The relative abundance, movement, and growth of rainbow trout (*Salmo gairdneri*) and brown trout (*Salmo trutta*) in the Rangitikei River New Zealand.

A thesis presented in partial fulfilment of the requirements for the degree of Master of Science with Honours in Zoology at Massey University.

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Abstract

The hypothesis tested was that rainbow and brown trout populations do not move between naturally defined sections of the Rangitikei River. It was found to be true for adult brown trout but false for rainbow trout.

Recaptures of tagged brown trout demonstrated that the majority of these fish living in the mid-reaches do not make seasonal movements between river sections.

Brown trout dwelling in the lower reaches were smaller than mid-reach brown trout. This difference, and the lack of tag returns indicating movement between the two sections, supports the hypothesis.

Recaptures of tagged rainbow trout demonstrated that the majority of these fish migrating from the mid-reaches in autumn and winter travel to the headwaters where they remain the following summer. Those rainbow trout which were recaptured in the headwaters after moving from the mid-reaches tended to migrate earlier in the winter than those captured, then later recaptured, in the mid-reaches.

Similarities in the size of rainbow trout spawning migrants captured in the lower reaches and the mid-reaches suggested that both groups spent at least their second and third years in the same area of the river, but low numbers of tag returns meant that no firm conclusions regarding rainbow trout movement between the mid and lower reaches could be made.

Limited data concerning movement during the summer period suggested that some rainbow and brown trout move within sections but evidence of individuals remaining in one place for extended periods was found also.

Reported behaviour of both species of trout in response to seasonal physiological changes and agonistic pressure, allied with stream bed morphology probably accounted for the observed distribution of young of the year, year one, year two and adult trout in the river.

Upstream migrating adults, of both species counted at two traps, were found to respond to fluctuations in water flow and were probably affected by moon phase so that migratory activity was saltatory. Rainbow trout tended to migrate earlier in the winter than brown trout. The movement of female brown trout followed the male brown trout migration but similar differences were not observed in the rainbow trout migrants.

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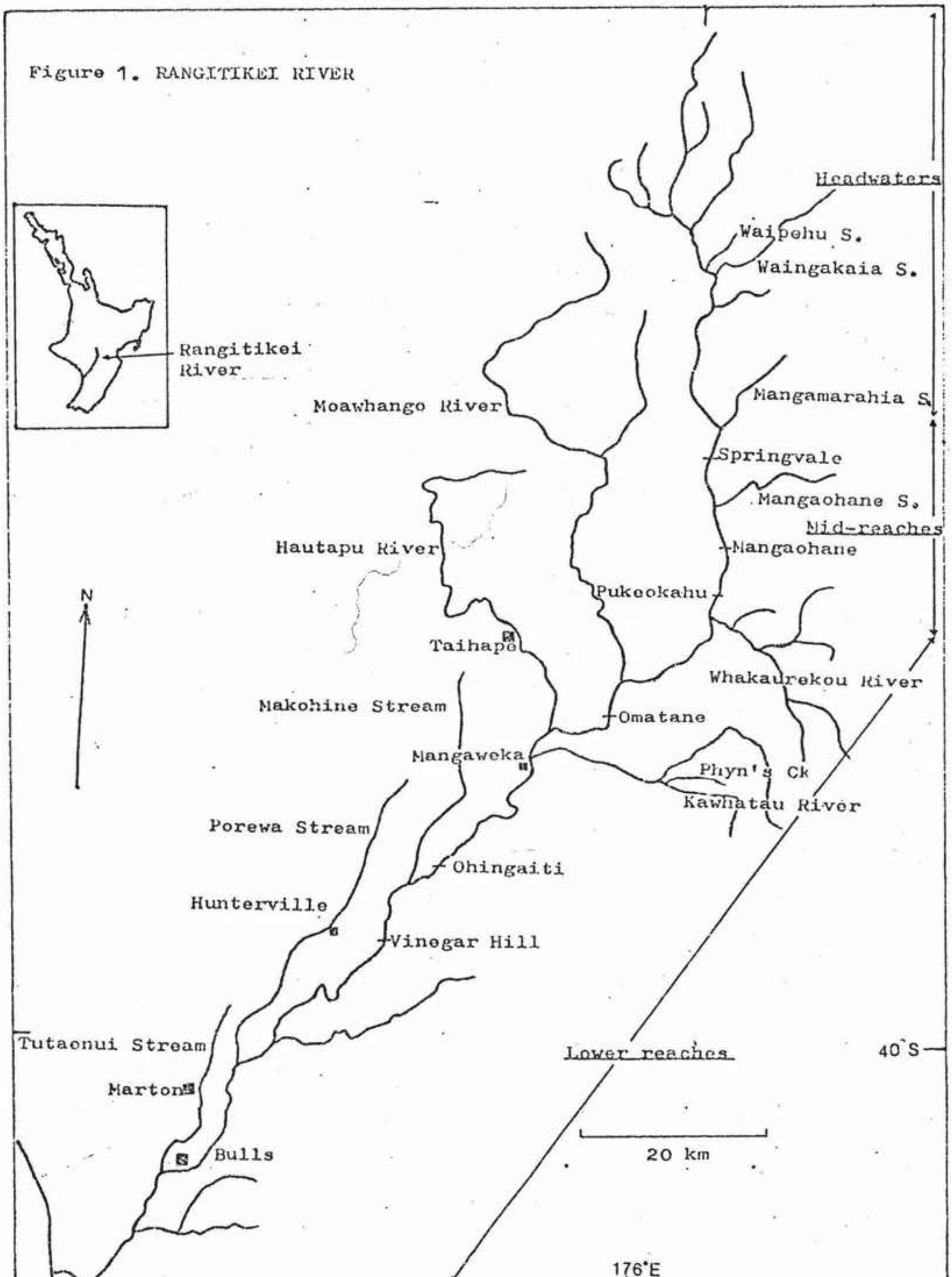


Figure 1. RANGITIKEI RIVER
Rangitikei River
Headwaters
Waipehu S.
Waingakaia S.
Mangamarahia S.
Moawhango River
Springvale
Mangaohane S.
Mid-reaches
Mangaohane
Hautapu River
Pukeokahu
N
Taihape
Whakaurekou River
Makohine Stream
Omatane
Mangaweka
Phyn's Ck
Kawhatau River
Porewa Stream
Ohingaiti
Hunterville
Vinegar Hill
Tutaenui Stream
Lower reaches
40°S
Marton
Bulls
20 km
176°E

1. Introduction

1.1 Physical Parameters

1.1.1 Location

The Rangitikei River (Figure 1) rises in the Kaimanawa Mountains, in the centre of the North Island, where it drains peaks such as Makorako (1727m), Waingakia (1623m) and Ngapuketura (1517m) and flows 241km to the sea at Tangimoana 40km south-east of Wanganui. It is the third longest North Island river and the fifth longest in New Zealand. The average flow of $88m^3$/sec. at Tangimoana rates it about sixth largest in the North Island (Tonkin and Taylor 1980).

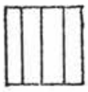
Major tributaries from the east drain the Ruahine Ranges. These are the Whakaurekou, Kawhatau and Mangawhariki Rivers which drain peaks such as Remutupo (1545m), Tupori (1524m), Rangioteatua (1703), Ohuinga (1683), Mangahuia (1581m) and Mangaweka (1733m).

The longest tributaries entering from the West are the Moawhango, Hautapu and Porewa. The largest of them, the Moawhango, drains marshy ground in the Western Kaimanawas which is a Defence Reserve. Since 1980 a power development scheme has diverted 62% of the Moawhango water out of the catchment, reducing the mean flow of the Rangitikei below the Moawhango confluence by 13% (Tonkin and Taylor 1980). The Hautapu and Porewa Rivers drain agricultural land.

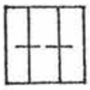
1.1.2 Geology - Figure 2.

The Ruahine Ranges which comprise the west Rangitikei watershed are mountains of predominantly well-dissected Mesozoic sedimentary strata. There are many faults in the rocks and the whole range is a wedge shaped horst. During the rise of the horst in the late Tertiary and Quarternary, areas to the west and east sank. These depressions filled with thick sequences of sediments.

Geological Divisions



Mesozoic metamorphic schist

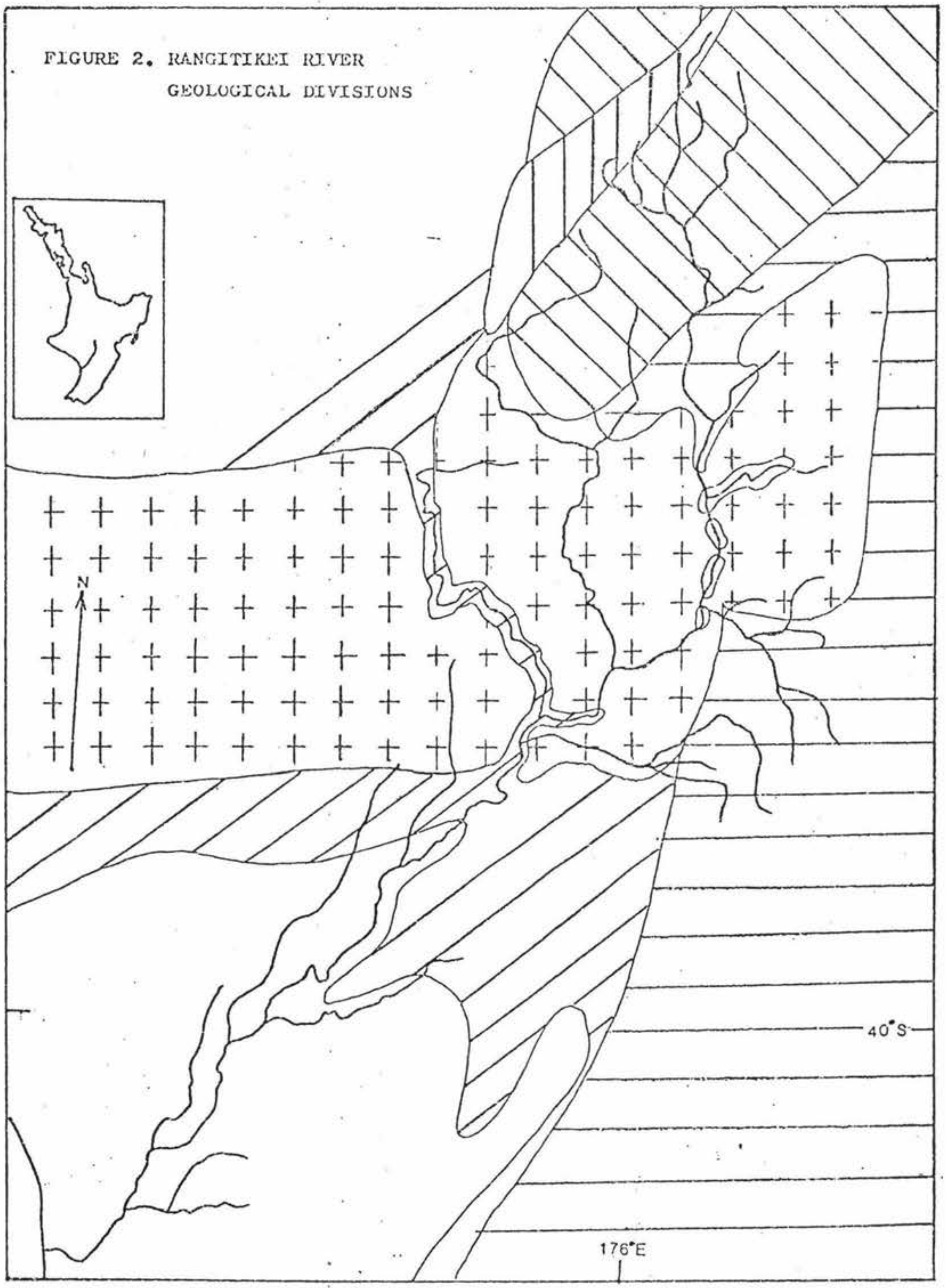


Pliocene marine sandstone and siltstone

Glacial aggradational gravel - upper quarternary

Kaimanawa Greywacke - Mesozoic

Ruahine Greywacke - Mesozoic



Reference: N.Z. Geological Survey 1972 D.S.I.R.

Rock types in the Ruahines and lowland areas vary from Jurassic greywacke - argillites and sandstones - found in the headwaters of the Mangawhariki, Pourangaki and Kawhatau to late Tertiary (Miocene) calcareous sandstones and siltstones in the Taihape area, marine fossiliferous sands and silts with their limestone horizons in the Hunterville area and non-marine undifferentiated sandy gravels, sands and silts in the river itself. In the Northern Ruahines, particularly in the Waikotore Stream watershed, Miocene coquina limestone is found, but in other tributaries of the Whakaurekou Jurassic greywacke, as is found further south, is predominant (New Zealand Geological Survey, Sheet 11).

The southern Kaimanawa ranges are composed of "Kaweka" greywacke, a Triassic-Jurassic dark grey argillite and redeposited sandstone. There are some volcanic bands, silts and limestones along with pumice tuffs in this area. Farther north in the mainstream headwaters the rocks are older - Permian-Triassic dark grey argillite and redeposited sandstone known as Kaimanawa greywacke. There is a small amount of Permian schist which shows strong cataclastic deformation. It is found mainly in the Moawhango watershed. There are a few pockets of grey brown quartzone ignimbrite of early Quarternary age - mainly in the Mangamaire River (New Zealand Geological Survey, Sheet 8).

Soils overlying these geological structures range from sandy Waitarere soils near the coast to loess derived soils inland to Hunterville, and volcanic types where the river drains the central North Island plateau (Tonkin and Taylor 1980) (Figure 3).

1.1.3 Run-off

A dendritic drainage pattern characterises the mid and upper reaches of the river. In the headwaters the river is deeply entrenched into the greywacke. While the slopes in the unit cells are steep the eroding ability of

Figure 3

1. Yellow-brown pumice soils, Urewera - Kaweka steepland

2. Central yellow-brown loams, Ohakune - Pokaka

3. Central yellow-brown earths, Wairama - Mangatea

4. Central yellow-grey earths, Taihape - Turakina steepland

5. Central yellow-brown earths, Raukuaiora - Rimutaka steepland

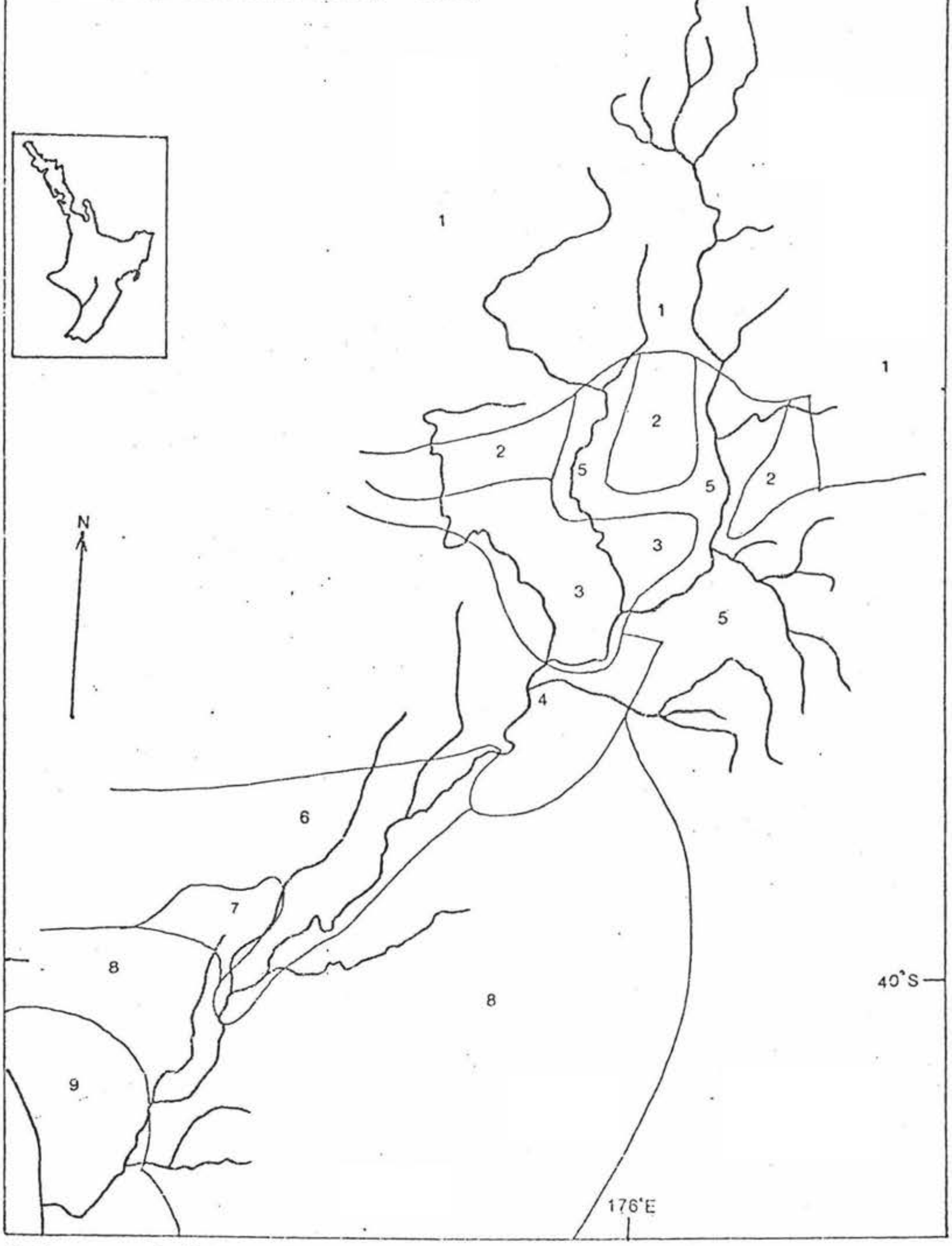
6. Central yellow-grey earths, Halcome - Raumai

7. Central yellow-brown earths, Atua - Mangaweka

8. Central yellow-brown earths, Tokomaru - Marton

9. Central yellow-brown sands, Foxton - Pukepuke - Carnarvon.

FIGURE 3. RANGITIKEI RIVER SOILS



Reference: Soil Map of New Zealand D.S.I.R. 1963 overland flow is low because of the surface resistance offered by the well developed vegetation cover in the area. In addition in many areas immediately adjacent to the river the slope angle approaches the vertical, lessening the overland flow. A combination of these factors, based on the resistant nature of the greywacke in the headwaters, results in a low sediment yield in the river at Springvale. No measurements have been made here and this assumption is based on calculations for the Moawhango and the characteristically clear flow of the river at Springvale (Tonkin and Taylor 1980).

The Ruahine tributaries are implicated in the increased bed load and sediment yield at Mangaweka which has an average of 3130 tonnes/day (Tonkin and Taylor 1980). The catchment area at Mangaweka is 2787km^2 and includes all the major tributaries. Heavy rainfalls, steeper gradient and more actively faulted rock in the Ruahines contribute to increases in bed load and sediment in the streams there.

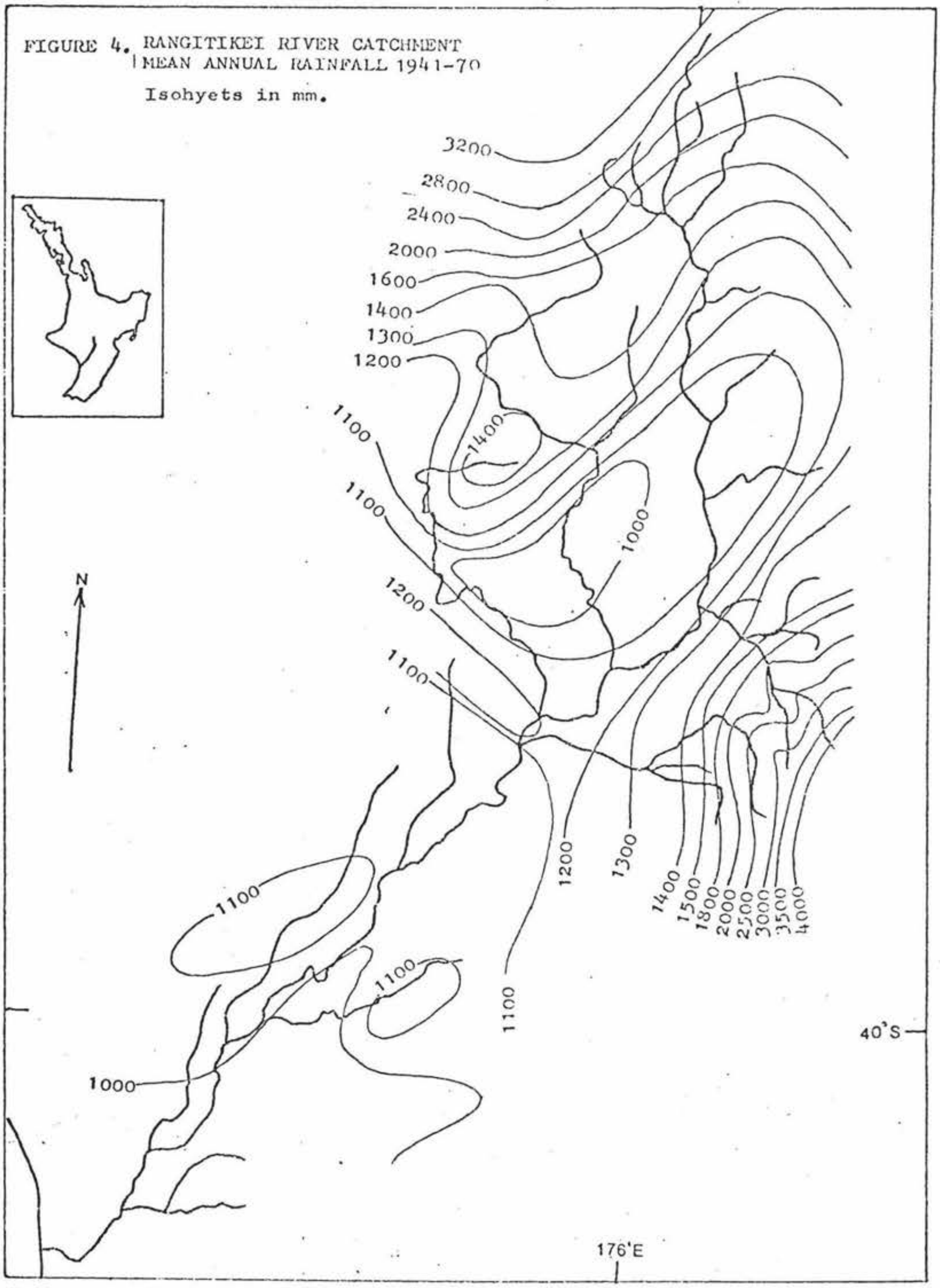
1.1.4 Precipitation

Greatest precipitation in the Rangitikei catchment occurs in the headwaters of the Kawhatau and Whakaurekou Rivers where > 4000mm per year falls. Kaimanawa headwaters receive up to 3000mm and the amount received in the catchment falls coastwards to below Marton where less than 1000mm of rainfall occurs each year (Figure 4).

Rain falls least from January to April and often in September while June and December are often the wettest months (Tonkin and Taylor 1980).

1.1.5 Mean Flows

At Springvale the mean flow is 19.8m^3/sec., at Mangaweka it is 62m^3/sec. and at Kakariki (near Bulls) it is 75.2m^3/sec. (Tonkin and Taylor 1980).



Reference: NZMS 19 sheet 3.

1.1.6 Low Flows

Seven day low flows of $15.2m^3|sec.$ at Kakariki can be expected every 2.33 years ($15.2m^3|sec.$ is the average annual low flow). Seven day low flows of $4.2m^3|sec.$ and $13.4m^3|sec.$ at Springvale and Mangaweka respectively are expected each 2.33 years also (Tonkin and Taylor 1980).

1.1.7 Flood Flows

The largest flood ever recorded on the Rangitikei occurred in 1987 and is estimated to have been $3800m^3|sec.$ Flood flows with return periods of 2.33, 10, 50 and 100 years are 830, 1290, 1750, and $1940m^3|sec.$ respectively (Tonkin and Taylor 1980).

1.1.8 Oxygen, pH, Coliforms and Salts

The headwaters and mid-reaches are characterised by high quality water:- Oxygen saturation, slight alkalinity, low dissolved salts and few faecal coliforms. There are minute but detectable amounts of Aluminium, Boron, Calcium, Cobalt, Chromium, Copper, Iron, Magnesium, Manganese, Molybdenum, Nickel, Phosphorous, Lead, Sulphur, Selenium, Tin, Strontium, and Zinc in the water at Springvale. Concentrations of Sodium and Calcium are slightly higher with Calcium being the most abundant at 3.8499mg| 1 ± 0.4%. The only increases detectable at Bulls are in concentrations of Sulphur (1.8140mg| 1 ± 0.3%), Sodium (4.6794mg| 1 ± 0.2%), Magnesium (2.1291mg | 1 ± 0.3%) and Calcium (13.350mg| 1 ± 0.8%). (Samples collected 17 December 1982 and analysed at the Department of Scientific and Industrial Research, Palmerston North, on 22 December 1982).

Slight increases in coliform levels occur below the Hautapu and Moawhango confluence. Inputs from the Kawhatau and Whakaurekou Rivers at normal flows tend to increase the water quality by diluting the bacterial load but at high flows turbidity in the form of suspended solids and bed load is increased by these rivers. Lower tributary inflows tend to be high in faecal coliform levels and dissolved salts but because they are small in relation to the main flow they have a minor impact on the river.

There is a general change in water quality (increase in temperature, faecal coliforms and dissolved salts) downstream but dissolved oxygen levels remain close to 100 percent saturation. These parameters exhibit greater variability downstream because of increased bacterial and nutrient loading from the developed catchment. Increased nutrient availability leads to greater algal growth - when combined with stable flows - and subsequent entrapment of inorganic suspended sediment. The products of photosynthesis and respiration (oxygen and carbon dioxide) and the use of these gases by algae results in a diurnal fluctuation of dissolved oxygen and pH.

1.1.9 Temperature

Greatest fluctuations occur in the area from Kakariki downstream where they may be as much as 20°C annually (5.2 - 25.3°C, Tonkin and Taylor 1980). In the mid and upper reaches temperatures reach at least 22°C (recorded at Springvale on 8 January 1984 at 1300 hours). In the winter in the Kaimanawa reaches 2°C has been recorded in the mainstream (Wildlife Service Drift Dive Survey June 1983). At Springvale in June and July 1983 when a few recordings were made the water temperature ranged from 2°C - 4°C - temperature taken at 10-11 a.m. And see Fig 24 1984 Temperatures.

1.1.10 Catchment and riparian Vegetation

Areas of greatest elevation in the Rangitikei Catchment are characterised by alpine vegetation. The tree line occurs at about 1400m and above this the dominant plants are snow tussocks, the most widespread of these is *Chionochloa pallens*, the mid ribbed snow tussock. Herbs such as *Ranunculus* spp. and *Celmisia* spp. are found in these areas but the most browseresistant are dominant where ungulate and possum numbers are high. These plants include Aciphylla spp. and the less palatable Celmisias . Subalpine (1400 - 1430m) vegetation in the Ruahines is dominated by Olearia colensoi, particularly in the south, and Dracophyllum recurvum.

Forest vegetation occurs from 1400m down to about 1000m in the Kaimanawas where scrublands occur. Much of this vegetation has been modified by fire, caused by volcanic activity and forest clearance by human settlers. Patches of forest occur well below 1000m but much ungrazed land is now dominated by manuka (Leptospermum scoparium) and kanuka (L. ericoides).

The forest in the northern part of the Kaimanawas is pure mountain beech (Nothofagus solandri var. cliffortoides) with local understories of kamahi (Weinmania racemosa) and broadleaf (Griselinia littoralis), but in general there is a complete lack of other tree species.

Red beech (Northofagus fusca) is found at lower altitudes in the forest zone. Bordering the river from Springvale to the Mangamaire River are dense stands of manuka and kanuka interspersed with beech, totara (Podocarpus totara) and a thick understory of mingimingi (Cyathodes spp.).

Ruahine forest is more varied than that of the Kaimanawas with highland softwood and beech mixtures occurring above the altitudinal limit of rimu (Dacridium cupressium) and pure beech associations in many areas. In the Waimaka and Kawhatau headwaters mountain beech is dominant with locally frequent Libocedrus spp. and understories of Phyllocladus alpinus Dacrydium biforme and Griselinia littoralis (Nichols 1970).

Agricultural development in the Rangitikei from Springvale downstream has altered the dominant riparian vegetation to introduced pasture grasses and discontinuous stands of totara and kowhai (Sophora spp.). The same applies to the main tributaries in the east - the Hautapu and the Moawhango, both having denser riparian cover than the main stream. Western tributaries, from Mangaweka upstream, flow from the Ruahine type vegetation through more open shingle riverbeds to the main river.

Willows (Salix spp.) are the dominant riverbank flora in the main river from Mangaweka to the sea. They are ubiquitous in the lower tributaries also.

Extensive areas of lupin (Lupinus sp.) and broom (Cytisus scoparius) occur in the shingle and sand of the large western tributaries and the main river downstream of these.

1.1.11 Aquatic Flora

Macrophytes are uncommon in most of the river. Filamentous green algae, stalked diatoms, and colonial blue-green algae occur in the main river. The green alga Ulothrix zonata is seasonally abundant and flourishes at times of low flow even in the cold mid-reaches in winter. Other filamentous algae such as Spirogyra grow abundantly in low flow summer periods in the lower and mid-reaches (B. Hicks, pers.comm.).

1.2 The Trout

1.2.1 Introduction of Stocks - refer also to the Appendix

1.2.1.1 Brown Trout (Salmo trutta)

According to Wellington Acclimatisation Society records, the first brown trout were introduced into the Rangitikei in 1887 when 50 "Lochleven" trout were liberated. While these trout were not recognised as brown trout at that time, taxonomists now consider these and many other local races or ecotypes to be one species (S. trutta) (Frost and Brown 1967, Stokell 1955). The first importations of brown trout to New Zealand came from the River Itchen, Bishopstoke, England. These fish were brought as eggs to Tasmania in 1864 where the fish became established (Scott 1964). The Canterbury Acclimatisation Society first introduced trout from these stocks in 1867 when 800 ova were obtained. Until 1874 other South Island Societies imported trout from the same stock and successful liberations were made, at least by the Otago and Canterbury Societies (Scott 1964). In 1883 the Wellington Society imported Lochleven trout which they raised successfully and liberated in "great quantities" (Stokell 1955). The Wellington Society maintained rearing ponds at Masterton and distributed trout to the Hawke's Bay Acclimatisation Society and Feilding Acclimatisation Society who liberated trout into the Rangitikei.

Sea trout - also <u>S.trutta</u> - were imported from the River Tweed and Hodder in Britain in 1868 and the early 1870s by the Otago, Southland and Canterbury Acclimatisation Societies. These fish became established in the southeast of the South Island (Scott 1964). The Wellington Society probably liberated sea trout into the Rangitikei, since from 1904 until 1919 sea trout were brought from the Opihi, and Temuka streams and Hakataramea hatchery.

The author of the "Pisciculture" section of the 1908 W.A.S. Annual report states: "The brown trout ova obtained from the Government Hatchery at Hakataramea was of most excellent quality, and coming from the magnificent sea run trout of the southern rivers, cannot fail to be a most beneficial change of blood". The Rangitikei received 585,000 of these fish (as fry) from 1906 to 1915. However, that these fish were sea trout is in dispute and the Wellington Society may have been correct when they called them sea-run brown trout since some members of mainly-river dwelling populations of brown trout migrate to and from the sea during their life (Scott 1964).

1.2.1.2 <u>Rainbow Trout</u> (<u>S.gairdneri</u>)

The first importations of rainbow trout to New Zealand were made by the Auckland Acclimatisation Society (A.A.S.) who imported live rainbow trout ova from Sonoma Creek, a tributary to San Francisco Bay, California (Scott et al. 1978). The basis of New Zealand's rainbow trout stocks have been derived from 22,000 ova imported in March and April 1983. At the time they were believed to be brook char (*Salvelinus fontinalis*) but by 1886 when they had matured it was realised they were *S. gairdneri*. The trout are of a migratory ecotype known on the West Coast of North America as steelhead.

In New Zealand these trout became established as self maintaining populations in the lakes of the Central North Island rather more rapidly than in the rivers of the country. The first record of rainbow trout being distributed to the Rangitikei River area was on 18 September 1899 when W.C. Birch of Moawhango received 1500 fry. On 7 October of that same year the Marton sub-committee of the W.A.S. received 1000 rainbow trout fry. Stokell (1955) observed of rainbow trout that "the fish has shown no evidence of ability to maintain itself permanently in streams". This was also noted in the 1920 Annual report of the W.A.S. despite good catches in the Rangitikei in 1914 and 1915. However in 1926 the Society reported that the Moawhango was "teeming with small rainbows", indicating that considerable natural reproduction was occurring. Rainbow trout liberations of fish purchased from Turangi and Rotorua continued until 1978 and at present a self sustaining population occurs in the river and several tributaries.

2. Methods

2.1 Introduction

Movement of trout within the river was studied in three ways; by capture - recapture methods using colour coded individually numbered tags; by estimation of changes in abundance; and by analysing angling catch statistics. Growth of trout was studied by comparing lengths of individual trout caught and recaptured where length measurements were known at capture and recapture times, and by back calculation of ages derived from scale reading. The hypothesis to be tested was that trout do not move between three sections of the river - the headwaters, mid-reaches and lower reaches, see Fig. 1. The sections were chosen on the basis of instream morphology. The headwaters section is an undeveloped area of steep valley walls where the river flows through greywacke. Riparian vegetation is comparatively unmodified (Plate 6). The mid-reach section is relatively short and runs through greywacke and limestone structures. Riparian modification varies from introduced pasture (Plate 3) to unmodified valley walls (Plate 4). The lower reaches are dominated by marine siltstones which in comparison with the other sections erode rapidly.

