the water is shallowest, or whole reaches may dry up. Riffle habitat and invertebrate populations can be reduced significantly, thereby adversely affecting the availability of food for fish.

A reduction in flow will make water shallower and slower flowing, which will change the fish habitat, as well as altering stream morphology and reducing the available cover. Shallower water can become hotter in summer, to the point where temperature may become critical for fish survival. In winter, the stream margins can freeze, which limits the habitat available for benthic invertebrates and fish.

Dewatering wells around mine margins may reduce the flow of ground water to the surface waters, thereby reducing stream levels.

8.3.3 Other Impacts

Large-scale mining can necessitate the re-routeing of streams around the mine site. The impact of this will depend on the quality of habitat provided by the new stream compared to the old.

Where surface mining goes deeper than the water table, or where a confined aquifer is disrupted, a permanent area of open water may be created.

Mining in areas below, or near to, sea level may disrupt the hydraulic characteristics of aquifers, and salt water may intrude. Freshwater habitats may become brackish, which will displace freshwater species.

Modifications to the topography of the mine dump area and land rehabilitation activities can modify the morphological characteristics of a catchment, affecting its drainage patterns and flow regimes. Streams can be modified, which can significantly alter their suitability as fish habitat, or they can be eliminated completely.

Finally, an increase in population associated with the new industry can increase pressure on the recreational and commercial fisheries of the area, which may lead to their deterioration. The discharge of sewage and other wastes from a larger population may also adversely affect water quality.

8.4 Site-specific Impacts and Potential Mitigation

8.4.1 Ashers-Waituna

8.4.1.1 Mine Dump

The proposed mine dump (Fig. 2) overlies the middle reaches of Gorge Creek. Dumping of overburden will completely destroy the aquatic habitat in this reach, and will displace the fish species present. Some brown trout spawning occurs in this section of Gorge Creek and this, too, would be lost.

It is proposed that the dump area should be contoured and oversown. Adequate settling ponds will be needed to ensure that downstream sediment loads (including those into the lower Mataura River) do not increase. Settling ponds must be in place before mining starts, although contouring and oversowing will not be possible until 5-10 years after mining begins, because this is the period proposed for mining and removal of overburden for each block. Given that slopes may be unstable for 5-10 years, there is considerable potential for sediment runoff problems. To ensure adequate downstream protection, the mine dump must be treated as a closed system, and an adequate method developed to minimise erosion and sedimentation before re-vegetation can begin.

It is also possible that the waters may be contaminated by substances other than sediment, such as leachate from overburden. Water storage and treatment facilities may be necessary to prevent off-site pollution.

Contouring of the mine dump will result in a new drainage system. The new watercourses should be constructed so as to provide suitable fish habitat to ensure recolonisation of the displaced species. Particular attention should be paid to marginal stream vegetation (by enhancing bank stability to reduce sediment sources) and to stream morphology (water depth, substrates, ratio of pools:riffles:runs).

The dump area is fairly small, and although the aquatic habitat will be lost completely, this is not expected to affect the long-term survival of any of the fish species in the study area.

8.4.1.2 The Mine

The mine itself (Fig. 2) overlies the headwaters of Gorge, Currans, Moffat, and Marr Creeks. In the vicinity of the dump boundary, these streams are small, with modified channels. Mining will destroy the upper catchments of all of these streams, thereby reducing their length and flow.

Given the lowering of the water table which will ensue from mine dewatering, and the fact that the streams now seldom exceed 0.5 m in depth, it is conceivable that all 4 streams may be dry for a considerable distance downstream from the mine boundary. In 1981, Southland Catchment Board low flow gauging data showed that the upper reaches of Currans Creek were dry (with 2 l/s flowing at the lower site), and Moffat and Marr Creeks were flowing at only 9 l/s and 8 l/s respectively. These data suggest that these reaches will probably become dry for long periods of time, if not permanently. Water quality will also be a problem. Seepage of contaminants and discharge of storm water from the mine into these streams may degrade the stream habitat downstream from the mine boundary.

The section of Gorge Creek to be mined is upstream from the mine dump. Depending on the sequence in which the mining blocks are mined, Gorge Creek may still be intact while the dump is being filled. Its waters may need to be diverted around the dump site to reduce water and sediment movement through the dump, and to maintain temporary aquatic habitats.

Moffat, Marr, and Currans Creeks hold the greatest diversity of native fish species in the area, including the 4 species that are uncommon or declining in numbers in the region: giant and banded kokopu, red-finned bullies, and lampreys. Mining will undoubtedly cause these species to decline further or even disappear from the region. Every effort should be made to protect existing habitat downstream from the mine boundary. Protection of stream water quality will depend on good management of effluents on the site. It may be possible to enhance the flow in Currans, Moffat, and Marr Creeks by discharging treated mine water at a suitable rate.

The possible intrusion of salt water into Ashers-Waituna streams as a consequence of mining is a major concern. An increase in salinity of Moffat, Marr, or Currans Creeks would undoubtedly lead to the disappearance of giant and banded kokopu populations, and may affect the numbers of red-finned bullies and lampreys. Populations of long-finned eels, inanga, brown trout, and common bullies would probably survive, because these species commonly live in brackish and estuarine waters. However, it is unlikely that these streams would be suitable for trout spawning, resulting in a considerable loss in the total area available to trout for spawning.

Mining will probably create a large, permanent waterbody, which may be brackish. Inflow and outflow will need to be considered carefully with respect to existing waterways and their water quality.

Stream reconstruction will probably be necessary, and this should take into account existing stream morphology (bank height, stream width, water depth, bed material, pool:riffle ratios, etc.) to ensure that suitable aquatic habitat is created.

8.4.1.3 Water Abstraction from the Mataura River

It is proposed that 0.58 m^3/s be abstracted from the Mataura River to supply make-up water for use in the plant. The mean flow of the Mataura River at Mataura Island is 98.6 m^3/s, and the lowest recorded flow was 10.8 m^3/s on 19 March 1978 (Riddell 1984). Minimum daily mean flows are lowest from January to April (inclusive), with 20-year-return-period values ranging from 8.1 m^3/s to 10.5 m^3/s.

Abstraction of 0.58 m^3/s probably will have little effect on the aquatic biology of the lower Mataura River at mean flow, because of the large volume of water available. However, its effect at low flow would be rather different. It is not possible to assess this specifically, but 2 main effects can be stated: reduction of water depth and velocity, with a consequent reduction in habitat available to fish; and deterioration in water quality. At the Mataura township, the Mataura River receives effluent from 4 main sources (freezing works, tannery, paper mill, and Mataura Borough sewage). Below the township, further abstractions and discharges occur and the water quality deteriorates markedly, particularly at times of low flow (McKenzie 1982). The impact of abstracting up to 5% of the total low flow on the river's ability to assimilate the existing level of effluent, and subsequently on the aquatic biota, cannot be quantified at present, but could be potentially damaging.

