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Taihoro Nukurangi

Native fish immigration into Lake Ellesmere during 1994

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NIWA Science and Technology Series No. 27

ISSN 1173-0382

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Christchurch

May 1996

Cataloguing-in-publication

Taylor, M.J.

Native fish immigration into Lake Ellesmere during 1994 / M. J. Taylor and E. Graynoth. Christchurch, New Zealand : National Institute of Water and Atmospheric Research Ltd, 1996 (NIWA Science and Technology series ; 27)

ISSN
ISBN 0-478-08386-6

The *NIWA Science and Technology Series* is published by NIWA (the National Institute of Water and Atmospheric Research Ltd.), New Zealand. It supersedes *NIWA Ecosystems Publications* (ISSN 1172-3726; published by NIWA Ecosystems, Hamilton), *New Zealand Freshwater Research Reports* (ISSN 1171-9842; published by NIWA Freshwater, Christchurch) and *Miscellaneous Publications, New Zealand Oceanographic Institute* (ISSN 0510-0054).

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1.0 SUMMARY

Lake Ellesmere is a large, shallow, coastal lake, situated in the South Island of New Zealand which supports important eel *(Anguilla australis)*, whitebait (*Galaxias maculatus*), and flounder (*Rhombosolea* spp.) fisheries. Its outlet to the sea is normally closed, except for intermittent, artificial openings at high lake levels and there is concern that long term closures may effect the recruitment from the sea of the juveniles of commercially important species. The aims of this study were to develop techniques to monitor the immigration of juvenile fish into Lake Ellesmere, to obtain preliminary information on the timing and size of fish migrations, and to assess the effects of lake mouth closures.

A total of 14 native fish and 2 introduced salmonids were captured in the lake, using seine nets, fyke nets and other techniques, during monthly sampling from July to December 1994. Fish were also collected from the lower reaches of the Rakaia and Waimakariri Rivers to determine fish migration patterns through a permanent outlet.

Lake Ellesmere was opened to the sea for seven days in June, 19 days in July and August, and for 14 days in October 1994. Juvenile yellowbelly flounders (*Rhombosolea leporina*) and sand flounders (*Rhombosolea plebeia*) entered the lake from June to August. Juvenile black flounders (*Rhombosolea retiaria*), shortfinned glass-eels (*Anguilla australis*) and inanga whitebait (*Galaxias maculatus*) entered the lake in October. The lake mouth then remained closed until June 1995 and this prevented adult shortfinned and longfinned eels (*Anguilla dieffenbachii*), and the larvae of common smelt (*Retropinna retropinna*), inanga, torrentfish (*Cheimarrichythys fosteri*), and common bully (*Gobiomorphus cotidianus*) from migrating to sea. Each month, from six to 10 different life stages of fish migrated through the Lake Ellesmere mouth, in addition to several marine species such as the yelloweyed mullet (*Aldrichetta forsteri*).

In summary at least seven species of fish enter Lake Ellesmere during the immigration peak in September and October and an equal number leave during the emigration peak in February and March. In order to maintain the fisheries, the lake should be opened for at least two weeks during late September and early October to permit the entry of juvenile black flounders, glass-eels, and whitebait. The mouth should also be opened from late March onwards to permit the emigration of female shortfin eels and other fish. This lake mouth opening regime might also encourage the establishment of emergent marginal and aquatic vegetation in the lake.

2.0 INTRODUCTION

Lake Ellesmere (Te Waihora) is situated on the east coast of the South Island of New Zealand, 34 km south west of Christchurch. It is a large, shallow, productive lake that supports New Zealand's single largest commercial eel fishery and significant flounder and whitebait fisheries (Jellyman 1992). It is also a very important traditional fishery for the Ngai Tahu and is representative of many low elevation lakes throughout the country. The lake outlet to the sea is normally closed, except for intermittent, artificial openings at high lake levels, and there is concern these closures may reduce the recruitment of juvenile eels (glass-eels), flounders and whitebait from the sea (Jellyman 1992).

The aims of this study were to develop techniques to monitor the immigration of juvenile fish into Lake Ellesmere; to obtain preliminary information on the timing and size of fish migrations, and to assess the effects of lake mouth closures. No information was collected on annual changes in migration patterns as funds were not available for long-term research. During 1994/95 the mouth was open on only two occasions. Therefore to determine fish migrations when the mouth was closed, fishing was also undertaken in the lower reaches of the Rakaia and Waimakariri Rivers which have permanent access from the sea.

3.0 STUDY AREA

3.1 Lake Ellesmere

The lake is roughly triangular in shape with a mean area of 189 km^2, depending upon lake level, and is the fifth largest lake in New Zealand (Horrell 1992). The lake is shallow, with mean and maximum depths of 1.4 m and 2.7 m respectively and is deepest near the mouth of the Selwyn River, and near its mouth at Taumutu (Fig. 1). The mean lake water level is 0.8 m.a.s.l, and ranges between 0.4 m and 1.5 m.a.s.l. although strong winds can elevate or depress water levels by approximately 0.5 m. The lake bed consists of mud, silt, and fine gravel.

The lake is separated from the sea by the Kaitorete Spit, a gravel bar that tapers in a southerly direction towards the outlet. The spit has a minimum width of 200 m and is occasionally over-topped by sea water in winter when rough seas coincide with a high tide. Approximately 1 $m^3.s^{-1}$ of sea water (depending on lake level) permeates through the spit and the lake is always brackish, even when the mouth is closed.

