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Headwater trout fisheries in New Zealand

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SUMMARY

New Zealand possesses a type of fishery that appears to be unique in the world: large, wild trout in the clear, upper reaches of scenic and often remote, back-country rivers. For convenience, such fisheries are collectively termed "headwater fisheries", although it is recognised that there are a number of distinct categories. From a survey of fishery managers, lists were drawn up of headwater rivers that fished well all season and of headwater rivers that fished well for early season only. A total of 89 all-season rivers (18 North Island, 71 South Island) were identified, of which 50% of North Island and 72% of South Island rivers were dominated by brown trout. Of the 41 early-season rivers, two of the three North Island rivers were dominated by rainbows, while three-quarters of the 38 South Island rivers were dominated by brown trout.

Scale samples and details on fish size and location were provided by anglers and fishing guides. Of the 2712 scale samples provided, 89% were from brown trout. For brown trout, 64% were recorded as males, compared with 54% for rainbows. There was considerable variation in size, with the largest fish of both species being females (brown trout 898 mm, 9.0 kg; rainbow trout 822 mm, 6.8 kg); male brown trout had the largest average length (577 mm), followed by female and male rainbow trout (553 and 542 mm respectively), and female brown trout (529 mm). Average condition for both species was practically identical, but there was a tendency for condition to decline with length in male brown trout.

Considerable difficulty was experienced in trying to age these large trout from scales. Firstly, 48% of the scale samples from brown trout and 14% of samples from rainbow trout contained replacement scales only, meaning that these fish could not be aged. Secondly, many of the scales in the remaining samples showed erosion at the margins, apparently attributable to spawning. Depending on the extent of erosion, several years of growth information could be lost, especially as growth in headwater trout was generally slow. A model of growth enabled some compensation for marginal erosion, and resulting ages were generally one year greater than the unadjusted ages. However, we could not estimate with confidence any age beyond nine years old. Thirdly, scales were difficult to interpret, and a second reading of the ages of one set gave only 54% agreement with the first reading.

Using the adjusted ages, most brown trout aged (n = 1119) were between three and seven years old, with the mean age of the largest samples being 5.8 years, and modal ages being five and six. Nine percent were nine years or older. Rainbow trout averaged slightly younger (5.6 years), with the modal age being five years, and the range generally from four to seven years. Compared with growth rates from other rivers and lakes in New Zealand, brown trout from headwater areas tend to grow slightly faster but rainbow trout slightly slower.

Results from drift dives of 10 South Island rivers gave density estimates of 3-55 large trout/km. Compared with published biomass estimates established for a wide range of New Zealand rivers, most of the 21 reaches dived had a "moderate" biomass of trout. Densities of benthic invertebrates were determined from three rivers only, but results suggested that invertebrates were not especially abundant, certainly not to the extent that would provide substantially enhanced conditions for growth compared with other rivers. As most anglers released fish, feeding studies were not carried out, although it is known that headwater trout are principally feeding from aquatic drift within the water column. Compared with other rivers within New Zealand, catch rates in headwater rivers can be high, and anglers can potentially crop a high proportion of resident trout during a single season.

Recaptures of tagged brown trout in the Oreti River, Southland, have shown that most large trout remain resident in the same pool during the angling season; for those trout that do move, there is a tendency for this to be upstream. Many large trout undergo some spawning migration each year, and it is postulated that this is the phase when upstream reaches become repopulated. Females typically dominate spawning migrations in both species, reflecting both the higher proportion of males already present in upstream areas (brown trout), and a greater post-spawning mortality among males resulting from spawning being both more protracted and debilitating for males than females. There was little evidence of sea-run fish among brown trout samples.

Possible changes in trout behaviour in response to fishing pressure were gauged from replies by experienced anglers to a questionnaire. Most anglers considered that there were progressively fewer trout available over the period of their angling experience, and that trout were generally less accessible to anglers because there had been some changes in the typical positions that trout occupied and in their feeding habits. There was general agreement that trout from remote and seldom fished locations take longer to "settle down" after being disturbed, than do trout from more frequently fished areas; some anglers considered that up to one week might be needed for some trout to resume normal behaviour. Most anglers considered that the length of time required for trout to "settle down"

increased during the season, partly in response to angling pressure, but also due to lower flows. There was also a suggestion that the length of the settling period had increased over the years of observation.

