



NEW ZEALAND MARINE DEPARTMENT

**FISHERIES TECHNICAL REPORT
No. 87**

**DISTRIBUTION OF NATIVE AND
INTRODUCED FISHES IN THE
HINDS RIVER SYSTEM**

E. D. LANE AND W. SKRZYNSKI

**WELLINGTON, NEW ZEALAND
1972**

FISHERIES TECHNICAL REPORT

NO. 87

DISTRIBUTION OF NATIVE AND INTRODUCED FISHES IN THE
HINDS RIVER SYSTEM

E.D. LANE⁽¹⁾ AND W. SKRZYNSKI
FISHERIES DIVISION
MARINE DEPARTMENT
WELLINGTON

(1) NOW AT BIOLOGY DEPARTMENT, CALIFORNIA STATE COLLEGE,
LONG BEACH, CALIFORNIA 90801, U.S.A.

CONTENTS

	<u>Page</u>
SUMMARY	1
INTRODUCTION	2
MATERIAL AND METHODS	3
THE RIVER	6
NATIVE FISHES	7
INTRODUCED FISHES	9
INTERSPECIFIC RELATIONS	10
GENERAL	10
<u>S. TRUTTA</u> AND <u>S. FONTINALIS</u>	11
DESCRIPTION OF PLATES	17
PLATES	18
ACKNOWLEDGEMENTS	24
REFERENCES	24
APPENDIX 1	28

SUMMARY

The Hinds River is about 40 miles long and flows to the east coast in the central part of the South Island of New Zealand. The catchment has been drastically changed by European colonists in the last century.

Eleven native and three introduced fish species have been recorded from the Hinds River and its tributaries. Their distribution and abundance are discussed.

The mutually exclusive distribution of Salmo trutta and Salvelinus fontinalis, with Salvelinus fontinalis in the upper tributaries and Salmo trutta throughout the rest of the river, is probably caused by temperature differences in association with other features.

INTRODUCTION

So far no comprehensive study has been published of a relative distribution of fish species in any river system in New Zealand. Allen (1951, pp. 60-68) in his classic study of a trout population in a small stream in Wellington district briefly discussed the distribution of native species in the stream and their relation to trout. Woods (1964, pp. 11-18) listed the fishes of the upper reaches of the large North Island rivers within the Tongariro power scheme area and discussed possible effects of the scheme mainly on eels and trout (pp. 78-201). McDowall discussed distribution of fishes in two rivers in Wellington district in relation to the species he studied: Gobiomorphus huttoni (1964) and Galaxias maculatus (1968a). Hopkins (1965 and 1970) examined relations between fish species in a small tributary of a large North Island river.

Such scarcity of knowledge on relative distribution and inter-relations of native and introduced fishes was recently highlighted, when a proposal to introduce another large predatory game fish to New Zealand was discussed (McDowall 1968b and c).

The present paper is an addition to that by Lane (1964) which described the S. trutta population of the Hinds River and mentioned other species only in relation to trout.

MATERIAL AND METHODS

Two 2 week surveys of the Hinds River were conducted in August (winter) and November (late spring) 1962. Thirty-two stations of lengths from 50 to 900 yards were selected throughout the system and fished with electric fishing equipment. The main object was the assessment of the S. trutta stock and all trout caught were measured and weighed. All other species were recorded (table 1) and their abundance was noted, but no detailed population estimates were attempted. Some stomach contents of most species were examined and these data are summarised in Lane (1964).

TABLE 1

Native and Introduced Fish Species in the Hinds
River System

NATIVEFamily GalaxiidaeNeochanna burrowsius (Phillipps)Galaxias maculatus (Jenyns)Galaxias vulgaris StokellFamily RetropinnidaeStokellia anisodon (Stokell)Family AnguillidaeAnguilla australis schmidti PhillippsAnguilla dieffenbachi GrayFamily EleotridaeGobiomorphus basalis (Gray)Philypnodon breviceps StokellPhilypnodon hubbsi StokellFamily CheimarrichthyidaeCheimarrichthys fosteri HaastFamily PleuronectidaeRhombosolea retiaria HuttonINTRODUCEDFamily SalmonidaeSalmo trutta LinnaeusSalvelinus fontinalis (Mitchill)Oncorhynchus tshawytscha (Walbaum)

THE RIVER

The Hinds, a rain fed river, about 40 miles long and with a catchment area of 120 sq. miles, flows to the east coast in the central part of the South Island of New Zealand. It originates in the foothills of the Southern Alps at the western edge of the Canterbury Plains.

