species. These results are thus probably indicative of the distribution only of skipjack. This species has been found mainly near the 100-fathom line between 18° and 20°C, especially in areas of temperature fluctuations. However, apparently favourable localities need not necessarily harbour surface schools of the species—a conclusion also supported overseas.

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BROWN TROUT *(SALMO TRUTTA)* IN THE HINDS RIVER

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This paper deals with data on the ecology of the brown trout collected during two visits to the Hinds River in 1962. Electric fishing and gill netting were used to capture 2,325 brown trout. Brook trout *(Salvelinus fontinalis)*, quinnat salmon *(Oncorhynchus tschawytcha)*, Eleotridae, Galaxiidae, Retropinnidae, torrent fish *(Cheimarrichthys)*, and eels were also captured.

THE RIVER

The Hinds River is a small stream rising as two branches in the foothills at the western edge of the Canterbury Plains. These branches converge at Mayfield and from there the river flows south west across the plains to the sea 12 miles south of Ashburton. At the mouth there is a small lagoon. From the confluence at Mayfield to the mouth the gradient is even and slight (Table 1). There are pools, runs and flats in approximately equal proportions, but no falls, stickles or cascades. (Definitions from Allen, 1951.) Both the branches are similar to the main river but with a steeper gradient and a few cascades; in the South Branch there is one man-made fall of 3 feet. The small tributary streams and ditches contain all the types of water listed above, although no falls are higher than 15 feet. The gradient of the tributary streams and ditches is often quite steep.

TABLE 1. *Summary of the river and tributary gradients.*

	A *Fall* (ft.)	*B* *Length* (miles)	*Ratio A:B* *(slope)*
Main River	900	27	1:160
North Br.	1100	17	1: 80
South Br.	1100	12	1: 60
Limestone Cr.	800	8	1: 50
Cravendale Cr.	600	4½	1: 40

All the tributary streams examined, the North Branch, and the main river, flow throughout the year. The South Branch has periodic dry periods, except at its headwaters and immediately below the entrance of Limestone Creek.

The bed of the main river and of both branches is shingle throughout, with small areas of boulders and. in the pools, sand. Mud is common along the banks. The bed of Limestone Creek is of similar composition to that of the main stream. The other small tributaries have large amounts of mud and little shingle.

The channel in the lower portion of the main river has been straightened by the Catchment Board. Bulldozing for shingle has modified areas of the main stream and the North and South Branches.

Cover consists almost totally of bank cover. There is one small backwater where filamentous green algae provide cover for the trout and some areas have sunken snags and willows along the bank affording underwater cover. The bank cover is summarized in Table 2.

TABLE 2. *Bank cover in the Hinds River system.*

Area	*% cover*	*Type*
Main Stream	35	Willow, gorse, broom, grass.
North Branch	35	Willow, gorse, broom, grass.
South Branch	10	Willow, gorse, broom, grass.
Limestone Cr.—Upper	10	Flax and grass.
—Lower	90	Flax, grass and willow.
Cravendale Cr.	100	Flax and grass.
South Br. Headwaters	100	Flax and grass.

The normal flows are summarized in Table 3. The figures do not include flood conditions.

TABLE 3. *Flows in the Hinds River system.*

Area	*Flow—(cusecs)*
Main Stream*	15–120
North Branch	15–100
South Branch	0– 15
Limestone Creek—Upper	2– 5
—Lower	5– 20
Cravendale Creek	0.25– 1
South Branch Headwaters	0.25– 0.5

* Four irrigation races enter the main stream (Fig. 1). These add 180 cusec to the river at their times of maximum flow. The irrigation water generally enters the river intermittently during the summer dry periods.

