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Taihoro Nukurangi

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Taihoro Nukurangi

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SUMMARY

The distribution, relative abundance, size, age, growth, and diet of brown and rainbow trout were established from gillnet surveys at fifteen sites around the shores of Lake Pukaki between 18 November 1982 and 26 June 1984. Redd counts were also conducted in some of the lake tributaries to identify the main spawning streams.

Brown trout outnumbered rainbow trout at all sites, with the species composition of the catch ranging from 69% brown trout at Tekapo B to 93% at lake shore sites.

Rainbow trout were smaller (mean length 282 mm and mean weight 283 g) and younger (1+ to 3+ years), than brown trout (336 mm, 501 g, and 1+ to 5+ years). Brown trout netted at stream mouth sites were significantly larger than those netted at Tekapo B and lake shore sites. Rainbows did not differ in size between the three sites.

Catch rates of trout were highest at Tekapo B, somewhat lower at stream mouths, and least at lake shore sites. Catch rates of trout in Lake Pukaki were lower than those recorded at comparable sites in other major lakes in the upper Waitaki catchment.

The stomach contents of trout differed between lake shore, stream mouth and Tekapo B sites. Bullies and galaxiids were preyed on at lake shore sites, and bullies and aquatic insect larvae at stream mouth sites, while galaxiids and terrestrial insects were the most common prey items at Tekapo B.

Redd counts suggested that the Jollies River, Glentanner Stream, and Ackland Tarn Stream are the main spawning tributaries for Lake Pukaki trout.

1. INTRODUCTION

Lake Pukaki is a large glacial lake situated in the headwaters of the upper Waitaki catchment (Fig. 1) (Jolly and Brown 1975). The level of the lake has been raised by 46 m to increase its water storage capacity for hydro-electric power generation, and it now has an area of 17 680 ha and a maximum depth of 108 m. Lake Pukaki is now the most important storage reservoir in New Zealand with lake levels currently fluctuating over 14 m. A feature of the lake is its milky-blue colour which is caused by a high concentration of fine glacial silt suspended in the water.

Lake Pukaki has usually been considered to have an insignificant recreational fishery because of its turbid water, eroded and fluctuating shoreline, and low fish numbers (Jowett 1978). A few anglers fish mouths of streams flowing into the lake, although the results of an angler diary scheme (Bloomberg *et al.* 1983) indicated that trout taken were in extremely poor condition.

Although the lake has limited fisheries significance, the New Zealand Electricity Division of the Ministry of Energy, now Electricity Corporation of New Zealand (ECNZ), funded this investigation of the lake's trout stocks as part of a five-year study programme designed to document the fish stocks and fisheries of the upper Waitaki catchment. This report describes data collected on the distribution, abundance, size, age, growth and diet of brown and rainbow trout in the lake. It also compares these with similar data from other waters in the region.

2. METHODS

Fifteen sites were selected around the shore of Lake Pukaki (Fig. 1). These sites were chosen to be representative of the three main types of littoral habitat in the lake: stream mouths (sites 4, 5, 7, 8, 10, 12); lake shore (sites 1, 2, 3, 6, 9, 11, 13, 15) and in the tailrace of the Tekapo B power station (site 14).

Stream mouth sites were located where small tributaries flowed into the lake and were characterised by relatively clear water (Secchi depth range 0.8 - 3.5 m), with low water velocity. Lake shore sites were chosen randomly, with the only condition that they were some distance from stream mouths and Tekapo B. Such sites were typical of most of the lake's shoreline and were characterised by comparatively still, turbid (0.3 - 0.7 m) water. The Tekapo B site was atypical of the lake's littoral zone, since it had clearer water (0.7 - 0.9 m) and a moderate flow velocity.

A preliminary netting survey was carried out at sites 6 and 14 in November and December 1982, otherwise all sites were netted at three- to four-month intervals from July 1983 to June 1984.

A sinking monofilament gill net (100 m long by 2 m deep with 65 mm stretched mesh) was set during daylight hours at right angles to the shore at each site. The net was lifted after a set of approximately one hour. Netted fish were identified to species, measured to the nearest millimetre (fork length), weighed to within 10 g, and then returned to the lake. Trout greater than 300 mm fork length were tagged just below