The Canterbury Plains are the largest homogenous flatland in New Zealand, about 120 miles long and up to 40 miles wide, gently sloping from 1000ft to sea level. Before European settlement in the middle of the last century, this area was covered almost exclusively by tussock grassland and was swampy in parts (Speight, Wall and Laing (Eds.) 1927). The Europeans made rapid and drastic changes through drainage and irrigation and the accompanying destruction of native plants and animals and the introduction of exotics. The Plains are now criss-crossed by a reticulated pattern of tree shelter - belts and irrigation ditches between which wheat and pastures flourish "and it is only in the broad wastes of shingle through which the great rivers make their way seaward across the Plains that anything like the ancient appearance of the country remains to us" (Speight, Wall and Laing (Eds.) 1927, p.2.).

The Hinds River (fig.1 and table 2) was changed completely with the surrounding countryside. Towards the end of the last century the swamp in its lower reaches, one of the largest in Canterbury, was drained, a straight channel cut through it and a fixed outlet to the sea established (Burdon 1950, pp. 213-222). Willows and other exotic trees were planted along the river in many places and the river bed has been repeatedly exploited for removal of shingle.

In the upper reaches the river is divided into two branches, into which flow several small tributaries. The slopes there vary from 1:40 to 1:80 and the main river has a fairly even slope of 1:160. The bed of the river is mostly wide and open, with no steep banks. It consists of loose shingle, with small areas of boulders and, in the pools, sand. Mud is common along the banks. The small tributaries, except Limestone Creek, have large amounts of mud and little shingle.

The cover, except for some areas with sunken snags and willows, consists almost totally of bank cover provided by willow, gorse, broom and grass and by flax and grass in the tributaries.

The normal flows in the upper tributaries are from 0.25 to 15 cusecs and in the main river from 15 to 120 cusecs at the mouth. The South Branch dries up periodically, except at its headwaters and immediately below the confluence of Limestone Creek. The flow regime is largely changed during the summer dry periods, when four irrigation races entering the main river add to it intermittently up to 180 cusecs. The river floods every few years and the peak discharge at the mouth, recorded in April 1951, was 11,500 cusecs (Soil Conservation and Rivers Control Council 1957). At the mouth the river forms a small lagoon.

The water is normally clear throughout the system except in the main river during periods of discharge of the silty irrigation water. Water samples taken near the mouth, in the North Branch and in the lower Limestone Creek were analysed for total dissolved solids and contained 45, 35, and 36 ppm. respectively. Water temperatures are summarised in table 3.

NATIVE FISHES

Eleven species of native fish were recorded during the surveys (table 1 and fig. 1).

Six of these species, which have partly marine life histories, were found mostly near the mouth. Only one black flounder, Rhombosolea retiaria was taken in August and only three smelt, Stokellia anisodon in November, both species at station 8 directly above the lagoon at the mouth. The largely marine S. anisodon is probably more abundant near the estuary at spawning times (McMillan 1961). The inanga, G. maculatus is very common near the mouth (station 8) and some whitebaiting is being done. Only a few G. maculatus were found higher up-stream at stations 1 and 2. The bullies, Gobiomorphus basalis and Philypnodon hubbsi were very common at station 8. G. basalis was less common at station 1 and none were found higher up the river. Its habitat appeared to be restricted to areas around the banks, where bank cover existed.

P. hubbsi was common also at station 1 and one specimen only was taken at station 2 in August. Its habitat is amongst loose stones in riffles and rapids. The torrent fish, Cheimarrichthys fosteri was fairly common only at station 8. At station 1 four were taken in November and at station 2 two were taken in August and three in November. None were taken at stations 9 and 16 but at station 32 one was taken in August and two in November. Its habitat appeared to be riffles and rapids with larger shingle and small boulders.

A few specimens of the rare Canterbury mudfish, Neochanna burrowsius were taken at station 11 in August in a small pool below a fall in the irrigation race. None could be found there and higher up the race subsequently. These few fish were probably swept down the race from smaller ditches, where they are usually found (Skrzynski 1968).

Both eels, the long-finned Anguilla dieffenbachi and the short-finned Anguilla australis were found at all stations fished. They were most abundant where good bank or weed cover existed and rare in rapid flowing water in the middle of the river bed. The eels are the largest and the most wide spread of the native freshwater fishes and in the Hinds, as in many other rivers in New Zealand, they may equal or even surpass the trout in terms of both numbers and the total biomass. No counts of each species were made but it appeared that the distribution in the Hinds followed the usual pattern, the short-finned eels being more common close to the sea and the long-finned eels, some of them very large, more common in the upper river and in the headwater streams.

