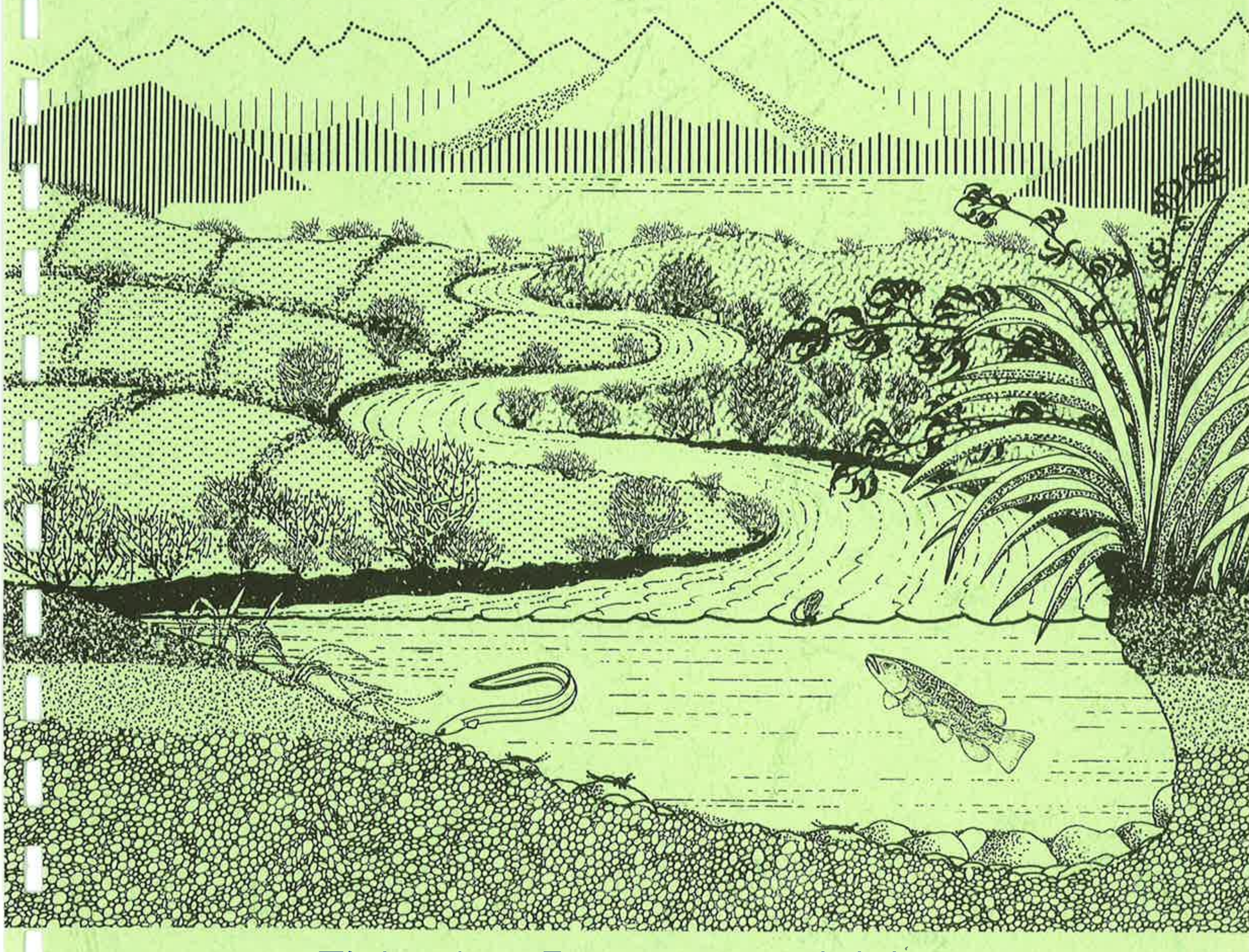
MAF Fisheries Research

The Lake Coleridge fishery

Fisheries Environmental Report No.65



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The Lake Coleridge fishery

by

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1. SUMMARY

Lake Coleridge is the most important sport fishing lake in the North Canterbury district. It is one of a very few lakes in the world where quinnat salmon can be caught from freshwater stocks. The anglers' catch comprises 90% quinnat salmon, 9% rainbow trout, and 1% brown trout. The catch rate of anglers varies from 0.3 to 0.59 fish per hour fished, and 50% of all the season's angling in the lake is done on the opening weekend of the season, the first complete weekend in November. Population estimates for takeable size fish of the three species were:

	1960	1979
Rainbow trout	6089 $\pm$ 2521	4958 $\pm$ 2496
Quinnat salmon	4955	-
Brown trout	2467	14 071

Angling cropping rate was estimated as:

	1960	1979
Quinnat salmon	30%	-
Rainbow trout	4.4%	5.2%
Brown trout	0.32%	0.4%

Mean lengths of angler caught and spawning fish of the three species showed no decline in size over the last thirty years.

Lake edge spawning does not occur, and no suitable areas for it were found in the lake.

Examination of management practices showed that stocking with rainbow trout contributed less than 1% return to the angler or to the

adult spawning runs. Bag limits were ineffective for managing the populations because they are so lightly exploited. Size limits similarly were unnecessary for salmon or trout. Bag and size limits are still part of the fishing regulations.

The impact of the Wilberforce diversion has been to create dirty water on occasions in two prime fishing areas, the Harper corner of the lake and the Lake Stream-O'Rourkes fan area. The diversion has allowed permanent egress for fish from the lake, but the extent to which it is used for this is unknown. The diversion has also allowed the lake to be held at its upper limit for extended periods and this has resulted in shoreline erosion with increased turbidity of the whole lake. It has affected fishing by confining angling to an increased shallow water area.

2. INTRODUCTION

Lake Coleridge lies 130 kilometres west of Christchurch (Fig.1). It supports an important recreational fishery for landlocked quinnat salmon, rainbow trout, and brown trout. Graynoth and Skrzynski (1974) and the Octa Associates Ltd (1976) list the lake as the most popular high country fishing lake in the North Canterbury district. Lake Coleridge is of particular value to anglers because three salmonid species may be caught in the one lake.

Management of the fishery is carried out by the North Canterbury Acclimatisation Society (NCAS), with some technical advice being provided by Fisheries Research Division (FRD). Before 1973, fisheries advice was provided by the Marine Department. This report presents the results of investigations begun in 1965 by the Fisheries Management

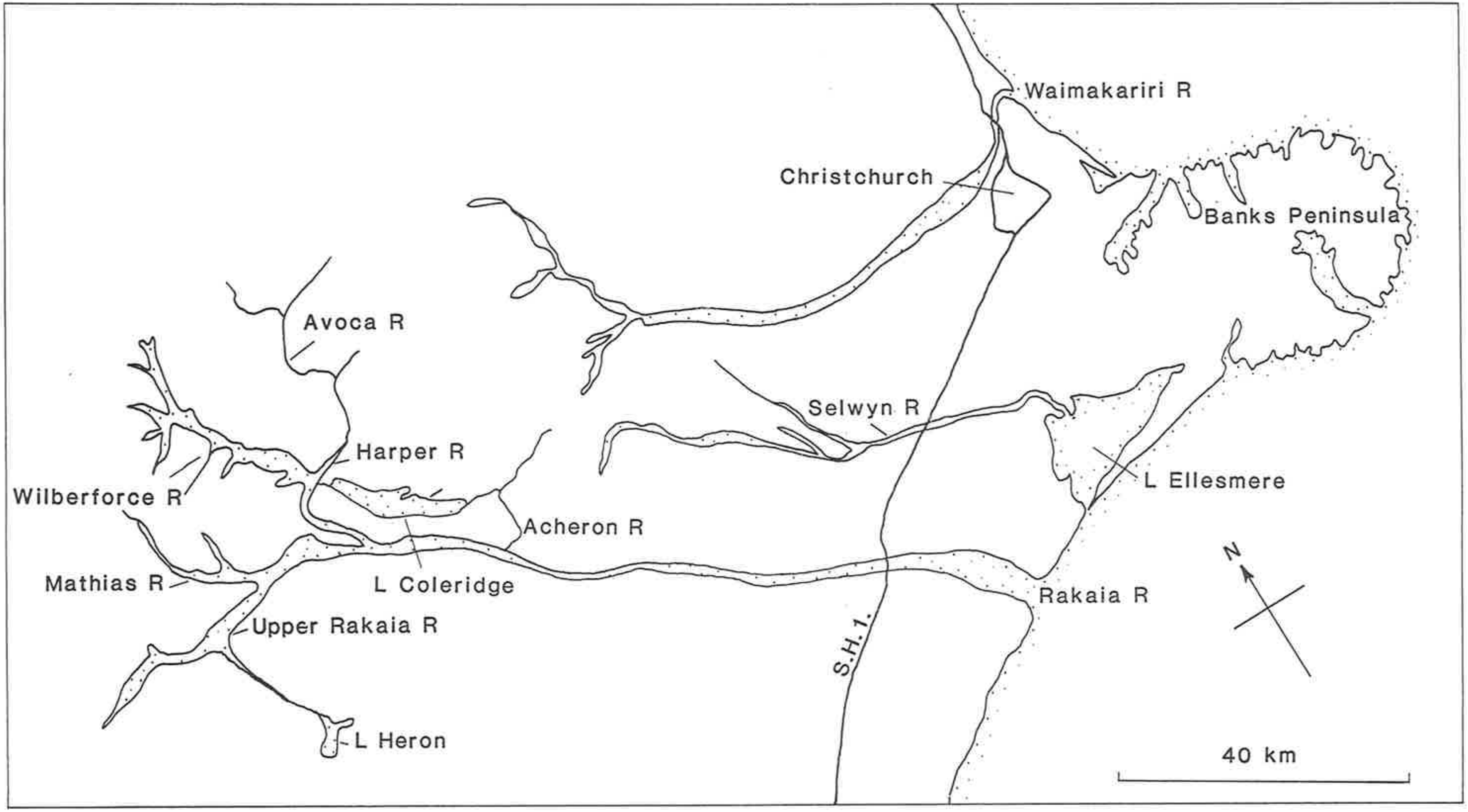

FIGURE 1. Locality map.

Division of the Marine Department to provide information for management of the salmonid fisheries. The NCAS required data on species catch composition, catch rates, population estimates of takeable sports fish, species growth rates, size restrictions, bag limits, stocking, and lake edge spawning. Information was also required on the impact of hydro-electric power (HEP) development on the recreational fishery. Comparative information found in scattered publications and often given in imperial measurements was converted into metric values and compiled with the material gathered during the investigation.

Recently Lake Coleridge has been included in investigations by the North Canterbury Catchment Board (Bowden 1983, Cathcart 1983) in relation to management proposals for the Rakaia River catchment.

3. LAKE COLERIDGE

3.1 Physical Characteristics

Lake Coleridge is glacial in origin (Haast 1865); its basin was carved out of greywacke basement rock during the Pleistocene glaciations. The Lake Coleridge area has two geological fault lines: one runs east-north-east with the Harper River, and the other runs almost at right angles to it. The lake is at an altitude of 509.6 m above sea level (a.s.l), and it is 17.8 km long with a maximum width of 3.4 km. It has an area of 32.9 sq.km (Irwin 1975) and a shoreline of 47.5 km. Maximum depth of the lake is 200 m, with an average depth of 95.7 m. It has a volume of 3.15 cu.km (Flain 1970). Lake Coleridge has a northerly orientation and is open to the prevailing strong north-west and weaker south-west winds. The north-westerly Fohn winds are frequent and often exceed 100 kph, with gusts up to 160 kph recorded. Winds may blow for several days, but often abate in the evenings and recommence around midday the next day. Because of this wind action Lake Coleridge water does not stratify. The lake has very low productivity and is classified as ultra oligotrophic (Burnet and Wallace 1973).

An important feature of Lake Coleridge is the wave-cut platform (Fig.2) which extends around the entire margin of the lake at a depth of 0-5 m when the lake is full (509.6 m). In some areas such as the HEP intakes, where wave action is pronounced because of exposure to the extended fetch of the wind, the edge of the wave-cut platform is up to 10.2 m deep. The wave-cut platform is clearly defined by its shallow slope, and it is composed of broken angular rocks with no plant growth. These rocks are regularly moved by wave action (Speight 1912) and thereby absorb the erosional effects of the wave energy. At the deep-water edge of the wave-cut platform is a sharp drop off to a steeper (21° slope) littoral zone which supports plant growth. This zone is silt covered and normally beyond the reach of wave action. Plant growth ceases at about 36 m because of lack of light for photosynthesis.

The silt slope without weed (sublittoral zone) continues to the flat bottom of the lake (benthic zone). The most productive area of the lake is the littoral zone, which anglers prefer to fish. If the lake is high anglers have difficulty fishing this zone: they prefer a lower lake with easier access to the zone.