Average daily bag limits for headwater rivers were reduced between 1989 and 1991. Limits for the South Island are more conservative than those for the North Island. The North Island angling season is longer than that for the South Island (average 9.4 and 6.9 months respectively). Catch-and-release appears widely practised, especially among guides, who release almost all fish caught by clients. At present there is only one section of one river (upper Lochy River, Lake Wakatipu) where catch-and-release is compulsory.

Although a number of site-specific environmental developments impact headwater fisheries, the biggest concern is hydro-electricity development which can affect upstream migration of large trout, and alter flow regimes. Of increasing concern are problems of continued access, including access by air, and the need in future to consider limiting numbers of anglers who are permitted to fish some sensitive waters. Overall management would substantially benefit from a more co-ordinated approach by the managers both of the fishery (Fish and Game Councils) and of much of the access land (Department of Conservation, and Landcorp).

1. INTRODUCTION

Since their introduction over 100 years ago, both brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) have been become very important components of the New Zealand freshwater fish fauna. Brown trout have been a particularly successful immigrant, colonising a wide range of locations and habitats. This has been due, partly, to their ability to migrate to and from the sea. Together, the two species form the basis of extremely important recreational fisheries.

The worth of a fishery is difficult to assess, being partly a subjective judgement. Part of that worth is the economic value of the fishery and associated service industries. In 1982-83, expenditure in the Taupo fishery was assessed as $16.7m (Shaw *et al.* 1985). A more recent evaluation of recreational fishing in New Zealand has been carried out by the National Research Bureau. Although freshwater angling was not specifically itemised throughout the report, it is possible to extrapolate from the data presented and arrive at a total figure of about $150 m (Jellyman 1992a). However, not all aspects of the introduction of trout have been positive. Trout have been linked with the reduction in both range and population size of a number of native species (McDowall 1990, Townsend and Crowl 1991). Despite these negative impacts, the overall benefits of liberation of trout in New Zealand have been such that McDowall (1989) stated that "If we were beginning today, I think that we might still introduce rainbow and brown trout, but we would be more discerning about where they were released".

New Zealand has always been able to provide a wide range of trout fishing experiences, including lake fishing, lowland river fishing, and back-country fishing. With the growing popularity of angling, coupled with the greater access to headwater areas by the use of helicopters, there has been increasing concern about the ability of back-country (headwater) fisheries to sustain current angling pressure. In response to this, in 1985, Don McCulloch, the then President of the North Island Council of the Acclimatisation Societies, tabled a remit at the annual meeting of the Freshwater Fisheries Advisory Council, suggesting that some investigation of headwater trout fisheries be commenced. Accordingly, the present study was commissioned, although no particular terms of reference were set. In the absence of any specific objectives, key questions were assumed to be to obtain an understanding of the age composition, abundance, and growth rates of stocks, and hence their vulnerability to exploitation.

Much of the information in this report about trout and their behaviour, and the scale samples, have been obtained from the fishery managers and interested anglers. It was apparent early on in the study that there was sometimes a reluctance on behalf of anglers to name certain rivers - in fact, many of the articles about wilderness fishing in angling magazines never actually name the location the author is writing about. In a recent book on back-country trout fishing (Orman 1991), while a number of the more well known rivers are named, the author refrains from naming others as "I would be betraying the trout and the rivers if I named them all".

In the present survey, the knowledge that naming rivers was regarded as inappropriate by some anglers created something of a dilemma. While there was never any intention to draw attention to particular rivers by publicising them further, it was also recognised that it is rather pointless to discuss the attributes of rivers without actually naming them. Further, there are several guide books now available that discuss the main features of many of our headwater rivers (e.g., Turner 1983, Shutt 1987). As a further gauge of the sensitivity of presenting a list of agreed headwater rivers, during a survey of regulations for the 1991/92 angling season, fishery managers were asked to indicate whether they had any objection to such a list being presented; none did. Accordingly, rivers are named.

Among trout fisheries worldwide, the headwater trout fisheries of New Zealand appear unique in having upstream populations of large fish (T. Northcote, University of British Columbia, pers. comm.). Perhaps the features of headwater fisheries most highly regarded by overseas anglers is the opportunity to "spot" and catch large wild trout in clear waters. Comments to this end come from various sources. For example, speaking of trout fishing in New Zealand, Entwhistle (1989), stated that "Fishing in clean rivers ... for wild fish is the most prestigious and sought after experience in the trout fishing world". Similar sentiments come from overseas writers like Lambroughton and Rizzotto (1990) "But if you go to New Zealand's gin-clear water, you will know you are fishing for large fish, because you can usually watch the fish and their reaction to each presentation of your fly".