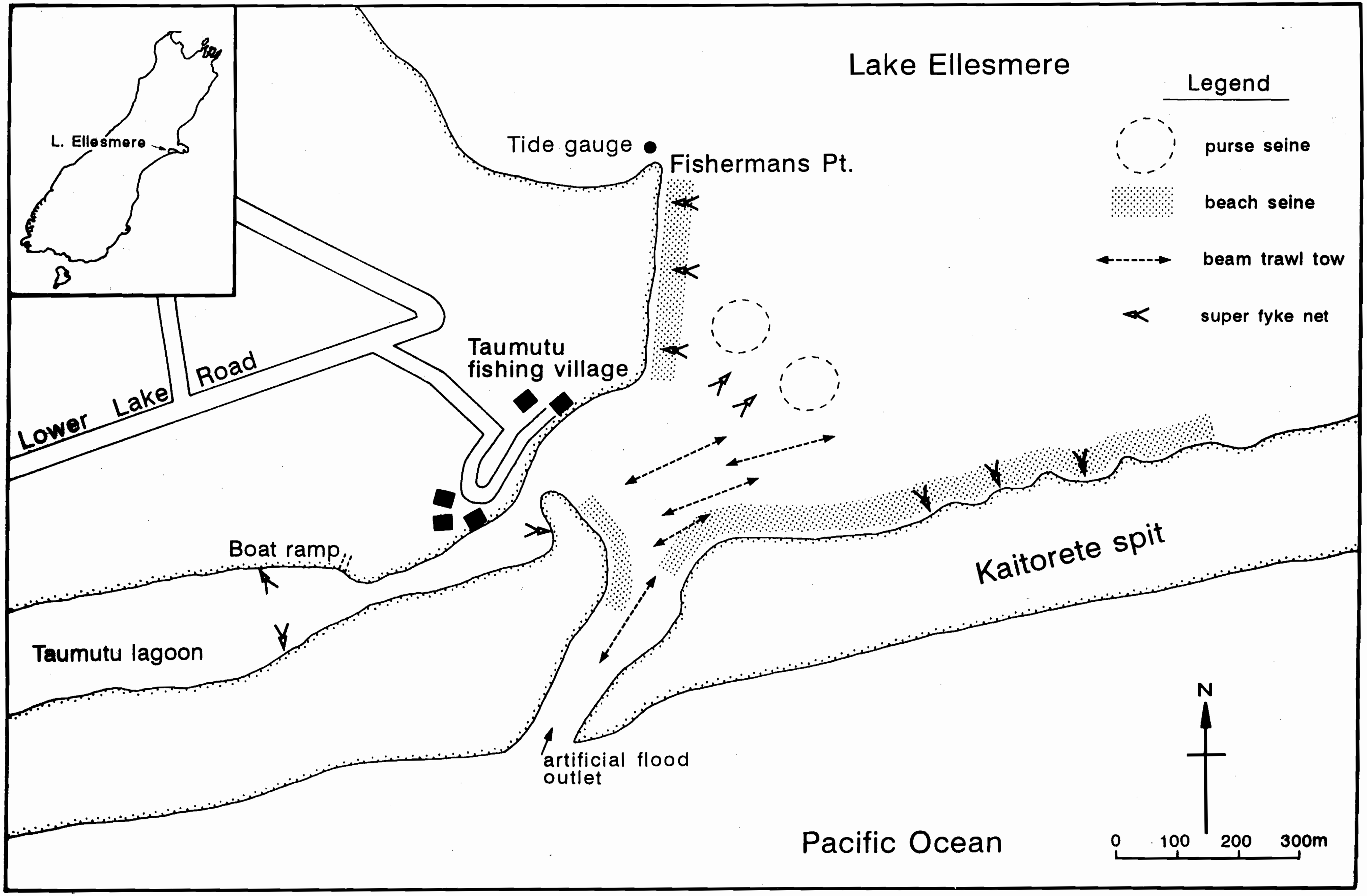

FIGURE 1 The Lake Ellesmere outlet and fishing locations.

When the lake reaches a target maximum level, as currently defined by the National Water Conservation (Lake Ellesmere) Order 1990 (NWCO), it is opened to the sea by the Canterbury Regional Council (CRC) at a cost of about $120,000 a year. The current target level for opening is 1.05 m.a.s.l. in summer (August to March), and 1.13 m.a.s.l. in winter (April to July). Lake openings take place on average 3.6 times a year and each persists on average for 18 days (Horrell 1992). Typically an initial channel 20 m wide and 170 m long is excavated through the gravel spit with bulldozers, and the force of the lake discharge enlarges this to 300 m wide (Horrell 1992). The initial outflow is approximately 154 to 176 $m^3.s^{-1}$, which decreases to 75 $m^3.s^{-1}$ over several days. The outflow velocity can be high (> 3 $m.s^{-1}$, pers. obs.), and most fish probably enter the lake on the rising tide (McDowall 1990). Marine fishes may also be attracted to the mouth to feed on small fish and invertebrates and are swept into the lake at high tide. The tidal range at this locality is usually about 1.7 m (NZ Nautical Almanac 1994), and on average 31 $m^3.s^{-1}$ flows in at high tide. Heavy southerly seas (wave height > 2.5 m) tend to close the outlet by washing gravels into the lake mouth, and the lake can only be reopened during calm periods (i.e. wave height <2m, for four days).

Analysis of lake openings from 1945 to 1994 (unpub. CRC data) shows that there are more openings nowadays but for shorter periods. This is because gravel scour decreases when the lake is opened at lower lake levels (Gerbeaux 1993) and the lake therefore closes sooner. As a consequence the average duration of the opening has reduced substantially from 125 days to approximately 50 days per annum.

The timing of lake openings has remained constant. Mid-winter to spring is the season when mouth openings are most frequent, although occasionally there have been years when the mouth has not been opened or opened only briefly (CRC, unpub. data 1945-1994). For example, over the last 19 years, the lake mouth was closed in the spring on three occasions; 1982, 1988, and 1991.

Prior to this study, the lake was opened for 72 days from January to the middle of March 1994, and for seven days in June. Table 1 provides a timetable of lake openings during 1994/95.

3.2 Waimakariri and Rakaia Rivers

The Waimakariri River is a large braided river (mean flow 116 $m^3.s^{-1}$) with a permanent discharge into Pegasus Bay some 15 km north of Christchurch (Eldon and Kelly 1985) (Fig. 2). The lower reaches of the river and the associated Brooklands Lagoon were fished each month from September to December 1994 (Table 2) to provide information on fish migrations

TABLE 1 Lake openings and fishing effort in Lake Ellesmere June 1994 to June 1995.

Month	Day	Mouth status	No. of beach seines	No. of beam trawls	No. of fyke net sets	Other
June	19	Opened				
	26	Closed				
July	16	Opened				
	19-20	Open	2	0	6	4
August	2-3	Open	8	0	0	4
	4	Closed				
September	16	Closed	4	0	0	0
	22	Open**				
	23	Closed				
	28	Closed	2	5	0	0
October	6	Opened				
	11-13	Open	0	2	5	1
	20	Closed				
	27-28	Closed	10	2	3	0
November	15-16	Closed	4	2	5	0
December	14	Closed	5	0	0	0
June	16	Open**				

* = Whitebait trapping, purse seines, trap net, benthic sledge, elver trawl hours.
** = Open for less than 24 hours