It is recommended that any water intake be adequately screened to prevent entrainment of fish.

8.4.1.4 The Processing Plant

It has been suggested that the processing plant be located at the headwaters of Jordan and Gorge Creeks, at about map reference S182:610988. There are no permanent watercourses in this area, but ephemeral channels drain into these 2 streams. The main effects of the plant would be elimination of the existing landscape, and discharge of effluent. It is desirable that the plant site be treated as a closed system, with all water being directed to a central processing plant for treatment. On-site seepage of contaminants into the ground water could be a problem, and should not be overlooked.

There should be no discharge into small streams within the area, because the likely volume of effluent could drastically alter their flow regimes. Discharge into the lower Mataura River is also undesirable, particularly in view of current effluent loadings. The best solution to the effluent disposal problem may be to provide a pipeline to the sea which would completely bypass the Mataura River and the Waituna catchment.

8.4.1.5 General Study Area

The proposed mine boundary appears to lie outside the catchment boundary of Waituna Creek, and so mining should have little direct effect on this stream. Should the boundary be changed to include part of this catchment, the suggestions made for Currans, Moffat, and Marr Creeks regarding water quality and quantity, and mitigation measures should be applied. However, because Waituna Creek's unique quartz gravel substrates provide such extensive brown trout spawning habitat, every effort should be made to maintain the stream in its present form. If salt water intrudes into this catchment, trout spawning habitat could be eliminated.

Potential impacts on Waituna Lagoon are a matter of considerable concern, particularly with respect to deterioration in water quality. Poor on-site management of water quality and disposal systems, including suspended sediment concentrations, could have severe consequences for the water quality and aquatic biota of the lagoon. The effects of mine dewatering on the lagoon is also a concern. A low ground water level at the northern boundary of the lagoon could have a substantial impact on marginal vegetation, and thus on habitat for inanga spawning.

Similarly, the lower Mataura River must be protected. Its importance nationally as a brown trout fishery, and regionally as a whitebait fishery and inanga spawning area, must not be threatened by an increased sediment load or further deterioration in water quality.

8.4.2 Benhar

8.4.2.1 Mine Dump

The mine dump (Fig. 3) overlies rolling land which has ephemeral watercourses of no known fishery value. Dumping of overburden will therefore have no direct on-site impact on aquatic habitats.

The rolling nature of the present landscape is likely to be retained in the post-mining contoured landscape, creating the potential for sediment from unstable slopes to be washed downstream. On-site settling ponds and contour banks will be necessary to prevent sediment from flowing into the watercourses, and precautions must be taken to prevent other contaminants from entering waterbodies.

8.4.2.2 The Mine

The proposed mine site overlies Lake Tuakitoto. Before mining starts, the lake must be completely drained, and 2 artificial channels will be constructed to carry surface water around the mine site into the existing Kaitangata channel. This will destroy the existing lake ecosystem and the lower reaches of Lake Tuakitoto's tributaries. The eel fishery will be lost completely, and the 2 eel species will be displaced, along with the populations of perch, brown trout, common bullies, and, most importantly, giant kokopu. Giant kokopu inhabit the lake and lower reaches of Two Stone Hill and Saddle Streams, and it seems likely that they may disappear from the study area altogether if mining proceeds.

Lowering of the water table near the mine box cut will have its greatest impact on the water level in Lovells Stream, in the northern part of the mine. This could be overcome by re-siting Lovells Stream well to the west, and the artificial channels must be completed well before mining starts. They will be several kilometres in length, so they should be enhanced for fishery purposes, particularly by creating areas for food production, resting, cover, and shade.

Dewatering of the area may require the treatment and discharge of effluent to maintain stream flows similar to those suggested in Section 8.4.1.2.

The mining operation will create a large, open, permanent waterbody which will be much deeper than the present lake. Post-mining rehabilitation should include re-diversion of all tributary streams into this the waterbody, with every effort being made to re-establish the displaced fish species, including the giant kokopu. However, this is unlikely to be successful. Therefore, as an alternative, a shallow, freshwater lake and swamp habitat of similar size (500 ha) could be developed within the lower Clutha catchment to compensate for the loss of Lake Tuakitoto. The present lake and its associated wetlands represent a type of aquatic habitat which is becoming increasingly rare in New Zealand. The replacement habitat should provide unrestricted access to and from the sea for those fish species with a marine phase in their life cycles. There is a suitable site in the lower Puerua River, and this should be investigated in detail if Benhar is the site finally selected for further studies.

8.4.2.3 Water Abstraction from the Clutha River

At Balclutha, the Clutha River has a mean flow of 570 m^3/s, and a lowest recorded daily mean flow of 54 m^3/s on 23 July 1956 (Otago Catchment Board and Regional Water Board 1985). River flows downstream from Roxburgh are controlled by hydro-electric power generation demands. Abstraction of 0.58 m^3/s from the Matau Branch of the river, near Stirling, should have little detectable effect on aquatic organisms in the lower Clutha River. However, any abstraction facility would need to be screened to prevent entrainment of fish.

8.4.2.4 The Processing Plant

Two possible sites have been suggested for the location of a processing plant: one in the neighbouring Tokomairiro catchment at map reference S171:627355, the other in the Frasers Stream subcatchment at about S171:605335. The same principles for re-capturing all on-site surface water, and preventing seepage of contaminants to the ground water (as described in Section 8.4.1.4) will apply. All of the plant effluent would need to be treated, and it is suggested that a pipeline to the sea be considered for effluent discharge, to eliminate any detrimental impact on the aquatic biology of the lower Clutha or Tokomairiro Rivers.

8.4.2.5 General Study Area

The worst effect on the study area would be the destruction of Lake Tuakitoto, which would displace the large eel population and possibly banish giant kokopu from the region. During drainage, efforts should be made to relocate these fish (particularly the giant kokopu) to other suitable habitats. The trout population will also be reduced; those in the lake will disappear, leaving only a small population in Lovells Stream. The artificial channel constructed on the western margin of the mine will be critical for maintaining access to the spawning reaches in Lovells Stream.

Protection of fish habitat and fisheries values in the lower Clutha River is essential, because the river provides regionally important recreational fisheries for quinnat salmon, brown trout, and whitebait. The greatest impact would be a reduction in water quality if plant and mine waste water were discharged directly to the river. This could adversely affect passage of migratory fish species, inanga spawning, and recreational use of the river.

8.4.3 Hawkdun

8.4.3.1 Mine Dump

The mine dump (Fig. 4) overlies the middle reaches of Rocks Creek and the tributaries that arise along the western terraces. The nature of the landscape and the pattern of stream flows suggest that tributaries entering Rocks Creek from the north are spring-fed.