3.2 The Catchment

The natural catchment area of the lake is 21 773 ha. This has been increased to 59 357 ha by diversion of the Harper River and the Acheron

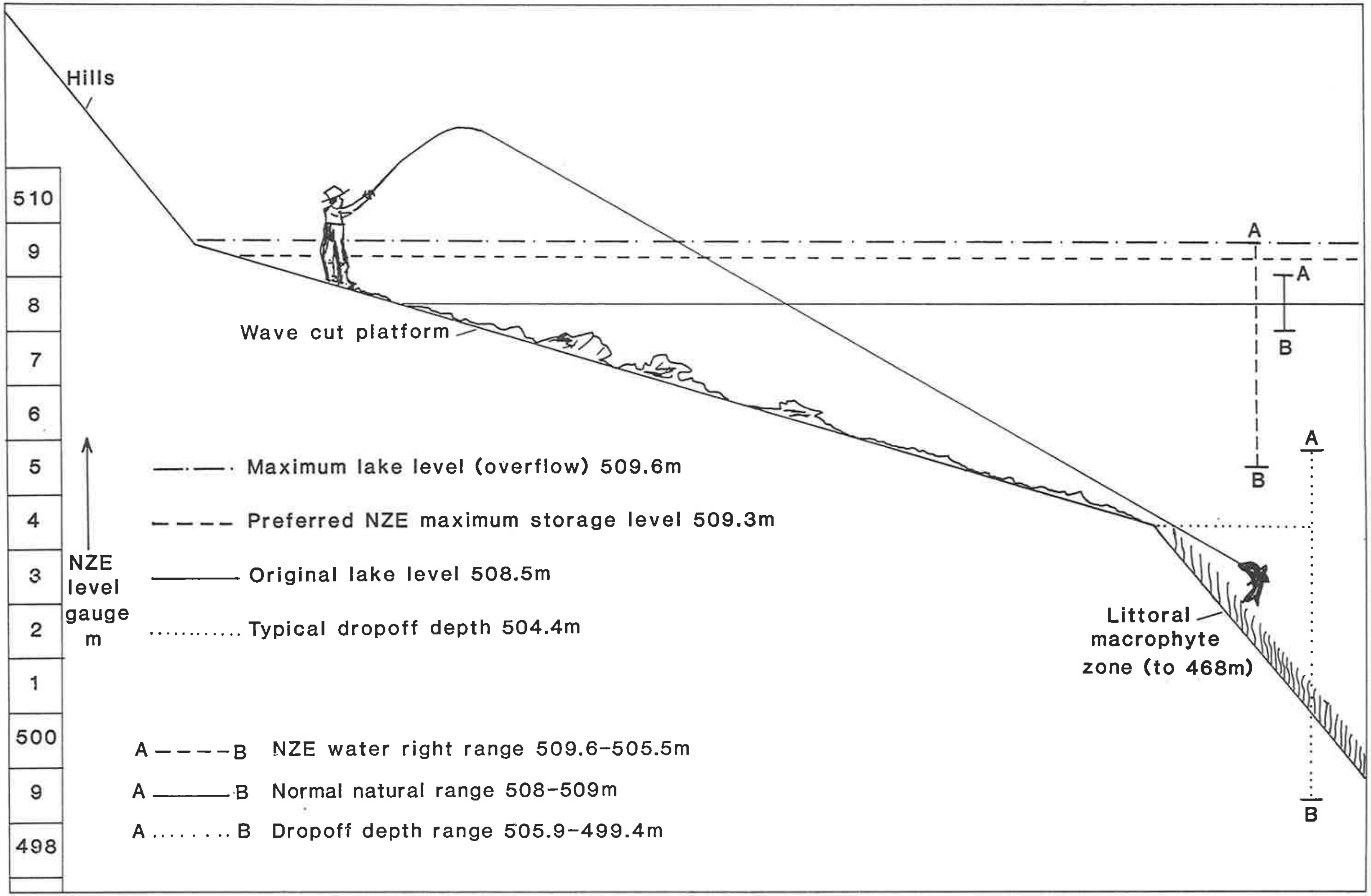

FIGURE 2. Lake Coleridge levels.

River into the lake for HEP (Stephen 1972). Diversion of part of the flow of the Wilberforce River in 1977 has substantially increased the catchment area by an unknown amount. Geologically about 30% of the catchment is composed of tertiary sands and clay, whilst the remainder is greywacke (Packard 1947).

The catchment is largely undeveloped and is predominantly tussock grassland, with some areas of beech forest (*Nothofagus* spp.), sub-alpine vegetation, and scrub. Less than 2% of the catchment is in pasture grassland and plantation.

The main natural tributary of the lake is the Ryton River. Smaller inflows are the Scamander Creek, Simois ("Twin") Stream, and Coleridge Stream (Fig.3).

3.3 Fish Stocks

Lake Coleridge contains four introduced salmonid species, quinnat salmon (*Oncorhynchus tshawytscha*), rainbow trout (*Salmo gairdnerii*), brown trout (*Salmo trutta*), and brook char (*Salvelinus fontinalis*). The quinnat salmon are a self-sustaining landlocked population, in contrast to most other stocks in New Zealand which are sea run. Landlocked quinnat salmon populations are also found in a few other South Island lakes (Flain 1972). Self-sustaining lake populations are not found within the natural range of quinnat (chinook) salmon in North America, with the notable recent exception of the Great Lakes introductions (Bergeson and Tody 1967). Rounsefell (1958) erroneously concluded that chinook (quinnat) are obligatory anadromous fish; this is clearly not so.

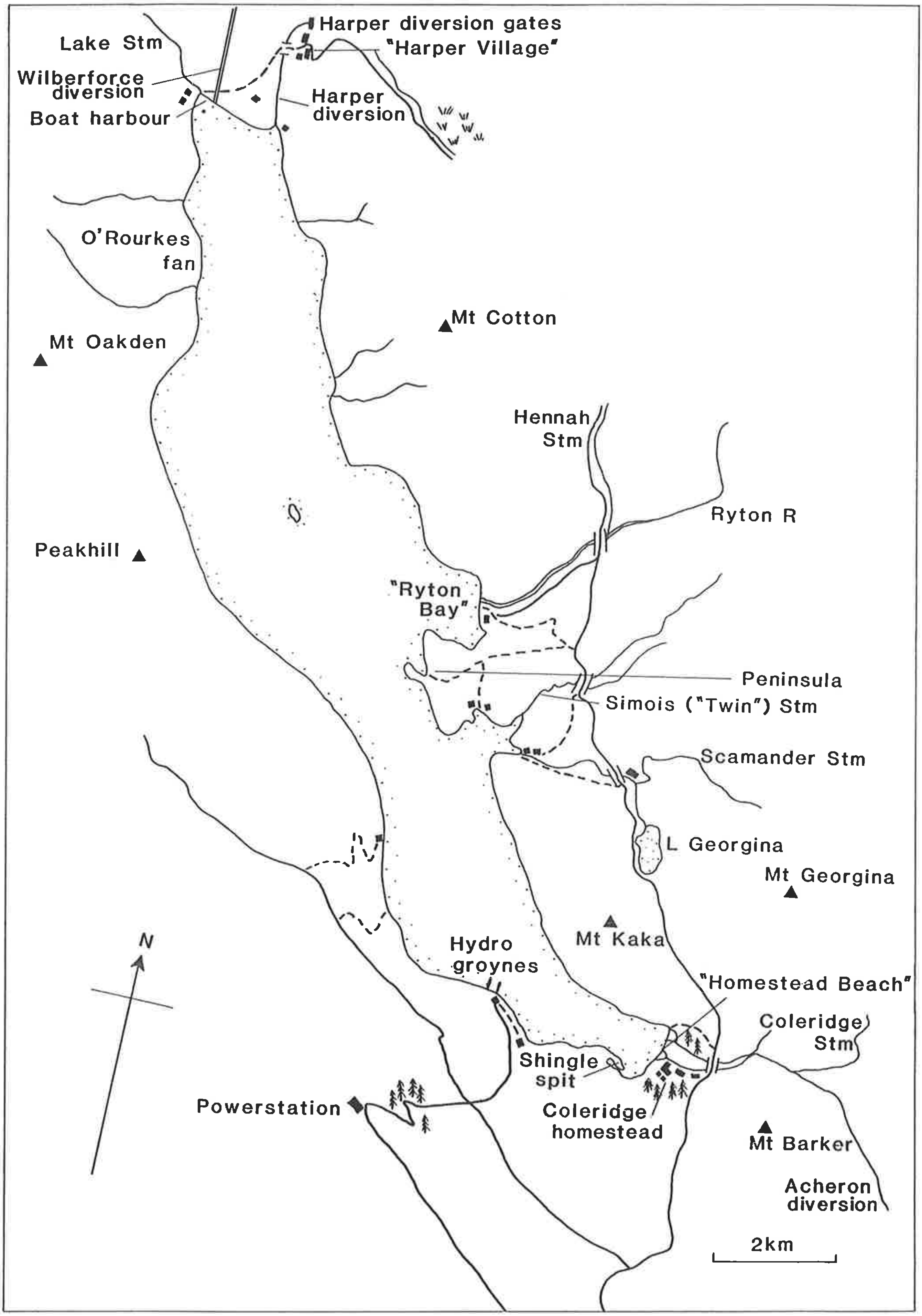

FIGURE 3. Lake Coleridge and surrounding area.

The main salmonid spawning areas are in the four tributaries, the Ryton River, Scamander Stream, Simois Stream, and Coleridge Stream. Access to the Harper River is prevented by a large concrete control gate. Diversion of part of the Wilberforce River into the lake in 1977 gave lake fish access to the river and its catchment. Sea run and river dwelling salmonids are known to use the Wilberforce River for spawning, but the extent to which the river is used by lake fish is unknown.

3.3.1 Quinnat Salmon

Quinnat salmon were first reported as being caught in appreciable numbers on the opening of the 1930/31 angling season (Black Gnat 1930). Scale readings show that three-year-old fish were present in the catch, so that salmon must have been present as early as 1927. In the absence of any stocking records preceeding this date (Table 1), it is reasonable to assume that diversion of the Harper River into Lake Coleridge resulted in the introduction of juvenile salmon into the lake. Sea run salmon were already present in the Rakaia river and its tributaries, including the Harper River.

3.3.2 Rainbow Trout

Rainbow trout were first stocked by the NCAS in 1909 (Table 1). A report in the Christchurch Press (Black Gnat 1931) indicates a well established sport fishery for rainbow and brown trout by 1931.

3.3.3 Brown Trout

Lake Coleridge was first stocked with brown trout in 1868 (Arthur 1881, Godby 1919). Since then, the NCAS has periodically released

TABLE 1. Liberations of quinnat salmon, Atlantic salmon, rainbow trout, and brown trout into Lake Coleridge by the North Canterbury Acclimatisation Society.

Date	Quinnat salmon	Atlantic salmon	Rainbow trout	Brown trout	Source*
1868				20 adults	1
1909			4 000 yearlings		2
1912			75 000 fry		2
1919			2000 fry		2
1924			20 000 fry		2
1925			10 000 fry		2
1926			50 000 fry		2
1928		40 000	15 000 fry	25 000 fry	1
1931	69 000	69 000			2 & 3
1932	69 000		100 000 fry	100 000 fry	2
1933			130 000 fry	200 000 fry	2
			130 000 fry	200 000 fry	2
			100 000 fry		1
1934			45 000 fry	80 000	2
			130 000 fry		1
1935			45 000 fry		1
1941			50 000 fry	49 750 fry	2
1947			100 000 fry		2
			100 000 fry		1
1949			135 500 fry		1
1950			135 000 fry		1
1952			2 504 fry and yearling	23 200 + 3 Selwyn adults	1
			107 700 fry		1
1953	18 sea run adults		107 000 fry		1
			453 adults?		1
1954			118 000 fry	11 500 fry	1
1957			118 000 fry	1 110 fingerlings	1
1958			63 000 fry		1
1959			687 000 ova planted		
			70 000 fry		1
1961			2 210 fingerlings		1
1962			200 fingerlings		1
1963			10 000 fingerlings		1
1965			37 000 fingerlings		1
			1 500 tagged fingerlings		1
1966			30 000 fingerlings of which 790 tagged		1
1967			80 500 fingerlings of which 500 tagged		1
1968	10 000 smolts		24 000 fin-clipped fingerlings		1
			15 000 fingerlings		
1969			38 500 fingerlings		1
1970	22 500 smolts		38 500 fingerlings		1
1971	17 800 smolts		10 080 fingerlings		1
1972	39 760 smolts		24 020 fingerlings		1
1973			24 900 fingerlings		1
Total	228 060 fry and smolts		2 987 067 ova, fry fingerlings and adults	490 580 fry, fingerlings and adults	

* 1 = Annual Report of the North Canterbury Acclimatisation Society.
2 = Files of the North Canterbury Acclimatisation Society.
3 = Stokell 1934.

brown trout into the lake (Table 1). Knowledge of the size of the population is uncertain: trapping and netting data (see Table 2) show that it is comparable in numbers with populations of the other two sport fish species.

3.3.4 Native Fish Species

Four species of native fish have been recorded in Lake Coleridge: the long-finned eel (*Anguilla dieffenbachii*), koaro (*Galaxias brevipinnis*), common bully (*Gobiomorphus cotidianus*), and upland bully (*Gobiomorphus breviceps*). Apart from eels, other native fish present in the lake have no direct recreational or commercial value.

4. HYDRO-ELECTRIC POWER (HEP)

4.1 HEP Operation

HEP operation at Lake Coleridge has been described by Stephen (1972). Details of the operating regime are given by Bowden (1983).

4.2 Lake Level Fluctuations

Haast (1866) noted that the level of Lake Coleridge after its formation was 46-55 m higher than its 1866 (pre-hydro) level (508.5 m) and recorded that the lake used to flow out at its eastern end down the Acheron River into the Rakaia River. The present natural outflow of the lake is at the north-west corner, into the Harper River. This natural outlet is controlled as part of the HEP development of the lake.

Lake levels have been recorded daily since the Lake Coleridge power station was commissioned in 1915. Power generation was initially from natural storage and inflows (up to 8 m^3/s). As power demand grew, so did the need to supplement the inflow. This was done by diverting the Harper River into the lake in 1920 (Fig.3). Even with this augmented input (11.5 m^3/s) the lake was subject to distinct reversed seasonal fluctuations. In 1977, part of the Wilberforce River flow was diverted into the lake and provided a further 30 m^3/s inflow. This, and the capture of an additional 20 m^3/s of Harper River water, has resulted in the lake level being controlled and maintained at a consistently high level all year round (Fig.4). This has also resulted on occasions in the lake being made much more turbid than usual from wave erosion of its margins.