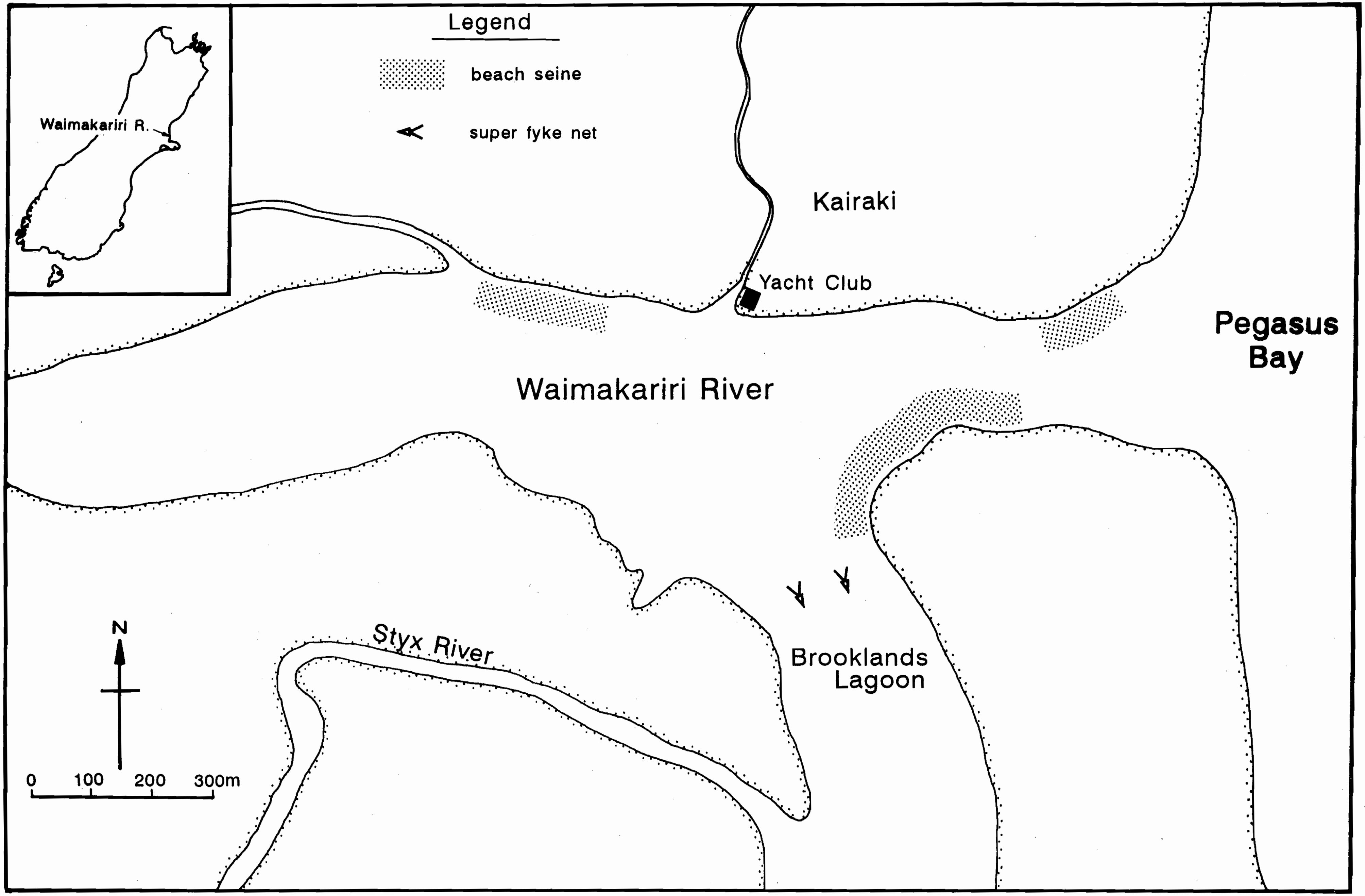

FIGURE 2 Approximate fishing areas near the Waimakariri River mouth from September to December.

TABLE 2 Times and location of fishing in the Waimakariri River and Brooklands lagoon

Month	Day	Method	No. of sets	Location
September	1	Elver trawl	1	Brooklands Lagoon
September	9	Fine mesh seine	2	Brooklands Lagoon
September	9	Fine mesh seine	1	River mainstem
October	6	Fine mesh seine	2	Brooklands Lagoon
December	13	Fine mesh seine	3	Brooklands Lagoon
December	13	Fine mesh seine	1	River mouth
December	13	Fine mesh seine	1	River mainstem

when the Lake Ellesmere month was closed (Table 1). The Rakaia River lagoon (Eldon and Greager 1983) was also fished in two occasions in August and September 1994.

4.0 METHODS

It was difficult to fish near the Lake Ellesmere mouth owing to the strong tidal currents. Seines and trawls were used only at high tide and fyke nets and traps were set either more than 500 m away from the mouth or in the sheltered Taumutu lagoon (Fig. 1).

4.1 Fyke nets

Fine-meshed fyke nets (1 mm stretched mesh) with two wings and a central leader (Chisnall *et al* in press) were set overnight in the boat harbour and at other locations (Fig. 1). These nets caught glass-eels and other small fish, which were separated from larger predatory fish by a size-selective mesh (22 mm). There was no difference in catch between nets with and without hoods, so hoods were left off in rough conditions. An attempt to set fyke nets in Brooklands Lagoon failed because tidal currents were too swift.

4.2 Fine mesh seine net

The margins of Lake Ellesmere were fished during the day with a seine net (20 m x 3.6 m, 3.5 mm mesh), attached to 25 m long hauling ropes. Seining took place in the vicinity of Taumutu village, and along both shorelines that form the south west corner of Lake Ellesmere. Seining locations were 300 m to 1000 m from the mouth (Fig. 1). Beaches of Brooklands Lagoon and the lower Waimakariri River were seined from 100 m to 1000 m from the mouth (Fig. 2).

4.3 Beam trawl

A small beam trawl (Buckingham 1973) was towed for 100 to 200 m in Lake Ellesmere (Fig. 1) using a 90 hp motorboat. The 2 m wide aluminium frame was slung with a 4 m long net (8 mm mesh) with a 2 m long codend (2 mm mesh). A complete trawl net of 2 mm mesh, accumulated excessive mud and snails and was not practical in Lake Ellesmere.

4.4 Elver trawl

The elver trawl comprised of a steel-framed, 1 m wide, open-ended cage covered with fine (1 mm bar) wire mesh. Steel tines were welded onto the bottom of the trawl to disturb the substrate and startle juvenile eels into the cage. Unfortunately the trawl caught very few elvers and was not used after several trials in Lake Ellesmere and the Waimakariri River.

4.5 Purse seine

A small purse seine was tested on Lake Ellesmere in July. The net (3 mm mesh) was set from a boat and formed a circle with a diameter of 12 m and a depth of 2 m. The net was not used in later months because it caught few flounders, eels and other benthic species.

4.6 Fish collection, identification and ageing

A random sub-sample of fish was identified and retained from each catch. For abundant species approximately one in 20 specimens was retained, but for less common species most were kept. Total numbers of each species were then estimated from the counts and ratio sub-sampled. Fish were preserved in the field in 40% isopropyl alcohol and measured in the laboratory.

Flounder fry were defined as fish < 20 mm and were identified by microscopic examination in the laboratory (Eldon and Smith 1986). Stokell's smelt (*Stokellia anisodon*) has never been found in Lake Ellesmere, and only common smelt were identified in this study. Common smelt were separated into marine migrants and lake residents by counting vertebrae from x-rays, by examining otoliths and by length frequency analysis. Fresh run marine migrants were more transparent than lake residents.

A sample of yellowbelly flounder juveniles and fry (lengths 15 - 47 mm, n = 24), collected on 3 August 1994 in Lake Ellesmere, were aged by grinding down their otoliths to thin sections and counting the number of fine rings present (at 400-600 X magnification). Smelt were aged by counting the number of annuli visible on whole otoliths under reflected light against a black background.

4.7 Fish species and size selectivity by fishing gear

The probable biases of different fishing gear were determined by examining length frequency distributions (Figs. 3, 4) and catch rates (Tables 3 and 4) of fish caught in Lake Ellesmere and the Waimakariri River. Purse seining was ineffective for benthic species and selected small common bullies and a limited size range of smelt (Fig. 3). The beam trawl caught a limited size range of smelt and a high percentage of large (> 60 mm) yellowbelly flounder (Fig. 4). The elver trawl failed to catch elvers and small flounder while fine-meshed fyke nets were best for shortfinned eels and glass-eels. The beach seine was least biased and captured a wide range of sizes of both benthic and midwater species, including torrentfish, whitebait, chinook salmon (*Onchorhynchus tshawytscha*), and sand flounder. It was ineffective for large eels and large flounders.

5.0 RESULTS

5.1 Eels

No glass-eels were caught in Lake Ellesmere until the mouth was opened in October, when 34 shortfinned glass-eels (mean length 55.5 mm, s.d. = 1.9 mm) were caught in fyke nets (Table 4). No glass-eels were caught using other techniques (Tables 3 and 4). Only a single glass eel was caught in the Waimakariri River by seining in September (Table 5) and catches were low probably because fyke nets could not be used.

