

ISSN 0111-4794

FISHERIES ENVIRONMENTAL REPORT NO. 30

FISHES OF
THE RAKAIA LAGOON



FISHERIES RESEARCH DIVISION
MINISTRY OF AGRICULTURE AND FISHERIES
CHRISTCHURCH

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N.Z. MINISTRY OF AGRICULTURE AND FISHERIES
CHRISTCHURCH

FEBRUARY
1983

FISHERIES ENVIRONMENTAL REPORTS

Edited by: S.F. Davis

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1. INTRODUCTION

This study was part of Fisheries Research Division's (FRD) programme to investigate the fisheries values of the lower Rakaia River in the face of urgent demands for irrigation water (Davis 1979), and to provide fisheries information to the North Canterbury Catchment Board to assist in their review of the Rakaia River water allocation plan (North Canterbury Catchment Board 1974). Further reports detailing results from other aspects of FRD's programme are currently in preparation.

Field work for this study took place between July 1980 and July 1981, except that some invertebrate work was somewhat later in starting and finishing. The aims of the study were to learn which species of fish utilised the Rakaia Lagoon, seasonal differences in the relative abundance of each species, and the extent of the lagoon's importance to fisheries generally, particularly as a rearing area for juvenile salmon. There are no published data on similar environments to the Rakaia Lagoon in New Zealand. Although fish populations of the nearby Avon-Heathcote Estuary were studied by Webb (1972, 1973a, b, c, d), and Kilner and Akroyd (1978) investigated the fish and invertebrate fauna of the Ahuriri Estuary in the North Island, the Rakaia Lagoon is unlike these estuaries in that there is no ebb and flow of the tide (see Section 2, description of study area). Data from this study therefore provide new information on the seasonal changes in species composition and relative abundance of fish populations at the mouth of a large South Island east coast braided river.

2. STUDY AREA

Barnes (1980) described a coastal lagoon as an area of salt or brackish water, separated from the adjacent sea by a low-lying sand or shingle barrier, and having a small mouth with little exchange or throughput of water, while estuaries were described as having relatively wide mouths and a large exchange or throughout-put of water in relation to their volume. By these criteria

the Rakaia study area was an estuary, since the water was fresh and there was a large through-put from a big river. However, there was no ebb and flow of the tide (although there was a tidal back-up of fresh water), and there were few, if any, predominantly estuarine life-forms. Local usage termed the area a lagoon and this word has been used here for lack of a better one.

The Rakaia Lagoon (Fig. 1) encompassed that stretch of water where the river, on reaching the coast, was deflected to run parallel to the shore for a variable distance before breaching its 20-150 m wide gravel bar. The lagoon comprised two distinct areas:

- (i) South-west of the mouth, wherever it occurred at any time (Fig. 1), the water flowed at a greater or lesser velocity according to the state of the tide, the power of the ocean waves and the discharge of the Rakaia River. There was never a reverse water flow, although occasionally rollers penetrated the mouth or spilled over the bar. Fresh water backed up for a variable distance at high tide, but frequently the single broad channel at this point was all that distinguished the lagoon from the braided river upstream.
- (ii) North-east of the mouth there was a ponding area of relatively slack water (Fig. 1), the level of which varied with the conditions listed above. There was a reverse flow of water here on flood tides, as the banked-up river flowed in, but the water was fresh, apart from rare influxes of sea water when rollers topped the bar.

The most striking feature of the whole lagoon was its changeability. The river mouth could occur at any point along a 4-5 km front, and at rare intervals there were two mouths. The movement of the mouth usually follows a pattern: a high flood breaches the bar opposite the mainstem of the river, allowing egress straight out to sea; prevailing winds and ocean currents deflect the mouth to the northeast, forming a channel of variable length (typically 200-300 m) through the shingle bar; over succeeding months, the mouth "creeps"

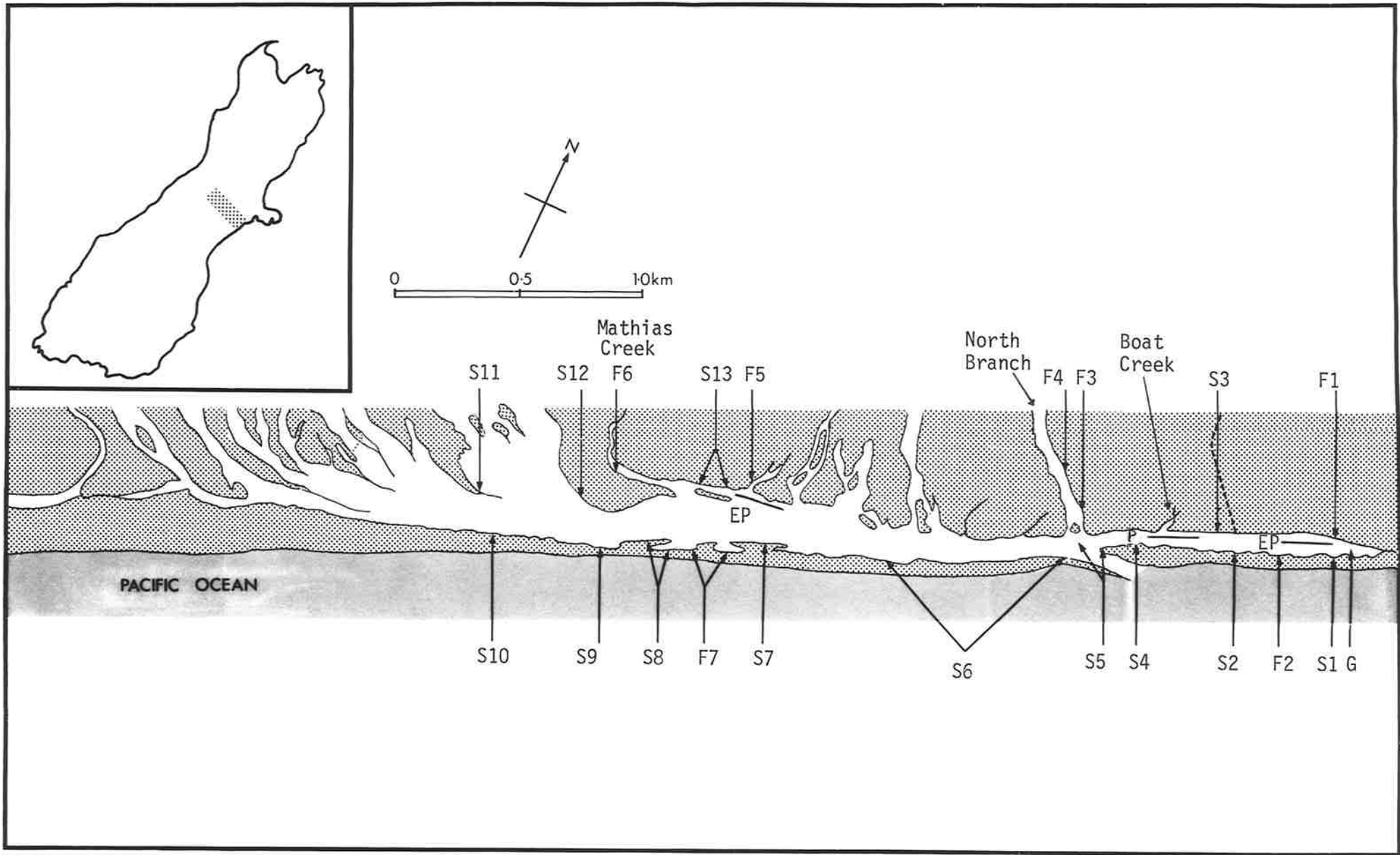


FIGURE 1. Rakaia Lagoon, showing sampling sites and location of the river mouth in July 1981. (Split indicator lines show where sites were moved due to changed river conditions.) S = seine net; F = fyke net; G = gill net; P = plankton transect; E = epibenthic transect.

northeastwards, sometimes remaining in the same place for many weeks, sometimes shifting several metres each day for a period, and this northward drift continues until a large flood again forces a new breach of the bar opposite the mainstem. This usually, but not invariably, results in closure of the old mouth, and the process begins all over again. Shortly after this study was completed, the mouth became so elongated that for a short time there were in effect two lagoons running parallel to each other.

During the study, water depth in the lagoon varied not only with short-term factors such as tides and floods, but also with the depth of the river mouth channel. Thus during winter low flow periods, when the river lacked the power to cut a deep mouth, the low-tide lagoon level exceeded high tide levels during summer. The maximum water depth was about 3 m, at the north-east end near sampling site S1 (Fig. 1), but most of the lagoon was considerably shallower than this.

Water clarity also varied greatly and was affected by snow melt in the upper catchment, which created blue-grey turbidity through spring and much of summer. Visibility in non-flood conditions was usually only a centimetre or two, while floods created turbid brown water. Generally, the lagoon was clearest during winter low flows and at the north-east end where clear groundwater seepage diluted the river water.

The topography of the lagoon was unpredictable and continually changing. Apart from the variable location of the mouth, the river deposited trees, shrubs and large quantities of gravel and glacial flour in the lagoon area. Banks and islands were constantly being formed and eroded. In addition, the sea pushed quantities of gravel into the lagoon along much of the bar, which the current carried back to sea.

Previously, a stream entered the north-eastern end of the lagoon, flowing parallel to the coast in the same manner that the Rakaia River approaches from the south-west (Fig. 1). During the 1930's, the stream was given direct

access to the sea via culverts. As a result, the sea has encroached on this end of the lagoon because there is now no current to keep it open. Several pools isolated from the lagoon by shingle fans thrown over by the sea are evidence that the lagoon is contracting. Local residents also claimed that the north-eastern end of the lagoon has narrowed to about half its former width.

The seaward shore of the lagoon comprised a bar of loose shingle of varying slope (Fig. 2). Where the current was swift, the bank was steep and offered no footing. At other places good beach seining sites were present. Bays formed by the closure of former mouths were easily sampled when new, but gradually filled with glacial silt and became unworkable. The inland shore of the lagoon comprised a mixture of debris-strewn gravel and mud beaches, and rush or grass covered mud steps (Fig. 3). The various braids of the Rakaia River entered at intervals and sometimes provided workable beach seine sites.

Mathias Creek, Boat Creek and the North Branch (Fig. 1) are small, spring-fed tributary streams, though the North Branch carries mainstem flood water at times and provides a passage for migrant juvenile salmon. There is another tributary stream at the south-western end of the lagoon which is not shown in Figure 1.

During the study period, macrophytes (*Myriophyllum* spp., *Elodea canadensis*, *Potamogeton cheesemani*, etc.) grew only in tributary streams and in the north-eastern end of the lagoon over a distance of about 800 m. In summer, growth of macrophytes and algae (*Nitella*, *Enteromorpha* spp.) was so prolific that fish sampling was seriously hampered in the north-eastern end of the lagoon.

3. MATERIALS

A 3.85 m fibreglass "Funfisher" dinghy powered by a 15 h.p. Johnson outboard motor provided an excellent, stable work boat, but the motor was



FIGURE 2. Collecting fish from a beach seine haul on the seaward shore of the Rakaia Lagoon.



FIGURE 3. Hauling the beach seine onto the seaward shore of the Rakaia Lagoon. The inland shore can be seen in the background.

inadequate for the loads involved. Hazardous navigation conditions resulted in continual damage to the propeller. However, a jet boat would have been no advantage at the slow operating speeds required, and would have been unmanageable for net setting.

A beach seine net, 30 x 3 m with 13 mm stretch mesh, fitted with two 10 m long bridles and 24 m long hauling ropes, was the principal sampling equipment used. A subsidiary net, 20 x 1.5 m, of the same material but with a 10 m lining panel of mosquito netting, was used in confined or shallow areas. A 40 x 3 m nylon monofilament gill net comprising 10 m each of 85 mm and 56 mm mesh, and 20 m of 38 mm mesh, was used regularly, while a 30 x 2 m nylon monofilament gill net with 15 mm mesh was used at two seine sites on two occasions when weed growth prevented seining. Single-ended commercial-type fyke nets and a mini fyke of 15 mm mesh were used to sample fish moving at night. Plankton samples were taken using twin nets of 203 micron mesh, with 29.5 mm diameter openings, mounted each side of the boat (Tarplee, Bryson and Sherfinski 1979). A diver-operated sled (Sibert, Kask and Brown 1977) with a 10 cm square opening fitted with a 530 micron mesh net, was used to sample the epibenthos. The sled was pushed along a 50 m transect and separate samples collected from each 10 m section.

4. METHODS

Netting took place over three days and two nights fortnightly from July 1980 to July 1981 - 27 sampling periods in all. Invertebrate samples were taken fortnightly from September 1980 to September 1981.

Beach seining was carried out by day at as many of 13 regular sites as possible (Fig. 1). These sites were selected on the basis of the availability of a beach, workable flow and freedom from snags. Many factors, such as movement of the mouth, presence of recreational flounder nets, etc. could render a site inoperable for one or several sampling periods. Conversely, it

TABLE 1. Sampling sites netted in the Rakaia Lagoon during July 1980-July 1981 (see Fig. 1 for location of each site).

Sample Period	Seine Net Sites													Fyke Net Sites							Gill Sites					
	1	2	3	4	5	6	7	8	9	10	11	12	13	*	1	2	3	4	5	6	7	*	1	*		
22-23.7.80	+	+	+	+	+	+	+	+	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	+	-
5-7.8.80	+	+	+	+	+	-	+	+	+	+	+	+	-	+	-	-	+	+	-	-	-	-	-	-	+	-
20-22.8.80	+	+	+	+	+	+	+	+	+	+	+	+	-	+	-	-	+	+	-	-	+	-	-	+	+	-
2-4.9.80	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	+	+	+	°	-	-	-	-	+	-
16-18.9.80	+	+	+	+	+	-	+	+	+	+	+	-	+	-	-	+	+	+	+	+	+	-	+	+	+	-
30.9-2.10.80	+	+	+	+	+	-	+	+	+	+	-	+	+	+	-	+	+	+	+	+	+	-	-	+	+	-
14-16.10.80	+	+	+	+	-	-	+	+	-	-	+	-	-	-	-	+	+	+	+	-	+	-	-	+	+	-
28-30.10.80	+	+	+	+	+	-	-	+	-	-	-	-	-	+	-	+	+	+	+	+	+	-	+	+	+	-
11-13.11.80	+	+	+	+	+	-	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	-	+	+	-
25-27.11.80	+	+	+	+	+	-	+	+	+	+	-	+	+	+	-	+	+	+	+	+	+	+	-	+	+	-
9-11.12.80	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	+	+	+	+	+	+	-	+	+	+
21-22.12.80	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	+	+	+	°	+	-	+	-	+	+	-
6-8.1.81	+	-	-	+	+	+	+	+	+	+	+	+	+	+	-	-	+	+	+	+	+	+	-	+	+	+
21-23.1.81	+	-	-	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	-	+	+	+
3-5.2.81	+	-	-	+	+	-	+	+	-	+	-	-	-	+	-	+	-	+	+	+	+	+	-	+	+	+
17-19.2.81	+	+	+	+	+	-	+	+	-	-	-	-	-	-	-	+	+	+	+	+	+	-	-	+	+	-
3-5.3.81	+	+	+	+	+	+	-	+	+	-	-	+	+	-	+	+	+	+	+	+	+	+	-	+	+	-
17-19.3.81	+	+	+	+	+	+	-	+	+	+	-	-	-	-	-	+	+	+	+	+	+	+	-	+	+	-
31.3-2.4.81	+	+	+	+	-	+	-	+	+	-	-	-	-	+	-	+	+	+	+	+	+	-	+	+	+	-
14-16.4.81	+	+	+	+	-	+	-	+	+	+	+	+	-	+	-	+	+	+	+	+	+	+	-	+	+	-
28-30.4.81	+	+	+	+	-	+	-	+	+	+	-	+	+	-	+	+	+	+	+	+	+	-	+	+	+	-
12-14.5.81	+	+	+	+	-	-	-	+	+	-	-	-	+	-	+	+	+	+	+	+	+	-	+	+	+	-
26-28.5.81	+	+	+	+	+	+	-	-	+	+	+	+	+	-	+	+	+	+	+	+	+	+	-	+	+	-
9-11.6.81	+	+	+	+	+	+	+	+	+	+	-	-	+	+	+	+	+	+	+	+	+	-	+	+	+	-
23-25.6.81	+	+	+	+	+	+	-	+	+	-	+	+	+	-	+	+	+	+	+	+	+	+	-	+	+	-
7-9.7.81	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	-	+	+	+	-
21-23.7.81	+	+	+	+	+	+	-	+	+	-	-	-	-	+	+	+	+	+	+	+	+	-	+	+	+	-

+ = Net set

- = No net set

* = Net set at irregular sites on an opportunistic basis

° = Effectiveness of fyke net doubtful

was occasionally possible to seine a locality not normally available (Table 1). It was not practical to sample sites in a given order or at a particular stage of the tide, and work was carried out as conditions permitted. Usually the net was set from a drum over the bow as the boat was manoeuvred in reverse (Fig. 4).

Ideally, sets were made parallel to the beach at the extremity of the ropes and bridal (i.e. 34 m from the shore) and the net hauled onto the beach (Fig. 3). However, many variations of this technique were required to cope with currents and snags. Fish captured in seine nets were normally undamaged.

Gillnetting was carried out regularly at night only, at one site (Fig. 1). Occasionally, extra sets were made elsewhere in the lagoon for various purposes, e.g. day-time sets were tried but were invariably unproductive. Mullet taken in the gill net were always dead on retrieval, and other species also suffered high mortality.