The next most widespread and abundant species was the upland bully, Philypnodon breviceps, which was found at almost every station, usually in large numbers, except for a few stations in the middle reaches of the river which were rather barren and devoid of cover. This area was bulldozed by the Catchment Board and subjected to changeable flows through the irrigation outfalls, which could damage the bully eggs and sweep down the juveniles.

Although P. breviceps is called the upland bully (Stokell 1955; Woods 1963) in fact it is very common both in the alpine and lowland streams in the South Island. It is a very adaptable fish and the authors have observed its eggs and juveniles in a variety of

conditions, both in the open shingle rivers (e.g. Hinds) and in very small stock races with little flow, where in the absence of suitable stones they spawned on tins, pieces of glass, wood, etc. P. breviceps is also known from lakes. Contrary to most New Zealand bullies it has no marine stage in its life history and the juveniles live in close proximity to the adults.

The common river Galaxias, G. vulgaris was abundant or common at most stations above the confluence of the North and South branches including station 21 at the confluence. It was not found in the Cravendale Creek (stations 4 and 26), which appears to be explained by the absence of shingle there, the bottom consisting of mud and sand. By contrast in the Limestone Creek, and at other stations where G. vulgaris was common, the bottom consisted mainly of medium to coarse shingle with very little sand and mud. G. vulgaris was found round rocks but was not restricted to rapid water. It was also not restricted to either banks or to the middle of the stream bed. The presence of shingle is probably a requirement for breeding of this species, which is confined to rivers and streams and is not known to migrate (Benzie 1968; McDowall 1970). It has not been established what limits the downstream distribution of this species, but so far it has been found only in the alpine or middle reaches of the rivers on the east coast of the South Island and one population in the upper Buller River on the West Coast just over the Lewis alpine pass (McDowall 1970).

INTRODUCED FISHES

European settlement in New Zealand in the second half of the last century was closely followed by the introduction of game fishes. No exact records are available for the Hinds River, but it is almost certain that the brown trout, Salmo trutta and the American brook trout, Salvelinus fontinalis were both liberated and became established before the end of the last century, S. trutta preceding S. fontinalis (Speight, Wall and Laing (Eds.) 1927; North Canterbury Acclimatisation Society, pers. comm.). The S. trutta population was described by Lane (1964). In comparison to S. trutta, S. fontinalis has a very limited distribution and was recorded only at stations 4, 5, 26, 27 and 28. It is reputedly present in the headwaters of the North Branch which were not investigated.

In the South Branch there is no flow for prolonged periods (station 6 had a few pools in August and was completely dry in November), so the S. trutta and S. fontinalis stocks are separated by a dry area. In the Limestone Creek there is a moderate number of S. trutta in the lower reaches (station 29), where the flow in August was estimated at 45 cusecs. It appeared that much of this flow came from paddock seepage, because the upper Limestone Creek had a flow of about 7 cusecs at the junction with the Cravendale Creek, which had an even smaller flow. The flow at station 28 in August was 7 cusecs. Therefore, in the Hinds River system S. fontinalis were found only in the headwater streams fed by springs with flows not exceeding 7 cusecs.

S. fontinalis in these conditions grows only to a small size. 313 individuals of age 1+ were measured during both surveys and of these only seven were above 30cm fork length, the largest was 34.5cm. The average size of 1+ fish was about 16cm, the majority being between 9 and 23cm. Fry were found only during the November survey. The average length of the 177 fry measured was 49.5mm and the size range from 30 to 66mm.

The quinnat salmon, Oncorhynchus tshawytscha has well established sea-run populations in the two large rivers immediately to the north (Ashburton) and south (Rangitata) of the Hinds. Liberations or spawning of O. tshawytscha in the Hinds River have never been recorded but one dead adult was found at station 1 in August. A few salmon smolts occurred, but only below irrigation outlets, through which they probably came from the Rangitata River.

INTERSPECIFIC RELATIONS

GENERAL:

In New Zealand the major changes in land use and the introduction of exotics came simultaneously and it is impossible to separate their respective, mostly adverse effects on the native fishes, prior knowledge of which was almost non-existent (McDowall 1968b).