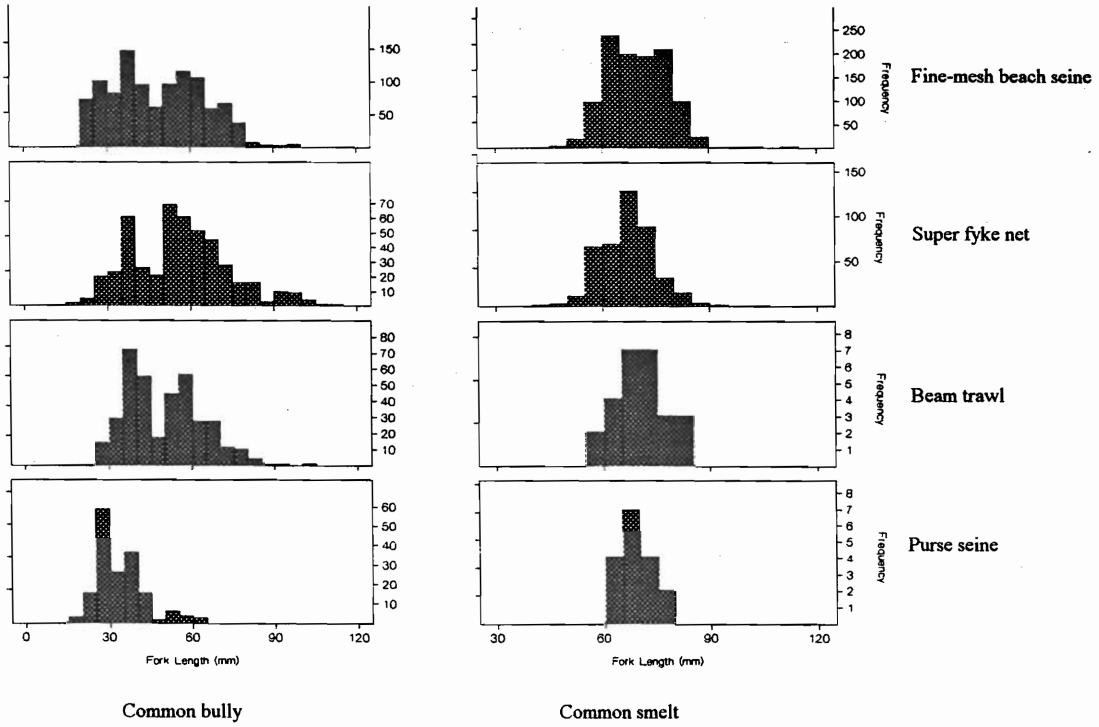

FIGURE 3 Length frequency distributions of common bully and common smelt caught in Lake Ellesmere and the Waimakariri River, using various fishing gear.

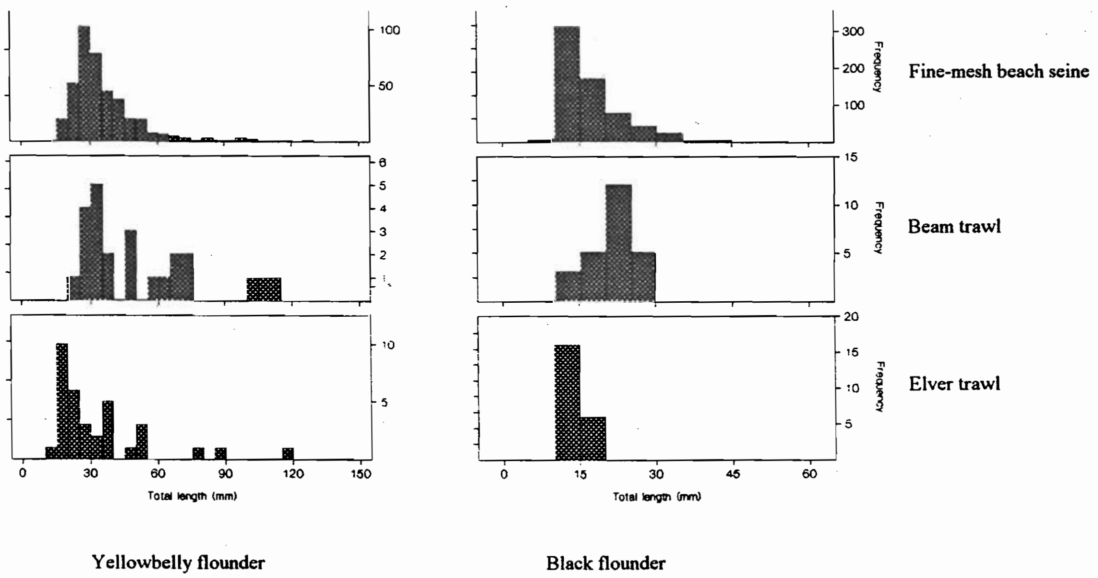

FIGURE 4 Length frequency distribution for yellowbelly flounder and black flounder caught in Lake Ellesmere and the Waimakariri River, using various fishing gear.

TABLE 3 Mean catch of freshwater fish species per seine haul in Lake Ellesmere.

	Month					
	Jul	Aug	Sep	Oct	Nov	Dec
Number of seine hauls	2	8	6	10	4	5
Immigrant fry and larvae						
Yellowbelly flounder	0.0	0.5	0.0	0.0	0.0	0.0
Black flounder	0.0	0.0	0.7	58	44	0.0
Sand flounder	0.0	0.0	0.0	0.0	0.0	0.0
Torrentfish	0.0	1.1	0.0	2.2	3.3	0.0
Resident juveniles and adults						
Shortfinned eel	0.5	0.4	0.0	0.1	0.3	0.4
Yellowbelly flounder	4.5	28	9.5	2.1	1.3	0.4
Black flounder	0.0	1.0	0.0	1.2	28.5	13.2
Sand flounder	1.5	5.4	0.83	0.2	0.3	0.0
Common smelt	26.5	23	24	46.5	70	29
Common bully	745	2908	115	*	*	56.4
Yelloweyed mullet	2.0	0.0	1.2	0.2	0.0	0.0

* = Not counted - several hundred to thousands.
Other species occasionally caught in seine nets included Sprat and Stargazer

Juvenile and adult shortfinned eels (mean length 169.9 mm, s.d. = 54.6 mm, n = 31) were also caught in Lake Ellesmere during this survey. The majority (55) were caught in fyke nets, while several (four) where caught using the beach seine. Fyke net catch rates were low in August and increased in October before declining in November (Table 4).

5.2 Flounders

The yellowbelly flounder is predominantly a marine species that occasionally lives in estuaries and shallow coastal lakes. Fry and juveniles (mean length = 31.8 mm, s.d. = 8.3 mm, n = 244) were moderately abundant in Lake Ellesmere when sampling began in late July and

TABLE 4 Mean catch of fish per fyke net set and beam trawl haul for Lake Ellesmere.