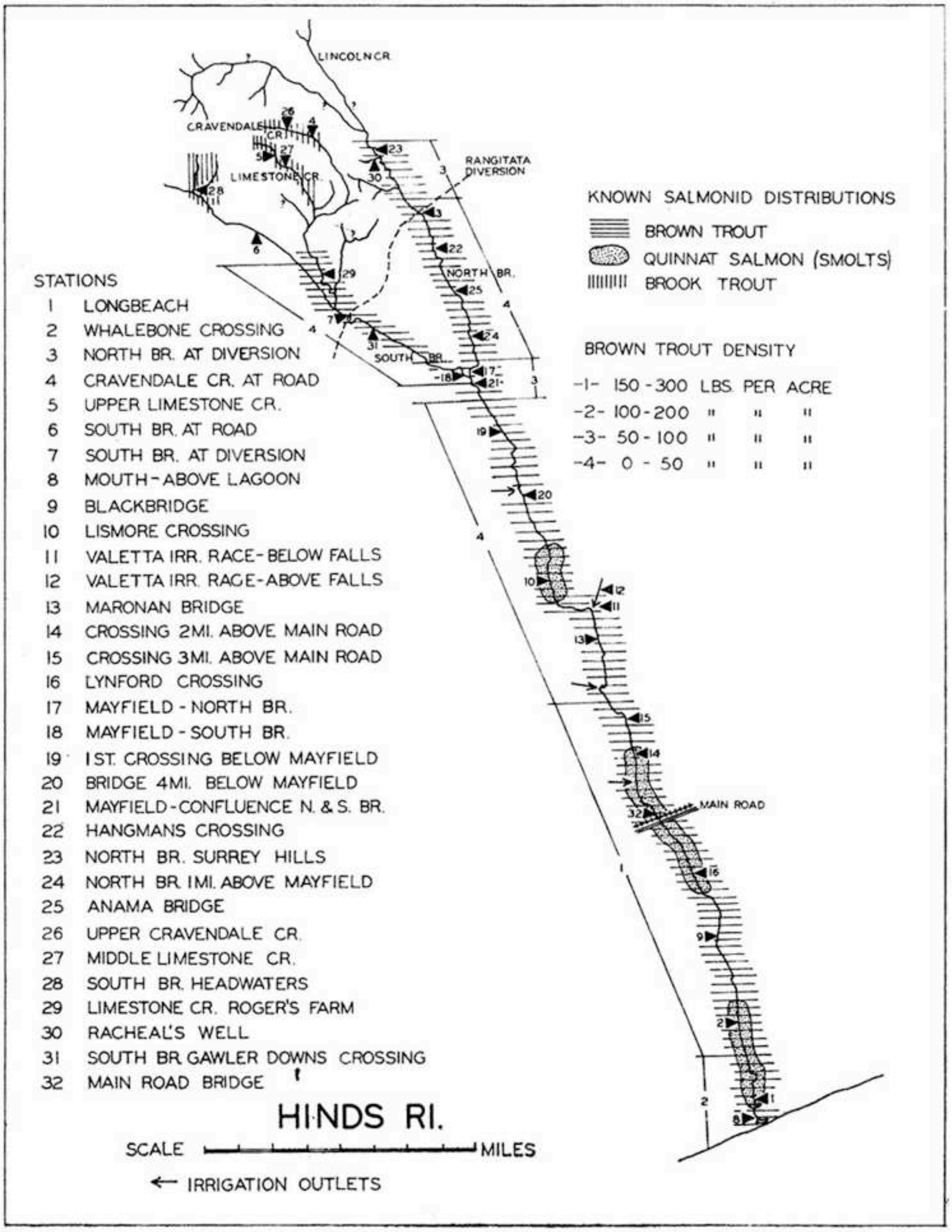

FIGURE 1. *Location of stations and distribut ion of salmonids in the Hinds River.*

The water is clear throughout the system except during the summer when silty irrigation water enters and causes it to become cloudy.

Water temperatures were recorded at each station at the time of visit. Daily maximum and minimum temperatures were also recorded at the highway bridge near Hinds township and at the top bridge on the North Branch. At the main highway bridge the average over five days gave a daily range of 3.5°C. to 8.5°C. during the winter, and 13°C. to 20°C. during the summer. The lowest temperature recorded was 2°C. in Cravendale Creek and the highest was 28°C. at the highway bridge.

Water samples were taken near the mouth of the main river, in the North Branch and in lower Limestone Creek. These were analysed for total dissolved solids. They contained 45, 35 and 36 p.p.m. respectively.

BROWN TROUT

The density of the trout population varied greatly over the length of the river (Fig. 1). The population at each station was estimated by dividing the electric fishing catch from a given area of water by the estimated proportion caught. The latter was assessed subjectively, taking into account the nature of the water fished, and using the results of second runs at some stations as a basis. The weight of the population was estimated by dividing the catch into 1 cm. size groups and determining the numbers and average weight of the fish in each group, the latter being based on the mean length-weight relationships or mean condition factor. To convert the population figures to densities the former were divided by estimates of area calculated from approximate measurement of length and average width. The method of estimating weight from length-weight relationships involves a small systematic under-estimate but the method of collecting tends to produce a slight over-estimate of mean size.