Dumping of overburden in this area will eliminate the present surface drainage system, thus diminishing the aquatic habitat and displacing the fish species present. The primary concern in this area will be to prevent sediment runoff from the site. As at Ashers-Waituna, the dump should be treated as a closed system for sediment; it should be contained completely within the dump site by the construction of contour banks and the use of settling ponds from the outset. The dump poses another problem in the proximity of its eastern boundary to the mainstem of the Manuherikia River. It will be extremely difficult to prevent sediment from flowing into this waterway. An artificial channel may be needed between the dump boundary and the river, to divert runoff into a settling pond at the downstream margin of the dump.

Some of the upper reaches of Rocks Creek drain through the proposed dump area. It is suggested that these be diverted south of the dump into the lower reaches of the creek, to prevent additional runoff through the dump site. This would also reduce the loss of upstream habitat.

Contaminants other than sediment may also be a problem, and their treatment should be planned for, to prevent any reduction in downstream water quality.

Contouring and oversowing of the area will create new drainage systems. The streams which will be destroyed are very stable and rocky, with little, if any, fine sediment. Reconstruction of waterways should take these characteristics into account, so that suitable aquatic habitats will be provided for the populations of brown trout and upland bullies currently inhabiting the area. Although good stable habitat will be lost, the survival of the present fish species should not be affected.

8.4.3.2 The Mine

The mine itself (Fig. 4) overlies the middle and upper reaches of the Rocks Creek tributaries, the middle reaches of the upper Manuherikia River, and the lower reaches of Kirkwoods, Little Bremner, and Big Bremner Creeks. Mining will destroy these habitats completely, and will cut off the headwaters of Rocks Creek tributaries and the 3 streams entering the upper Manuherikia River on the true left bank.

It is proposed that the upper Manuherikia River be diverted beyond the north-east boundary of the mine, and that a non-leaky channel be constructed into which the left bank tributaries will flow. This channel must be built well before mining begins, and its non-leaky nature may mean that it will be difficult to create a natural system. However, current information suggests that the channel will be at least 3 km long, so it will be necesssary to provide adequate flows for fish passage and suitable areas for shade, cover, food production, and resting.

Once mining has been completed, the river will be diverted back into its existing channel, which, it is understood, will not have been destroyed by mining. To ensure this, adequate riparian strips will be needed on either side of the present channel. Remedial work such as bank stabilisation and replanting will probably be needed at the river channel crossings, to ensure that stability is maintained once the upper Manuherikia River begins to flow back down its original course. Pre-mining surveys of stream morphology will be necessary to ensure that the aquatic habitat created by post-mining rehabilitation is similar to that now present.

The impact of mining on water quantity in this area could be devastating if the proposed drainage barrier is not installed upstream from the mine. Ground water drawdowns could dry up as much as 1.5 km of stream channels, given that the water in the upper Manuherikia mainstem seldom averages more than 1 m in depth at a normal flow. Treated drainage water will probably be needed for stream flow enhancement in this area. The effect of truncating the spring-fed tributaries of Rocks Creek is difficult to gauge, but would presumably also decrease the downstream flow. As at the other sites, it will be important to prevent sediment-laden water from discharging into watercourses.

Three fish species are found in the mine area: brown trout, brook char, and upland bullies. Populations of these will be displaced totally by the mine, although the species are unlikely to disappear from the region. Nevertheless, it will be necessary to protect their remaining habitats.

8.4.3.3 Impoundment of the Manuherikia West Branch

Construction of a dam on the West Branch of the upper Manuherikia River will prevent fish from migrating upstream, destroy part of the river ecosystem, and create a new lake ecosystem. If fish passage into the West Branch is to be maintained, a fish pass will be needed on the impoundment structure. Considerable planning will be required to define realistic residual flows to ensure the maintenance of aquatic biota downstream, and a set of lake level operating rules may need to be devised to minimise water level fluctuations, if the new lake ecosystem is to be thought desirable as a fishery.

8.4.3.4 The Processing Plant

Two possible locations for a processing plant have been identified: one on a wide terrace adjacent to the Manuherikia River below Falls Dam, at about map reference S125:585875, and the other within the catchments of 2 small tributaries (Mata and Station Creeks, which enter the Manuherikia River below Falls Dam), at about map reference S125:580975. This site would need to be treated as a closed water system, to ensure that all surface water is treated before discharge, and seepage of contaminants into the ground water must be controlled by good on-site management. Plant and mine effluent is likely to be discharged finally into the Manuherikia River. No details are available on the chemical composition of the effluent or on the proposed discharge site, but these could have a considerable impact on water quality in the lower Manuherikia River.

8.4.3.5 General Study Area

In this area, 2 potential effects are paramount. First is the problem of effluent disposal, for which there appears to be no alternative but discharge into the Manuherikia River. Consequently, water quality could suffer for a considerable distance downstream. The second major effect will be on water quantity. In an area already short of water, disruption of the ground water level and surface drainage systems, and the large demand for processing water, may well dry up the streams. At worst, this would reduce the available fish habitat, particularly for brown trout, which are the dominant inhabitants of the Manuherikia River downstream from the proposed mine site. Brook char would be little affected, except for their passage into the West Branch of the Manuherikia. The upland bully population may also be reduced, as they inhabit Rocks Creek and the Manuherikia mainstem. Populations of common river galaxias would survive in Johnstons Creek, but could be eliminated from the lower reaches of the West Branch if an impoundment is constructed as proposed.

Drying of the upper Manuherikia mainstem and the Falls Dam reservoir in the same season would substantially reduce the habitat available for adult brown trout and probably diminish the angling resource for subsequent years. However, even if the present mine proposals proceed, there will still be adequate spawning grounds to maintain brown trout stocks in the catchment. Provided that stream flows are maintained at an adequate level, and water quality does not deteriorate significantly, the fisheries of the upper Manuherikia catchment should be able to persist if lignite mining proceeds.

8.5 Evaluation of Impacts

To evaluate the overall impact of lignite mining at each of the 3 sites, a set of criteria has been developed to rank and compare the potential effects on each study area (Table 32). As with the biological rankings (Section 7.2.1), a 1-5 rating system was adopted, with 1 representing "total loss" of amenity value, and 5 "no foreseen loss".

The rankings assigned to each study area were made on the basis of the following assumptions:

1. Mine and processing plant effluent from Ashers-Waituna and Benhar would be discharged into the sea.
2. Mine and processing plant effluent from Hawkdun would be treated on the site and discharged into the Manuherikia River.
3. The quantity of both surface and ground water would be altered drastically at Ashers-Waituna and Benhar.
4. Mining at Ashers-Waituna would not affect the catchment of Waituna Creek.
5. In spite of every effort to collect and treat effluents at any site, accidental discharges will occur from time to time, to the detriment of downstream water quality.
6. Despite efforts to prevent sediment runoff from the dump and the mine sites, an increased downstream sediment load will be inevitable.
7. No account has been taken of the potential for salt water intrusion at Ashers-Waituna or Benhar. This matter is of particular concern at Ashers-Waituna, and could have major implications for aquatic and terrestrial communities.