5. METHODS

The fisheries investigations on Lake Coleridge involved several sampling methods. These were:

1. Sampling angler caught fish (creel census).
2. Trapping spawning runs.
3. Marking and tagging.
4. Electric fishing.
5. Diving.
6. Ageing from scales and otoliths.

5.1 Creel Census

To obtain information on anglers' catches, a creel census was conducted on each opening weekend of the angling season from 1964 to 1967, and also in 1969, 1970, and 1973. During the creel census each angler's catch was examined, and the species composition and areas the

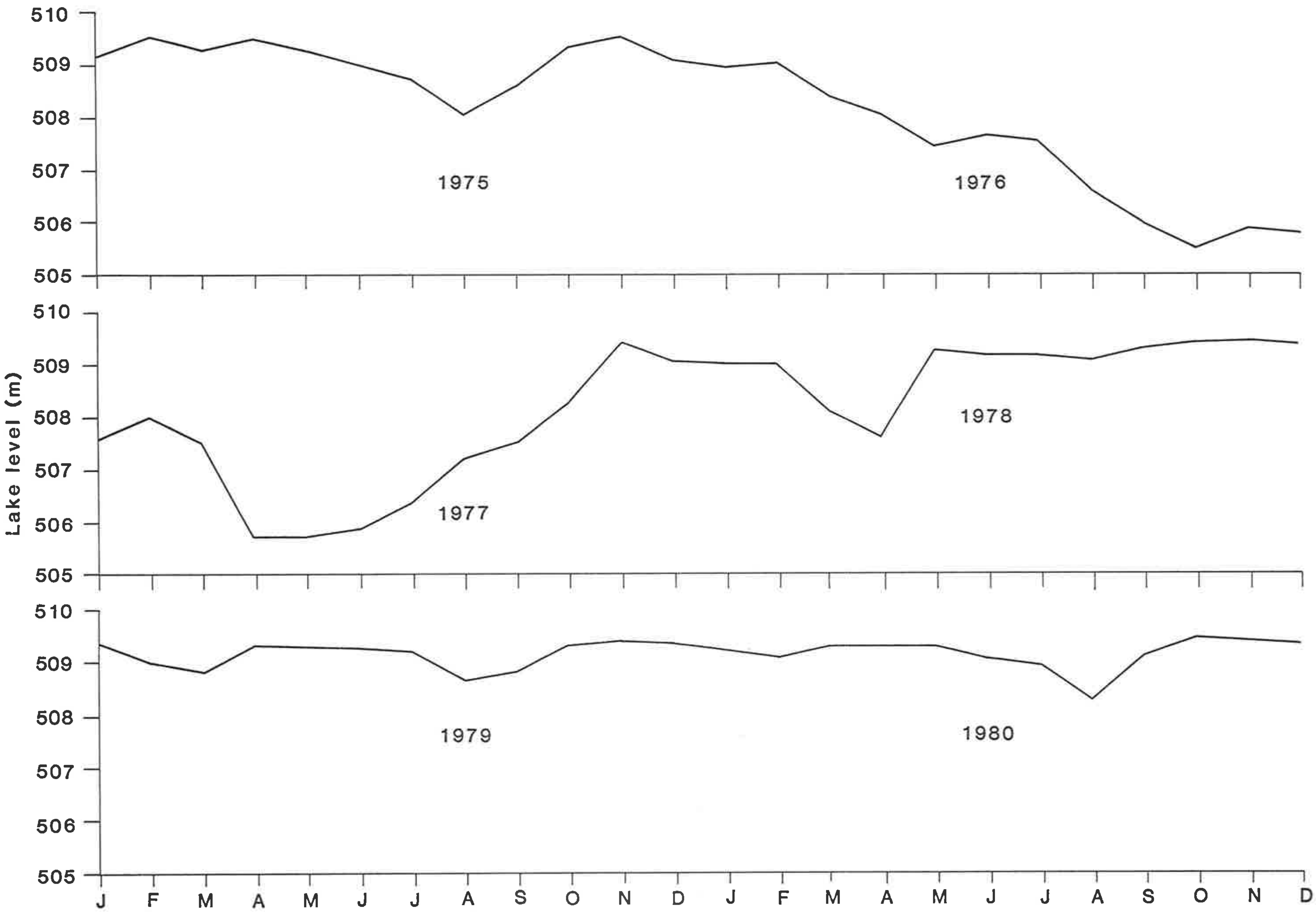

FIGURE 4. Monthly lake levels 1975-80, before and after diversion of the Wilberforce River.

fish were caught in were recorded. The fork length and weight of each fish was noted along with its sex. Scale samples were also collected for ageing. During the 1965/66 fishing season (November-April) a whole seasons creel census was conducted (Wing and Johnson 1966). This was designed to establish seasonal variation in catch composition and also the level of fishing pressure. Beginning on the opening weekend, creel censuses were conducted each weekend and on 1 day each week throughout the fishing season. The weekday sampling was begun on the Monday after the opening weekend and was followed by sampling on Tuesday of the next week, Wednesday of the following week and so on until the end of the season.

Additional information was gathered on how long anglers spent fishing and on the method of fishing. Anglers were also asked the species and numbers of undersized fish they caught and put back into the lake.

5.2 Trapping of Spawning Runs

Salmonid spawning runs into the Ryton River, Scamander Stream, Simois Stream, and Coleridge Stream were trapped by the NCAS during 1931, 1935, 1954-57, 1961, 1967, 1969-74 and 1978-79. In most years the total run was not trapped because of floods or because the duration of trapping did not extend over the entire spawning run. In addition to trapping by the NCAS, spawning runs were also trapped by Boud and Watson (1959) and Eldon and Cunningham (1960). The 1960 trapping by Eldon and Cunningham was the most complete of any; it covered the entire period of the salmon, brown trout, and rainbow trout spawning runs, and was virtually uninterrupted by floods.

During trapping the species of fish caught, fork length, weight, and sex were recorded. Most earlier measurements were recorded in imperial units and these have been converted to metric for comparitive purposes. In 1967, 1972, and 1977 scale samples were collected from rainbow trout trapped during the spawning run.

5.3 Marking and Tagging

In 1960 all rainbow trout that were trapped during the spawning run had their adipose fin removed (Eldon and Cunningham 1960). During the opening weekend after trapping, a creel census was conducted and the numbers of fin-clipped and unclipped rainbow trout caught were recorded. These data were used to obtain an estimate of the size of the adult, takeable rainbow trout population. The effect of stocking with rainbow trout was also examined by tagging. Tagged rainbow trout were released into the lake by the NCAS each year from 1965 to 1967. During the opening weekend creel census for 1967 and 1968 any tagged rainbow trout caught by anglers were recorded, and during the 1969 and 1970 trappings of rainbow trout spawning runs, tagged fish were also noted.

In 1968, 24 000 fin-clipped rainbow trout fingerlings were released into the lake at the Ryton River beach and at the boat harbour (Flain 1967). Angler's catches were examined for fin-clipped and unclipped rainbow trout during the 1969 and 1970 opening weekend creel censuses. The number of fin-clipped fish was also recorded during trapping of the rainbow trout spawning runs from 1970 to 1972. From these experiments the ratios of marked to unmarked fish recorded in creel censuses and trapping of spawning runs have been used to assess the effectiveness of stocking, by determining the survival of marked fish from release to time of capture by anglers or by trapping.

5.4 Electric Fishing

Electric fishing was done with a generator powered, pulsed d.c. electric fishing machine (Burnet 1959). Between November 1955 and May 1966 a 3 m x 64 m section of the Hennah Stream was fished on seven occasions to provide information on the early growth of salmonids. In April 1970 the Hennah diversion was electric fished to obtain samples of "precocious" yearling quinnat salmon.

5.5 Diving

On 18 and 21 May 1967 divers were towed around the margins of the lake from the boat harbour to a point opposite the peninsula (9 km) in an attempt to observe lake edge spawning of salmonids. Other areas examined were in the vicinity of the hydro intakes, the Murchison homestead (eastern) end of the lake, and the peninsula and Ryton areas. Random spot dives were also made around the rest of the margin of the lake.

5.6 Ageing

Quinnat salmon, rainbow trout, and brown trout were aged by use of scales and otoliths. These were collected during creel censuses, trapping of spawning fish, and from carcasses of spawned fish.

All scale samples were read using a Maruzen scale projector with a magnification of X38. Otoliths were read with the naked eye by transmitted light from a high intensity light source. Fish were aged to determine the age structure of the anglers' catch and the spawning runs, and to determine growth rates. For rainbow and brown trout the age at first spawning and the incidence of repetitive spawning were determined.

6. RESULTS

6.1 Creel Census

6.1.1 Species Composition of Anglers' Catch

Analysis of anglers' catch between 1951 and 1983 showed that salmon was the predominant species caught; it contributed 62.5% or more in any one year (Table 2).

Hardy (1960) recorded that salmon made up 62.5% of the anglers' catch in 1954, though Ellis (unpublished fishing competition diary) recorded salmon as 92.7% of the catch for the same season. Hardy's figures for the 1954 season are also anomalous in comparison with figures from other years. If Hardy's figures for the 1954 season are excluded, then in the years where all three species were recorded in the anglers' catch salmon ranged from 78.4% to 95.5% of the catch (these values coming from the 1957 and 1955 seasons respectively).

The second most common species caught by anglers was rainbow trout, which made up from 2.5% to 20.9% of the anglers' catch (these values being from the 1955 and 1979 seasons respectively, with Hardy's figures for 1954 excluded).

The least common species caught by anglers was brown trout. These comprised from 0.3% to 7.8% of the anglers' catch (1954 and 1951 seasons).

Table 2 shows that the anglers' catch is not representative of the true proportions of the sports fish species in the lake. Comparison of Eldon's 1960 trapping figures with those from angling creels clearly

TABLE 2. Species composition of catches from Lake Coleridge by angling, trapping, and netting.

		Quinnat salmon		Rainbow trout		Brown trout		
Date	Method	No. caught	% total catch	No. caught	% total catch	No. caught	% total catch	Source*
1951	Angling	68	88.3	3	3.9	6	7.8	1
1952	Angling	27	96.4	1	3.6	0	0.0	1
1954	Angling	252	92.7	19	7.0	1	0.3	1
1954	Angling	399	62.5	231	36.2	8	1.3	2
1955	Angling	193	95.5	5	2.5	4	2.0	1
1956	Angling	69	100.0	0	0.0	0	0.0	1
1957	Angling	29	78.4	7	18.9	1	2.7	1
1958	Angling	30	93.8	2	6.2	0	0.0	1
1959	Angling	35	87.5	4	10.0	1	2.5	1
1960	Angling	743	84.3	134	15.2	4	0.5	3
1961	Angling	53	98.2	1	1.8	0	0.0	1
1962	Angling	24	88.9	3	11.1	0	0.0	1
1963	Angling	16	94.1	1	5.9	0	0.0	1
1964	Angling	126	81.8	28	18.2	0	0.0	4
1965	Angling	1 368	81.7	278	16.6	28	1.7	5
1966	Angling	508	87.4	67	11.5	6	1.0	6
1967	Angling	615	83.7	114	15.5	6	0.8	6
1968	Angling	15	100.0	0	0.0	0	0.0	1
1969	Angling	663	82.1	132	16.3	13	1.6	6
1970	Angling	985	89.5	98	8.9	18	1.6	6
1978	Angling	434	84.9	68	13.3	9	1.8	7b
1979	Angling	454	74.1	128	20.9	31	5.1	7c
1982	Angling	412	85.3	59	12.2	12	2.4	7d
1983	Angling	374	78.9	76	16.0	24	5.0	7e
1959†	Trapping	53	14.4	172	46.7	143	38.9	8
1960	Trapping	660	36.7	811	45.1	328	18.2	9
1961†	Trapping	354	55.9	252	39.8	27	4.3	10
1978†	Trapping	113	10.6	184	17.2	773	72.2	7a
1979†	Trapping	371	21.3	345	19.8	1 023	58.8	7c
1962	Netting	15	21.4	37	52.9	18	25.7	4

* 1 = P.G. Ellis diary (unpublished).
2 = Hardy 1960.
3 = G.A. Eldon (unpublished).
4 = Cudby *et al.* 1966.
5 = Wing and Johnson 1966 (unpublished).
6 = Author.
7a = NCAS Annual Report 1978.
7b = NCAS Annual Report 1980.
7c = NCAS Annual Report 1982.
7d = NCAS Annual Report 1983.
7e = NCAS Annual Report 1984.
8 = Boud and Watson 1959.
9 = Eldon and Cunningham 1960.
10 = NCAS records.

† = Incomplete trapping.

shows that rainbow and brown trout are much more numerous than the anglers' returns indicate. Further support for this comes from the 1962 netting results of Cudby, Galloway, Boud, Moore, and Cunningham (1966) where rainbow and brown trout proportions are much higher than those shown in anglers' catches for that year.

6.1.2 Catch Composition by Area

Data collected during the opening weekend of the 1967 angling season were used to determine the species composition of the anglers' catch from four main areas fished around the lake (Table 3). These were the O'Rourkes fan area, Harper River inflow area, "Ryton Bay" area, including the peninsula, and "Homestead Beach" and hydro groynes area of the lake (Fig.3).

The species composition of the catch was similar from all areas except Ryton Bay. This difference was largely due to a small group of anglers who were fishing from the peninsula and were targeting successfully for rainbow trout. Removal of their catch data from the Ryton sample resulted in all four areas being similar in species catch composition.