Fyke nets (Fig. 5) were set overnight at seven regular and some occasional sites (Fig. 1). Times of setting and lifting varied, but each net fished through one night high tide. Due to large variations in water level from day to day, netting efficiency could not be controlled or monitored. Fish taken in fyke nets were usually alive, but delicate species such as smelt were often injured.

A plankton sample was taken fortnightly from September 1980 to September 1981 at high tide, river conditions permitting, at each of three transects (Fig. 1). Consistency in the volume of water sampled was obtained by counting 200 revolutions of a boat-mounted current meter. Thus, water volume, state of the tide and sampling station were constant at each sampling. Sample depth was constant relative to the boat, but varied with water levels in the lagoon. On completion of each tow, the nets were washed and the contents preserved in 8% formalin.



FIGURE 4. Setting the beach seine net from the bow of a 'Funfisher' dinghy.



FIGURE 5. Collecting a fyke net from the North Branch.

An epibenthic sample was collected fortnightly from December 1980 to August 1981 at high tide, river conditions permitting, at each of two 50 m transects. Each transect was divided into five 10 m lengths. Samples were preserved in 8% formalin. Results of the invertebrate survey will be reported in detail elsewhere.

All fish were measured, except where numbers were so great that sub-sampling was appropriate. Live fish were anaesthetised with benzocaine before being handled, and were released later unless required for stomach analysis or confirmation of species (i.e. smelts). Trout were also weighed and sampled for scales, and healthy trout and eels were tagged with 'Floy' streamer-type tags. Tagging was done primarily to learn something of the movement of these fish within the Rakaia River.

Two methods were used to assess fish stomach contents in the laboratory - volumetric (percent composition) and percent occurrence. The volume of each stomach examined was assessed for fullness using the points method of Eldon (1979) and a scale of 0-40. Each food item was assigned points in relation to the proportion of the total stomach contents it represented, and these were summed and expressed as a percentage for each food category. Percent occurrence was the proportion of stomachs in which each food category was found.

Water temperatures were usually recorded at each seine site during netting. Temperatures ranged from a low of 6°C in June 1981 to a high of 21°C in February 1981, but variations of as much as 6°C were noted between sampling sites on some days in summer. The temperature at site S1 was more stable than elsewhere in the lagoon, generally being higher than other sites in winter and lower in summer. Mean temperatures recorded during each sampling period are presented in Figure 6 to show the pattern of annual variation.

5. THE FISHES

Fourteen indigenous and four introduced species of fish were recorded

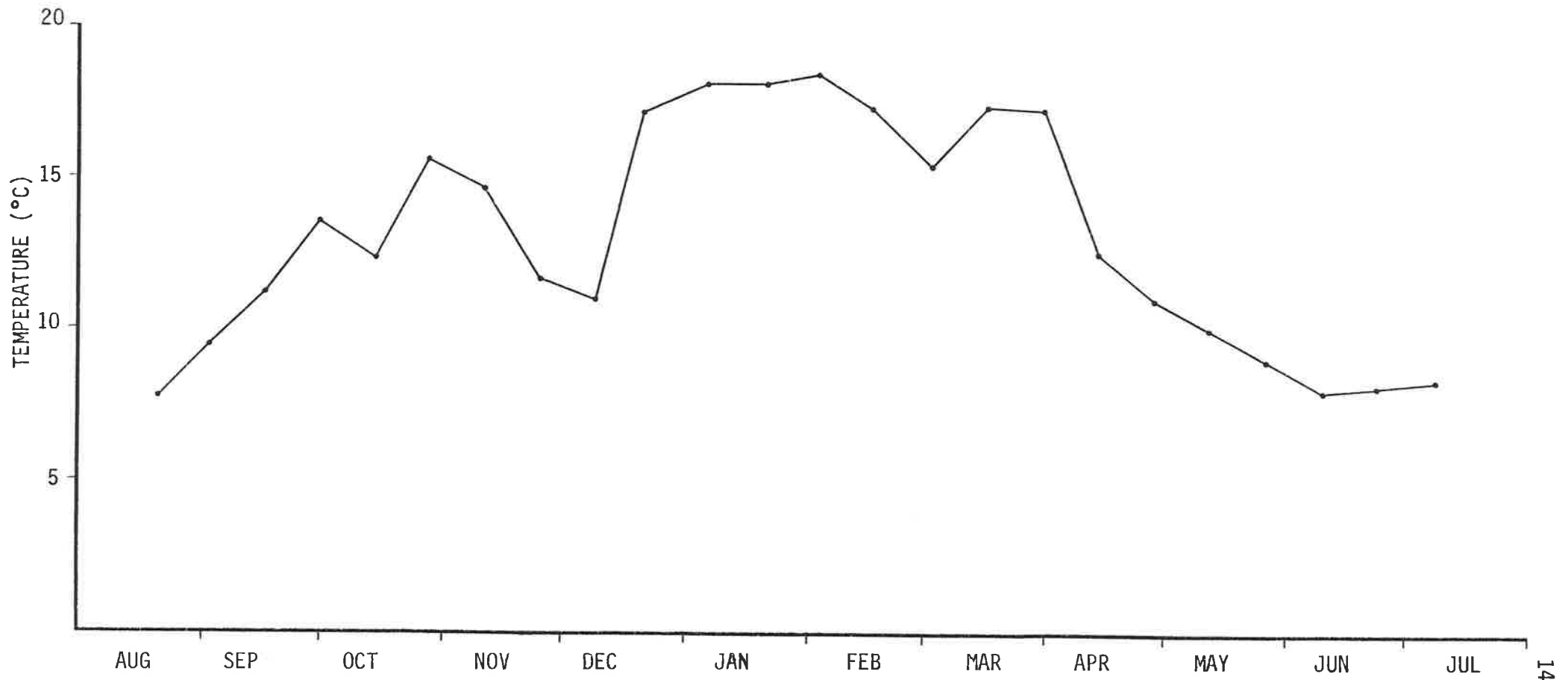


FIGURE 6. Mean temperatures recorded fortnightly at seine net sampling sites in Rakaia Lagoon, August 1980 - July 1981.

from the Rakaia Lagoon and a further indigenous species, the koaro (*Galaxias brevipinnis*), is known to pass through on migration (Table 2). However, four indigenous species - giant bully (*Gobiomorphus gobioides*), upland bully (*G. breviceps*), lamprey (*Geotria australis*) and kahawai (*Arripis trutta*) - and two introduced species - rainbow trout (*Salmo gairdnerii*) and perch (*Perca fluviatilis*) - numbered fewer than six individuals each during the 13 months study (Tables 3 and 4), although kahawai were observed in large numbers immediately offshore. Two other species, bluegilled bully (*Gobiomorphus hubbsi*) and torrentfish (*Cheimarrichthys fosteri*) occurred only as juveniles passing through the lagoon on their upstream migration, but the latter species was present in the lagoon for several weeks.

Species providing recreational fisheries were quinnat salmon (*Oncorhynchus tshawytscha*), brown trout (*Salmo trutta*) and, very occasionally, rainbow trout (*S. gairdnerii*), whitebait (*Galaxias maculatus*, and to a very minor extent *G. brevipinnis*), black flounder (*Rhombosolea retiaria*), yelloweyed mullet (*Aldrichetta forsteri*) and longfinned and shortfinned eels (*Anguilla dieffenbachii* and *A. australis*). Eels have been exploited commercially in the lagoon (Davis 1979), but no commercial fishing took place during this study.

Fluctuations in catches between sample periods (Table 3) do not necessarily reflect fish abundance. Conditions in the lagoon were so variable due to floods, tides and turbidity (Table 5), that netting effort could not be constant (Table 1). However, the data indicate overall seasonal trends.

5.1 Quinnat Salmon

This study was concerned only with juvenile salmon, as adults were not sampled by the methods used. The first fry of the 1980 year class were caught at the end of July 1980 at a time when fingerlings from the previous year class (1979) were still present (Fig. 7). Eight weeks later, the yearlings had gone and fish of the year were common. Catches declined markedly over the period late December to late January, but increased again in February 1981 (Table 3).

TABLE 2. Fish species recorded from Rakaia Lagoon, compared with species lists from Lake Ellesmere (Ryan 1974, FRD unpublished data), Avon-Heathcote Estuary (Webb 1972, 1973d; FRD unpublished data) and Ahuriri Estuary (Kilner and Akroyd 1978).

Common name	Scientific name	Rakaia Lagoon	Lake Ellesmere	Avon-Heathcote Estuary	Ahuriri Estuary
Quinnat salmon	<i>Oncorhynchus tshawytscha</i>	+	OT	-	-
Brown trout	<i>Salmo trutta</i>	+	+	OT	OT
Rainbow trout	<i>Salmo gairdnerii</i>	OT	-	-	-
Perch	<i>Perca fluviatilis</i>	OT	+	-	-
Common smelt	<i>Retropinna retropinna</i>	+	+	OT	+
Stokell's smelt	<i>Stokellia anisodon</i>	+	-	OT	-
Inanga	<i>Galaxias maculatus</i>	+	+	OT	+
Koaro	<i>Galaxias brevipinnis</i>	OT	-	-	-
Common bully	<i>Gobiomorphus cotidianus</i>	+	+	+	+
Bluegilled bully	<i>Gobiomorphus hubbsi</i>	OT	-	-	-
Upland bully	<i>Gobiomorphus breviceps</i>	OT	-	-	-
Giant bully	<i>Gobiomorphus gobioides</i>	OT	+	OT	-
Redfinned bully	<i>Gobiomorphus huttoni</i>	-	-	OT	-
Torrentfish	<i>Cheimarrichthys fosteri</i>	+	-	-	-
Black flounder	<i>Rhombosolea retiaria</i>	+	+	-	+
Yellow-bellied flounder	<i>Rhombosolea leporina</i>	-*	+	+	+
Sand flounder	<i>Rhombosolea plebeia</i>	-	+	+	+
Greenback flounder	<i>Rhombosolea tapirina</i>	-	OT	-	-
Longfinned eel	<i>Anguilla dieffenbachii</i>	+	+	OT	OT
Shortfinned eel	<i>Anguilla australis</i>	+	+	OT	+
Yellow-eyed mullet	<i>Aldrichetta forsteri</i>	+	+	+	+
Kahawai	<i>Arripis trutta</i>	OT	+	+	+
Lamprey	<i>Geotria australis</i>	OT	OT	-	-
Spotted stargazer	<i>Geniagnus monopterygius</i>	-	-	OT	OT
Goldfish	<i>Carassius auratus</i>	-	+	-	-
Common sole	<i>Peltorhamphus novaezeelandiae</i>	-	OT	+	OT
Cockabully	<i>Tripterygion nigripenne</i>	-	-	+	+
Spotty	<i>Pseudolabrus celidotus</i>	-	-	+	OT

TABLE 2. (Cont'd)

Common name	Scientific name	Rakaia Lagoon	Lake Ellesmere	Avon-Heathcote Estuary	Ahuriri Estuary
Clingfish	<i>Trachelocheilichthys pinnulatus</i>	-	-	OT	-
Sprat	<i>Maugaclupea antipodum</i>	-	+	-	-
Whiting	<i>Merlangius australis</i>	-	OT	-	-
Blue mackerel	<i>Scomber japonicus</i>	-	-	-	OT
Garfish	<i>Reporhamphus ihi</i>	-	-	OT	OT
Sandfish	<i>Crapatalus novaezelandiae</i>	-	+	OT	-
Sand eel	<i>Gonorynchus forsteri</i>	-	OT	-	-
Sunfish	<i>Mola mola</i>	-	1 record	-	-
Red cod	<i>Physiculus bachus</i>	-	OT	OT	OT
Globe fish	<i>Spheroides richiei</i>	-	-	+	-
Rockfish	<i>Acanthoclinus quadridactylus</i>	-	-	OT	-
Moki	<i>Latridopsis ciliaris</i>	-	-	OT	OT
Thornfish	<i>Bovichtus variegatus</i>	-	-	OT	-
Barracouta	<i>Thyrisites atun</i>	-	-	OT	OT
Kingfish	<i>Seriola grandis</i>	-	-	-	OT
Parore	<i>Girella tricuspidata</i>	-	-	-	+
Grey mullet	<i>Mugil cephalus</i>	-	-	-	+
Red gurnard	<i>Trigla kumu</i>	-	-	OT	-
Trevally	<i>Caranx lutescens</i>	-	-	-	OT
Snapper	<i>Chrysophrys auratus</i>	-	-	-	OT
Rig	<i>Mustelus antarcticus</i>	-	OT	OT	-
Seahorse	<i>Hippocampus abdominalis</i>	-	-	OT	-
Elephant fish	<i>Callorhynchus milii</i>	-	OT	-	-
Spiny dogfish	<i>Squalus acanthias</i>	-	OT	-	OT
School shark	<i>Galeorhinus australis</i>	-	-	-	OT
Basking shark	<i>Halsydrus maximus maccoyi</i>	-	OT	-	-
Skate	<i>Zearaja nasuta</i>	-	OT	-	OT
Gurnard	<i>Chelidonichthys kumu</i>	-	-	-	OT

+ = resident or regular visitor

OT = occasionally present or transitory

- = not recorded

-* = recorded since this study

TABLE 3. Numbers of each species of fish caught during each sampling period in the Rakaia Lagoon, July 1980 - July 1981.

Species	July		August		September			October		November		December	
	22-23	5-7	20-22	2-4	16-18	30-2	14-16	28-30	11-13	25-27	9-11	21-22	
Quinnat salmon	81	73	66	61	106	241	42	51	39	42	15	5	
Brown trout ^o	9	12	22	11	17	10	5	8	14	21	12	12	
Rainbow trout ^o	0	0	0	0	0	0	0	0	0	0	0	0	
Perch	0	0	0	0	0	0	0	0	0	0	0	1	
Common smelt	0	7	5	20	3	63	18	24	33	51	13	4	
Stokell's smelt	1	0	1	1	0	4	4	668	590	2939	57725*	293	
Inanga#	4	4	10	30	65	55	78	156	88	225	118	226	
Common bully	1	6	6	9	11	12	14	66	43	69	36	56	
Bluegilled bully	0	0	0	0	0	0	0	0	0	0	0	0	
Upland bully	0	0	0	0	0	0	0	0	0	0	1	0	
Giant bully	0	0	0	0	0	0	0	1	0	0	0	1	
Torrentfish	2	1	0	9	6	0	0	0	0	3	0	0	
Black flounder	1	1	7	2	6	29	5	18	34	43	57	7	
Longfinned eel ^o	0	1	4	5	35	2	5	44	24	12	3	7	
Shortfinned eel ^o	0	1	3	14	7	6	1	37	26	24	4	26	
Yelloweyed mullet	0	0	0	0	2	2	8	6	4	17	8	14	
Kahawai	0	0	0	0	0	0	0	0	0	0	0	0	
Lamprey	0	0	0	0	0	0	0	0	0	0	0	0	
Stargazer	0	0	0	0	0	0	0	0	0	0	0	0	
TOTAL (all species)	99	106	124	162	258	424	180	1079	895	3446	57992	652	

^o = Includes recaptures of tagged fish

= Excludes fresh-run whitebait

* = Estimates

TABLE 3. (Cont'd)

Species	January		February		March			April		May		June		July		Total
	6-8	21-23	3-5	17-19	3-5	17-19	31-2	14-16	28-30	12-14	26-28	9-11	23-25	7-9	21-23	
Quinnat salmon	1	2	42	2	37	5	16	18	34	14	5	29	30	16	90	1163
Brown trout ^o	9	3	6	7	1	5	13	6	14	15	2	6	16	20	3	279
Rainbow trout ^o	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	2
Perch	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2
Common smelt	36	20	19	6	152	139	17	75	27	43	2	21	10	10	0	818
Stokell's smelt	1727*	3468*	100	409*	944	322	101	0	9	11	1	13	4	0	1	69336
Inanga#	131	590	284	358	221	20	77	153	117	118	39	136	37	31	29	3400
Common bully	50	114	20	72	20	58	35	18	26	69	37	13	15	18	14	908
Bluegilled bully	0	0	0	0	0	0	0	0	189	0	8	0	1	0	0	198
Upland bully	0	0	0	0	0	0	0	0	1	2	0	1	0	0	0	5
Giant bully	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Torrentfish	0	1	0	0	0	0	0	0	54	89	8	19	25	7	8	232
Black flounder	38	67	18	17	21	25	23	13	16	56	14	16	20	10	13	577
Longfinned eel ^o	18	32	23	15	8	11	24	7	1	19	1	14	8	8	6	337
Shortfinned eel ^o	27	28	8	84	23	19	16	9	0	22	2	1	0	2	0	390
Yelloweyed mullet	59	225	81	136	42	124	58	91	39	24	8	1	0	0	0	949
Kahawai	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	2
Lamprey	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Stargazer	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2
TOTAL (all species)	2096	4552	602	1106	1469	728	380	391	528	482	127	271	166	124	164	78603

^o = Includes recaptures of tagged fish

= Excludes fresh-run whitebait

* = Estimates

TABLE 4. Number of each species of fish caught at each sampling site in the Rakaia Lagoon, July 1980 - July 1981.