2.2 Trapping migrating trout to tag and recapture

Since river dwelling brown trout "move upstream to spawn' (Frost & Brown 1967) and the rainbow trout originated from migratory stocks, a trap placed on the river between supposed rearing grounds and spawning grounds would be likely to catch both species of trout. The Wellington Acclimatisation Society had at times considerable success in catching mainly brown trout this way on several rivers of its district including a Rangitikei Tributary - Phyn's Creek (W.A.S. Annual Reports 1900 - 1970). Fish traps have been widely used by fishery managers in New Zealand to capture wild trout for the purpose of artificially propagating the species. Traps on streams such as the Ngongotaha, and Hatchery stream, a tribuary of the Tongariro River are more or less permanent structures on small streams with only small changes in volume of flow. The Rangitikei at Springvale is a much larger river than these streams. (Mean flow $19.8m^3$/sec - width 47m, mean depth 0.4m at trap site).

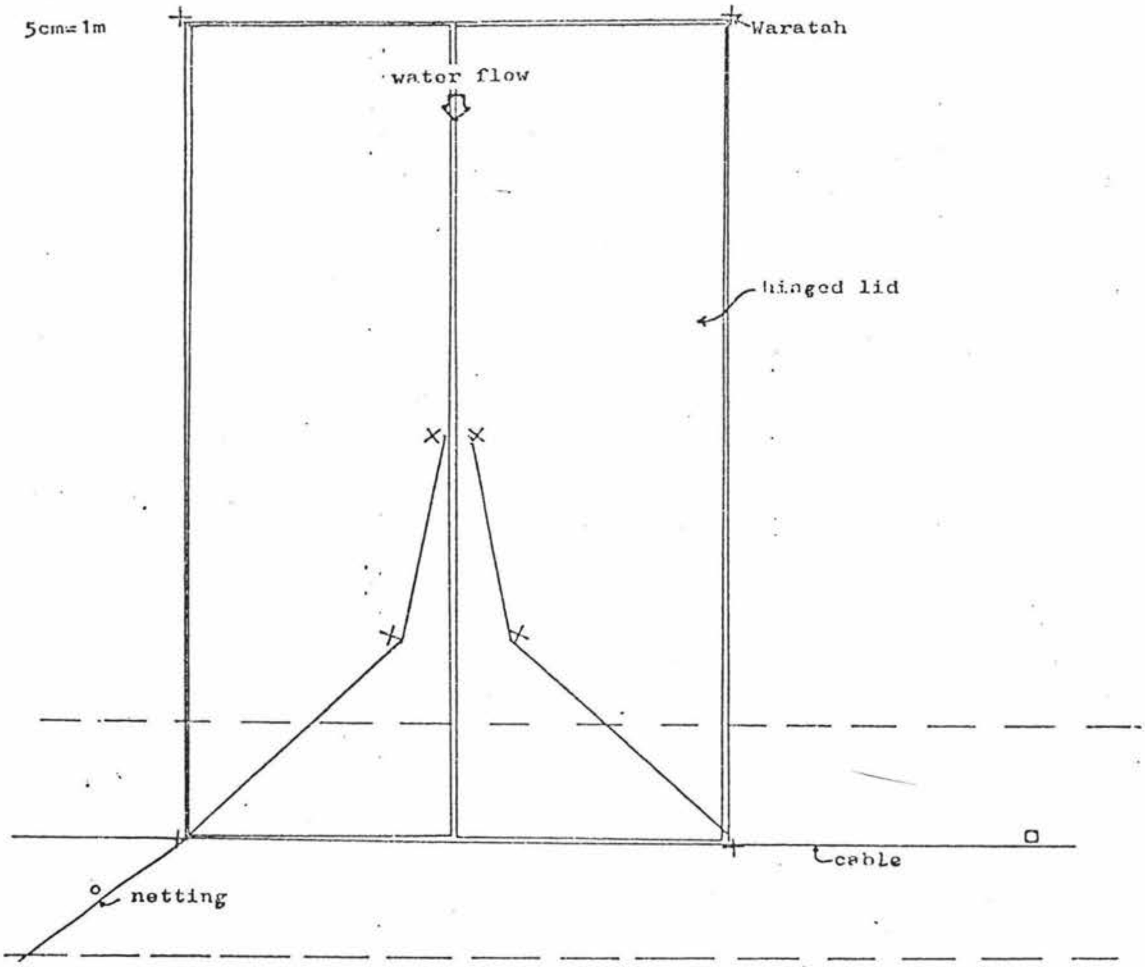
A flood flow of $350m^3$/sec has a return period of 2.33 years here (Tonkin and Taylor 1980). Because of the likelihood of rapid increases in the water volume a securely fastened, adjustable barrier was needed. Traps such as those described by Whalls (1955) and Swales (1981) were not considered suitable for this location.

2.2.1 Springvale Trap Description

The device was designed and constructed for the project by Peter Taylor (W.A.S. Field Officer) and members of the W.A.S. executive after consultations with Fisheries Research Division, Ministry of Agriculture and Fisheries. It is a winch operated variable barrier type trap (Fig 5.) (Plate 5). A steel wire cable of 1.3cm diameter attached to a winch on one bank and hook on the other supported the wire netting which functioned as a barrier. Both the winch and the hook were attached to $1m^3$ concrete blocks. At maximum tension the cable was held 1m above the water surface at average flow. Tension on the cable was applied by the winch and maintained by a winch mounted centrifugal lever operated brake. The barrier consisted of 1m high 5cm chain link mesh netting. The barrier fence was attached to the cable at the top and a 1m wide 5cm chain link mesh wire apron on the river bed.

FIGURE 5
SPRINGVALE TRAP PEN Top view

5cm= 1m



SPRINGVALE BARRIER
Cross section

5cm= 1m

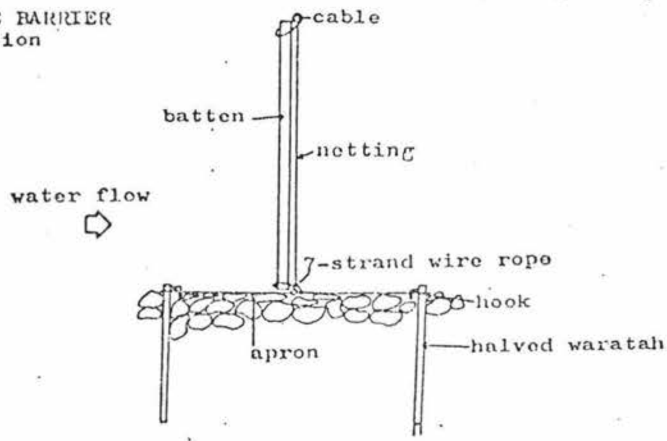
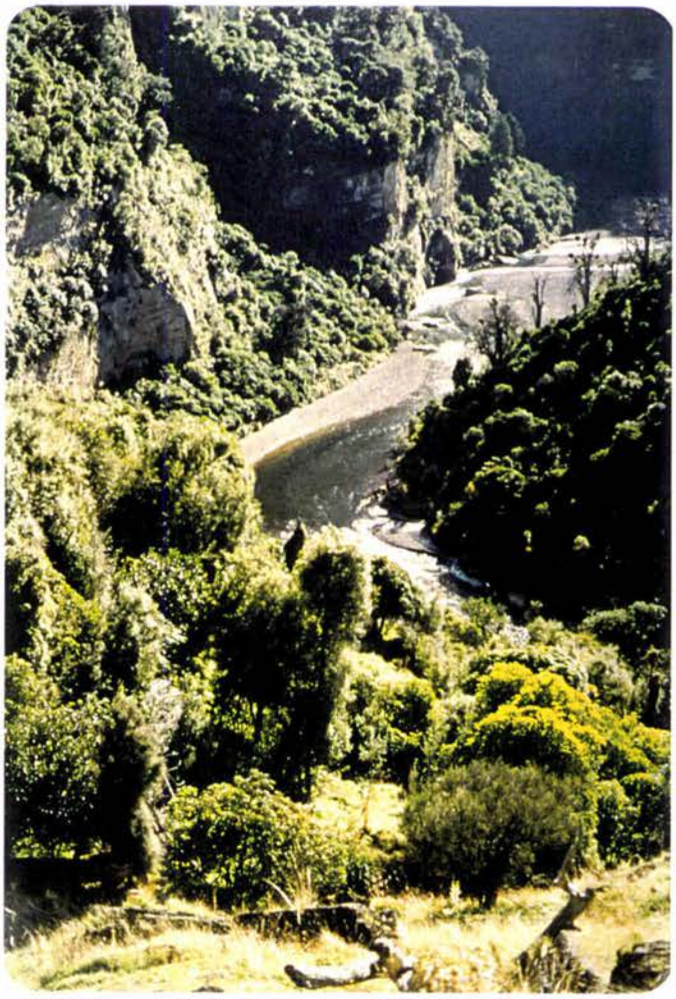
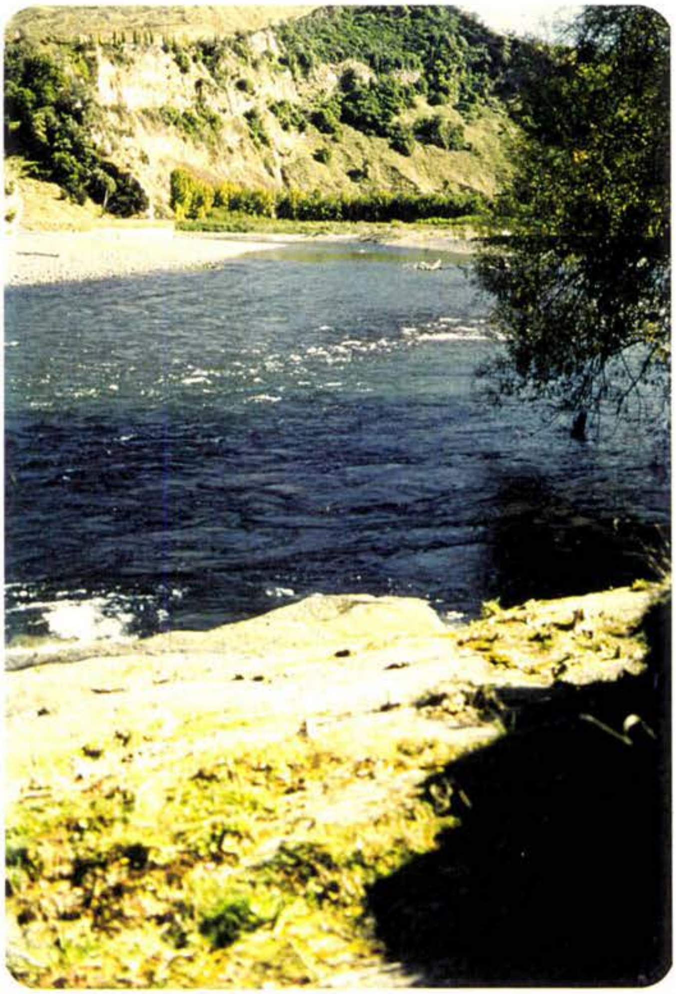


Plate 1 The lower - mid-reach transition zone just below the Whakaurekou River confluence. Here the river becomes more open and the greywacke banks are replaced with marine mudstone.

Plate 2 The lower reaches below Vinegar Hill.





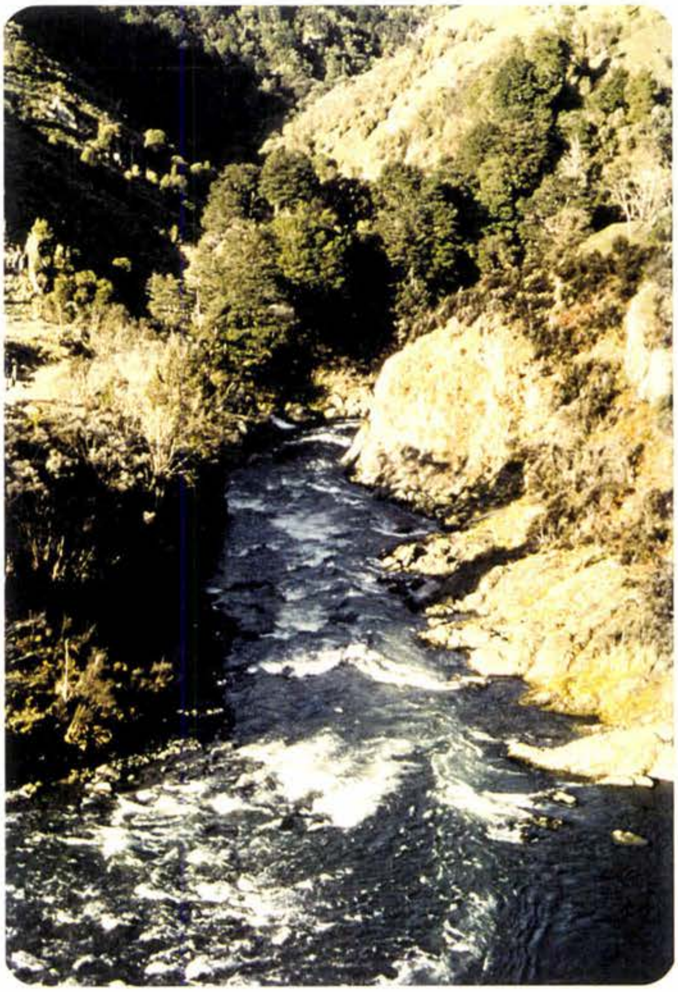


Plate 3 Part of the pastoral slower flowing section of the mid-reaches. This area is dominated by large brown trout.

Plate 4 Part of the turbulent section of the mid-reaches between Mangaohane and Pukeokahu.

Plate 5 Springvale fish trap, barrier erected, low flow conditions.

Plate 6 Phyn's Creek trap, low flow conditions.

The leading and trailing edges of the apron were threaded with No 8 wire (every 4th link upstream, every 6th link downstream) which was tied off and strained to iron waratah stakes embedded in the river bed at each end of the barrier. Waratah stakes cut in half with a tempered 1cm cylindrical steel hook welded to the top were driven into the bed of the river so that the apron was held closely to the substrate. The stakes were placed 1m apart on the leading edge and 3m apart on the trailing edge of the apron. The centre of the apron, directly under the vertically held barrier netting, was threaded with a 7 strand wire wound rope through every 5th hole, which was tied to the netting barrier at every triangle point, and strained to the embedded railway irons.

Tanalised Pinus radiata battens (1m x 25mm x 25mm) were attached to the upper cable and the lower centre wire, and placed 3.5m apart along the length of the barrier - maintaining the height of the netting across the full width of the river. The barrier had a downstream angle of 3 degrees.

The theoretical critical loading point when the barrier had to be lowered was when the water level equalled the height of the cable across the width of the river flowing at 1m/sec. This corresponded to a calculated weight of 2t on the netting. In practise the barrier was lowered before this since the flexibility of the system allowed water to flow over the top of the barrier before the river reached 1m above mean flow at the trap site. Suspended debris added considerably to the weight of water on the barrier since less water could pass through the netting. Therefore when the water level reached the top of the netting in midstream the brake was manually released, allowing the barrier netting to lie flat on the substrate.

A float actuated mercury switch situated 1km upstream from the barrier activated an alarm which warned of a rise in river level. Two operators were present to respond to the alarm at all times during the trapping period.

The trapping pen was situated close to the winch bank, in the deepest portion of the river cross section. It was constructed of 5cm chain link mesh netting laced with 0.9mm wire onto frames of 2.5cm nominal bore light galvanised iron pipe. Dimensions were: Sides 1.1m x 3m, Front 1.1m x 2m. The rear (downstream) side was formed into an upstream tapering 'V', the narrowest portion was a slot 10cm wide. A wire hinged lid of two equal parts, comprising similar material to the sides was placed on top. The pen was enclosed at the base by 5cm chain link mesh laced onto the framework. The construction of the pen did not allow for lowering during floods therefore it had to be securely fastened in place.

It was secured by 2m long waratah stakes driven in adjacent to the corners of the pen and wired with No. 8 wire. Additionally two waratahs were deeply embedded into the substrate 1.5m and 3m upstream of the centre of the pen. No. 8 wire was strained from the pen corners to the most downstream placed of these, which was strained to the upstream waratah.

A flexible netting extension of the barrier was wired to the pen to prevent fish passage between the barrier and the pen, and to allow for movement of the barrier at flood flows.

The 5m distance between the pen and the winch bank was barricaded by collapsable netting supported by waratah stakes. A downstream apron only was wired to this netting and secured by large river boulders.

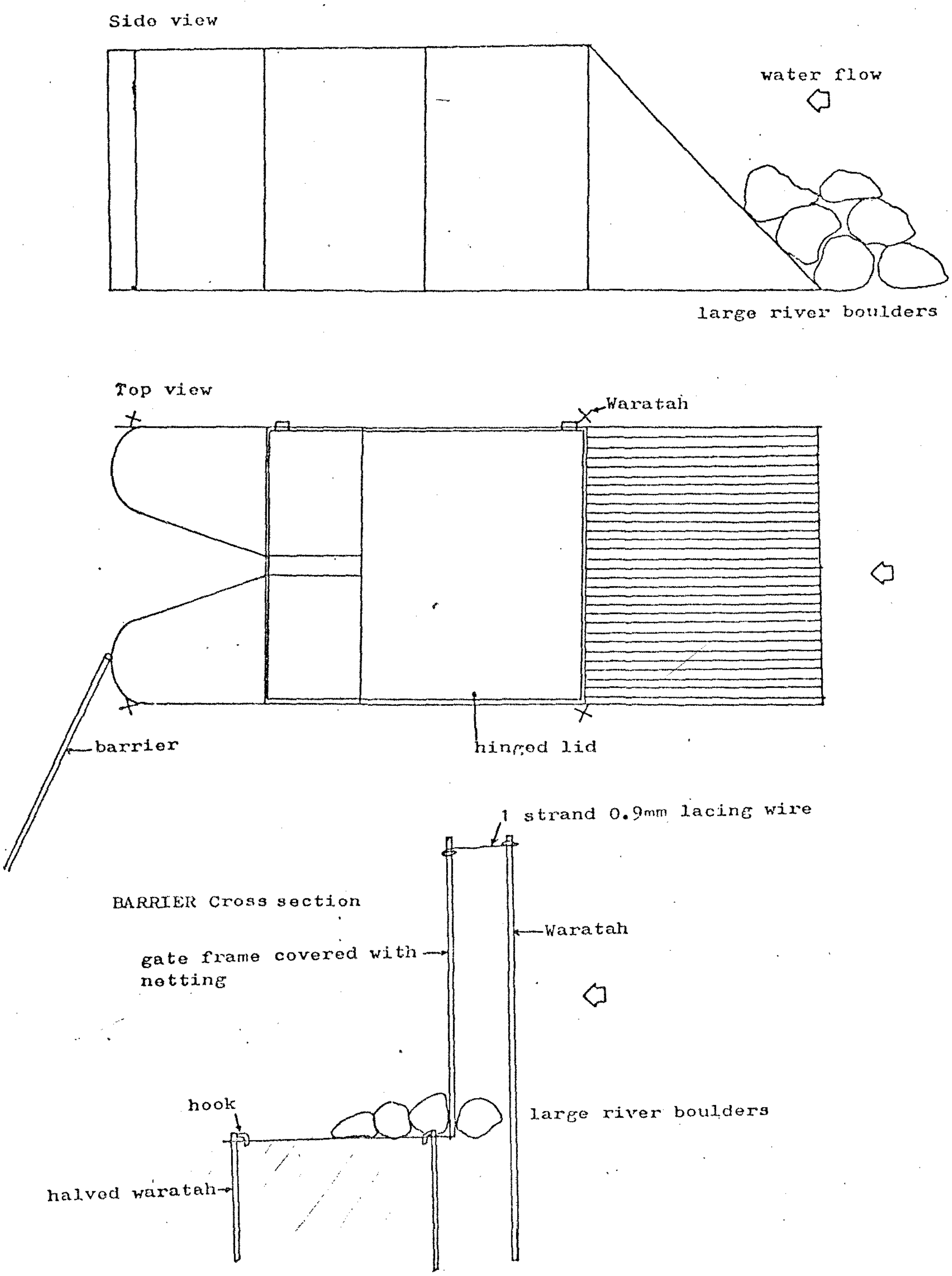
2.2.2 Mangakokeke (Phyn's) Trap Description

The Mangakokeke or Phyn's Creek is a small (ca $0.3m^3$/sec mean flow) tributary of the Pourangaki River. Phyn's Creek enters the Pourangaki close to it's confluence with the Kawhatau River (NZMS 1 N139 433014). A portable trapping pen of the kind used by W.A.S. to catch trout for propagation purposes was used (Fig. 6. Plate 8). Pen dimensions were: Base 0.93m x 2.44m; sides 3.03m x 0.78m (including inverted 'V' of downstream side), front 0.93m x 0.78m.

The front (upstream side) of the trap was inclined 45° with the lower edge projecting upstream. Chain link mesh netting as used at Springvale covered the 1.5cm diameter iron reinforcing rod framework except on the front which comprised 1.5cm reinforcing rods lying vertically 5cm apart. A lockable hinged lid provided access to the interior. For the main barrier a framework of 1m x 3m 2.5cm nominal bore light galvanised iron pipe, covered with 5cm chain link mesh netting was used. A 1m wide 5cm chain link mesh apron on the downstream side was used to secure the barrier to the substrate. Waratah stakes 2m long were driven into the substrate adjacent to the four corners of the pen, which was wired to these. The barrier was held upright by lacing it to waratahs driven into the river bed just upstream of the barrier ends. One turn of light wire was used to secure the barrier in an upright

FIGURE 6. PHYN'S CREEK TRAP

1mm=1.56cm



position in normal flows but allowed it to be pushed over by flood flows, preventing scouring under the barrier and the pen.

2.2.3 Trap Operation

Both traps were attended at least twice daily. Captured trout were measured, checked for tags or fin clips, tagged and released upstream. Adjustments were made to the physical structure of the devices as necessary. The Springvale Trap was operated from April 8 to August 8 1983, and from March 19 to July 11 1984. The Phyn's Creek trap was operated from June 30 to July 13 1983 and May 14 to July 10 1984.

2.3 Other methods of trout capture

2.3.1. Hand netting

Divers equipped with wetsuits, snorkels, masks, fins, and woollen gloves caught trout with long handled nets during the summer of 1983-1984. 'Handnetting' involved two divers who swam together counting and netting trout as they swam downstream. The trout were netted using an aluminium frame net with a triangular opening of 40cm sides, and a handle 0.9m long. Attached to the net frame was soft nylon knotless 1cm diameter mesh netting with a bag 1m deep. A split garden hose wired to the frame of the net over the netting protected the netting where it was secured to the frame. Only brown trout were caught by this method (Plate 4). They were brought to the surface, fork length measured, checked for tags or fin clips then tagged and clipped if appropriate and released. Rainbow trout were not able to be caught by this method since their escape reaction usually took them into the water column, unlike the brown trout which often remained motionless on the substrate in the presence of a diver. A relief diver rowed a 3m inflatable dingy down the river with the inwater divers. Food, measuring and tagging equipment, and clothes were carried this way. Divers took turns in rowing the raft and netting trout.

2.3.2 Angling

Trout were caught with artificial fly and artifical lures. The trout were handled using a small meshed net similar to the hand-netting net. They were tagged, measured and released as for other methods (Plate 3.)

2.3.3 Seine netting

A few trout were caught by this method but in general limited access, high stream velocity, numerous submerged obstructions and uneven substrate restricted the efficiency of seine netting.

2.4 Tags and Tagging Materials.

The 'spagetti' tags used comprised 6cm of coloured vinyl tubing covering 9cm of nylon monofilment with 'T' anchor. (Dell 1968). Individual numbers and the W.A.S. address were printed on the coloured tube. Five colours were used throughout the system. The river was divided into four longitudinal sections of roughly equal length - one colour corresponding to each section and its tributaries. Springvale trap-caught trout were given tags of a separate colour. The colours chosen; white, sky blue, yellow, brown and bright green were visible to divers. An applicator gun, built by Incom Marking Systems N.Z. Ltd, was used. Tags were manufactured by Floy Tag and Manufacturing Inc. Seattle (see Plates 9 and 10).

2.5 Fin Clipping

The trout were diffentially fin clipped so that tag loss could be estimated and trout smaller than 15cm could be marked. Half pelvic clips were used - right pelvic identified trout originally marked below Pukeokahu and left pelvic clipped fish were marked above Pukeokahu. Waterfalls exist near Pukeokahu and these were treated as possible velocity barriers, dividing the river longitudinally. All trout passing through the Springvale trap were given an adipose clip except rainbow trout in 1984 which were not clipped.

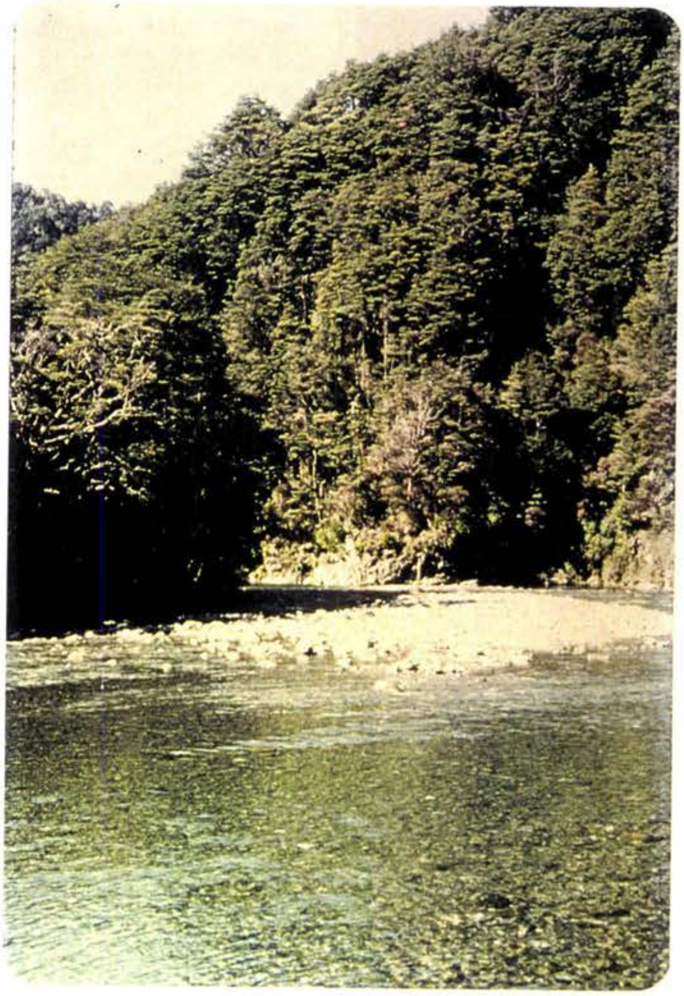
2.6 Measuring Trout

At the Springvale trap unanaesthetized trout were weighed individually in a plastic tray in 1983, and an aluminium cone in 1984, suspended under a spring balance with 10g graduations. Fork length (F.L) measurements to the nearest 5mm were made on a measuring board. The trout were taken from the pen using a 40 x 30cm scoop net with a 60cm deep bag constructed of 0.5mm polypropelene interlocking weave mesh.

At Phyn's Creek the trout were weighed in a short handled landing net and F.L. measured on a board. Trout caught by angling, seine, and hand netting were measured with a tape.

Plate 5 Drift diving in the mid-reaches

Plate 6 The headwaters above the Waignakaia Stream.



2.7 Estimation of changes in abundance

2.7.1 Handnetting

see sect. 2.2.4.1

Handnetting dives were conducted once above the Springvale Bridge, twice from the Springvale Bridge to Mangaohāne, three times from Pukeokahu to Mokai, once from Omatane to Utiku, three times from Otara Rd to Makohine and two times from Vinegar Hill to the Mangapipi Stream in 1984 and three times from Utiku to Mangaweka in March 1983 (Fig. 7).

Counts were made at different times in January and February 1984 at Pukeokahu, Makohine and Vinegar Hill. Usually two divers could not search the entire river, therefore their attention was focussed on the deepest sections of the pool. Where no obvious deep side occurred divers scanned as much of the river as they could see.

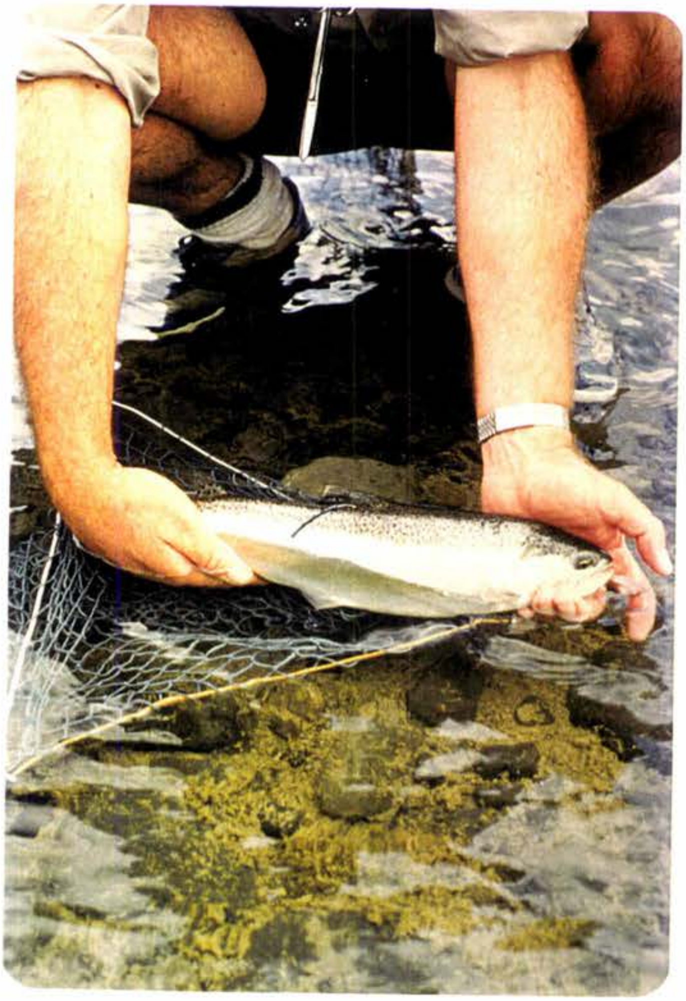
2.7.2 Drift Diving

Drift diving (Plate 5) is a method of estimating fish populations over long stretches of river which are impossible to sample by usual methods (Northcote and Wilkie 1963). Temperatures greater than 10°C are desirable since cold water accelerates the onset of fatigue. There is likely to be a negative correlation with efficiency of estimation and amount of instream cover; large rocks and vegetation, turbulence, and turbidity for example.

Sufficient divers were required so that the width of the river was visually searched. Divers swam side by side downstream with the current. Each diver searched an

Plate 9 A two year old rainbow trout, tagged and pelvic fin clipped in the lower reaches.

Plate 10 A hand net caught brown trout tagged, and about to be released.



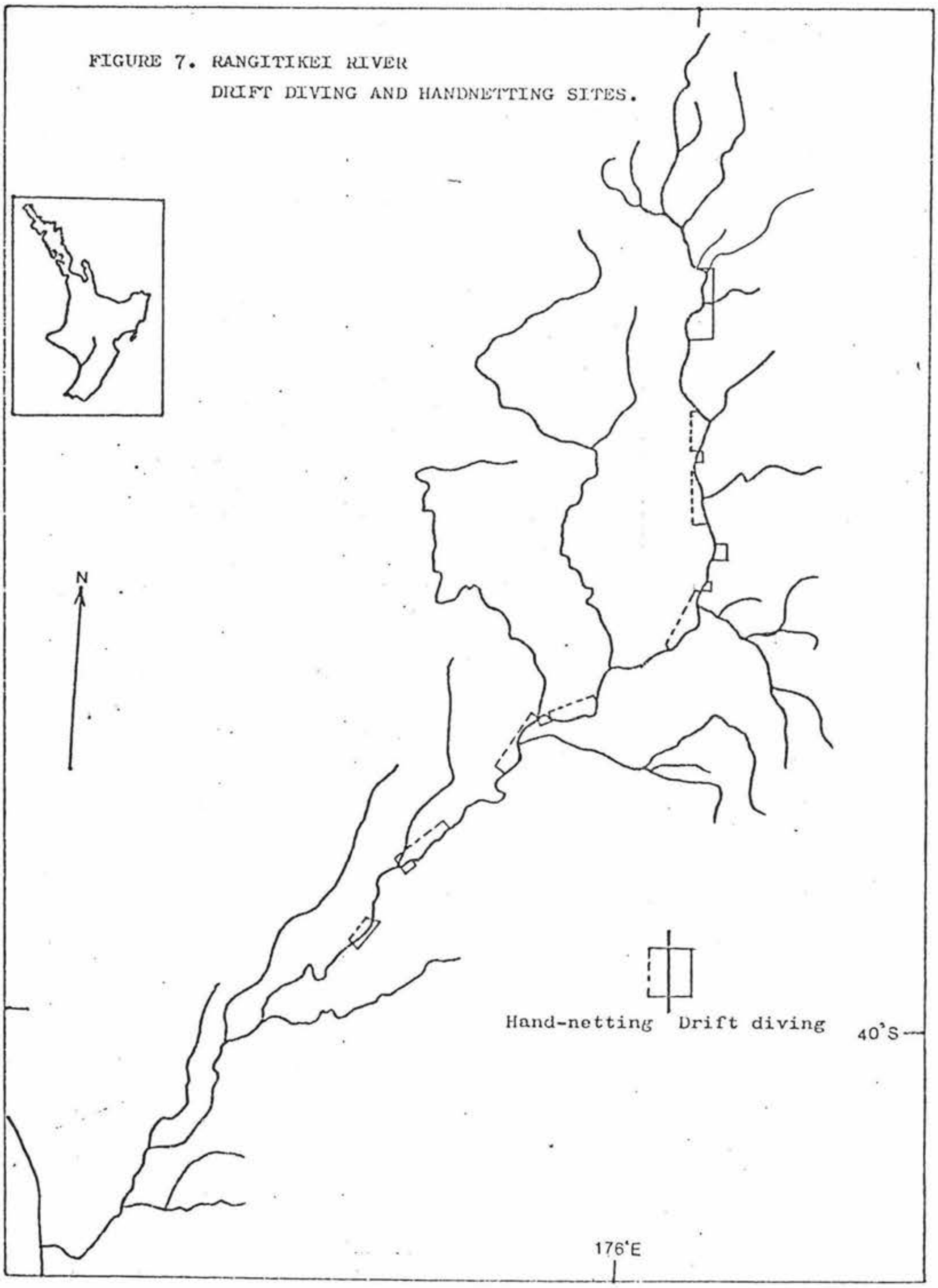


FIGURE 7. RANGITIKEI RIVER
DRIFT DIVING AND HANDNETTING SITES.
N
Hand-netting
Drift diving
40'S
176'E

area from directly underneath to the surface towards the deep side of the river - scanning a 90° arc. Fish which passed through this area on their way upstream were counted by the diver, other fish were not counted. A bank observer was used on one occasion to check the movement of fish out of the habitat unit. In deeper water, ($>$ 3m) divers paired and took turns to search underwater. Divers were required to keep in line and search under large rocks and logs if they were in their search area. Water clarity estimates were made for each diver - usually using a secchi disc. Visibility varied between 4 and $>$ 10m and in all cases exceeded the distance between divers except at Vinegar Hill where only one dive was made.