TABLE 32. Criteria used to rank the potential impacts of lignite mining on each study area

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1. ECOSYSTEM LOSS

   1. Total loss of ecosystem type
   2. Severe loss of ecosystem type
   3. Moderate loss of ecosystem type
   4. Limited loss of ecosystem type
   5. No foreseeable loss

2. FISH STOCKS (NATIVE AND INTRODUCED)

   1. Loss of fish fauna, including relatively rare species with restricted distribution
   2. Reduction in fish fauna, including relatively rare species with restricted distribution
   3. Loss of relatively common fish species
   4. Reduction of relatively common fish species
   5. No foreseeable loss or reduction of fish species

3. IMPACT ON HABITAT VALUE TO ALL FISH SPECIES

(A) Spawning, rearing, and adult phases of life cycle

   1. Total loss or reduction in suitability of available habitat
   2. Severe loss or reduction in suitability of available habitat
   3. Moderate loss or reduction in suitability of available habitat
   4. Limited loss or reduction in suitability of available habitat
   5. No foreseeable loss or reduction in suitable available habitat

(B) Fish migration

   1. Total restriction of fish passage for all fish
   2. Severe restriction of fish passage for most fish species for most of the year
   3. Partial restriction of fish passage for some fish species for most of the year
   4. Partial restriction of fish passage for some fish species for some of the year
   5. No forseeable change in fish passage

4. FISHERY VALUE FOR RECREATIONAL, COMMERCIAL, AND TRADITIONAL FISHING

   1. Total loss of existing fishery values
   2. Severe loss of existing fishery values
   3. Moderate loss of existing fishery values
   4. Limited loss of existing fishery values
   5. No foreseeable loss of existing fishery values

Rankings have been assigned for each study area, to take account of off-site effects. The relative rankings are presented in Table 33, and the following sections explain the reasons for these. It should be emphasised that these rankings represent minimum foreseeable effects on the basis of the assumptions outlined above.

8.5.1 Ecosystem Loss

8.5.1.1 Lakes, Estuaries, and Reservoirs

Waituna Lagoon received a 2-ranking, because of the potential for its water quality to deteriorate, and the impact that this would have on this unmodified and rare ecosystem. Benhar was ranked 1, because of the total loss of Lake Tuakitoto if mining proceeds. The Falls Dam reservoir received a 4-ranking because, although its water quality would probably deteriorate, the ecosystem is manmade and represents a type which is common in this region.

8.5.1.2 Streams

Ashers-Waituna streams were ranked 2 for the potentially severe loss of habitat in streams such as Moffat, Currans, Marr, and Gorge Creeks. Benhar streams received a 2-ranking, because there would be some loss of habitat for giant kokopu, which have a restricted national distribution. However, this could be replaced by the construction of artificial streams. Hawkdun streams were ranked 4, as few tributaries would be lost, and all westward-flowing streams would remain intact.

8.5.1.3 Rivers

The lower Mataura River was ranked 4, because its water quality might deteriorate further. The lower Clutha River was also ranked 4 for the same reason. The upper Manuherikia River received a 3-ranking, because of the likelihood of river drying and water quality problems.

TABLE 33. Relative rankings of potential impacts of lignite mining on the 3 study areas

	Variables	Ashers-Waituna	Benhar	Hawkdun
Ecosystem loss	Lakes/estuaries/reservoirs	2	1	4
	Streams	2	2	4
	Rivers	4	4	3

Ecosystems		Waituna Lagoon	Tributary streams	Lower Mataura River	Lake Tuakitoto	Tributary streams	Lower Clutha River	Falls Dam reservoir	Tributary streams	Upper Manuherikia River
Fish stocks	Native	2	1	4	1	1	4	4	4	4
	Introduced	4	4	4	3	4	4	4	4	4
Habitat value for all fish species	Spawning	4	1	4	1	1	4	5	3	2
	Rearing	4	1	4	1	1	4	4	3	3
	Adult	4	1	4	1	1	4	4	4	3
	Fish migration	5	2	5	1	4	5	5	5	3
Fishery use	Recreational	4	5	4	1	4	4	4	4	4
	Commercial	5	5	4	1	1	4	4	5	5
	Traditional	5	5	4	5	5	5	5	5	5

8.5.2 Fish Stocks

8.5.2.1 Native Fish

At Waituna Lagoon, the estuarine fish fauna is likely to become less abundant and diverse (ranked 2), and giant kokopu populations could be lost completely from the tributaries (ranked 1). In the lower Mataura River, a general reduction of common species, in particular inanga, is likely, and a 4-ranking was assigned.

Lake Tuakitoto and its tributaries received a 1-ranking, for the total loss of giant kokopu populations which is likely from both ecosystems. Some reduction in the common fish species in the lower Clutha River is possible, and a 4-ranking was assigned.

All of the Hawkdun ecosystem types were ranked 4, because of a likely reduction in populations of the fairly common upland bully.

8.5.2.2 Introduced Fish

All ecosystems received a 4-ranking, with the exception of Lake Tuakitoto, which was ranked 3 for the potential loss of brown trout and perch populations.

8.5.3 Value of Habitat to Fish

8.5.3.1 Spawning

Waituna Lagoon and the lower Mataura River were ranked 4, for the potential deterioration in spawning habitat for inanga, flounders, smelt, and cockabullies as a consequence of water quality problems. Waituna tributaries received a 1-ranking, because of the effect of changes in water quantity and quality on giant kokopu populations in Currans, Moffat, and Marr Creeks, and potential loss of trout spawning habitat through salt water intrusion.

Lake Tuakitoto and the lower reaches of Two Stone Hill and Saddle Streams are thought to be giant kokopu spawning habitat and their possible total loss earned them a 1-ranking. Because the lower Clutha River should receive a limited impact, it was ranked 4.

The Falls Dam reservoir contains no spawning habitat (ranked 5), whereas the destruction of tributary streams and the construction of an impoundment on the West Branch will result in a moderate loss of habitat, which earned a 3-ranking for Rocks Creek. With the possibility of stream drying, deterioration in water quality, and construction of an artificial channel, all of which will destroy spawning habitat, the upper Manuherikia mainstem was ranked 2.

8.5.3.2 Rearing

Waituna Lagoon, the lower Mataura and Clutha Rivers, and the Falls Dam reservoir all received a 4-ranking, as a small loss of suitable habitat through a deterioration in water quality is considered to be likely. Waituna tributaries, and Lake Tuakitoto and its tributaries, were assigned a 1-ranking because rearing habitat, particularly for giant kokopu, is likely to be lost completely, as well as lake habitat for eels, perch, brown trout, and upland bullies.