Species	Sampling Site																							Total	
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	Other Seine Sites	F1	F2	F3	F4	F5	F6	F7	Other Fyke Sites	Gill Net Site		Other
Quinnat salmon	288	32	34	96	136	7	145	124	13	46	40	130	47	1	5	4	0	2	3	0	0	1	9	0	1163
Brown trout ^o	23	5	18	29	5	6	1	23	3	3	2	2	12	0	5	5	1	1	4	4	4	0	112	11	279
Rainbow trout ^o	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2
Perch	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2
Common smelt and Stokell's smelt)	100	472	169	1310	1390	7006*	1172	41397*	681	10383*	13	260	2103	3000*	2	10	2	61	88	508	0	0	0	27	70154
Inanga#	1608	619	586	59	0	1	0	1	0	0	0	0	0	0	95	49	183	0	1	116	0	0	0	82	3400
Common bully	27	40	133	129	46	6	7	103	27	13	0	9	44	21	40	36	63	31	48	61	15	0	3	6	908
Bluegilled bully	0	0	0	1	8	0	0	0	0	0	0	0	1	188	0	0	0	0	0	0	0	0	0	0	198
Upland bully	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	5
Giant bully	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2
Torrentfish	0	0	0	37	40	78	3	8	8	0	0	5	1	52	0	0	0	0	0	0	0	0	0	0	232
Black flounder	14	4	6	129	79	30	7	21	4	9	2	10	25	6	38	28	0	91	25	15	29	0	4	1	577
Longfinned eel ^o	1	0	0	0	0	0	0	1	0	0	0	0	1	0	28	22	4	29	12	186	50	3	0	0	337
Shortfinned eel ^o	2	0	0	14	0	0	0	0	0	0	0	0	0	0	126	58	30	23	16	110	11	0	0	0	390
Yellow-eyed mullet	14	32	38	65	14	218	1	7	0	0	0	0	0	48	12	20	0	8	5	2	6	0	370	89	949
Kahawai	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	2
Lamprey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Stargazer	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	2
TOTAL (all species)	2078	1204	988	1870	1718	7352	1336	41685	736	10454	57	416	2235	3318	351	232	283	247	202	1003	116	4	501	217	78603

^o = Includes recaptures of tagged fish
 * = Estimates
 # = Excludes fresh-run whitebait

S = Seine net site
 F = Fyke net site

TABLE 5. Water turbidity at netting sites in the Rakaia Lagoon during July 1980 - July 1981.

Sample Period	Seine Site Localities													G*	
	1	2	3	4	5	6	7	8	9	10	11	12	13		
22-23 Jul 80	C	C	C	C	C	C	C	C	C	C	-	C	C	-	C
5-7 Aug 80	C	C	C	M	M	-	C	C	C	C	C	C	C	-	C
20-22 Aug 80	M	M	M	M	M	T	T	T	T	T	T	T	T	-	M
2-4 Sep 80	C	T	T	T	T	T	T	T	T	T	T	T	-	-	M
16-18 Sep 80	C	C	C	M	M	-	T	T	T	T	-	T	-	C	
30 Sep- 2 Oct 80	C	T	T	M	T	-	T	T	T	T	-	T	T	M	
14-16 Oct 80	C	C	C	M	-	-	M	M	-	-	M	-	-	C	
28-30 Oct 80	C	C	T	M	M	-	-	M	-	-	-	-	M	T	
11-13 Nov 80	M	M	C	M	M	-	T	T	M	T	M	M	T	C	
25-27 Nov 80	C	M	T	T	T	-	T	T	T	T	-	-	T	M	
9-11 Dec 80	C	M	M	M	M	M	M	T	M	M	-	-	T	M	
21-22 Dec 80	T	T	T	T	-	-	-	-	-	-	-	-	-	T	
6-8 Jan 81	C	-	-	T	T	T	T	T	T	T	-	-	T	M	
21-23 Jan 81	M	-	-	C	C	C	C	T	C	C	-	C	-	C	
3-5 Feb 81	C	-	-	M	M	-	M	M	-	M	-	-	C	M	
17-19 Feb 81	M	T	T	T	T	-	T	T	-	-	-	-	-	T	
3-5 Mar 81	C	M	C	M	M	C	-	M	M	-	-	M	M	C	
17-19 Mar 81	T	T	T	T	T	T	-	T	T	T	-	-	-	M	
31 Mar- 2 Apr 81	C	T	T	T	-	T	T	T	T	-	-	-	T	C	
14-16 Apr 81	M	M	M	M	-	M	M	M	M	M	M	-	M	M	
28-30 Apr 81	M	M	M	M	-	T	-	T	T	T	-	T	T	M	
12-14 May 81	C	T	T	T	-	T	-	T	T	T	-	-	T	M	
26-28 May 81	C	C	C	C	C	C	-	C	C	C	C	C	-	M	
9-11 Jun 81	M	M	M	T	T	M	T	T	M	-	-	T	T	C	
23-25 Jun 81	C	C	C	C	C	C	-	C	C	-	C	C	C	C	
7-9 Jul 81	M	M	M	M	M	M	M	M	M	-	M	M	M	M	
21-23 Jul 81	C	C	C	C	C	C	-	C	C	-	-	-	-	C	

G* = Gill net site

C = Clear

M = Moderately turbid

T = Turbid

- = Not sampled

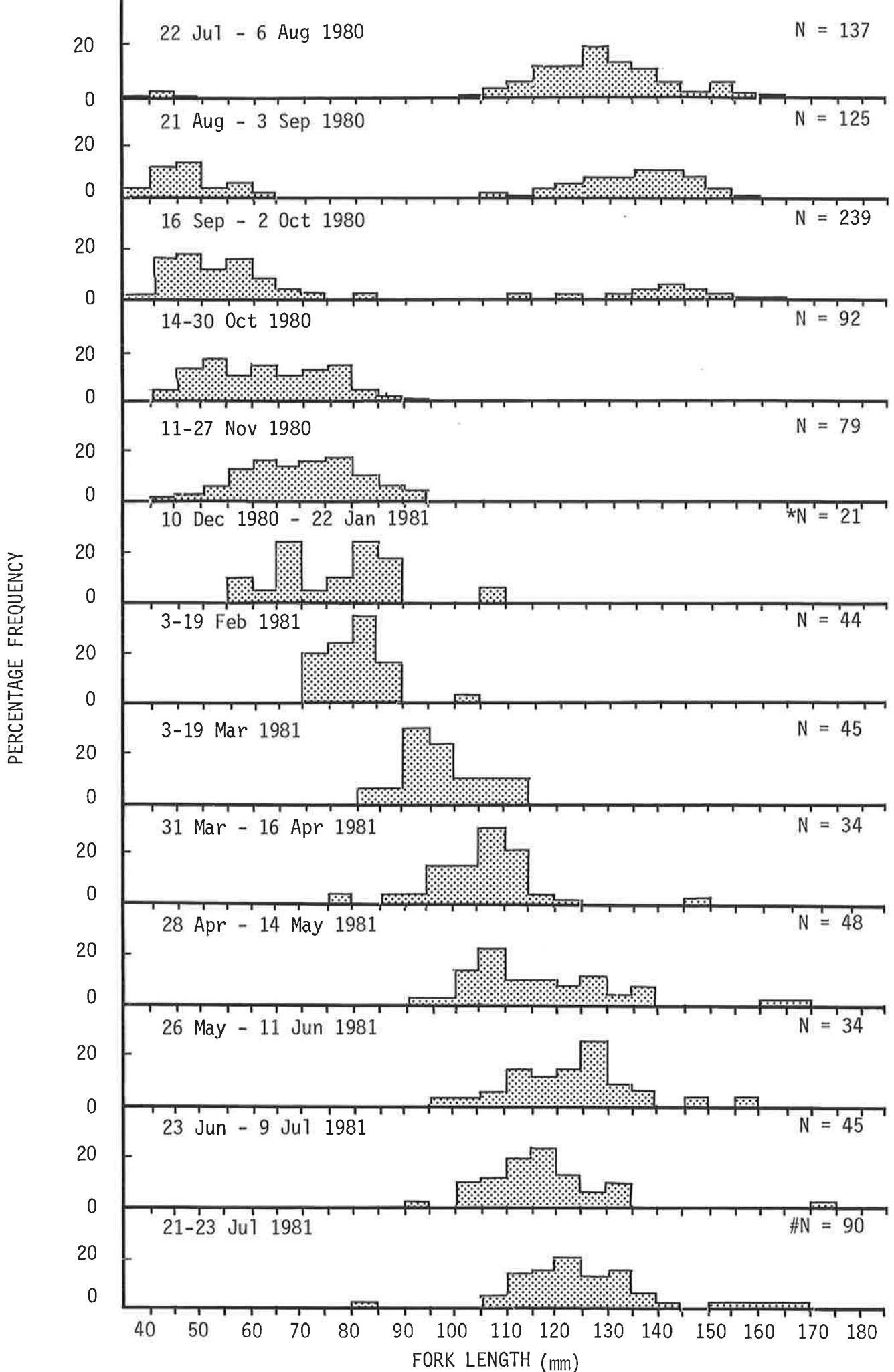


FIGURE 7. Length frequency of quinnat salmon sampled from the Rakaia Lagoon, July 1980 - July 1981. (Notes: * = Sample period is twice as long; # = Sample period is half as long; N = number of fish measured, not total number in sample.)

There are no data from other studies to suggest a natural increase of outmigration in late summer. However, in recent years there has been considerable rearing of juvenile salmon - both hatchery produced and artificially retained wild stock - at Glenariffe and elsewhere on the Rakaia River. On ten different dates between 21 January and 24 April 1981, a total of 633,407 juvenile salmon were liberated into the Rakaia River system (Table 6). Almost 21,000 of these were released directly into Rakaia Lagoon on 22 January 1981 by the Salmon Enhancement Team of FRD. All these latter fish were adipose fin-clipped and tagged with coded wire nose tags, but in most other releases a percentage only was tagged and fin-clipped (Table 6).

Therefore, increased catch rates in February 1981 directly followed a liberation of salmon into the lagoon, and 83.3% of the sample on 5 February 1981 comprised tagged fish (35 of 42). The seven untagged fish may have been from an upstream liberation made on 21 January 1981, or may have been wild stock.

All tagged fish retained from samples taken during 3 February to 27 May 1981 were from the single lagoon release on 22 January (Table 7). The 84 untagged salmon caught during that period (Table 6) may have been wild stock or may have come from the 74.5% of other releases of salmon which were not tagged (Table 6), i.e. excluding the lagoon release on 22 January. From 10 June to the end of the study, 53 (32.3%) of the 164 juvenile salmon caught were tagged fish. Three of the four tagged fish retained had been released at Glenariffe (Table 7).

Clearly most of our late summer and subsequent catches of juvenile salmon in 1981 were the result of hatchery releases. Not more than 25% (84 of 340) of these fish could have been wild stock.

Data on downstream migrating salmon collected by three inclined plane traps which operated three days a week between the State Highway 1 bridge and the lagoon from September 1980 to June 1981 (FRD unpublished data), complement the lagoon findings (Fig. 8). Salmon catches in these traps ceased in December

TABLE 6. Salmon releases into the Rakaia River and lagoon catches of juvenile salmon during January-July 1981.

Date	Salmon releases			Lagoon catches			
	No. released	No. tagged	% tagged	No. caught	No. tagged	% tagged	Cumulative catch
21 Jan	111 680	42 397	37.9				
22 Jan*	20 944	20 944	100.0				
5 Feb				42	35	83.3	42
19 Feb				2	1	50.0	44
20 Feb	121 171	21 171	17.5				
5 Mar				40	18	45.0	84
11-13 Mar	160 723	42 500	26.4				
19 Mar				5	5	100.0	89
2 Apr				16	9	56.3	105
12-14 Apr	211 777	43 126	20.4				
16 Apr				18	9	50.0	123
21-24 Apr	7 112	7 112	100.0				
30 Apr				34	9	26.5	157
14 May				14	4	28.6	171
26 May				5	2	40.0	176
11 Jun				29	17	58.6	205
25 Jun				29	2	6.9	234
9 Jul				16	3	18.8	250
23 Jul				90	31	34.4	340
TOTALS	633 407	177 250	27.8	340	145	42.7	-

* Released directly into the lagoon.

TABLE 7. Tagged quinnat salmon recaptured in Rakaia Lagoon, February - July 1981.

Date of recapture	Original release location	Date of release	No. of days to recapture	Additional tagged fish not kept	Total tagged fish recaptured
3 Feb	Lagoon	22 Jan	12		
3 Feb	Lagoon	22 Jan	12		
3 Feb	Lagoon	22 Jan	12		
3 Feb	Lagoon	22 Jan	12		
3 Feb	Lagoon	22 Jan	12	26	35
3 Feb	Lagoon	22 Jan	12		
3 Feb	Lagoon	22 Jan	12		
3 Feb	Lagoon	22 Jan	12		
3 Feb	Lagoon	22 Jan	12		
18 Feb	-	-	-	1	1
4 Mar	-	-	-	18	18
19 Mar	Lagoon	22 Jan	56		
19 Mar	Lagoon	22 Jan	56	2	5
19 Mar	Lagoon	22 Jan	56		
31 Mar	Lagoon	22 Jan	68	7	9
31 Mar	Lagoon	22 Jan	68		
14 Apr	Lagoon	22 Jan	82		
14 Apr	Lagoon	22 Jan	82	6	9
14 Apr	Lagoon	22 Jan	82		
29 Apr	-	-	-	9	9
12 May	Lagoon	22 Jan	111	3	4
27 May	-	-	-	2	2
10 Jun	Lagoon	22 Jan	140	15	17
10 Jun	Glenariffe	14 Apr	57		
23 Jun	Glenariffe	14 Apr	70	1	2
8 Jul	-	-	-	3	3
21 Jul	Glenariffe	20 Feb	151	30	31
TOTAL				123	145

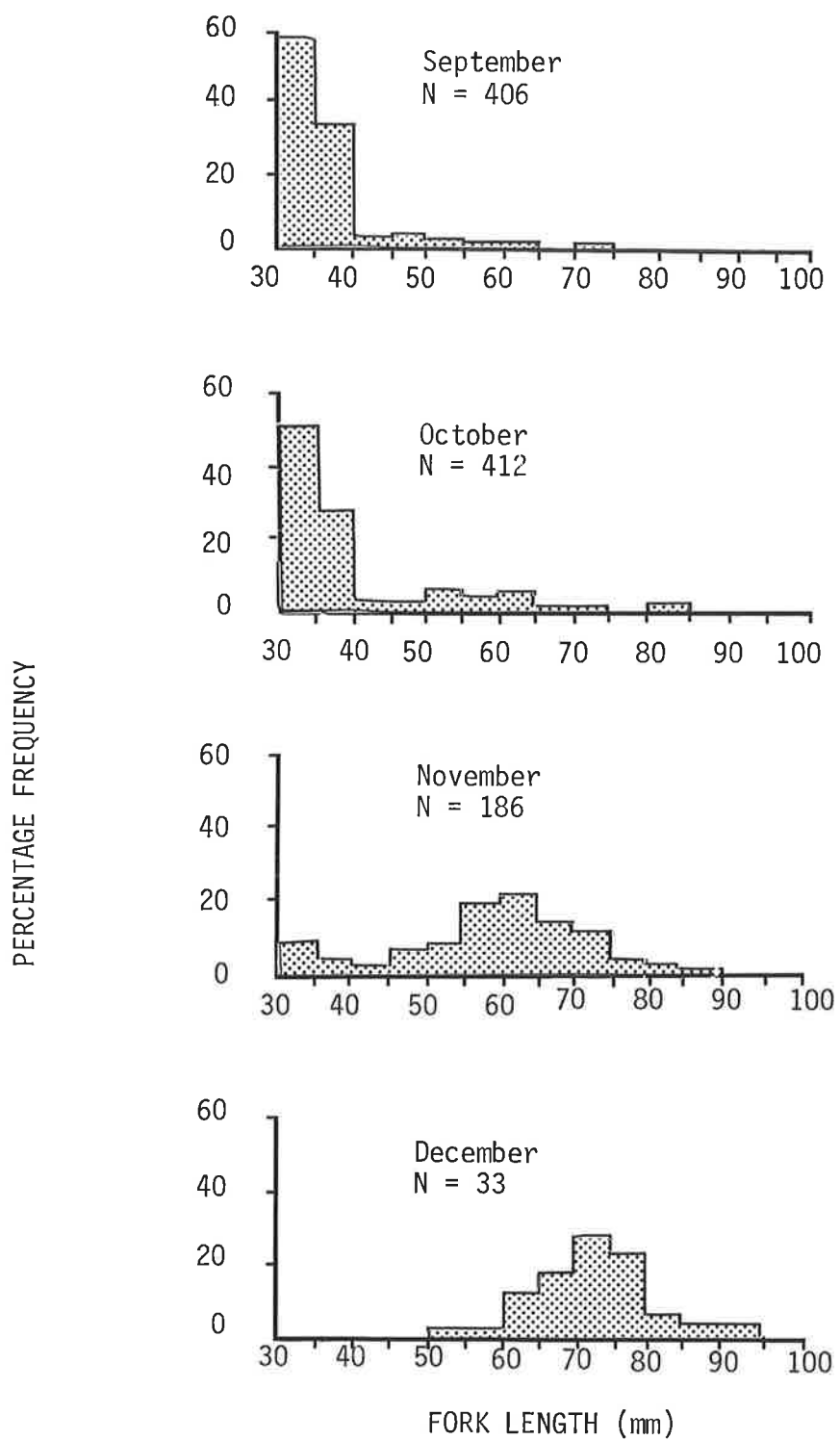


FIGURE 8. Length frequency of quinnat salmon captured by inclined plane traps located in the lower 6 km of the Rakaia River mainstem during 1980.

1980, although subsequently one fish was caught in March and two in May 1981.

This raises the question of the origin of yearling salmon recorded when the lagoon project first commenced. Of 282 yearlings recorded from July to the end of September 1980, when they ceased to appear in our catches (Fig. 7), only three (1.06%) had been tagged. Releases into the Rakaia from the end of December 1979 to mid-April 1980 had totalled 457,659, of which 34% were tagged. The three final releases from 24 March to 21 April had comprised only 19.2% of tagged fish, but clearly the indications are that the lagoon catches during July-September 1980 contained a high proportion of wild stock.