These errors are probably small compared to those involved in determining the number of fish in an area. No true estimation of probable error is possible but it is hoped that the results are reliable to within ±20%. The 0+ fish are omitted in all estimates. Table 4 below gives the results. The stations are in order going upstream.

TABLE 4. *Trout population estimates.*

Locality	*Station No.*	*No. of fish in Station*	*No. of fish per acre*	*Lb./acre*
Mouth	8	100–S125*	110–S135*	63–S113*
	1	S60*–64	S220*–230	105–S146*
	2	149–S150	700–S750	107–S208*
	9	S150*–250	S375–625	251
	16	S75* –250	S300*–1000	S121*–283
Highway Bridge	32	S100*–200	S400*– 800	S248*–293
	14	S175*–400	S260*– 550	S117*–260*
	15	S140*–200	S550*– 800	220–S266*
	13	10	15	–
Valetta tail race	11	10–75*	50–700*	–
	12	0	0	0
	10	10	50	–
	20	5	10	–
	19	7	25	–
Mayfield confluence	21	10–S15*	30*	11*
North Branch	17	50–S75*	45–S121*	50–S300*
	24	5	20	–
	25	5	20	–
	22	S 5*–10	S 10*–20	21
	3	S 5 –10	S 30 –50	22
	23	5–S15	10 –S50	S63
South Branch	18	0	0	0
	31	5	–	–
	7	5	10	–
	6	0	0	0
	28†	0	0	0
Limestone Creek	29	5	50	–
	27† & 5†	0	0	0
Cravendale Creek	4† & 26†	0	0	0

S indicates summer survey. * excluding fish of less than 17.5 cm. fork length.
† areas where *Salvelinus fontinalis* are found.

Comparison of the brown trout densities in the Hinds River with other streams shows a high density in the lower third of the system, varying between 63 and 293 lb. per acre. The remaining two-thirds of the Hinds system has a low density of brown trout with the exception of Stations 17 and 23. The headwaters are devoid of brown trout although they contain brook trout.

The lack of trout in the South Branch was no doubt due to the fact that this stream dries up for extensive periods each year.

Burnet (1959) gives figures for Doyleston Drain, 39-135 lb. per acre, and Hanmer Road Drain, 49-99 lb. per acre, both for the period 1954-58. He estimates a density of 310 lb. per acre in the 1960 peak year on the South Branch of the Waimakariri River (pers. comm.). Allen (1951) found the trout density in the Horokiwi Stream to vary from 58 to 255 lb. per acre.

The analysis devised by Cassie (1954), plotting length frenquency on probability paper, was used to calculate growth rates. The winter survey results are given in Table 5.

TABLE 5. *Age and length estimates in cm.*

Age	*Mean fork length*	*95% range*	*Standard deviation*
I	14.4	10.5–18.5	2.0
II	24.9	20.0–30.0	2.7
III	35.8	30.0–41.5	2.8
IV?	45.8?	41.5–50.0	–

The fish measured in the summer survey yielded similar results; however, the modes were not as clearly defined as the winter survey and a Cassie analysis was found impracticable for these fish. In order to eliminate, as far as possible, the variation in growth which may occur in different parts of the river, growth rates were calculated combining only two stations (9 and 15). The results are shown in Figure 2. The waves show variation in growth rate between summer and winter.

Survival and mortality (including emigration) can be estimated from these data. The survival and mortality below the age of I+ cannot be estimated because (a) trout fry were apparently released in the Hinds River system and separation of the native brown trout and the introduced brown trout is impossible, and (b) the methods of fishing were strongly biased toward capture of larger fish. The total catch