Month	Jul	Oct	Nov	Aug	Sep	Oct	Nov
Method	Fyke	Fyke	Fyket	Trawl	Trawl	Trawl	Trawl
No. fyke net sets or trawls	6	8	5	3	5	4	2
Immigrant fry and larvae							
Glass eel	0.0	4.3	0.0	0.0	0.0	0.0	0.0
Yellowbelly flounder	0.0	0.0	0.0	2.6	0.0	0.0	0.0
Black flounder	0.0	0.5	0.2	0.0	0.0	1.0	2.0
Sand flounder	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Inanga whitebait	0.3	7.4	0.2	0.0	0.0	0.0	0.0
Torrentfish	0.2	0.5	0.0	1.0	0.2	1.2	0.0
Resident juveniles and adults							
Shortfinned eel	0.7	5.6	1.2	0.0	0.0	0.3	0.0
Yellowbelly flounder	0.0	0.5	0.0	0.0	2.8	0.8	0.0
Black flounder	0.0	0.1	0.0	0.0	0.2	00	8.5
Common smelt	53	14.6	9.2	0.0	2.2	2.0	5.5
Common bully	1149	1500	50.6	3780	58	*	50.5
Yelloweyed mullet	0.8	0.1	0.0	0.0	0.0	0.0	0.0
Inanga	0.5	1.1	0.0	0.0	0.0	0.0	0.0

* = not counted

early August 1994 (Table 3). The lake mouth remained closed through most of August and September (Table 1) and it appears that relatively few additional juveniles or fry entered the lake during October when the mouth was reopened. Length frequency measurements (Fig. 5) indicated that the initial cohort showed a steady increase in size, (approximately 0.3 mm per day), and that there was no additional recruitment of fry. Catch rates declined from August onwards (Table 3) presumably as fish died and migrated away from the lake mouth.

The number of rings (45 to 154) on the otoliths of yellowbelly flounder from Lake Ellesmere was linearly related ($r = 0.91$) to fish length (0.293 mm per ring, s.d. = 0.037, $n = 22$). As 0.293 mm is very similar to daily growth rates in the lake this supports the assumption that

TABLE 5 Mean catch of fish species per seine haul in the Rakaia and Waimakariri River lagoons.

Month	Aug	Sep	Sep	Oct	Dec
Location	Rakaia	Rakaia	Waimakariri	Waimakariri	Waimakariri
Number of seine hauls	2	5	3	5	5
Immigrant fry and larvae					
Glass eels	0.0	0.0	0.3	0.0	0.0
Yellowbelly flounder	0.0	0.0	4.33	0.4	0.0
Black flounder	0.0	0.0	0.33	28.4	0.0
Sand flounder	0.0	0.0	0.0	0.2	0.0
Inanga whitebait	0.0	0.0	4.0	15.6	37.6
Torrentfish	0.0	0.0	14.3	0.6	0.0
Quinnat salmon	0.0	10.6	1.0	0.0	0.4
Resident juveniles and adults					
Shortfinned eel	0.0	0.0	0.3	0.0	0.0
Yellowbelly flounder	0.5	0.0	18.33	3.0	0.4
Black flounder	0.0	0.0	0.0	0.0	0.0
Sand flounder	0.0	0.0	0.0	0.0	0.2
Common smelt	0.0	0.0	2.0	2.4	30.8
Common bully	0.0	0.2	19	34.4	0.4

ring were laid down daily. The age of fry and juveniles (< 75 mm in length) caught in early August was therefore estimated by dividing their length by 0.293. Fish averaged 107 days old (range 61 - 221 days) and the first ring formed on average on the 18 April (s.d. 27.8 days, n = 235). If the fish entered during the June opening they should have averaged about 19.2 mm in length, some 13 mm smaller than those caught in early August.

All otoliths had distinctive check at an average count of 44.2 rings (s.d. = 10.1, n = 24). There was no relationship between the date when this check was formed and the dates when Lake Ellesmere was open. Therefore this check appears to be unrelated to the entry of flounders into freshwater and may be related to their metamorphosis.

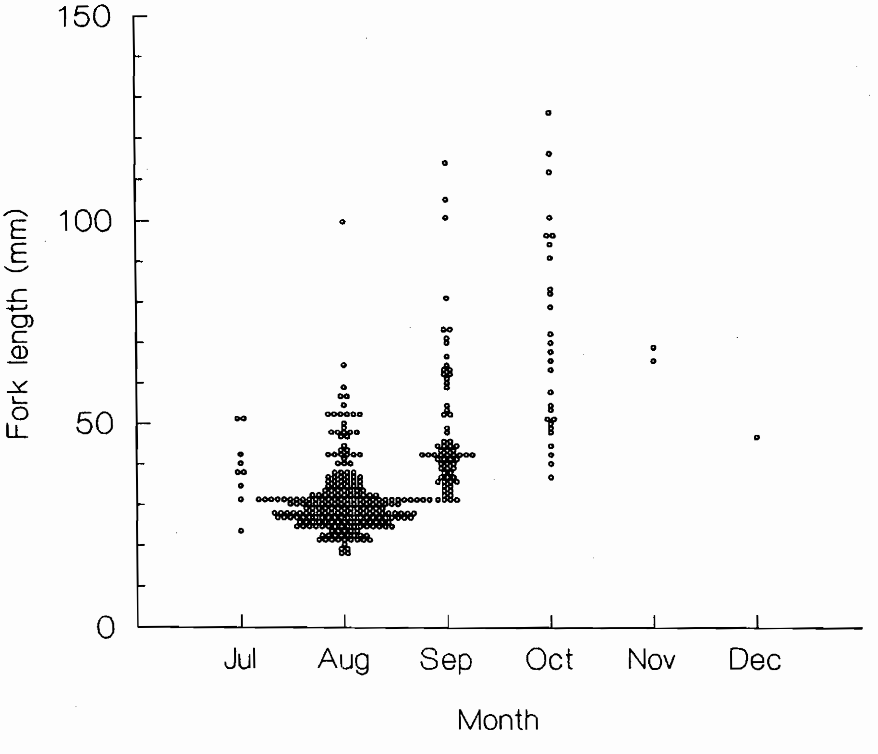

FIGURE 5 Growth of juvenile yellowbelly flounder in Lake Ellesmere.

In the Waimakariri River, large numbers of yellowbelly flounder (mean length = 27.2 mm, s.d. = 10.1 mm, n = 116) were caught later in the year during September and to a lesser extent in October (Table 5). Yellowbelly flounder have not been recorded from the Rakaia Lagoon (Eldon and Greager 1983), and no juveniles were captured during this study.

Large numbers of black flounder fry (mean length = 13.2 mm, s.d. = 1.8 mm, n = 401) entered Lake Ellesmere and the Waimakariri River during October (Tables 3 and 5, Fig 5). The smallest black flounder immigrants examined were transparent and 9 mm in length. The lake mouth was closed during November, and resident fry grew approximately 0.3 mm per day (Fig. 6). The Waimakariri River was not sampled in November and no fry were recorded in December.

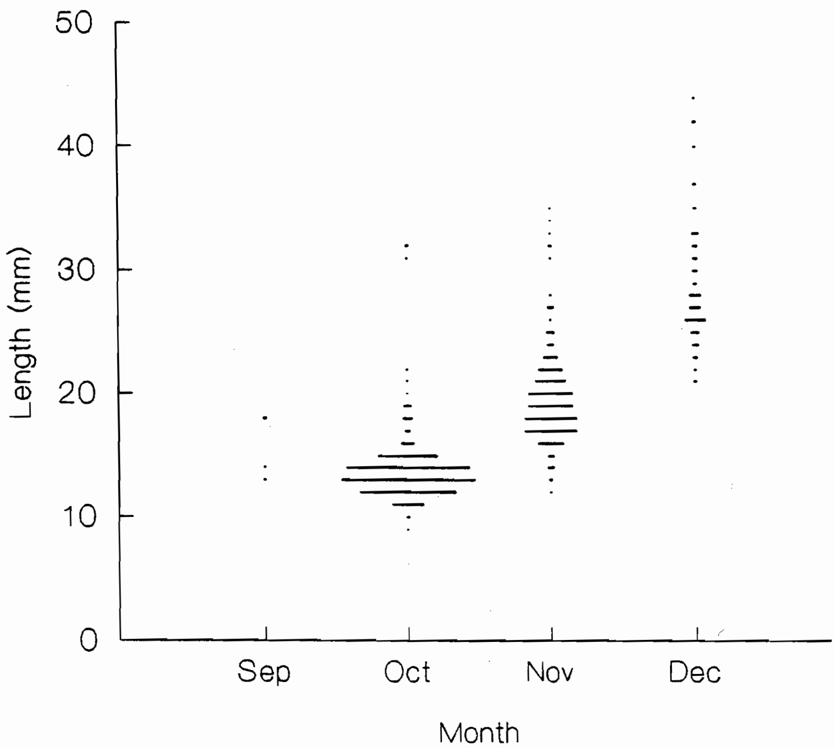

FIGURE 6 Growth of juvenile black flounder in Lake Ellesmere.