6.1.3 Catch Rate

Whole season and bi-monthly catch rates for all species combined for the 1953/54 and 1965/66 seasons are shown in Table 4. The catch rate for the 1953/54 season was higher than in the 1965/66 season, and the bi-monthly catch rate for 1953/54 (0.39-0.62 fish per hour) was more variable than for 1965/66 (0.32-0.35 fish per hour).

Over fifty per cent of all angling was done in the first 2 months of the season (Table 4), and most of it occurred at the opening weekend.

Table 5 shows the whole season and bi-monthly catch rates for the 1953/54 and 1965/66 seasons, for the separate species. The catch rate for salmon in the 1953/54 season was higher than in the 1965/66 season, but it showed a clear decrease through the season, as opposed to a consistent catch rate throughout 1965/66.

Rainbow trout catch rates for both seasons were generally consistent throughout, but showed a small increase in the months of January and February.

For brown trout there were insufficient data to allow comparisons of catch rates between seasons.

Catch rates for Coleridge are compared with those for other lakes in Table 6. The range of 0.3 to 0.59 fish per hour for Coleridge compares favourably with other well known fishing lakes.

TABLE 3. Species catch composition by area, Lake Coleridge opening 1967.

Area	Quinnat salmon No. caught	Quinnat salmon % catch	Rainbow trout No. caught	Rainbow trout % catch	Brown trout No. caught	Brown trout % catch	Total
O'Rourkes	138	90.8	13	8.5	1	0.7	152
Harper	135	89.4	14	9.3	2	1.3	151
"Ryton Bay"*	221(218)	74.1(83.2)	74(42)	24.8(16.0)	3(2)	1.0(0.8)	298(262)
"Homestead Beach"/ Hydro groynes	119	90.8	12	9.2	0	0.0	131

* Biased for rainbow trout, a party of six anglers were fishing specifically and successfully for rainbow trout off the peninsula. Their catch was 3 quinnat salmon, 32 rainbow trout and 1 brown trout. Corrected figures are shown in brackets.

TABLE 4. Whole season 1953/54 and 1965/66 catch rates with bi-monthly catch rates, all species combined. (Includes hours fished for no fish caught.) Numbers of undersized fish put back are tabulated.

Date	No. caught	Hours fished	Fish per hour	% of total angling effort	Undersized put back Quinnat	Rainbow	Brown
1953/54							
Whole season	458	840.75	0.55	100.0	108	22	0
Nov-Dec 1953	343	556.25	0.62	66.2	96	10	0
Jan-Feb 1954	93	238.00	0.39	28.3	11	9	0
Mar-Apr 1954	22	46.50	0.47	5.5	1	3	0
1965/66							
Whole season	1 088	3 361.25	0.32	100.0	390	20	1
Nov-Dec 1965	660	2 064.50	0.32	61.4	342	13	0
Jan-Feb 1966	298	928.25	0.32	27.6	46	5	1
Mar-Apr 1966	130	368.50	0.35	11.0	2	2	0

TABLE 5. Whole season 1953/54 and 1965/66 catch rates with bi-monthly catch rates, species separate. (Does not include hours fished for no fish caught; based on those returns where only one species was caught and no others.)

	Quinnat salmon			Rainbow trout			Brown trout		
Date	No. caught	Hours fished	Fish per hour	No. caught	Hours fished	Fish per hour	No. caught	Hours fished	Fish per hour
1953/54									
Whole season	209	328.25	0.64	27	99.25	0.27	2	2.5	0.8
Nov-Dec 1953	195	281.50	0.69	20	64.25	0.27	0	0.0	0.0
Jan-Feb 1954	14	47.00	0.30	4	12.00	0.33	0	0.0	0.0
Mar-Apr 1954	0	0.00	0.00	6	23.00	0.26	2	2.5	0.8
1965/66									
Whole season	648	1 525.75	0.43	89	230.75	0.39	7	19	0.37
Nov-Dec 1965	477	1 137.00	0.42	41	110.25	0.37	3	9	0.33
Jan-Feb 1966	123	276.50	0.45	24	55.25	0.44	3	8.5	0.35
Mar-Apr 1966	48	112.25	0.43	24	65.25	0.37	1	1.5	0.66

TABLE 6. Catch per unit of effort for Lake Coleridge and comparisons with other lakes.

Lake	Season	Fish per hour	Source*
Coleridge	1951/52	0.42	1
	1953/54	0.59	2
	1956/57	0.31	3
	1957/58	0.31	3
	1960/61	0.42	4
	1962/63	0.30	3
	1967/68	0.30	3
Alexandrina	1947/52	0.36	1
Rotorua	1947/52	0.56	1
Taupo	1947/52	0.51	1
Southern Lakes	1947/52	0.62	1
Manapouri	1962/63	0.33	5
Te Anau	1962/63	0.61	5

* 1 = Allen and Cunningham 1957; 2 = Hardy 1960; 3 = Graynoth and Skrzynski 1974; 4 = Cudby *et al.* 1966; 5 = Hutchinson 1963.

6.1.4 Size and Age Composition of Salmon Catch

From data obtained from the whole season 1965/66 creel census, length-frequency curves were plotted for three 2-monthly periods (Fig.5). Scale samples collected on the opening weekend of the season allowed the mean lengths of year classes of salmon caught by anglers to be determined. These are included in Figure 5.

It is evident from the figure that the first bi-monthly length-frequency curve is bi-modal and corresponds with the mean lengths for 3- and 4-year-old salmon determined by scale readings. The second bi-monthly curve is also bi-modal, but it is displaced by growth of the fish; it is also evident that the proportion of 3-year-old fish is reducing. The third bi-monthly length-frequency curve is displaced further by growth, and the ratio of 3- to 4-year-old fish is further reduced. It is also evident that another year class of fish has grown sufficiently to be legally taken by the anglers (at about 37 cm fork length). These would be 2-year-old fish entering the fishery.

From scale samples and length data collected during the 1965/66 season it was possible to estimate the bi-monthly ratio of 3- to 4-year old salmon. These, and data from an aged sample from the 1967 spawning run, are shown in Figure 6. It shows more obviously the change in the age structure of the anglers' catch of salmon. They catch fewer 3- and more 4-year-old fish as the season progresses. The ratio of 3- to 4-year-old fish is also very much higher at the start of the season than it is at the end of the season or on the spawning grounds.

Aged samples from angler caught fish and from spawning runs show this occurs in other years (Table 7).

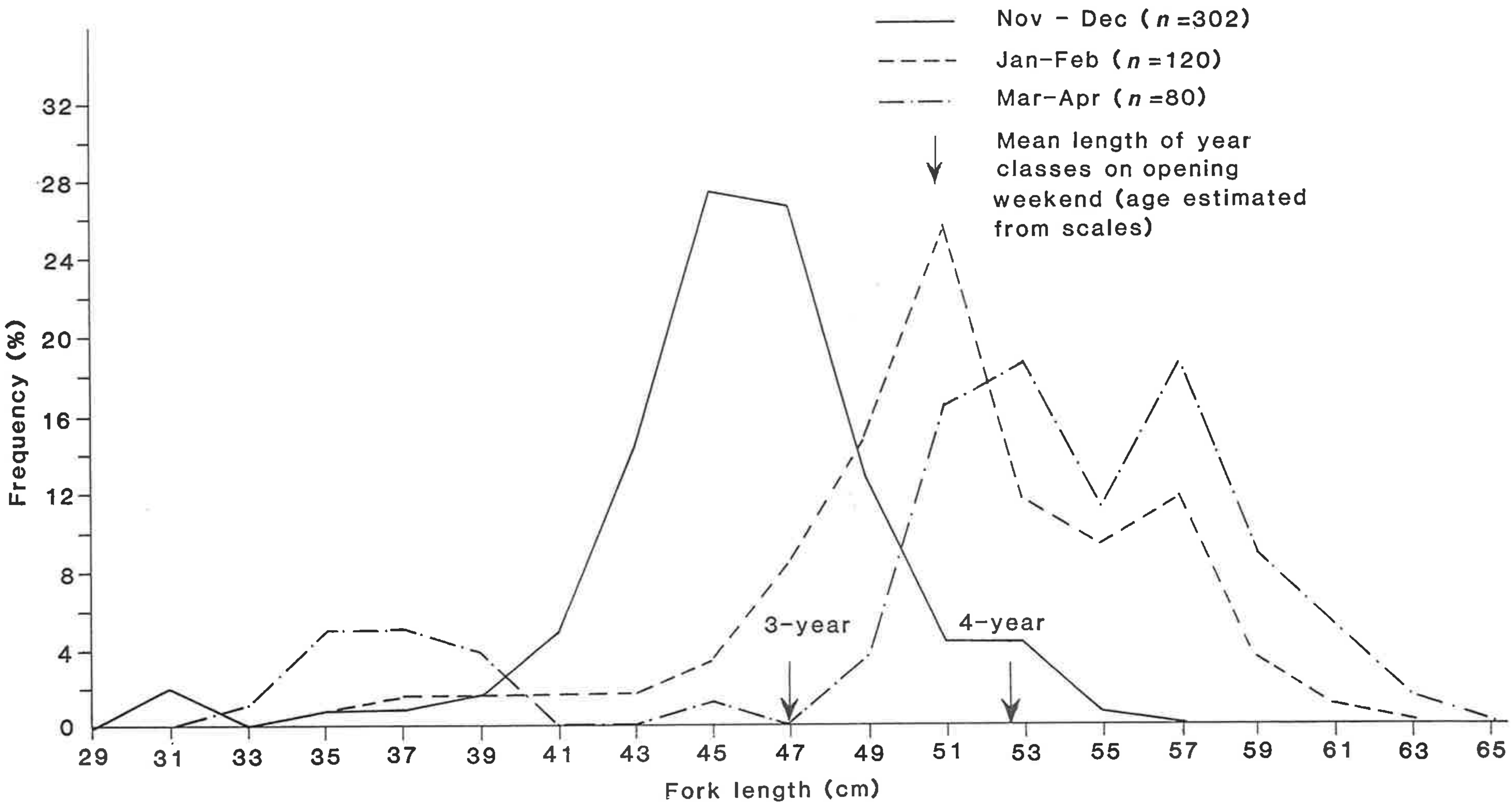

FIGURE 5. Angler caught quinnat salmon length-frequency curves for November-December 1965, and January-February and March-April 1966.

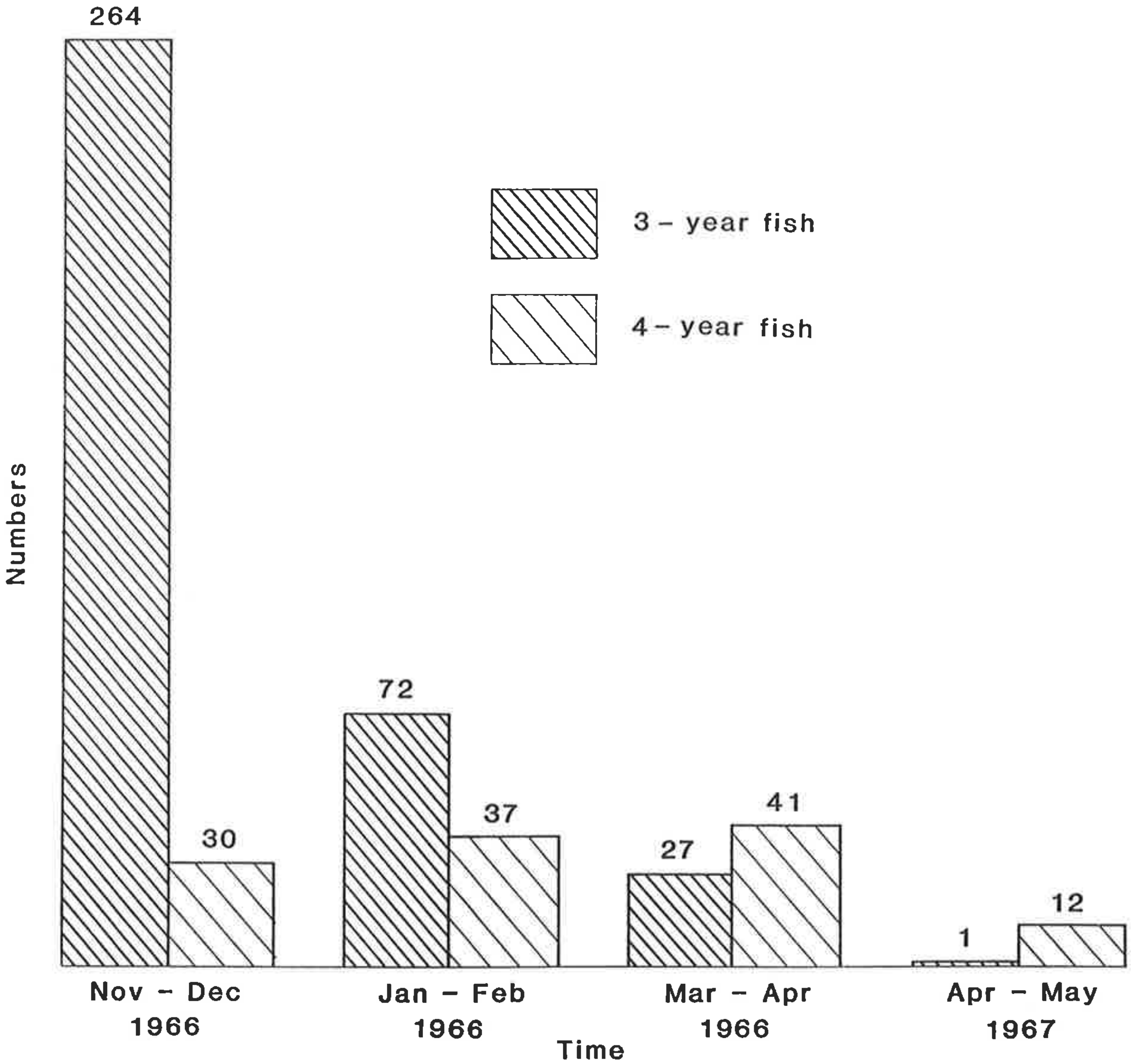

FIGURE 6. Bi-monthly ratio of 3- to 4-year-old salmon for the 1965/66 angling season and 1967 spawning run.