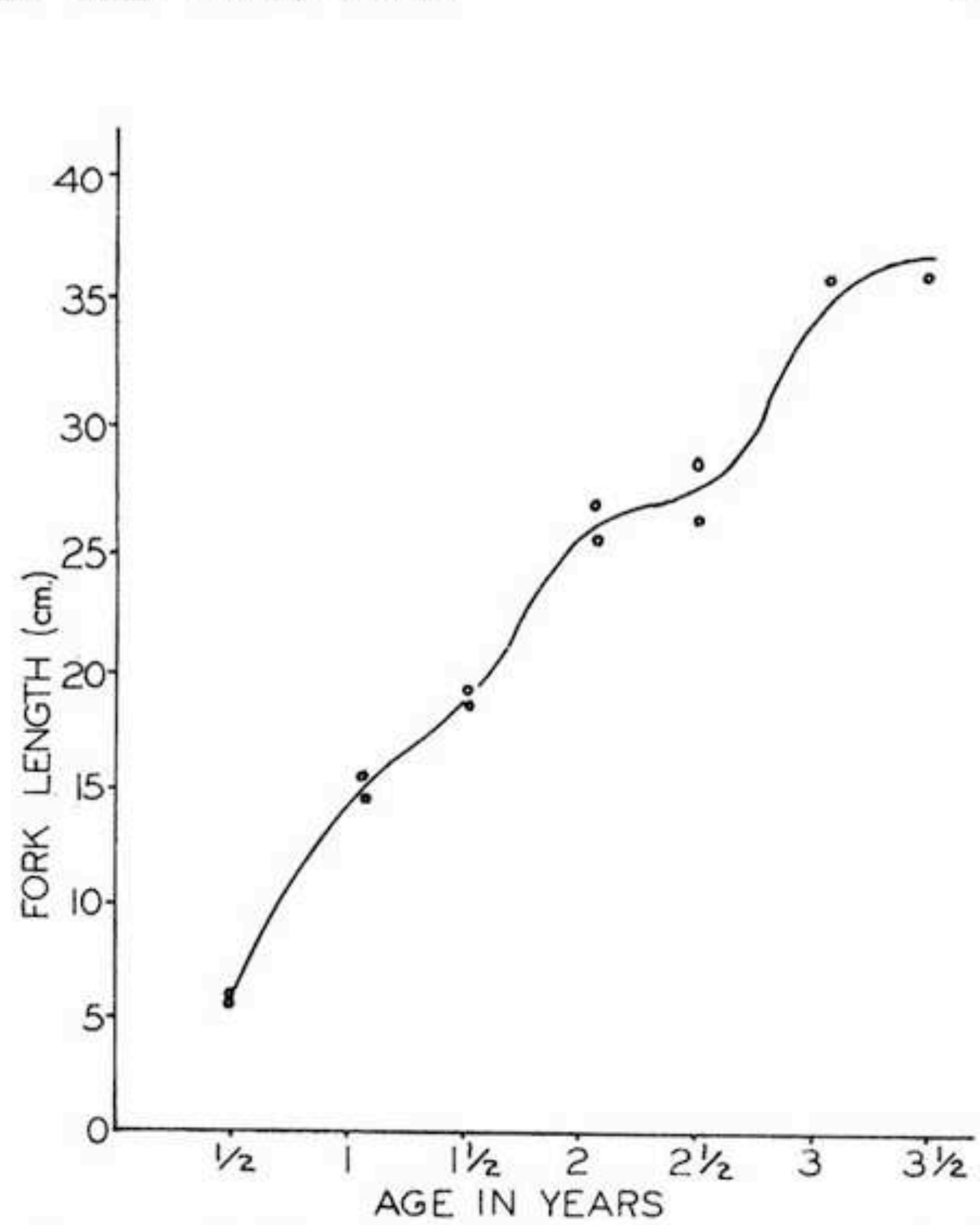

FIGURE 2. *Growth of brown trout at stations 9 and* 15.

by ages is as follows: 0+ 344; I–I+ 685; II–II+ 1049; III–III+ 199; IV and older 28. The assumptions are made that fish of age II and older were captured in their true proportion and that the year class strength from II up is similar. Fishing mortality is very low and can be ignored. The loss calculated is therefore a combination of natural mortality and emigration. Following the method of Heincke (1913) as given in Ricker (1958) for incomplete breakdown of old fish the following is obtained:

$$1 - S = \frac{Nt_1}{Nt_1 + Nt_2 + Nt_3}$$

where $1 - S$ = total loss
Nt_1 is the number of fish of age II–II+
Nt_2 is the number of fish of age III–III+
Nt_3 is the number of fish of age IV and older.

$$\therefore 1 - S = \frac{1049}{1049 + 199 + 28} = .822$$

∴ total loss, averaged from age II onwards, equals 82% and survival for the same period 18%.

If the same method is applied to the winter data only, the loss calculated is 91% and survival 9%.

A similar method devised by Robson and Chapman (undated) was also used. This gave a loss rate of 83% which agrees closely with the Heincke method.