All native species are carnivorous and they utilise a common source of food, aquatic insects and other invertebrates, which now they have to share with the mostly larger exotics. Only the eels and introduced salmonids are fish feeders to any significant degree, preying mainly on smaller native species, but large eels taking some trout also (Allen 1961; Burnet 1952). In the Hinds River all native fishes (except N. burrowsius) and young S. trutta feed principally on Ephemeroptera (43 and 93% of total number of food organisms respectively) and adult S. trutta on fish (40%) and Trichoptera (40%) (Lane 1964). The competition for food between native fishes and young S. trutta in the Hinds River may be not as severe as the figures above suggest, because slight differences in the species and size composition of their diet probably exist, similar to those found by Hopkins (1965 and 1970). The percentage of fish in adult S. trutta diet in the Hinds River was very high compared to that found by Allen (1951). This may be correlated with the large numbers of the relatively open living P. breviceps, which was probably the species most often taken by S. trutta.

Competition for cover, which is scarce in the wide, open bed of the Hinds River may be more important than competition for food. The middle reaches with the least cover (stations 13 to 19) showed lower densities or absence of the most widespread and abundant species (trout, eels and P. breviceps). Burnet (1952) found the amount of cover to be a limiting factor in eel populations and this may apply to other species also.

SALMO TRUTTA AND SALVELINUS FONTINALIS: *

In contrast to Salmo gairdneri and especially the widespread S. trutta, S. fontinalis has generally been unable to establish itself in New Zealand, except in a few waters, usually upstream from these two species. Several authors noted this, but none has offered a documented explanation (Allen 1956; Stokell 1955; Woods 1963 and 1964). Allen and Woods mentioned competition from trout and Stokell the unsuitability of habitat. S. fontinalis was imported to New Zealand after the brown trout was generally well established and it appears that it was liberated in waters already containing brown trout.

* See also Appendix 1, p. 28

The Hinds River lies in an area climatically similar to the warmer extremities of S. fontinalis native range in North America. The distribution of S. trutta and S. fontinalis in the Hinds River parallels their distribution in the Shelter Valley Stream and other streams in southern Ontario, Canada. In both cases S. fontinalis is in the headwaters and S. trutta in the lower three quarters of the streams, with little or no overlap. The Hinds River and the Shelter Valley Stream are generally similar. The principal characteristics of the zones occupied by the two species are listed in table 2. The differences in these characteristics between the two zones are examined below to determine the causes of such distribution of the two species in the Hinds River.

1. Burton and Odum (1945) working on streams in Virginia found that S. fontinalis tended to occupy waters cooler than 20°C and postulated 19°C as a separation point in S. fontinalis and S. gairdneri distribution, the latter preferring temperatures warmer than 19°C. Creaser (1930) also found that S. fontinalis was rarely present in water above 19°C and Fry (1951) that it sought cooler water when the temperature exceeded 19°C. S. fontinalis acclimatised to 15-20°C showed a preferred (selected) temperature between 15.5 and 17.5°C (Ferguson 1958) and these acclimatised to lower temperatures, showed lower preferred temperatures (Graham 1948). Fry et al (1946) recorded that in water of 28°C S. fontinalis acclimatised at 15°C suffered 50% mortality in less than 60 minutes and S. fontinalis fry acclimatised at 20°C suffered the same mortality in about 100 minutes. Brett (1944) found the lethal temperature of S. fontinalis native to a lake to be 26.1°C and 26.6°C on two dates, when the lake water temperatures were 18°C and 20°C respectively. Huntsman (1946) recorded S. fontinalis mortality in two streams when the temperatures ranged from 25.4 to 31.4 and from 23.6 to 31.1°C.

Comparison of these findings with the temperatures recorded in the Hinds River (table 3) indicates that preferred temperature of S. fontinalis is often exceeded in the lower reaches of the river in summer. The highest temperature recorded from the upper tributaries was 16°C, well below the lethal limits. No continual temperature records are available, however, since these headwater streams are spring fed and have many pools shaded by bank cover, it is unlikely that their temperature ever exceeds 26°C. Therefore, it appears

TABLE 2Characteristics of a small river comparable to both the
Hinds River and Shelter Valley StreamLower and Middle parts of river (S. trutta zone - fish comparatively
large)

1. Temperature of water in summer warm.
2. Many species of fish present.
3. Large stream - one main channel.
4. Few or no springs in main stream.
5. Water level and flow fluctuate greatly.
6. Turbidity varies.
7. Slope slight.

Headwaters (S. fontinalis zone - fish comparatively small)

1. Temperature of water in summer cool.
2. Few species of fish present.
3. Several small tributaries.
4. Springs feed tributaries and branches.
5. Water level and flow relatively constant.
6. Water usually clear.
7. Slope greater than in lower parts of river.

that not only are S. fontinalis absent from the lower reaches of the Hinds River, because the temperature occasionally exceeds their lethal limits, but also, that the temperature in the tributaries is closest to their preferred range.