Catch rates of juvenile sand flounder in Lake Ellesmere followed a similar pattern to yellowbelly flounder (Table 3). Most juveniles were caught in August (mean length = 43.8 mm, s.d. =8.0 mm, n = 39), followed by a sharp decline in catch rates over succeeding months. The larger size of juveniles and the lack of fry suggests that sand flounder migrate into the lake earlier than yellowbelly and black flounder. Insufficient juvenile fish were caught to establish growth rates and only one sand flounder was caught in the Waimakariri River.

5.3 Whitebait

Although the first whitebait were caught in Lake Ellesmere in July, fyke net catches increased markedly after the mouth was opened in October (Table 4). Waimakariri River whitebait were present when sampling began in September, and catch rates increased until fishing stopped in

December (Table 5). There was no significant difference in fish size between Lake Ellesmere and the Waimakariri River (mean length = 49.0 mm, s.d. = 2.3 mm, n = 349).

Only a few adult inanga (mean length = 86.3 mm, s.d. = 9.8 mm, n = 11) were caught in fyke nets within Lake Ellesmere (Table 4) and most probably live either along the shoreline associated with marginal vegetation (G. Glova pers. comm.) or in the lowland tributaries of the lake.

5.4 Common smelt

High numbers of common smelt (mean length = 67.5 mm, s.d. = 8.2 mm, n = 1395) were caught in fyke and seine nets throughout the study period (Table 3 and 4). These fish are either resident for their entire life cycle in Lake Ellesmere or are of marine origin entering the lake to spawn (McDowall 1990). Vertebral counts and otolith examination (Table 6) showed that the two smallest size classes (modal lengths 58 mm and 70 mm, Fig. 7) caught in July and August, were slow-growing, yearling and two-year-old lake-resident fish. The largest fish (modal length 80 mm) were fast-growing, yearling, marine migrants. Length frequency analysis (Fig. 7) indicated that the majority of smelt caught were lake resident. Also only a few large transparent marine migrants were seen in the catches, after the lake was opened in July and October and none were seen in later months.

TABLE 6 Year classes of common smelt caught in Lake Ellesmere.

Length range (mm)	n	Age* (years)	Body pigmentation	Origin	Vertebral count
55 - 65	10	1+	transparent	lacustrine	55 -57
63 - 82	20	2+	silvery	lacustrine	55 - 58
75 - 82	4	1+	transparent	marine	60

* specimens were aged by otolith examination.

Smelt caught near the Waimakariri River mouth (mean length = 77.4 mm, s.d. = 3.4 mm, n = 166) were probably marine migrants as they were similar in size to migrants from Lake Ellesmere (Fig. 7, Table 6). A few fish exceeded 100 mm in length and these could be two year-olds. Catch rates were low in September and October but increased in December (Table 5).

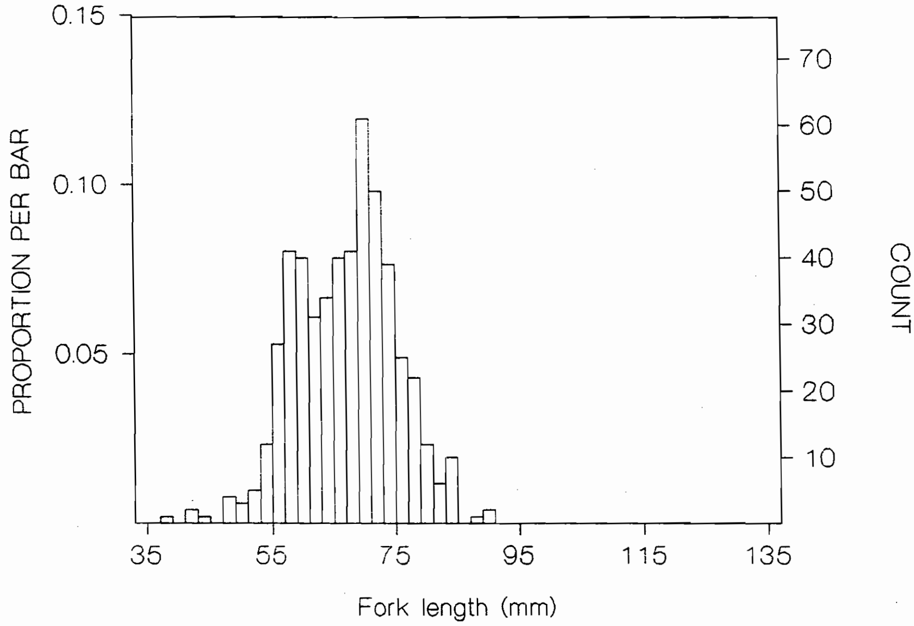

FIGURE 7a The length frequency of Lake Ellesmere common smelt collected in July and August.

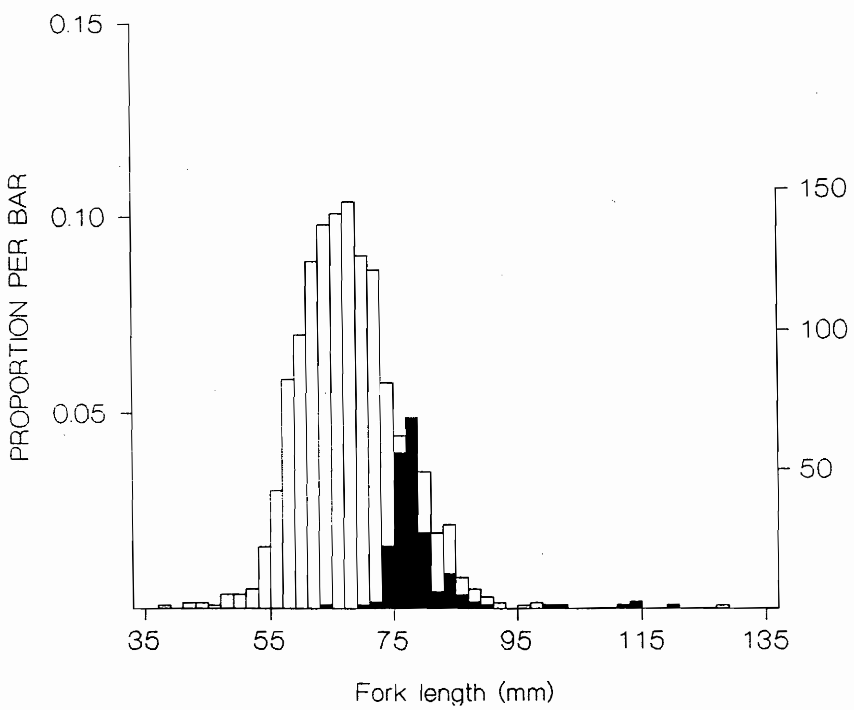

FIGURE 7b Length frequency distribution of Waimakariri River (black) and Lake Ellesmere (white) common smelt.