Diet and food availability were examined. The young trout (age I and less) feed almost exclusively on bottom fauna with occasional flying insects. The older fish feed on bottom fauna and native fish with occasional flying insects. Bottom fauna was sampled during August and November and the following groups were found, in order of abundance: Ephemeroptera, Trichoptera, Coleoptera, Diptera, Annelida, Mollusca and Neuroptera. The average numbers of animals per square foot in November was 153 (range 21–871), the average in August was 117 (range 4–291).

The results of analysis of the trout stomachs are given in Table 6.

TABLE 6. *Trout stomach analysis.*

Age Group	*Area*	*Stomach Contents*	*% of Total*	
Adult	River	Fish	40%	(including trout)
		Trichoptera	40%	
		Diptera	7%	(mostly adults)
		Coleoptera	4%	
		Mollusca	3%	
		Plecoptera	2%	
		Ephemeroptera	2%	
		Other invertebrates	2%	
Adult	Lagoon	Mollusca	80%	
		Trichoptera	17%	
		Coleoptera	2%	
		Other invertebrates & fish	1%	
Young	River	Ephemeroptera	93%	
		Crustacea	4%	
		Trichoptera	2%	
		Diptera	1%	(often adults)

It can be seen that the young fish feed almost completely on Ephemeroptera with only 2% Trichoptera and no fish, while the older fish feed almost totally on fish and Trichoptera with only 2% Ephemeroptera. The fish from the lagoon (adults) feed almost totally on Mollusca and Trichoptera: this probably reflects food availability.

There are eleven species of native fish in the Hinds River and the possibility of competition for food between these species and the trout was examined.

The diet of the native fish, as found in stomach analyses is: Ephemeroptera 43%, Diptera 24%, Trichoptera 18%, Coleoptera 7%, other invertebrates and larval fish 8%. With one exception there was no significant difference in diet, therefore the figures lump all species except *Galaxias burrowsius*. Stomach analysis of this species showed a diet of 99% crustacea. The results of stomach content analysis are summarized, in terms of possible food competition, in Table 7.

The trout stomachs examined were taken in August and November; no information for the remainder of the year is available.

It is impossible at our present stage of knowledge of the Hinds River to give with any certainty the factors which contribute to the limitation of trout in size and number. However, some correlations and factors have been suggested from the work. In the main river there is a positive correlation between native fish numbers and trout numbers. No correlation was found between the trout population and the bottom fauna numbers. Generally speaking the bottom fauna counts were fairly constant throughout the whole stream. One area with a very high bottom count (Station 23) had very low trout density. Two stations were found which had very low bottom fauna counts (Station 9 summer and Station 20 winter). Of these one had a high trout density and the other a low trout density. Although the diet of young and adult trout appears to be very different their distribution in the river was very similar.

TABLE 7. *Possible food competition.*

Fish	*Food*	*Possible Competitor*	*Food*	*Possibility of Competition*
Adult trout	Fish and Trichoptera	Young trout	Ephemeroptera	No
Adult trout	As above.	Native fish	Ephemeroptera and Diptera	No
Young trout	Ephemeroptera	Native fish	As above	Yes

The size of the trout appears to vary conversely with density. In the North Branch where the trout density is generally sparse, the individual size of the fish was large (up to $8\frac{1}{2}$ lb.). In the lower third of the river, where the density is high, few fish taken weighed over $1\frac{1}{2}$ pounds. Station 8 (the mouth), and the lagoon, did not follow this pattern; however, in this area sea run trout were captured during the winter survey and these fish may account for the few larger fish. A similar pattern of size distribution in the upper, middle and lower stretches of a river was found for the Oreti River, although no indication of the presence of sea-run fish is given—Allen and Cunningham (1957).

There is little apparent correlation between cover and fish number or size, although in areas of little cover there was seldom high trout density.

Pollution in the form of silt is added to the river in the summer dry season through the irrigation outlets. This appeared to have little effect.

In lower Cravendale Creek, lower Limestone Creek and the lower South Branch the native fish were infected with a disease manifested by external white spots. This was tentatively identified as "white spot disease". This may have some effect upon the trout population although the few trout in these areas were not affected.

No physical factors were found which would have an obvious limiting effect, nor any chemical or biological factors except those mentioned.

REGULATIONS

The present regulations allow only fly fishing with a size 12 or smaller hook. The bag limit is 12 fish per day with a minimum size of 10 inches. The length of the season is 7 months from 1 October to 30 April.