5.2 Brown Trout

Trout catches in the Rakaia Lagoon were fairly uniform throughout the year (Table 3). No trout less than 100 mm fork length were sampled during the study (Fig. 9), indicating that the lagoon was not a nursery area for trout. There was a small influx of fish in the 100-120 mm size range in early March 1981, with a subsequent increase in the percentage of the lagoon population represented by this year class. However, the numbers of trout caught during this study were insufficient to show year classes of older fish. Although some scales were collected for the purposes of aging, most have not yet been analysed.

Trout colouration was mostly silver-grey, which is usually indicative of sea-run fish. However, the glacial origin of Rakaia River water may have some influence. Brightly coloured fish, typical of most freshwater habitats, were seldom observed, suggesting that few trout resided in the clearer water of the north-eastern end of the lagoon.

Our sampling programme resulted in two brown trout which had been tagged at FRD's trap at Glenariffe (in the headwaters of the Rakaia River, about 100 km upstream), being recaptured in the lagoon during the study period. The trout caught on 27 November 1980 (Table 8) was a 2+ fish (aged from scales taken at recapture).

Of the 279 brown trout caught in Rakaia Lagoon, 113 were tagged before

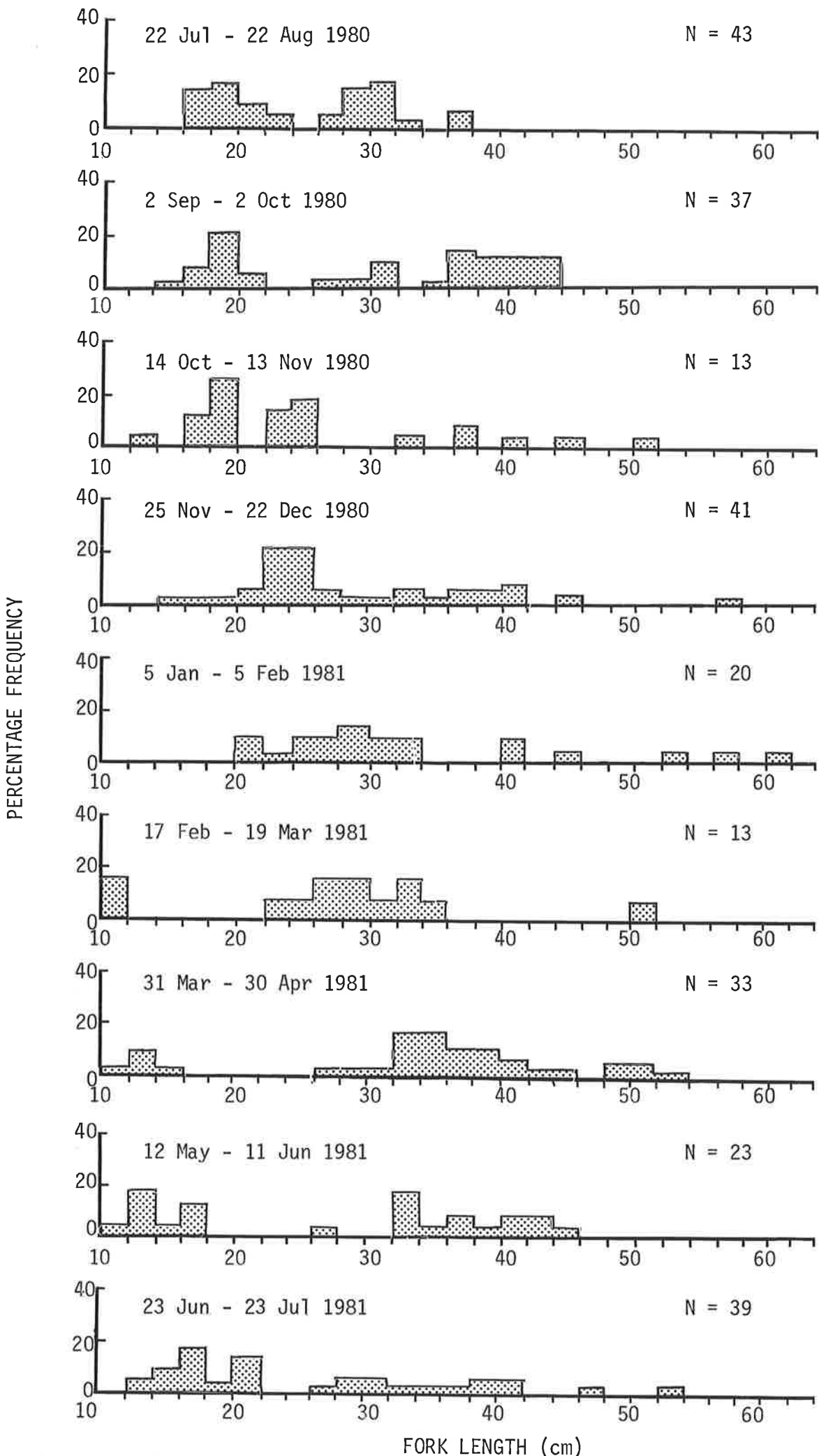


FIGURE 9. Length frequency of brown trout sampled from the Rakaia Lagoon, July 1980 - July 1981. (N = number of fish measured.)

TABLE 8. Recaptures of trout tagged in the Rakaia Lagoon during August 1980 - July 1981.

Date Tagged	Length at tagging	Date recaptured	Length at recapture	No. of days at large	Growth rate (mm/day)
20.8.80	312	6.1.81	415	139	0.74
3.9.80	427	15.11.80	457	73	0.41
3.9.80	396	10.12.80	416	98	0.20
3.9.80	372	3.1.82	514	489	0.29
2.10.80	369	? .2.82	508	487+	0.28
25.11.80	237	24.1.81	254	60	0.28
11.12.80	450	20.12.81	-	374	-
6.1.81	250	18.3.81	280	71	0.42
17.3.81	356	24.6.81	380	99	0.24
#28.4.81	424	14.10.81	430	169	0.04
13.5.81	422	19.3.82	533	310	0.36
28.5.81	412	23.7.81	415	56	0.05
*10.6.81	493	8.7.81	490	28	-
25.6.81	415	21.10.81	445	118	0.25
°14.8.80	257	27.11.80	326	88	0.78
°1.11.80	165	8.7.81	280	249	0.46

Recaptured at Rangitata Lagoon

* Rainbow trout

° Tagged at Glenariffe, recaptured at Rakaia Lagoon during this study

- No data

release. During the study period seven of these tagged fish were recaptured (five by FRD staff and two by anglers). A further six tagged trout were caught by anglers over the ensuing eight months, one being caught at the Rangitata River Lagoon, 64 km down the coast (Table 8). Thus 12.4% of trout tagged in the Rakaia Lagoon were recaptured over a 19 month period, which is a high recovery rate.

Growth rates of tagged fish ranged from 0.04 - 0.74 mm/day (Table 8). The slowest growing fish (0.04 and 0.05 mm/day) were at large over the winter period, while the fish with the fastest growth (0.74 mm/day) was at large during spring and summer. Growth rates of those fish which were recaptured after a year or longer should represent annual growth increments more accurately. The data suggest that annual growth of Rakaia adult trout is of the order of 100+ mm per annum. This compares with 30-40 mm/annum for adult brown trout in the Manganui-a-te-Ao River in the central North Island (Cudby and Strickland in preparation) and about 110 mm/annum in the Waitaki River System (S.J. Wing pers. comm.). Growth rates of trout are greatest during their first and second years. For example, the fastest known growth rates for trout in New Zealand are rainbow trout from the Rotorua Lakes, which can grow up to 40 cm from age 1+ to age 2+ (D.K. Rowe pers. comm.).

5.3 Rainbow Trout

Only one specimen was caught during the study (Tables 3 and 4), and it was measured, tagged and released. It was recaptured close to the original tagging site one month later (Table 8).

Anglers report that numbers of rainbow trout occur at the mouth at rare intervals (years apart), but we have no first-hand knowledge of this. Rainbow trout are well known in the upper reaches of the Rakaia River, but are seldom recorded below the gorge.

5.4 Perch

Two specimens only were recorded from the lagoon and we know of one other

caught by FRD staff 3 km upstream of the lagoon in January 1979. The Rakaia River is a totally unsuitable habitat for perch and there is evidently no population in the lagoon, although it would appear possible for one to establish there.

5.5 Stokell's Smelt

In some respects the least well known of the Rakaia fishes, Stokell's smelt proved to be so numerous that it was often impractical to count the catch, and only estimates were made of numbers. This species comprised 88.3% of all fish caught in the lagoon and was present in large numbers from October to March (Table 3). The peak influx was in late November-early December, with over 83% being caught in the sample period 9-11 December.

Stokell's smelt is primarily sea-dwelling, but it enters fresh water to spawn and the river is therefore essential to its survival. Spawning has been described as "almost exclusively in fresh water above tidal influence" (McMillan 1961, p. 143) and as beginning "immediately the shoals reach the stretches of river entering the [Rangitata] lagoon" (Ibid, p. 140). Presumably, McMillan's findings for the Rangitata Lagoon would be true also for the Rakaia, except that some smelt captured in the Rakaia Lagoon appeared to be not fully mature and were possibly some days or weeks off spawning. McMillan (1961) also made the observation that because of its large numbers, Stokell's smelt was very important in the ecology of the Rangitata. This would certainly be true for the Rakaia, where the species was present in thousands for many weeks.

There was a noticeable reduction in the size of fish caught as the season progressed (Fig. 10). This is a phenomenon known for other species entering fresh water from the sea, e.g. whitebait (McDowall and Eldon 1980). Males outnumbered females in our samples by just over 2:1 (Table 9), but the sex ratio varied greatly between samples. Generally, shoals appeared to comprise predominantly one sex or the other.

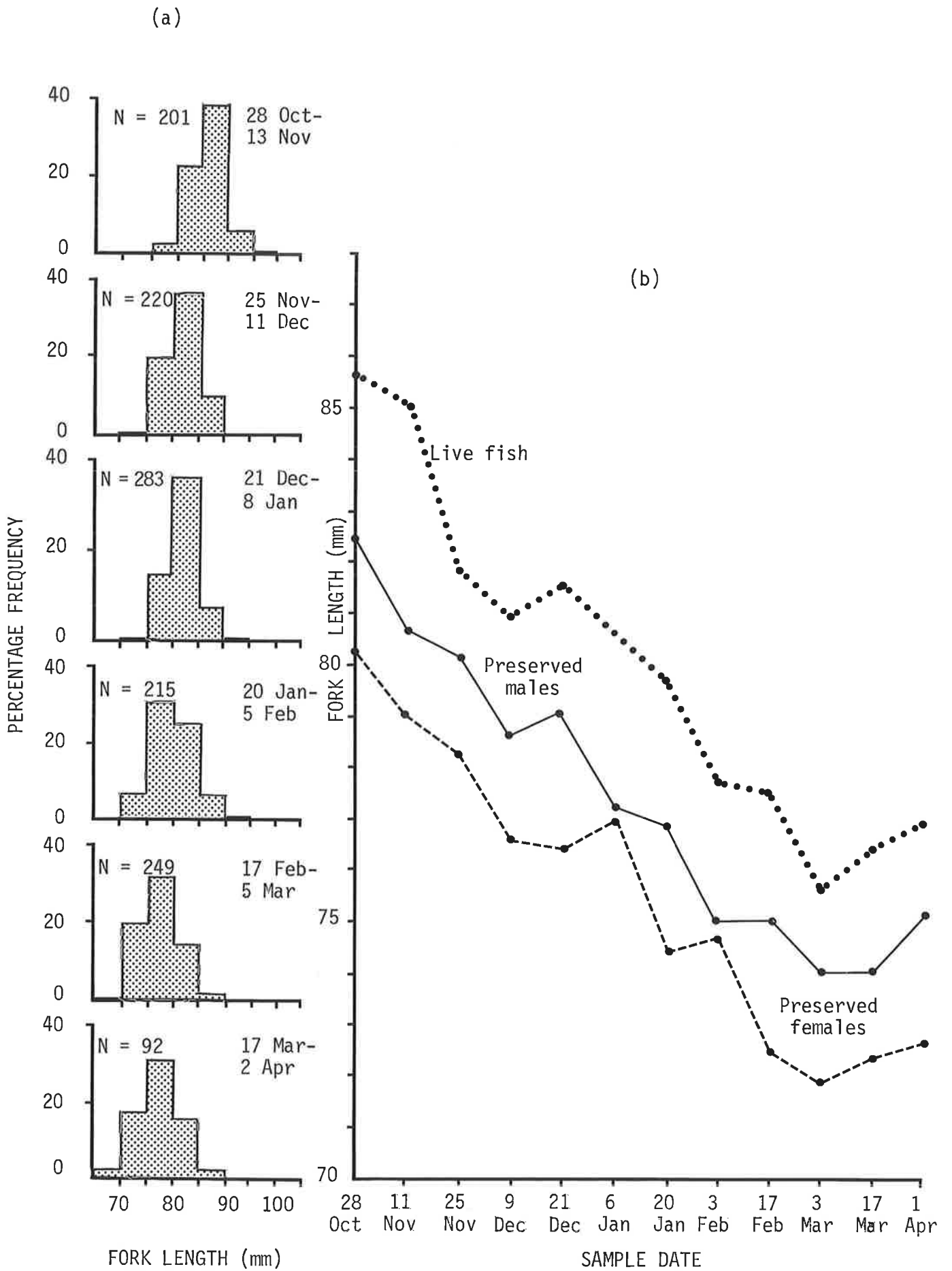


FIGURE 10. Length frequency (a) and mean lengths (b) of sub-samples of Stokell's smelt taken from Rakaia Lagoon, October 1980 - April 1981.

TABLE 9. Sex ratio of sub-samples of Stokell's smelt taken from Rakaia Lagoon, October 1980 - April 1981.

Sample date	Ratio Male : Female	N
28-30 Oct	1.08 : 1	164
11-13 Nov	18.3 : 1	154
25-27 Nov	1.71 : 1	423
9-11 Dec	6.62 : 1	358
21-22 Dec	2.65 : 1	62
6-8 Jan	1.61 : 1	159
20-22 Jan	1.15 : 1	181
3-5 Feb	-	n.s.
17-19 Feb	6.80 : 1	117
3-5 Mar	6.22 : 1	166
17-19 Mar	0.76 : 1	97
31 Mar-2 Apr	0.23 : 1	54

n.s. = no sample

Contrary to the findings of McMillan (1961), we found that females of Stokell's smelt, like those of common smelt (McDowall 1978, p.43) frequently bore nuptial tubercles at maturity. These were certainly not as prominent as those of males, but occurred on the anal and paired fins frequently, and on the scales occasionally. Scale tubercles were smaller but more numerous than on males.

5.6 Common Smelt

This species was recorded in all months but numbers fluctuated greatly from one sample period to the next (Table 3). However this may be a reflection of the limitations of our sampling techniques rather than of actual numbers present. Smelt tend to congregate in fast-moving shoals and a set which successfully enclosed a large shoal could unduly affect the results. It is

clear, however, that in the Rakaia Lagoon, common smelt are far less abundant than Stoke11's smelt (Tables 3 and 4).

Some aspects of the life history of common smelt in lake-limited populations are known (Jolly 1967), but for diadromous smelt the data are scanty and largely inferred. Spawning is probably similar to that of Stoke11's smelt, but whereas breeding shoals of that species appear to comprise a single year class, common smelt found to be ripe during our study comprised several year classes (Fig. 11).

5.7 Inanga

Adults of this whitebait species were the second most abundant fish caught in the lagoon (Tables 3 and 4), comprising 4.3% of all fish sampled. They were present throughout the year, chiefly in summer at the north-eastern end, or in tributary streams, and were also observed in adjacent pools near Mathias Creek and the North Branch of the Rakaia (Fig. 1). Juveniles (fresh-run whitebait) provide a recreational fishery at the Rakaia River mouth and in the surf (Davis 1980) from early September until 30 November. The sampling programme did not include whitebaiting and the new season's fish did not show up in our samples until November (Fig. 12). All data presented here refer to pigmented post-whitebait.

Inanga are known to spawn in tidal areas in autumn, and to some extent at other seasons, depositing their eggs in vegetation near high spring tide level (McDowall 1968). Results suggest that wetlands in the vicinity of the North Branch, site F3 (Fig. 1), may be a spawning area. The net site here was in a small gut which drained some grassy pools at low tide. Of the 183 inanga captured at this site, 174 were taken in a single night following the full moon in late January, as they made their way up the gut. Although this is considered early for spawning, the fish were gravid and were presumed to comprise a spawning shoal. Subsequent searches for eggs were unsuccessful but the potential spawning area was extensive and not fully examined.