No such clear explanation in respect of temperature can be found for absence of S. trutta in the upper reaches. The lowest temperatures there are not lethal and data on optimum temperatures for S. trutta do not show clearly why it should be excluded (Brown 1946; Swift 1961). In New Zealand S. trutta exists in some waters colder than the Hinds River headwaters, although in Canada it shows preference for waters warmer than S. fontinalis (Dymond 1955).

There is evidence in other species that, if possible, a fish will select optimal temperatures for growth and metabolism (Hurley and Woodall 1968; Norris 1963) and as put by Fry and Hart (1948) "selection may be directed to temperatures at which the maximum scope for metabolic activity is available." If this is so, such exact "selection" would depend upon the fishes' thermal history, which is unknown for the Hinds River stocks of S. fontinalis and S. trutta.

2. The larger number of species in the lower part of the Hinds River should not eliminate S. fontinalis as there are many instances where it exists in waters with a large number of other species. The upper reaches of the Shelter Valley Stream have twice as many other species as the upper reaches and about the same number as the lower reaches of the Hinds River. Presence of a large predator, S. trutta, could be detrimental, but in the Shelter Valley Stream and other North American streams S. fontinalis overlaps with it in the middle reaches (Dymond 1955). Also, in some areas, S. fontinalis co-exists with other large predators, e.g. pike, Esox lucius in Gods Lake and River in northern Manitoba.

3. S. trutta maintains populations in many small streams in New Zealand; it occurs in a tributary of the Hinds River (station 30) with a flow of less than 1 cusec.

4. S. fontinalis is known to prefer springs in its spawning areas, while S. trutta has no such requirement. This could separate the two species at spawning time, but would not prevent them from mixing in other periods.

TABLE 3

Summary of water temperatures in the Hinds River (°C)

		Max. temperature (1)	Min. daytime temperature (1)	Average daytime temperature (1)	Average daily high temperature	Mean daily variation (2)
August 1962	Headwaters	7.4	2.0	4.8	-	-
	Main Stream	9.3	6.5	7.7	-	3.5 - 8.5
November 1962	Headwaters	16	-	-	15.5 (1)	-
	Main Stream	28	-	-	20 (2)	13 - 20

(1) Based on temperatures recorded when stations were visited.

(2) Based on 5 days continual monitoring at station 32 (Lane 1964).

5. and 6. Constant flow conditions and lack of turbidity are preferred by S. trutta and on their own would tend to induce it to enter the upper reaches.

7. Slope should have little effect on the distribution of S. fontinalis, as in its native range it exists in conditions varying from lakes to rapid rivers. S. trutta in New Zealand inhabits a similarly wide range of habitats.

The above discussion shows that the temperature is the only one of the characteristics listed in table 2 which may influence the mutually exclusive distribution of S. fontinalis and S. trutta in the Hinds River. Although the temperature differences may be the major factor in such distribution of the particular stocks of the two species established in the Hinds River, some other factors must support this and may be even more important in maintaining their continual separation. In Shelter Valley Stream S. fontinalis spread throughout the whole system during the spring when the water is cool but in summer they return to the cool water of the upper reaches.

Such seasonal downstream migration was not observed in the Hinds River and as suggested by Dr D. Scott (pers. comm.) it is possible that this stock of S. fontinalis, besides having a preference for lower temperatures, has an inherent tendency to move into the headwaters, which would prevent it from entering the lower reaches. At the same time this small sized stock may be so well adapted to life in the restricted habitat of the upper tributaries that it is able to competitively exclude S. trutta.

DESCRIPTION OF PLATES

(see fig. 1 for location of stations)

- Plate 1 (A) Station 8, immediately above lagoon.
 (B) Station 1, P. breviceps, G. maculatus, eel and S. trutta habitat (August 1962).
 (C) Station 1, riffles - P. hubbsi and C. fosteri habitat (August).
- Plate 2 (A) Station 9) High density of S. trutta.
 (B) Station 16)
 (C) Station 32 (August) high density of S. trutta.
- Plate 3 (A) Station 14) Upper limit of high S. trutta density.
 (B) Station 15)
 (C) Station 21 (August) Low density of S. trutta.
- Plate 4 (A) Station 22)
 (B) Station 3) (August) Low S. trutta density, G. vulgaris
 (C) Station 23) common.
- Plate 5 (A) Station 18 (August), no trout, dry in November.
 (B) Station 31 (August), only one S. trutta taken.
- Plate 6 (A) Station 29 (August), near the upper limit of S. trutta.
 (B) Station 5 November). Pool in which 9 S. fontinalis were caught.
 (C) Station 27 (August).
- Plate 7 (A) Station 28, general view.
 (B) Station 28 (August)) These two stations had larger
 (C) Station 26 (August)) populations of S. fontinalis than
 stations 5 and 27.