A moderate loss of rearing habitat in Hawkdun tributary streams and the possibility of the upper Manuherikia mainstem drying up resulted in a 3-ranking being assigned for both ecosystems.

8.5.3.3 Adult Habitat

Loss of adult fish habitat in Waituna Lagoon, the lower Mataura and Clutha Rivers, the Falls Dam reservoir, and the Manuherikia tributaries would be small, and all were given a 4-ranking. However, there is potential for a considerable loss of adult habitat, particularly for giant kokopu, in Ashers-Waituna tributaries, and a total loss of habitat in Lake Tuakitoto and its tributaries, so a 1-ranking was assigned. Moderate loss of adult habitat in the upper Manuherikia River is envisaged, which warranted a 3-ranking.

8.5.3.4 Migration

No further restrictions on fish passage are foreseen at Waituna Lagoon, the lower Mataura or Clutha Rivers, the Falls Dam reservoir, or the Manuherikia tributaries. However the potential for streams at

Ashers-Waituna to dry up could restrict fish migrations severely, particularly during low flows, and these streams were ranked 2.

Fish passage in Tuakitoto tributaries may be partly restricted, particularly if the long artificial channels are unattractive to fish, and for this reason a 4-ranking was assigned.

The potential for drying and the proposed construction of an impoundment on the West Branch resulted in a 3-ranking being assigned for the upper Manuherikia mainstem, whereas Lake Tuakitoto was ranked 1.

8.5.4 Fishery Value

8.5.4.1 Recreational

A limited loss of recreational amenity value is foreseen for Waituna Lagoon and the lower Mataura and Clutha Rivers, as a consequence of deterioration in water quality and a possible decline in brown trout and whitebait populations. Tributary streams at Ashers-Waituna have no known recreational fishery value.

Opportunities for recreational fishing at Lake Tuakitoto will be lost completely (ranked 1), and the value of the Tuakitoto tributaries and the Falls Dam reservoir for recreational angling is also likely to drop (ranked 4). Tributary streams at Hawkdun and the upper Manuherikia mainstem have limited local value and will sustain some loss of amenity value (ranked 4).

8.5.4.2 Commercial

The whitebait fisheries of the lower Mataura and Clutha Rivers may diminish slightly, and the eel fishery in Lake Tuakitoto and its tributaries will probably be lost completely. All other ecosystems are likely to retain their present status.

8.5.4.3 Traditional

The lower Mataura eel and lamprey fisheries may deteriorate, but this is the only foreseeable loss of value for traditional fisheries.

8.5.5 Ranking of Impacts on Study Areas

The total destruction of Lake Tuakitoto means that the impact of lignite mining at the Benhar site will be severe (Table 34). On the basis of the assumptions outlined at the beginning of this section (8.5), the impact at Ashers-Waituna would be slightly less severe than at Benhar, and that at Hawkdun would be least.

However, given a different set of assumptions (e.g., that mining would directly affect Waituna Creek, that effluent was not discharged into the sea, that salt water would probably intrude, or that the Ashers-Waituna tributaries, Waituna Lagoon, or the lower Mataura River could be contaminated by effluent, the overall impact on the Ashers-Waituna area would probably be as severe as that at Benhar.

TABLE 34. Summary of rankings of potential impacts of lignite mining on the 3 study areas

Study area	Number of rankings assigned				
	1	2	3	4	5
Ashers-Waituna	4	4	0	15	7
Benhar	13	1	1	11	4
Hawkdun	0	1	6	15	8

9. CONCLUSIONS

9.1 Relative Assessment of Study Areas

9.1.1 Ashers-Waituna

Waituna Lagoon is a fairly unmodified estuarine ecosystem of a type which has a limited national distribution. Its tributary streams provide a considerable area of high quality spawning habitat for a large number of migratory brown trout, and also support a population of giant kokopu. For these reasons, and because of the diversity of fish species it contains, this area is nationally important. It is equally important for its botanical and wildlife values.

The lower Mataura River and Toetoes Harbour are nationally important for their recreational brown trout fishery and for the diversity of fish species that they contain. They also support recreational and commercial whitebait fisheries of regional importance.

If lignite mining and synfuels production are established here, the greatest impact on the site will be the loss of reaches of some tributary streams, with the consequent loss of their fish populations. However, the impact off the site is likely to be even worse. Mine dewatering will lower the level of ground water in the area, which will affect stream flows and possibly lagoon water levels, thereby reducing the value of these waters as fish habitat. Salt water may intrude into the ground water, and the increased salinity of the streams will render them unsuitable as habitat for their present populations of freshwater fish and benthic invertebrates, and for trout spawning.

Effluent and run-off from the mine site are likely to reduce the quality of water in Waituna Lagoon and its tributary streams. It is doubtful whether the Mataura River could assimilate any more effluent, so, because of its nationally important trout fishery, discharge into that river should be avoided. Abstraction of water from the Mataura River for use in a processing plant could have an adverse effect on the fish stocks and fishery values, particularly during low summer flows.

9.1.2 Benhar

Lake Tuakitoto and its tributary streams form a freshwater lake and swamp habitat of a size which is becoming increasingly rare in New Zealand. Although the ecosystem is nationally important for wildlife, it is only regionally important for its fisheries, despite the presence of giant kokopu in 2 of the tributary streams. However, if further studies can show that kokopu are more widely distributed throughout the area than is currently thought, its status as a habitat for giant kokopu should be reviewed. An important feature of the lake is the size of its eel stock.

The lower Clutha River sustains a considerable recreational fishing pressure for whitebait, salmon, sea-run and river-resident brown trout, and other marine and estuarine fish species. It provides a pathway for migration throughout the whole of the lower Clutha catchment, including the regionally important Pomahaka River, and it is likely that inanga spawn in its tidal reaches. These values combine to make the lower Clutha River nationally important for its fisheries.

Of the 3 study areas, the Benhar site would suffer the most severe impact if lignite mining were to proceed. Lake Tuakitoto would be drained completely, and the lower reaches of the inflowing tributary streams would be destroyed. This woulid eliminate the giant kokopu population and the commercial eel fishery, and would reduce the habitat and populations of eels, perch, common bullies, and brown trout within the region.

If site management and effluent control are adequate, the impact off the site should be relatively minor, but the environmental sensitivity of the lower Clutha River ecosystem should not be overlooked.

9.1.3 Hawkdun

The upper Manuherikia catchment and the Falls Dam reservoir are only locally important for their fisheries. The fish species they contain are common throughout the region, although the co-existence of mixed populations of brook char and brown trout in the tributary streams is unusual. The reservoir and upper Manuherikia mainstem support a locally important trout fishery.

Hawkdun is considered to be the least environmentally sensitive site for lignite development. The effect on the site would be the loss of reaches in some of the tributary streams and in part of the Manuherikia mainstem. Off the site, a reach of the West Branch would be flooded, and the downstream water quality would deteriorate. However, the effect on this site should be much less severe than is anticipated for either of the other 2 sites.