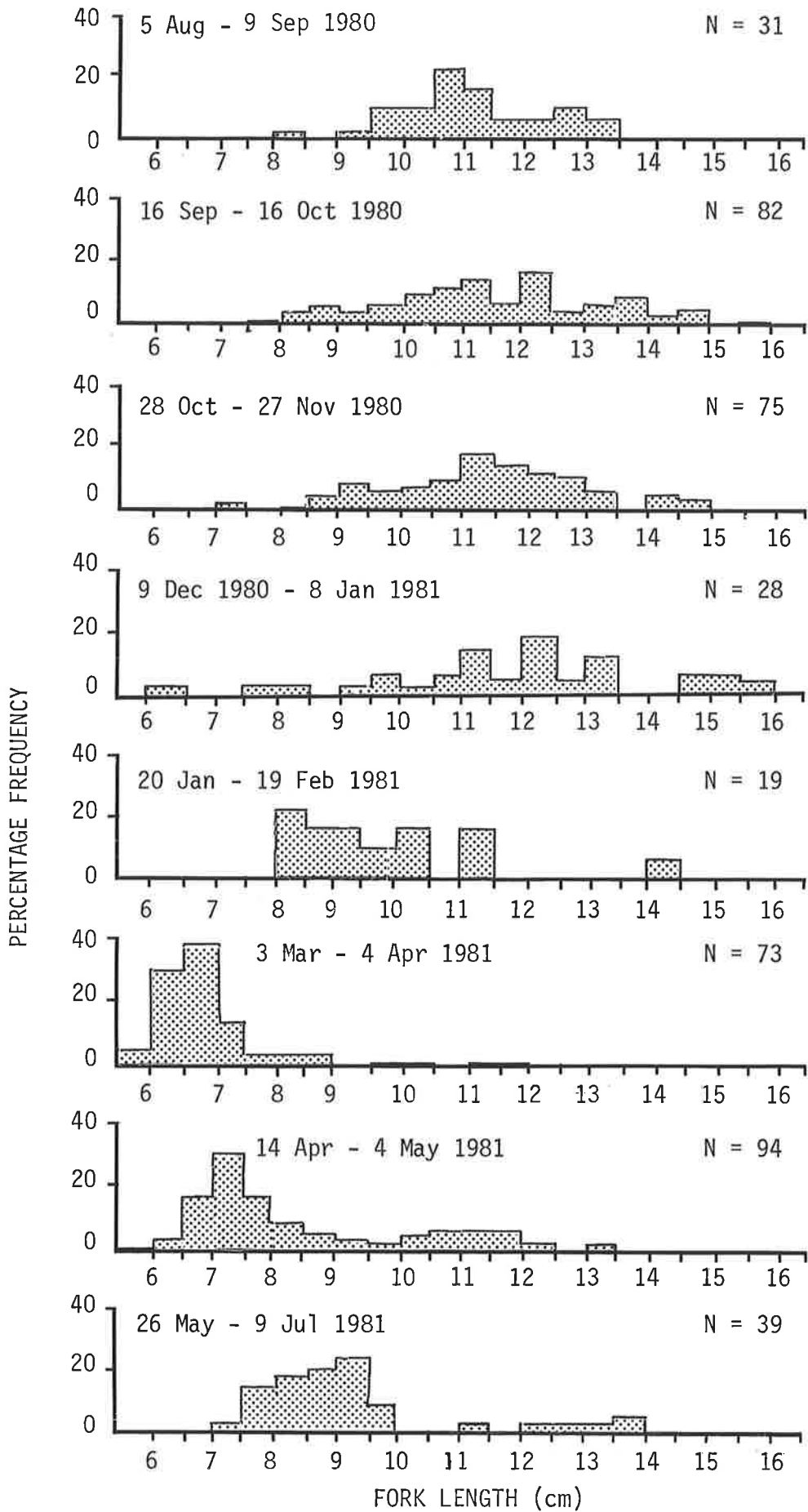


FIGURE 11. Length frequency of common smelt sampled from the Rakaia Lagoon, August 1980 - July 1981.

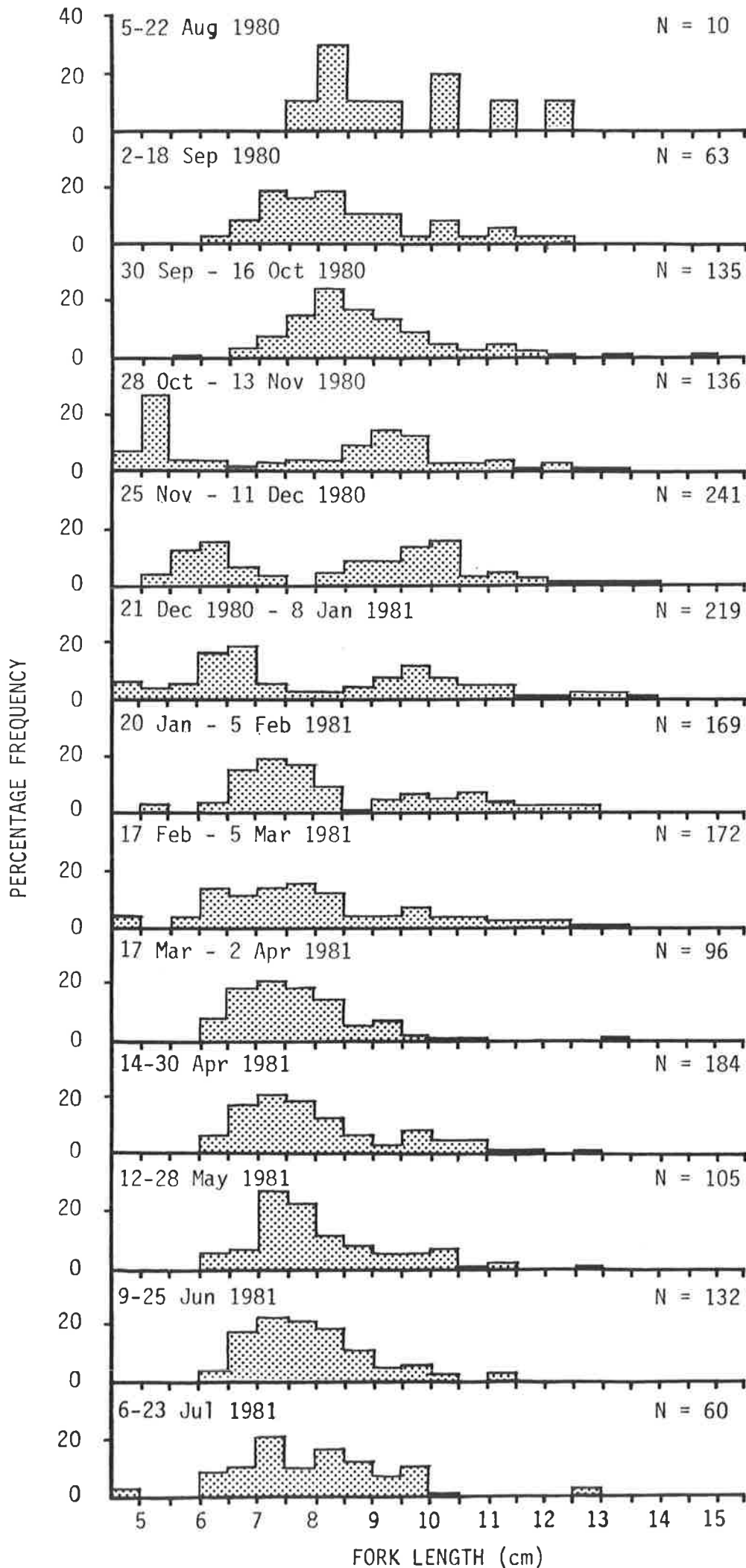


FIGURE 12. Length frequency of inanga (excluding whitebait) sampled from Rakaia Lagoon, August 1980 - July 1981.

5.8 Common Bully

This species was recorded regularly (Table 3) and was widespread (Table 4), being the fifth most abundant species caught during the study. However, it was considered to be surprisingly sparse relative to its apparent abundance in other waters (McDowall 1978). Lengths recorded ranged from 17-160 mm, with a mean of 74 mm (Fig. 13). Only 1% of fish exceeded 139 mm.

Stephens (1982) studied a landlocked population of this species, but very little is known of the life history and ecology of the migratory form. Spawning takes place in fresh water but the larvae are marine, juveniles returning to the river when 15-20 mm long. The common bully does not penetrate far up the Rakaia River and its upstream limit appears to be within 4 km of the lagoon.

5.9 Bluegilled Bully

Juveniles of this species pass through the lagoon in transit from their marine larval habitat to their adult habitat in rapids of the mainstem of the Rakaia River. Adults are found from just above the lagoon almost to the Rakaia Gorge, but none was seen in the lagoon itself.

Juveniles were recorded from April to June, but their small size (Fig. 14) probably caused them to be missed during netting at other times. A large number was found washed into a tidal pool beside the mouth at the end of April, together with juvenile torrentfish. Both these species occur in the catches of whitebaiters in spring (McDowall 1965), so it appears there are two migrations into fresh water, one in spring and one in autumn.

Nothing is known about the outward passage of larval bluegilled bullies through the lagoon, but this is believed to occur during floods over protracted periods twice a year - once for each subsequent invasion of juveniles.

5.10 Giant Bully

Only two specimens were recorded during this study (Table 3). The Rakaia Lagoon does not appear to be a suitable habitat for this little understood species.

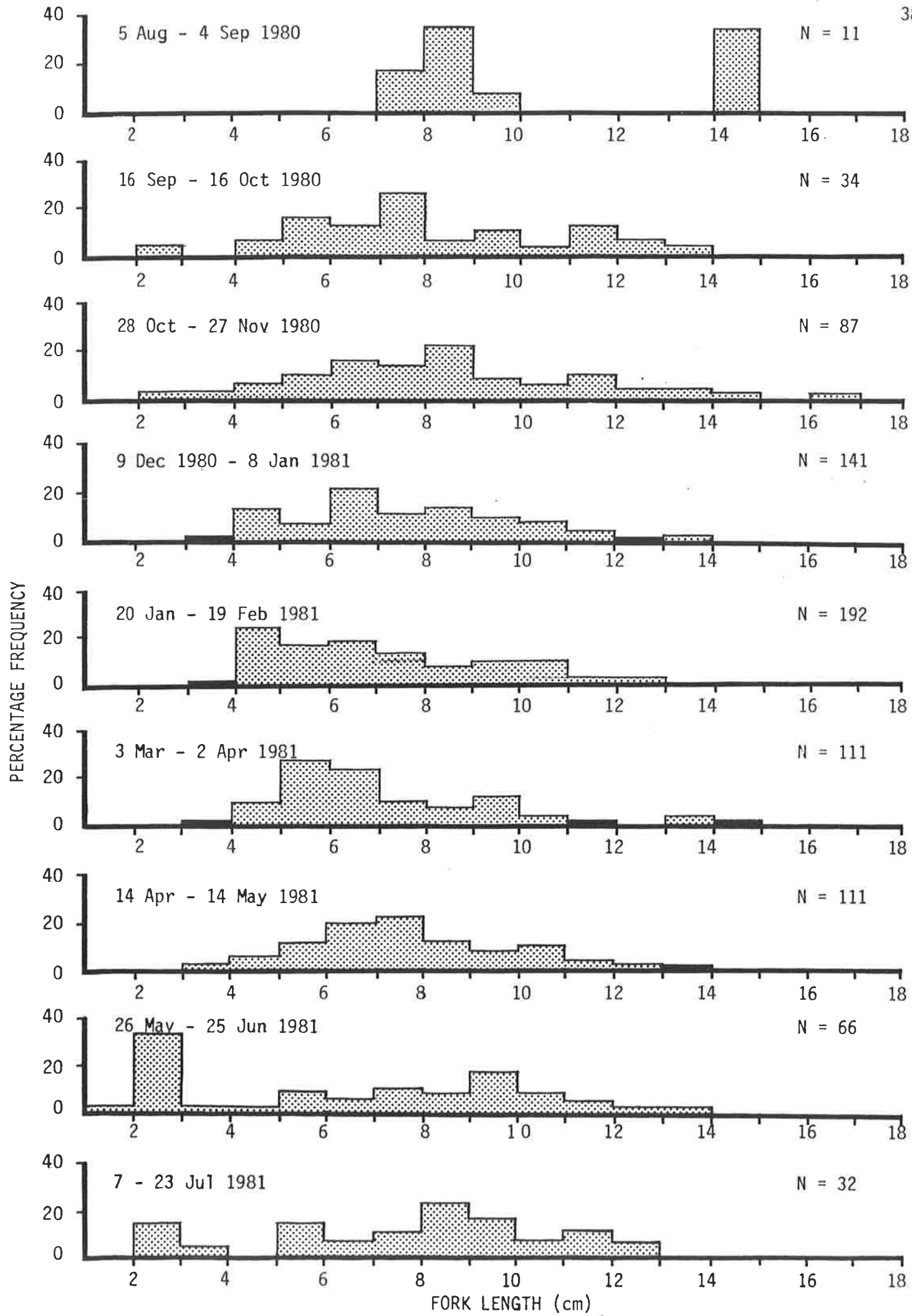


FIGURE 13. Length frequency of common bullies sampled from Rakaia Lagoon, August 1980 - July 1981.

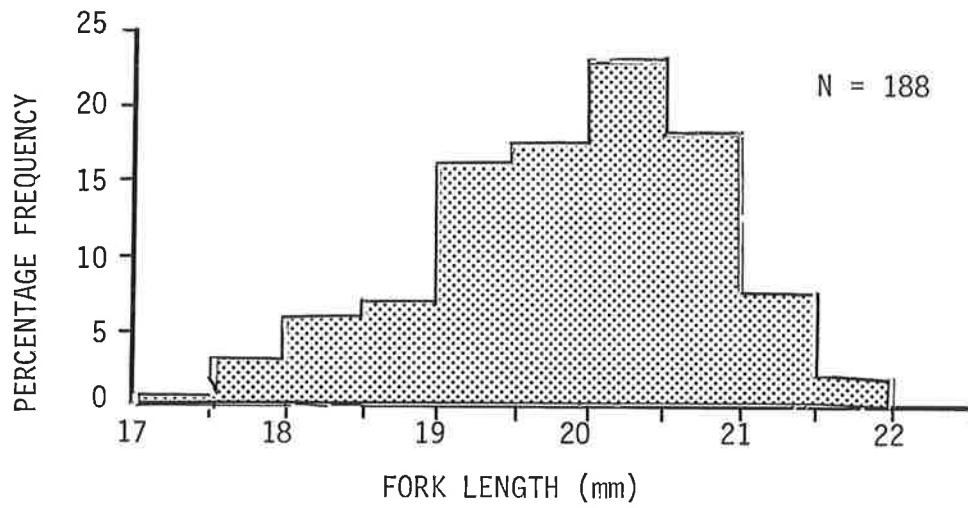


FIGURE 14. Length frequency of preserved bluegilled bullies sampled from Rakaia Lagoon on 28 April 1981. (Note: Live fish would be 1-2 mm longer.)

5.11 Upland Bully

This species was recorded from the lagoon on only three occasions (five specimens) (Table 3). Evidently it is present in the lagoon only as strays from upstream, where it is fairly common.

5.12 Torrentfish

There are many conflicting data about the life history of torrentfish and no studies have been successfully concluded (Mair 1880, Phillipps 1929, Stoke11 1955, FRD unpublished data). Adults inhabit fast waters in the mainstem, but larvae are marine. Juveniles migrate through the lagoon on their way upstream and a few were recorded from July to September 1980, with two juveniles and one adult caught in November and one larger fish of 54 mm in January 1981 (Table 3). No more were recorded until the end of April 1981, when 54 were found together with juvenile bluegilled bullies in a tide pool. Two weeks later another sizable sample (89) was obtained from the seine sites and a few fish were then collected each sample period until the project ended in July 1981.

It is clear from our data that juvenile torrentfish enter the lagoon in autumn. What is not shown clearly is that there is also a major spring invasion. This is known from whitebaiters who catch many young torrentfish throughout the whitebait season - September to November (S.P. Hawke pers. comm.).

It appears that, like bluegilled bullies, either there are two spawning seasons or a very protracted season. Whichever is the case, there are juveniles present in the lagoon for many months and their size range (Fig. 15) indicates that they do not all migrate straight through, but may remain for a few weeks. The outmigration of eggs or larvae probably takes place on floods. There is no evidence for adults spawning at sea.