(A)



(B)



(C)

18.



(A)



(B)



(C)

PLATE 2



(A)



(B)



(C)



(A)



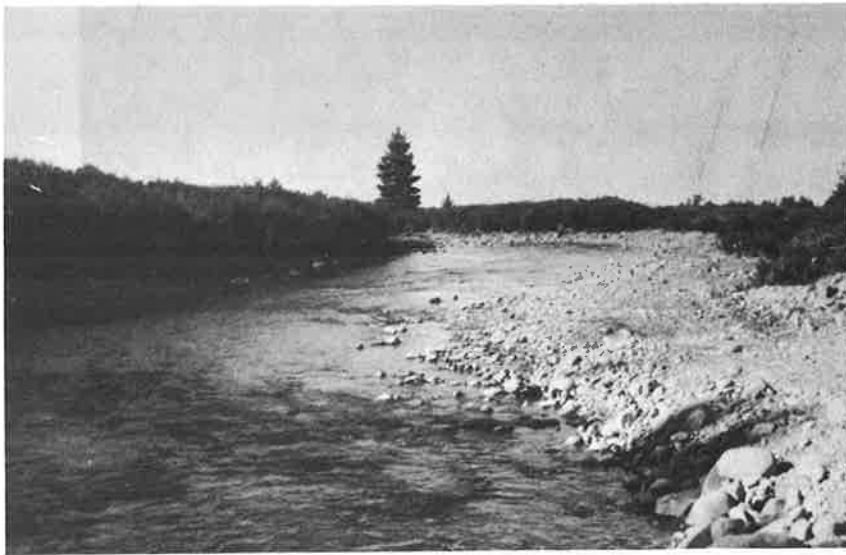
(B)



(C)



(A)



(B)

PLATE 5



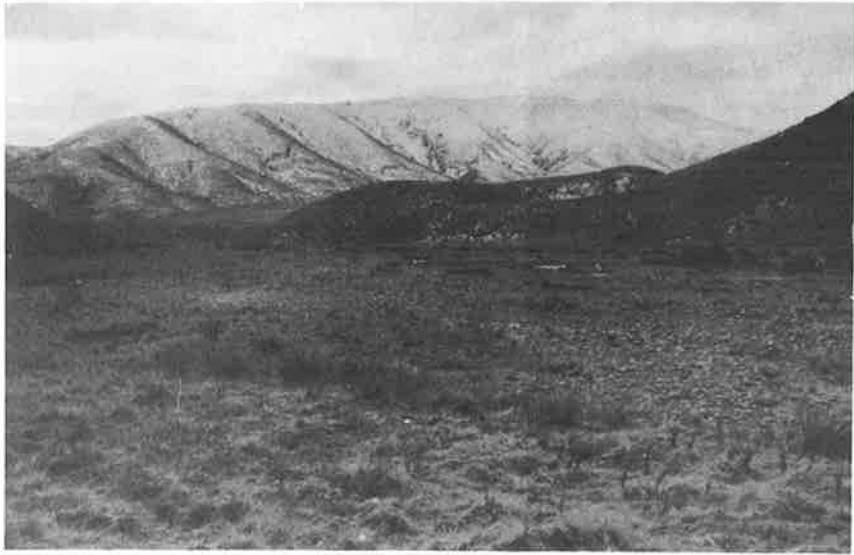
(A)



(B)



(C)



(A)



(B)



(C)

ACKNOWLEDGEMENTS

Thanks for the comments at various stages of the preparation of this report are due to several members of the staff of the Fisheries Research and Fisheries Divisions of the Marine Department, Mr J.M. Moreland, Dominion Museum, Dr D. Scott of University of Otago, Dunedin.