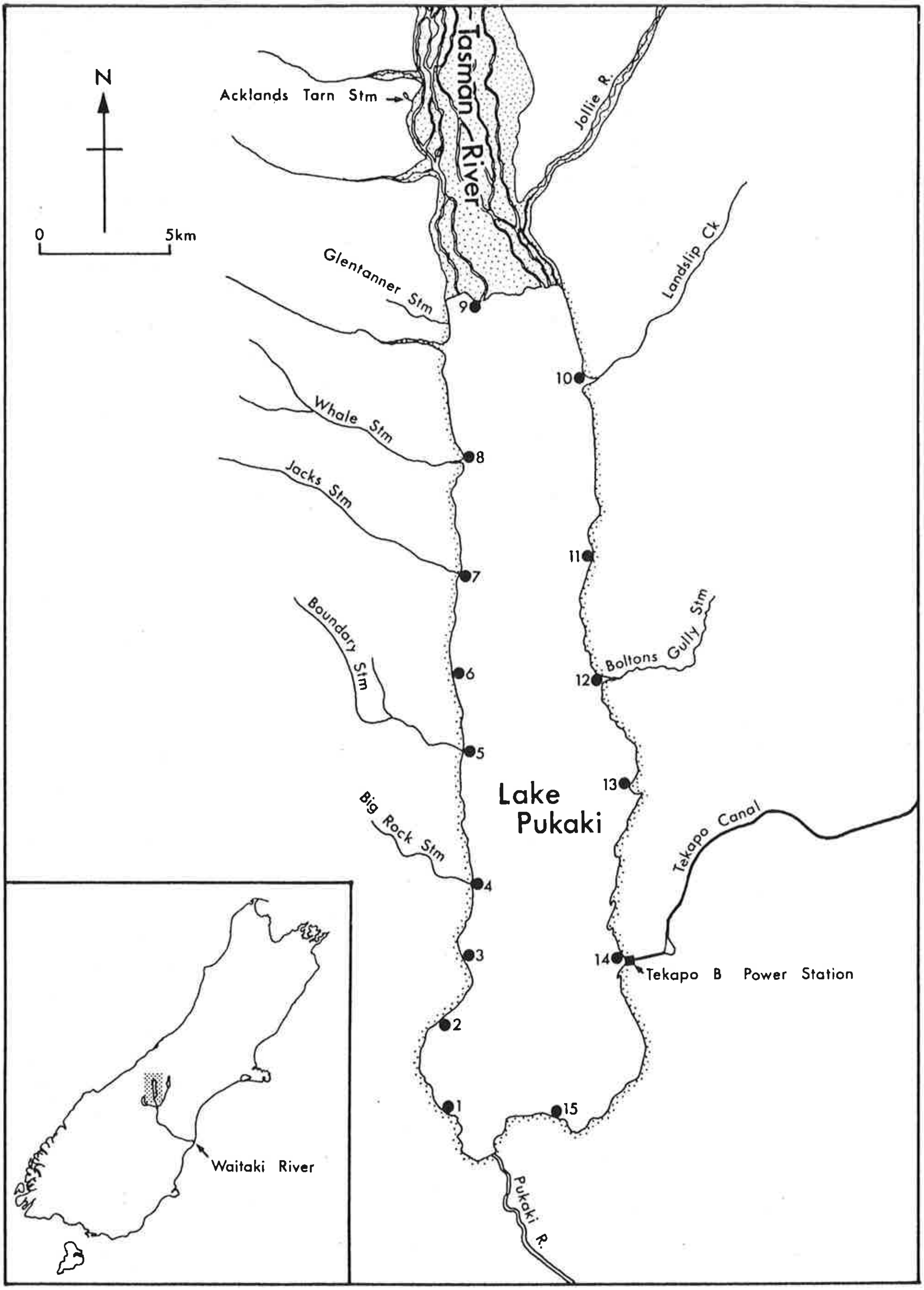

FIGURE 1. Map of Lake Pukaki showing the location of netting sites.

the dorsal fin with a numbered Floy anchor tag. A return address was printed on the tags, so that anglers could send recapture details to MAF, Oamaru.

Scales were taken from 43 brown and 11 rainbow trout for estimation of age and growth. Scales were removed from between the dorsal fin and lateral line, dry mounted between glass microscope slides and examined under ×40 power using a Projectina-Optik micro-projector. Scale measurements were made along the anterior axis from the focus to each annulus and to the edge of the scale, and age was estimated (see Tesch 1968 for a description of ageing technique). Replacement scales and scales which were unreadable (n = 23) were discarded.

Length at age was back calculated from scales, using the following formula (Tesch 1968):

$$L_n - c = S_n / S (L - c)$$

where:

L_n = length of trout when annulus n was completed;

L = length of fish at time scale was obtained;

S_n = radius from scale focus to completed annulus n;

S = scale radius;

c = correlation factor for allometric growth, which is equal to the y intercept of the regression line of trout length on scale radius. The c values used were: brown trout 24.6 mm (r = 0.97) and rainbow trout 24.5 mm (r = 0.98), as derived by S. Bloomberg.

The condition factor of trout was calculated using the formula:

$$CF = \frac{W * 10^7}{L^3}$$

where CF is condition factor, W is weight in grams, and L is fork length in millimetres.

The stomachs of eight brown and seven rainbow trout which died in the nets between October 1983 and March 1984 were removed and preserved in 10% formalin. Stomachs were later dissected and their contents identified (at least to taxonomic Order), and allotted points according to the proportion of the stomach contents they represented by volume (Hynes 1950).

Surface water temperatures and a Secchi disc reading were recorded at each site after netting was completed.