9.2 Recommendations

1. If a decision is made to proceed with site-specific studies for a lignite mine and synfuels facility, it is recommended that Hawkdun be chosen, because the aquatic biology of this site would be the least severely affected.

2. If the Ashers-Waituna site is selected for more detailed study, it is recommended that its hydrology and its potential for salt water intrusion as a consequence of mine dewatering be given priority. Development of this site would have a severe impact on its aquatic biological values if salt water were to intrude or if the Waituna Creek catchment was disturbed.

3. If the Benhar site is selected for more detailed study, it is recommended that, at an early stage, an alternative site be chosen for the creation of a substitute habitat for Lake Tuakitoto and its wetlands. The lower Puerua River catchment contains a possible location.

10. ACKNOWLEDGMENTS

We sincerely thank Maurice Rodway of the Southland Acclimatisation Society for helpful discussions throughout this study; Ross Dungey, Ian Mathieson, Sue Maturin, Andy Russell, Rob Soulsby, Mark Sutton, and Monty Wright of the Otago and Southland Acclimatisation Societies for assistance with field work, photographs, and laboratory analysis; Paul Sagar of FFC for identification of benthic invertebrates and zooplankton, and for advice on Section 5 of the manuscript; and Greg Kelly of FFC for preparing the maps and mounting the photographs for the final report. We are also grateful to George Wilkinson for his friendly guidance throughout the study, and, finally, to Carol Whaitiri for her application and dedication in typing the final report.

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APPENDIX I. Classification of Natural Water under the Water and Soil Conservation Act (1967).

Fourth Schedule
Standards for Class D Waters

The quality of Class D waters shall conform to the following requirements:

(a) The natural water temperature shall not be changed by more than 3 degrees Celsius:

(b) The acidity or alkalinity of the waters as measured by the pH shall be within the range of 6.0 to 9.0 except when due to natural causes:

(c) The waters shall not be tainted so as to make them unpalatable, nor contain toxic substances to the extent that they are unsafe for consumption by farm animals, nor shall they emit objectionable odours:

(d) There shall be no destruction of natural aquatic life by reason of a concentration of toxic substances:

(e) The natural colour and clarity of the waters shall not be changed to a conspicuous extent:

(f) The oxygen content in solution in the waters shall not be reduced below 5 milligrams per litre.

Sixth Schedule
Standards for Class SB Waters

The quality of Class SB waters shall conform to the following requirements:

(a) The natural water temperature shall not be changed by more than 3 degrees Celsius:

(b) The natural pH of the waters shall not be changed by more than 0.1 unit and at no time shall be less than 6.7 or greater than 8.5:

(c) There shall be no destruction of natural aquatic life by reason of a concentration of toxic substances nor shall the waters emit objectionable odours:

(d) The natural colour and clarity of the waters shall not be changed to a conspicuous extent:

(e) The dissolved oxygen content in solution in the water shall not be reduced below 5 milligrams per litre:

(f) Based on not fewer than 5 samples taken over not more than a 30-day period, the median value of the faecal coliform bacteria content of the waters shall not exceed 200 per 100 millilitres.

Seventh Schedule
Standards for Class SC Waters

The quality of Class SC waters shall conform to the following requirements:

(a) The natural water temperature shall not be changed by more than 3 degrees Celsius:

(b) The natural pH of the waters shall not be changed by more than 0.1 unit and at no time shall be less than 6.7 or greater than 8.5:

(c) There shall be no destruction of natural aquatic life by reason of a concentration of toxic substances nor shall the waters emit objectionable odours:

(d) The natural colour and clarity of the waters shall not be changed to a conspicuous extent:

(e) The dissolved oxygen content in solution in the waters shall not be reduced below 5 milligrams per litre.

APPENDIX II. Results of electric fishing, trapping, and netting in the Ashers-Waituna study area, 1985.

Site	Map Reference	Sampling Method*	Distance surveyed (m)	Brown trout	L.F eel	S.F eel	Lamprey	Common bully	R.F. bully	Upland bully	Inanga	Giant kokopu	Banded kokopu	Common smelt	Black flounder	Yellow-belly flounder	Sand flounder	Cocka bully	Yellow -eyed mullet	Star-gazer	Fresh water crayfish
				Fish species and numbers caught																	
Waituna Ck	S177:589018	EF	30	16	5			5													
Waituna Ck	S182:553988	EF	85	28	16			1			25	1									
Jordan Ck	S182:589987	EF	65	21	5						21	1									
Waituna Ck	S182:551963	EF	170	103	110			3			343				6						
Marr Ck	S182:539907	EF	100	59	50		1	60			9		3								4
Waituna Ck	S182:513864	EF	150	19	7			103	10		323			1							
Waituna Ck	S182:518548	GT/FN	-		5			7			+										
Moffat Ck	S182:544874	EF	85		18			26	1		90	5									
Currans Ck	S182:624889	EF	60	3	35			38			32	1									
Currans trib.	S182:615857	GT/FN	-		5							9									
Currans Ck	S182:610863	GT	-		5						+										
Waituna L.	S182:614847	GT/FN	-		1			1			1										
Waituna L.	S182:543842	GT	-			2		50			41										
Waituna L.	S182:543842	GT	-			2		6			6					1		1			
Waituna L.	S182:628833	SN	-	2		1		36			1			246	23				3		
Waituna L.†	S182:578835	SN	-					5						136	5	3	3	5			
Bog Pond	S182:563871	GT/FN	-																		64
Bog Pond	S182:589961	GT/FN	-																		15
Gorge Ck	S182:613937	EF	30	4	10					2	1										
Gorge Ck	S182:640933	EF	40	6	16			6			2										+
Toetoes Hb.	S182:712830	SN	-													51				1	

* Sampling method: EF = electric fishing.
GT = gee trap.
FN = fyke net.
SN = seine net.

† = 176 juvenile flounders also captured at this site.

+ = observed, but numbers not recorded.

APPENDIX III. Summary of Waituna trout spawning survey redd counts.