TABLE 7. Comparison of the age structure of angler caught and spawning quinnat salmon.

	Angler caught (November)			Spawning runs (May)		
	Age			Age		
Date	3	4	Ratio 3:4	3	4	Ratio 3:4
1930	14	0	14:0			
1931	9	5	1.8:1			
1953	142	29	4.9:1			
1965	42	1	42:1			
1966	427	55	7.8:1			
1967	532	41	13:1	1	12	0.1:1
1969	579	68	8.5:1	59	18	3.3:1
1970	923	44	21:1	31	20	1.6:1
1973	42	0	42:0	18	22	0.8:1
1978*	137	24	5.7:1	100	7	14.3:1
1979*	43	28	1.5:1	39	77	0.5:1
1982*	55	9	6.1:1			
1983*	173	31	5.6:1			

* Webb 1984b.

The progressive decrease in the proportion of 3-year-old salmon in the anglers' catch indicates that anglers are affecting the salmon population, because 3-year-olds are normally the main year class in the population.

Of the three species caught, most undersized fish put back are salmon (Table 4). Increased mortality due to stress would be expected for these fish.

6.2 Spawning Runs

6.2.1 Quinnat Salmon

Spawning runs begin in early April, peak around mid May, and finish at the beginning of July (Eldon and Cunningham 1960). Examination of scales and otoliths from carcasses of spawned fish showed that most

(59.4%) quinnat spawn in their third year of life and smaller proportions in their fourth (34.6%), second (5%), and fifth years (1%) (Table 8). The 2-year-old "grilse" were all males, whereas all other year classes comprised about equal numbers of males and females. Only five 5-year-old fish, and none older, have been identified from all the samples of scales and otoliths examined from Lake Coleridge.

TABLE 8. Ages and lengths of spawned carcasses of quinnat salmon, Ryton River.

	Age 2		Age 3		Age 4		Age 5	
Date	No.	Mean length (cm)	No.	Mean length (cm)	No.	Mean length (cm)	No.	Mean length (cm)
1969	-	-	59	44.6	18	50.0	-	-
1970	16	35.9	31	46.8	20	51.2	-	-
1973	4	39.5	18	52.8	22	57.7	-	-
1978*	1	30.0	100	44.1	7	49.2	-	-
1979*	-	-	39	47.8	77	50.2	4	54.7
Average mean length		36.3		45.8		51.4		54.7

* Webb 1984a.

Mean lengths of salmon from spawning runs sampled between 1931 and 1979 have ranged from 42.7 cm (in 1955) to 53.9 cm (in 1973), and in most years have been about 45.5 cm (Fig.7).

Two-year-old spawners averaged 36.3 cm in length, three-year-olds 45.8 cm, four-year-olds 51.4 cm, and five-year-olds 54.7 cm (Table 8).

Precocious yearling male salmon were sampled during electric fishing in the Hennah Stream on 8 April 1970. From a sample of 20 yearling fish, 2 were precocious males (fork length 13.0 and 14.8 cm). Mean length of immature fish was 8.1 cm (range 6.8-9.6 cm).

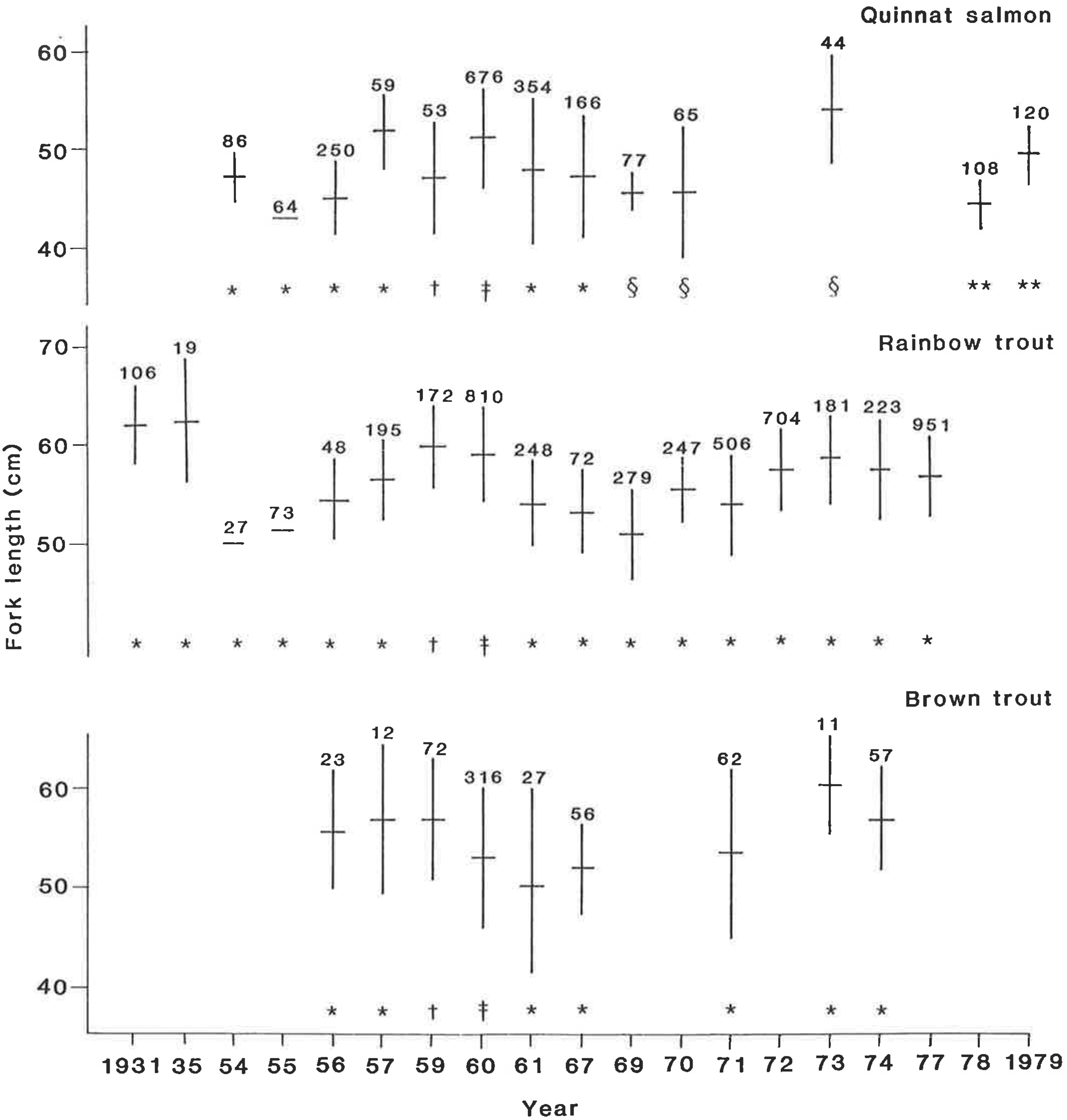

FIGURE 7. Mean lengths, standard deviations, and numbers in samples for spawning quinnat salmon, rainbow trout, and brown trout. (Sources of data: * NCAS records; † Boud 1959; ‡ Eldon 1960; § MAF records; ** Webb 1984.

6.2.2 Rainbow Trout

Spawning runs of rainbow trout commence about mid June, peak about 23 July, and finish in mid September (Eldon and Cunningham 1960). Scale readings from 1972 and 1977 Ryton River spawners showed that most rainbow trout matured in their fifth and sixth year and a smaller number in their fourth year (Table 9). Spawning marks on scales showed evidence of some fish spawning twice and a few three times (Table 10). The oldest spawning fish sampled were in their seventh year.

Mean lengths of spawning rainbow trout in runs sampled from 1931-79 have ranged from 50.0 cm in 1954 to 62.5 cm in 1935, with a mean about 55.0 cm (Fig.7). The few 3-year-old spawners sampled (Table 9) averaged 50.8 cm in length, the 4-year-olds 51.8 cm, the 5-year-olds 56.8 cm, the 6-year-olds 61.4 cm, and the 7-year-olds 68.0 cm. The similar sizes of the 3- and 4-year-old fish is likely to be due to some faster growing 3-year-olds maturing early and entering the spawning run.

6.2.3 Brown Trout

Comprehensive trapping results (Eldon and Cunningham 1960) showed that the brown trout spawning run started at the end of May, peaked around 25 June, and finished toward the end of July.

No data are available on the age structure of the brown trout spawning run. Scale samples from anglers' catch show that the age at first spawning is 3 years and some fish spawn repetitively (Table 10). It is also evident that brown trout up to at least 7 years old are present in the spawning run. Mean lengths of spawning brown trout runs sampled have ranged from 50.3 cm in 1961 to 60.5 cm in 1973. The average was 54.0 cm (Fig.7).

TABLE 9. Ages, lengths, and weights of spawning rainbow trout, Ryton River.

Date	Age 3			Age 4			Age 5			Age 6			Age 7		
	No.	Mean length (cm)	Mean weight (g)	No.	Mean length (cm)	Mean weight (g)	No.	Mean length (cm)	Mean weight (g)	No.	Mean length (cm)	Mean weight (g)	No.	Mean length (cm)	Mean weight (g)
Males															
1972	3	50.8	1 647	6	53.7	2 020	18	59.5	2 827	7	61.2	2 943			
1977				22	52.3		186	58.0		33	62.1				
Females															
1972				20	54.5	2 188	50	57.6	2 555	16	61.2	2 910			
1977				47	50.1		388	56.0		72	61.2		2	68.0	
Mean length (years and sex combined)															
	3	50.8		95	51.8		642	56.8		128	61.4		2	68.0	

TABLE 10. Age and incidence of repetitive spawning in rainbow and brown trout.

Date	Age 2	3	4	5	6	7	Repetitive spawning Maiden	X1	X2	X3
Rainbow trout										
1966 spawners		7	7	7	2		13	4	5	1
1966 creel			6	27	7	1	28	7	5	1
1967 creel	1	38	26	24	9		70	19	8	1
1970 creel	1	25	29	37	3		54	23	17	1
1977 spawners			69	574	105	2	706	27	16	1
Brown trout										
1970 creel		3	3	9	1	1	11	2	3	1

6.2.4 Lake Edge Spawning

Divers were towed around the margin of the lake from the boat harbour to opposite the peninsula, about 9 km, on 18 and 21 May 1967 in search of any evidence of lake edge spawning: none was found. Further surveys by towed divers around the hydro intakes, the homestead (eastern) end of the lake, and the peninsula and Ryton area, with spot dives all around the lake margin, produced no evidence of lake edge spawning. The dives showed that the substrate was unsuitable for spawning. Shallow areas up to 10 m deep consisted of mobile coarse angular rocks continuously moved by wave action. Beyond this were steep silt-covered slopes overgrown with weed down to 36 m, below which the the weed stopped, but the silt slope continued to the flat deep bottom of the lake. Thus the lake margins were clearly unsuitable for spawning.

6.3 Marking and Tagging

6.3.1 Population and Standing Crop Estimates of the Sport Fishery

Population estimates were calculated for the numbers of takeable rainbow trout, brown trout, and quinnat salmon in the sport fishery for 1960 and 1979. From these estimates the standing crop of takeable size fish for each of the three species was calculated.

Eldon and Cunningham (1960) fin-clipped 811 adult rainbow trout spawners. A creel census was conducted on the following opening weekend of the 1960 angling season (unpublished). There were 17 (13%) marked rainbow trout present in 134 examined. By use of the formula -

$$N = \frac{(n_1 + 1)\ (n_2 + 1)}{(m_2 + 1)} - 1$$

where N = population estimate,

n_1 = total number marked and released,

n_2 = total number recovered,

m_2 = number of marked fish recovered

- the estimate for the takeable rainbow trout population in the lake for 1960 was 6089 ± 2521 fish, or 1.9 fish per hectare. (Confidence limits for the estimate were determined at the 95% level by obtaining the variance with the formula -

$$\sigma^2 = \frac{(n_1 + 1)\ (n_2 + 1)\ (n_1 - m_2)\ (n_2 - m_2)}{(m_2 + 1)^2\ (m_2 + 2)}$$

The estimate does not allow for mortalities of some spent spawners which would cause the result to be an over-estimate.)

The proportions of each species in the total catches trapped during spawning runs are probably the nearest indication of their proportions in the lake population.

Trapping by Eldon and Cunningham (1960) was the most comprehensive and complete so far carried out. Using the estimated population of rainbow trout for 1960 and the proportions of the three species trapped (811 rainbow trout, 660 quinnat salmon, 328 brown trout) an indirect estimate of the 1960 population numbers for salmon and brown trout could be derived.

For salmon this estimate was 4955 (1.5 fish per hectare) and for brown trout 2467 (0.7 fish per hectare) giving a total takeable sport fish population of 13 511 (4.1 fish per hectare).

Mean weights of each species in the 1960 trapping multiplied by the population estimates, gave the total weight of the three species of sport fish in the lake for 1960. For quinnat it was 8988 kg (2.7 kg/ha), for rainbow trout 15 465 kg (4.7 kg/ha) and for brown trout 4699 kg (1.4 kg/ha); a total of 29 152 kg (8.9 kg/ha).