Redd counts were conducted in some of the spawning tributaries of Lake Pukaki from June 1979 to June 1982. Counts were carried out on foot and the number of redds and distance surveyed were recorded.

3. RESULTS

3.1 Number, species composition and size of netted trout

A total of 155 brown trout and 39 rainbow trout was netted from November 1982 to June 1984 (Table 1). Species composition of the catch differed between habitat types, and ranged from 69% brown trout at Tekapo B to 78% at stream mouths and 93% at lake shore sites.

TABLE 1. Number, mean length, weight, and condition factor of brown and rainbow trout netted at each type of habitat.

Habitat type	Species	Number of trout netted	Mean length ± SD (mm)	n	Mean weight ± SD (mm)	n	Mean condition factor ± SD	n
Lake shore	Brown trout	54	304 ± 51	53	336 ± 210	53	117 ± 12	51
	Rainbow trout	4	266 ± 266	4	218 ± 102	4	114 ± 15	4
Stream mouth	Brown trout	58	359 ± 110	54	694 ± 584	53	118 ± 12	53
	Rainbow trout	16	286 ± 50	16	307 ± 154	15	120 ± 17	15
Tekapo B	Brown trout	43	314 ± 656	43	395 ± 112	42	117 ± 14	42
	Rainbow trout	19	282 ± 45	19	277 ± 136	19	115 ± 8	8

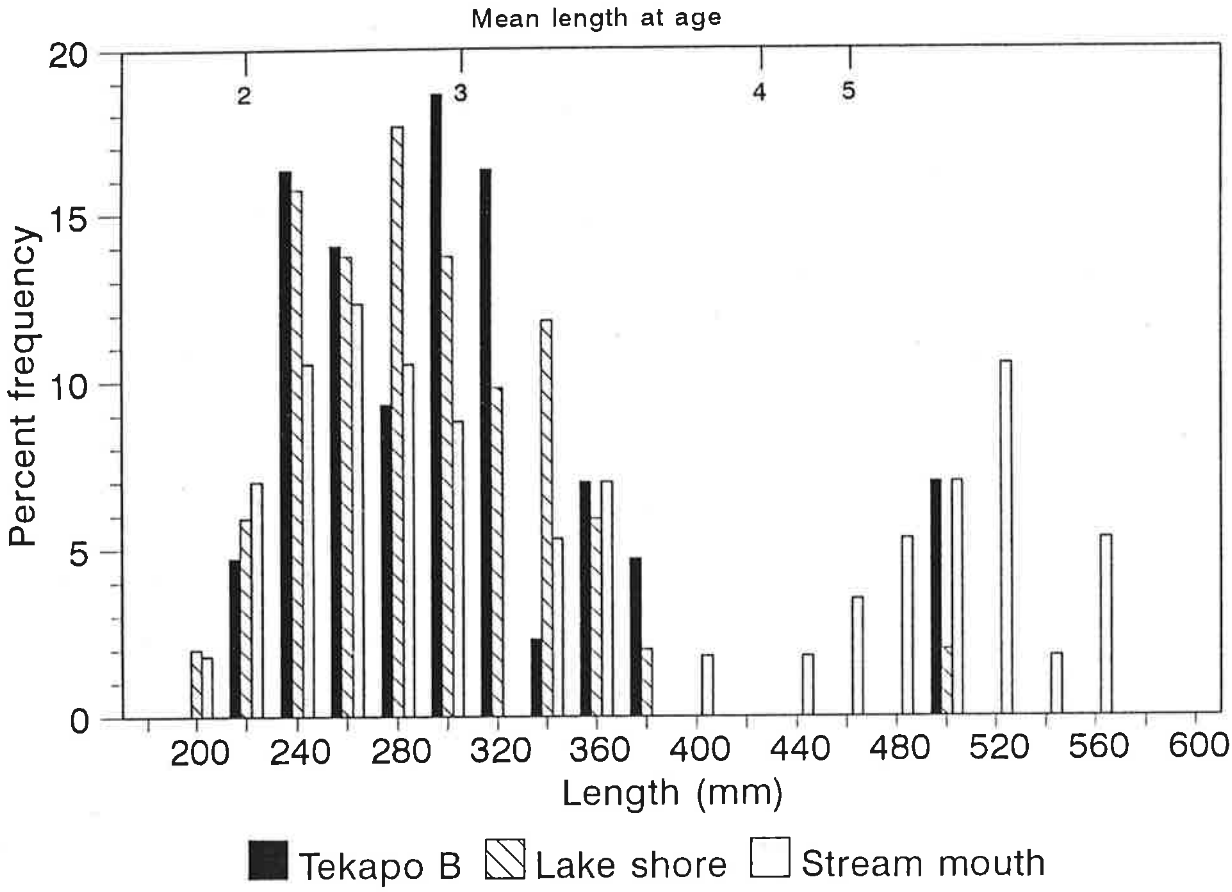

FIGURE 2. Length-frequency distribution of brown trout netted at each habitat.