2. METHODS

2.1 Definition and identification of "headwater rivers"

Although the term "headwater fisheries" has been adopted in this report, this usage is one of convenience and does not adequately describe the variety of rivers and associated trout stocks. For example, while most of the rivers described in this report will have fish of largest average size in the upper reaches, there are rivers like the Von where the whole river is regarded as a "headwater" fishery. Other descriptions frequently used are "back-country", "wilderness", and "trophy" fisheries. It is suggested here that while the terms "headwater" and "back-country" are reasonably synonymous, "wilderness" and "trophy" fisheries are particular types of "headwater" fisheries.

Our first task therefore, was to establish a definition for "headwater" rivers. We then needed to identify and list important headwater fisheries.

The National Angler Survey carried out in 1980 (Teirney *et al.* 1982), identified three river categories - wilderness, scenic, and recreational. Wilderness rivers were characterised by remoteness, lack of road access, exceptional ratings for solitude and scenic beauty, low usage, and, generally, large fish. Scenic rivers were rather similar to wilderness rivers, often being remote and having exceptional ratings for solitude and scenic beauty. However, ratings for size of fish and catch rate were not as high as in wilderness rivers. The distinguishing feature between these two river types was that all scenic rivers were readily accessible by road and so were more heavily fished than the wilderness rivers.

In terms of their location, headwater rivers can be considered as either "wilderness" or "scenic", and the criteria provided by the National Angler Survey are suitable descriptors of the angling experience. However, the National Angler Survey did not seek much information on the fish stocks themselves. Consequently, for the present study we devised a survey form, aimed at fishery managers, which requested information on some attributes of the fish stocks. Thus, to identify where the most important headwater rivers are, we used a combination of this survey of fisheries managers and an examination of the National Angler Survey database, using various criteria.

In July 1989, a survey form was sent to all Acclimatisation Society areas and the two Department of Conservation (DOC) conservancy areas. A copy of the questionnaire and accompanying notes is given in Appendix I. In addition to a request for rivers to be classified as either those that fish well all season ("A" list rivers) or those that fish well for early season only ("B" list rivers), managers were also asked to provide some information on access, usage, present management, and attributes. (Note that since this survey was carried out, the Acclimatisation Societies have become restructured into Fish and Game Councils with some attendant boundary changes.)

These groupings recognise that, as well as classifying headwater rivers by their value to anglers and the characteristics of their fish stocks, rivers can be classified by a more "functional" description of the type of population they contain. Many of the "B" list rivers are small tributaries of lakes where early season fishing takes advantage of lake fish which have moved into rivers for spawning and then continued in residence (e.g., Lochy, Von, Greenstone, Caples Rivers); with the onset of summer with consequent lower flows and warmer water temperatures, many of these fish (especially rainbows) will drop progressively downstream and re-enter the lake. In contrast, larger lake tributaries like the Clinton, Makarora, and Sabine, maintain a more stable resident population of trout.

2.2 Characterisation of the fish stocks

To obtain information on the fish themselves, anglers were asked to supply scale samples from fish they caught (for age estimation), as well as details of species, length, weight and condition. A list of 102 anglers was compiled from various sources, i.e., from a list of members of the New Zealand Professional Fishing Guides Association, from anglers personally known or recommended to the authors, and from those who responded to articles in MAF's quarterly magazine *Freshwater Catch* (now ceased publication) or to "request for assistance" sheets left at sports goods shops or included among fishing licences. At the beginning of each angling season, participating anglers were sent a letter explaining the overall programme and giving some of the results of work to date, a note explaining how to take scale samples and handle fish to be released, and about 20 scale envelopes.

Information on species, location, and size of fish was recorded on a computer database. For those fish that could be successfully aged from their scales, information on age was recorded on a second database. Both databases used the catchment numbering system of the Soil Conservation and Rivers Control Council 1956.