The water temperature during the dives varied between 14 and 22°C. Repeated drift dives were conducted twice at each of five places from January 10 to March 3 1984. One dive was conducted at Vinegar Hill on 18 January 1984 (Fig 7.).

2.7.3 Bank Observations

Bank observations of areas likely to contain concentrations of spawning trout were made. Recruitment areas were identified and considered in relation to other observations which pertained to trout migrations in the river. Bank observers used polarised glasses and wide brimmed hats which minimised interference from reflected glare.

2.8 Analysis of Angling Catch Statistics

A concurrent study of angler performance and attitudes was conducted by the W.A.S. (Rodway 1984). Trout caught by the anglers interviewed in this survey represented angler caught fish from throughout the Rangitikei River system. Lengths of trout were used to construct a size distribution of trout in the river. Insufficient numbers of brown trout were caught by anglers for a riverwide analysis therefore this method is relevant only to rainbow trout. The measurements were made by anglers themselves where figures were obtained from anglers diaries which were returned, and by myself and other W.A.S. survey personnel who interviewed anglers and caught trout as part of the tagging programme. In some instances anglers forwarded only weight information. Lengths were calculated from these by taking mean condition factors of length and weight measured trout in the Rangitikei and then calculating lengths from given weights. Condition factor is given by:

$$C.F. = \frac{W \times 3612.8}{L^3} \quad (1)$$

Where W = weight in grams

L = length in centimetres

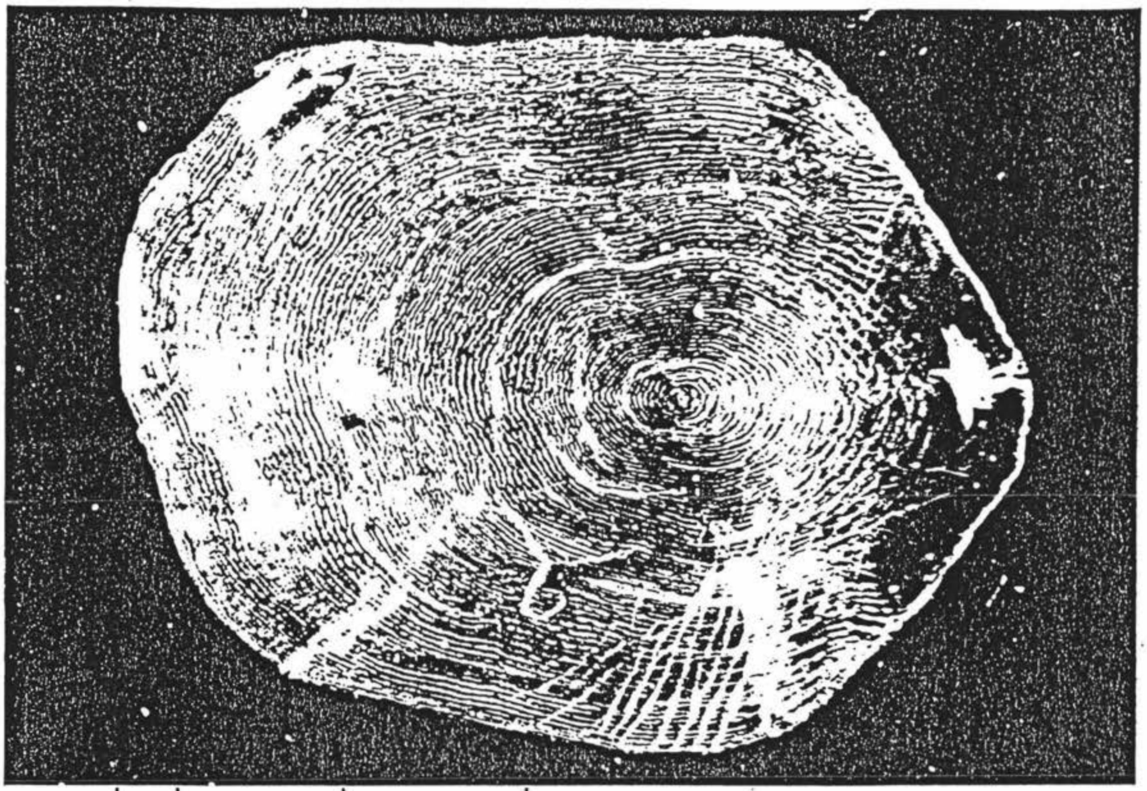
2.9 Growth

Recaptured trout which had had their lengths measured reliably were used to estimate growth rates of both species in the Rangitikei. The measurements supplied by anglers were considered, in most cases, to be too inaccurate to be used for this purpose but to be adequate to construct size distributions with size classes of 10cm.

Scale samples were collected from 160 trout. (99 brown and 61 rainbow trout samples) and the annuli were examined. Age and growth estimates were made where clear patterns were visible (Plates 11 - 14).

Plate 11 Scale of a rainbow trout 50cm long caught on 13 June at the Springvale trap, in its 4th year. Length at age 1, 14cm; age 2, 32cm; age 3, 45cm; age 4, 50cm.

Plate 12 Scale of a 24cm long rainbow trout caught in the lower reaches, eleven months old.



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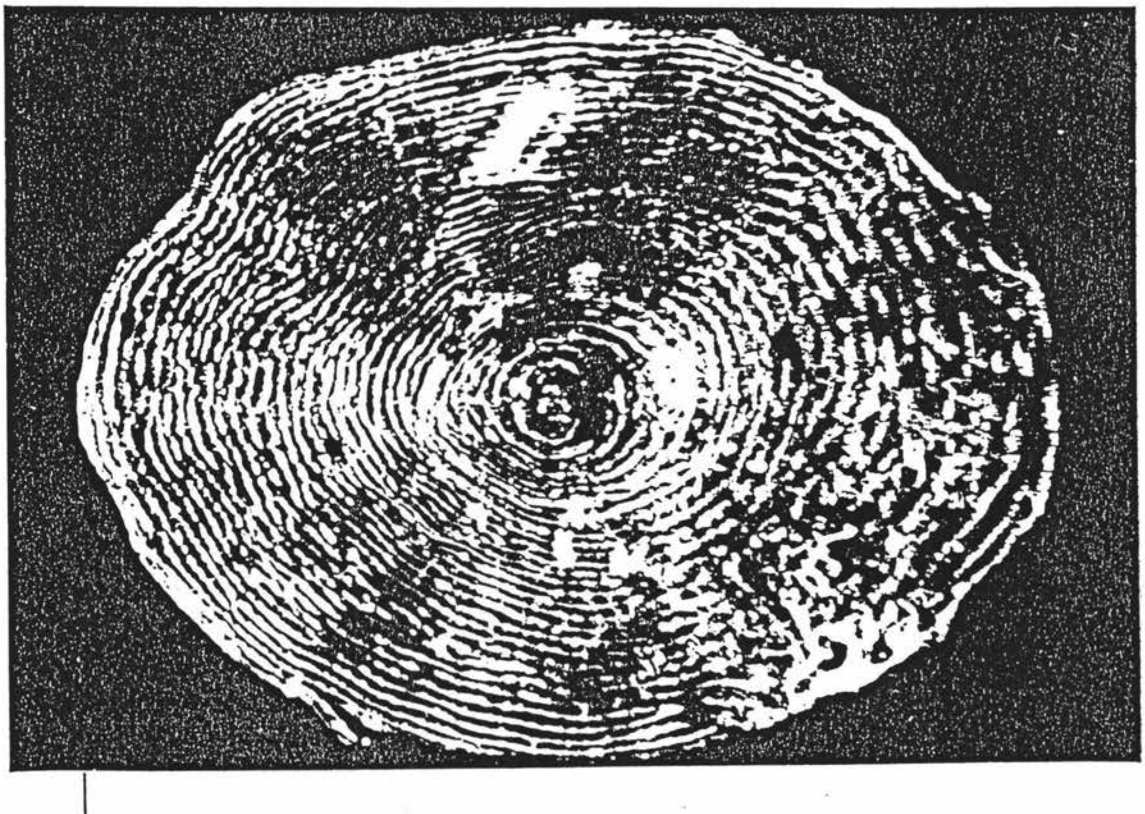

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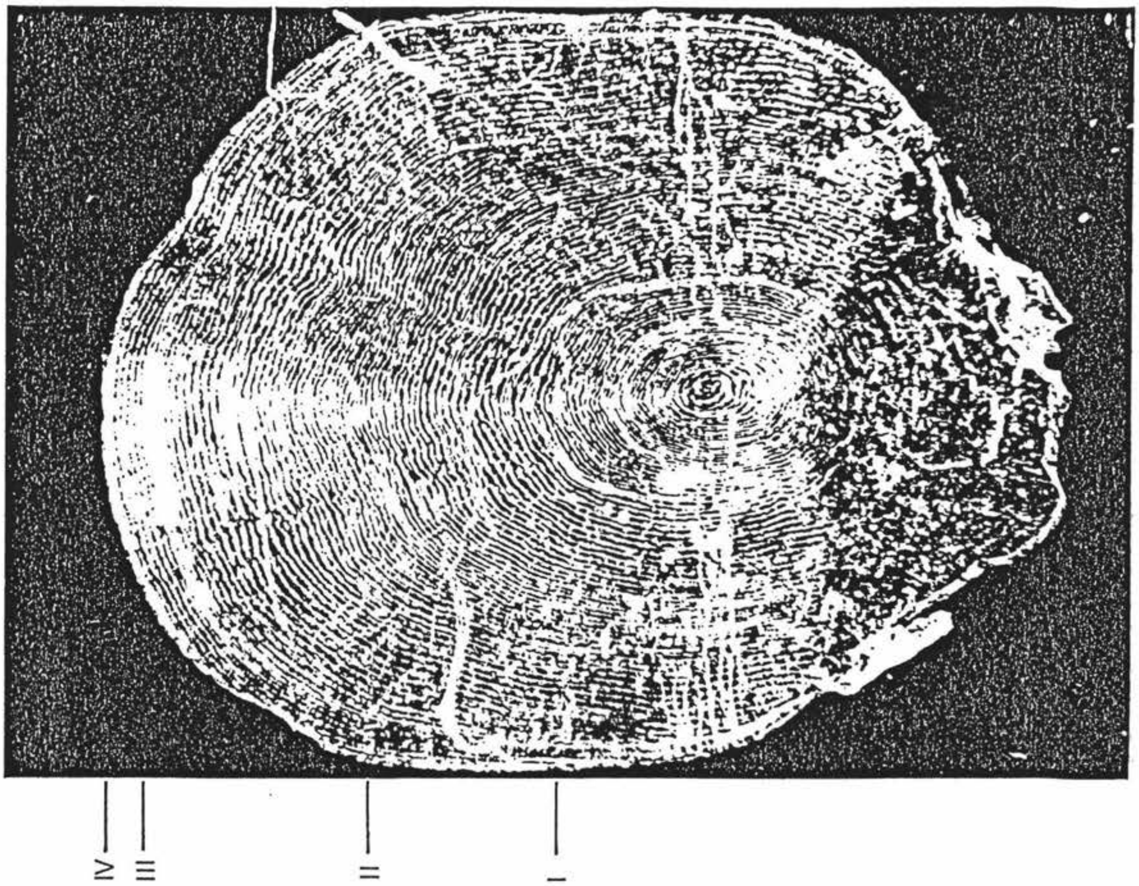
Plate 13 Scale of a 55cm brown trout caught at the Springvale trap in the winter of 1983 near the end of its 4th year. Length at age 1, 14cm; age 2, 32cm; age 3, 51cm; age 4, 55cm.

Plate 14 Scale of a 54cm brown trout caught in the Springvale area on 28 November 1983, in its 4th year. Length at age 1, 13cm; age 2, 34cm; age 3, 49cm; age 3 years 2 months, 54cm.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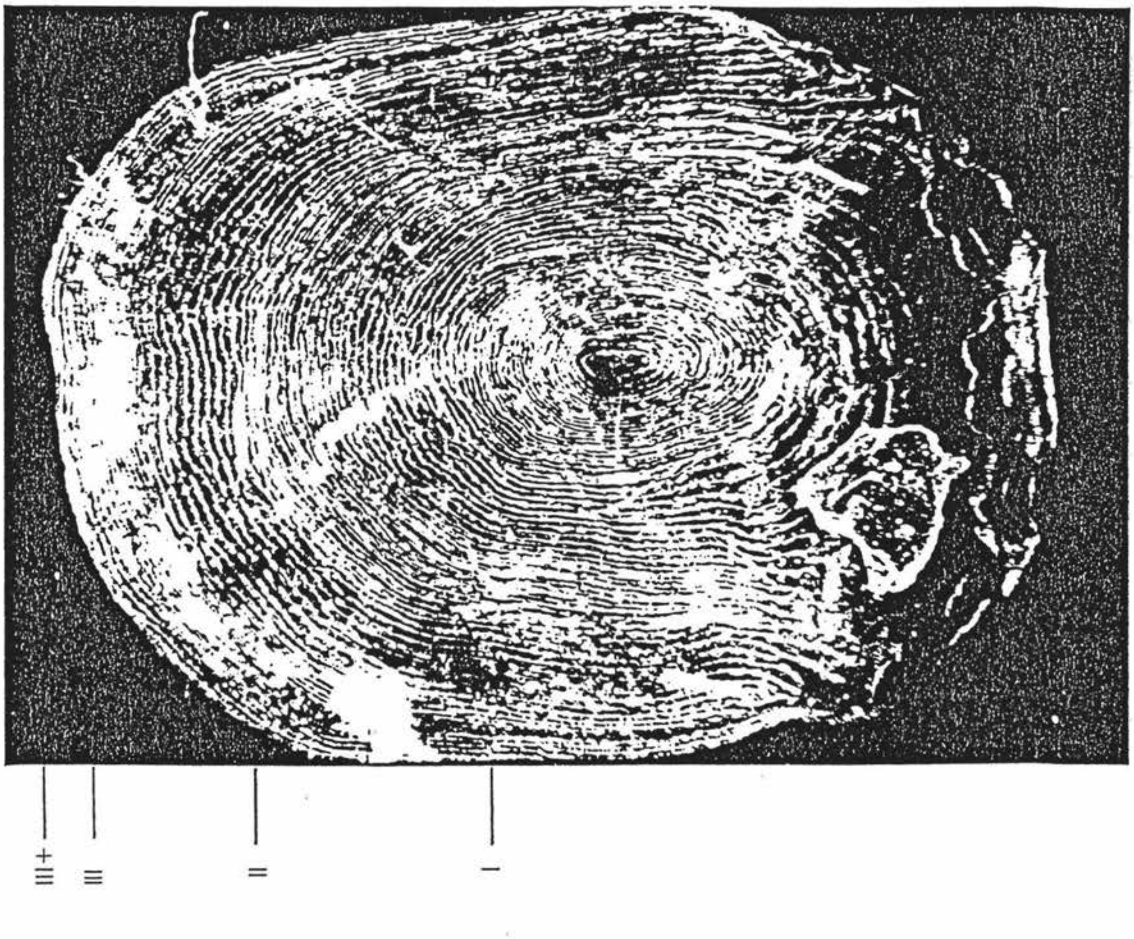
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3. Results

3.1 Size of Trap Caught Trout

The 493 brown trout caught at the Springvale trap in both years had a mean length of 54cm. The maximum length was 74cm and the minimum was 26cm. The mean weight was 2.1kg; maximum 3.7kg and minimum 0.2kg. A significant variation occurred from year to year. In 1983 the mean length was 56cm (n = 265) and in 1984 it was 52cm (n = 228). Fig. 8. A two sample t-test supports the hypothesis that differences occurred ($t = 4.85$, $p < 0.005$). A smaller, but still significant difference occurred between the weights recorded in the two years ($t = 2.21$, $p < 0.035$). Fig 9.

The 388 rainbow trout caught at the Springvale trap in both years, had a mean length of 49cm. The maximum was 65cm and the minimum 30cm. The mean weight was 1.5kg; maximum 3.5kg, minimum 0.4kg. No significant variation in length or weight occurred between years in the rainbow trout caught at the Springvale trap (1983 n = 215, 1984 n = 173) Figs 10 and 11.

In 1983 thirteen brown trout were caught in the Phyn's Creek trap from June 30 to July 11. They had a mean length of 54cm and a mean weight of 1.8kg. In 1984 when the trap was modified, Fig 6 and placed near the confluence of Phyn's Creek and the Pourangaki River 163 brown trout were caught. These fish had a mean length of 50cm and a mean weight of 1.5kg. No rainbow trout were caught in 1983 but 22 were caught in 1984. These fish averaged 48cm and 1.5kg.

Figure 8.
Length of Springvale trap caught brown trout 1983 - 1984

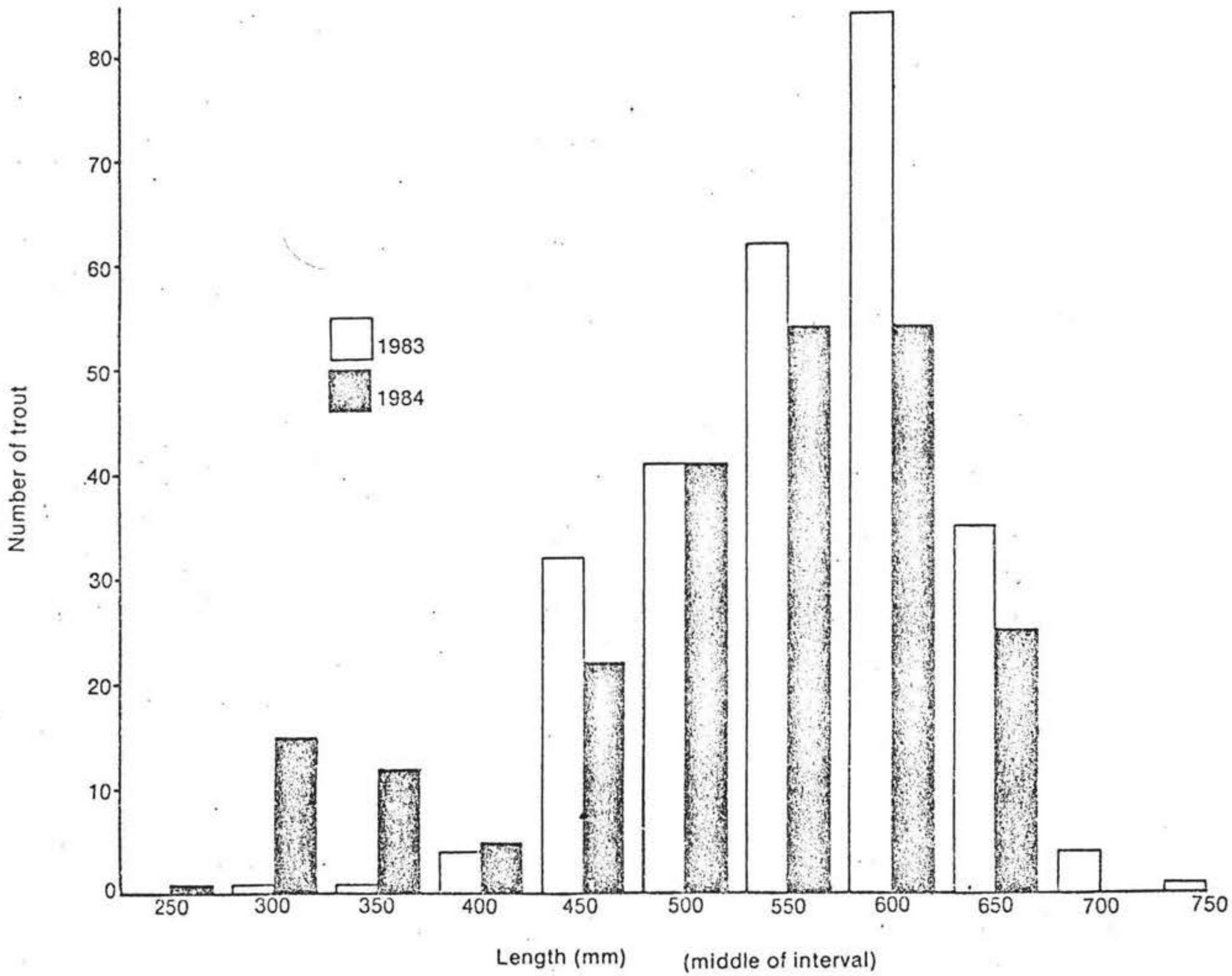


Figure 9.

Distribution of weights of brown trout caught at the Springvale Trap 1983 and 1984

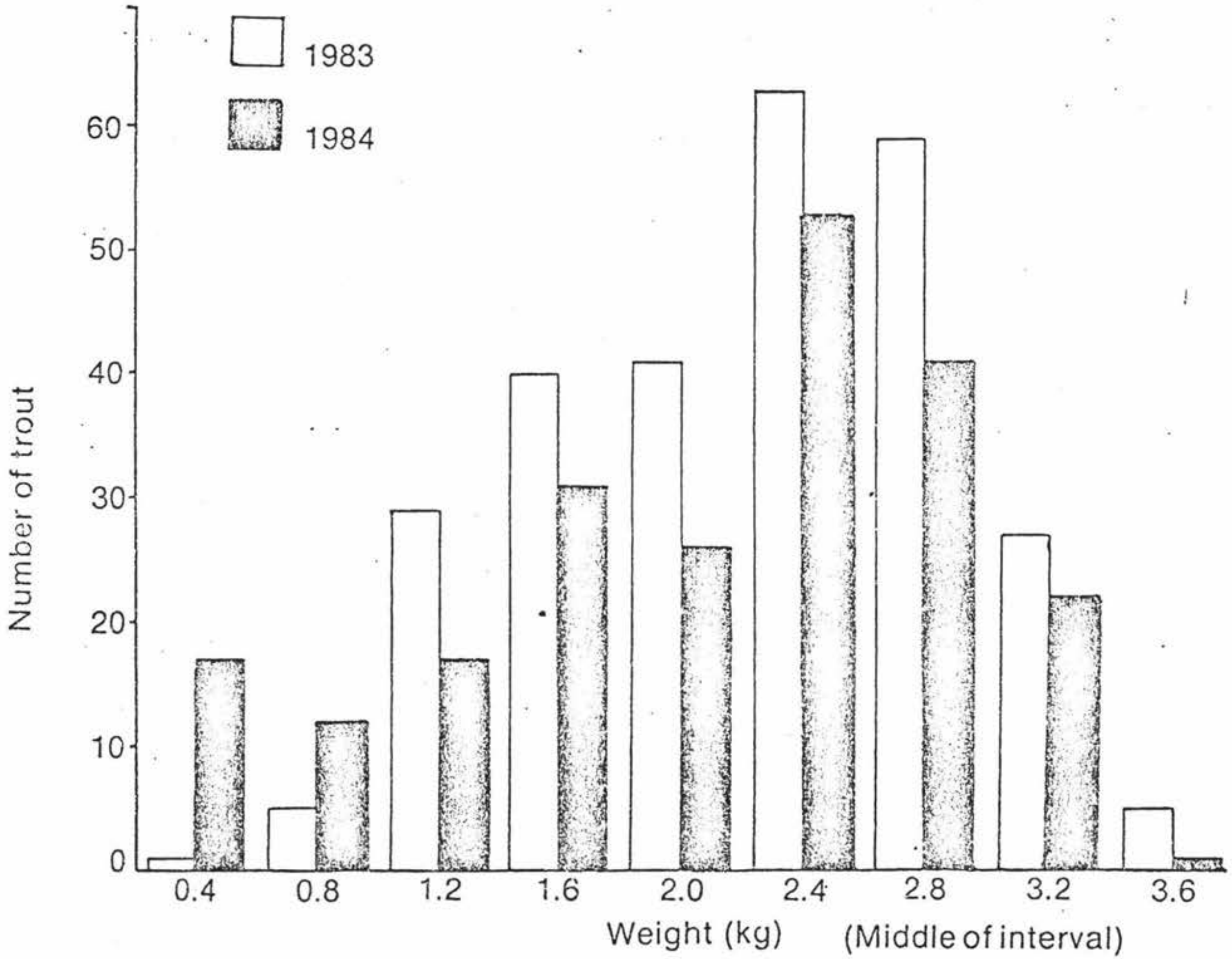


Figure 10.

Distribution of lengths of rainbow trout caught in the Springvale trap 1983-84.

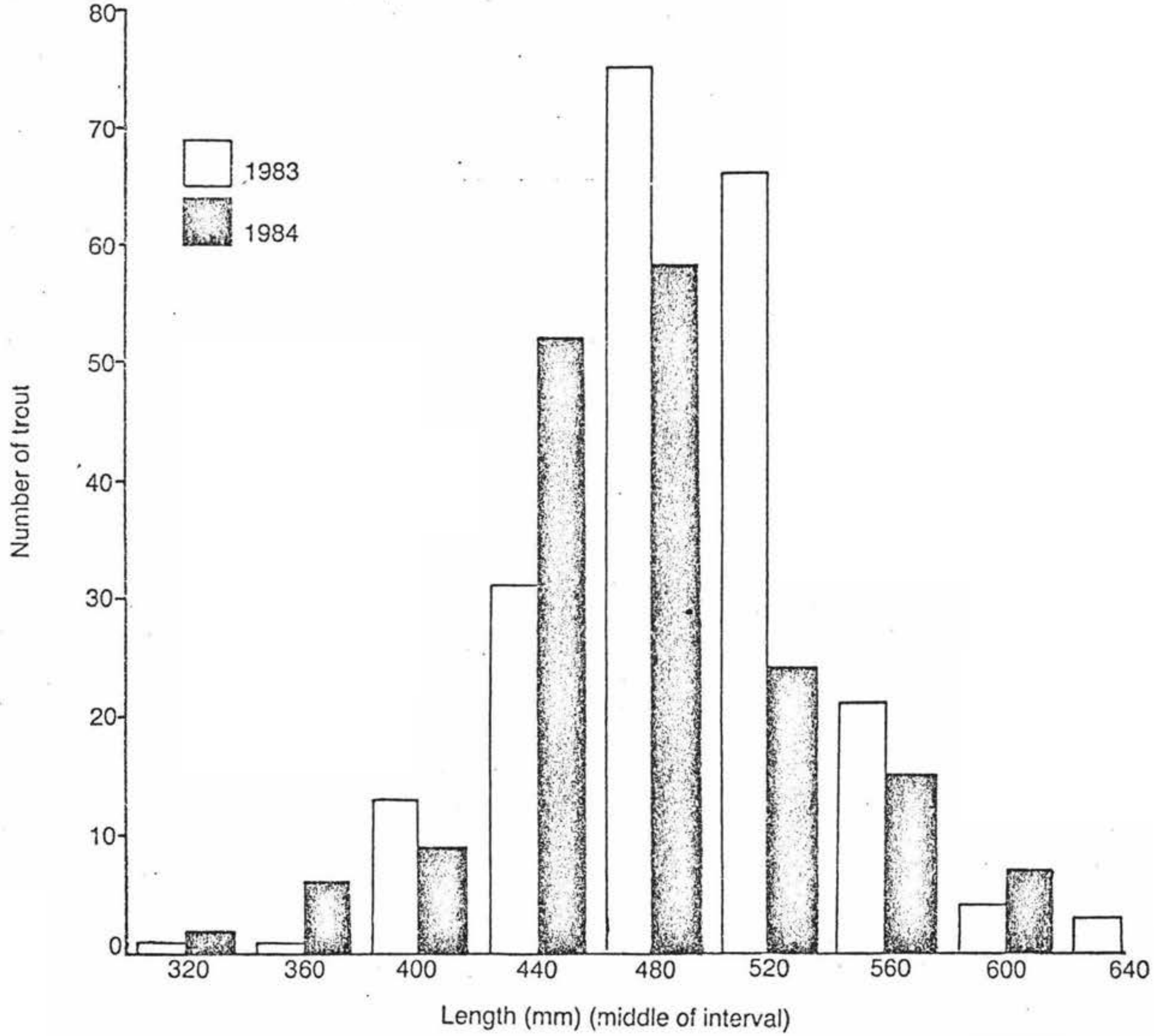
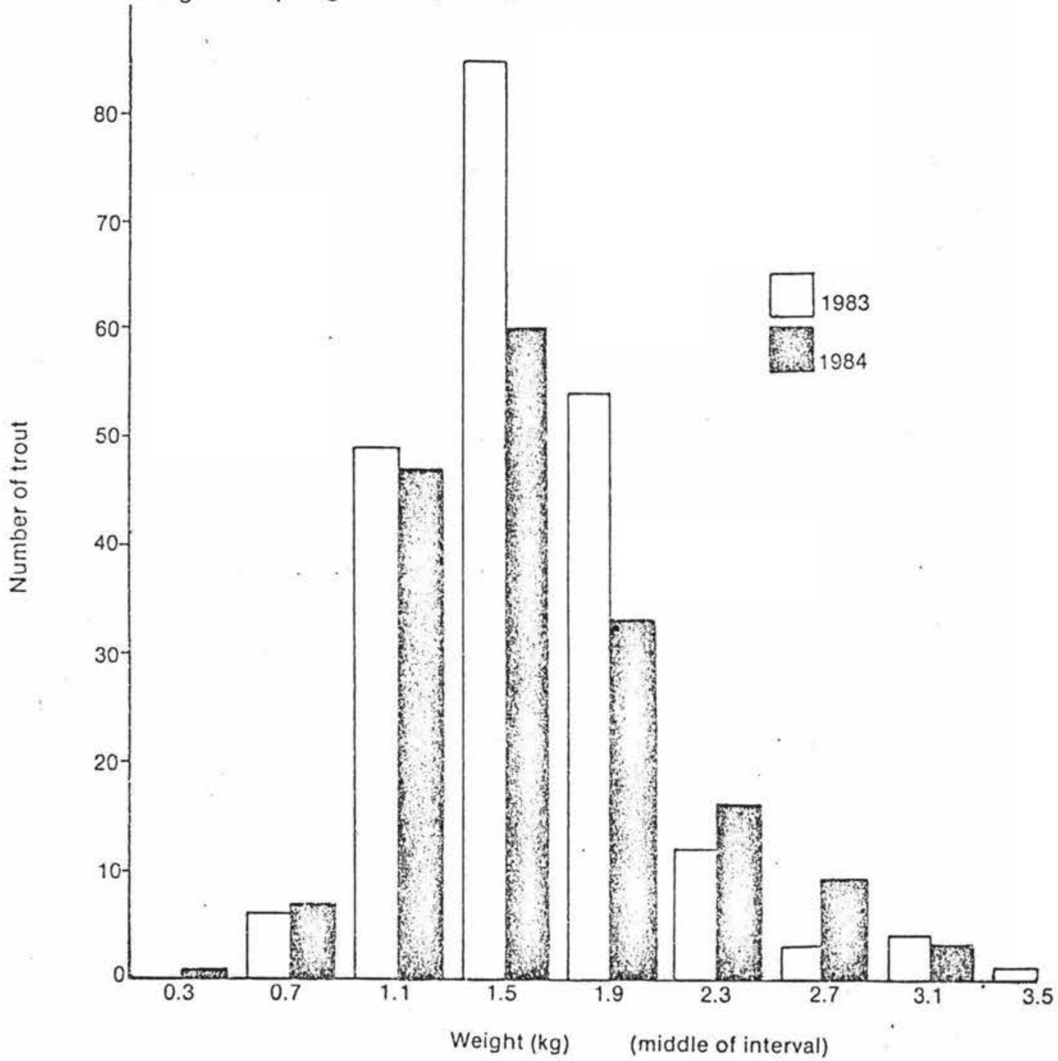


Figure 11.

Weight of Springvale trap caught rainbow trout 1983 - 1984



The brown trout caught here differed significantly in mean length from the mean of all brown trout caught at the Springvale trap ($t = 14.76$ $p < 0.005$) but there was no difference in the mean lengths of the rainbow trout caught in the two traps.

3.2 Size of Trout caught by angling and handnetting

A total of 96 brown trout were caught by handnetting in the river in two summers, 1982-1983 and 1983-1984. Of these 55 were caught in the mid-reaches near Springvale and Mangaohane and 41 were caught in the lower reaches between Omatane and Mangaweka. The distributions of the lengths of these trout are not similar (Chi-square = 10.16 $p < 0.010$), nor are the means of the lengths ($t = 2.79$, $p < 0.005$). (See Fig. 14. and Table 1). From October 1981 to March 1984, 349 rainbow trout caught by angling were measured These trout were classified according to area and it was found that significant differences occurred between the mean lengths of the trout caught in the headwaters, and the mid and lower reaches (Table 1). The distribution of lengths from the mid and lower reaches was also found to differ significantly (Chi-square = 36.93 $p < 0.001$). (See Fig 13).