Length-frequency data for brown trout (Fig. 2) showed that most large fish were captured near stream mouths. Mean length and weight of brown trout netted at stream mouths were therefore larger than those of trout captured elsewhere (Table 1). Condition factors of brown trout averaged 117 and did not differ greatly between sites or sampling periods. Mean length and weight of brown trout (327 mm and 482 g) were larger than rainbow trout (282 mm and 283 g), and this was due to the complete absence of large rainbows (>360 mm) in the catches (Fig. 3). The mean length and weight and length-frequency distribution of rainbow trout did not differ markedly between habitats, although mean condition factor was slightly higher at stream mouths than at lake shore sites and Tekapo B.

The length-weight relationship was determined by linear regression to be:

for brown trout,

$$\log W = -4.52 + 2.83 \log L \ (r = 0.99)$$

and for rainbow trout,

$$\log W = -5.04 + 3.04 \log L \ (r = 0.97),$$

where L is length in millimetres and W is weight in grams.

3.2 Catch per unit effort

Mean catch per unit effort (CPUE) differed widely between habitat types, varying from 1.7 fish/hour at lake shore sites to 3.2 fish/hour at stream mouths to 6.3 fish/hour at Tekapo B (Table 2). A CPUE of zero was

TABLE 2. Mean catch per unit effort (fish/100 m net/hour) for each sampling period and type of habitat.

		Habitat type		
Season	Sampling period	Lake shore	Stream mouths	Tekapo B
Summer	18 Nov 1982	1.0	-	-
Summer	19 Dec 1982	-	-	6.3
Winter	26 Jul-29 Jul 1983	0.4	1.3	2.0
Spring	18 Oct-30 Nov 1983	1.3	3.9	5.8
Summer	22 Feb-07 Mar 1984	2.5	4.6	9.0
Autumn	28 Jun 1984	2.4	2.4	4.0
Mean		1.7	3.2	5.4

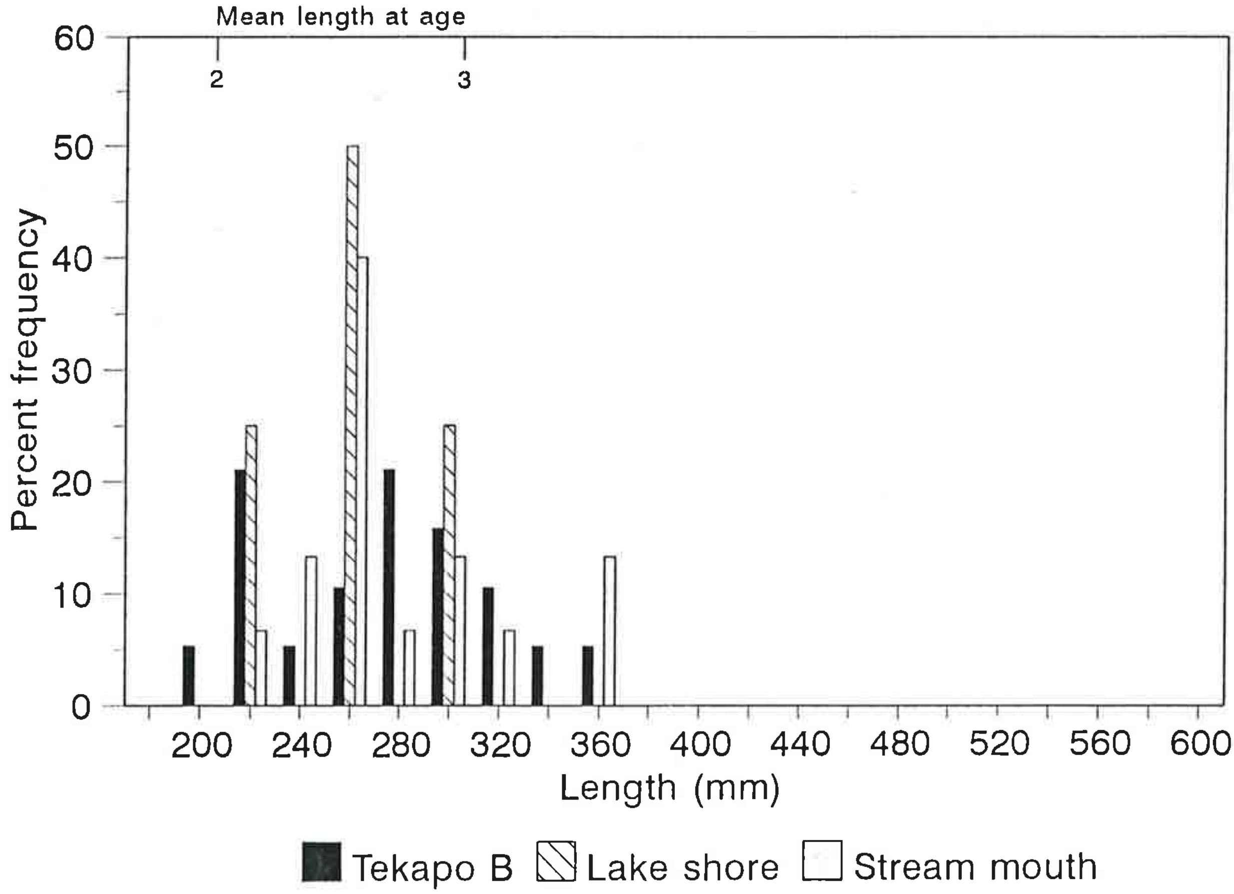

FIGURE 3. Length-frequency distribution of rainbow trout netted at each habitat.

recorded on numerous occasions while the highest catch rate was 10.3 fish/hour at Tekapo B on 9 December 1982.