REFERENCES

- ALLEN, K.R. 1951 - The Horokiwi Stream: a study of a trout population. Fish. Bull. N.Z. 10. 238 pp.
- _____ 1956 - The geography of New Zealand's freshwater fish. N.Z. Sci. Rev. 14:3-9.
- _____ 1961 - Relations between Salmonidae and the native freshwater fauna in New Zealand. Proc. N.Z. ecol. Soc. 8:66-70.
- BENZIE, V. 1968 - The life history of Galaxias vulgaris Stokell, with a comparison with G. maculatus attenuatus. N.Z. J1 mar. Freshwat. Res. 2: 628-53.
- BRETT, J.R. 1944 - Some lethal temperature relations of Algonquin Park fishes. Publ. Ont. Fish. Res. Lab. 63. 49 pp.
- BROWN, M.E. 1946 - The growth of brown trout (Salmo trutta Linn.) III. The effect of temperature on the growth of two-year-old trout. J. Exptl. Biol. 22: 145-55.
- BURDON, R.M. 1950 - "New Zealand notables: series three". Caxton Press, Auckland. 247 pp.
- BURNET, A.M.R. 1952 - Studies on the ecology of the New Zealand long-finned eel, Anguilla dieffenbachii Gray. Aust. J. mar. Freshwat. Res. 3: 32-63.
- BURTON, G.W. AND ODUM, E.P. 1945 - The distribution of stream fish in the vicinity of Mountain Lake, Virginia. Ecol. 26: 182-94.

- *CREASER, C.W. 1930 - Relative importance of hydrogen-ion concentration, temperature, dissolved oxygen, and carbon dioxide tensions on habitat selection by brook trout. *Ecol.* 10: 246-62.
- DYMOND, J.R. 1955 - The Introduction of foreign fishes in Canada. *Verh. int. Ver. Limnol.* 12: 543-53.
- FERGUSON, R.G. 1958 - The preferred temperature of fish and their midsummer distribution in temperate lakes and streams. *J. Fish. Res. Bd. Can.* 15: 607-24.
- *FRY, F.E.J. 1951 - Some environmental relations of the speckled trout (Salvelinus fontinalis). *Proc. N.E. Atl. Fish. Conf.* (cyclostyled).
- FRY, F.E.J. AND HART, J.S. 1948 - Cruising speed of goldfish in relation to water temperature. *J. Fish. Res. Bd. Can.* 7: 169-75.
- FRY, F.E.J.; HART, J.S. AND WALKER, K.F. 1946 - Lethal temperature relations for a sample of young speckled trout, Salvelinus fontinalis. *Publ. Ont. Fish. Res. Lab.* 66. 35 pp.
- GRAHAM, J.M. 1948 - Some relations of temperature and oxygen to the activity of the speckled trout Salvelinus fontinalis (Mitchill). Unpublished Masters Thesis. University of Toronto.
- HOPKINS, C.L. 1965 - Feeding relationships in a mixed population of freshwater fish. *N.Z. J. Sci.* 8: 149-57.
- _____ 1970 - Some aspects of the bionomics of fish in a brown trout nursery stream. *Fish. Res. Bull. N.Z.* 4. 38 pp.
- *HUNTSMAN, A.G. 1946 - Heat stroke in Canadian maritime stream fishes. *J. Fish. Res. Bd. Can.* 6: 476-82.
- HURLEY, D.A. AND WOODALL, W.L. 1968 - Responses of young pink salmon to vertical temperature and salinity gradients. *Inter. Pac. Salmon Fish. Comm. Prog. Rept.* 19. 80 pp.

- LANE, E.D. 1964 - Brown trout (Salmo trutta) in the Hinds River. Proc. N.Z. ecol. Soc. 11: 10-6.
- McDOWALL, R.M. 1964 - Studies on the biology of the red-finned bully Gobiomorphus huttoni (Ogilby): Part I. - Habitat and species inter-relationships. Trans. R. Soc. N.Z. Zool. 4: 175-82.
- _____ 1968a - Galaxias maculatus (Jenyns), the New Zealand whitebait. Fish. Res. Bull. N.Z. 2. 84 pp.
- _____ 1968b - Interactions of the native and alien faunas of New Zealand and the problem of fish introductions. Trans. Am. Fish. Soc. 97: 1-11.
- _____ 1968c - The proposed introduction of the large mouth black bass Micropterus salmoides (Lacepede) into New Zealand. N.Z. Jl mar. Freshwat. Res. 2: 149-61.
- _____ 1970 - The galaxiid fishes of New Zealand. Bull. Mus. comp. Zool. Harv. 139: 341-431.
- McMILLAN, H.M. 1961 - An addition to the knowledge of the fish, Retropinna anisodon Stokell (Retropinnidae). Trans. R. Soc. N.Z. Zool. 1: 139-44.
- NORRIS, K.S. 1963 - The functions of temperature in the ecology of the percoid fish Girella nigricans (Ayers). Ecol. Monog. 33(1): 23-62.
- SKRZYNSKI, W. 1968 - The Canterbury mudfish, Galaxias burrowsius Phillipps, a vanishing species. N.Z. Jl mar. Freshwat. Res. 2: 688-97.
- SOIL CONSERVATION AND RIVERS CONTROL COUNCIL, 1957 - "Floods in New Zealand 1920-53 with notes on some earlier floods." Government Printer, Wellington. 239 pp.
- SPEIGHT, R.; WALL, A.; LAING, R.M. (Eds.) 1927 - "Natural history of Canterbury." Philosophical Institute of Canterbury, Christchurch. 299 pp.