5.13 Black Flounder

This was the only species of flatfish recorded from the Rakaia Lagoon. It was present throughout the year (Table 3) but catches fluctuated, influenced

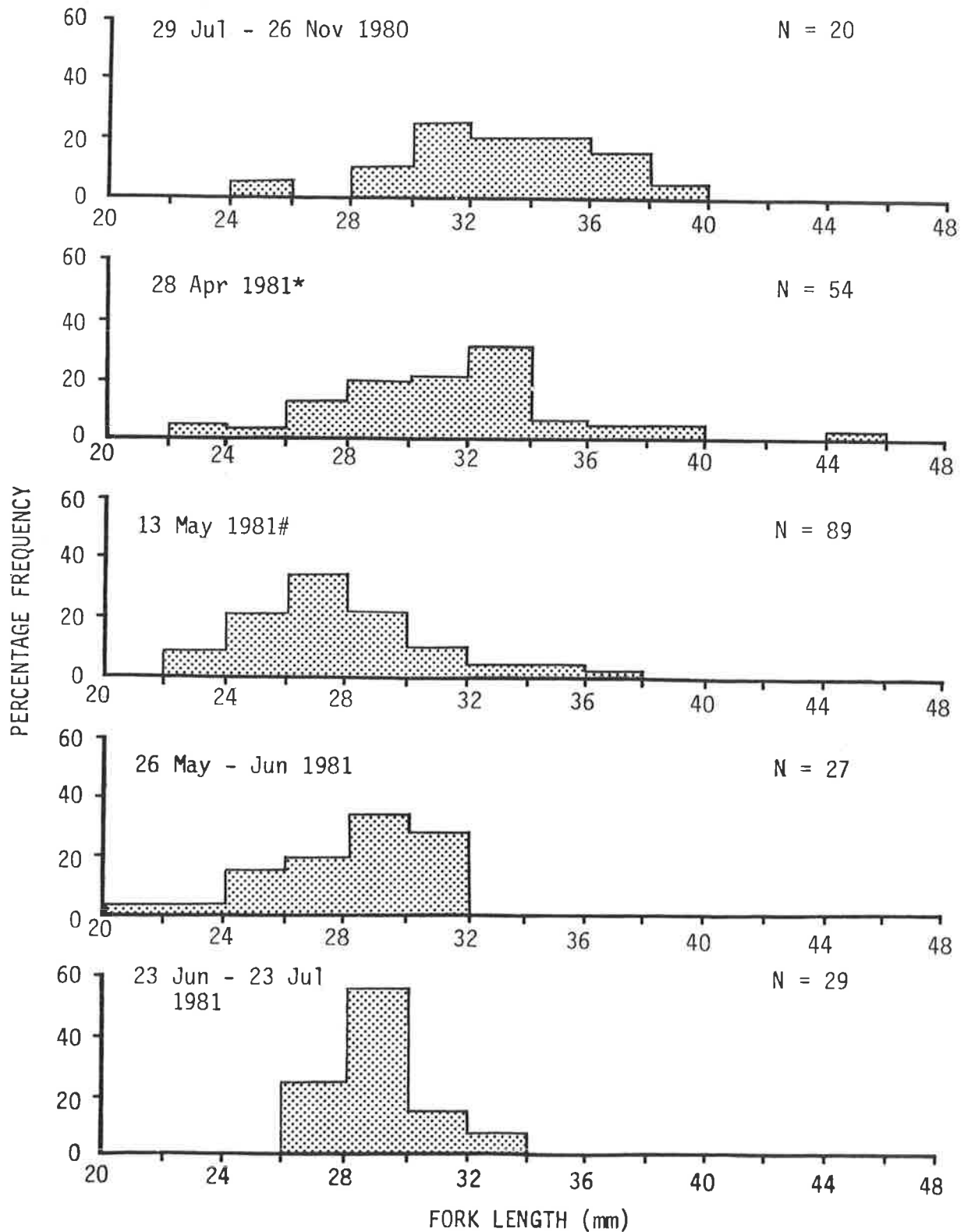


FIGURE 15. Length frequency of preserved torrentfish juveniles sampled from Rakaia Lagoon, July 1980 - July 1981. (* = sample collected from tide pool; # = single seine haul near mouth.)

in part by factors affecting netting efficiency, and in part by competition from recreational flounder fisherfolk.

The flounder fishery is not a large component of the recreational value of the Rakaia River, but it has some significance. At times there were as many as ten nets present, mainly at the north-eastern end but also in the bays and slacker water of the south-west end. Most flounder fishing was by local residents who set gill nets regularly. Very small, almost transparent, flounders are taken accidentally by whitebaiters in the surf at the Rakaia mouth as early as September (S.P. Hawke pers. comm.). However, our sampling equipment did not catch these fish until November (Fig. 16), and then only a few were collected by the seine net.

Nothing is known of the spawning habits of black flounders. Numbers in the lagoon decreased during winter, following a temporary increase in early May. K. Deverall (pers. comm.) recorded a downstream movement of black flounders in the Waitaki River system in June-July 1981. Since post-larval flounders are evident at the Rakaia mouth in September, it seems reasonable to infer that spawning takes place at sea during winter.

5.14 Longfinned Eel and Shortfinned Eel

The biology of eels in New Zealand is well understood (Jellyman and Todd 1982). Both species, usually caught in fyke nets, were recorded in the Rakaia Lagoon in about equal numbers (337 longfinned : 390 shortfinned), though each tended to predominate in certain localities (Table 4). Shortfins were more abundant in the north-eastern end of the lagoon (F1 and F2), while longfins dominated the south-western end, in the bays formed by the closure of former river mouths (F7) (Fig. 1).

Between 3 September 1980 and 18 March 1981, 222 longfinned and 288 shortfinned eels were tagged. Recapture data were disappointing (Table 10) and provided little information on movements. Only 4.5% of eels tagged were recaptured, with longfins averaging 75 days at large and shortfins averaging

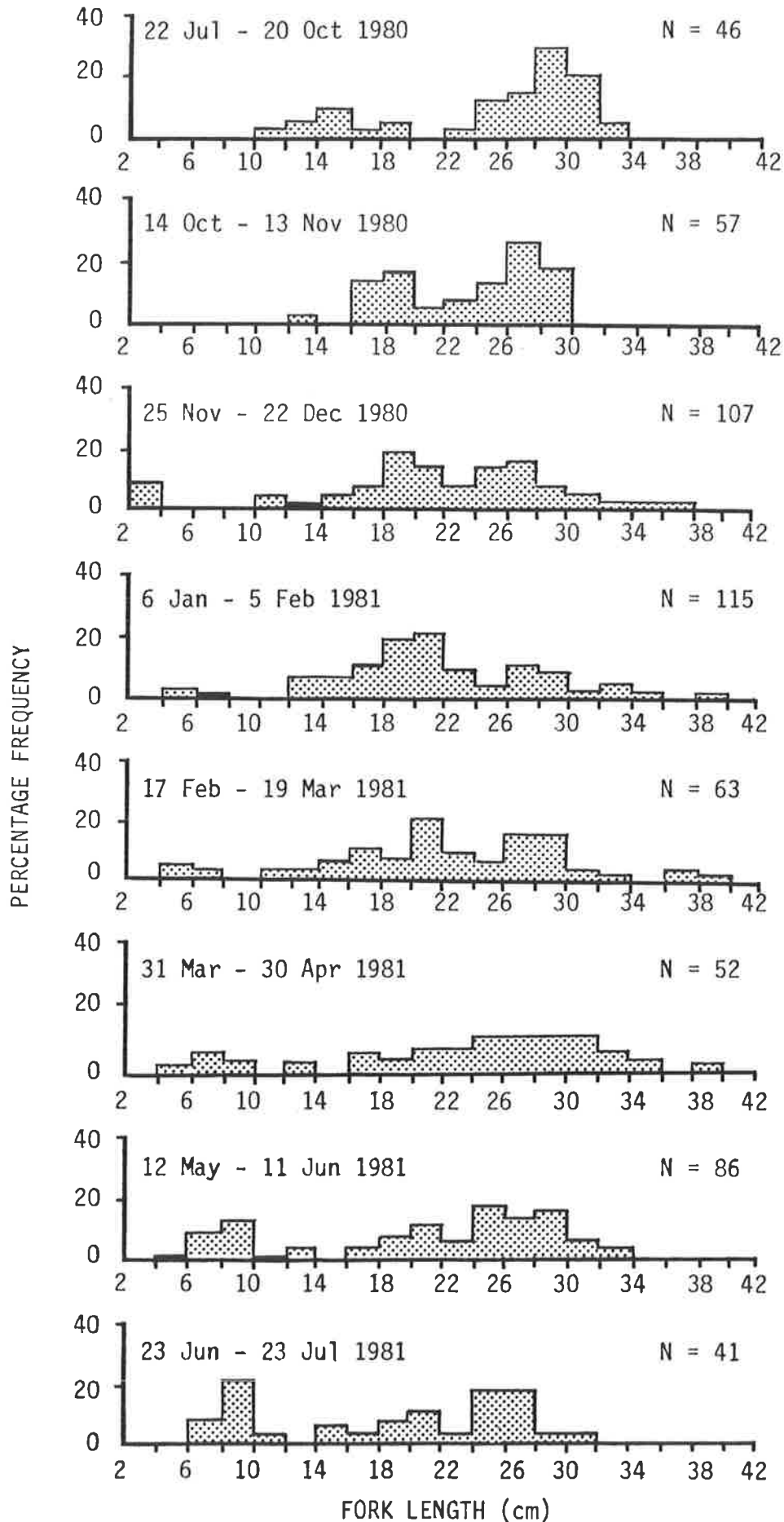


FIGURE 16. Length frequency of black flounders sampled from Rakaia Lagoon, July 1980 - July 1981.

TABLE 10. Recaptures of eels tagged in the Rakaia Lagoon during August 1980 - July 1981.

Date of tagging	Date of recapture	No. of days at large	*Site of tagging	*Site of recapture
<u>Longfinned eels</u>				
18.9.80	12.11.80	55	F6	F6
18.9.80	7.1.81	111	F6	F6
15.10.80	5.2.81	112	F6	F6
12.11.80	10.6.81	179	F6	F6
27.11.80	23.12.80	26	F7	S9
27.11.80	7.1.81	41	S8	F6
7.1.81	17.2.81	42	F1	F1
21.1.81	13.5.81	112	F3	F4
4.2.81	2.4.81	56	F6	F6
18.3.81	1.4.81	14	F2	F2
<u>Shortfinned eels</u>				
29.10.80	18.2.81	112	F3	F3
29.10.80	17.2.81	113	F1	F1
29.10.80	17.2.81	113	F1	F1
12.11.80	27.11.80	25	F6	F6
27.11.80	6.1.81	42	F1	F1
27.11.80	10.12.80	13	F5	F5
7.1.81	5.3.81	56	F3	F3
7.1.81	21.1.81	14	F3	F3
7.1.81	19.5.82	497	F6	F6
21.1.81	13.5.81	112	F1	F1
21.1.81	28.5.81	126	F3	F4
4.2.81	18.2.81	14	F1	F1
18.2.81	4.3.81	13	F6	F6
18.3.81	13.5.81	56	F6	F6

* See Figure 1 for locations

62 days. The positive data indicated very little movement, most recaptures being at or close to the tagging site. However, so few recaptures may indicate that eels had moved out of the netting areas, or had become net shy.

During the study period no commercial eel fishing took place in the lagoon, although it is understood that some commercial activity had taken place in the previous (1979) summer. As eels are long-lived and very slow growing (Cairns 1941, Todd 1980), any commercial activity could have influenced our results.

However, length frequencies (Fig. 17) indicated an unexploited population, with mean lengths of 575 mm for shortfins and 678 mm for longfins. These are similar to the length frequencies of Lake Ellesmere eels prior to the lake becoming a commercial fishery (FRD unpublished data). The length frequency of Lake Ellesmere shortfins at the corresponding time of the Rakaia Lagoon study had a skewed distribution, showing evidence of heavy commercial exploitation of fish over 380 mm; the mean length was only 400 mm (FRD unpublished data).

Longfinned eels once formed an important part of the Lake Ellesmere fishery, but have now almost disappeared from the lake. The mean length of only 61 longfins recorded from Lake Ellesmere recently was the same as for shortfins - 400 mm.

Catches of eels in the Rakaia Lagoon during this study were not large, and indicated that commercial fishing probably would not have been sustained for even a few nights during 1980-81.

5.15 Lamprey

This species is little seen but is widespread in New Zealand, and in some places runs in sufficient numbers to form a local fishery (Todd 1979a). Adults enter fresh water from the sea in winter and spring and move up into the spawning grounds, which occur in both lowland and high country waters, where they appear to spend several months before breeding. Juveniles are highly cryptic, living buried in silt for years before migrating to sea.

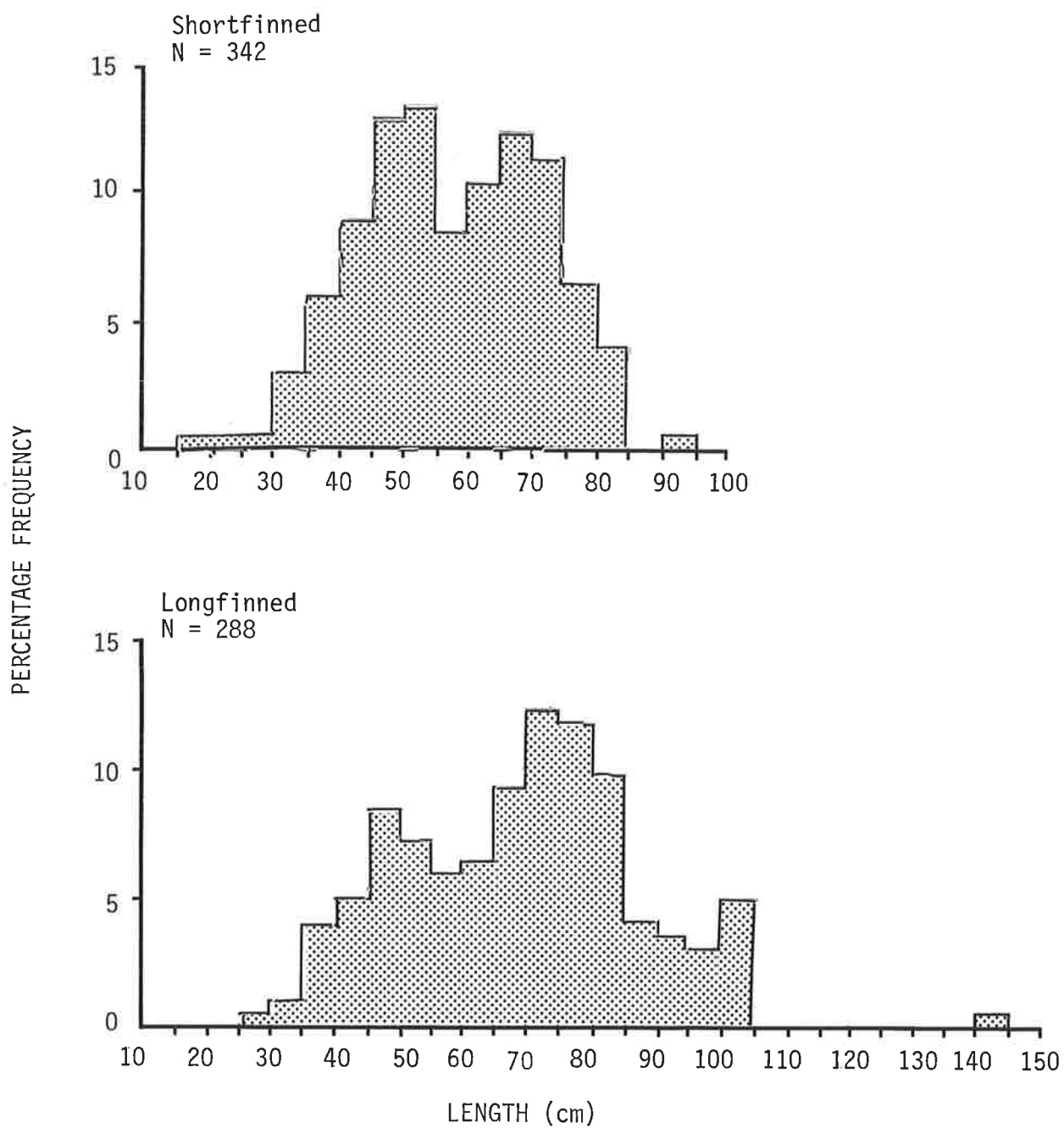


FIGURE 17. Length frequency of eels sampled from Rakaia Lagoon, July 1980 - July 1981.

A single adult lamprey was captured in the Rakaia Lagoon in a fyke net in July 1981 (Table 3). Adults and juveniles have been recorded previously from Glenariffe and elsewhere in the Rakaia catchment. Nothing is known of their abundance in the Rakaia system, but the paucity of records indicates that there are probably few.

5.16 Yelloweyed Mullet

Elsewhere (e.g. Lake Ellesmere) this species is commercially exploited as well as being sought after by recreational net and line fisherfolk. Some recreational gill netting for mullet takes place in the Rakaia Lagoon, but it is not so extensive as that for flounders.

Mullet appear to move freely between fresh and salt water. In the lagoon they were present from September to June, but were in large numbers only from January to April (Table 3). This is in contrast to nearby Lake Ellesmere where mullet are present throughout the winter (Gorman 1962).

Juvenile mullet (less than 100 mm long) were rarely recorded (Fig. 18), although they were seen from the beach at times and featured in the stomach contents of kahawai caught outside the mouth by anglers. Few large mullet (greater than 260 mm) occurred in our catches. However, there was a bias against catching large mullet in some of our sampling, with the 85 mm gill net panel too large and the 56 mm panel too small to take these fish. Nevertheless, the beach seine net was capable of catching all size groups present (Fig. 19), although mullet are very mobile fish and difficult to catch in a seine net unless conditions are favourable. Many fish were caught with the gill net (Table 4). Mullet were the fourth most numerous fish in our catches and may have been first in terms of biomass during summer.

5.17 Kahawai

This is essentially a marine species which sometimes enters river mouths. It was seen frequently in summer, massing at the surface of the sea in the outflow from the Rakaia Lagoon. Occasionally shoals would extend over a hectare or more.