The NCAS trapped the spawning run of salmonids in the Ryton River during 1979. It did not sample the complete run of quinnat salmon because of the time the trap was put in. Fish numbers trapped were - 121 quinnat salmon, 345 rainbow trout (which were all tagged) and 1023 brown trout. During the following opening weekend of the 1979 season, a creel census sampled 454 quinnat salmon, 128 rainbow trout (of which 9 were previously tagged) and 31 brown trout.

The population estimate for the rainbow trout from these figures was 4958 $\pm$ 2496 (1.5 fish per hectare) and for brown trout 14 071 (4.5 fish per hectare). Incomplete trapping of quinnat salmon did not allow a population estimate to be made.

Mean weights of each species from the 1979 trapping multiplied by the population estimates, gave a total weight of 9837 kg (3.0 kg/ha) for rainbow trout and 24 876 kg (7.6 kg/ha) for brown trout.

6.3.2 Angler Cropping Estimates

During the 1960 opening weekend creel census 743 quinnat salmon, 134 rainbow trout, and 4 brown trout were caught. This represented about 50% of the whole season's catch (Wing and Johnson 1966). By doubling these figures an indication of angler cropping rates on the estimated populations could be determined. For salmon it was 30.0% of the population, for rainbow trout 4.4%, and for brown trout 0.32%.

Application of the same procedure to the 1979 figures, where the creel census showed that 128 rainbow trout and 31 brown trout were caught, gave cropping rates of 5.2% for rainbow trout and 0.4% for brown trout.

6.3.3 Stocking with Marked Rainbow Trout

To assess the effectiveness of rainbow trout stocking carried out over many years by the NCAS (Table 1) 24 000 fingerling rainbow trout were adipose fin-clipped on 23 and 24 September 1968. It was noted during fin clipping that 6 out of the 24 000 (0.025%) naturally lacked an adipose fin. The clipped fish were held until 30 September 1968 when they were transported to the lake and released - 8000 into the boat harbour and 16 000 into "Ryton Bay". Mortalities at this stage were 77 fish (0.28%) and most occurred within 24 hours of clipping (Flain 1968). The average size at release was 11.6 cm. No mortalities were observed by divers immediately after the fish were released. However, many fish did show obvious stress effects, either by lying on the bottom or swimming in a disorientated and quite uncharacteristic fashion. The latter behaviour may also have been partly due to the fish no longer being confined within raceway walls and also to a lack of current.

Some of these fish were observed being eaten by gulls. At the Ryton release the more active fish formed shoals; one large shoal was followed as it moved out into the lake. At first the shoal swam near the surface, but as it moved out into deeper water it also gradually moved down deeper into the water. Sporadic bunching of the shoal occurred without apparent reason until a depth of about 12 m was reached when adult lake resident salmon were seen to feed on the shoal.

The fingerlings released at the boat harbour were checked by divers at night. Ten days after release 91 of 102 rainbow trout fingerlings seen were fin-clipped. Forty days after release 37 of 56 seen were fin-clipped, and 70 days after release none of 26 fish seen were clipped. During these counts it was observed that the incidence of fin-clipped fish to unclipped fish increased as the boat harbour exit to the lake was approached, which indicated that the fin-clipped fish were leaving the area. On the first two counts, several large rainbow trout were observed patrolling the area at the mouth of the boat harbour - sightings which were notably atypical for rainbow trout.

During the following 4 years the angler catch and spawning runs were examined for fin-clipped hatchery fish.

On the opening weekend of the 1969 angling season 4 out of 132 takeable rainbow trout caught were fin-clipped. One undersized fin-clipped fish was put back and two were found in a few salmon stomachs examined. On the 1970 opening weekend 1 fin-clipped rainbow trout was recorded out of 98 takeable fish.

From the combined catch for the 1969 and 1970 opening weekends, 5 out of 230 rainbow trout taken were from the 24 000 fin-clipped hatchery release. If it is assumed that this is 50% of a full season's catch

(Wing and Johnson 1966) this would be equivalent to 10 (2.2%) fish for the two full seasons' catch of rainbow trout. Rainbow trout make up about 15% of the anglers' catch (Table 2) therefore the fin-clipped fish provided less than 1% of the total sports fish catch from the lake.

In 1970, none of 247 rainbow trout trapped were fin-clipped. In 1971, 9 out of 506 were fin-clipped, and in 1972 none out of 703 were clipped. Hence a total of 9 out of 1456 rainbow trout trapped were fin-clipped - a contribution of 0.6% to the spawning runs.

The NCAS released 1500 tagged yearling rainbow trout in 1965, 790 in 1966, and 500 in 1967, a total of 2790 tagged fish. Creel census information was collected on the opening weekends of the 1967, 1968, and 1969 fishing seasons. No tagged fish were seen in the total 313 rainbow trout examined.

The 1969 and 1970 spawning runs were trapped. In 1969, 1 out of 279 trapped fish was tagged and in 1970 1 out of 247. Thus, out of a total 526 fish trapped, 2 (0.4%) were tagged - a very similar figure to the fin-clipping results.

6.4 Growth and Size

6.4.1 Quinnat Salmon

Figure 8 shows the mean length, standard deviation, and range for juvenile salmonids captured by monthly electric fishing of the Hennah Stream in 1954 and 1955 (A.M.R. Burnett unpublished data).

Juvenile quinnat were present (at 3.8 cm long) in October until April of the following year (at 8.2 cm long). They were notably absent

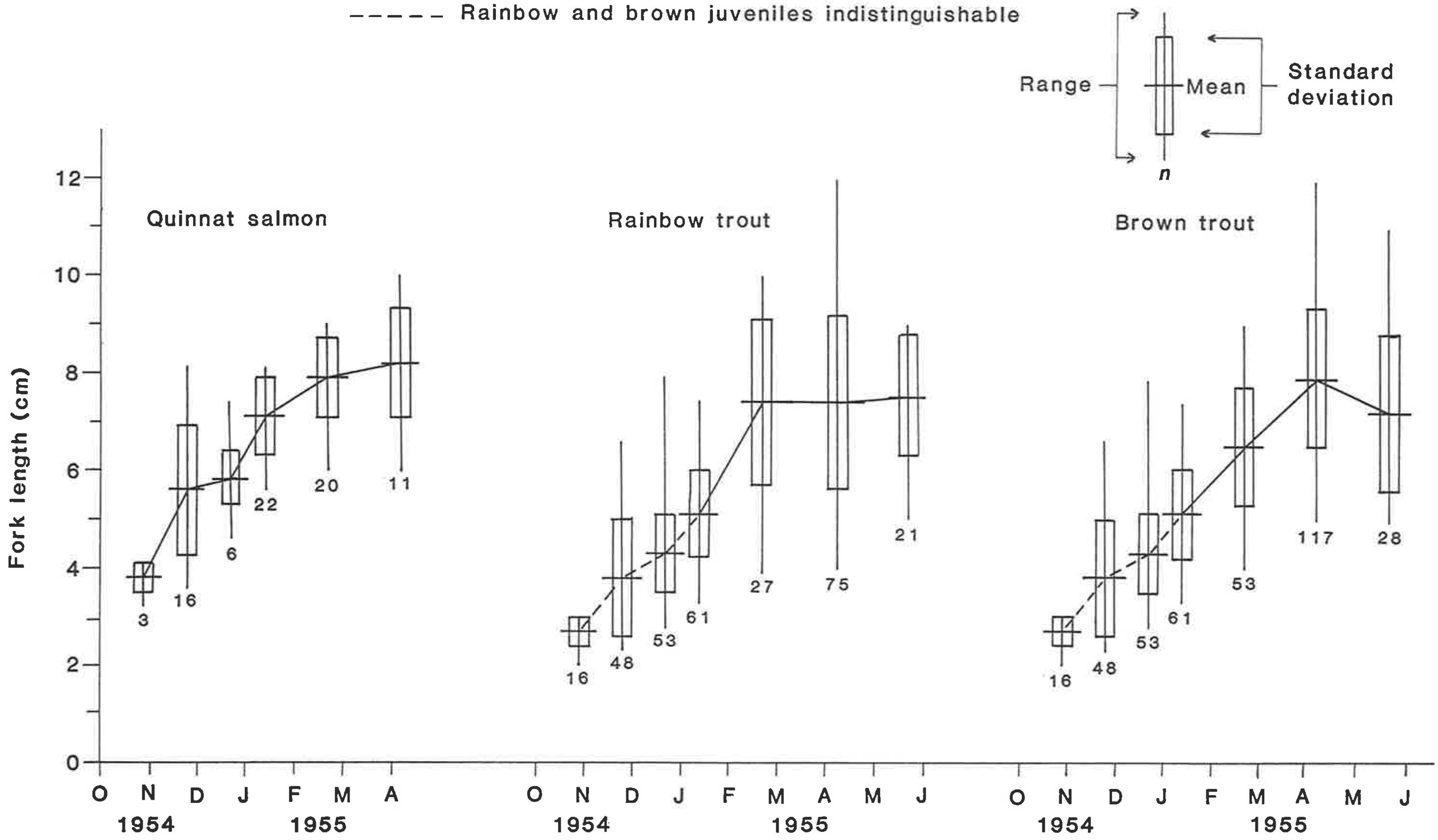

FIGURE 8. Lengths of salmonids taken in monthly electric fishing in a 3 m x 64 m section of Hannah Stream, from November 1954-June 1955.

in the May sample, presumably because they had left the stream to enter the lake. A growth curve (Fig.9) for salmon was constructed using data from several sources. Salmon fry are known to emerge in August at about 3 cm fork length. The early growth in the stream was plotted from the electric fishing results. The mean lengths and the ranges of the means for aged salmon from the 1966/67 and 1969/70 opening weekend samples were plotted against time, as were the mean lengths and ranges of means for aged spawners from the 1969, 1970, and 1973 spawning runs. The resultant curve was drawn by eye.

Figure 10 shows the mean lengths and standard deviations of quinnat salmon caught by anglers on opening weekends at Lake Coleridge from 1930 to 1983. It is evident from the large size of salmon caught in 1930 and 1931 that the salmon grew well after their initial introduction. Mean lengths and weights of a small sample of aged fish also show substantially larger fish in the 1930 and 1931 opening weekends than in later years (Table 11).

There is a gap in the data from 1931 to 1949 which presumably would have shown a decline in the mean size of the salmon as they reached a balance in their new environment and with its food resources. From 1949 to 1983 variations in mean size are evident, but no obvious trend such as a decline in size of salmon in the anglers' catch (Fig. 10) or in the mean length of salmon year classes (Table 11) is apparent.

6.4.2 Rainbow Trout

Growth rates for juvenile rainbow trout are shown in Figure 8. Juveniles were present in the Hennah Stream from October (at 2.7 cm fork length) to May the following year (at 7.5 cm fork length) when electric fishing was discontinued.

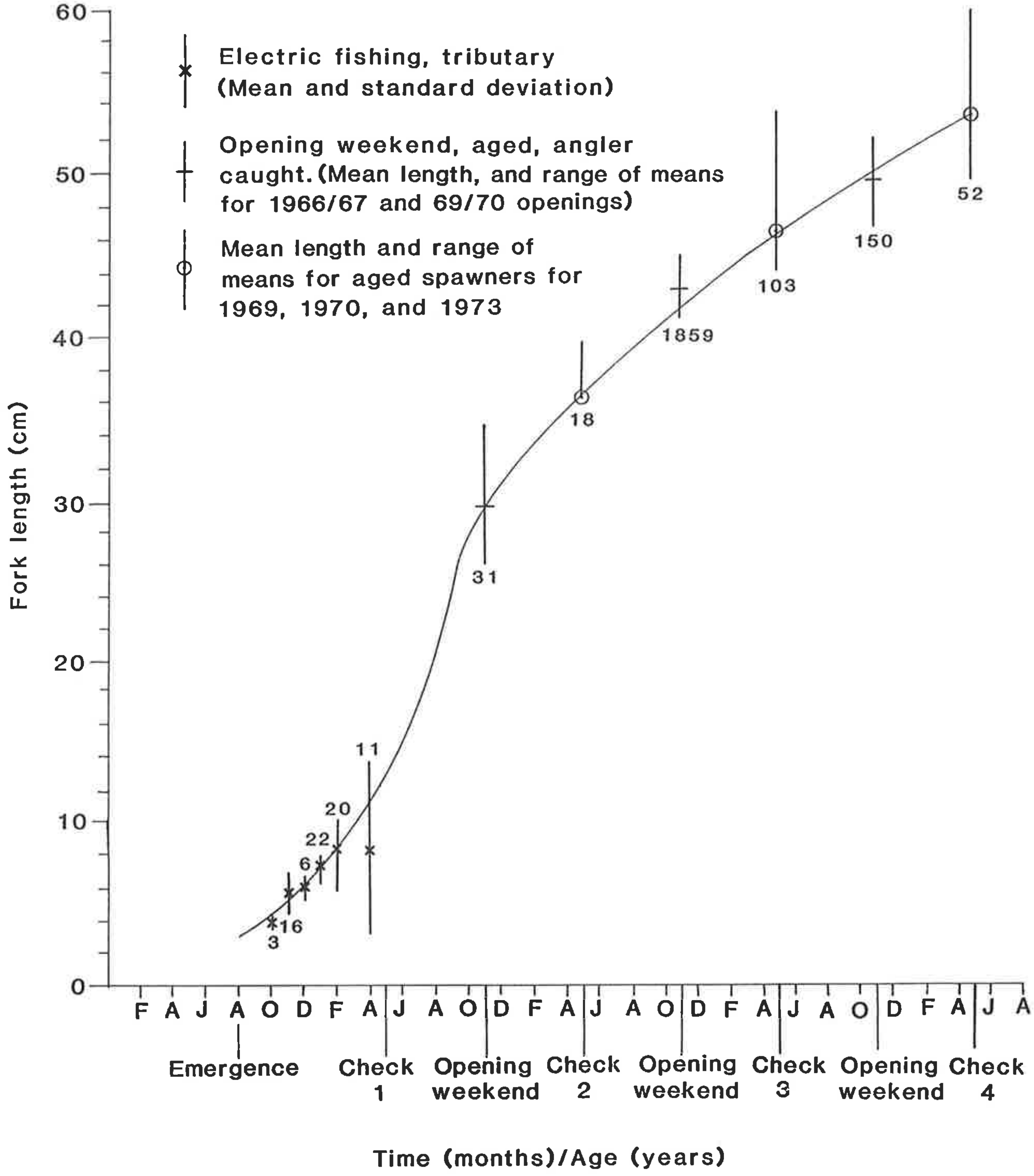

FIGURE 9. Growth curve for Lake Coleridge quinnat salmon.