Mean CPUE was directly related to water temperature. It was lowest in July 1983 and June 1984 and highest in February-March 1984 (Fig. 4). A similar seasonal change in gillnet catch rates was recorded in Lakes Benmore (McCarter 1987), and Ruataniwha (E. Graynoth pers. comm.) and has been partly attributed to the effect of water temperature on biological activity.

3.3 Age and growth of trout

Brown trout were aged from 1+ to 5+ years and had mean back-calculated lengths at age of 101, 214, 312, 428 and 459 mm at ages 1 to 5 years, respectively (Table 3). Rainbow trout were aged 1+ to 3+ years and had mean back-calculated lengths at age of 87, 192 and 299 mm at ages 1, 2 and 3 years respectively. The number of trout aged was too small to compare growth rates at the three different types of sites.

Length-frequency distributions with superimposed mean back-calculated lengths at age (Fig. 2) suggested that brown trout mostly were aged 2+ to 3+ years, with some of the larger fish netted at stream mouth sites being older than the maximum estimated age of 5+ years. This, and two recaptures of tagged fish (Section 3.5) after long periods at liberty, supports the view that ages of larger brown trout, as determined from scales, may be considerable underestimates. Based on the length-frequency distributions, it is unlikely that any rainbow trout caught were older than 3+ years of age (Fig. 3).

3.4 Stomach contents analysis

Stomach contents of the eight brown trout and seven rainbow trout examined were pooled by species and sampling date (Table 4). The diet of trout netted at lake shore sites consisted exclusively of small fishes which were often difficult to identify but appeared to be either bullies or galaxiids. Trout netted at stream mouths had eaten bullies, mayfly and caddisfly larvae, and a few stonefly and dipteran larvae. Fish netted at Tekapo B had eaten galaxiids and terrestrial beetles and small numbers of adult diptera and caddisfly larvae. Stomach fullness averaged 4.1 (range 1-8) and was slightly lower at lake shore sites than at stream mouths and Tekapo B.