5.5 Common bully

Common bullies were the most abundant fish present in Lake Ellesmere and approximately 57,000 fish were caught (mean length = 50.4 mm, s.d. = 16.0 mm, n = 1,910). The highest catches were in fyke nets in October (Table 4), and beach seines in July and August (Table 3). Length frequency analysis (Fig. 8) indicated that bullies ranged in age from under-yearlings to possibly four-year-olds. Spawning probably took place around the lake margins from November onwards, because small pelagic fry were caught in the centre of the lake during the summer (pers. obs.).

Common bullies were less abundant in the Waimakariri and Rakaia Rivers than Lake Ellesmere and smaller in size. Most fish ranged from 22 to 28 mm in length, and were probably less than one year old. Several (five) larger fish, from 30 mm to 64 mm, were caught in September and were probably one to three years old.

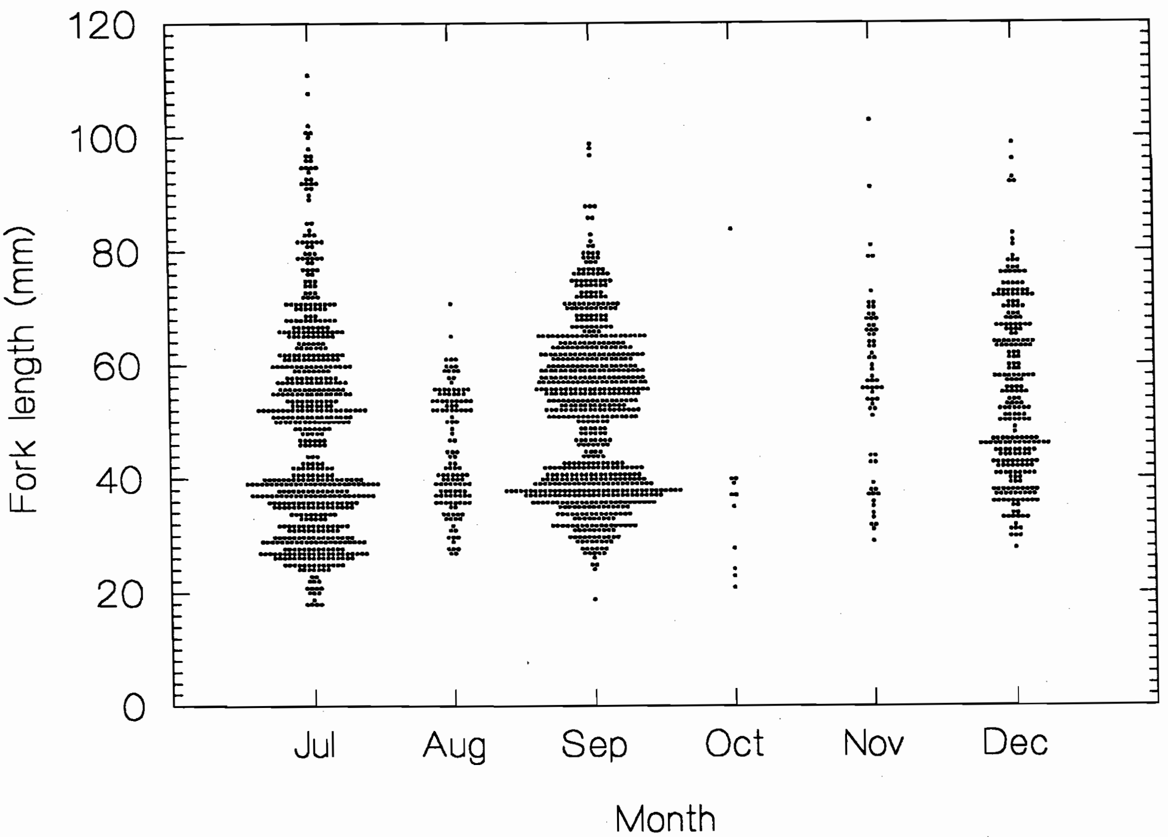

FIGURE 8 Length frequency of common bullies from Lake Ellesmere.

5.6 Torrentfish

Juvenile torrentfish were mainly caught from August to November in both Lake Ellesmere and the Waimakariri River (Tables 3, 4, 5). The highest catch rate occurred in September in the Waimakariri River. Juveniles (mean length = 30.6 mm, range = 24 - 45 mm, s.d. = 4.0 mm, n = 94) were slightly larger than fresh run immigrants (22-34 mm, McDowall 1994), probably due to growth in fresh water.

5.7 Other fish

The yelloweyed mullet is present in Lake Ellesmere throughout the year although it is primarily a marine fish (McDowall 1990). Mullet (mean length = 101.3 mm, s.d. = 44.7 mm, n = 25) were collected in July, October, and September mainly using the beach seine. Insufficient fish were caught to determine when these fish entered the lake although, based on studies in the Waimakariri River (Eldon and Kelly 1985), peak emigration probably occurs during February and March. Other freshwater fish caught in Lake Ellesmere included one brown trout (*Salmo trutta*), three chinook salmon fry and a lamprey macrophthalmia (*Geotria australis*) (102 mm, 19 July).

Four basking sharks (*Cetorhinus maximus*) entered Lake Ellesmere when the mouth was opened in October. One of these large (approximately 5 m long) fish became grounded and died at Taumutu while the remaining sharks managed to leave the lake on the high tide.

Five small stargazers (92-115 mm) were caught in Lake Ellesmere and the Waimakariri River. Most (four) were the marine stargazer (*Crapatalus novaezelandie*) and one the estuarine stargazer (*Leptoscopus macropygus*). The estuarine stargazer is thought to spawn in the sea, although juveniles are caught in lagoons and lowland rivers (McDowall 1990).

Five small (14 mm - 98 mm) common sole (*Peltorhamphus novaezeelandiae*) were seined from Lake Ellesmere and the Waimakariri River. This marine species enters the lake to feed when it is open to the sea.

Two red cod (*Pseudophycis bacchus*) and 60 stout sprats (*Sprattus muelleri*) (mean length = 61.4 mm, s.d. = 7.7 mm) were also caught in Lake Ellesmere.

6.0 TIMING OF FISH MIGRATIONS AND THE EFFECTS OF LAKE ELLESMERE MOUTH CLOSURES

6.1 Eels

The entry of both species of glass-eel into fresh water begins in July, with the longfinned eel migration stopping in November, and shortfinned eel migration ceasing in December (Jellyman 1977). Glass-eels were caught in Lake Ellesmere in October which is the normal peak of the runs (Table 7).

It seems unlikely that glass-eels could enter Lake Ellesmere when its mouth is closed (Jellyman *et al* 1995). Although glass-eels can penetrate closed river mouths through coarse gravels, the Lake Ellesmere gravel spit is wide and compacted. However, because eels are so long-lived, the loss of one year's recruitment would not lead to the collapse of the fishery providing access is available during following seasons.