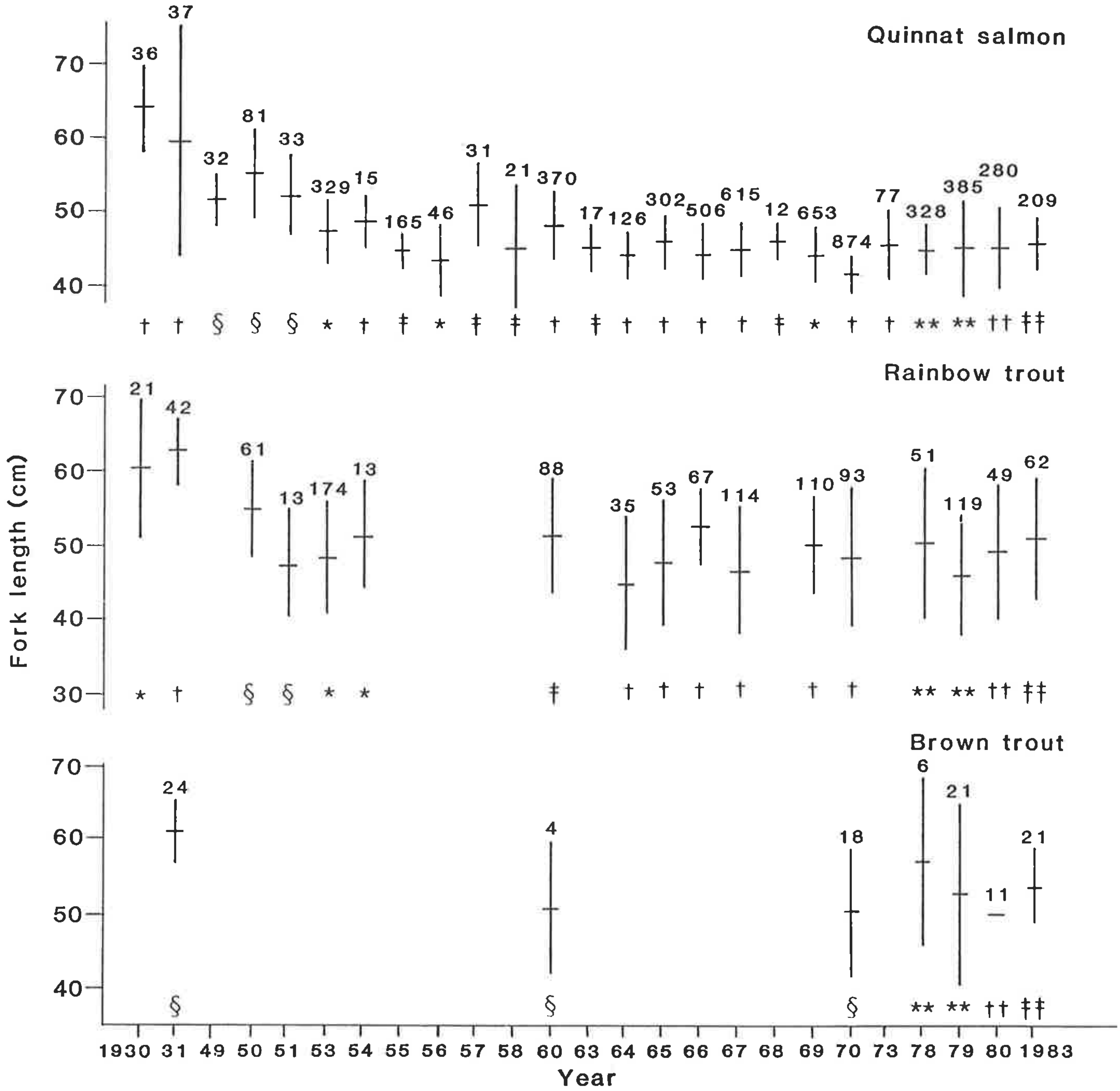

FIGURE 10. Mean lengths, standard deviations, and numbers in samples for quinnat salmon, rainbow trout, and brown trout caught by anglers on openings of Lake Coleridge fishing seasons.
(Sources of data: * NCAS records; † MAF records; ‡ P.G. Ellis diary; § angling diary scheme; ** Webb 1982; †† Webb 1983; ‡‡ Webb 1984.)

TABLE 11. Lengths and weights of angler caught quinnat salmon, opening weekends, Lake Coleridge.

	Age 2			Age 3			Age 4		
Date	No.	Mean length (cm)	Mean weight (g)	No.	Mean length (cm)	Mean weight (g)	No.	Mean length (cm)	Mean weight (g)
1930	1	44.5	681	14	67.2	2 400			
1931	4	30.8	340	9	65.4	2 497	5	68.3	3 042
1953	1	45.7	794	142	46.4	1 002	29	53.2	1 389
1954				10	46.5	1 142	5	51.8	1 135
1965	3	42.3	840	42	46.8	1 038	1	52.6	1 590
1966	4	26.6	225	427	43.7	884	55	50.5	1 257
1967	9	28.7	249	532	44.7	932	41	51.6	1 328
1969	11	25.8	216	579	43.6	836	68	49.8	1 155
1970	18	30.2	420	923	41.4	670	44	47.3	996
1973	5	29.2		42	46.4				
1978* 1979	4	29.7		180	43.7		52	51.9	
1982†	4	33.5		55	46.3		9	49.8	
1983‡	1	34.0		58	45.6		11	50.0	

* = Webb 1982.
† = Webb 1983.
‡ = Webb 1984b.

The sampling team was unable to differentiate between rainbow and brown trout fry in the early months (October - December).

A growth curve (Fig.11) for rainbow trout was constructed in a similar way to the quinnat salmon growth curve. Rainbow trout were introduced into the lake as early as 1909 (Table 1) and should have developed fairly stable growth patterns by the time they were first sampled in 1930. However, it is evident that fish caught in the 1930 and 1931 seasons were larger than present day fish (Fig.10). Growth rates of fish sampled for age (Table 12) confirms this, as do comparisons of fish measured from the spawning run (Fig.7).

From 1950 to the present there has been no obvious trend in the size of rainbow trout from the anglers' catch (Fig.10). There has also been

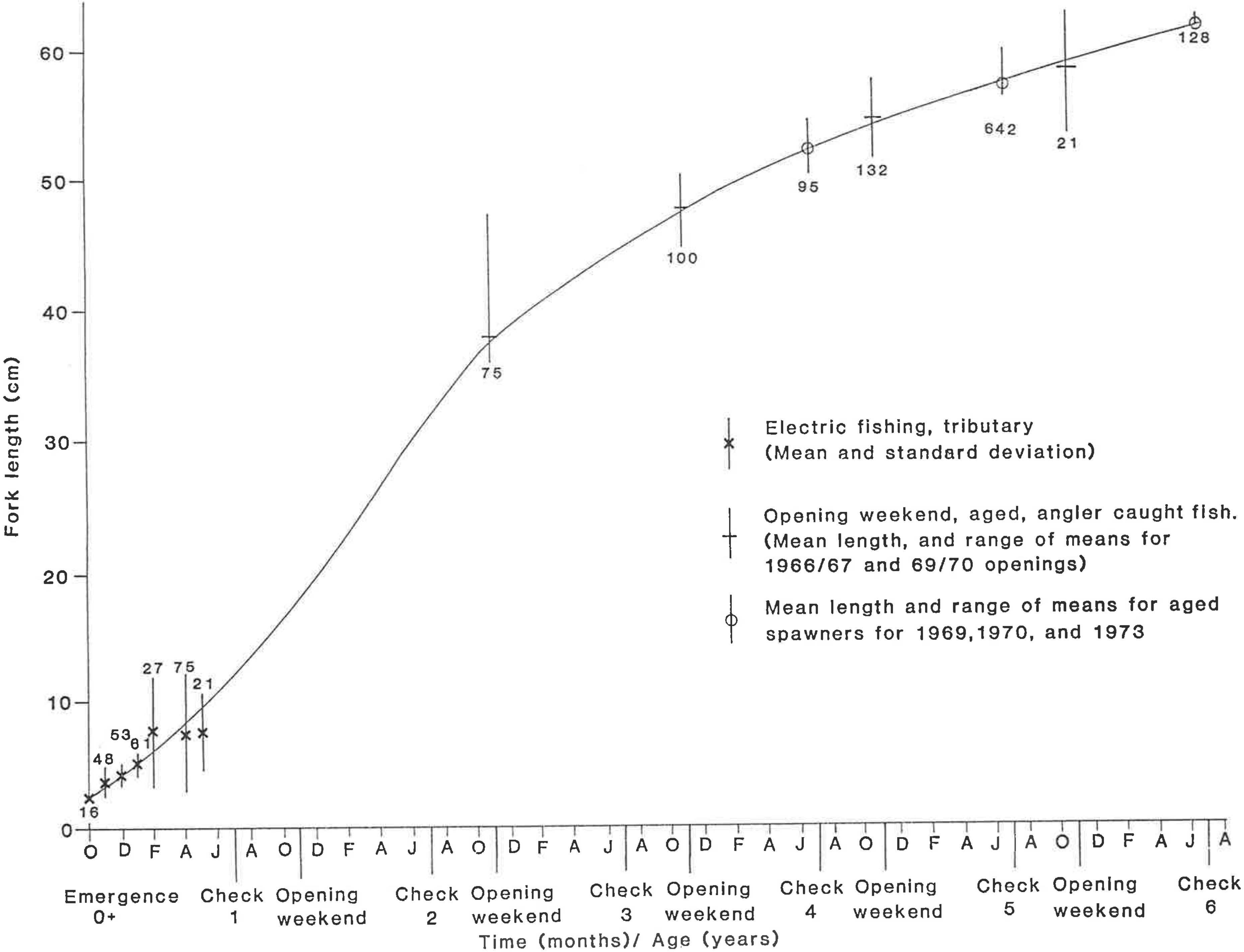

FIGURE 11. Growth curve for Lake Coleridge rainbow trout.

TABLE 12. Lengths and weights of angler caught rainbow trout, opening weekends, Lake Coleridge.

Date	Age 2			Age 3			Age 4			Age 5			Age 6			Age 7			Age 8		
	No.	Mean length (cm)	Mean weight (g)	No.	Mean length (cm)	Mean weight (g)	No.	Mean length (cm)	Mean weight (g)	No.	Mean length (cm)	Mean weight (g)	No.	Mean length (cm)	Mean weight (g)	No.	Mean length (cm)	Mean weight (g)	No.	Mean length (cm)	Mean weight (g)
1931							3	57.8	2 043	6	61.6	2 611	11	63.2	2 982	1	63.2	2 982	1	69.8	3 065
1953	1	34.3	396	29	39.6	715	53	48.1	1 244	29	53.4	1 538	8	56.7	1 733	2	55.3	1 930	2	59.7	2 270
1954							4	45.1	908	3	54.3	1 135									
1965				7	43.1	897	6	49.5	1 532	7	56.5	1 965	1	61.7	2 630						
1966							6	46.6	1 246	27	51.7	1 411	7	55.4	1 737	1	55.5	1 950			
1967	1	34.0	648	38	37.6	1 233	26	44.7	1 576	24	54.6	1 796	9	57.6							
1969				13	37.8	570	41	47.4	1 280	52	54.2	1 438	2	61.8	2 138						
1970	1	29.3	283	25	35.8	587	29	50.2	1 274	37	55.0	1 582	3	59.8	2 220						
1978* and 1979	3	29.0		39	38.2		40	45.8		45	54.8		13	61.3		1	47.8				
1982†	3	31.3		9	41.5		17	51.0		12	57.7		1	64.0							
1983‡	3	34.0		12	42.6		23	50.6		14	58.2		4	64.7							

* = Webb 1982.
† = Webb 1983.
‡ = Webb 1984b.

no obvious trend in the size of spawning fish measured from 1954 to 1977 (Fig.7). Again, there have been significant variations in sizes of fish caught by anglers and those taken from the spawning runs, but this is almost certainly due to the variations in proportions of year classes in the anglers' catch and in the spawning run (Tables 9 and 12).

6.4.3 Brown Trout

Though there is clearly a large population of brown trout in the lake, data on the population are sparse. Few brown trout are taken by anglers and, apart from Eldon's trapping, little trapping data are available. Data from anglers' catches between 1931 and 1983 are presented for completeness (Fig.10), but there are too few data from which to draw any valid conclusions.