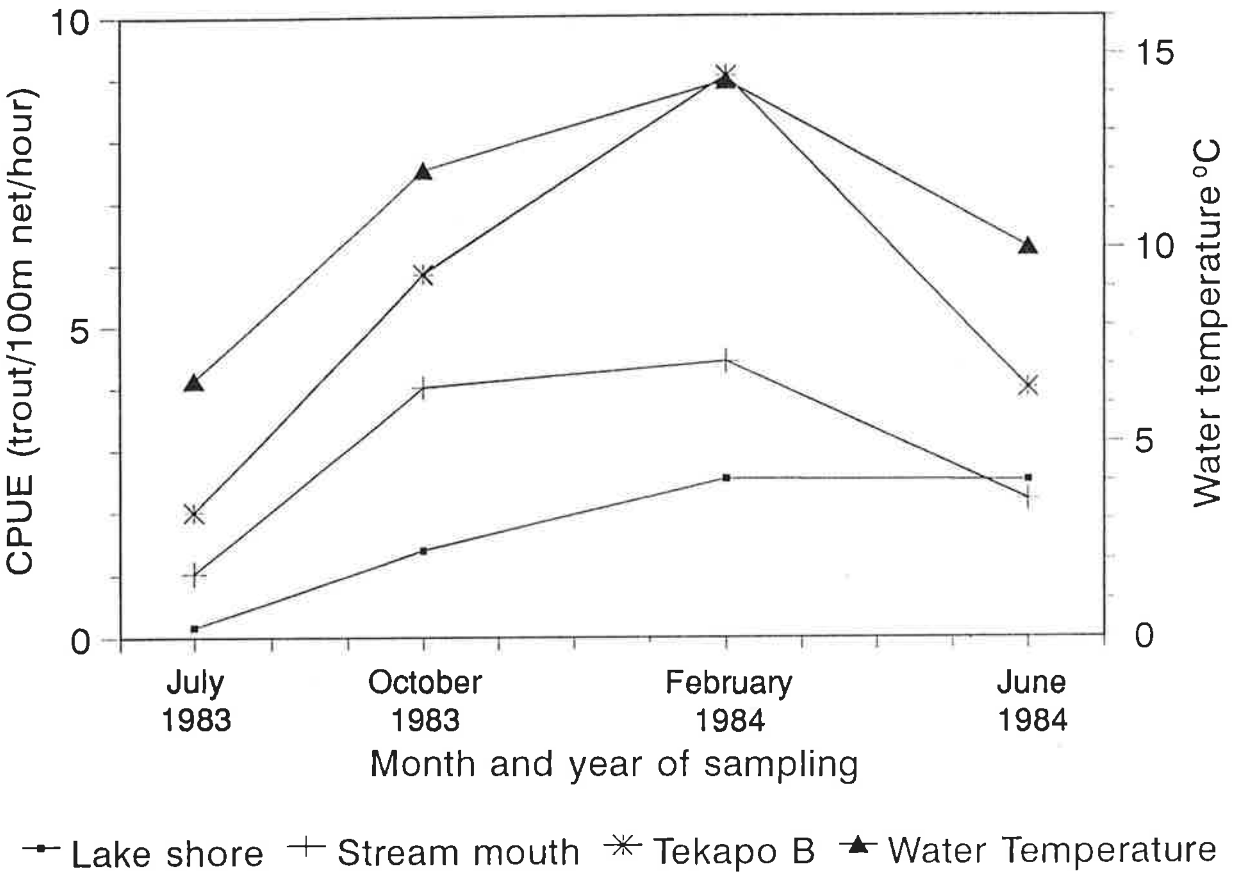

FIGURE 4. Seasonal changes in mean catch per unit effort (CPUE) and water temperatures in Lake Pukaki.

TABLE 3. Age, mean length at capture and mean back-calculated length at age of trout sampled in Lake Pukaki.

Species	Age at capture (year)	Number of trout aged	Mean length at capture ± SD (mm)	Age (years) Mean back-calculated length at age ± SD (mm) 1	2	3	4	5
Brown trout	1+	3	239 ± 25	93 ± 2				
	2+	7	288 ± 35	95 ± 17	194 ± 21			
	3+	8	343 ± 43	102 ± 32	221 ± 59	299 ± 51		
	4+	3	470 ± 105	114 ± 48	228 ± 75	333 ± 99	437 ± 108	
	5+	3	502 ± 9	110 ± 17	225 ± 33	329 ± 40	418 ± 33	459 ± 17
Mean ± SD				101 ± 26	214 ± 47	312 ± 59	428 ± 72	459 ± 17
Annual increment				101	113	98	116	31
Rainbow trout	1+	1	244	94				
	2+	4	298 ± 35	88 ± 2	191 ± 15			
	3+	2	351 ± 16	81 ± 16	195 ± 7	299 ± 18		
Mean ± SD				87 ± 8	192 ± 13	299 ± 18		
Annual increment				87	105	103		

TABLE 4. Stomach contents of brown and rainbow trout netted at each type of habitat.

	Probable source of prey	Habitat type Lake shore	 Stream mouth	 Tekapo B
Number of stomachs examined		6	6	3
Mean stomach fullness (range)		3.8 (1-8)	4.2 (2-7)	4.3 (3-6)
Food type (% abundance by volume)				
Fish				
Gobiomorphus sp.	lake	83.0	49.2	-
Galaxias sp.	lake	17.0	-	33.0
Insects				
Coleoptera adults	terrestrial	-	-	65.0
Diptera adults	terrestrial	-	-	0.5
Diptera larvae				
Neocurupira sp.	tributary stream	-	0.9	-
Ephemeroptera larvae				
Nesameletus sp.	tributary stream	-	15.8	-
Unidentified sp.	tributary stream	-	8.3	-
Plecoptera larvae				
Megaleptoperla diminuta	tributary stream	-	0.3	-
Spaniocercoides hudsoni	tributary stream	-	0.8	-
Tricoptera larvae				
Confluens olingoides	tributary stream	-	1.7	-
Hudsonema aliena	tributary stream	-	0.8	-
Olinga feredayi	tributary stream	-	14.8	-
Philorheithrus agilis	tributary stream	-	1.7	-
Pycnocentria evecta	tributary stream	-	4.4	1.5
Hydrobiosidae	tributary stream	-	1.3	-

3.5 Recaptured trout

Altogether, 88 brown trout and 22 rainbow trout were tagged between November 1982 and June 1984 at 14 sites around Lake Pukaki (Table 5). Four brown trout, but no rainbow trout, were reported recaptured by anglers (Table 6). One of the brown trout was recaptured twice, the first time during the gillnetting programme and the second by an angler. Two of the recaptures were made within three years of release, while the other two were some six to eight years later. All four recaptures were of fish tagged at stream mouths, and all four were recaptured at their original tagging site (Table 6).