Chi-square analysis of the distribution of lengths of trout caught other than in the traps suggest size differences in the trout populations which confirm the trap observations on brown trout and refute those on rainbow trout (Figs 12. and 13.).

Figure 12
Relative length distribution of brown trout caught by trapping and hand netting in mid and lower reaches of the Rangitikei River

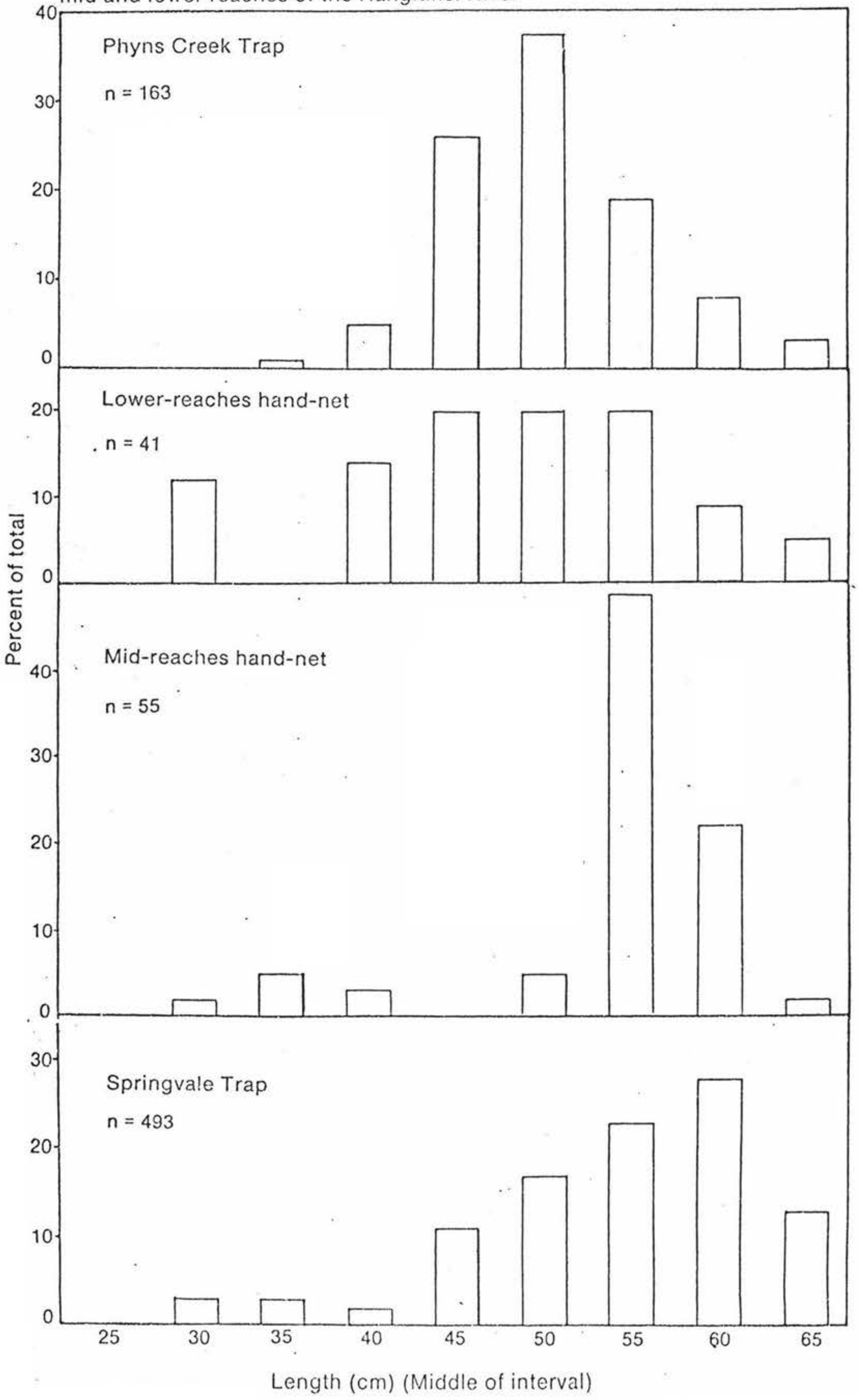


Figure 13
Length distribution (expressed as percent) of rainbow trout by area caught in the Rangitikei River 1981-1984

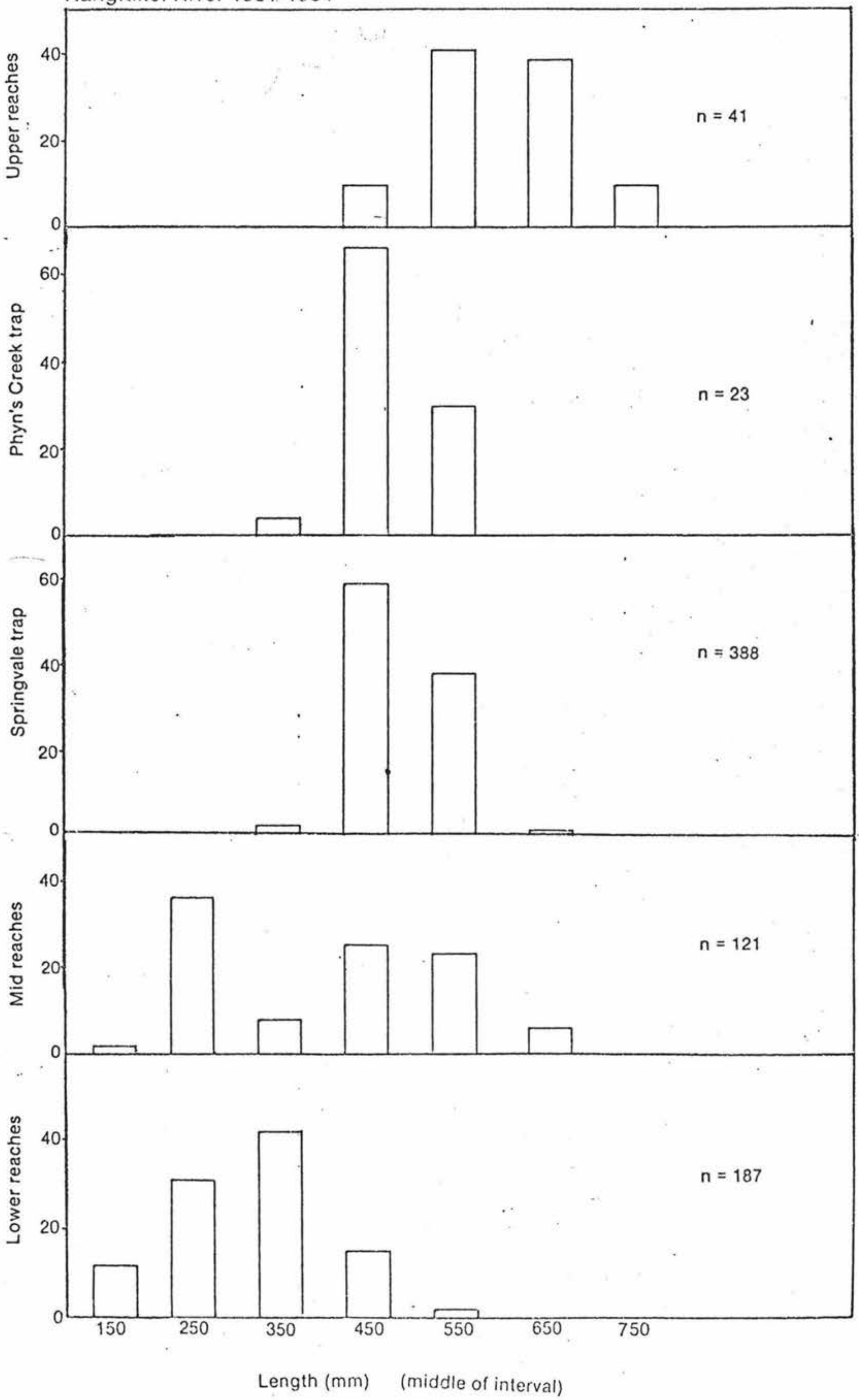


Figure 14

Distribution of lengths of brown trout caught by handnetting in the Mid and Lower Reaches

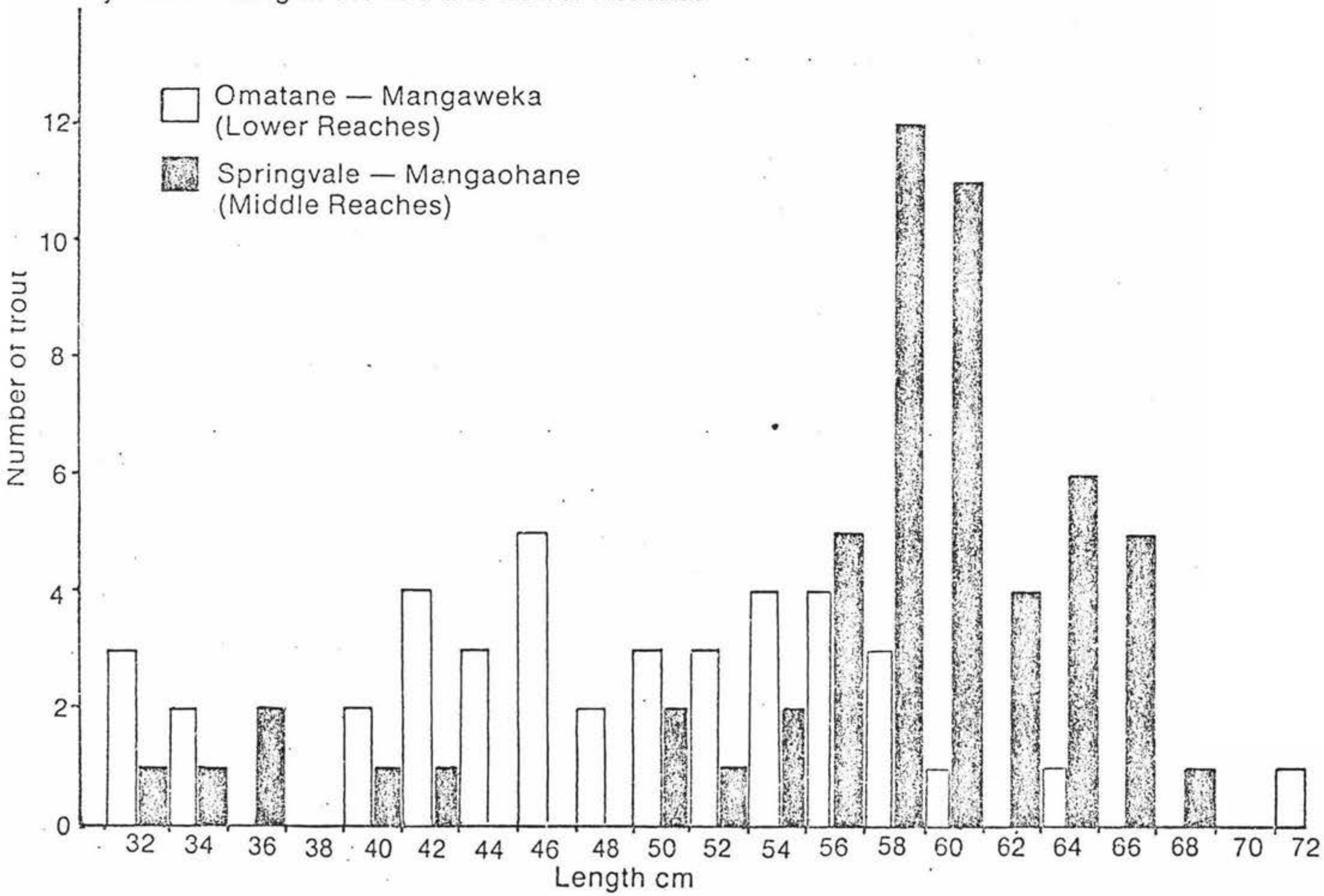


Table 1 Sizes of trout caught in the Rangitikei River

	Mean Length (cm)			
Brown Trout	Handnetting	n	Trap	n
Mid-reaches	58	55	54	493
Lower reaches	46	41	50	163
Rainbow trout	Angling		Trap	
Mid-reaches	42	121	49	388
Lower reaches	32	187	48	22
Upper reaches	60	41	-	-

3.3 Growth

3.3.1 Change in length between captures

Growth, estimated by measuring trout at the beginning and end of a known period in the river, varied from 0.00 to 0.45mm per day in both brown and rainbow trout (Tables 2 and 3). Twenty brown trout recaptured after at least 30 days had a mean growth rate of 0.10mm (range 0.00 to 0.43mm) per day (3.6cm per year). The mean length at first capture of these fish was 56cm (range 46 - 65cm). Twenty one rainbow trout recaptured after at least 30 days had a mean growth rate of 0.26mm (range 0.07 to 0.45mm) per day (9.5cm per year). The mean length of these trout at first capture was 49cm (range 35 - 60 cm) (See Tables 2 and 3).

3.3.2 Back Calculations

The growth and age of trout in the Rangitikei were estimated according to the method of Lea, given in Bagenal (1978). Scales of 61 rainbow trout and 99 brown trout were examined with a projecting compound microscope so that the seasonal variation in circuli and dimensions of each scale could be determined.

Table 2

Growth of Rainbow trout calculated from capture - recaptures with initial and final lengths known.

Length (cm) Start	End	Period	Days	Area	Growth mm/day
400	410	Mar-June	41	Lower to Mid-reaches	0.24
350	380	June-Dec	87	Lower reaches	0.34
460	540	Apr-Jan	252	Mid to Upper	0.32
485	510	May-Nov	170	Mid to Upper	0.15
600	625	Nov-Jan	55	Upper	0.45
515	550	July-Jan	201	Mid to Upper	0.17
510	580	May-Feb	252	Mid to Upper	0.28
510	600	Apr-Feb	276	Mid to Upper	0.33
520	550	Apr-Feb	293	Mid	0.10
470	520	July-Dec	178	Mid	0.28
485	520	July-Nov	179	Mid	0.19
460	560	July-Mar	235	Mid	0.42
350	450	1 year	370	Mid	0.27
565	580	July-Feb	215	Mid	0.07
510	580	Apr-Jan	240	Mid-Upper	0.29
540	620	May-Feb	240	Mid-Upper	0.33
490	570	Apr-Feb	270	Mid-Upper	0.30
*535	610	1yr 1mnth	371	Mid	0.21
500	510	Apr-May	41	Mid	0.24
*530	575	1yr 1mnth	404	Mid	0.11
*490	590	July-June	310	Mid	0.32

*Trap caught both times.

Table 3

Growth of brown trout calculated from capture-recaptures with initial and final lengths known.

Length (mm) Start	End	Period	Days	Area	Growth mm/day
480	645	2yrs 3mnth	798	Mid-reaches	0.21
560	570	June-Nov	180	Mid-reaches	0.05
555	570	June-Nov	180	Mid-reaches	0.08
490	530	June-Jan	193	Mid-reaches	0.21
650	670	Apr-Jan	261	Mid-reaches	0.08
540	540	Jan-Feb	14	Lower-reaches	0.00
540	540	Jan-Feb	14	Lower-reaches	0.00
650	700	Nov-Mar	111	Mid-reaches	0.45
630	640	Apr-Jan	215	Mid-reaches	0.05
*565	595	1yr +	385	Mid-reaches	0.09
565	580	Jan-May	125	Mid-reaches	0.12
610	630	Jan-May	126	Mid-reaches	0.16
*635	635	about 1yr	349	Mid-reaches	0.00
*540	575	about 1yr	348	Mid-reaches	0.10
*490	540	about 1yr	333	Mid-reaches	0.15
*590	600	Apr-May	23	Mid-reaches	0.43
460	460	Jan-May	120	Mid-reaches	0.00
*470	475	Mar-May	69	Mid-reaches	0.07
*580	585	Apr-June	47	Mid-reaches	0.11
*560	595	1yr 1mnth	381	Mid-reaches	0.09
600	600	Jan-June	125	Mid-reaches	0.00
*590	590	1yr 1mnth	398	Mid-reaches	0.00
*540	555	1yr 1mnth	390	Mid-reaches	0.04

*Trap caught both times.

Table 4

Calculated growth rates - back calculation.

Brown trout		Rainbow trout	
0 - 130mm	0.35mm/day	0 - 145mm	0.40mm/day
130 - 350mm	0.60mm/day	145 - 380mm	0.64mm/day
350 - 490mm	0.38mm/day	380 - 495mm	0.31mm/day
490 - 550mm	0.16mm/day	495 - 560mm	0.18mm/day
550 - 590mm	0.11mm/day		
590 - 630mm	0.11mm/day		
Overall	0.28mm/day		0.38mm/day

Figs 15, 16, 17 and 18 show growth curves and size distributions at each age for these trout. Brown trout up to 20cm were in their first year, those between 23cm and 39cm were almost certainly in their second year and those longer than 43cm were likely to have been in their third year or older.

In both species maximum growth occurred in their second year. Rates of growth paralleled each other with the rainbow trout growing slightly more in their first two years (Table 4). The variability in estimated size increased with age so that by the third year in both species considerable overlap occurred (Fig 17. and 18.). Therefore, from the third year size alone would not be a reliable estimator of age.

The mean length of all brown trout of 3 and 4 years was 49 and 55cm respectively. Five trout caught in the lower reaches of 40, 43, 48, 44, 46cm were estimated to be 3, 3, 4, 4, and 4 years old respectively. This suggested that brown trout living in the lower reaches grow more slowly than those in the mid-reaches.

Most trout used in these estimations were caught in the winter but five rainbow and 21 brown trout were caught at other seasons. They were up to six months older or younger than winter caught trout placed in the same age category. Several of the brown trout not caught in the trap were captured in the autumn, just prior to the trap installation. These trout,

Figure 15
Estimated growth of Rangitikei River brown trout derived from back-calculation methods

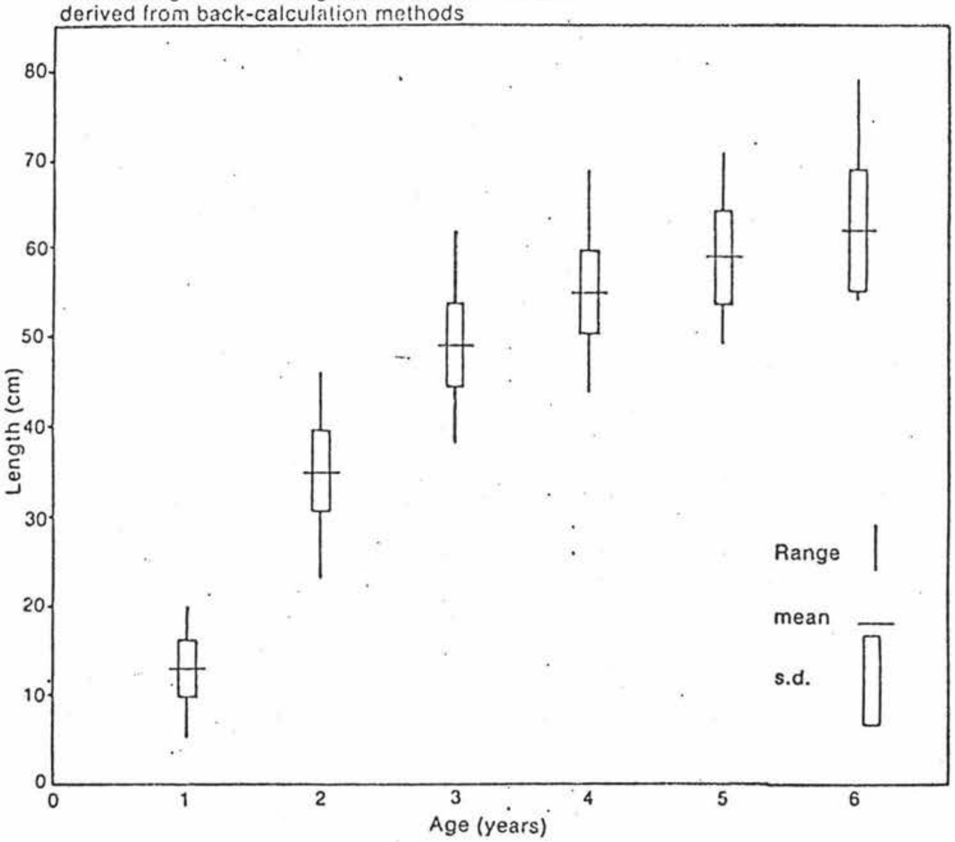


Figure 16
Estimated growth of Rangitikei River rainbow trout derived from back-calculation methods

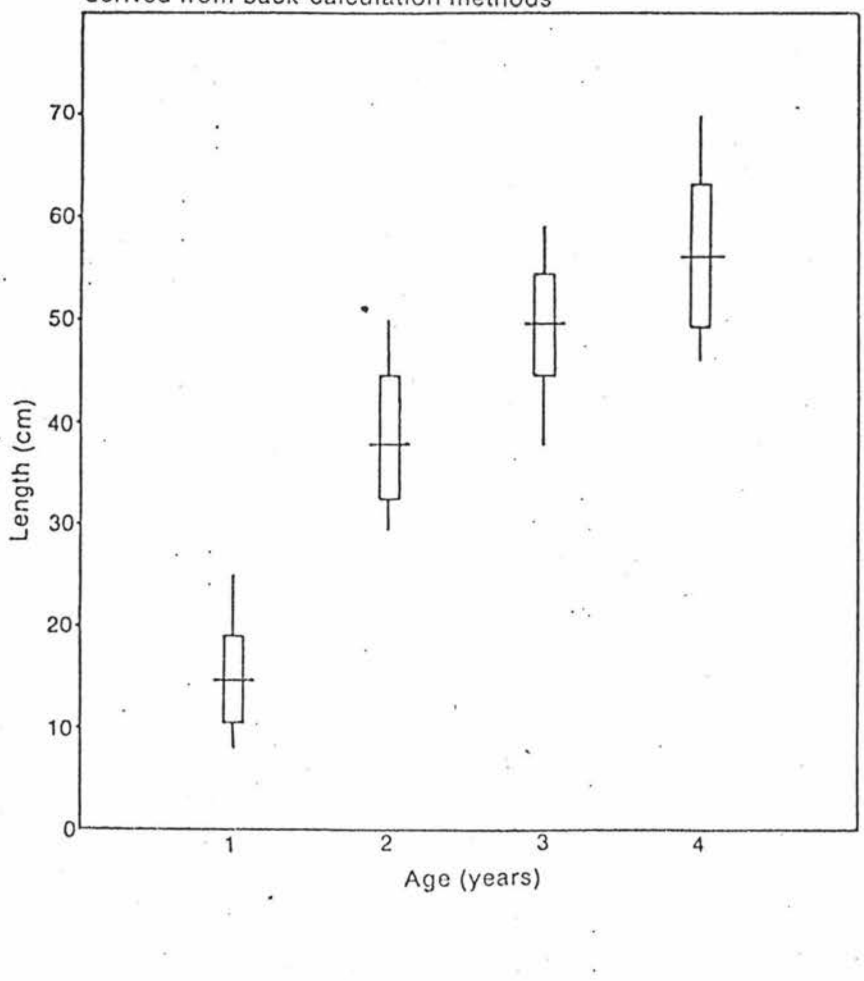


Figure 17
Age grouped size distribution of Rangitikei River
Brown Trout estimated by back-calculation

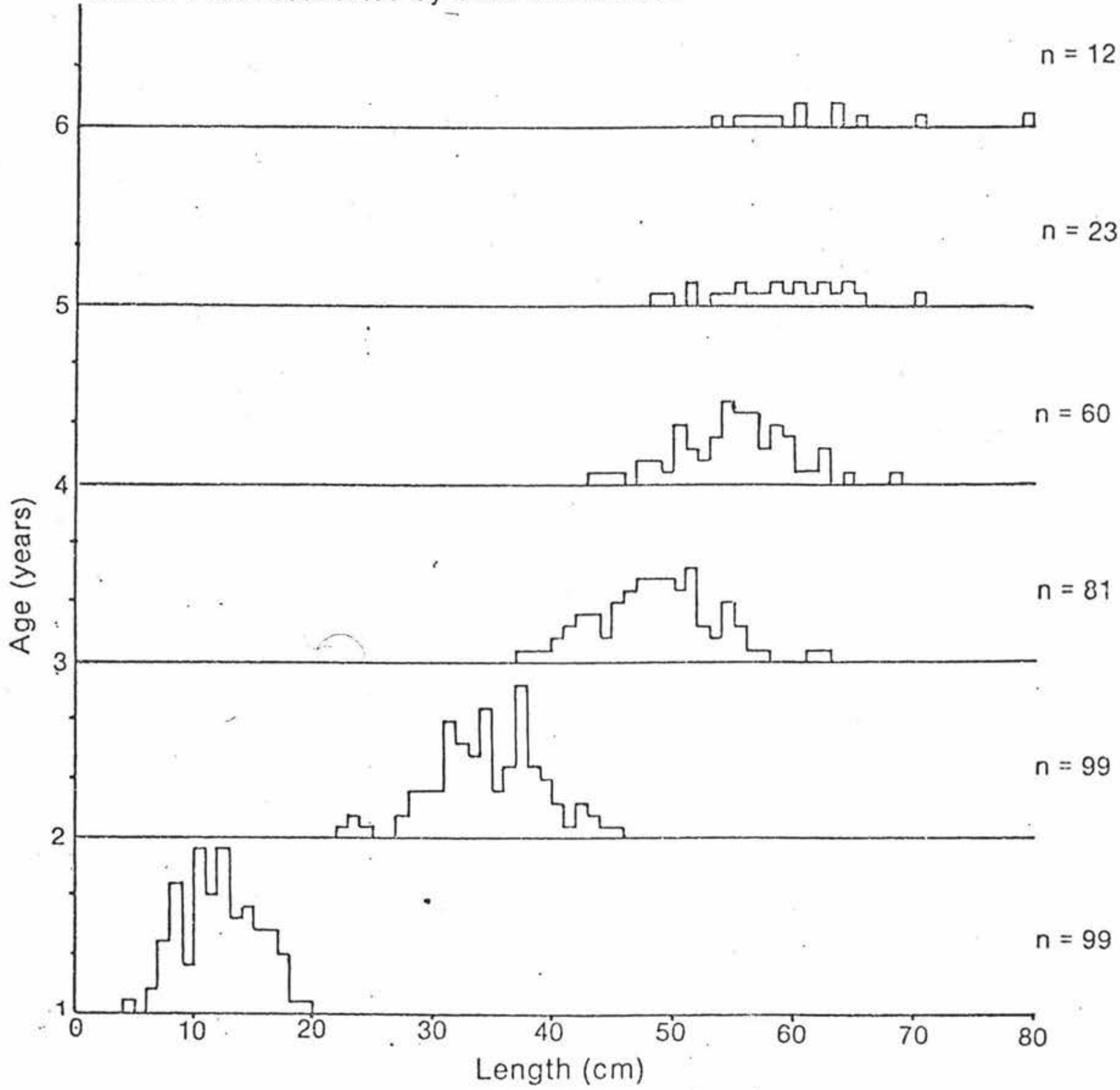
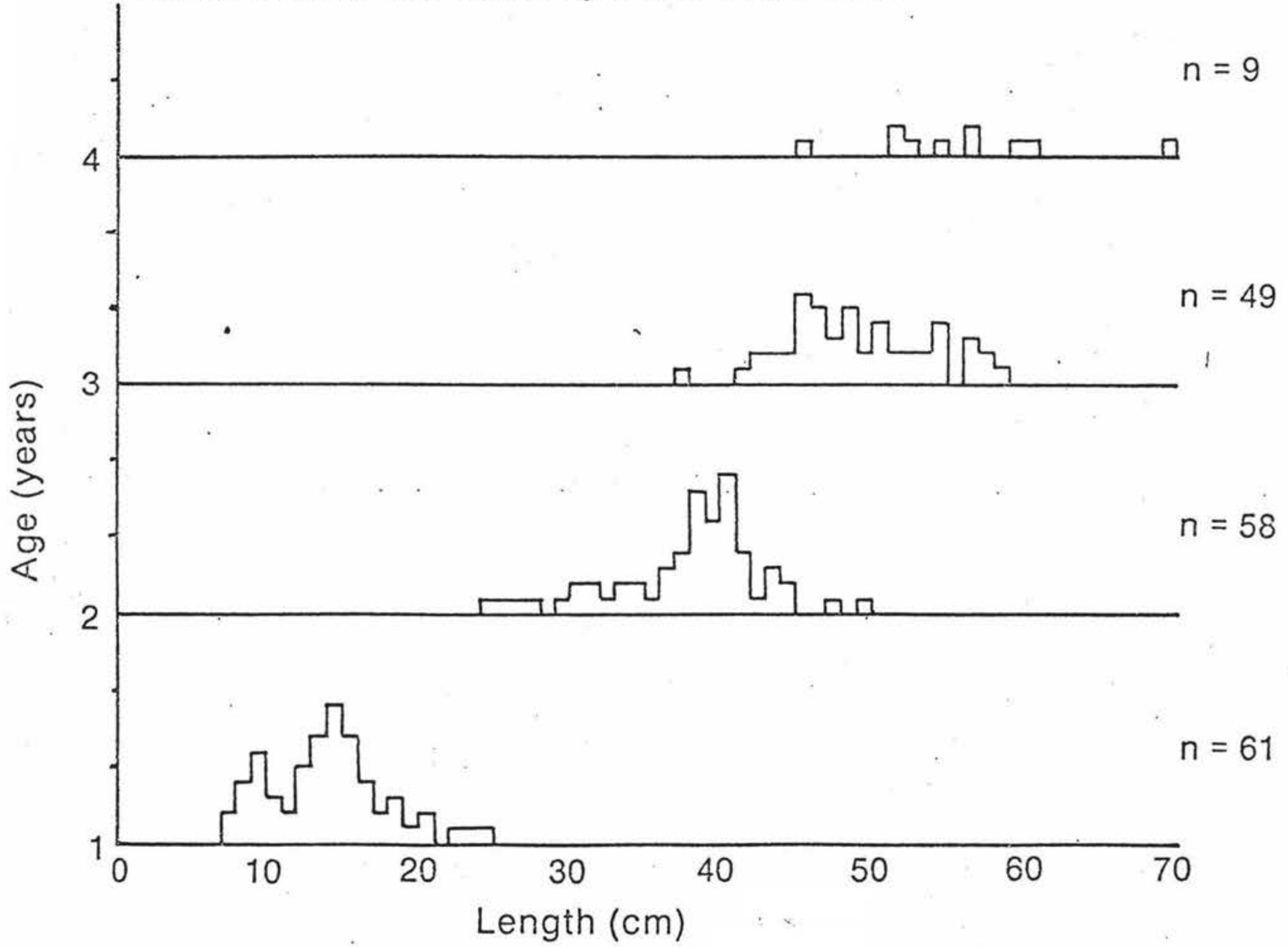


Figure 18
Age grouped size distribution of Rangitikei River Rainbow trout estimated by back-calculation



where recorded, would tend to be smaller for a given age and, like the summer and spring caught trout, add to the variability of the size distribution for each age class. Because of the preponderance of winter caught trout (Rainbows 92%, Browns 79%) these effects are not likely to alter the growth curves for each species. For the purposes of this age determination the 1st October has been taken as the beginning of the year as used by Allen (1951). Since the peak spawning time at Springvale was the middle of June and this time between fertilisation and hatching at the ambient temperatures (6-9°C) is in the vicinity of 50 to 77 days (Frost and Brown 1964), brown trout alevins would emerge from the gravel at Springvale from the end of July to the middle of August. Plates 9 - 12 show examples of scales used to calculate age and growth of trout in the river.

3.4 Movement

3.4.1 Changes in abundance and distribution

3.4.1.1 Drift diving observations

Table 5

Average numbers of brown and rainbow trout observed during drift diving activities in January and February 1984

Location	Species	Date	Large	Med	Small	Date	Large	Med	Small
Springvale	Rainbow	10/1/84	6	3	31	14/2/84	2	17	25
	Brown		45	6	30		30	8	15
Mangaohane	Rainbow	11/1/84	26	12	23	15/2/84	16	11	15
	Brown		32	4	2		26	11	3
Pukeokahu	Rainbow	17/1/84	9	31	22	17/2/84	2	45	11
	Brown		18	7	6		12	18	1

cont'd...

Utiku	Rainbow	16/1/84	9	40	13	4/3/84	24	34	7
	Brown		9	13	13		9	39	13
Makohine	Rainbow	17/1/84	10	10	0	4/3/84	24	24	1
	Brown		19	12	1		13	13	0

The mean number of trout seen in two dives taken less than 24hr apart was used. Excessive variability in each replicate precluded the use of the observations for population estimation but estimates of changes in abundance over time were possible.

Analysis of variance of these data was used in an attempt to identify statistically significant differences in numbers of trout in the river with respect to the variables of; location, time, species, and size (as in Table 5). Significant differences were observed. The major contributions to the variability were:

1. A change in size distribution over time
2. A difference in the species composition from site to site
3. A difference in the size distribution of each species from site to site.

Changes in numbers over time were not significant.

Table 6

Changes in average numbers of trout in specified size groups from early to late drift diving counts.

Size	Change in numbers from January to February dives
Large	no change
Medium	increase
Small	decrease

F-ratio = 10.09 $p < 0.001$

Table 7

Differences in the population of brown and rainbow trout at each site.