Adult shortfinned eels undertake a spawning migration from Lake Ellesmere to the sea between late January and early May, with a peak from mid-February to mid-March (Table 7, Todd 1981). In 1995 this migration was blocked by the closure of the lake mouth (although some migrants were seen crossing the bar). Many of the mature adults trapped in the lake are caught by eel fishermen who prefer the lake to remain closed at this time. The surviving migrant eels may attempt to migrate in future years (D.J. Jellyman pers. comm.). Therefore although lake closure in autumn could increase eel catches it may reduce the escapement of spawning adults and therefore glass eel recruitment into the national fishery.

6.2 Flounders

This study indicated that adult yellowbelly flounder spawn at sea in autumn and that fry entered Lake Ellesmere during June and July, and the Waimakariri River during August and September. This is quite different from the Hauraki Gulf where flounders spawn in the spring, from September to November (Colman 1973). The reasons for this difference are unknown. Black flounder fry migrations (Table 7), begin in September, peak in October, and terminate in November based on the results of this study and other local studies (Eldon and Greager 1983, Eldon and Kelly 1985).

The species of flounder caught vary substantially from year to year presumably depending upon lake opening times (Jellyman 1992). There is also a highly significant relationship ($p < 0.001$, $r^2 = 0.39$) between flounder catches (all species) over the years 1937 to 1971 and the

TABLE 7. Timetable of the principal species of fish migrating through the Lake Ellesmere mouth.

Key to relative abundance of migrants	**Abundant**	**Common**	**Scarce**	**Nil**
This study	xxxxxx	xxx	x	
Other studies (McDowall 1995, Eldon and Kelly 1985)	00000	000	0	

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Fish entering the lake												
Shortfinned glass eel							0	0000	0000000	0000000	xxxxxxx	000
Longfinned glass eel							0	0000	0000	0000	0	
Yellowbelly flounder - fry			0	0000	0000	xxxxxxx	xxxxxxx	xxxxxxx	xxxx	x		
Black flounder - fry									0000	xxxxxxx	0000	
Sand flounder - fry					x	xxx	x					
Inanga - whitebait	0	0	0	0	0	0	x	x	xxxx	xxxxxxx	xxxxxxx	xxxxxxx
Common smelt - adult	0	0					x	x	x	x	0	0000
Common bully - juvenile			0000	0000000	0000							
Torrentfish - juvenile				0000	0000	000000	0	x	xxxx	x	x	
Fish leaving the lake												
Shortfinned eel - adult		0000000	0000000	0000000								
Longfinned eel - adult			0	0000	0000							
Yellowbelly flounder - adult	0	0000	0000	0								
Black flounder - adult						0000	0000					
Sand flounder - adult		0000	0000									
Inanga - larvae	0	0000	0000	0000	0	0	0	0	0	0	0	0
Common smelt - larvae	0	0000	0000	0000							0	0
Common bully - larvae	0000000	0000000									0	0000000
Torrentfish - larvae		0	0	0	0							
Total number of life history types	6	9	10	10	8	6	8	6	8	8	9	6

duration of lake openings during spring three years previously (M. Main, CRC pers. comm.). Therefore the lake needs to be opened during October to stock the lake with black flounder fry and maintain the fishery for this species. Openings from possibly June to August may also be needed to recruit yellowbelly and sand flounder fry, although some enter as large juvenile and adults at other times of the year (Roy French pers. comm.).

6.3 Whitebait

Inanga (*Galaxias maculatus*) were observed spawning amongst emergent raupo in Waikewai Creek (near Taumutu) in March and April 1990 (Taylor *et al* 1992) and may also have spawned in raupo around the lake margins prior to 1968. Newly hatched larvae are flushed out to sea and enter freshwater six months later as whitebait. The runs occur year round and peak between September and October (McDowall 1990). Whitebait were caught in Lake Ellesmere after the mouth was opened in October but later runs were blocked by mouth closure that reduced the duration and size of the 1994 whitebait run (Table 7).

Closure of the lake mouth in autumn will trap inanga larvae in Lake Ellesmere. There is no information on whether or not these larvae will survive in Lake Ellesmere and contribute to future stocks.

6.4 Common smelt

Common smelt are present throughout the year in the Waimakariri River, with a December invasion of marine migrants (Eldon and Kelly 1985). Although we found some marine migrants present in Lake Ellesmere in July and October, most were caught in the Waimakariri in December. Therefore most marine migrants probably enter Lake Ellesmere in summer from December onwards (Table 7) and would be influenced by the frequency and duration of the Lake Ellesmere mouth opening. However lake resident smelt are extremely abundant and this population will not be effected by lake mouth openings.

6.5 Common bully

Common bullies can form either lake-locked or sea-run populations (McDowall 1990). In Lake Ellesmere most fish are probably lake resident owing to the temporary nature of the mouth openings. Spawning probably takes place from November onwards and fry live in the pelagic zone until they reached 15-20 mm in length when they move into the shallow littoral zone. Closure of Lake Ellesmere throughout the 1994/95 summer trapped bully fry within the lake and probably prevented marine-resident juveniles from re-entering the lake in the autumn (Table 7). However there is little information available on the migration timing of juvenile bullies in Canterbury and it is possible some enter during the winter and spring (G. Glova pers. comm.), although few were caught in our nets (Fig. 8). Nevertheless, huge numbers of bullies are present in the lake and lake mouth opening regimes are unlikely to have any significant effect on the stocks.

6.6 Torrentfish

No surveys were undertaken from late autumn to early winter (April to June) when most juvenile torrentfish enter the lower Waimakariri and Rakaia Rivers (Table 7) (Eldon and Greager 1983, Eldon and Kelly 1985). Therefore although torrentfish could enter Lake Ellesmere over possibly eight months, their migration was probably truncated by lake closure during 1994/95.

Adult torrentfish are uncommon in the Lake Ellesmere catchment and juvenile fish are probably recruited from nearby braided rivers, such as the Ashley and Rakaia, where they are more abundant. No adults were caught during this study and only one was caught in the LII river during a comprehensive survey of the tributaries (Hardy 1989). Adults may be uncommon due to periodic lake closure and a lack of adult habitat.

7.0 RECOMMENDATIONS

1 In order to maintain the eel, black flounder, and whitebait fisheries the Lake Ellesmere mouth should be opened for two weeks or more during late September and early October every year. The lake can be opened at any lake level between 15 September and 15 October (NWCO) and it should not be too difficult to modify the date of opening to maximise fish recruitment.

Short periods of low lake levels during a September and October opening will facilitate plant propagation, while high lake levels during the summer will encourage plant growth (Gerbeaux 1993). Therefore lake opening in spring would also encourage the re-establishment of emergent marginal and aquatic vegetation and thereby benefit fish stocks by providing aquatic cover and reducing water turbidity.

2 If the lake is high in autumn the mouth should be opened to permit the emigration of trapped adult eels and flounder and the larvae of inanga, smelt and bullies. Although it is biologically desirable to open the lake in autumn this could reduce the eel harvest and may have adverse effects on other lake users. An opening from late March onwards would be best as this would permit the commercial harvest of shortfin males during February and March and the escapement of shortfin females and longfin eels from April onwards (Jellyman *et al* 1995).

8.0 ACKNOWLEDGEMENTS

We thank Des Dawson, and other eel fisherman operating on Lake Ellesmere, and Ray Dineen and Malcolm Main of the Canterbury Regional Council for their generous assistance, encouragement and advice. Ben Chisnall, Greg Kelly and Fred Lucas assisted with the field work; Greg Kelly drafted the location maps and Bob McDowall and Don Jellyman reviewed the manuscript. This research was funded by FRST (Contract CO1409).

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