Stream	Survey section	Map reference	Distance (km)	Redd counts 1964	1966	1970	1978	1979	1984	1985
Waituna	AB	S182:524845-518892	4.5	9	)	15	34	20	27	37
Creek	BC	S182:518892-526916	3.2	6	)15	32	39	45	64	80
	CD	S182:526916-553969	5.4	16	)	34	63	236	231	231
	DE	S182:553969-553988	1.8	8	1	7	15	69	152	48
	EF	S182:553988-S177:576007	2.9	35	-	31	122	148	43	140
	FG	S177:576007-589018	1.4	97	37	55	33	35	75	106
	GH	S177:589018-614032	2.6	98	-	123	156	255	179	357
	HI	S177:614032-623040	3.5	36	72	0	0	17	97	95
	BJ(Marr Ck)	S182:518892-535906	1.9	9	4	2	26	29	25	23
	JK(Marr Ck)	S182:535906-557912	1.1	30	14	15	9	64	58	56
	Jordan Ck	S182:553969-596989	4.2	17	-	101	74	215	221	241
	Jordan Ck Trib.	S182:583986-586994	0.8	-	-	-	-	-	42	69
	McMillan Trib.	S177:591018-599030	1.6	-	-	-	-	38	89	79
	Brown Drain	S177:605026-607032	0.4	-	-	-	-	14	4	11
	Total redds (average density/km)			361(11.1)	143(6.2)	415(14.3)	571(17.6)	1185(34.4)	1307(37.1)	1573(44.6)
Moffat	LM	S182:527843-535866	2.2	11	1	2	0	4	0	2
Creek	MN	S182:538866-545874	1.1	15	4	4	5	6	0	2
	NO	S182:545874-570890	3.4	16	11	0	0	0	0	0
	MP	S182:538866-546868	0.8	5	-	0	1	0	0	2
	Total Redds (average density/km)			47(7.3)	16(2.4)	6(0.8)	6(0.8)	10(1.3)	0(0)	6(0.8)
Currans	QR	S182:613850-610864	1.3	0	)	0	0	0	0	0
Creek	RS	S182:610864-625895	3.2	31	)9	24	35	2	0	0
	ST	S182:626845-612900	2.4	8	)	7	-	35	37	46
	Total redds (average density/km)			39(5.7)	9(1.3)	31(4.5)	35(7.8)	37(5.4)	37(5.4)	46(6.7)
	Grand total of redds in Waituna system			447	168	452	612	1232	1344	1625
Gorge	1.	S182:640933-618937	2.3							47
Creek	2.	S182:618937-616957	2.0							54
	3.	S182:618937-607937	1.4							59
	Total redds (average density/km)									160(28.1)

- = not surveyed.

APPENDIX IV. Results of electric fishing, trapping, and netting in the Benhar study area.

Site	Map reference	Sampling method*	Distance surveyed (m)	Fish species and numbers caught: Brown trout	Perch	L.F eel	S.F eel	Common bully	Giant kokopu	Inanga	Freshwater crayfish	Common smelt	Black flounder	Giant bully
Lovells Stream	S171:568360	EF	200	9	1	2								
Lovells Stream†	S171:578356	EF	40	49		-					-			
Lovells Stream†	S171:590354	EF	60	68	1	4								
Drainage Ditch	S171:598348	EF	200		5	-								
Lovells Stream	S171:593344	EF	185	18	4	7				8				
Lovells Stream	S171:594343	EF	222	22	36	10								
Lovells Stream	S171:591340	EF	100	3	19	2								
Lovells Stream†	S171:592342	EF	48	22	4	-						1		
Lovells Stream	S171:592338	EF	200		14	-								
Frasers Stream	S171:599341	EF	70	15	35	3								
Frasers Stream	S171:594338	EF	100	2	-	-				1				
Drainage Ditch	S171:589318	EF	50											
Kokopu Creek	S179:599294	EF	168	14	69	1		28	20					
Kokopu Creek	S179:591282	EF	30		551	1		1						
McCrosties Creek	S179:594268	EF	200		21				-					
McCrosties Creek	S179:595269	EF	50		-	-								
McCrosties Creek	S179:595269	EF	30		-				-	-		-		
McCrosties Creek	S179:595269	EF	200	-	-									
L.Tuakitoto Western Shore, Middle Lagoon	S179:585280	FN		2	7		1							
L.Tuakitoto NW of Middle Lagoon	S179:582290	FN		3	20	+	+							
L. Tuakitoto NW of Middle Lagoon	S179:586288	FN			8		4	1						
L. Tuakitoto middle of Middle Lagoon	S179:587291	FN		1	10		28							
L. Tuakitoto, Main Lagoon, NE Shore	S179:591281	FN		8	117	o	o							
L. Tuakitoto, Main Lagoon, W Shore	S179:583280	EF								-				
L. Tuakitoto, SE of Main Lagoon	S179:592272	FN			-	-	-							
L.Tuakitoto, NE of Main Lagoon	S179:591285	GT/EF			2		7							

APPENDIX IV. (ctd.)

Site	Map reference	Sampling method*	Distance surveyed (m)	Brown trout	Perch	L.F eel	S.F eel	Common bully	Giant kokopu	Inanga	Freshwater crayfish	Common smelt	Black flounder	Giant bully
				Fish species and numbers caught										
L.Tuakitoto, W of Main Lagoon	S179:583274	EF			12	-	-			1				
L.Tuakitoto, western shore of main lake	S179:583274	FN			-		-							
L.Tuakitoto, eastern shore of main lagoon	S179:591282	EF			-	-		-						
L.Tuakitoto, eastern shore of main lagoon	S179:590275	EF	150		5		1							
L.Tuakitoto, western shore of main lagoon	S179:585268	EF	80		14	-	-	1						
L.Tuakitoto, SW corner, main lagoon	S179:582272	FN			9									
L.Tuakitoto, SW corner, main lagoon	S179:582272	FN		1	6		2							
L.Tuakitoto, SW corner, main lagoon	S179:582272	FN			8		28							
L.Tuakitoto, SW corner, main lagoon	S179:587266	FN			3									
L.Tuakitoto, SW corner, main lagoon	S179:586267	FN			34		151							
L.Tuakitoto, sill at outlet	S179:594267	WN					4	1						
L.Tuakitoto, sill at outlet	S179:594267	WN					1							
L.Tuakitoto, sill at outlet	S179:594266	EF	100	1	3		1	2						
Outlet channel	S179:595261	WN												
Puerua Estuary	S179:565125	FN		6			28						114	6
Puerua deviation channel	S179:554120 - 545134	FN		13	20		11		1				24	

* Sampling method: EF = electric fishing.
GT = gee trap.
FN = fyke net.
WN = whitebait net.

\- = observed, but numbers not recorded.
† = 1983 data.
\+ = 31 eels caught but not identified to species.
o = 70 eels caught but not identified to species.

APENDIX V. Summary of Benhar trout spawning survey redd counts.

Stream	Map reference	Distance (km)	1984	1985	Availability of spawning habitat*
Lovells Stream	S171 547371-567360	2.5	28	-	common
Lovells Stream	S171 555366-567360	1.3	-	35	common
Lovells Stream	S171 585356-592345	2.0	30	-	common
Lovells Stream	S171 590355-592345	1.5	-	20	common
Frasers Stream	S171 606344-598340	1.0	-	21	common
Stony Creek	S171 561325-568325	1.0	-	1	common
McCrosties Creek	S179 602270-594267	0.6	-	0	nil
Kokopu Creek	S179 603294-590285	1.3	-	0	nil
Unnamed tributary	S171 565304-573307	0.6	-	0	nil
Unnamed tributary	S171 565312-571311	0.6	-	0	nil

\- = not surveyed.