Site	Rainbow	Brown
Springvale	smaller	larger
Mangaohane	no significant difference	
Pukeokahu	larger	smaller
Utiku	no significant difference	
Makohine	no significant difference	

F-ratio = 5.03 $p < 0.001$

Table 8

Differences * in the numbers of trout with respect to species and size at each site.
(Number of + indicates relative abundance)

Species, size

Site	Rainbow			Brown		
	Large	Medium	Small	Large	Medium	Small
Springvale	+	+	+++	++++	+	+++
Mangaohane	++	+	++	+++	+	+
Pukeokahu	+	++++	+	++	++	+
Utiku	+	++++	+	+	+++	+
Makohine	++	++	+	++	++	+

F-ratio = 4.14 p 0.001

*These differences accounted for 16% of the 52% explained variation.

3.4.1.2 Handnetting Observations

Table 9

Numbers of brown and rainbow trout observed during handnetting activities, November 1983 to February 1984.

Springvale - Mangaohane

	Rainbow Trout			Brown Trout		
	Large	Med.	Small	Large	Med.	Small
3|1|84	18	15	4	113	18	6
13|2|84	8	0	0	45	2	1

(poorer visibility)

Table 9 (cont'd)

	Rainbow trout			Brown trout		
	Large	Med.	Small	Large	Med.	Small
Pukeokahu - Mokai						
28/11/83	0	7	2	33	7	0
4/1/84	17	5	21	31	10	5
1/2/84	15	9	11	23	9	8
Utiku - Mangaweka						
5/1/84	8	19	23	26	21	18
	16	30	8	37	21	15
	18	26	22	37	16	22
Ohingaiti - Makohine						
2/12/83	0	3	2	7	7	2
25/1/84	8	13	0	16	9	4
2/3/84	9	22	2	25	21	11

Analysis of variance suggested that variations in the observed distributions were in part accounted for by an asymetric size distribution of the brown trout from site to site, $F = 7.78$ $p < 0.001$ and an apparent change in the numbers of trout with time at Springvale - Mangaohane $F = 6.16$ $p < 0.001$. Other changes in numbers recorded from site to site over time in Table 9 are not significant.

3.4.2 Recaptures

A total of 116 tagged brown trout and 77 tagged rainbow trout were recaptured or observed from October 1981 to October 1984.

3.4.2.1 Brown Trout

Table 10

Brown trout recaptures in relation to total number tagged

Potential movement	Total tagged*	Recapt	%
Trap to Trap	265	40	15
Trap to Mid-reaches	265	49	18
Trap to Lower reaches	265	3	1
Mid-reaches to Trap	55	10	25
Lower reaches to Trap	50	1	2
Elsewhere[1]	132	11	8
Trap to Headwaters	265	1	0.04

* Number tagged up to the beginning of recapture period eg For Trap to Trap - number tagged in the trap in 1983; Midreaches to trap - number tagged up to the beginning of 1984 trapping season.

1 Trout which were not tagged or recaptured in the trap and were caught by handnetting or angling.

Table 11

Methods of Capture - Brown Trout

	1983	1984
Trap (Springvale)	265	228
Trap (Phyn's Creek)	13	163
Handnetting	38	86
Angling	10	0

Table 12

Methods of Recapture (Both years) - Brown trout	
Trap	51
Handnetting	18
Angling	10
Diver observation	37 (25 tags, 12 fin clips)

Movement in Relation to Capture Site

Springvale Trap (Not including trap recaptured - trap tagged trout)

Forty trap-tagged brown trout were observed or caught downstream from the trap and 13 trout tagged below the trap were recaptured in the trap. Ten tagged brown trout were located upstream of the trap. Fig. 19.

Thirteen capture-recaptures occurred entirely away from the Springvale trap. These are presented in Table 13.

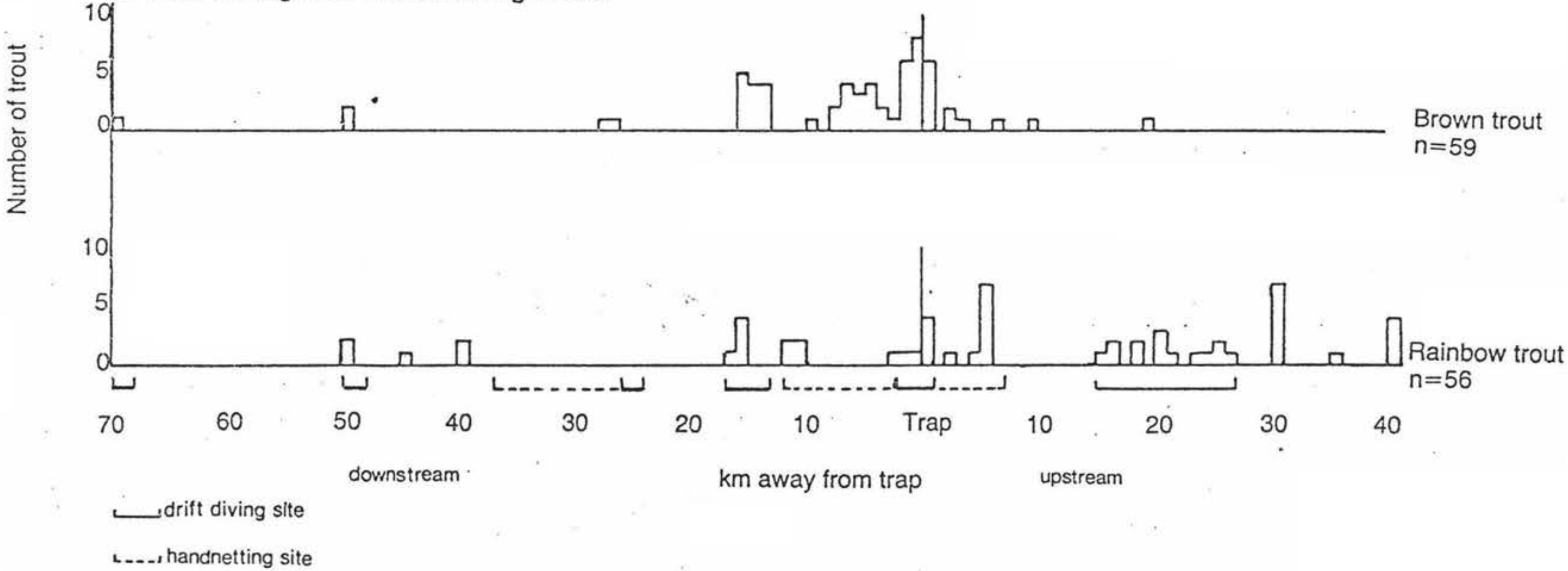
Table 13

Captures and recaptures of brown trout not caught in the Springvale trap.

	Movement(km)	Direction of movement	Time (days)
Mangaweka	Nil	-	7
Mangaweka	Nil	-	7
Mangaweka	Nil	-	7
*Springvale area	20	?	-
Pukeokahu	Nil	-	28
Makohine	Nil	-	35
*Springvale area	20	?	-
Pukeokahu	5	Downstream	64
Utiku	0	-	14
Utiku	0	-	14
Ohingaiti	10	Upstream	90
Phyn's Creek-Bulls	95	Downstream	60
Phyn's Creek-Tangimoana	115	Downstream	140

Figure 19

Other capture location of trout captured or recaptured at the Springvale trap, in relation to drift diving and handnetting sites.



* - Colour-coded tags, indicating the trout that carried them were tagged in the Springvale area were observed by divers in this area.

Tag Loss

The estimated tag loss after one year in brown trout was 60.9%. This figure was derived from the number of recaptured 1983 trap-tagged trout which had lost their tag but were recognised by their clipped adipose fin (14) divided by the total number of trap tagged 1983 trout recaptured in the trap in 1984 (23).

3.4.2.2 Rainbow Trout

Table 14

Rainbow Trout recaptures in relation to the total number tagged

Potential movement	Total tagged	Recapts.	%
*Trap to trap	215	12	5.5
Trap to mid-reaches	215	13	6.0
Trap to lower reaches	215	3	1.0
Trap to Headwaters	215	26	12.0
Mid-reaches to trap	14	1	7.1
Lower reaches to trap	78	2	2.5
Elsewhere	99	8	8.0

*Twelve other trout have been recaptured. Ten were caught less than 5km above the Springvale trap just after they were first captured in the trap in 1984, and two others at Mangaweka (see Table 16).

Table 15

Methods of Capture - Rainbow Trout	1983	1984
Trap	215	173
Angling	71	28

Table 15

Methods of Recapture - Rainbow Trout	
Trap	12
Angling	49
Diver observation	16

Table 17

Captures and recaptures of rainbow trout not caught in the Springvale trap

Location	Movement(km)		Time(days)
Utiku	Nil	-	.7
Bulls-Utiku	90		90
Waingakia	1		55
Makohine	Nil	-	22
Whakaurekou Confluence	Nil	-	135
Whakaurekou River	10	-	.7
Whakaurekou River	10	-	7
Mangaweka	Nil	-	180
Phyn's Creek - Mangaweka	15		60

Tag Loss - Rainbow Trout

Tag loss was estimated as for brown trout. Eight one year apart trap - trap recaptures occurred, 5 of these trout had lost their tags therefore 62.5% of these fish had lost their tags.

Estimates of tag loss over shorter periods for both species were made from angling and handnetting records where these fish were recaptured by trained personnel. Nine trap caught brown trout were caught up to six months after the fish were originally tagged. One of these had lost it's tag. Sixteen brown trout caught twice in the trap in 1983, which were free up to 83 days had retained their tags. Thirteen rainbow trout caught from one to 91 days after tagging in 1983 sustained no tag loss. Therefore it is likely that few trout lost their tags up to at least six months after being tagged.

3.4.3 Effort spent on recapturing trout

Angling

Each Wellington Acclimatisation Society (W.A.S.) angler is required to purchase a licence which has a message asking him to return tags found in trout caught in the Rangitikei. Angling effort on the Rangitikei is discontinuous. A W.A.S. angling survey (Rodway 1983) suggested that angling density was similar in the mid and lower reaches where access was facilitated by road ends or bridges. The headwater area is known to be popular with anglers from many parts of New Zealand and overseas. The relatively large number of tags returned from anglers fishing in this area suggests angling density there is high.

Handnetting

Three days handnetting were spent at each of the following locations Pukeokahu-Mokai, Springvale-Mangaohane, Utiku-Mangaweka and Ohingaiti-Makohine. One day each was spent above Springvale, from Omatane to Utiku and at Vinegar Hill (Fig 7.).

Drift Diving

Two days drift diving occurred at each of: Springvale, Mangaohane, Pukeokahu, Utiku and Makohine. One day was spent drift diving at Vinegar Hill and one day from the Waipehu Stream to the Pinnacles Creek in the headwaters. (Fig 7.).

Table 18

Proportion of trap tagged trout seen at each drift diving site suring the first dive at each place (large trout only)

Site	Rainbow			Brown		
	Total	No.Tagged	%	Total	No.tagged	%
Headwaters	143	9	6.3	46	1	2.2
*(M.A.F. survey	29	3	10.0)			
Springvale	6	0	0	45	8	17.7
Mangaohane	26	2	7.7	32	11	34
Pukeokahu	9	0	0	18	0	0
Utiku	9	1	11	9	0	0
Makohine	10	0	0	19	1	5.3
Vinegar Hill	2	0	0	9	0	0

*Ministry of Agriculture and Fisheries Diving Survey 28/3/84 (E.J.Cudby Pers.Comm.)

Trapping

Trapping effort at Springvale and Phyn's Creek was uniform with respect to site since the devices are passive capture - recapture mechanisms.

3.4.4 Movement of trout into traps

Several variables appeared to effect the timing of trout movement into the traps.

3.4.4.1 Time of Year

Figures 20, 21 and 22 show the cumulative percentages of trout captures at Springvale in 1983 and 1984 and at Phyn's Creek in 1984. Data from Phyn's Creek in 1983 are too few to be meaningful. Rainbow trout were later migrants at Phyn's Creek;(Chi-square =25.71, $p < 0.001$) (captures to June 26 - Fig 22.), but at Springvale in both years rainbow trout were earlier;(Chi-square = 46.71 $p < 0.001$ 1983, and Chi square =229.7 $p < 0.001$ 1984).

.Figure 20

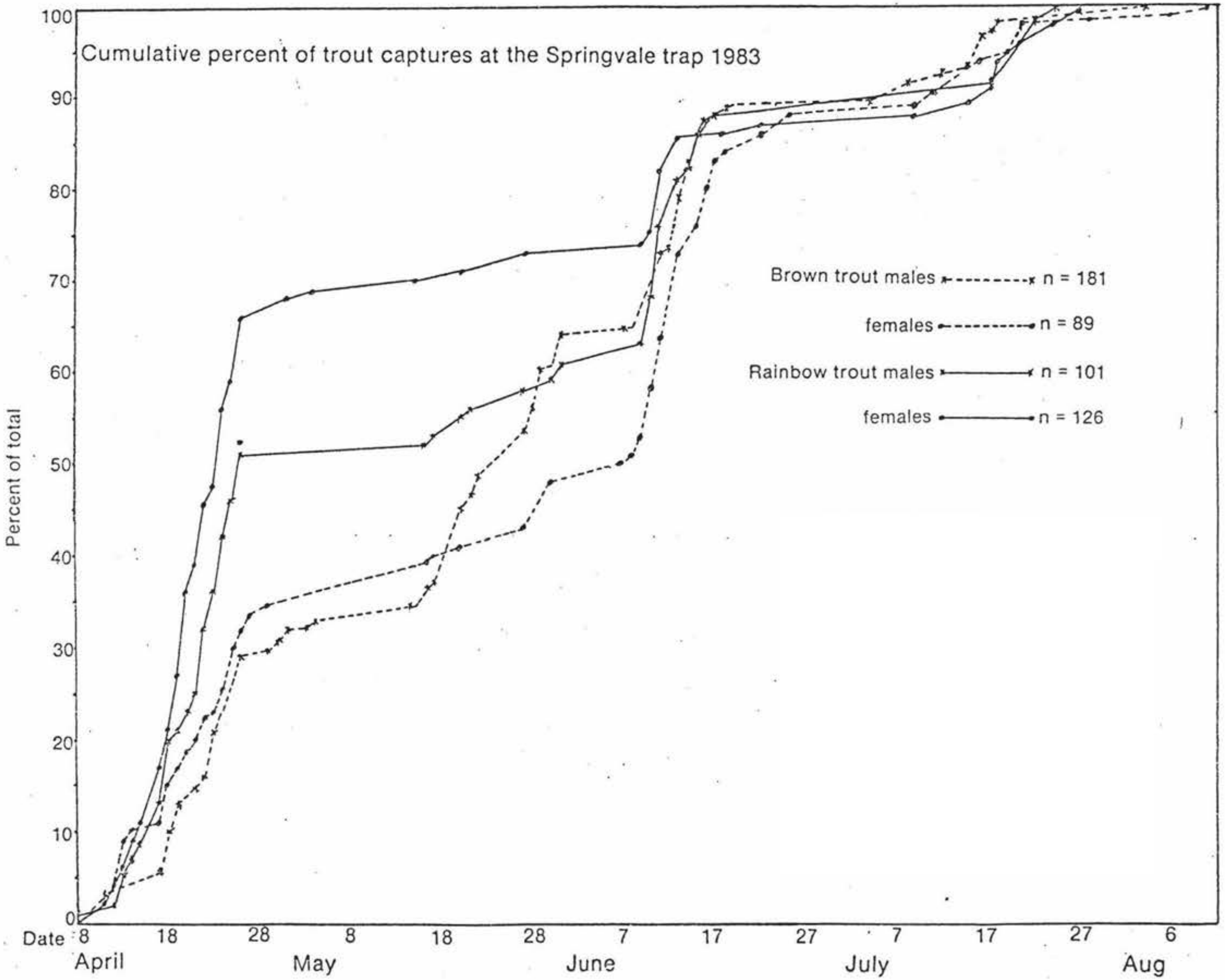

Cumulative percent of trout captures at the Springvale trap 1983
Percent of total
100
90
80
70
60
50
40
30
20
10
0
Date 8
18
28
8
18
28
7
17
27
7
17
27
6
April
May
June
July
Aug
Brown trout males n = 181
females n = 89
Rainbow trout males n = 101
females n = 126

Figure 21

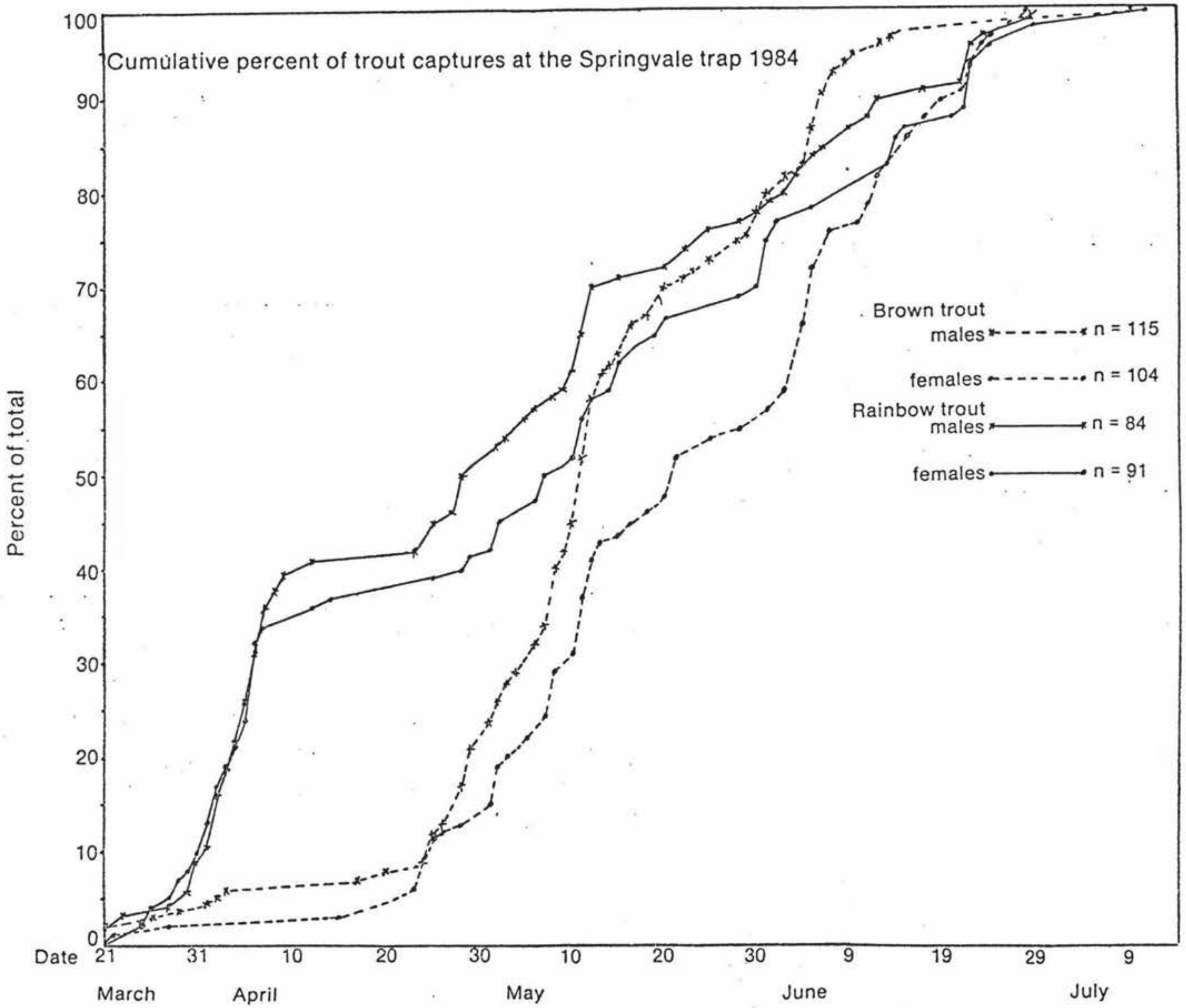
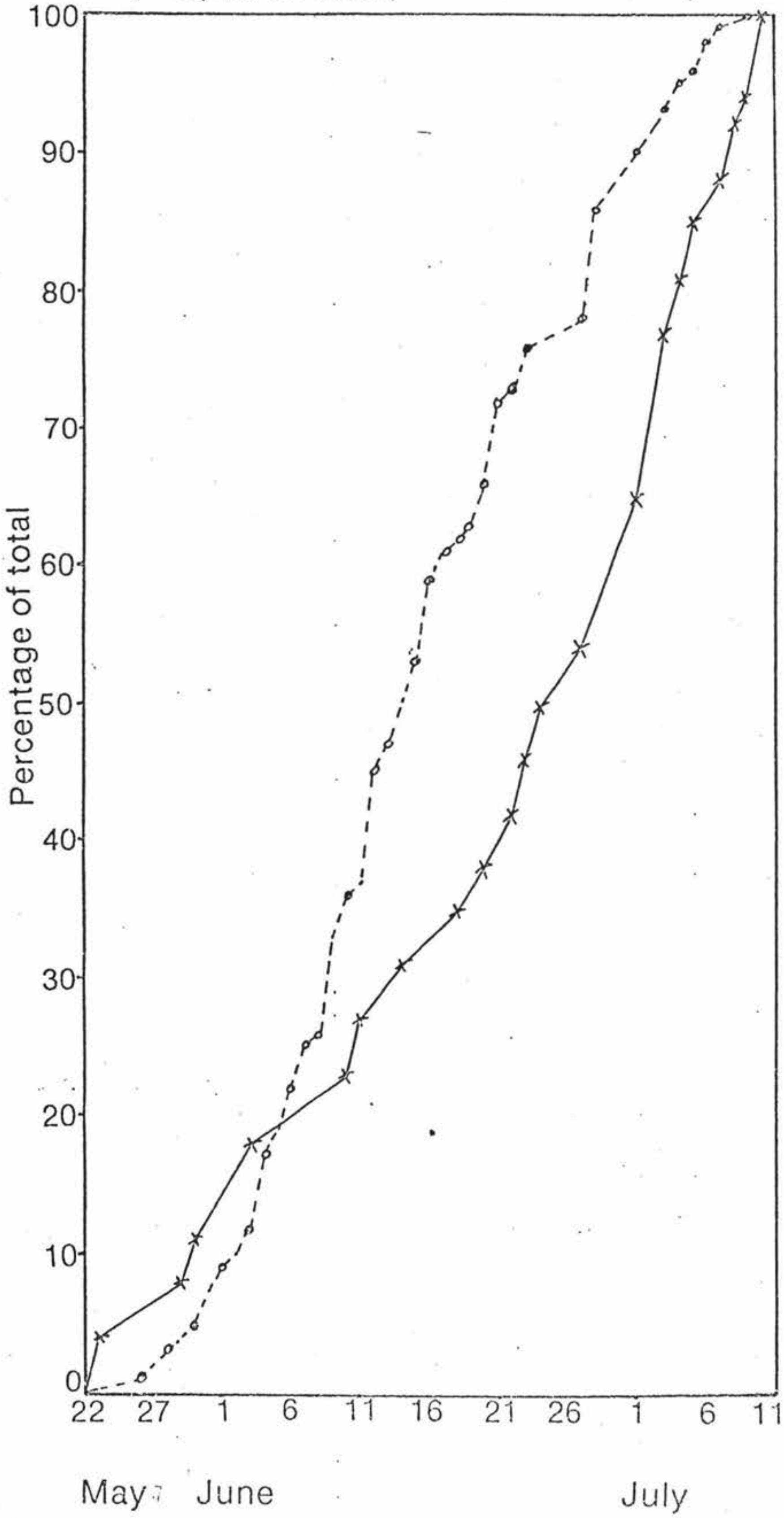

Cumulative percent of trout captures at the Springvale trap 1984
Percent of total
100
90
80
70
60
50
40
30
20
10
0
Date 21
31
10
20
30
10
20
30
9
19
29
9
March
April
May
June
July
Brown trout
males n = 115
females n = 104
Rainbow trout
males n = 84
females n = 91

Figure 22

Cumulative percentage of Phyns Creek trap captures 1984



The dates when differences were compared were April 28 1983, and April 25 1984.

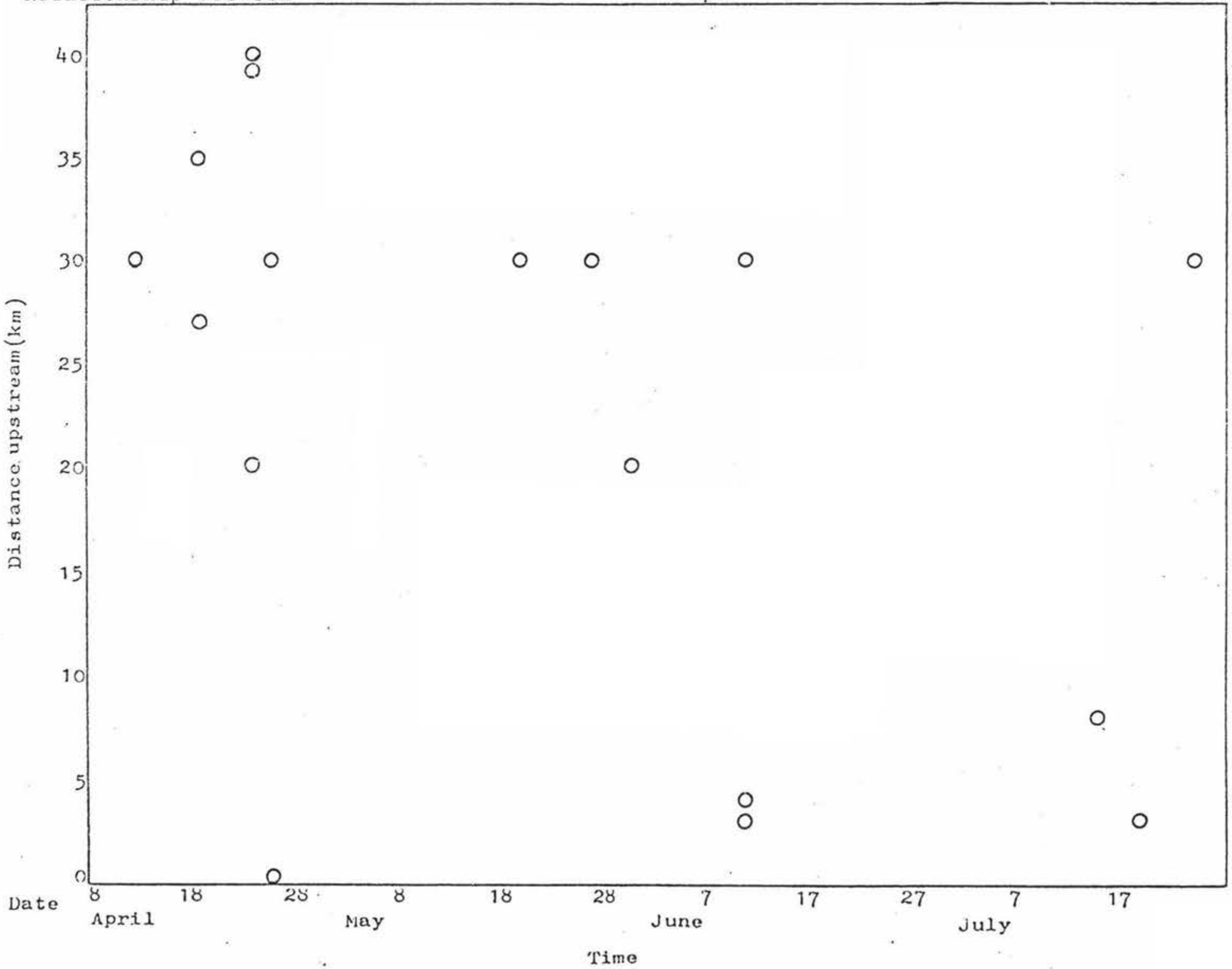
Female brown trout migrated later than male brown trout; (1983, Chi-square = 12.59, $p < 0.0001$, June 7; 1984 Chi-square = 7.21, $p < 0.010$, May 30).
Sex segration within the rainbow trout migrants was not significant except for the month of May in 1983 when significantly more females had passed through the trap (Chi-square = 9.13, $p < 0.010$).

In 1983, from 8-28 April, 9-17 June and 17-27 August 82% and 81% of male and female rainbows respectively, moved into the Springvale trap. These time intervals amounted to 26% of the total time available. In 1983 brown trout movements showed a similar, but less marked, stepped progression towards the total. In the same periods as the rainbows 60% male and 73% female brown trout attempted to move past the trap. Except for a peak from 31 March to 10 April rainbow trout showed a more even distribution over time in 1984. Similarly the brown trout were less 'stepped' in 1984 once the run commenced about April 20.

Recaptured rainbow trout which migrated in the first group of migrants in 1983 (April) were slightly smaller when tagged than those migrating later in the year. The mean length of the early migrants was 49cm (n = 13) and was 52cm for the later trout (n = 13); ($t = 4.2$, $p < 0.005$). Estimated mean growth for rainbow trout of this size was 7mm per year and even though winter growth is likely to be slower (Bagenal and Tesch 1978, Frost and Brown 1967) this difference between the two groups of trout could be non-significant when the time factor is considered. However a small size difference occurred between trout travelling to the headwaters and those remaining in the mid-reaches. The mean length of the known headwater

Figure 23

Relationship between time of entry into the Springvale trap and distance moved upstream of rainbow trout.



migrants was 50cm ($n = 12$) and 51cm ($n = 20$) for the mid-reach migrants, ($t = 1.43$ $p < 0.010$). Headwater migrating rainbow trout and those migrating to the mid-reaches also appeared to differ in the time of entering the trap. Of the twelve rainbow trout recaptured by anglers in the headwaters seven had moved into the trap by April, eleven by the end of May and the other two in June and July. However the correlation is non-significant, $r = -0.33$ (Fig 23).

3.4.4.2 Water Temperature

In 1984 when water temperatures were recorded most trout entered the trap at 6 or 7°C. However many trout entered at other temperatures (Figure 24).

3.4.4.3 Moon Phase

For the purposes of determining activity in relation to moon phase the lunar month was divided into eighths, each phase was given a numeral and the number of trout entering the trap at each time was recorded against it (Fig 25). Number 4 represents Full moon, 0 New moon and 7 nearly New moon. The histogram, (Fig 24) suggests a difference in the numbers entering before Full moon and after. There is a highly significant difference between the means of the phases 0-3 and 4-7 ($t = 27.74$ $p < 0.005$). However, analysis of variance suggests a non-significant difference in the distribution ($F = 1.17$). When an analysis of co-variance was applied to the data the distribution of trout captures was found to be affected by the moon phase and water level together ($F = 2.095$ $p < 0.048$) (Figs 26 and 27).

3.4.4.4 Water Level

Figs 26 and 27 show water level fluctuations recorded at the trapsite. Peaks in trout numbers following increases in river flow on April 10-14, April 17-26, July 4-9, July 14-19 1983 and April 21-27, May 1-3, May 11-12, June 4-8, June 20-24 1984 (Fig 26 and 27) strongly suggest movements are initiated by increased flows.