Under these conditions very few fish are being taken in the sport fishery while natural mortality and emigration are removing 80-90% of the fish over II+ years annually.

The present size limit of 10 inches total length is about equal to the average length of the age II fish. This age group is the only age class of any size available to the fishery, very high loss occurring after II. If the size limit was reduced to 9 inches almost all the age II fish would be available while the age I and I+ fish would still be protected. A decrease in age II fish due to fishing is likely to increase the number of older fish and probably would not materially increase the present annual mortality.

The present lure restriction (fly only; maximum hook size 12) serves only to lower the total catch and to reduce the chances of capture of the larger fish. (The larger fish were usually found under rather dense willow cover making fly fishing extremely difficult). To increase the catch and if possible make easier the catching of the large fish, it is suggested that the lure restrictions be liberalised to include all flies, spinners (threadline fishing) and the use of worms.

The present closed season is designed for two reasons; to protect the fish on the spawning areas, and to allow those fish which have spawned to return to good condition. Information gained during the winter survey and a physical examination of the river suggests that unless the river is very heavily fished this protection of spawning beds is unwarranted. (Catchment Board activity is more damaging than thousands of anglers and has little noticeable effect.) Condition during the winter can only be described as good for over two-thirds of the fish (similar results were found during the summer survey); therefore, the second reason for a restrictive season is not valid. A twelve month open season is suggested for the Hinds River. The present bag limit of twelve fish is seldom reached and so has no practical effect. If the previously mentioned regulation changes are made the limit may be reached more often. At present I see no reason to alter this bag limit.

SUMMARY

1. The Hinds River system, on the basis of the trout population, can be divided into four regions—
   (a) lower third—high density, small size.
   (b) upper portion main river—low density, small size.
   (c) North Branch—low density, larger size.
   (d) South Branch and tributaries—low density, small size; presence of *Salvelinus fontinalis*.
2. There appears to be a change in the diet of the trout with age. Those age I and under feed primarily on Ephemeroptera, those over age I feed primarily on fish and Trichoptera.
3. Competition for food between the native fish and young brown trout is a distinct possibility as both have Ephemeroptera as their main food supply.

4. The mean fork lengths at ages I to IV are 14.4 cm., 24.9 cm., 35.8 cm., 45.8 cm. respectively.
5. Estimates of the annual mortality plus emigration rate from age II on vary between 80 and 90%.
6. There is a positive correlation between native fish density and brown trout density in the main river; however, no correlation was found between bottom fauna density and trout density.
7. There appears to be a negative correlation between trout size and density.
8. The present regulations are having an adverse effect on the fishable trout population and the following changes are recommended:
   (a) size limit reduced to 9 inches total length;
   (b) lure restrictions be liberalized to allow all flies, threadline spinners and worms;
   (c) the present 7 month season be extended to 12 months.

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A SURVEY OF LAKE ROXBURGH, A RECENT HYDRO-ELECTRIC DAM

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INTRODUCTION

This survey was carried out for the Otago Acclimatisation Society which was considering the introduction of the Mackinaw Char or Lake Trout *(Salvelinus namaycush)*.

As the lake was formed by the impoundment of the Clutha River in July, 1956 it was 5½ years old when the data were collected in January, 1962, and is still undergoing fairly rapid development. A description of the lake at this stage may be of value as a basis for study of its later development and for comparison with other similar dams such as the Waitaki and Benmore dams on the Waitaki River.

Though Lake Roxburgh lies in the rain shadow area of Central Otago, with an annual mean rainfall of less than 20 inches, its catchment area drains the much higher rainfall area on the east side of the Southern Alps. The catchment area lies almost entirely on schist. Lakes Hawea, Wanaka and Wakatipu act as settling ponds at the foot of the Alps, but the Clutha River gains a considerable load of sediment from tributaries such as the Shotover, Nevis and Manuherikia Rivers.

The Alexandra Bridge was taken as an arbitary upper limit of the lake as there is no clear cut distinction between river and lake. Shingle and Gorge Creeks are the two largest creeks that drain into the lake itself.

MORPHOMETRY

The data in Table 1 were provided by the New Zealand Electricity Department or extracted from a contour map (1000 ft. = 1 inch) made by the Ministry of Works prior to the building of the dam. All measurements using length and width were taken at the 131.1 metre (430 ft.) contour.