The mean annual growth rate of the smallest brown trout (a 320 mm female) was 46 mm per summer at liberty. A 493 mm male grew by about 27 mm per summer, while the two larger males (505 and 541 mm when tagged) which were at liberty for six to eight years, grew by only 8 - 9 mm per summer. The growth rates for the two fish which were at liberty for three summers or less, were comparable to the mean back-calculated growth rates of similar sized trout. However, the measured growth rates of the two larger, older, brown trout at liberty for six to eight years, were much less than the back-calculated growth rates estimated from scales for the oldest fish aged. This suggests that ages estimated from the scales of older

TABLE 5. Numbers of trout tagged and released at sites in Lake Pukaki between November 1982 and June 1984.

	Site																
Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Brown trout	1	0	3	5	8	6	12	7	0	1	3	5	7	4	25	1	88
Rainbow trout	0	0	1	0	5	1	0	2	0	0	0	0	0	0	13	0	22

TABLE 6. Details of brown trout recaptured from the tagging programme in Lake Pukaki in 1982-84.

	Trout no. (in order of release date)				
	1	2		3	4
Sex	F	M		M	M
Release data					
Date	18.11.82	26.10.83		30.11.83	07.03.84
Site	5	7		10	5
Length (mm)	320	493		541	505
Weight (g)	380	1460		1640	1500
Condition factor	116	122		101	116
Recapture data					
Date	09.02.85	28.06.84	11.02.85	14.04.90	29.04.92
Site	5	7	7	10	5
Length (mm)	457	520	-	600*	580*
Weight (g)	1022	1880	2384*	1600*	1700*
Condition factor	107	134	-	74	87
Recapture method	A	G	A	A	A
Days at liberty	813	245	228	2325	2973
Length change (mm)	137	27	-	59*	75*
Weight change (g)	642	420	504*	-40*	200*
Length change (mm/yr)	61	40	-	9*	9*
Length change/summer at liberty (mm)	46	27	-	8*	9*

A = angler recapture.
G = research gillnet.
* = data based on angler estimates.

fish are probably considerable underestimates. A likely cause is erosion of scale margins with increasing age.

3.6 Redd surveys

Redd surveys showed that trout spawned in the Jollie River and Glentanner and Acklands Tarn Streams (Table 7). The highest numbers were seen in sections of the Glentanner Stream where up to 47 redds per kilometre were recorded.

Low water clarity prevented redd counts in most sections of the Tasman River. However, a 0.5 km reach of clear water, downstream of the Acklands Tarn Stream confluence, was surveyed and no redds were observed.

A few redds were seen at the mouths of Boundary and Jacks Streams where clear water and suitable sized substrate were present. However, no redds were observed upstream of the lake in these tributaries

TABLE 7. Summary of redd counts conducted in spawning tributaries of Lake Pukaki from June 1979 to June 1982.

Month	Year	Area surveyed	Distance surveyed (km)	Number of redds observed	Redds/km
June	1979	Jollie River - bridge upstream	2.0	9	4.5
		Jollie River - springfed stream	1.5	4	2.7
		Glentanner Stream - river to culvert	1.0	47	47.0
Sept	1980	Jollie River - bridge upstream	4.0	27	6.8
		Jollie River - springfed stream	1.5	31	20.7
		Glentanner Stream - river to culvert	1.0	26	26.0
		Acklands Tarn Stream - outlet to Tasman River	1.5	40	26.7
		Boundary Stream - mouth	-	3	-
		Jacks Stream - mouth	-	7	-
Jun/Jul	1981	Jollie River - bridge upstream	2.0	0	-
		Jollie River - springfed stream	1.5	8	5.3
		Glentanner Stream - river to culvert	1.0	9	9.0
		Acklands Tarn Stream - outlet to Tasman River	1.5	10	6.7
Sept	1981	Glentanner Stream - river to culvert	1.0	13	13
		Acklands Tarn Stream - outlet to Tasman River	-	9	-
		Tasman River - Acklands Tarn Stream confluence downstream	0.5	0	-
June	1982	Acklands Tarn Stream - outlet to Tasman River	1.5	9	6

because they were either too shallow or too steep for upstream migration and spawning.

4. DISCUSSION

Catch rates, usually expressed as catch per unit effort (CPUE), are often used as an index of fish abundance even though they are affected by such factors as water clarity and fish movements (Ryan 1984). CPUE in Lake Pukaki indicated that trout were most abundant at Tekapo B and stream mouths where there would have been a comparatively good supply of food. The mean catch rate at lake shore sites was only 1.7 fish/100 m net/hour, which is several times lower than that recorded in other lakes in the catchment (Table 8), and 16 times less than that in Lake Alexandrina which supports high densities of trout. Such values indicate that trout densities throughout most of Lake Pukaki were extremely low.

This result is not surprising since Pukaki is one of the most turbid and oligotrophic lakes in the South Island (Timms 1982). The catchment of this lake is largely undeveloped, the rock basement is greywacke which results in low nutrient levels, while light penetration is limited by high levels of suspended glacial silt. Lakes Tekapo, Ohau, Ruataniwha, and Benmore are also oligotrophic, but they are usually less turbid and more productive than Lake Pukaki.