Figure 24

Water temperature and trout movement into the Springvale trap 1983-84

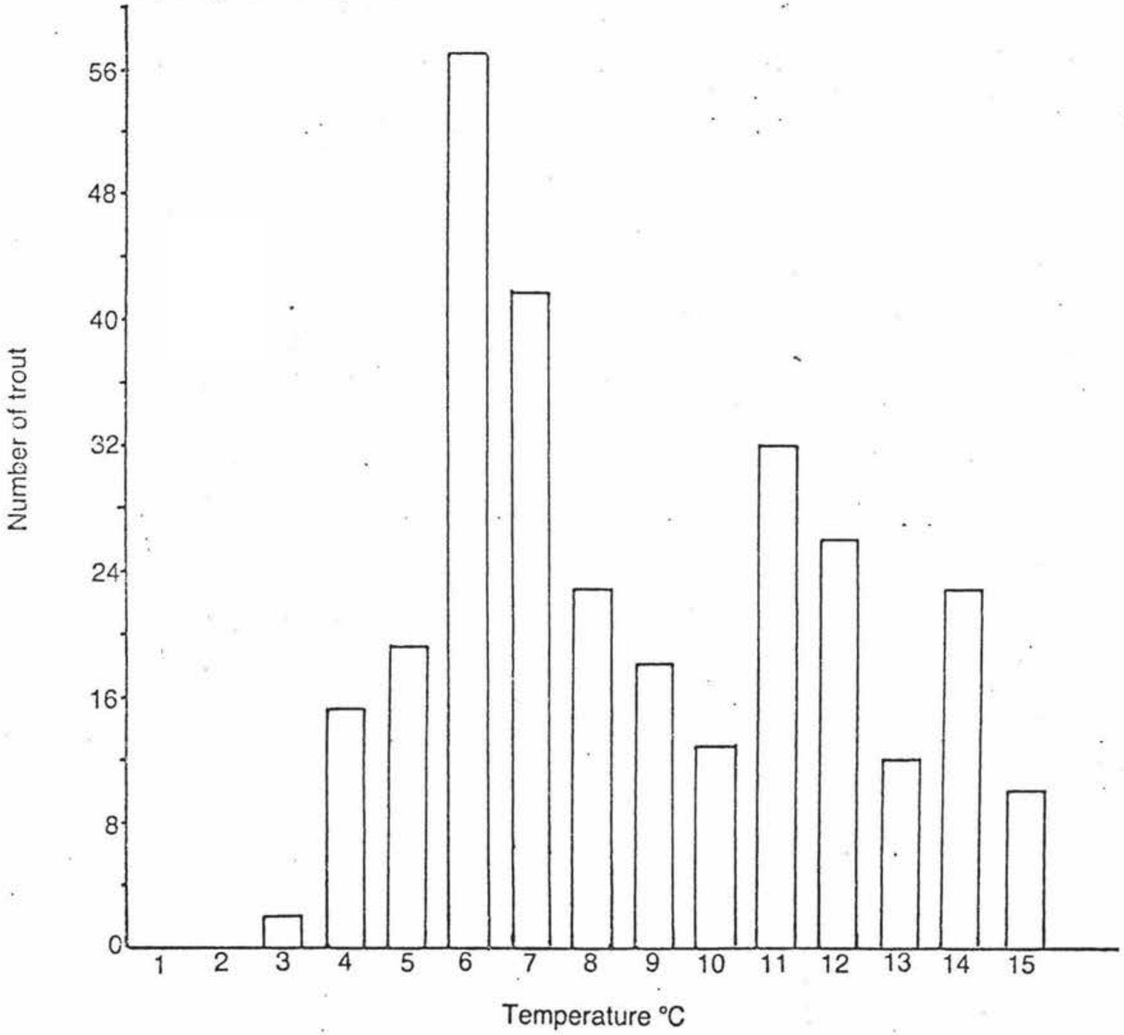


Figure 25

Lunar periodicity and trout movement into the Springvale trap 1983-1984

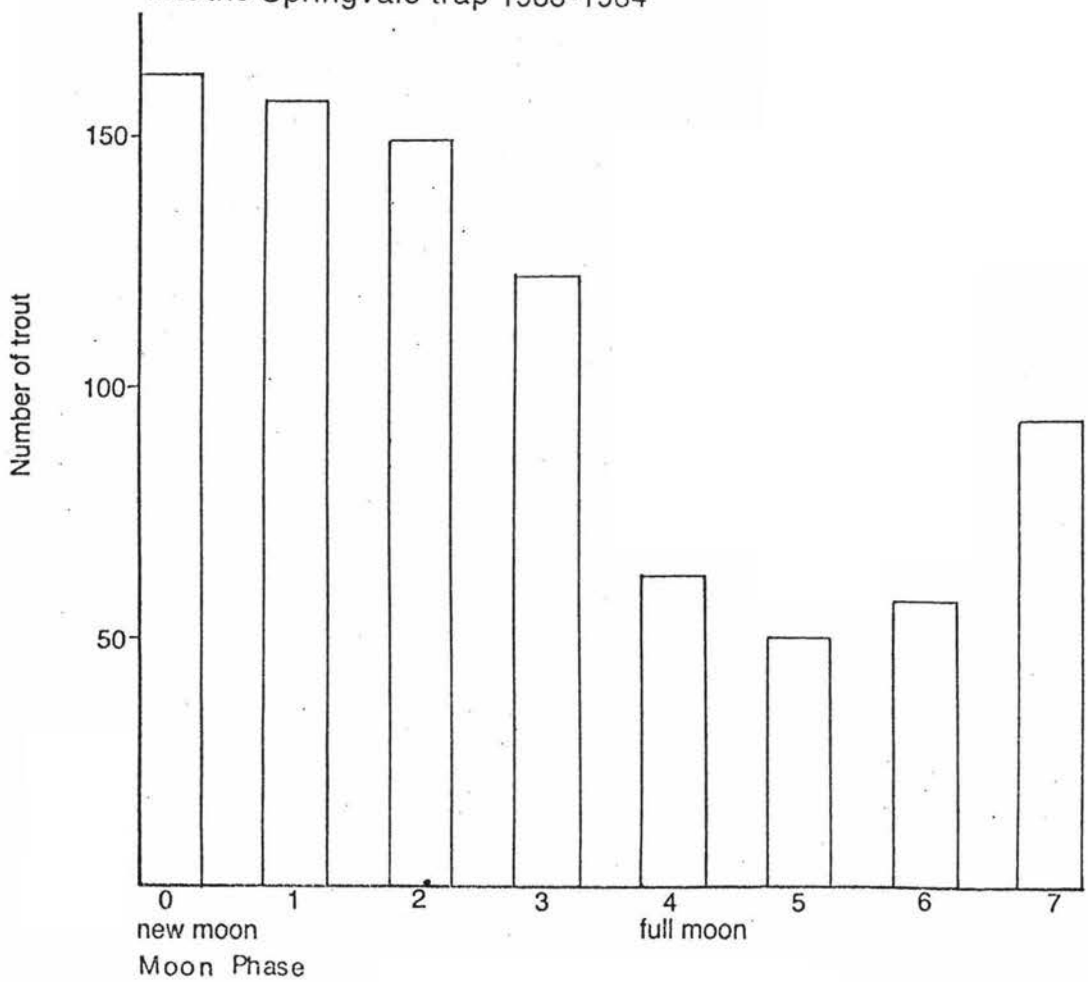
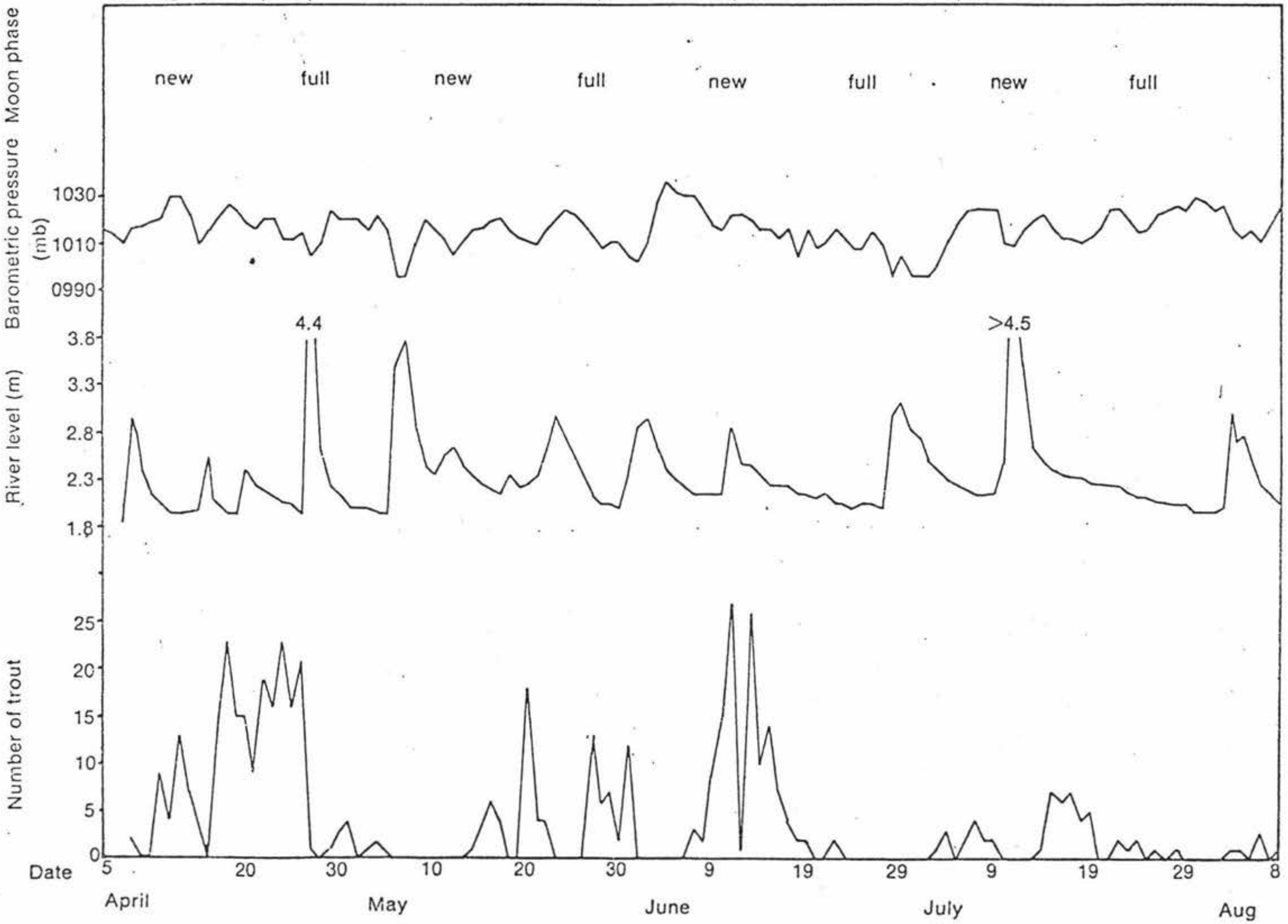


Figure 26
Springvale trap captures 1983 with river level, barometric pressure, and moon phase



Analysis of variance supports the contention that river level affects trout movement (F-ratio = 3.862, $p < 0.005$). At the Springvale trap 607 trout were recaptured during falling water levels, 178 on rising water levels and 96 when no change was recorded.

3.4.4.5 Barometric pressure

Fluctuations on a daily basis were recorded for the Springvale and Phyn's Creek areas by using New Zealand Meterological Service Daily Weather Charts. Changes occurred with declines coinciding with water level increases. The rain associated with reduction in air pressure affected water flow inconsistently because of the aspect of the headwater catchment. Easterly rain was more likely to cause a rise in river level than southwest rain. On a few occasions increases in trout activity occurred during pressure falls but before increases in waterflow; for example on 5-8 June 1983 and 24-25 April 1984 at Springvale (Figs 26 and 27). Water levels were not recorded at Phyn's Creek but it was observed that increases in water flow and trout activity were positively correlated. At the Springvale trap 450 trout were caught during falling air pressure phases, 119 when the air pressure was steady and 309 on a 'rising' barometer.

3.5 Recruitment areas in the Rangitikei

Brown trout, primarily from the mid-reaches used two areas near the Springvale Trap to spawn. Other spawning brown trout were observed in the main river from Mangaohane to Springvale, but single pairs of trout were observed only. These were in a low density compared to the aggregations at the Springvale Bridge and close to the trap site. Maximum bank counts there were: on 14/6/83, 120 brown trout just above the trap, and 21 under the bridge; on 16/6/84 70 in the vicinity of trap and 20 under the bridge. Brown trout also used the Mangaohane Stream in smaller numbers. Phyn's Creek was used

Figure 27

Springvale trap captures 1984 with river level, barometric pressure, and moon phase

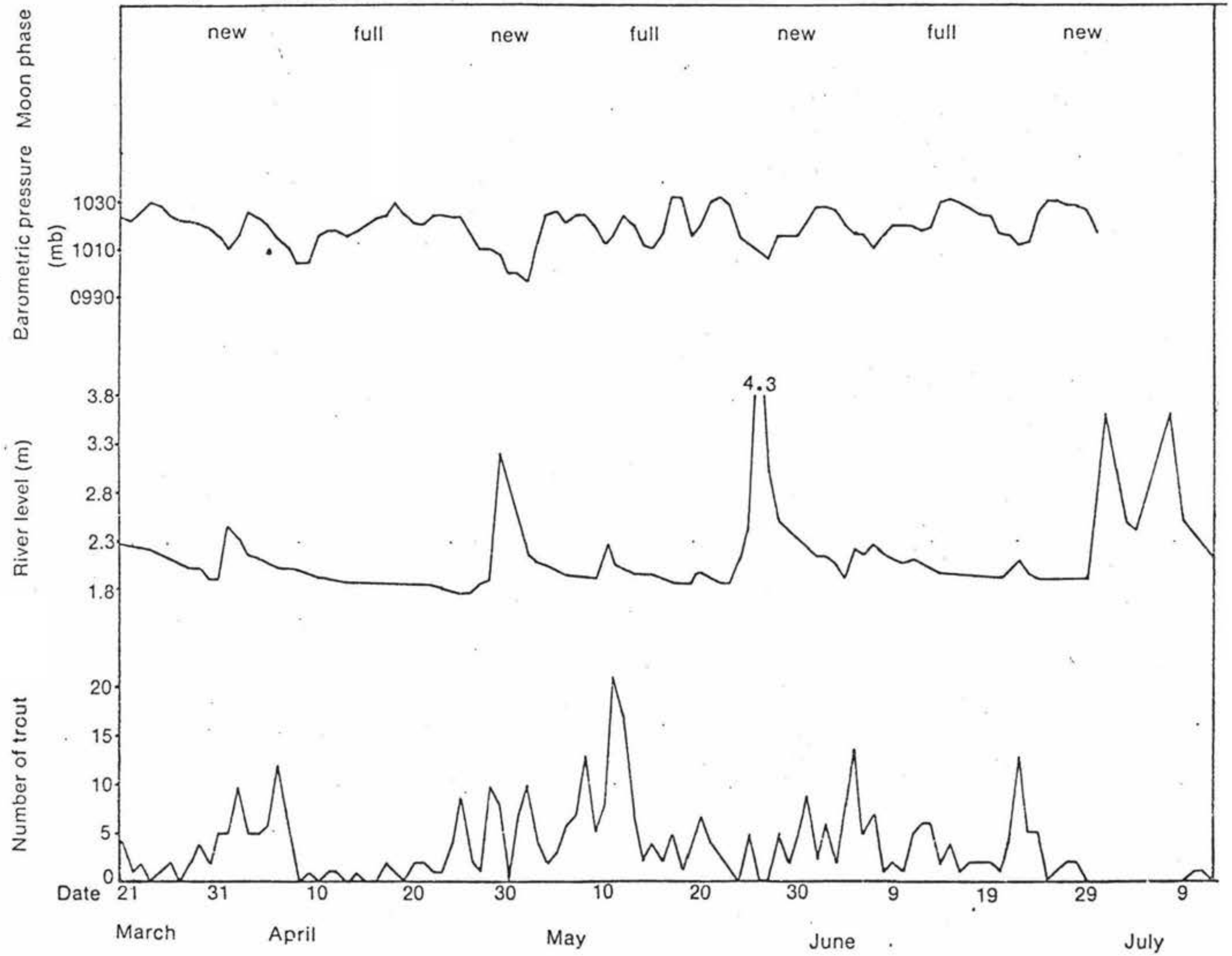
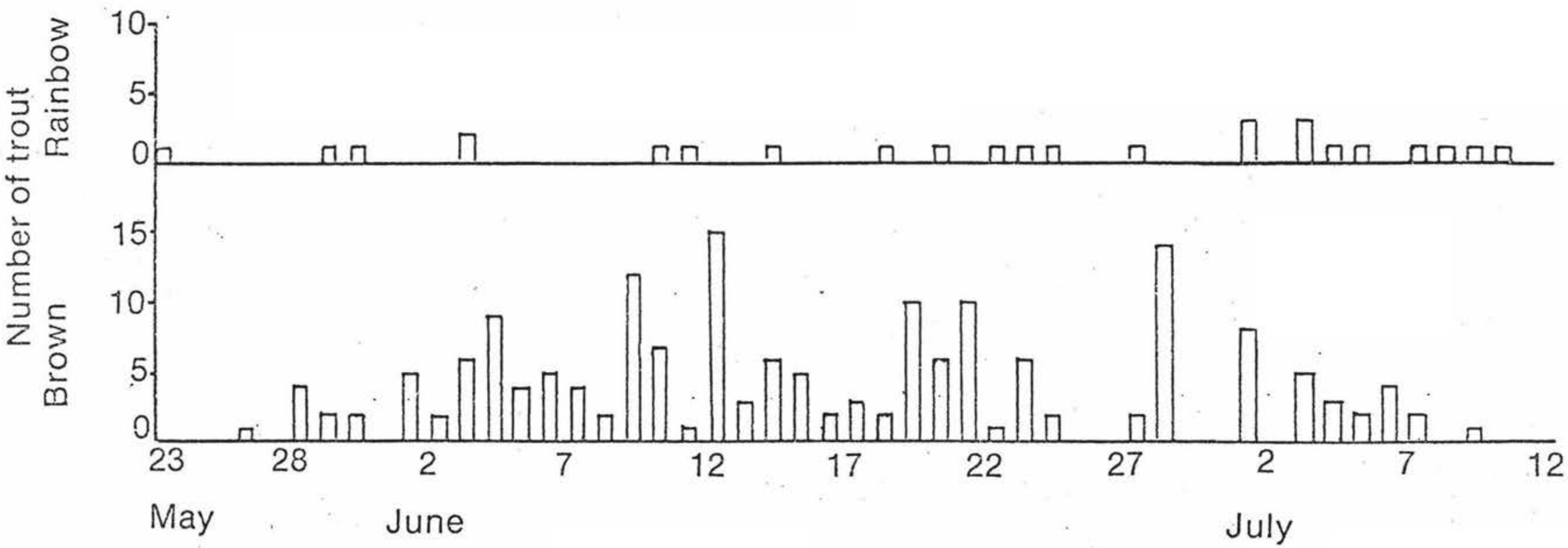


Figure 28
Movement of brown and rainbow trout into
Phyn's Creek trap May 23 - July 12 1984



by lower reach brown trout for reproduction purposes. (Fig 28).

During drift diving observations in January and February 1984 brown trout fry were abundant near Springvale, scarce at Mangaohane, Pukeokahu and Utiku and absent at Makohine.

Spawning aggregations of rainbow trout were not observed in the mid-reaches but some spawning does occur there. A mature post spawning male rainbow trout was caught in the Mangamarahia Stream on 28 July 1983 where eight redds were observed. One pair of rainbow trout was observed constructing a redd in the Mangaohane Stream on 25 June 1983 where one other 40cm rainbow trout was observed. Thirty seven rainbow trout which passed through the Springvale trap from June 9 to August 6 were judged to have ripe gonads.

Some rainbow trout use Phyn's Creek as a spawning tributary. (Fig. 2). On 13-14 April 1984 52 'large' rainbow trout were observed from the bank in 8km of the Whakaurekou and lower Maropea Rivers. It is likely that these rivers are used by lower reach rainbow trout for spawning purposes.

During drift diving observations large numbers of young of the year rainbow trout were observed at Utiku, similar trout were common at Pukeokahu and Mangaohane.

Discussion

Introduction

Certain assumptions must be made to validate the conclusions in this study. The most important one is that trout return to their natal locality to breed.

While it is recognised that some straying occurs many studies have shown that trout do return accurately to their natal stream (Harden Jones, 1958; Lindsey, et al 1959; Brannon and Salo, 1981). Published studies on the movement of brown and rainbow trout in New Zealand suggest variable behaviour occurs (Allen, 1951; Davis, et al 1983). However results obtained from the mid-reach sections of the Rangitikei River strongly suggest that straying is minimal and return migration to the natal area is the typical behaviour. The observations on rainbow trout in the Rangitikei system also suggest that downstream migration of juveniles followed by their return migration at maturity is also typical of this species. Recruitment to the spawning migration from elsewhere except in a minor way, cannot be considered as a likely event. It is assumed that tagging and handling the trout do not bias the results.

Mortalities from handling and tagging were expected to be low. Angler caught trout were taken on artificial flies only where mortalities have been observed to as high as 11.3% (Bjorn and Mallett 1964). Trap caught trout were handled for a short length of time only. Handling trout does alter the metabolic processes in trout which affect their survival (Bouck and Ball, 1966; Stevens, 1972; Nicola and Cordone, 1973; Reingold, 1975; Meons and Hatch, 1976; Wydoski et al, 1976; Pettit, 1977). The handling and marking methods used in this survey were not expected to modify the survival of handled trout. However about 1% of trout tagged at the trap in 1983 were found dead a day later; other deaths resulting from handling could not be measured. If a higher than expected number of fish died or lost their tags the amount of movement would be underestimated. In this study within year tag loss was low but between year tag loss was high - the loss of tags appeared to be a function of time.

Discussion

4.1 Movement - a consideration of the evidence

4.1.1 Sampling Methods

It is recognised that methods of sampling fish populations have a large bearing on the apparent size distribution of a population of fish so that samples taken by one method do not represent the population as a whole (Allen, 1963; Ricker, 1969; Bagenal, 1978). The effect of different methods of catching trout in the Rangitikei is demonstrated in Fig. 13. Trapping, catches mainly mature migrating trout of both species, angling tends to catch 1-2 year old rainbow trout, and handnetting catches mainly large brown trout. Young of the year trout are not captured by these methods. However, the combination of methods used, including underwater observations compensates for the bias inherent in each individual method so that comparisons of size distributions in sections could help in defining movement patterns.

4.1.2 Growth estimates - validation of the method

Growth rates estimated from back - calculations are in the range of those recorded in the Horokiwi (Allen, 1951) and Rakaia (Davis et al, 1983), but differ from trout growth in small Wisconsin streams studied by Avery and Hunt (1981), in six Pennsylvania streams studied by McFadden and Cooper (1962) and in a Danish brook where year old trout were about 10cm long (Mortensen, 1977). Parrot (1932) estimated the age and growth of trout in several New Zealand rivers and his results suggested growth was rather slower than that observed in the Rangitikei in this study. Parrot (1935) reports that mean lengths of 123 rainbow trout taken in the Rangitikei River between Mangaweka and Vinegar Hill over three summers from 1930-1934 were 45cm, 39cm and 38cm ~~long on average~~ with ages of 3.7, 3.2 and 3.1 years respectively.

They were therefore smaller than the mean size of similar aged trout recorded in the present survey. The direct observations and indirect estimations in the present study suggest however that Parrot underestimated the first years' growth (See Allen 1951). A small number of rainbow trout caught in the headwaters by the Wildlife Service suggested the back calculations estimated size at age one accurately. Two December caught trout which were 1 year and two months old were 186 and 188mm long respectively. Ten young of the year rainbow trout caught in June (9 months old) had a mean length of 91.6mm (s.d.6.3mm). (P. Mylechreest pers.comm).

From measurements made on other New Zealand trout populations and by other workers it seems likely that the method of calculating lengths of trout in the present study is valid.

4.1.3 Brown Trout Movement - Adults

Handnetting and trapping tends to select large brown trout. Handnetted and trap caught trout in the mid-reaches and the lower reaches had different mean sizes even though the methods of sampling were the same (Figure 12, 14). Scales examined from brown trout in the lower reaches tended to confirm that mature brown trout there, were smaller than similarly aged brown trout in the mid-reaches. This difference plus the low number of tagged brown trout occurring outside their region of origin suggests brown trout living in the Springvale - Mangaohane area do not mix with, and are spatially separated from, those brown trout living in the lower reaches. Allen (1951) found growth varied from section to section in the Horokiwi and he concluded: "had substantial movement taken place uniformity of growth according to region would not have occurred ... the Horokiwi is composed of a succession of distinct local populations". But Ringler (1983) discovered growth of individuals is likely to be variable. Sample sizes involved in the

Rangitikei should smooth out these effects.

Brown trout exhibit considerable variability in annual movement. Allen (1951) found no migration of spawning brown trout and that 80% of the population of the Horokiwi moved less than 80m in their lives. Frost and Brown (1967) found that trout living in the rivers Thurso and Tweed ascended fish passes and weirs to migrate into tributaries to spawn. Soloman (1976, 1981b), describes brown trout movement before spawning in a chalk stream as limited. Stefanich (1951) found that most fish in Prickley Pear Creek, Montana,were recaptured in the area of their original capture. Shuck (1943) discovered that brown trout exhibited a tendency to 'stay at home' except for the period of spawning migration when they moved several miles upstream.

Migratory brown trout which spend part of their lives at sea have been introduced to New Zealand (Scott, 1964) and some of these fish may have been introduced to the Rangitikei River (Appendix).

One brown trout was recaptured outside of the Rangitikei systems - at Lake Onoke in the Ruamahunga River estuary 360km away from its original capture site at Springvale. Fish exhibiting this marine phase apparently occur in a lower percentage of the total than trout in the Rakaia River where 6% strayed to other systems and the Waitaki where 1% strayed (Davis et al, 1983). While these data are not strictly comparable because differences in relocation effort are not measurable, and the number returned in this study was low, it may be that the Rangitikei offers more suitable brown trout habitat than the apparently "less hospitable environment" of the Rakaia (Davis et al, 1983).

Allen (1951) found no evidence of Horokiwi trout going to sea although Hobbs (1948) reported that there was abundant evidence of brown trout in coastal waters. There is little evidence however to support the contention that large numbers of Rangitikei River brown trout have a sea going phase. However the estuary is a destination for some Phyn's Creek spawning trout (Table 13).

4.1.4 <u>Brown trout movement - Juveniles</u>

Twenty four brown trout less than 40cm were tagged and none were recaptured but one and two year old brown trout ("small" and "medium" sized) were observed ~~in~~ by drift diving ~~counts~~. They were the dominant size classes at Pukeokahu, Utiku and Makohine on at least one occasion. Medium sized trout were well represented in the handnetting ~~observations~~ samples at Utiku to Mangaweka and at Ohingaiti. Analysis of variance suggests medium sized brown trout occur in significantly greater numbers only at Pukeokahu - suggesting this area may be one which these trout prefer when compared to other sites. The Pukeokahu site is representative of a 9km section of the mid-reaches which is rapidly flowing (about 20m/km fall), and contains many rapids (see plate 4). Agonistic interactions and predatory behavour of larger conspecifics in the more pool-dominated habitat of the mid-reaches closer to the major mid-reach spawning site may prevent large numbers of one and two year old brown trout residing there. Territorial behavour is a mechanism effecting dispersion of young brown trout (Kalleburg, 1958; Solomon and Templeton, 1976; Mortensen, 1977a; Godin, 1981; Solomon, 1981). This initial dispersal is followed by further redistribution as the fish grow and require larger territories (Chapman, 1962). Solomon and Templeton (1976) who studied chalk stream trout consider this behaviour to be similar to upland streams where movements are less localised. In the Rangitikei, habitat available to trout exists in the form of large rocks, variable water depth and variable water velocity. Water velocity and variability in the substrate affect the microhabitat suitable for brown trout so that where lines of vision are obstructed a higher population density exists (Kalleberg, 1958). Where visual isolation and overhead cover was reduced Wiley and Dufek (1980) found trout biomass to be low. In the Rangitikei down to just below the Whakaurekou River confluence erosion resistant greywacke and limestone predominates in the river bed (Fig. 2.). These structures provide more cover than the softer siltstones found in the river below the Whakaurekou. Handnetting observations suggest fewer brown trout live here. Therefore this geological transition may be a biological boundary to the majority of mid-reach brown trout.

Opaque water in plunge pools and rapids also visually partition sections of river and probably act in a similar manner, allowing more trout to live in a relatively confined area. When environmental isolation is increased aggressive interactions decrease (Chapman, 1966). As feeding increases in the spring (Bachman, 1984), the level of aggressive interactions increase (Hartman, 1963), suggesting that springtime is a period of increased movement. Therefore cost (energy expenditure) minimisation by Rangitikei brown trout through the reduction of agonistic encounters, combined with ultimate increased reproductive success, may cause one to two year old brown trout to move to deeper water. Because the mid-reaches in the vicinity of the spawning site is slow flowing (Plate 3) and contains many adult brown trout, yearlings are probably forced to disperse downstream to places which satisfy their habitat requirements where downstream movement ceases.

Reproductive fitness is positively correlated with size in trout since the largest females produce more eggs (McFadden, 1967) and large male trout are more able to defend females on the spawning site (Frost and Brown 1967), selective pressure for rapid and sustained growth is likely to occur (Bachman, 1981).

Furthermore fat reserves of the parents affects the survival of some freshwater fish (Bagenal, 1978) so that fatter adults produce progeny which are reproductively more successful. Brown trout in the Rangitikei ~~which~~ maximise their fitness ~~must~~ by dispersing to regions which allow them to grow maximally. This means they must find a place they can occupy which affords maximum potential profit (see Fausch, 1984). This pattern of dispersal is an example of that hypothesised by Baker (1978) in which individuals with a high resource holding power establish themselves at a shorter distance from the spawning grounds and those individuals with less resource holding power are forced to perform a longer migration. For these migrants to survive, the cost of migrating farther must be less than the cost of remaining close to the spawning area. It seems likely that the opportunity to live in an area of low agonistic pressure involving greater migration effort is favoured over low migration effort and high number of aggressive encounters. Bachman (1981) found that brown trout in Spruce Creek, Pennsylvania, had established territories by the time they were yearlings but before that tended to move about constantly. Observations on brown trout born at Springvale suggest that young of the year trout live in riffles and stream margins as do trout fry in the River Indalsalven (Lindroth, 1955). Several hundred brown trout fingerlings were caught in a side channel 1km below the Springvale spawning site in February 1981 (Hicks and Watson, 1983). However many yearling trout, ("medium" and "small" size) have not taken up home ranges in this region and therefore must exist elsewhere. The most likely location is in the more turbulent sections of the mid-reaches. Most published studies of brown trout emphasise territorial interactions as being space regulators in brown trout populations. Recent work (Bachman, 1984), suggests that in stable spring fed streams brown trout have overlapping home ranges where agonistic behaviour occupies a small proportion of the time-budget of individual trout. The Rangitikei River, however experiences fluctuations in water flow and is unlike a stable spring-fed stream. Juvenile brown trout here probably go through stages that reflect the descriptions of trout studied by Solomon and Templeton (1976), but over distances of up to 25km in the mid-reaches and an unknown distance in the lower reaches. The most reasonable interpretation of the data indicates a probable initial downstream distribution of fry in the order of several hundred metres, then later (next spring) dispersal downstream as far as Pukeokahu, followed by residence there to maturity with a return migration to spawn. Downstream migration of adult brown trout has been documented in the lower reaches (See Table 13.). Adult trout may return to the vicinity of their pre-spawning locality but tend to occupy pools rather than riffles and rapids. Mortensen (1977) found insignificant movement after the initial fry stage so it is clear that considerable variation is likely. In the Rangitikei, disperal rather than en masse emigration occurs since small and medium sized brown trout can be found at all drift diving and handnetting sites (Tables 5,9). However the turbulent section of the river 16-25 km below the Springvale spawning site may be a refuge of this size class. Shuck (1943) found smaller fish in Crystal Creek to be more numerous in fast water where they were larger than small fish of the same cohort living in slow water. That brown trout live in areas of 'fast' water is documented. Bachman (1984) reported brown trout typically utilising feeding stations where the water velocities were 60-70cm/sec "millimetres overhead". Water velocity gradients are steep over non-uniform substrates allowing trout to station themselves in slow flowing water adjacent to swift water. In the mid-reaches of the Rangitikei these substrate configurations are common.

At least two other mechanisms exist which could account for the movement of young brown trout away from the spawning site. Piscivory in large trout is known to occur (Burnet, 1959; Chapman, 1966; Frost and Brown, 1967; Godin, 1981; Thorpe, 1981). The mean size of trout caught by handnetting in the Springvale area is 58cm (n = 55) confirming that potentially piscivorous fish live there. The reaction of young trout to this type of pressure would be similar to that of the more typical agonistic threat. Physiological states alter in salmonids on an annual basis and this has been implicated in their downstream movement, as well as their spawning migration (Hoar, 1953; Northcote, 1958, 1981; Solomon, 1981; Thorpe, 1981).

While most brown trout appeared to move downstream following emergence from the gravel or after spawning, some upstream movement after spawning, did occur. Twelve tagged brown trout were recovered from above the trap. There was considerable movement up and downstream in the vicinity of the trap during winter. Fourteen brown trout were caught in the winter of 1983. Time at large varied from 11 to 83 days. This restlessness could account for the small number of trout which have apparently moved downstream to spawn and upstream the following summer, assuming trout return to their summer location as they have been reported to do (LaBar, 1971; Bachman, 1984). The small number of trout moving upstream after spawning may be related to homing mechanisms. Salmonids respond to olfactory stimuli and return to known sites from upstream is not possible by this means. Miller (1954) found that cutthroat trout "showed much less ability to move towards or find their homes when placed upstream of them when compared to trout placed downstream of their homes". The trout caught upstream of the trap after spawning, like those recovered farther away than the mid-reaches represent a minority of the population living in the mid-reaches.

The Utiku area in the lower reaches is another which has a relatively high proportion of small and medium sized brown trout. This site contains a section of moderately turbulent riffles and rapids which is apparently suitable habitat for this size of trout. It is not known what proportion of these trout are hatched in the lower reaches but known habits of brown trout suggest they are the majority. Spawning aggregations are unknown in the lower reaches except at

Fhyn's Creek where 163 brown trout were captured in 1984. The Hautapu and Moawhango Rivers, both of which have self sustaining populations of brown trout, may be recruitment areas but interchange of individuals between these tributaries and the main river has not been measured. Impassable waterfalls exist in both of these rivers less than 10km upstream from their confluences with the Rangitikei, therefore potential interchange is restricted to their lower parts, which, because of their substrate, offer limited reproductive potential. Recruitment of juvenile trout from these waters seems unlikely because downstream migrating juveniles from the above falls population would be unable to return to their natal areas to spawn. Downstream movement with zero possibility of return constitutes an unstable evolutionary strategy because upstream populations will gradually be depleted. Trout which dispersed short distances from the natal area would constitute the stable strategy. Above falls stocks of rainbow trout have been shown not to move downstream, when compared with below fall stocks (Northcote, 1981). While most work describing movements of trout fry show that downstream directionality predominates trout living in outlet streams have been shown to display genetically and environmentally mediated upstream dispersal (Kelso et al, 1981). The progeny of rainbow trout spawning in the outlet of Loon Lake move upstream to enter the lake and few are lost from the system through downstream movement (Lindsey et al, 1959). Environmental mechanisms at least are implicated in the survival of young rainbow trout hatched in the outlet of Lake Tarawera. Rainbow trout spawn in this river (P.Mylechreest, pers, comm.) and their progeny are required to disperse upstream to the lake where juvenile growth occurs. Dispersal downstream is primarily a function of territoriality, density and habitat type. Because quantification of the appropriate parameters in the Moawhango and Hautapu Rivers have not been measured out-migration levels into the Rangitikei remain unknown but because of known behaviour of similar stocks studied elsewhere recruitment from these sources is likely to be small. Since Utiku is upstream of the confluence of the Kawhatau River (which carries the Phyn's Creek water into the Rangitikei) it is unlikely the small trout in the Utiku region go to Phyn's Creek to spawn when mature. Therefore it is likely that mainstream spawning by brown trout in this region occurs. However, the possibility that Phyn's Creek trout do grow in this region then move downstream and up the Kawhatau to Phyn's Creek on their spawning migration does exist. While this behaviour is uncharacteristic it has been observed in rainbow trout (Cederholm and Scarlet, 1981). Nursery streams are known to provide recruitment to larger rivers (Nichols, 1957 ; Davis et al, 1983). Even though none of the 20 brown trout tagged in the Rangitikei below the Kawhatau were caught in the Phyn's Creek trap it is likely that this tributary does function as a nursery area for mainstream brown trout living in the lower reaches. Two post spawning brown trout tagged in Phyn's Creek in 1984 were caught at Bulls and Tangimoana later that year suggesting that brown trout in the lower reaches are more mobile than those of the mid-reaches and may even approach the habits of the migratory Rakaia brown trout.