- STOKELL, G. 1955 - "Fresh water fishes of New Zealand." Simpson and Williams, Christchurch. 145 pp.
- SWIFT, D.R. 1961 - The annual growth-rate cycle in brown trout (Salmo trutta Linn.). J. Exp. Biol. 38: 595-604.
- WOODS, C.S. 1963 - "Native and introduced freshwater fishes." Reed, Wellington. 64 pp.
- _____ 1964 - "Fisheries aspects of the Tongariro Power Development Project." New Zealand Marine Department, Wellington. Fisheries Technical Report 10. 214 pp.

*References cited from Macan, T.T. 1961. Factors that limit the range of freshwater animals. Biol. Rev. 36: 151-98.

APPENDIX I

Since the completion of this report, an unpublished report by Derisley F. Hobbs on the major trout waters in the Ashburton Acclimatisation District was found in the Marine Department records. The report is based on facts collected by Hobbs during his visit to the district in February 1946 and includes notes on the Hinds River, most of which are concerned with S. fontinalis. This part is reproduced below in full.

"The stock of American brook trout in the Hinds is potentially a most valuable asset. I am informed that prior to the great flood of February 1945 this species was substantially confined to the headwaters in the vicinity of Surrey Hills. In February of this year it was the dominant (and possibly exclusive) species down as far as the Maronan Road crossing (station 13 of 1962 survey). Four or five miles lower samples showed 117 brown trout to 106 S. fontinalis and included few fish of either species hatched last winter. I am informed that brook trout occur in substantial numbers for at least two miles below the Main South Road (station 32). Fish observed ranged mainly from 7 to 11 inches in length. As these fish are still very abundant in the headwaters and because the fish down below include very few yearlings, it would appear that the flood by dispersing widely a stock earlier confined to a small area, increased the chances of survival of individual fish.

It is impossible to foretell how the brook trout and brown trout will fare in competition with one another. Because all brook trout now in their second year were maturing and brown trout seemed unlikely to spawn until their third year, it is possible that temporarily the brook trout will increase still further. Substantial portions of the reaches into which brook trout have extended their range are frequently affected by drought. In the long run there may be a tendency for the earlier distribution of brook trout and brown trout to re-establish itself.

A series of pools were examined in the drought stricken section of the Hinds following days of record high temperature. In clear shingle pools in the main bed no dead fish were found and it seemed that percolating water of low temperature kept fish in good order until the pools actually dried out or became so shallow that hawks and gulls could remove fish. One small pool in an old river channel contained much silt and organic detritus. In this losses of brown and brook trout had taken place. Of 134 trout of both species, alive or dead, removed from this pool, 41 were brown and 93 were S. fontinalis. Of the brown 44% had died but only 13% of S. fontinalis had succumbed. The observed higher loss of brown was consistent with other observations. Brown trout showed much more discomfort when mud was stirred up in the pool and again during transportation. As trout of both species were much the same size - 7 to 11 inches, it seems evident that under equal conditions brook trout is less affected by low oxygen content."

Hobbs (1948) p.134* mentioned the mortality noted above as one of the only two examples known to him of trout mortality in New Zealand waters directly attributable to high temperatures. He stated that air temperatures at that time exceeded 94°F. As stressed by Hobbs the mortality was apparently caused by "oxygen deficiency during high water temperature". From literature it appears that S. fontinalis may be able to withstand for short periods lower oxygen concentrations than S. trutta. Many other factors, such as acidity of water, may have contributed to the different mortality of the two species mentioned by Hobbs.

This fact does not contradict the conclusion that the S. fontinalis stock in the Hinds system is normally limited in distribution to the upper tributaries, at least partly because of the lower temperatures there. It indicates, however, that the temperatures "preferred" by these fish are much lower than the lethal temperature.

There are no other records of as widespread distribution of S. fontinalis in the Hinds as that mentioned by Hobbs. Therefore, it may be assumed that it was caused by the unusually large flood and that S. fontinalis dispersed in the main river did not breed successfully and gradually died out some time after Hobbs' inspection.

*Hobbs, D.F. 1948 - Trout fisheries in New Zealand: their development and management. Fish. Bull. N.Z. 9. 175 pp.