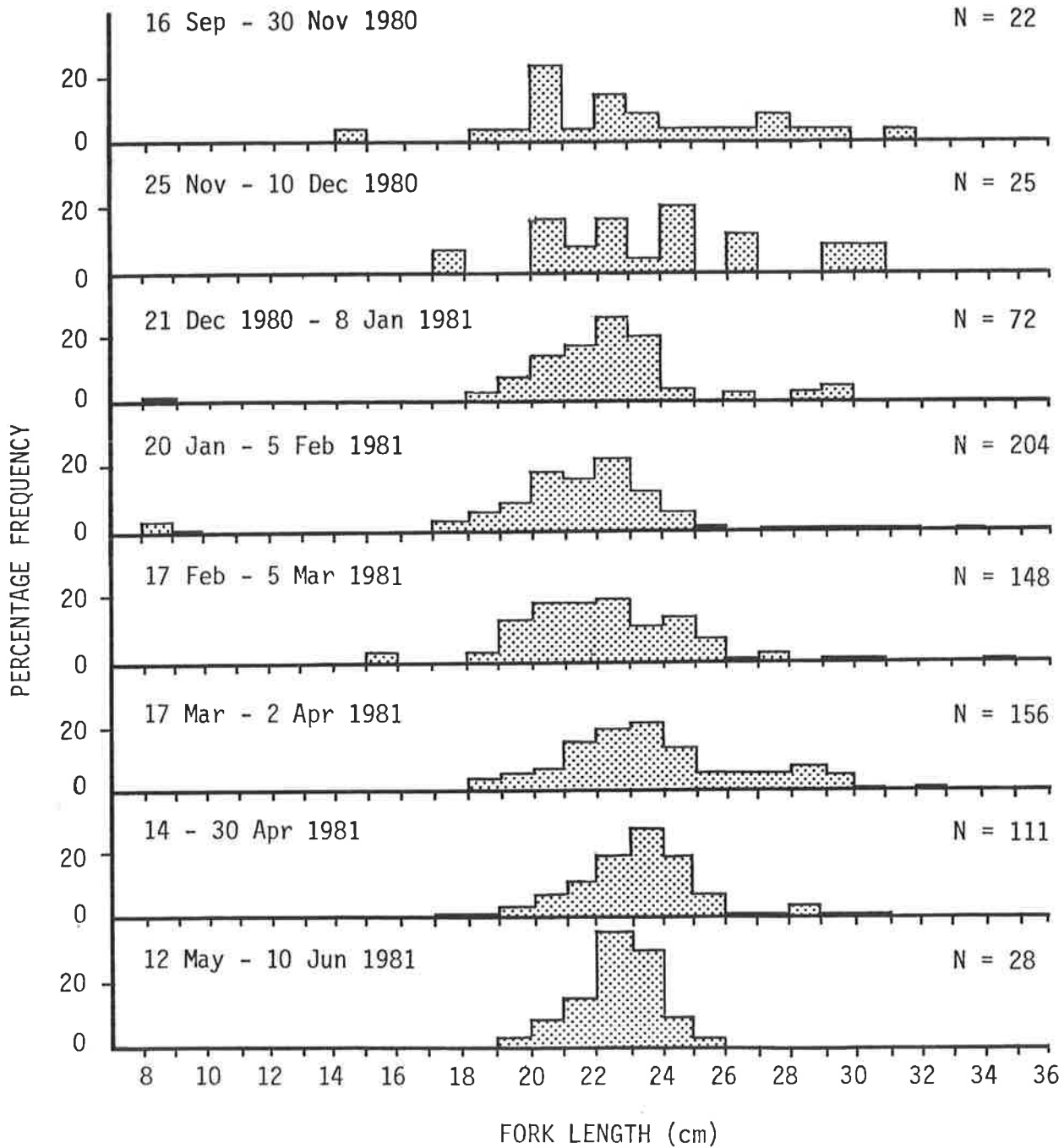


FIGURE 18. Length frequency of yelloweyed mullet sampled from Rakaia Lagoon, September 1980 - June 1981.

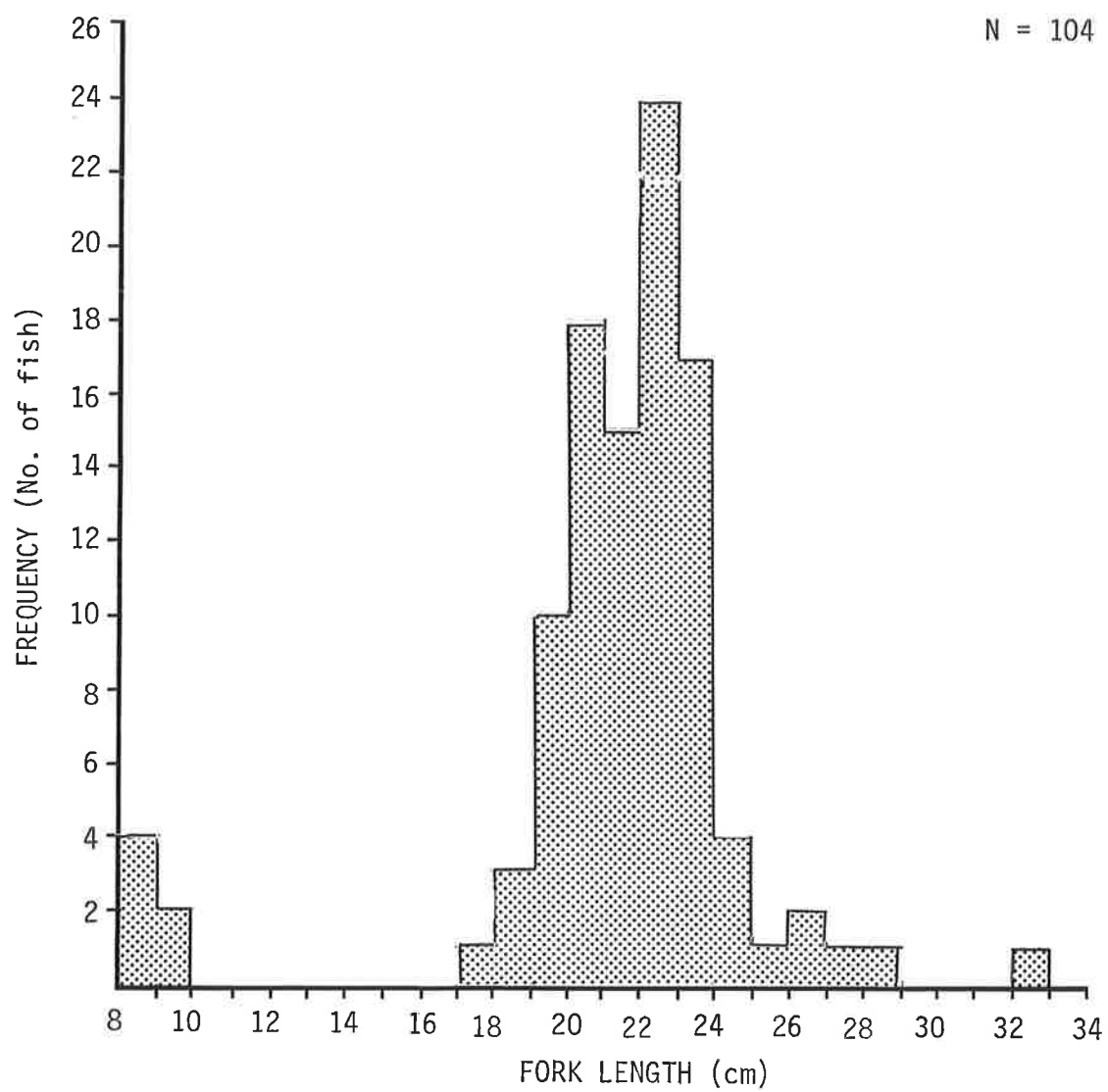


FIGURE 19. Length frequency of yelloweyed mullet taken in a single seine haul from the Rakaia Lagoon, 20 January 1981.

However, few actually entered the lagoon and on only two occasions was one caught. Kahawai are powerful swimmers which might be expected to evade a seine net, but they are also large and frequently swim near the surface, especially when feeding on small fish, which can be observed breaking the surface in their attempts to escape. Thus kahawai present in the lagoon might be expected to attract attention, but none was seen other than the actual captures.

5.18 Koaro

Although not sampled during this study, the whitebait of this species are known to comprise a small percentage of the Rakaia whitebait run (FRD unpublished data). Adults inhabit tributaries upstream, e.g. Boundary Stream.

6. FOOD OF FISHES

The stable north-eastern of the lagoon contained a rich invertebrate fauna, both among the macrophytes and in the water column. However, the south-western end provided poor habitat on its unstable, shifting bed, and was extremely sparse in food organisms. Between these areas, in the region of net sites F4 and S5 (Fig. 1), was a transitional zone of moderate fauna density.

Stomach analysis of nine species of fish showed that the same basic food types were eaten by most fishes, but in different proportions (Table 11). These data reflect the habitat from which most specimens of a species were collected. Yelloweyed mullet were sampled mainly from the north-eastern weed-grown end of the lagoon (Table 4). *Potamopyrgus antipodarum*, a gastropod (Mollusca: Hydrobiidae), was common there and ranked highly in the volume of mullet stomach contents. As this fish is omnivorous, it is possible that some invertebrates were ingested accidentally when the fish was browsing vegetation, but *Potamopyrgus* could easily be rejected if unwanted. *Paracalliope fluviatilis* (Amphipoda: Eusiridae) was also abundant in this area and figured prominently in mullet stomachs, and in the diet of inanga, flounder, trout and salmon juveniles.

Diptera larvae were the most numerous food item taken by fish, being of

TABLE 11. Diet of nine species of fish from the Rakaia Lagoon, July 1980-July 1981. (% comp. = Proportion by volume of stomach contents each food item represented; % occ = proportion of stomachs in which each food item was found; l = larvae, p = pupae, I = Imago; * (N) = number of fish with food in stomach.)

Species	Inanga		Common smelt		Stokell's smelt		Common bully		Torrent-fish		Yelloweyed mullet		Black flounder		Brown trout		Salmon juveniles	
	% comp.	% occ.	% comp.	% occ.	% comp.	% occ.	% comp.	% occ.	% comp.	% occ.	% comp.	% occ.	% comp.	% occ.	% comp.	% occ.	% comp.	% occ.
Fish remains	-	-	3.2	2.4	2.8	1.8	0.3	0.6	-	-	1.6	1.2	1.2	2.6	42.8	34.0	0.7	1.9
Diptera l	16.6	56.5	20.5	75.2	17.0	63.3	18.1	61.1	11.0	44.6	1.0	16.7	21.3	79.2	0.7	10.6	18.5	72.6
Diptera p	2.7	14.3	10.9	41.2	6.8	21.1	2.1	17.9	0.3	1.8	0.1	3.6	3.0	37.7	2.3	21.3	18.1	56.1
Diptera I	-	-	7.5	17.0	1.5	12.0	<0.1	0.6	-	-	0.1	4.8	-	-	0.2	2.1	4.6	19.1
Ephemeroptera l	1.1	4.0	6.1	24.8	15.6	23.5	5.9	15.4	18.4	28.6	0.2	1.2	4.8	14.3	0.2	4.3	7.9	34.4
Ephemeroptera I	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1	0.6
Trichoptera l	13.5	61.9	9.5	37.6	4.9	21.1	10.7	34.6	2.5	14.3	2.7	34.5	1.5	14.3	3.0	25.5	7.7	35.0
Trichoptera p	-	-	-	-	0.4	1.2	-	-	-	-	-	-	-	-	-	-	-	-
Trichoptera I	-	-	0.9	4.2	1.0	3.6	-	-	-	-	<0.1	1.2	-	-	0.5	6.4	1.0	10.8
Plecoptera l	0.1	0.4	0.2	1.2	<0.1	0.6	0.5	3.1	-	-	-	-	0.4	5.2	0.1	2.1	1.3	5.7
Coleoptera l	0.6	3.1	0.4	0.6	0.1	1.2	1.0	6.8	1.4	1.8	0.1	1.2	0.2	2.6	<0.1	2.1	0.4	5.7
Coleoptera I	0.4	2.7	3.4	13.3	3.1	11.4	<0.1	0.6	-	-	0.5	4.8	-	-	4.6	12.8	0.1	1.9
Hemiptera I	-	-	0.2	1.8	2.3	8.4	-	-	0.1	1.8	0.2	4.8	-	-	1.8	2.1	0.4	4.5
Odonata l	1.7	3.6	<0.1	0.6	-	-	2.2	4.9	-	-	0.1	1.2	0.1	1.3	0.9	10.6	1.8	5.7
Odonata I	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.2	2.1	-	-
Arachnida	-	-	1.0	4.8	1.9	9.0	0.2	1.2	-	-	-	-	-	-	<0.1	2.1	0.3	4.5
Crustacea	9.0	30.5	0.8	5.5	1.0	7.2	0.2	4.3	<0.1	1.8	1.1	4.8	0.4	7.8	0.9	4.3	7.5	12.1
Amphipoda	15.2	28.3	3.0	6.1	2.1	7.2	3.8	16.0	37.5	48.2	10.7	36.9	4.6	15.6	18.0	38.3	8.6	24.2
Mollusca	8.4	27.4	<0.1	0.6	-	-	12.3	29.0	-	-	56.0	59.4	1.4	13.0	13.1	34.0	0.2	3.8
Oligochaeta	-	-	0.4	0.6	0.9	0.6	-	-	-	-	-	-	4.0	5.2	-	-	0.2	0.6
Other (aquatic)	-	-	-	-	0.1	2.4	-	-	-	-	-	-	-	-	-	-	<0.1	0.6
Other (terrestrial)	<0.1	0.4	1.2	6.1	2.1	13.9	0.2	1.2	0.8	1.8	0.3	3.6	0.1	2.6	0.2	8.5	0.2	8.9
Veg. debris and residue	30.7	75.3	30.7	77.6	36.3	77.7	42.5	89.5	28.0	62.5	25.3	83.3	57.0	90.9	10.4	34.0	20.3	66.2
No. fish examined	240	*(223)	175	*(165)	191	*(166)	181	*(162)	63	*(56)	99	*(84)	87	*(77)	56	*(47)	159	*(157)

little consequence only to trout and mullet. They were particularly important to flounders, although these fish had a surprisingly varied diet, considering their specialised shape. Flounders' food probably reflected the fish's wide distribution and year-round presence in the lagoon (Tables 3 and 4).

The wide-ranging habits of smelts were reflected in the large variety of food eaten by these fishes - prey were taken from the bottom, the water column and the surface. Ephemeroptera larvae were common in their diet and may have been drifting in the water column, displaced from upstream.

Common bullies, although fairly sedentary, occurred in a wide range of habitats, and once again their stomach contents reflected this. The presence of Odonata larvae in their stomachs was of particular interest, for these insects were not taken by many fishes, occurring only in small numbers in the diet of inanga, brown trout and juvenile salmon.

Juvenile salmon were heavily dependent on Diptera larvae and also took imagos, but did not obtain as much of their food from the surface as they did upstream in the Rakaia River (Sagar and Eldon in prep.). Nevertheless, their diet was more varied than that of other species. Cladocerans (Crustacea) featured in the diet of salmon and inanga, indicating mid-water feeding.

Trout were largely piscivorous, feeding mainly on smelt, but also taking slower moving prey such as *Potamopyrgus*. Surface food was absent from their diet.

Juvenile torrentfish were found to contain two marine amphipod species and freshwater insect larvae, indicating that they feed actively while in migration from the sea to their adult habitat. This is not always the case with migratory species, e.g. whitebait cease to feed before entering fresh water (McDowall and Eldon 1980).

The two kahawai caught inside the lagoon contained only residue material, while of the two perch caught, one had an empty gut and the other had eaten a bully.

7. DISCUSSION

Nineteen species of fish were recorded from the Rakaia Lagoon during this study, of which three were entirely fresh water dwelling, 14 were migratory and two marine. Before the study commenced, expectations were that the lagoon would provide an important buffer zone between the Rakaia River and the sea, and be a significant rearing ground for juvenile quinnat salmon, inanga, and possibly other species of fish. However, in reality there was no buffer zone. Upstream (south-west) of the river mouth, the lagoon was little different from the Rakaia mainstem, with a swift flow, unstable bed and lack of cover for fish. North-east of the mouth was a small productive ponding area, which provided good but limited habitat for a small number of inanga, smelt, eels and bullies, with some trout, flounders and mullet also utilising the area. The stable tributary streams of the lagoon (Boat Creek, North Branch, Mathias Creek) provided habitat for native fishes, but did not hold many salmonids.

The Rakaia Lagoon entirely lacked a marine invertebrate fauna. Sea anemones (Anthozoa) and chitons (Amphineura) were absent, while such molluscs and crustaceans as occurred were freshwater species.

Table 2 compares the fish population of the Rakaia Lagoon with those in Lake Ellesmere, the Avon-Heathcote Estuary and the Ahuriri Estuary. Lake Ellesmere is a large, shallow, highly eutrophic lake (Hughes, McColl and Rawlence 1974), with a periodic opening to the sea, while the Avon-Heathcote (Knox and Kilner 1973) and Ahuriri (Kilner and Akroyd 1978) Estuaries are river mouths with extensive tidal reaches and a broad range of marine and brackish water fauna. The number of fish species present in each of these habitats was 29, compared with only 19 for the Rakaia Lagoon. Lake Ellesmere contained two freshwater, 10 migratory and 17 marine species. No freshwater fish were recorded from the Avon-Heathcote or Ahuriri Estuaries, which contained nine migratory, 20 marine, and seven migratory and 22 marine species respectively. These data indicate that the productivity of the Rakaia Lagoon was not comparable with that of an estuary.

The salmon run in the Rakaia River is the prime interest of many members of the public. The importance of the fishery to anglers is well known and has been the subject of several studies (West and Goode in prep., Unwin and Davis in prep.) and much fisheries research effort (Galloway 1979). Despite this, many details of salmon behaviour in the river are still unknown and under investigation.

Until recently, it was assumed that the mainstem of the Rakaia River was too hostile an environment to provide a rearing ground for juvenile salmon. It was thought that only the lagoon provided suitable rearing habitat for salmon, and also that it was important as a transitional habitat between the freshwater and marine environment. However, the results of the present study, together with data from other sampling programmes conducted by FRD further upstream over the period 1978-1981, suggest that the lagoon is of relatively minor importance as a salmon rearing habitat. In terms of catch per seine haul, for example, the lagoon produced far fewer salmon juveniles than some of the up-river sites, where average catches of up to 30 fish were typical, with one haul producing over 300 fish (C.L. Hopkins pers. comm.). In fact, the river sampling programme had originally included the lagoon, but this was abandoned as a sampling site during the 1978/79 season due to the lack of salmon fingerlings caught there. Present data suggest that the lagoon holds greater concentrations of yearling salmon than any of the up-river sites, but even so their contribution to the total yearling stock is not likely to be large considering the relatively small area of the lagoon.