2.2.1 Estimation of age

Anglers participating in the scale sampling programme were asked to collect scales from the area midway between the lateral line and dorsal fin. Upon receipt of scale samples, up to five readable scales were selected and placed sculptured-side up on a gummed page. Scales from ten fish could be stored per page, and acetate impressions of scales were than made by using heat and pressure. The acetate impressions were later examined using a Nikon scale projector at ×50 magnification.

For ageing, the number of annuli per scale was recorded, with the first complete year being designated as age one. An annulus was defined as the last circuli of the interface between a zone of closely and widely spaced circuli. As most of the scales were from large, old fish, it was difficult to detect annuli on the scale margins when only a few circuli had been laid down during the year's growth. For consistency in assigning age, mid August was chosen as the date of annulus formation (Graynoth *et al.* 1993a, b). The confidence that the scale reader had in the age was recorded according to an arbitrary 10-point scale (1 = very low confidence, 10 = very high confidence). For later back-calculation of length at previous age, the radius from the centre of the scale nucleus to each annulus and the total scale radius were also recorded.The presence of any spawning marks was also noted.

Misshapen, damaged, and replacement scales were ignored, although measurements were taken from eroded scales. Of the 2387 scale samples examined for their suitability for ageing, 52% of those from brown trout, and 86% of those from rainbows, were suitable; the remainder were replacement scales, lacking the detail of life prior to replacement. Given that most scale samples comprised at least 10 scales and that only one of these had to be a non-replacement scale for the sample to be aged, then a rejection rate of 48% is indicative of a very high rate of scale loss in large brown trout.

In general the scales were difficult to read due to erosion, broken circuli and poor differentiation of annuli. Most scales were given a readability of <4 and there was a tendency for the scales of large fish to have lower readability. The assignment of age was partially subjective, based on experience, expectation of the radius where the first annulus should be, and sometimes the length of fish. The difficulty of reading scales is demonstrated in Table 1 which gives the results of a repeat reading of a sample of scales from one location (upper Wairau River) by the original reader. In the second reading, only 54% of scales were given the same age as on the first reading; a further 34% were ± one year.

TABLE 1. Comparison of repeat reading of scales by the same scale reader, on samples (n = 53) of brown trout from the upper Wairau River.

Second reading Age (years)	First reading Age (years): 2	3	4	5	6	7	
2	2		1				3
3		5	5				10
4		2	9	2		1	14
5			3	11	1		15
6			2	2	3	2	9
7				1	1		2
	2	7	20	16	5	3	

Analysis of fish >400 mm in length showed that only 4.8% of brown trout and 6.8% of rainbow trout showed discernible spawning marks. This seems exceptionally low and therefore it was concluded that spawning does not always produce discernible marks on the scales.

The radius of each annuli was used to back-calculate the length of the fish at a given age using the Fraser and Lee modification of the direct proportionality formula (Tesch 1968),

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

where

L_n = length of fish when annulus was completed
L = length of fish at capture
S_n = radius to completed annulus n
S = scale radius
c = constant of proportionality derived from the regression equation of scale width on fork length (Francis 1990)

The relationship between scale radius and fork length was determined from uneroded scales taken from yearling trout caught in the Tekapo River, and from trout netted in Lakes Ruataniwha (Graynoth *et al.* 1993a) and Coleridge (Graynoth *et al.* 1993b). For brown trout the equation used was:

$$S = -17.125 + 0.634 * L \quad (r = 0.99),$$

and for rainbow trout

$$S = -16.117 + 0.601 * L \quad (r = 0.99).$$

Both species therefore had identical constants of proportionality of 27 mm.

Back-calculated length frequencies at age 1 and 2 were symmetrical and there was no evidence of any bimodality which would have occurred if checks in the first summer of life were occasionally misread as annuli (Allen 1951, Burnet 1969, McCarter 1987).

Condition was calculated for all trout with length and weight data, using:

$$k = w * 100\,000/L^3$$

where

w = weight in grams
L = length in mm.

2.2.2 Growth rates and the problem of eroded scales

Scale erosion, or, more correctly, scale absorption (Crichton 1935), commonly occurs during the spawning period and can lead to the loss of annuli (Percival and Burnet 1963). Many scales, especially from large old male brown trout, had significant scale erosion at their margins. Eroded scales were identifiable by having a "ragged" outer margin, which invariably meant that the marginal circuli were interrupted and discontinuous. Some fish had scales which were only 60% of the size of scales expected from fish of that length. In these cases one or more years growth at the margins of the scale was absorbed and reading of the remaining annuli would have resulted in the age of these fish being under-estimated. Also back-calculated lengths from eroded scales are over-estimated, because the reduction in scale radius increases the proportion of scale width occupied by earlier radii.