The turbid and oligotrophic nature of Lake Pukaki also accounts for the comparatively poor condition and slow growth of trout netted in this study (Table 8). It is widely acknowledged that high turbidity levels depress invertebrate and fish populations (Lloyd *et al.* 1987). Lake Pukaki has an extremely depauperate benthic invertebrate fauna in terms of both biomass and species diversity (Timms 1982) and many important prey species for trout are absent (e.g., *Physa* sp., *Gyraulus corinna*, *Lymnaea stagnalis* (Gastropoda), *Pisidium* sp. (Bivalvia), and *Macroplelopia* sp. (Diptera). Drift invertebrates were common at stream mouths and Tekapo B, but *Potamopyrgus antipodarum* (Gastropoda), *Phreodrilus mauienensis* (Oligochaeta), and chironomid larvae were the only benthic macroinvertebrates found in Lake Pukaki. McCarter (1986) found that in Lake Benmore, both species of trout fed mainly on small molluscs gleaned from the littoral weed beds. In Lake Pukaki, however, no molluscs were found in the trout stomachs examined, and two of the three snail species found in Benmore were absent from Pukaki altogether.

TABLE 8. A comparison of the species composition, CPUE, mean length, weight, condition factor, and length at age of trout in Lake Pukaki and four other upper Waitaki lakes.

	Pukaki	Alexandrina[1]	Ohau[2]	Ruataniwha[3]	Benmore Haldon Arm[4]	Benmore Ahuriri Arm[4]
Species composition (% rainbow trout)	7-31	91	20-60	45	27	28
CPUE (fish/100 m net/hour)	1.7-5.4	27.2	4.7	4.2	8.6	5.5
Brown trout						
Mean length (mm)	336	430*	296	285	327	326
Mean weight (g)	501	-	308	281	410	434
Mean condition factor	111	130	109	122	111	111
Mean length at age 1	101	171	-	139	128	121
Mean length at age 2	214	326	-	329	258	240
Mean length at age 3	312	388	-	409	325	322
Rainbow trout						
Mean length (mm)	282	335*	336	274	307	287
Mean weight (g)	283	-	500	295	400	316
Mean condition factor	117	120	131	139	125	122
Mean length at age 1	86	231	-	122	128	107
Mean length at age 2	192	346	-	350	265	250
Mean length at age 3	299	422	-	384	375	366

[1] = Page (1986).
[2] = Freshwater Fisheries Research Centre, Oamaru, unpublished data.
[3] = E. Graynoth *et al.* pers. comm.
[4] = McCarter (1987) and Freshwater Fisheries Research, Oamaru, unpublished data.
* = mesh size of nets used in Lake Alexandrina ranged from 25-90 mm.

The scarcity of food in Pukaki is likely to be accentuated by high levels of suspended sediment which reduce the visibility of prey. Trout are visual feeders and low water clarity reduces the reactive distance to a prey organism (Ware 1973). The level of suspended sediments in Lake Pukaki is probably too low to reduce survival rates but could well be high enough to affect growth rates of trout.

The proportion of rainbow to brown trout was considerably less in Lake Pukaki than in other upper Waitaki lakes (Table 8) and rivers (Bloomberg *et al.* 1983). Within Lake Pukaki, rainbow trout were markedly less abundant (22-31% of the catch) than brown trout at stream mouths and Tekapo B, and comprised just 7% of the catch around the rest of the lake shore.

This disparate distribution between littoral habitats may be the result of interspecific competition between brown and rainbow trout. Brown trout have been shown to displace rainbows from preferred habitats when they exist together (Gatz *et al.* 1987). Such interspecific competition is most likely to occur when food is limiting (Larkin 1956), as is likely within the littoral zone of Lake Pukaki. The high turbidity levels could limit food availability by depressing the abundance of prey items, and by limiting the ability of the trout to find food.

The recapture of four tagged brown trout at their original tagging sites, after up to eight years at liberty, supports the inference from the netting data that fish are attracted to, and remain around, the stream mouths, where the food supply is greatest.

The majority of trout in Lake Pukaki are thought to spawn in tributaries of the Tasman River. Streams flowing into Lake Pukaki are too steep and too shallow for upstream migration and spawning, while the Tasman River itself is unsuitable for spawning because it is very unstable and silty. Redds were observed in the Jollies River, Glentanner Stream and Acklands Tarn Stream, suggesting that these were the main spawning areas for trout in Lake Pukaki. However, these tributaries are relatively small, suggesting that the amount of spawning habitat available for trout in Lake Pukaki is limited.

In summary, compared to other large lakes in the upper Waitaki catchment, Lake Pukaki supports low numbers of trout which are in poor condition. A high concentration of suspended sediments appears to be the main reason for this, although other factors such as fluctuating lake levels, low nutrient levels and a lack of spawning habitat may also limit the number and quality of trout. The number and quality of trout in Lake Pukaki suggests that it is unlikely to be highly rated by anglers although trout are moderately abundant around stream mouths and Tekapo B.

5. ACKNOWLEDGEMENTS

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