A breakdown of juvenile salmon catches in the lagoon prior to the release of hatchery fish is presented in Table 12. The seine sites at the north-eastern end were easier to sample than others, and were worked more consistently (Table 1). The data show that some fry of the year frequented the deep water at seine site S1, but catch rates were lower than upstream (south-west) of the mouth (Table 12). Catch rates of yearlings were approximately equal in the two areas, but most salmon caught in the ponding area were taken from sites close to the confluence

TABLE 12. Distribution of quinnat salmon in seine net catches, and the mean catch per set, July-December 1980, prior to the lagoon release of tagged fish. (58 sets made in ponding area north-east of mouth; 60 sets made south-west of mouth.)

Year class	Ponding area								South-west of mouth								Total Caught	
	S1	S2	S3	S4	S5	Sub Total	No. per set	S6	S7	S8	S9	S10	S11	S12	S13	Sub Total		No. per set
1979 (yearlings)	4	3	2	40	95	144	2.48	0	14	32	7	7	0	72	0	132	2.2	276
1980 (fry)	118	28	27	22	8	203	3.50	2	130	61	1	31	13	47	36	321	5.35	524
TOTALS	122	31	29	62	103	347	5.98	2	144	93	8	38	13	119	36	453	7.55	800

of the North Branch, not in the still water. Further, these fish were found to have been feeding on Ephemeroptera larvae and other running-water invertebrates which were not present in the lagoon. Possibly the North Branch provides more salmonid habitat than was apparent from our work in the lowest reaches. Much remains to be learnt about juvenile salmon utilisation of the braids of the lower river, particularly in view of the time tagged fish spend in the area, as shown by the period between liberation and recapture of some fish, including the three tagged at Glenariffe (Table 7).

There are conflicting data on the importance of brown trout to Rakaia anglers. In the past, the Rakaia brown trout fishery was thought to be negligible except for sea-run fish at the mouth. However the 1978-79 (Unwin 1980) and 1979-80 (Unwin 1981) Rakaia angling surveys estimated that 10 747- 12 800 and 5 510 trout respectively were caught in the river. The survey data indicate that trout are taken throughout the Rakaia system, although there is evidence that in 1978/79, about one third of trout catches were made at the mouth (S.F. Davis pers. comm.).

It is difficult to reconcile these large angler catches with the small number of trout caught in our lagoon netting programme in 1980-81. A possible explanation is that there was a population of trout which moved in and out of the river mouth feeding on the numerous migratory fishes (whitebait, smelts, torrentfish, glass eels, bullies and juvenile flounders). The velocity of the current, even at high tide, precluded netting of the outlet, but the channel is heavily fished by anglers every summer. Early in the fishing season, many anglers fish for trout. Later in the season, most anglers fish for salmon, but doubtless some trout are taken by salmon anglers. Local anglers report that trout catches at the mouth vary greatly from season to season.

It is known that there is some movement of brown trout between South Island east coast rivers (FRD unpublished data). Therefore, it is also possible that some trout caught by anglers at the Rakaia mouth did not originate in the Rakaia. There may be recruitment to the Rakaia from other river systems, or there may be nomadic trout moving up and down the coast which move in to river

mouths to feed.

Perch are presumed to reach the Rakaia River from the Ashburton system, where they occur in Lake Clearwater and elsewhere (Boud et al. undated), via the Rangitata Diversion Race (RDR). The RDR abstracts water from the Ashburton River (where there is no fish screen), and discharges at Highbank power station, and the Ashburton Acclimatisation Society has found perch in the RDR near Highbank when salvaging trout and salmon (J. Tonkin pers. comm.). The establishment of perch in the Rakaia Lagoon should be avoided. It is a highly piscivorous species (Griffiths 1976) which might prey on juvenile salmon when they first arrive at the ponding area, and would certainly prey on whitebait and bullies.

Although great numbers of smelt, particularly Stokell's smelt, enter the Rakaia to spawn, it is doubtful if the lagoon is important in their life history. Both species of smelt spawn in the river, but would do so regardless of the presence of a lagoon. A few common smelt utilised the lagoon throughout the year, but their numbers were small. By comparison, the vast numbers of Stokell's smelt in the lower river during spring and early summer must have a profound effect on the ecology of the area.

Inanga occupy all the quiet waters of the lagoon, including the limited wetlands on its margins. Diversion of the stream which once flowed into the north-eastern tip of the lagoon must have deprived the locality of a great deal of whitebait habitat, as the lagoon would once have narrowed gradually into a long coastal swamp of the kind much favoured by inanga. Inanga spawn in the wetlands around the lagoon, and may also utilise the lagoon margins in the vicinity of S1 and F1 (Fig. 1).

There is a popular whitebait fishery at the Rakaia River mouth (Davis 1980). However, it is unlikely that the size of the Rakaia whitebait run is dependent on the spawning success of inanga in the Rakaia Lagoon, as whitebait do not seem to return to their river of origin, as salmon do.

Bullies are traditionally recognised as important trout food. However, it

seems unlikely that bullies in the lagoon play a significant role in this regard, due to their low densities.

The presence of a fairly broad size range of juvenile torrentfish in the lagoon (Fig. 15) was unexpected. It was thought that this species would migrate straight through, as do juvenile bluegilled bullies and koaro, but some fish were often present at S5 (Fig. 1), just inside the mouth. It appears these fish may spend several weeks at the mouth feeding before migrating to their adult habitat.

The occurrence of only one species of flatfish most highlights the difference between the Rakaia Lagoon and more typical estuarine situations. Only the black flounder, unrecorded in the Avon-Heathcote Estuary where three other flatfish species are common, was present in the lagoon (Table 2). At Lake Ellesmere, black, yellow-bellied and sand flounders are common (Todd 1979b), and the greenback flounder and common sole have also been recorded (Ryan 1974). Black flounders were recorded from all parts of the Rakaia Lagoon (Table 4), but occurred predominantly in the North Branch and near its confluence. A muddy bed and the absence of macrophytes probably accounted for this distribution pattern.

For some local inhabitants, flounders are an important facet of the recreational value of the Rakaia Lagoon. Flounders provide small but regular catches during the warmer months.

There was not a great area of habitat for eels in the lagoon, except at the north-eastern extremity (shortfinned), Mathias Creek (both species) and the bays along the coastal bar (longfinned). These latter were ephemeral habitats which had filled with silt by the completion of this study. Although some commercial eeling apparently has occurred in the lagoon in the past, densities recorded in this study were insufficient to support more than occasional, casual fishing.

Few juvenile mullet occurred in the lagoon (Figs. 18 and 19), but they appeared to be abundant immediately offshore. (They featured in the stomach

contents of kahawai caught by anglers, and many were netted from a tidal pool outside the mouth on 22 January 1981.) This indicated that juveniles were either unable or unwilling to negotiate the mouth, contrasting with the Ahuriri Estuary, where Kilner and Akroyd (1978) recorded mullet of 40-50 mm. Gorman (1962) indicated that mullet breed in Lake Ellesmere. Adult mullet were abundant in the lagoon in summer and were taken mainly just inside the mouth with a seine net, or at the north-eastern end with the gill net.

Some local residents fish for mullet with set nets, but the recreational fishery is not large. The species has an importance unrelated to numbers caught, however, for it is popular with children who can learn the basics of angling, while their parents are occupied fishing for trout and salmon.

8. CONCLUSIONS

The greater part of the Rakaia Lagoon is not an outstanding fisheries habitat because of shifting gravel, high silt loads and the constantly changing topography. However, the north-eastern end and the tributary streams provide a limited habitat for some species, particularly inanga, and the north-eastern end also provides a feeding ground for yelloweyed mullet. Juvenile salmon do use the lagoon, but because of the limited habitat available, it is not of great significance to the species.

Low river levels tend to create a higher lagoon level, because the river lacks sufficient velocity to cut a deep mouth. On a long-term basis, this might increase the value of the lagoon to some species - inanga, salmon and shortfinned eels for example - provided they still had access to it through the river mouth.

Of more significance to the river and the overall Rakaia fishery than the lagoon, however, is the mouth. Through this vital link between marine and freshwater habitats, 17 species of fish are known to move, 13 of necessity as

part of their life cycle. Of the 78 603 fish recorded in this study (Table 3) only 9 individuals would never move through the mouth at some stage of their life history.

Concentrations of migratory fish always attract predators. Thus, the closure, or partial closure of a migration passage may not simply delay movement, it can result in mass mortality by stress and predation above and beyond that which occurs naturally. It is vital to the ecology of any river such as the Rakaia, and possibly to a much wider environment, that the mouth remain open for fish passage at all times, since migrations occur in all seasons.

Water abstraction for irrigation is likely to extend from September to April. During this period, the upstream migrations of two species each of whitebait, smelt, bullies and eels, and also of black flounders and salmon take place. Downstream migrations in the same period include the larval movement of whitebait, bullies, smelt and torrentfish, and the outmigration of juvenile salmon. Adult eels also migrate to sea towards the end of this period.

Other movements which occur during summer are those of kahawai and mullet. Exclusion of the few kahawai which enter the lagoon would be of little consequence to the ecology of the lagoon or to the species, but exclusion of mullet would eliminate the small recreational fishery for this species and possibly could have an effect on the species itself, if temporary freshwater residence is a necessary feature of its life history.

Some consequences of river mouth closure were dramatically illustrated by the decline of the Ashburton River salmon fishery between 1967 and 1981 (Eldon, Davis and Unwin 1982). Salmon are a large and much sought after game fish for which there is much documentation of facts. Fewer data for other species do not mean they are less affected by reduced flows, but simply that the effects are less well known. Although the Rakaia Lagoon is not in itself a crucial habitat for fish, because of its limited area, the mouth is essential in providing access to and from the sea for the migratory populations of fish inhabiting the Rakaia River.

9. ACKNOWLEDGEMENTS

We thank Marty Bonnett and other, temporary, staff who assisted occasionally in the field, Steve Knight for laboratory analysis of fish stomach contents and Chris Kime for drafting the figures for this report.

10. LITERATURE CITED

- Barnes, R.S.K. 1980. Coastal Lagoons. Cambridge University Press. 106 pp.
- Boud, R., Eldon, G.A. and Watson, R.C. Undated. (1958). An investigation of the trout food supply in Lakes Clearwater, Emma and Camp. N.Z. Marine Department, Freshwater Fisheries Advisory Service, Investigation Report Job No. 11. 8 pp.
- Cairns, D. 1941. Life-history of the two species of New Zealand fresh-water eel. Part I. - Taxonomy, age, and growth, migration and distribution. N.Z. Journal of Science and Technology B23(2): 53-72.
- Cudby, E.J. and Strickland, R.R. In preparation. The Manganui-a-te-Ao fishery. N.Z. Ministry of Agriculture and Fisheries, Fisheries Environmental Report No. 14.
- Davis, S.F. 1979. Fish and fishery values of the Rakaia River: A preliminary report. N.Z. Ministry of Agriculture and Fisheries, Fisheries Environmental Report No. 2. 52 pp.
- Davis, S.F. 1980. The Rakaia River whitebait fishery. Freshwater Catch No. 8: 15-16.
- Eldon, G.A. 1979. Food of the Canterbury mudfish, *Neochanna burrowsius* (Salmoniformes: Galaxiidae). N.Z. Journal of Marine and Freshwater Research 13(2): 255-261.

- Eldon, G.A., Davis, S.F. and Unwin, M.J. 1982. Submission on the Ashburton River water allocation plan. N.Z. Ministry of Agriculture and Fisheries, Fisheries Environmental Report No. 23. 32 pp.
- Gorman, T.B.S. 1962. Yellow-eyed mullet *Aldrichetta forsteri* (Cuvier and Valenciennes) in Lake Ellesmere. N.Z. Marine Department, Fisheries Technical Report No. 7. 20 pp.
- Galloway, J.R. 1979. Salmon research at Glenariffe. N.Z. Ministry of Agriculture and Fisheries, Fisheries Research Division Information Leaflet No. 8. (2nd Ed.). 19 pp.
- Griffiths, W.E. 1976. Food and feeding habits of European perch in the Selwyn River, Canterbury, New Zealand. N.Z. Journal of Marine and Freshwater Research 10(3): 417-428.
- Hughes, H.R., McColl, R.H.S., Rawlence, D.J. 1974. Lake Ellesmere, Canterbury, New Zealand. A review of the lake and its catchment. Department of Scientific and Industrial Research Information Series No. 99. 27 pp.
- Jellyman, D.J. and Todd, P.R. 1982. New Zealand freshwater eels: Their biology and fishery. N.Z. Ministry of Agriculture and Fisheries, Fisheries Research Division Information Leaflet No. 11. 19 pp.
- Jolly, V.H. 1967. Observations on the smelt *Retropinna lacustris* Stokes. N.Z. Journal of Science 10(1): 330-355.
- Kilner, A.R. and Akroyd, J.M. 1978. Fish and invertebrate macrofauna of Ahuriri Estuary, Napier. N.Z. Ministry of Agriculture and Fisheries, Fisheries Technical Report No. 153. 79 pp.
- Knox, G.A. and Kilner, A.R. 1973. The Ecology of the Avon-Heathcote Estuary. Report to the Christchurch Drainage Board by the Estuarine Research Unit, University of Canterbury, Christchurch. 358 pp.

- McDowall, R.M. 1965. The composition of the New Zealand whitebait catch, 1964. N.Z. Journal of Science 8(3): 285-300.
- McDowall, R.M. 1968. *Galaxias maculatus* (Jenyns), the New Zealand whitebait. N.Z. Marine Department, Fisheries Research Bulletin No. 2. 84 pp.
- McDowall, R.M. 1978. New Zealand Freshwater Fishes - A Guide and Natural History. Heinemann Educational Books, Auckland. 230 pp.
- McDowall, R.M. and Eldon, G.A. 1980. The ecology of whitebait migrations (Galaxiidae: *Galaxias* spp.). N.Z. Ministry of Agriculture and Fisheries, Fisheries Research Division Bulletin No. 20. 172 pp.
- McMillan, H.M. 1961. An addition to the knowledge of the fish *Retropinna anisodon* Stokell (Retropinnidae). Transactions of the Royal Society of N.Z. (Zoology) 1: 139-144.
- Mair, F.L.S. 1880. Notes on fishes in the upper Whanganui River. Transactions and Proceedings of the N.Z. Institute 12: 315-316.
- North Canterbury Catchment Board. 1974. Rakaia River Water Management Plan. 5 pp, plus figs.
- Phillipps, W.J. 1929. Notes on the freshwater fish papanoko (*Cheimarrichthys fosteri* Haast). N.Z. Journal of Science and Technology 11: 166-168.
- Ryan, P.A. 1974. The fish of Lake Ellesmere, Canterbury. Mauri Ora 2: 131-136.
- Sagar, P.M. and Eldon, G.A. In preparation. Food and feeding of fish in the Rakaia River, New Zealand. N.Z. Journal of Marine and Freshwater Research.
- Stephens, R.T.T. 1982. Reproduction, growth and mortality of the common bully, *Gobiomorphus cotidianus* McDowall, in a eutrophic New Zealand lake. Journal of Fish Biology 20(3): 259-270.

- Sibert, J., Kask, B.A., and Brown, T.J. 1977. A diver-operated sled for sampling the epibenthos. Fisheries and Marine Service Technical Report 738. Pacific Biological Station, Fisheries and Marine Service Research and Resources Services, Nanaimo, B.C.
- Stokell, G. 1955. Freshwater Fishes of New Zealand. Simpson and Williams, Christchurch. 145 pp.
- Tarplee, W.H., Bryson, W.T. and Sherfinski, R.G. 1979. Portable push-net apparatus for sampling ichthyoplankton. The Progressive Fish Culturist 41(4): 213-215.
- Todd, P.R. 1979a. Wanganui lamprey fishery. Catch '79: 19-20.
- Todd, P.R. 1979b. Lake Ellesmere's flounder fishery. Freshwater Catch No. 5: 7.
- Todd, P.R. 1980. Size and age of migrating New Zealand freshwater eels (*Anguilla* spp.). N.Z. Journal of Marine and Freshwater Research 14(3): 283-293.
- Unwin, M.J. 1980. Rakaia angler survey. Freshwater Catch No. 6: 9-10.
- Unwin, M.J. 1981. Rakaia angler survey. Freshwater Catch No. 12: 3-4.
- Unwin, M.J. and Davis, S.F. In preparation. Recreational fisheries of the Rakaia River. N.Z. Ministry of Agriculture and Fisheries, Fisheries Environmental Report.
- Webb, B.F. 1972. Fish populations of the Avon-Heathcote estuary. 1. General ecology, distribution and length-frequency. N.Z. Journal of Marine and Freshwater Research 6(4): 570-601.
- Webb, B.F. 1973a. Fish populations of the Avon-Heathcote estuary. 2. Breeding and gonad maturity. N.Z. Journal of Marine and Freshwater Research 7(1 & 2): 45-66.

- Webb, B.F. 1973b. Fish populations of the Avon-Heathcote estuary. 3. Gut contents. N.Z. Journal of Marine and Freshwater Research 7(3): 223-234.
- Webb, B.F. 1973c. Fish populations of the Avon-Heathcote estuary. 4. Parasites. N.Z. Journal of Marine and Freshwater Research 7(4): 301-305.
- Webb, B.F. 1973d. Fish populations of the Avon-Heathcote estuary. 5. Records of less common species. N.Z. Journal of Marine and Freshwater Research 7(4): 307-321.
- West, I.F. and Goode, R.H. In preparation. A postal sample survey of anglers fishing for sea-run quinnat salmon (*Oncorhynchus tshawytscha*) on the Rakaia River, Canterbury, New Zealand, for the seasons 1973/74 and 1974/75.