* Scale of availability of spawning habitat: Nil
Present
Common
Abundant

APPENDIX VI. Results of electric fishing, drift diving, and seine netting in the Hawkdun study area.

Site	Map reference	Date	Sampling method*	Distance surveyed (m)	Fish species and numbers caught: Brown trout	Brook char	Common river galaxias	Upland bully
Camp Creek	S116:599129	26.1.82	EF	70	33	60	-	-
East Branch	S116:601128	26.1.82	EF	50	9	23	-	-
East Branch	S116:607109	23.2.81	EF	22	3	2	-	-
Johnstons Creek	S125:612043	23.2.81	EF	55	25	24	5	-
Johnstons Creek	S125:610090	30.4.84	EF	-	+	+	+	+
West Branch	S125:607072	23.2.81	EF	60	30	6	-	-
West Branch	S125:610072	30.4.84	EF	60	+	+	+	+
Manuherikia River	S125:624054 - 612072	2.11.81	DD	2000	+	+	-	+
Manuherikia River	S125:628040	23.2.81	EF	75	8	-	-	-
Manuherikia River	S125:637998	23.2.81	EF	70	26	-	-	5
Healeys Creek	S125:638998	23.2.81	EF	53	145	9	-	10
Manuherikia River	S125:633954	24.2.81	EF	70	36	-	-	2
Hut Creek	S125:634955	24.2.81	EF	20	61	-	-	5
Spring Creek	S125:633956	24.2.81	EF	18	52	-	-	7
Rocks Creek	S125:596025	24.2.81	EF	33	29	-	-	-
Johnstones Creek	S126:702897	26.1.82	EF	75	42	82	-	-
Johnstones Creek	S126:695900	26.1.82	EF	70	24	13	-	-
Unnamed tributary	S116:612101	12.6.85	EF	80	35	3	-	-
East Branch	S116:612100	12.6.85	EF	80	-	2	-	-
Johnstons Creek	S125:612092	6.3.85	EF	35	3	25	5	-
Manuherikia River	S125:620059	6.3.85	EF	40	21	8	-	2
Kirkwoods Creek	S125:632070	5.3.85	EF	33	14	6	-	-
Little Bremner Ck.	S125:639065	12.6.85	EF	100	32	11	-	-
Big Bremner Creek	S125:635049	5.3.85	EF	42	3	25	-	-
Manuherikia River	S125:628040	23.2.81	EF	75	8	1	-	-
Rocks Creek Trib.	S125:626013	13.6.85	EF	80	35	-	-	2
Rocks Creek Trib.	S125:630996	6.3.85	EF	31	29	-	-	3
Rocks Creek	S125:613003	5.3.85	EF	45	39	-	-	3
Tunnel Creek	S125:596003	6.3.85	EF	35	15	-	-	-
Rocks Creek	S125:632973	6.3.85	EF	44	61	-	-	11
Ten Chain Creek	S126:661985	12.6.85	EF	80	20	-	-	-
Gate Creek	S125:634946	12.6.85	EF	110	77	-	-	3
Falls Dam reservoir	S125:628938	7.3.85	SN	-	56	-	-	8

* Sampling method:
EF = electric fishing.
DD = drift diving.
SN = seine net.
\+ = observed, but numbers not recorded.
\- = not recorded.

APPENDIX VII. Summary of Hawkdun trout spawning survey redd counts.

Stream	Map reference	Distance (km)	1979	1980	1981	1985	Availability of spawning habitat*
Camp Creek	S116:597131-601128	0.4	-	-	-	0	Present
East Branch	S116:605113-610105	1.1	-	-	-	0	Present
East Branch	S125:613076-610074	0.3	-	-	-	0	Present
East Branch	S125:612104-612099	0.5	-	-	-	0	Present
Boundary Ck.	S125:626056-631068	1.3	-	-	-	20	Common
East Branch	S125:613077-611075	0.4	-	2	-	0	Common
East Branch	S125:610089-611085	0.4	-	0	-	-	Nil
West Branch	S125:575091-589083	1.5	-	-	0	-	Common
West Branch	S125:591081-606072	1.6	-	-	-	4	Present
Manuherikia R.	S125:630028-631021	0.6	-	-	-	0	Present
Manuherikia R.	S125:637994-634978	1.5	-	-	-	0	Present
Manuherikia R.	S125:633970-632949	1.8	-	-	-	2	Common
Manuherikia R.	S125:619061-623057	0.7	-	-	-	1	Common
Manuherikia R.	S125:631953-631948	0.4	5	4	0	-	Common
Manuherikia R.	S125:637000-637997	0.15	-	-	1	-	Common
Manuherikia R.	S125:629037-628039	0.25	-	-	2	-	Common
Manuherikia R.	S125:614072-613073	0.15	-	-	1	-	Common
West Branch	S125:609072-607071	0.3	-	2	0	0	Present
Unnamed creek	S125:613100-612099	0.1	-	-	-	0	Nil
Rocks Ck Trib.	S125:630018-628005	1.1	-	-	-	2	Present
Rocks Ck Trib.	S125:639999-631993	0.5	-	-	-	0	Nil
Rocks Ck.	S125:590025-597025	0.6	-	-	3	4	Common
Rocks Ck.	S125:597025-612003	2.5	-	-	-	8	Common
Rocks Ck.	S125:612003-614000	1.9	-	-	-	0	Present
Rocks Ck.	S125:614000-631993	1.6	-	-	-	0	Present
Rocks Ck.	S125:631992-631956	3.3	-	-	-	0	Present
Rocks Ck.	S125:631973-632959	2.0	-	11	6	-	Common
Rocks Ck.	S125:630998-631973	2.5	-	2	-	-	Common
Rocks Ck.	S125:598024-597025	0.2	-	-	2	-	Common
Hut Ck.	S125:640959-633955	0.8	-	-	-	9	Common
Hut Ck.	S125:644958-640958	0.4	-	-	-	0	Present
Hut Ck.	S125:633954-633948	0.8	27	21	13	-	Abundant
Healeys Ck.	S125:637998-637997	0.2	-	-	3	-	Common
Spring Ck.	S125:633949-634952	0.4	12	0	0	-	Abundant
Spring Ck.	S125:638998-639000	0.2	-	-	-	0	Present
Gate Ck.	S125:632945-635945	0.4	-	-	-	0	Nil
Johnstones Ck.	S125:646936-634938	0.8	-	-	5	2	Common
Johnstones Ck.	S125:675918-678916	0.4	-	-	11	-	Common
Pig Gully Ck.	S125:625923-624926	0.2	-	-	25	-	Abundant

\- = not surveyed.
* Scale of availability of spawning habitat: Nil
Present
Common
Abundant