4.1.5 Rainbow Trout - movement and distribution of size classes

Direct evidence from tagging and indirect evidence from size distributions suggest rainbow trout share a pattern of dispersal similar to that of the brown trout, except that longer distances may be involved in the case of the rainbow trout. It is possible that the placement of the Springvale trap has had a bearing on the apparent movement of trout in the river. It is at the major spawning location of brown trout living in the mid-reaches. It is therefore expected, according to known brown trout behaviour to find the majority of tagged trout downstream of the trap in subsequent summers. The trap placement has not deliminated downstream movement of juveniles and unequivocal evidence of the extent of this movement is lacking. The extent of rainbow trout downstream dispersal has not been determined absolutely either except that dispersal of large numbers of headwater rainbows downstream of the Springvale trap occurs and deductions from observed size distributions provide evidence for dispersal to at least 25km below the trap. A proportion of the rainbow trout migrating upstream past the Springvale trap spent part of their life in the lower reaches 40-50km below the trap,as evidenced by the 5 trout known to have made this journey (Table 14).

Rainbow trout caught at Phyn's Creek and Springvale show no significant differences in mean size or in the distribution of their sizes (Fig 13.). Those caught by anglers do show a size difference with respect to location. Trap caught trout probably reflect the sizes of sexually mature trout in the region in which they were caught but angling is likely to be biased towards the younger trout in the mid and lower reaches and possibly larger trout in the headwaters. Measurement of this bias is possible by estimating size distributions by other methods. Drift diving in the headwaters supports the angler catch data, suggesting that a skew towards large rainbow trout does exist. During a drift dive in February 1984 97.2% of all rainbow trout observed over 15cm were classed as large (over 40cm). Several young of the year trout less than 20cm were seen but these fish were confined to the shallow margins and the riffle areas. Since few 20-40cm trout were seen it is likely that the angler catch data for the headwaters closely reflects the true population distribution of trout over 20cm there in the summer. Other drift diving observations suggest a similar proportion of 'medium' sized rainbow trout (20 - 40cm) live in the headwaters during the summer. A Ministry of Agriculture and Fisheries Drift Dive Survey on 28|3|84 and 30|3|84 classified 16.1% of the rainbow trout they saw as medium sized fish.

Medium sized rainbow trout found in the upper reaches are likely to be between one and two years old (Figure 16). The scarcity of rainbow trout of this size in the headwaters during the late summer and autumn suggests that the headwaters is not an area where most 1 and 2 year old rainbow trout live. In addition, the scarcity of rainbow trout spawning in the mid-reaches but the abundance of mid-sized and small rainbow trout at the mid-reach drift diving sites of Springvale, Mangaohane and Pukeokahu also suggests that many headwater hatched rainbow trout do not grow to maturity there but live in some regions of the mid-reaches while growing in maturity. Diving (Table 5) angling (Fig.13) and recaptures (Fig. 20.) support this hypothesis. Drift diving observations in the headwaters suggested that yearling rainbows aggregated into schools where their densities were high in summer, but were absent by autumn (J.Gibbs (Wildlife Service) pers. comm.) That the headwater tributaries and mainstream are recruitment areas for the rainbow trout has been established by Hicks and Watson (in prep) and by this work in which small rainbow fry were observed in the main-stream margins near the Waipehu Stream on 5|11|83 and large fry near, and in the Waingakia Stream on 2|3|84. Rainbow trout caught by anglers in the headwaters had a mean length of 60cm, few under 50cm were caught, suggesting, along with the drift diving observations that the headwaters support mostly mature adult rainbow trout, and juveniles up to one year old which live in the tributaries and riffle areas, (see also Turner n.d.).

The highest proportion of recaptured trap-tagged rainbow trout were recaptured in the headwaters (Table 14, Fig.20). Ignoring, for the moment, recapture effort, this result suggests most mature rainbow trout which pass through the Springvale trap spawn in the headwaters and remain there. When even recapture efforts are applied, such as a single drift dive count, the headwaters are implicated as a major sink for mid-reach migrating trout (Table 18). The high percentage of trap tagged trout seen at Utiku must be viewed with caution since only one fish was involved. Angler returns from the headwaters added greatly to the total number of tagged trout returned, and may over-represent the number of trout in the area. Butler (1962) discovered that voluntary tag returns did not reflect the true percentage of tagged fish in a fishery and the number of tags returned was not constantly proportional to the number of trout caught. Anglers who fished the Rangitikei headwaters were enthusiasts, (Rodway, 1984) and more likely to return tags than those from the lower reaches who were more casual and valued the river less. Mid-reach anglers represented attitudes midway between the two. Moring (1980) estimated that not more than 52% of anglers returned tags from trout caught in Mill Creek, Oregon. A measure of the likelihood of recognition and return of tags was not possible except for these qualitative differences as the number of trout tagged and returned was too low for an estimate of tag return rate to be made (Paulik 1961). The return of tags from anglers and drift diving observations do strongly suggest however, that a large proportion of the rainbow trout passing through the Springvale area remain in the headwaters the following summer. The annual recruitment from the mid-reaches to the headwaters is not accurately known because the proportion of large trout already in the headwaters is unknown. The mean size of the trout in the headwaters suggests the population is of trout at least 4 years old. One 61cm headwater rainbow trout was estimated to be 4 years old from scale analysis. It is likely that a high level of recruitment of mature trout from downstream plus sustained growth of post spawning trout and high survival of these trout contribute to the large size of the trout in the headwaters.

4.1.6 Rainbow trout size distribution - evidence for dispersal

In 1951 Allen proposed that brown trout growth differences provide evidence for spatial stability of populations of brown trout in the Horokiwi. Differences in brown trout size and growth in the Rangitikei support the hypothesis of limited movement also. For growth to be uniform, either growth conditions need to be similar over a wide area - in this case the mid and lower reaches - or trout populations need to spend some time in both which the brown trout evidence refutes, thus masking the effect of differing growth rates. While brown trout size differences occur, rainbow trout caught in the traps in the mid-reaches and lower reaches are similar in size. The similar size distribution of trap caught rainbow trout suggests an overlap of the rearing areas of rainbow trout captured at Phyn's Creek and Springvale exists.

A sample of what was probably a spawning run of rainbow trout, taken in the Whakaurekou River on 13-14 April 1983, had a size distribution similar to that of trap caught rainbows (60% 40-50cm, 40% 50-60cm n = 10).

If this sample is representative of the reproductive population of this river then all adult migratory rainbow trout in the Rangitikei so far described exhibit a very similar size distribution. Kwain (1977) found that 67.7% of migratory rainbows in Stokely Creek, a tributary of Lake Superior, were first time spawners. The size distribution of migrating rainbow trout in the Rangitikei suggests a similar population distribution occurs here. For overlapping ranges of rainbow trout to occur, an area or areas of the river which function as common rearing grounds must exist. Observed behaviour of other rainbow trout populations indicate that areas which fulfil these requirements should be downstream of the spawning grounds. Drift diving counts suggest the turbulent section of river between and including the Pukeokahu and Mangaohane drift diving stations has populations of one and two year old rainbow trout. Since this area is in the mid-reaches juvenile trout from the Whakaurekou River, Phyn's Creek and any other lower reach spawning area would have to move upstream considerable distances then move downstream again to return to their natal streams at maturity. This pattern of movement would be uncharacteristic of rainbow trout populations. Almost without exception the direction of any pre-spawning migration performed by fish that spawn in running water is upstream rather than downstream (Hynes, 1970). Although Cederholm and Scarlett (1981) found that some rainbow trout move downstream in large rivers before swimming up tributaries. Handnetting observations from Pukeokahu to Mokai indicate that relatively small numbers of mid-sized rainbow trout live there. The density of rainbow trout near Utiku is greater. Drift diving (Table 14) and angling strongly suggest that an area from 3km above Utiku downstream to Mangaweka is an area of high year one and two rainbow trout numbers. In March 1983 38 rainbow troutcaught by anglers during a tagging operation in the Utiku-Mangaweka area had a mean length of 37cm. The mean size of two year old rainbow trout estimated from back calculations of 53 trap caught and 8 lower reach caught rainbow trout is 37cm. (Fig 16.). Five rainbow trout caught in the same month at Pukeokahu had a mean length of 35cm. The high catch rate achieved in collecting these samples (0.77 fish per hour) reflects the relatively high density of trout in these areas. Drift diving observations in these areas complement the high catch rate in pointing to high densities in comparison to other areas of the Rangitikei.

Three of the five lower reach rainbow trout captured in the trap came from or went to the Utiku-Mangaweka area. The two others were recaptured at Omatane after being tagged in the Springvale trap. These two and the one trap tagged trout observed at Utiku do not conform to the pattern of headwater recaptured rainbows which remain in the headwaters following their migration out of the mid-reaches the previous winter.

Areas of the river below Mangaweka to the sea are also rainbow trout rearing areas. Figure 13 indicates that there are many trout 12-24 months old here. Note 'Lower reaches' in Figure 13 includes trout caught at Utiku and Mangaweka.

Most of these fall into the 30-40cm size class. Many 20-30cm long rainbow trout are caught by anglers in the lower reaches in September and October of each year (R.McKenzie, pers com). These twelve month old trout are likely to have hatched in lower reach tributaries such as the Whakaurekou or Phyn's Creek. They appear to be the wrong size and in the wrong place to have hatched in the headwaters. Twelve to fifteen month old rainbow trout probably from the headwaters, were observed at Springvale by drift divers (Table 8) and appear in anglers catches (Fig. 13.). Six 28-30cm rainbow trout were found in the Springvale trap barrier in March (5) and May (1) in 1984. These trout were facing downstream suggesting they were actively swimming downstream at the time of their entrapment. Such behaviour is consistent with the theory of downstream disperal of rainbow trout yearlings although they probably were a sample of the later ones to do so. It is unlikely, therefore, that large numbers of these trout occur in the lower reaches below Vinegar Hill at twelve months of age. Five to six month old rainbow trout, probably hatched in lower reach tributaries were observed in large numbers by drift divers at Utiku in March 1984. These trout were not recorded in Table 8 because they were classed as fingerlings. They were seen in groups of 5-20 in turbulent water around boulders and other obstructions. Accurate enumeration was impossible. Rainbow trout of this size were also seen at Mangaohane and Pukeokahu, implicating the mid-reaches as rainbow trout recruitment areas. It is suggested that the young of the year trout observed at Utiku in March are a sample of the rainbow trout which would be found lower down in the river the following September and October.

4.1.7 Rainbow trout - recruitment areas

Tag returns, bank observations of spawning activities and diving observations suggest that some rainbow trout return to the mid-reaches after spawning and that there is some rainbow trout spawning in mid-reach localities. Twelve trap tagged rainbow trout, just under half the number recaptured in the headwaters, were recaptured in the trap. (Table 14). This comparison should be viewed cautiously since methods of recapture were not the same. However drift diving observations of tagged trout in the headwaters and at Manggohane indicate similar proportions of tagged fish exist in these two areas (Table 18), but as low numbers were involved at Mangaohane no firm conclusions can be drawn. The trout recaptured or observed in the mid-reaches probably would have spawned above the trap and moved downstream again the following spring to a summer locality. Rainbow trout spawning in the mid-reaches might be restricted to the mainstream, since only the Mangamarahia Stream, 3km above the trap, appears suitable for spawning. It is also possible that some trout spawn in the headwaters and return to the mid-reaches the following summer. Drift diving counts suggested the area near Mangaohane is one area where these post spawning rainbow trout live. Young of the year rainbows seen at Mangaohane and Pukeokahu provide evidence for nearby spawning areas. However, except for the Mangaohane Stream where in 1983 one pair of rainbow trout was observed constructing a redd, no observations of mid-reach rainbow trout spawning have been made.

Conclusions

Observations of the movement and distribution of the Rangitikei rainbow trout population suggests it is likely to exist in one of two phases.

1. There may be at least two distinct populations. One group contains those fish living in the headwaters and mid-reaches during their life. Most of these trout spawn in the headwaters, spend their first year there then move downstream to spend two years in the mid-reaches before migrating back upstream as adults to spawn and remain in the headwaters. Variable movement occurs but the common theme is that they do not venture into the lower reaches. The other population(s) lives entirely in the lower reaches using tributaries such as the Whakarekou to spawn.

Alternatively high proportions of the rainbow trout population of the Rangitikei may utilise the whole river during their life cycle. The maximum movement would involve headwater hatched rainbow trout growing in their second and third years in the lower reaches. Once again considerable variation would be expected.

Such relatively long range movement if it occurred, would imply that mechanisms other than intra-specific aggression are operating to ensure dispersal of rainbow trout throughout the Rangitikei. Some possible mechanisms are discussed in the next section.

4.1.8 Rainbow trout - mechanisms for dispersal

The rainbow trout introduced into the Rangitikei system (Appendix) came from migratory stocks (Scott, et al 1978). Seagoing habits have not been reported in Rangitikei rainbow trout although they are caught in the estuary (T.Kroos, pers. comm) and one caught at Vinegar Hill in December 1983 had marine or estuarine crabs in its stomach (P.Mitchell, pers. comm). However schooling behaviour of juveniles and extensive movement are observed so it is likely that in-river migrations in excess of 50km occur in a large proportion of the rainbow trout population. Mechanisms such as intra and inter-specific competition and innate but environmentally mediated migratory tendencies are both therefore likely to be involved in the dispersal of the rainbow trout in the river. Certain characteristics of the Rangitikei could permit these mechanisms to operate. Young of the year rainbow trout have been observed to frequent tributaries and turbulent sections of the river which are avoided by larger trout. As these small trout grow, spatial requirements force them into contact with larger trout. In the Rangitikei headwaters mature trout live in the pools and juveniles are apparently excluded. A dispersal, as occurs with brown trout, moves the yearlings downstream. The presence of large brown and rainbow trout throughout the mid and upper reaches restricts juvenile distribution to riffle and broken water sections. Predatory behaviour exhibited by large brown trout towards juvenile rainbow trout (Johnston, 1981) probably also occurs in the Rangitikei and would enhance the effects of agonism wherever the juveniles encountered larger trout. The occurrence of juvenile rainbow trout in turbulent sections of the river at Pukeokahu and Utiku and their absence in large pools at Springvale and Mangaohane which did contain large brown trout suggests this mechanism is operating (see Table 8). Large brown trout and medium rainbow trout are not found together. The observation that small rainbow trout are found with large brown trout at Springvale arises from the existence of a 100m section in the Springvale drift dive site which was a shallow riffle, apparently providing suitable yearling rainbow trout habitat.

Dispersal of rainbow trout from spawning areas like brown trout has been described elsewhere. Moor (1953) considers the intensity of the territorial behaviour in stream dwelling salmonids to be in part responsible for migratory tendencies. Aggressive behaviour is implicated in the downstream movement of coho salmon fry (Chapman, 1962). Sympatric populations of coho and steelhead (anadromous rainbow trout) segregate themselves with microhabitat preference and intra-specific interactions determining their distribution (Allee, 1981). Habitat partitioning appears to be occurring in the Rangitikei, although size differences may be more important than species differences. Steelhead trout are known to move to faster, deeper water as body growth occurs (Chapman and Bjornn, 1969). Observations on Coho salmon juveniles in Columbia River hatchery showed size selective migration occurring, larger juveniles migrating and smaller ones remaining in the natal area (Washington, 1981). This situation appears to exist amongst the rainbow trout in the Rangitikei headwaters, although age is likely to be of more importance. The presence of some one and two year old rainbow trout in the headwaters is to be expected if the density dependent - agonistic behaviour dispersal model holds since suitable habitat exists for some juveniles in the headwaters. Stauffer (1972) found that rainbow trout migrated from Black River into Lake Michigan at age I, although age II trout were present in the outmigrants, and he found that moderate to large numbers of juvenile rainbows remained in the river as residents. Superimposed on the density dependent dispersal behaviour are annual changes in physiologicial state which predispose juvenile rainbow trout, and brown trout, to migrate downstream (Groot, 1981). Physiological changes promoting smoltification occur in steelhead juveniles even if environmental conditions are held artificially uniform (Groot, 1981), although normally these changes, including modification of enzyme activity which controls electrolyte balance essential for changes in environmental salinity, are influenced by photoperiod and temperature (Zaugg, 1981). There is however, wide genetic and environmentally mediated variability in migrating behaviour which varies within species of salmonids (Godin, 1981; Schreck, 1981). This variation may explain the retention of young of the year rainbow trout residing in the headwaters and the outmigration of this age group from the steeper, less stable Whakaurekou system - assuming twelve month old rainbow trout in the lower reaches are from this and other Ruahine tributaries, and the six month old rainbows at Utiku are recruited from this source also.

4.1.9 Movement between downstream and return migration phases

The observations of movements of juveniles and adults leaves two periods in the lives of Rangitikei rainbow trout when spatial stability probably occurs. There are the periods of post emigration from natal areas and post spawning residence. Table 16 gives capture - recapture times and movements of summer caught and recaptured trout. Except for one trout moving upstream 90km from Bulls to Utiku in 90 days, movement over the periods between captures was limited. Observations of river dwelling populations of rainbow trout follow the restricted movement pattern of brown trout (Gerkin, 1950, 1958). Shefanich (1951) found that even though rainbow trout moved more than brown trout over summer periods their movement was within sections rather than between sections of Prickley Pear Creek. Even less movement was recorded by Cargill (1980) who suggested that rainbow trout he studied occupied home territories throughout their lifetime. Juvenile steelhead observed by Edmuson et al (1968) stayed in small areas of Johnson Creek, Idaho for long periods of the summer. In the upper Salmon River, Idaho, Bjornn and Mallet (1964) found some evidence that rainbow trout make extensive non-spawning movements, but low numbers of recaptures prevented them making any definite conclusions.

Conclusions must be tentative in the case of the Rangitikei since a low number of trout were involved, but it is likely that long summer residence at one place does occur in non-mature and mature rainbow trout although a portion of the juvenile population (eg Bulls - Utiku trout) is mobile this time.

.2 Upstream movement of adults as measured by trap captures

.2.1 Changes over time

Even though trapping began two weeks earlier in 1984 large numbers of rainbow trout moved into the trap at Springvale at the beginning of both trapping seasons. Figs 20,21,26 and 27.

Saltatory movement was characteristic of both species although it was less marked in brown trout, particularly those entering Phyn's Creek. Fig 28. This pattern of movement is probably environmentally and physiologically mediated suggesting that cyclical or irregular events cause increases in migratory activity. The environmental parameters measured during the trapping period are given in Figs 26-27. River level fluctuations, as described in the results appeared to cause an increase in migratory activity. Small increases in river flow were followed by an increase in movement. Large increases on 25 May 1984 and 26 April 1983 were not followed by corresponding large fish captures, although a large increase in July 1983 was followed by a 'run' of 26 fish in six days. The trap was inoperative during flow events exceeding 2.5m so may have allowed trout to pass unnoticed immediately after a large 'fresh'. However since Gustafson (1951) found very high flows inhibited brown trout migration trout movement at times of peak flow in the Rangitikei might have been minimal. In the Tekapo River it is likely that runs of trout decrease during the peak of the flood and increase toward the tail of the flood (E.Graynoth pers.comm.). Libovársky, (1976) found that an increase in water flow increased the number of trout migrating upstream into Haduvka Brook, and that fine weather reduced the activity - an observation also made at Springvale. Most fish of lotic waters are stimulated to move by rising water (Hynes, 1970). This enables them to pass over riffles with greater safety because the discharge is spread out and provides areas of deeper water which fish can negotiate.

4.2.2 Water Temperature

Changes in water temperature could not be meaningfully correlated with fish movement because other factors such as changes in water flow were operating at the same time.

4.2.3 Moon Phases

Lunar periodicity appeared to affect migratory activity with more trout migrating during and after the new moon, when compared to the period during and up to 12 days after the full moon (Fig 25). Similar periodicity was discovered by Castonguay et al (1982) for migrating brook charr. The smallest catches of migrating eels in Lake Ellesmere and Onoke occur during full moon phases and eels migrating from the Makara Stream also show lunar periodicity (Todd, 1981). Grau (1981) listed the lunar cycle as a factory which, with others, could affect the initiation of salmonid migration. McDowall (1969) reviews lunar rhythmicity in animals, suggesting the selective value lies in the "advantage of responding to stimuli which correlate with recurring environmental conditions". Moonlight varies with the phase of the moon irrespective of cloud cover so that at new moon phases it is much darker at night. Light is generally inhibitory to migrating lotic fish (Hynes, 1970) and this factor in itself may explain the observed differences. In the Rangitikei at Springvale the water is clear (Secchi disc readings in excess of 10m are usual) so it is not surprising that bright moonlight may inhibit movement.

4.2.4 Barometric Pressure

Change in barometric pressure was associated with river level increase (Figs 26-27). Associations of trout movement with barometric pressure levels and changes do not appear to be acting alone in affecting migratory activity. Fish respond to changes in air pressure (Alexander. 1978), although it is not known if trout responded to this variable or if the result was an artefact of the trapping method. The trap was more likely to be operating immediately before a depression and not operating immediately after because of high water levels.

4.2.5 Physiological Changes, predators and survival strategies

The uneven migratory pattern observed here (see also Libovarsky. 1976), in addition to being mediated by environmental constraints is also probably related to physiological changes ultimately related to reproductive fitness. Energy expenditure and predation risk is decreased in periods of moderate increases in flow since this correlates with a decrease in number of impassable barriers such as shallows or narrow, swift currents (Baker. 1979). Increased water flow may also increase the concentration of recognisable odours in the river. Olfaction is used by salmonids in locating natal areas (Stabel, 1981; Brannon, 1981). Increased precipitation causes overland flow so that inorganic and organic material enters the river at a higher concentration than at low flows. This postulated increased stimulus may lower the migratory threshold and cause trout to move upstream. An alternative olfactory hypothesis has been proposed in which homing salmonids locate their natal stream by detecting odours of conspecifics there. If this mechanism operated an increase in flow would decrease the concentration of recognisable odours and therefore would not provide a stimulus to migrate. Brannon (1981) summarises the evidence for both suggesting that environmental elements, independent of conspecifics, are responsible for accurate homing. Therefore an increase in flow may, in addition to providing extra water depth, provide a stronger olfactory stimulus.

Migration in the dark is likely to reduce predator risk. Trout hunt visually (Ware, 1972; Bisson, 1978; Ringler, 1979), and exhibit crepuscular or diurnal feeding habits. While mature rainbow trout or brown trout are not likely to be eaten by other mature trout in the Rangitikei, night time activity by migrants would reduce agonistic encounters. Since the predator avoidance behaviour would involve few costs it is likely to be retained even though selective pressure is relaxed. Night time captures at Springvale exceeded day time captures but some movement did occur during the day at Springvale, as it did at Phyn's Creek.

4.2.6 Evidence for separate strains of rainbow trout

The probability that most rainbow trout which migrate to the headwaters do so early in the winter suggests that there may be different stocks or reproductively isolated groups of rainbow trout in the Rangitikei River mid-reaches. The early migration is not likely to be caused by the extra distance since this is 30-40km only. One trout was observed to accomplish 30km of upstream travel in 11 days in April 1983. Different stocks of trout have been described within river systems elsewhere. Smith (1960) distinguished between two stocks by the timing of their runs and some anatomical features. (See also Boreman (1981). Stabel (1981) states, as evidence for the existence of different stocks, the seasonal peaks in runs of fish - as occur in the Rangitikei - but even within runs destination specificity can occur. Tag returns suggest this occurs in the Rangitikei also. The existence of these stocks implies a high return rate of trout to their own natal areas which as mentioned seems to be the case in the Rangitikei.

4.2.7 Upstream migration of juveniles

It appears that, in the Rangitikei, non-mature brown trout may accompany the mature trout to the spawning grounds although the evidence is not consistent. In 1984 28 brown trout less than 40cm were caught in the trap and of these the 16 less than 35cm would have been immature. In 1983 only two fish less than 35mm were caught. Juvenile trout are known to migrate with adult conspecifics (Johnston, 1981) and juveniles do make seasonal migrations upstream of their summer rearing areas (Cederholm and Scarlett, 1981), but because of the inconsistency of captures over the two years at Springvale no firm conclusions can be drawn.

.2.8 Sex Segregation

Female brown trout migrated later than male brown trout at Springvale (Fig 20 and 21) and at Phyn's Creek. Differences in temporal distribution of rainbow trout sexes were not so apparent except that females in 1983 were predominant for a few days in April. A similar pattern occurred in Haduvka Brook (Libovarsky 1976). The functional utility of this behaviour is probably related to reproductive success. Female salmonids are the dominant sex in redd building activity (Tautz and Groot, 1975) and observations at Springvale indicate that males attempt to defend or monopolise females - which are redd building. Keenleyside (1979) contends that females establish nesting territories to which one or more males are attracted. However, in birds where migratory sexual segregation occurs, males arrive at the nesting site first and establish territories to which females are attracted (Baker 1979). This would seem to be a likely function of the temporal difference seen in brown trout reproductive strategies too although females may be involved in defending their nesting area from other females (Keenleyside, 1979). Since salmonid mating systems are similar (Tautz and Groot, 1975) it is not clear why the rainbow trout caught at the Springvale trap do not display the same timing variation. One possible explanation is that the distance from the known headwater spawning sites where a majority of the rainbow trout travel to, at least 25km upstream, masks the difference.

4.3 Conclusions

The evidence strongly suggests that the adult brown trout population of the mid-reaches is made up of large fish which spawn mainly in the vicinity of Springvale. The progeny of these fish spend their first year close to this spawning site in the stream margins and riffles. One and two year old brown trout are distributed throughout the deeper riffles and rapids of the mid-reaches where they remain until maturity. Some sub-adults may move about on a seasonal basis. A proportion of the brown trout which live above the Springvale spawning site move downstream to spawn there, and some mid-reach fish move out of the system, but these groups represent a minority of the mid-reach brown trout population. Lower reach brown trout use Phyn's Creek as a spawning area but other, undiscovered, recruitment areas probably exist. These trout are smaller on average than the trout of the mid-reaches and it is likely that mixing of these populations does not occur. Brown trout of the lower reaches may be more mobile than those of the mid-reaches.

Rainbow trout found in the mid-reaches are likely to have been hatched in the headwaters although some mid-reach recruitment and adult residence occurs. Juvenile outmigration from the headwaters is an annual event so that the mid-reaches and possibly the lower reaches are required rearing areas for the population of adult rainbow trout found in the headwaters. Young rainbow trout one year old or less found in the lower reaches, especially below Vinegar Hill, are likely to have come from the Whakaurekou River, Phyn's Creek, and other, undiscovered, lower reach recruitment areas.

Upstream migration by adults appeared to be mediated by water level changes and the lunar cycle. Most trout were caught after an increase in water flow during periods following the new moon. Night time movement was most common. Most rainbow trout that were recaptured in the headwaters moved there early in the winter, suggesting that groups of rainbow trout with differing behaviour patterns live in the Rangitikei. Sexual segregation of brown trout migrants was observed although this observation was not made for rainbow trout.

While variable behaviour patterns in response to environmental heterogeneity is observed in the Rangitikei River trout populations it is still possible to identify the dominant behavioural patterns of each species of trout in the river.

REFERENCES

ALLEE, B.A. (1981) The role of interspecific competition in the distribution of salmonids in streams. p.111-112 In Salmon and Trout Migratory Behaviour Symposium E.L.Brannon and E.O.Salo Eds. School of Fisheries. University of Washington, Seattle

ALLEN, K.R. (1951) The Horokiwi Stream: A study of a trout population N.Z.Marine Department Bulletin No.10 238pp

ALEXANDER, R.McN. (1978). Functional design in fishes Hutchinson. London. 160pp

____________ (1963) The influence of behaviour on the capture of fish with baits. I.C.N.A.F. Special Publication No.5

AVERY, E.L. and R.L.Hunt (1981) Population dynamics of wild brown trout and associated sport fisheries in four Central Wisconsin streams. Department of Natural Resources Wisconsin Technical Bulletin No. 121 26pp

BACHMAN, R.A. (1981) A growth model for drift feeding salmonids: a selective pressure for migration p128-135. In Salmon and Trout Migratory Behaviour Symposium E.L.Brannon and E.O.Salo, Eds. School of Fisheries. University of Washington Seattle.

____________ (1984) Foraging behaviour of free ranging wild and hatchery brown trout in a stream. Transactions of the American Fisheries Society 113: 1-32

BAGENAL, T. (1978) Methods for assessment of fish production in fresh waters 3rd ed. Blackwell Scientific Publications. 365pp.

____________ and F.W.Tesch (1978) Age and Growth pp101-136. In Methods for Assessment of Fish Production in Fresh Waters. T.Bagenal ed. Blackwell Scientific Publications.

BAKER, R.R. (1978) The evolutionary ecology of animal migration Hodder and Stoughton 1012pp

BISSON, P.A. (1978) Dielfood selection by two sizes of rainbow trout in an experimental stream. Journal of the Fisheries Research Board of Canada 35: 971-975.

BJORNN, T.C. and C.H. Mallet (1964) Movements of planted and wild trout in an Idaho River system. Transactions of the American Fisheries Society 93(1): 70-76

BOREMAN, J. (1981) Characteristics of fall and spring migrant rainbow trout in Cayuga Inlet, New York. New York Fish and Game Journal 28(1): 100-107

BOUCK, G.R. and R.C.Ball (1966) Influence of capture methods on blood characteristics and mortality in the rainbow trout. Transactions of the American Fisheries Society 95: 170-176

BRANNON, E.L. (1981) Orientation mechanisms of homing salmonids pp219-227 In Salmon and Trout Migratory Behaviour Symposium. E.L.Brannon and E.O.Salo eds. School of Fisheries. University of Washington. Seattle.

________________ and E.O.Salo (1981) Eds. Salmon and Trout Migratory Behaviour Symposium School of Fisheries University of Washington. Seattle.

BURNET, A.M.R. (1959) Some observations on natural fluctuations of trout population numbers New Zealand Journal of Science 2(3): 410-421

BUTLER, R.L. (1962) Recognition and return of trout tags by Californian anglers. California Fish and Game 48:

CARGILL, A.S. (1980) Lack of rainbow trout movement in a small stream. Transactions of the American Fisheries Society 109: 484-490

CASTONGUAY, M. and G.J.Fitzgerald (1982) Life history and movements of anadramous brook charr Salvelinus fontinalis in the St Jean River, Gaspe, Quebec. Canadian Journal of Zoology 30: 3084-3091

CEDERHOLM, C.J. and W.J.Scarlett (1981) Seasonal immigrations of juvenile salmonids into four small tributaries of the Clearwater River Washington, 1977-1981. pp98-110 In Salmon and Trout Migratory Behaviour Symposium. E.L. Brannon and E.O.Salo Eds. School of Fisheries. University of Washington. Seattle.

CHAPMAN, D.W. (1962) Aggressive behaviour of juvenile coho salmon as a cause of emigration. Journal of the Fisheries Research Board of Canada 19: 1047-1080

______________________ (1966) Food and Space as regulators of salmonid populations in streams. The American Naturalist 193: 345-357

______________________ and T.C.Bjornn (1968) Distribution of salmonids in streams, with special reference to food and feeding pp 153-176 H.R.MacMillan Lectures in Fisheries, Symposium on Salmon and Trout in Streams. University of British Columbia. Institute of Fisheries.

DAVIS, S.F., G.A.Eldon, G.J.Glova, and P.M.Sagar (1983) Fish populations of the lower Rakaia River N.Z. Ministry of Agriculture and Fisheries, Fisheries Environmental Report No.33 109pp

DELL, M.B. (1968) A new fish tag and rapid cartridge-fed applicator. Transactions of the American Fisheries Society 97(1): 57-59

EDMUNSON, E.H., F.E.Everest and D.W.Chapman (1968) Permanence of station in juvenile chinnook salmon and steelhead trout. Journal of the Fisheries Research Board of Canada 25: 1453-1464

FAUSCH, K.D. (1984) Profitable stream positions for salmonids: relating specific growth rate to net energy gain. Canadian Journal of Zoology 62: 441-451

FROST, W.E. and M.E. Brown (1967) The Trout. Collins. London 286pp

GERKING, S.D. (1950) Stability of a stream fish population. Journal of Wildlife Management 14(2): 193-202

________________ (1958) The restricted movement of fish populations. Biological Review 34: 221-242

GODIN, J.J. (1981) Migration of salmonid fishes during early life history phases: Daily and annual timing. pp 22-49 In Salmon and Trout Migratory Behaviour Symposium. E.L.Brannon and E.O. Salo Eds. School of Fisheries. University of Washington. Seattle.

GRAU, E.G. (1981) Is the lunar cycle a factor timing the onset of salmonid migration? pp 184-189. In Salmon and Trout Migratory Behaviour Symposium E. L. Brannon and E.O. Salo Eds. School of Fisheries. University of Washington. Seattle.

GROOT, C. (1981) Modifications on a theme - a perspective on migratory behaviour of Pacific salmon. pp 1 -21. In Salmon and Trout Migratory Behaviour Symposium. E. L. Brannon and E.O. Salo Eds. School of Fisheries. University of Washington. Seattle.