Table 13 gives the mean lengths and weights of angler caught, aged brown trout taken on opening weekends; again it is evident there are too few data on which to draw conclusions. Figure 7 shows the mean lengths and standard deviations of brown trout spawners trapped over the years 1956-74. During this period there is no obvious trend other than some variation from year to year around a stable growth rate. The individual yearly variations are almost certainly due to variations in proportions of year classes making up the spawning runs.

TABLE 13. Lengths and weights of angler caught brown trout, opening weekends, Lake Coleridge.

Date	Age 2			Age 3			Age 4			Age 5			Age 6			Age 7		
	No.	Mean length (cm)	Mean weight (g)	No.	Mean length (cm)	Mean weight (g)	No.	Mean length (cm)	Mean weight (g)	No.	Mean length (cm)	Mean weight (g)	No.	Mean length (cm)	Mean weight (g)	No.	Mean length (cm)	Mean weight (g)
1931							1	61.0	2 724	7	59.7	2 513	5	64.8	2 860	2	62.2	4 199
1970				3	36.0		3	43.2	962	9	54.8	1 698	1	65.8	2 962	1	58.2	
1978* and 1979				8	38.3		9	49.9		9	52.8		10	63.3		1	71.0	
1984**	1	31.0		2	39.0		6	50.7		8	57.8		2	67.5		1	70.0	

* = Webb 1982.

† = Webb 1984b.

7. DISCUSSION

7.1 Quinnat Salmon

The freshwater, self-sustaining quinnat salmon stocks that occur in some New Zealand lakes, of which Lake Coleridge is one of the more notable, are most unusual. New Zealand is the only country in the world where this occurs without the need for continued stocking.

Stokell (1955) stated that the freshwater quinnat produced infertile offspring and therefore could not exist for more than two generations. Rounsefell (1958) designated the chinook (quinnat) salmon as an obligatory anadromous fish. The proven viability of eggs and sperm from freshwater salmon stripped for rearing by the NCAS, and the continued existence of stocks of quinnat salmon in the lake for many years, invalidates both of these conclusions.

Records of freshwater stocks in North America relate to residual fish trapped by impoundments (Sherrin 1886) or to lakes artificially stocked with salmon (Fairbanks 1881, Kendall 1913, Hoover 1936, McAffee 1966, Bergeson 1967). These populations have only been maintained by stocking. This is also true for freshwater populations in Australia (Butcher 1947, Cadwallader and Eden 1981, Rogan 1981).

The life cycle of quinnat salmon in Lake Coleridge is similar to that of anadromous stocks that occur in the Rakaia River. Most fish mature in the third year, fewer in the fourth, and very few in the fifth year. Some fish mature in the second year, mostly males, and a proportion of juveniles which remain in the spawning tributary mature as yearling fish, these are all males. Whether or not all die after spawning is unknown, but certainly most die. However, their existence totally in freshwater raises the question that some might survive spawning, as do yearling precocious males of sea run stocks.

A major difference between the freshwater and anadromous stocks is size: 3- and 4-year-old Coleridge salmon average 45 and 51 cm respectively whereas sea run 3- and 4-year-old salmon average 75 and 85 cm respectively. The difference is evidently due to a limited food supply in the lake when compared with that in the ocean.

Eldon and Cunningham (1960) showed a peak for the spawning run occurred towards the end of May, a full month after that which normally occurs for Glenariffe (Rakaia) salmon, which peak at the middle and end of April (Galloway 1972).

7.2 Bag and Size Limits

The rationale behind bag limits is to ensure that excessive cropping of fish stocks by anglers does not occur. To set bag limits there is a need to know what constitutes a typical population size for the water in question, and what proportion of the population may be cropped without depressing numbers of spawning fish to the point where fishing success declines in subsequent seasons.

Size limits are to ensure that fish grow and mature to a size where they spawn at least once before they can be cropped from the population. If they are caught before this size is reached it is required that they are put back into the water alive.

For Lake Coleridge, as for most other waters throughout New Zealand, adequate information to establish the need for or the extent of these limits is lacking. Some of the results obtained in the present investigation indicate that such limitations are unnecessary.

Salmon usually provide about 90% of the anglers' catch from the lake and an estimate of cropping for the 1960 season was 30% of the population.

Unwin and Davis 1983 estimated cropping rates of about 50% by anglers on the Rakaia River salmon runs for the 1978/79 and 1979/80 seasons. Despite this high cropping rate the size of runs in the Glenariffe Stream have shown no apparent effect. It would seem reasonable to suggest that with a lower cropping rate, the population of salmon in the lake would be unaffected.

When the population estimates of takeable rainbow and brown trout are considered with the estimated angler cropping for the 1960 season (4.4% for rainbow and 0.32% for brown trout) the need for bag limits clearly does not exist. A proportion of these fish spawn repetitively, therefore the population will be less affected by angling pressure than the salmon.

The results indicate that there was no need for bag limits for salmon during the period investigated and much less need for bag limits of rainbow and brown trout. Salmon normally spawn once only and die. The need for a size limit for salmon to enable them to reach spawning size is irrelevant, unless there is evidence that the numbers of salmon reaching maturity are insufficient to maintain the population. This does not appear to be so, therefore a size limit appears to be superfluous. For rainbow trout the bulk of first spawners occurred about size 45-55 cm and for brown trout about 40-50 cm. Fish caught earlier in the angling season would obviously not be so large. Thus, in view of the size limit for Coleridge trout (25 cm) a substantial proportion of the anglers' catch would have included trout which had failed to spawn at least once. Scale readings also indicated a high incidence of maiden fish in the anglers' catch. Consequently, the size limit, even if it were necessary, would not have been an effective mechanism for population protection.

For Lake Coleridge rainbow and brown trout there is no need for a size limit, and the restrictions in force are ineffective in what they set out to achieve. There is also strong evidence to support the view that such restrictions are unnecessary in the first place. However, anglers do seem to have a predilection for self-imposed handicaps with regard to catching fish. Therefore the concept of little or no regulation of the lake fishery until such time as measurable effects of angling on a population can be shown does not seem to find favour amongst the majority of the angling fraternity.

7.3 Effect of Stocking

Most effort by the NCAS was concentrated on stocking the lake with rainbow trout, then brown trout, and little on quinnat salmon. Returns of rainbow trout to the anglers' catch were less than 1% as were contributions to spawning runs. Hence, the effect of stocking rainbow trout was minimal.

The angler catch showed the greatest number of fish caught were salmon, with substantially fewer rainbow trout and very few brown trout. Indications are that stocking, if necessary, would be more useful for quinnat salmon than for rainbow or brown trout.

7.4 Effect of Hydro-electric Power Development on the Recreational Fishery

The diversion of the Harper River into Lake Coleridge is a notified water right under the Water and Soil Conservation Act 1967 with a maximum of 99 m^3/s, but with no water quality conditions. Since the Harper River was diverted into the lake there has been little concern expressed about its effect on the lake except with respect to spawning rainbow trout.

The Harper diversion control gates prevent spawning fish from moving out of the lake and gaining access to upstream spawning waters. The NCAS has sought to have a fish ladder built to provide such access, particularly for rainbow trout, large numbers of which have been observed annually attempting to pass the diversion gates. Foot surveys in 1956 (Cranfield, Williams, and Young 1956) and by the author in May 1967 showed the presence of rainbow and brown trout above the diversion gates. Clearly these resident fish utilise the spawning waters above the diversion gates and many of their progeny will be diverted into the lake. The annual reappearance of rainbow trout attempting to negotiate the diversion gates to spawn lends support to this view.

Diversion of part of the Wilberforce River into the lake by way of the Oakden Canal has a condition placed on the water right, namely a limit of 350 tonnes per day of suspended solid. This condition has not been complied with for up to 25% of the time that it has been monitored and during these times of excess suspended solids between 68% and 85% of the total annual sediment load has entered the lake (Lineham 1984). Excess silt-laden Harper River flows, which previously passed down the Harper bed to the Wilberforce River and out to the sea via the Rakaia

River, are now captured by the Wilberforce diversion. Consequently, the clarity of the lake water has been reduced.

The Wilberforce diversion has allowed the Electricity Division, Ministry of Energy (NZE) to hold the lake more consistently at a high level, which provides them with a greater head of water and storage. This has resulted in increased shoreline erosion and turbidity.

Silt-laden, discoloured waters from the Harper and Wilberforce diversions do on occasions degrade the water quality markedly at the western end of the lake. This has always been a major fishing area and anglers have expressed concern about the degraded water quality. The ability of NZE to hold the lake high also means that anglers are moved further away from the deeper littoral zone where fish feed. Consequently, a smaller proportion of each cast is fishing in this area and a larger proportion fishes the shallow water as the cast is recovered.

It has been suggested that the inflows into the lake be reduced and the level allowed to fall shortly before opening weekend, which would result in cleaner water and better fishing conditions for the opening, when up to 50% of the angling for the season is done.

The Wilberforce diversion makes it possible for lake fish to gain access to the upper reaches of the Wilberforce or under certain flow conditions to the headwaters of the Harper River. It also allows fish to move out of the lake and gain access to the Rakaia River. The extent of these movements is unknown.

The NCAS unsuccessfully tried to have the NZE place fish screens in the Wilberforce diversion canal to prevent losses from the lake.

Anglers' catch data before and after the diversion show no obvious changes, and population estimates are too crude to rely on. Therefore, it is unlikely that the impact of the scheme on the fish populations will ever be fully evaluated.

Schemes for increased storage and generating capacity have been proposed which could entail levels of up to 24 m higher than the present maximum and 18 m lower than the present minimum (Southern Energy Group 1976).

8. CONCLUSIONS

1. Lake Coleridge supports a recreational fishery based on quinnat salmon, rainbow trout, and brown trout. These species usually provide about 90%, 9%, and 1% of the anglers' catch respectively. This does not reflect the relative abundance of each species in the lake.

2. Catch rates of the three species measured in the 1953/54 and 1965/66 seasons varied from 0.64 to 0.43 fish per hour for salmon, 0.27 to 0.39 fish per hour for rainbow trout, and 0.8 to 0.37 fish per hour for brown trout.

3. Apart from a few samples *circa* 1930 when fish were larger, there is no evidence of a trend in fish size over the period 1949-82.

4. Similarly there is no evidence of any trend in growth rates for the three species in the lake over the period 1949-82. Samples examined from around 1930 do indicate a faster growth rate at that time.

5. Crude population estimates for takeable rainbow trout, brown trout, and quinnat salmon were made from mark and recapture data coupled with trapping data. The estimates were:

Quinnat salmon (1960) 4955

Rainbow trout (1960) 6089 ± 2521 (95% confidence limits)

(1979) 4958 ± 2496 (95% confidence limits)

Brown trout (1960) 2467

(1979) 14 071

6. Cropping rates by anglers were estimated to be:

Quinnat salmon (1960) 30.0%

Rainbow trout (1960) 4.4%

(1979) 5.2%

Brown trout (1960) 0.32%

(1979) 0.4%

7. The cropping rates for rainbow and brown trout do not support the management practice of bag limits imposed on the angler. Though the cropping rate is higher for quinnat salmon it is still unlikely that bag limits achieve any purpose. For all three species size limits also seem unnecessary and ineffective.

8. Previous extensive stocking of the lake with rainbow and brown trout was ineffective. Few of the stocked fish were ever caught by anglers or appeared in the spawning runs. The NCAS no longer stocks rainbow or brown trout into Coleridge.

9. The majority of the anglers' catch is quinnat salmon and the lake should be managed accordingly. Enhancement of the salmon stocks is more likely to provide returns to the anglers. Since 1981 the NCAS has implemented programmes of spawning stream improvements in an attempt to enhance the fishery (Fitzgerald 1981).

10. The most important spawning tributary of the lake is the Ryton River; other spawning tributaries are Simois (Twin) Stream, and

Scamander and Coleridge Streams. The numbers of rainbow and brown trout diverted into the lake from the Harper headwaters are not known and nor is the effect of opening up access to the Wilberforce headwaters via the Wilberforce canal.

There was no evidence of suitable areas for lake edge spawning found during the investigation.

11. The diversion of the Harper River by NZE is generally considered to have introduced salmon into the lake and by accident provided the most frequently caught sport fish. The diversion undoubtedly contributes juveniles of rainbow and brown trout, which reside and spawn above it, to the lake and it also carries food organisms into the lake. Silt loads generally have been localised in their effect, but unfortunately in a region of high angling activity.

12. Similarly, the Wilberforce diversion would provide some rainbow and brown trout from its headwaters and also additional food. Unlike the Harper diversion it does allow egress for fish from the lake, but the extent of this is unknown.

    Silt loads are localised in their effect, but also occur in a region of high angling activity. The Wilberforce diversion has allowed NZE to maintain the lake at a consistently high level and this has resulted in shoreline erosion on occasions, with resultant widespread discolouration of the lake.

13. From the data presented, this lake is primarily a freshwater salmon sport fishery and should be managed accordingly. The salmon has the following advantages. It is readily caught, it is a good eating fish, it has the fastest growth rate of the three sport species

present and the earliest age of maturity. It provides good sport for anglers of all ages and requires minimal fishing skills.

Salmon have the disadvantage that they do not spawn repetitively like rainbow and brown trout. Therefore, years of poor spawning success have a distinct effect on salmon abundance and may affect the anglers' catch. There is no evidence that rainbow or brown trout are presently in need of management.

14. To avoid endless opinion and controversy there is a need to know the normal level of stocks of the three species in the lake and what impact changes to the lake have on these stocks and on the anglers success in catching fish.

Analysis of trapping data will give an indication of low years to come. The release of marked fish and monitoring of recaptures sampled from the anglers catch could provide population estimates. Surveys by towed divers might provide more rapid and better population estimates still. Adequate information obtained could then be the basis for negotiation on compensation works for the fishery.

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