GUSTAFSON, K.J. (1951) Movements and age of trout Salmo trutta Linne, in Lake Storsjon, Jamtland. Report of the Institute of Freshwater Research Drottningholm 32: 43-49

HARDEN-JONES, F.R. (1968) Fish Migration Edward Arnold, London. 325pp

HARTMAN, G.F. (1963) Observations on the behaviour of juvenile brown trout in a stream aquarium during winter and spring. Journal of the Fisheries Research Board of Canada 20: 769-787

HICKS, B.J. and Watson, N.R.N. (1983) Quinnat salmon (Oncorhynchus tshawytscha) spawning in the Rangitikei River. N.Z. Journal of Marine and Freshwater Research 17: 17-19

HOAR, W.S. (1953) Control and timing of fish migration. Biological Review 28: 437-452

HOBBS, D.F. (1948) Trout fisheries in New Zealand, their development and management. N.Z. Marine Department, Fisheries Bulletin No.9 175pp

HYNES, H.B.N. (1970) The ecology of running waters Liverpool University Press. 555pp

JOHNSTON, J.M. (1981) Life histories of anadramous cutthroat with emphasis on migratory behaviour. pp 123-127 . In Salmon and Trout Migratory Behaviour Symposium. E.L. Brannon and E.O. Salo Eds. School of Fisheries. University of Washington. Seattle.

KALLEBURG. H. (1958) Observations in a stream tank of territoriality and competition in juvenile salmon and trout (Salmo salar L. and S.trutta L.) Report of the Institute of Freshwater Research Drottningholm, 39: 55-98

KEENLEYSIDE, M.H.A. (1979) Diversity and Adaptation in Fish Behaviour Springer-Verlag Berlin Heidelberg New York 208 pp.

KELSO, B.W., T.G. Northcote, and C.F. Wehrhahn. (1981) Genetic and environmental aspects of the response to water currents by rainbow trout (Salmo gairdneri) originating from inlet and outlet streams of two lakes. Canadian Journal of Zoology 59: 2177-2185.

KWAIN, W. (1977) Life history of rainbow trout (Salmo gairdneri) in Batchawana Bay, Eastern Lake Superior. Journal of the Fisheries Research Board of Canada 28: 771-775

LABAR, G.W. (1971) Movement and homing of cutthroat trout (Salmo clarki) in Clear and Bridge Creeks, Yellowstone National Park. Transactions of the American Fisheries Society 100(1): 41-49

LIBOVARSKY, J. (1976) On the ecology of the spawning migration of brown trout. Zoologicke Listy 25(2): 175-182

LINDROTH, A. (1955) Distribution, territorial behaviour and movements of sea trout fry in the River Indalsalven. Report of the Institute of Freshwater Research Drottningholm 36: 104-119

LINDSEY, C.C., T.G. Northcote and G.F. Hartman. (1959) Homing of rainbow trout to inlet and outlet spawning streams at Loon Lake, British Columbia. Journal of the Fisheries Research Board of Canada 16: 695-719

McDOWALL, R.M. (1969) Lunar rhythms in aquatic animals, a general review Tuatara 17: 133-144

McFADDEN, J.T. (1967) Numérical changes and population regulation in brook trout Salvelinus fontinalis. Journal of the Fisheries Research Board of Canada 24(7): 1425 -1459

____________________ and E.L. Cooper (1962) An ecological comparison of six populations of brown trout (Salmo trutta). Transactions of the American Fisheries Society 91: 53-62

MEARS, H.C. and R.W. Hatch (1976) Overwinter survival of fingerling brook trout with single and multiple fin clips. Transactions of the American Fisheries Society 105: 669 - 674

MORING, J.R. (1980) Non reporting of recaptures of tagged rainbow trout from an Oregon stream. Progressive Fish Culturist 42(2): 113-115

MORTENSEN, E. (1977) The population dynamics of young trout (Salmon trutta L.) in a Danish Brook Journal of Fish Biology 10: 23-33

NICOLA, S.J. and A.J.Cordone (1973) Effects of fin removal on survival and growth of rainbow trout (Salmo gairdneri) in a natural environment. Transactions of the American Fisheries Society 102(4): 753-758

NICHOLS, A.G. (1958) The population of a trout stream and the survival of released fish. Australian Journal of Marine and Freshwater Research 9: 319-350

NICHOLS, J.L. (1970) Explanatory notes to Ruahine Forest Class Map N.Z.Forest Service Mapping Series 6 Sheet 13.

NORTHCOTE, T.G. (1958) Effect of photoperiodism on response of juvenile trout to water currents. Nature 181: 1283-1284

________________ (1981) Juvenile current response, growth and maturity of above and below waterfall stocks of rainbow trout. Salmo gairdneri. Journal of Fish Biology 18: 741-751

________________ and D.W.Wilkie (1963) Underwater census of stream fish populations. Transactions of the American Fisheries Society 92: 146-151

PARROTT, A.W. (1932) The age and growth of trout in New Zealand. New Zealand Marine Department Fisheries Bulletin No.4. 48 pp

________________ (1935) Observations on the biology of rainbow trout (Salmo irideus) in New Zealand. The Rangitikei River. Paper No. 3. N.Z.Shooting and Fishing Gazette 1 January 1935 pp 5-8

PAULIK, G.J. (1961) Detection of incomplete reporting of tags. Journal of the Fisheries Research Board of Canada 18(5): 817-829.

PETTIT, S.W. (1977) Comparative reproductive success of caught and released and unplayed hatchery female steelhead trout (Salmo gairdneri) from the Clearwater River, Idaho. Transactions of the American Fisheries Society 106: 431-435

REINGOLD, M. (1975) Effects of displacing, hooking and releasing on migrating adult steelhead trout. Transactions of the American Fisheries Society 104(3): 458-460

RICKER, W.E. (1969) Effects of size-selective mortality and sampling bias on estimates of growth, mortality production and yield. Journal of the Fisheries Research Board of Canada 26: 479-541

RINGLER, N.H. (1979) Selective predation by drift feeding brown trout (Salmo trutta).Journal of the Fisheries Research Board of Canada 36: 392-403

RODWAY, M.A. (1984) A survey of angler use and opinion on the Rangitikei River. Wellington Acclimatisation Society Management Report 43pp

SCHRECK, C.B. (1981) Parr-smott transformation and behaviour p 164-172 In Salmon and Trout Migratory Behaviour Symposium E.L.Brannon and E.O.Salo Eds. School of Fisheries. University of Washington. Seattle.

SCHUCK, H.A. (1943) Survival, population density, growth and movement of the wild brown trout in Crystal Creek. Transactions of the American Fisheries Society 73: 209-230

SCOTT, D. (1964) The migratory trout (Salmo trutta L.) in New Zealand. 1 The introduction of stocks. Transactions of the Royal Society of New Zealand 4(17): 209-227

SCOTT, D., J.Hewitson and J.C.Fraser (1978) The origins of rainbow trout, Salmo gairdneri, Richardson, in New Zealand. California Fish and Game 64(3) 210-218

SMITH, S.B. (1960) A note on two stocks of steelhead trout (Salmo gairdneri) in Capilano River, British Columbia. Journal of the Fisheries Research Board of Canada 17(5): 739-742

SOLOMON, D.J. (1981) Migration and dispersal of juvenile brown and sea trout.pp 136-145 Salmon and trout migratory behaviour symposium. E.L.Brannon and E.O.Salo Eds. School of Fisheries. University of Washington. Seattle.

________________ and R.G.Templeton (1976) Movements of brown trout in a chalk stream. Journal of Fish Biology 9: 411-423

STABEL, O.B. (1981) Detection of natural odourants by Atlantic salmon parr using positive rheotaxis olfactometry.pp71-78 In Salmon and Trout Migratory Behaviour Symposium E.L.Brannon and E.O.Salo Eds. School of Fisheries.University of Washington. Seattle.

STAUFFER, T.M. (1972) Age, growth and downstream migration of juvenile rainbow trout in a Lake Michigan tributary. Transactions of the American Fisheries Society 101(1): 18-28

STEFANICH, F.A. (1951) The population and movement of fish in Prickley Pear Creek, Montana. Transactions of the American Fisheries Society 81: 260-274

STEVENS, E.D. (1972) Change in body weight caused by handling and exercise in fish. Journal of the Fisheries Research Board of Canada 29: 202-203

STOKELL, G. (1955) Freshwater fishes of New Zealand Simpson and Williams. Christchurch 145pp.

SWALES, G. (1981) A lightweight, portable fish trap for use in small lowland rivers. Fisheries Management 12(3): 83-88

TAUTZ, A.F. and Groot, C. (1975) Spawning behaviour of chum salmon (Oncorhynchus keta) and rainbow trout (Salmo gairdneri) Journal of the Fisheries Research Board of Canada 32: 633-642

THORPE, J.E. (1981) Migration in salmonids with special reference to juvenile movements in freshwater. pp86-97. Salmon and Trout Migratory Behaviour Symposium E.L.Brannon and E.O.Salo, Eds. School of Fisheries. University of Washington. Seattle.

TODD, P.R. (1981) Timing and periodicity of migrating New Zealand freshwater eels (Anquilla spp.). New Zealand Journal of Marine and Freshwater Research 15: 225-235.

TONKIN and Taylor (1980) Water resources of the Rangitikei River. Prepared for the Rangitikei-Wanganui Catchment Board Marton. 142pp.

TURNER, D.J.P. n.d. Fisheries surveys of the upper Rangitikei and Moawhango catchments. New Zealand Ministry of Agriculture and Fisheries Fisheries Technical Report No. 156 24pp

WARE, D.M. (1972) Predation by rainbow trout (Salmo gairdneri) the influence of hunger prey density and prey size. Journal of the Fisheries Research Board of Canada 29: 1193-1201

WASHINGTON, P.M. (1981) The influence of the size of juvenile coho salmon (Oncorhynchus kisutch) on seaward migration and survival. pp 146-152. In Salmon and Trout Migratory Behaviour Symposium. E.L.Brannon and E.O.Salo. Eds. School of Fisheries. University of Washington. Seattle.

WELLINGTON ACCLIMATISATION SOCIETY Annual Reports 1886-1983

WHALLS, M.J., K.E.Proshek and D.S.Shetter (1955) A new two way fish trap for streams. Progressive Fish Culturist 17(3): 103-109

WILEY, R.W. and D.J.Dufek (1980). Standing crop of trout in the Fontenelle tailwater of the Green River. Transactions of the American Fisheries Society 109: 168-175

WYDOSKI, R.G., G.A.Wedemeyer, and N.C.Nelson (1976). Physiological response to hooking stress in hatchery and wild rainbow trout (Salmo gairdneri). Transactions of the American Fisheries Society 105: 601-606

ZAUGG, W.G. (1981) Relationships between smolt indicies and migration in controlled and natural environments. pp 173-183 Salmon and Trout Migratory Behaviour Symposium E.L.Brannon and

E.O.Salo Eds. School of Fisheries. University of Washington. Seattle.

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APPENDIX TROUT FISHING IN THE RANGITIKEI RIVER SINCE 1886

ARTIFICIAL RECRUITMENT OF STOCKS AS RECORDED IN ANNUAL REPORTS OF THE WELLINGTON ACCLIMATISATION SOCIETY

Year	Brown Trout	Release Location	Origin of Trout	Rainbow Trout	Release Location	Origin of Trout	Comments from Annual Reports
1886	1,530	Rangitikei *	Masterton Ponds and Otago				These were "Loch Leven" trout. Yearlings (yr)
1887	50yr						
1889	8,492 1,000	Rangitikei Rangitikei	Masterton Ponds				Loch Leven trout
1891	12,500	Rangitikei	Masterton Ponds			Rainbow trout obtained from the Auckland Society	Loch Leven trout 500 'Fontinalis' (*Salvelinus fontinalis*) also released
1892						A few more Rainbow trout from Auckland	No recorded released
1893	2,000 9,000 720yr	Rangitikei Rangitikei Rangitikei	Waipoua River Wairarapa				Loch Leven trout Brown trout Brown trout yearlings
1894	40,000	Rangitikei	Wairarapa River				
1895	10,000	Rangitikei	Wairarapa River & Masterton Ponds				
1897	52,000	Rangitikei	Masterton Ponds				
1898							No recorded released
1899	124,000 17,500	Marton area Hunterville Moawhango R Hautapu R	Wairarapa Rivers and Masterton Ponds	1,500 1,000	Moawhango Marton	Masterton Ponds	"Fair fishing in the Rangitikei River" - Marton area
1900	15,000	Hunterville	Masterton Ponds				Favourable reports have been received of trout liberated in the several streams and lakes of the district.
1902	35,000	Rangitikei and tributaries	Masterton Ponds	45,000	Rangitikei and tributaries	Masterton Ponds	

* An unspecified number, probably a minority likely to have been released into lakes such as Namu Namu and Duddings.

Year	Brown Trout	Release Location	Origin of Trout	Rainbow Trout	Release Location	Origin of Trout	Comments from Annual Reports
1903	15,000	Lower River	Masterton Ponds & Tupurupuru Strm (nr Gladstone)	40,000	Lower River	Masterton	
1904	25,000 45,000	Marton Marton	Masterton Ponds 'Searun' trout from Opihi & Temuka Strm. Local rivers.	12,000 30	Marton Marton	Auckland Society and Masterton	Most hatchery (Masterton) rainbows died with "gill disease". 30 of the large rainbows not affected were released into the Rangitikei. About 1000 others were retained at the hatchery.
1905	32,000	Mostly in Rangitikei	Wairarapa streams & Invercargill	22,000	Below Bulls	Masterton Ponds	"Fish seem to be more plentiful than in recent years".
1906	25,000 15,000	Marton Marton	Wairarapa streams Gvt Hakataramea	28,000	Marton	Auckland Society & Rotorua	15,000 brown trout were "sea run" - "efforts to establish rainbow trout in the Rangitikei have at last been successful". "Loch Leven and brown trout are fairly plentiful".
1907	50,000 50,000	Hunterville Marton	Sea run trout from Marine Dept (Hakataramea)	1,000 950	Marton Hunterville	Tourist Dept (Rotorua?)	
1908	20,000) 470yr.) 20,000) 630yr.)	Hunterville Marton	Hakataramea				"trout do not thrive well in the Porewa. The stream is full of eels which no doubt keep them under".
1910	30,000 28,000 25,000 500yr.	Marton Hunterville Mangaweka Marton and Hunterville	Hakataramea	3,000	Mangaweka	Rotorua	
1911	20,000 500yr.	Hautapu Moawhango	Hakataramea	16,000 20,000	(Hautapu (Moawhango Marton and Mangaweka	Tongariro	Most rainbows to the Hautapu. "Young rainbows caught in Hautapu".

Year	Brown Trout	Release Location	Origin of Trout	Rainbow Trout	Release Location	Origin of Trout	Comments from Annual Reports
1912	20,000	Taihape	Hakataramea	10,000	Taihape	Rotorua	
	750yr.)						
	27,000	Hunterville					
	27,500)	Mangaweka					
	500yr.)						
	27,000	Marton					
1913	10,000)	Taihape	Hakataramea	35,000	Taihape	Taupo	
	500yr.)						
	28,000	Mangaweka		25,000	Mangaweka		
	27,000	Hunterville		45,000	Marton		
	400yr.	Marton					
1914	27,000)	Taihape	Hakataramea	12,000	Taihape	Taupo	Rainbows plentiful towards
	30,000	Mangaweka		12,000	Mangaweka		end of season. Fish up to
	12,000	Hunterville		20,000	Marton		7lb in several catches
	30,000	Marton					
1915	27,000)	Taihape	Hakataramea	9,000	Taihape	Taupo	Fish up to 8lb reported, 75%
	200yr.)						rainbow. "Best sport in
	200yr.	Hunterville		5,000			district in Rangitikei".
	30,000)	Marton					
	300yr.)						
1916	21,000)	Taihape	Hakataramea	9,000	Taihape	Not stated,	
	200yr.)					probably Taupo	
	240yr.	Hunterville	North Canterbury	10,000	Hunterville		
	300yr.	Marton		10,000	Marton		
1917	30,000)	Taihape		20,000	Taihape	Rotorua	Hunterville branch reports "The
	200yr.)			10,000	Mangaweka		past season was poor with hardly
	250yr.	Hunterville	North Canterbury	23,000	Hunterville		any fish having been taken".
	300yr.	Marton		35,000	Marton		
1918	15,000)	Taihape	Wairarapa Streams	20,000	Taihape	Rotorua	"Poor fishing in the Rangitikei
	180yr.)		mostly Waipoua	10,000	Mangaweka		and Hautapu" - "has broken
				23,000	Hunterville		hearts". Marton - "Fishing
				35,000	Marton		worst on record".
1919	51,000)	Taihape	Waipoua, Otago	20,000	Taihape	Taupo	Attempts were made to trap the
	250yr.)		& Hakataramea	10,000	Mangaweka		Porewa Stream near Marton but
				36,000	Hunterville		these were unsuccessful. Season
				50,000	Marton		described as "good". A 15lb rain
							bow caught at Rata(nr.Hunterville)

Year	Brown Trout	Release Location	Origin of Trout	Rainbow Trout	Release Location	Origin of Trout	Comments from Annual Reports
1920	34,000) 400yr.)	Taihape	Waipoua Otago	19,000 10,000 30,000 45,000	Taihape Mangaweka Hunterville Marton	Rotorua L.Hawea	"Rangitikei disappointing - rainbows will not acclimatise well to rivers running straight to the sea". "Many anglers fished upstream from the mouth for many miles without success" The Moawhango produced 4 rainbows, average 10lb, to one angler
1921	42,000) 425yr.) 10,000	Taihape Mangaweka	Wairarapa Streams- mainly Waipoua	27,000 8,000 27,000 28,500	Taihape Mangaweka Hunterville Marton	Otago and Internal Affairs Dept	Half of Hunterville's allocation went to local lakes e.g. Namu Namu. Marton area reported poor fishing
1922	61,500 30,000 60,000 63,000	Taihape Mangaweka Hunterville Marton	Waipoua and Mangaterere Streams (Wairarapa)	Nil			"Fine sport on Rangitikei". A 10½lb and two 7lb browns reported. "Rainbow trout fairly plentiful... Splended specimen of both species in all parts of the river".
1923	42,000 21,000 42,000 42,000	Taihape Mangaweka Hunterville Marton	Waipoua and Mangaterere	16,000 12,000 12,000 12,000	Taihape Mangaweka Hunterville Marton	Rotorua	Fishing was "uniformly good"
1924	24,000 21,000 27,000 30,000	Taihape Mangaweka Hunterville Marton	Otago and Wairarapa Streams	17,000 12,000 12,000 12,000	Taihape Mangaweka Hunterville Marton	Rotorua	"Rangitikei offers poor trout fishing - will probably automatically become a salmon river "Rangitikei - "not a brown trout river" - "fishing not up to usual standard". "River entirely discarded by anglers in the latter portion of the season.

Year	Brown Trout	Release Location	Origin of Trout	Rainbow Trout	Release Location	Origin of Trout	Comments from Annual Reports
1925	42,000	Taihape	Wairarapa	25,000	Taihape	Rotorua	"Rangitikei was sulky - some fish from its beautiful waters but not enough to go around - seems to be a subject matter for expert examination".
	30,000	Mangaweka	Otago, and Lake Te Anau	19,000) 400yr.)	Mangaweka		
	45,000	Hunterville		18,000) 500yr.)	Hunterville		
	45,000	Marton		18,000) 350yr.)	Marton		
1926	45,000	Taihape	Lake Te Anau	15,000	Taihape	Lake Hawea	"Fishing disappointing despite heavy liberations". "Most disappointing". "Very disappoint ing, very poor bags. Poaching the cause. Moawhango teeming with small rainbows - hardly ever any fish over 1lb caught".
	51,000	Mangaweka		500yr.	Mangaweka		
	45,000	Hunterville		10,000) 500yr.)	Hunterville		
	44,000	Marton		16,000) 550yr.)	Marton		
1927	45,000	Taihape	Lake Te Anau	17,000	Taihape	Taupo	"Fair Sport". Fishing dis-appointing as usual - Marton area
	30,000	Mangaweka		17,000) 700yr.)	Mangaweka		
	45,000	Hunterville		13,000) 600yr.)	Hunterville		
	44,000	Marton		18,000) 700yr.)	Marton		
1928	55,000	Taihape	Lake Te Anau	21,000) 350yr.)	Taihape	Taupo	"Fishing on Rangitikei a decided improvement". "Good sport". "good reports from upper Rangi-tikei but poor in lower reaches" Fishing around Taihape was very successful except in Hautapu where "tons of sawdust were brought down by floods."
	45,000	Mangaweka		21,000) 700yr.)	Mangaweka		
	55,000	Hunterville		21,000) 700yr.)	Hunterville		
	65,000	Marton		21,000) 760yr.)	Marton		
1929	102,000	Taihape	Otago and Lake Te Anau	37,000) 1,000yr.)	Taihape	Taupo	"Best fishing for years".
	48,000	Mangaweka		21,000) 1,000yr.)	Mangaweka		
	189,000	Hunterville Marton		45,000 2,000	Hunterville Marton		

Year	Brown Trout	Release Location	Origin of Trout	Rainbow Trout	Release Location	Origin of Trout	Comments from Annual Reports
1930	130,000 60,000 180,000	Taihape Mangaweka Hunterville Marton	North Canterbury and Otago	30,000) 1,500yr.) 20,000) 1,000) 30,000 2,000	Taihape Mangaweka Hunterville Marton	Taupo	"Rainbows first liberated in headwaters of the Moawhango". Hautapu good, bigger fish in Moawhango. Upper Rangitikei good lower reaches disappointing.
1931	100,000	Taihape	Southland	75,000) 2,000yr.) 30,000) 1,000yr.) 5,000) 1,800yr.)	Taihape Mangaweka Hunterville	Taupo	Rangitikei better than usual eg 4 fish/day 2½ - 3.3/4lbs. Taihape liberated fish in main river from Utiku to Springvale. Lower Moawhango and Otupau Stream. "Stocking proved a great success".
1932	80,000 50,000	Taihape Mangaweka	Wairarapa and Lake Te Anau	55,000 25,000 5,000) 4,850yr.)	Taihape Mangaweka Hunterville	Internal Affairs	"Fishing very good, improving every year". "Salmon seen at Rewa and Onepuhi". Fishing in Rangitikei excellent.
1933	60,000	Taihape (Hautapu)	Lake Te Anau & Wairarapa	35,000 20,000 13,000	Taihape Mangaweka Rangitikei	Internal Affairs	"Fishing good". "Fishing excellent - 90% rainbow'
1935	80,000	Taihape	-	90,000 40,000) 1,500yr.) 4,500yr. 30,000	Taihape Mangaweka Hunterville Marton	Internal Affairs	Doubts about releasing fry and yearlings were raised. It was suggested destroying shags and eels might be a better way of maintaining stocks. "Fishing worst on record - due to floods "Good catches when river clear"
1937				150,000) 7,000yr.)	Taihape Mangaweka Hunterville		"Trout Conservation" replaced "Pisciculture" as the fishing heading in the annual report". "Rangitikei best for several yrs Brown & Rainbow trout fishing good - if heavily stocked... provide excellent fishing for an unlimited number of anglers". "Lower reaches poor - a great disappointment.

Year	Brown Trout	Release Location	Origin of Trout	Rainbow Trout	Release Location	Origin of Trout	Comments from Annual Reports
1938	80,000	Taihape	Wairarapa and Otago	80,000 100,000 2,000fing. 6,000fing.	Taihape Mangaweka Hunterville Rangiwahia		"Rangitikei and tributaries excellent, really fine fish caught in the Rangitikei".
1939	30,000	Taihape		100,000 6,000yr. 2,000	Rangitikei Mangaweka		Marton-Bulls area - anglers had a "fair measure of success".The lower river is "seldom fished".
1940	60,000	Hautapu		100,000	Rangitikei		Fishing "mediocre" Marton-Bulls area. Hobbs (Marine Department scientist) suggests stocking unnecessary. Taihape branch disagrees. Hunterville reports "Brown trout holding their own despite no stocking".
1941-1943							No stocking - War effect. "Pisciculture" returns as heading. Used the war period to study effects of no stocking.
1944	40,000 20,000	Taihape Mangaweka	Otago				"Poor weather" but when waters cleared there was "abundant evidence of trout populations". But elsewhere - "How utterly wrong is the assumption that stocking is unnecessary. Proved by the compulsory closing of the Masterton hatchery - the reduction in population is due to a cessation in artificial stocking
1945	25,000	Taihape					Poor fishing in Wellington District. "Erosion a serious problem - rivers are moving shingle beds where fish cannot live" (In Tararuas).
1946	55,000 50,000 1,000	Rangitikei Taihape Rangiwahia	Local Streams and Internal Affairs	20,000 1,000fing. 10,000 500fing.	Taihape Rangitikei Rangiwahia		Hautapu good. Rangitikei fished fairly well - good fish particlarly in upper reaches.

Year	Brown Trout	Release Location	Origin of Trout	Rainbow Trout	Release Location	Origin of Trout	Comments from Annual Reports
1947	69,000 63,000	Marton Taihape		30,000yr. 500yr.) 1,000)	Taihape Marton-Bulls		"Good bags and fine fish" - Bulls area. "Best for number of years - policy of consistent stocking".
1948							No reports of releases - missed from annual report 1949. Hautapu - "Excellent" Marton-Bulls "an improvement".
1950	40,000 1,600 1,500 30,000 25,000 25,000	Hautapu Pourangaki Mangawhariki Phyn's Creek Pakihikura Porewa	Pourangaki River (Phyn's)	25,000) 1,000yr.) 25,000 6,000	Kawhatau Tributaries above Taihape Main river		"The Rangitikei has a very high reputation, yielded some magnificent specimens of rainbow trout.
1951	2,000fing. 1,000 ") 28,000) 27,000	Hautapu Phyn's Pakihikura	Waipoua	55,000 5,000fing.	Taihape(for Rangitikei) Lower reaches		"Large head of fish near Springvale". Calculations of Diary Scheme data and liberated fish survivals indicated that 93% of fish caught by anglers were recruited from natural spawning.
1952	10,000fing. 5,000yr. 3,000yr.	Taihape Rangitikei Hunterville	Wellington Society Streams	3,000	Rangitikei		River flooded often
1954	40,000 10,000	Rangitikei Taihape	Queenstown Makakahi	10,000fing.	Taihape		"A satisfactory season".
1955		No releases. Natural spawning taking place satisfactorily. K.R.Allen showed that the number of fry released in a "typical" NZ stream e.g. Horokiwi has little effect of stream stocks. Fishing near Marton-Bulls was described as "not worth the bother" but at Rangiwahia further upstream the fishing was "not particularly good but improved towards the end of the season".					

Year	Brown Trout	Release Location	Origin of Trout	Rainbow Trout	Release Location	Origin of Trout	Comments from Annual Reports
1956		No liberations. In the Taihape area the Rangitikei "as usual provided very good fishing after Christmas when it yielded good bags. The upper reaches are carrying many big fish". The Hautapu needed stocking, it was thought. The Kawhatau had "very few fish", the Rangiwahia Chairman said "All rivers need restocking each year". K.R.Allen, in a report, to the Society said "the resulting increase in stock from liberations is rarely more than a few per cent. Anglers take less than 30% of the population". The Marton report said the fishing was poor in the Rangitikei but Rangiwahia reported "good bags from the Rangitikei for most of the season".					
1957	80,000	Taihape	Mangatainoka Makakahi	30,000(fing.)	Taihape		Generally poor fishing reported.
1958	5,000ova) 40,000) 30,000	Taihape Rangiwahia					"Fishing improved"
1959	50,000 50,000Vb.	Taihape Mangawhairiki	Mangatainoka and Lake Wanaka	50,000 50,000	Upper Rangitikei Moawhango	Turangi	"Rangitikei rewards anglers consistently. All rivers except Mangawhairiki showed "marked improvement".
1960	200,000	Rangitikei System	Waipoua Mangatainoka Wanaka	95,000 25,000	Taihape Hunterville	Ngongotaha (Rotorua)	"Rangitikei and tributaries fished extremely well".
1961	65,000 50,000	Rangiwahia Taihape	Wanaka Queenstown Wellington streams	140,000 20,000 25,000	Taihape Rangiwahia Hunterville	Ngongotaha	Rangitikei offered "excellent fishing". Although Hunterville area reported "fish not as plentiful
1962	90,000	Hautapu and Mangaweka		50,000 20,000(fing.) 2,500(fing.)	Aorangi Stream Kawhatau Mangawhairiki	Ngongotaha	Changed policy on stocking to "more emphasis on older fish".
1963	250,000Vb.) 40,000) 20,000	Rangiwahia Hunterville		100,000Vb. 25,000 25,000) 40,000Vb.) 10,000	Taihape Rangiwahia Hunterville Marton-Bulls	Internal Affairs Dept	Fishing poor in lower river,good above Vinegar Hill. "Heavy releases needed" - Marton-Bulls Fish in high condition and fighting spirit" -Rangiwahia
1964	30,000 10,000 20,000	Hautapu Kawhatau Mangawhairiki		30,000Vb. 40,000Vb. 10,000(fing.)	Aorangi Otupae Rewa	Internal Affairs Dept	Hautapu "good". Hunterville-Rangitikei poor. Marton-Bulls Fishing in Rangitikei "far from being good".

Year	Brown Trout	Release Location	Origin of Trout	Rainbow Trout	Release Location	Origin of Trout	Comments from Annual Reports
1965	45,000	)Hautapu		10,000	Rangitikei	Internal Affairs Dept	The Rangitikei is a "heartbreak" Hatapu - "excelled itself". At Hunterville "fishing not as good
	3,000(fing.)						
	3,000	" Mangawhairiki		60,000	Kawhatau		
	20,000	)Mangarere		60,000	Mangawhairiki		
	2,000(fing.)			60,000	Hunterville		
	5,000	" Marton-Bulls					
1966	5,000Vb.	)Hautapu		30,000yr.	Kawhatau	Internal Affairs Dept	100 rainbow yearlings liberated at Hunterville were tagged.
	50,000	)		30,000	Mangaweka		
	2,000	Kakariki		20,000yr.	Hunterville		
				20,000	Rewa		
1967-1968	10,000	Taihape		2,000yr.	Hunterville	Internal Affairs Dept	79 brown trout tagged in Mangawhairiki and 100 in the Hautapu. At Hunterville - "fishing rather disappointing". Taihape and Rangiwahia reported better fishing
	79,	2yr. Mangawhairiki		100, 2yr.)	Taihape		
				40,000	)		
				2,000	Hunterville		
1969	32(fing)	Utiku	Waipoua	30,000	Mangawhairiki	Internal Affairs Dept	
tagged	100 2yr.	Hautapu	Mangatainoka	10,000	Pakihikura		
tagged	700 16mo.	Hunterville		5,500	Utiku-Springvale		
tagged	200 wild fish	Hautapu		3,500fing.	Utiku-Mokai		
				2,350	Moawhango		
1970-1971 Tagged	2,000yr)	Hautapu	Ova from Wellington district rivers	Tagged 2,800yr	Taihape & Hunterville	Internal Affairs Dept	An electric fishing survey carried out on the Hautapu showed the survival rate of hatchery reared yearlings there was reasonable and that hatchery reared fish made up a "substantial percentage of the fish population in some sections of the river".
	3,800	)		Tagged 3,800yr	Hautapu		
				1,000yr	Moawhango		
				1,000yr	Mangawhairiki		
1971-1972	Tagged 1,200(25cm)	Hautapu	No ova purchased	Tagged 2,000yr.	Taihape	No ova purchased	No recaptures reported except in Hautapu from electric fishing Fishing very good in the Rangitikei near Rangiwahia but elsewhere "disappointing".
	40,000	)Mangawhairiki		Tagged 1,000yr.	Hunterville		
	1,000yr.	)		3,500fing.	Taihape		

Year	Brown Trout	Release Location	Origin of Trout	Rainbow Trout	Release Location	Origin of Trout	Comments from Annual Reports
1973	7,000fing. 12,000fing. 6,000fing. 40,000 9,000fing.	Taihape Hunterville Rangiwahia Pakihikura Hautapu				Ova purchased from Internal Affairs Dept	Upper Rangitikei providing sizeable trout. Taihape and Hunterville - fishing poor,in reported 'best season for some years - 3lb average'.
1974			Trout trapped in Wairarapa and Manawatu Rivers	3,000 25cm 6,000 32cm 5,000 30cm	Marton-Bulls Taihape Marton-Bulls		All fishing reports were good. Cover shows photo of A Blatchford with 3.6kg and 5.4kg rainbows from Rangitikei headwaters.
1975	1,000 28cm	Hautapu	Wairarapa	10,000 2,500fing 20,000	Mangawhairiki Kawhatau	Ova purchased from outside Wellington District	Rangitikei has a very fine stock of fish near Hunterville. Taihape branch reported splendid fishing.
1976	1,000yr.	Hautapu		5,500yr. 18,500yr. 3,000yr.	Taihape Rangitikei Kawhatau		Reports varied from good, and satisfactory to poor.
1977	No trapping done. Society decided to protect the habitat instead. A fisheries officer was appointed. Fishing on the Rangitikei was reported as being good. The Hunterville Branch said "I am sure liberations are the main reason". Some rainbow yearlings were liberated.						
1978	The river received good reports. 6,500 rainbow yearlings were released. These trout came from Rotorua.						
1979	Excellent fishing reported in the river.						
1980	"Rangitikei fished very well". "Trout abound in the lower Rangitikei". "Fishing not as good but anglers satisfied".						
1982	"Best season for 15 years". "Reports of good fishing numerous". "Poor season's fishing" near Rangiwahia. "Hautapu fished quite well despite no liberations for several years".						
1983	"Fishing in the Rangitikei as good as ever". "Rangitikei provided excellent sport".						

NOTES - Trout were released as unfed fry in most cases. Otherwise Fing. Fingerling (to 150mm) Yr. Yearling (1 year old) or older fish - size given in parenthesis. Vb. - Vibert boxes used.

Many of the trout allocated to Marton-Bulls and Hunterville were released into local lakes. Some trout allocated to Taihape were released into the Turakina River.

Other Societies notably the Feilding Society (Amalgamated with Wellington Acclimatisation Society in 1938) and Hawkes Bay Society, which has as part of its western border the Rangitikei probably released trout into the Rangitikei e.g. 1897/8 17,000 brown trout and 10,000 brook trout (*Salvelinus fontinalis*) were released into the Rangitikei System by the Hawkes Bay Society.