To obtain more accurate estimates of back-calculated lengths and ages from eroded scales, two adjustments were made. Firstly, back-calculated lengths were corrected and then the number of annuli missing was estimated.

Trials showed that if scale erosion was modelled by reducing scale width by a certain percentage, then back-calculated lengths were positively and linearly related to the reciprocal of scale size ($1/SS$) where (SS = observed scale radius/expected radius for uneroded scales). The slope of the regression of length against scale size increased with age but always intersected the Y axis at a length of 27 mm.

Back-calculated fork lengths (L_n) at ages one to six were therefore plotted against the reciprocal of scale size ($1/SS$) for a sample of 96 brown trout from the Wairau River (Figure 1). As expected, fish with small eroded scales appeared to grow faster. Regression equations were calculated to determine the influence of scale size on back-calculated lengths at each age (unpublished data). Unlike the modelled data the intercept on the Y axis was not constant and was always greater than 27

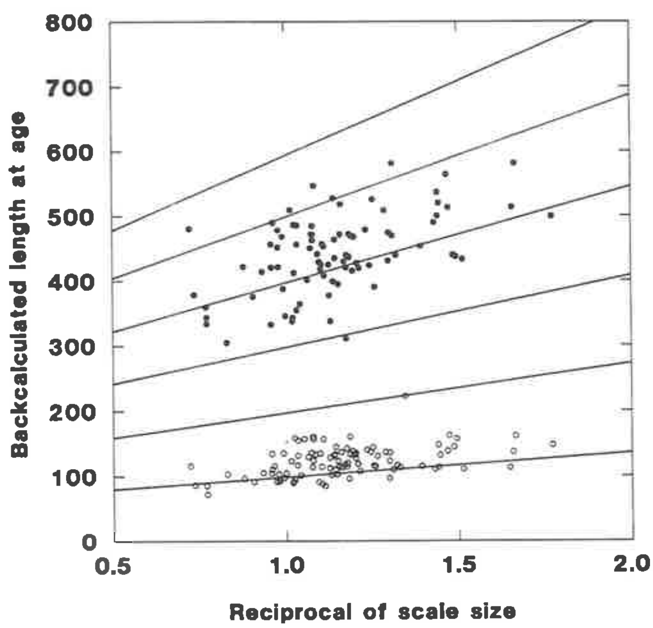

FIGURE 1. Influence of scale size on back-calculated lengths at ages 1 (○) and 4 (●) for brown trout from the upper Wairau River. See text for equation. Lines based on fish with scale size = 1.0, at 100 mm increments.

mm. However, the intercept on the X axis was approximately constant (mean = 1.56, range = 1.42 to 1.76 for ages 1-4) and, as in the model, the slope increased with age (Figure 1). The estimated length (EL_n) at scale size 1.0 was therefore calculated for all ages using the following equation.

$$EL_n = L_n * 2.56/((1/SS) + 1.56).$$

For fish with small eroded scales the back-calculated length at earlier ages was reduced substantially (Figure 1). Fish with scale sizes close to 1.0 had only minor changes to their estimated lengths at age. Tests showed that this relationship proved suitable for the data from other localities, and so was used throughout the study.

To estimate the number of annuli lost due to scale erosion, it was assumed that the growth rate (mm/year) in the missing portion decreased linearly with length (von Bertalanffy model). Examination of the data showed that this model was valid and that maximum length when growth ceased (length at infinity) ranged from 600 to 780 mm for different rivers.

A computer programme was written to calculate growth curves using estimated lengths at age (EL_n) for each fish and to estimate the number of annuli lost. As an example of the effect of this adjustment, the mean age at capture of brown trout from the Wairau River increased from 4.8 to 5.9 years and the maximum age from seven to about 13 years of age (Table 2).

TABLE 2. Comparison of original estimates of age at capture with revised estimates for Wairau River brown trout.

Revised age (years)	Original age (years): 2	3	4	5	6	7	All
2	3						3
3		2					2
4		5	10				15
5		1	8	17			26
6			3	8	4		15
7			2	5	9	2	18
8				1	9		10
9			1	1	2		4
10						1	1
11						1	1
12							
13					1		1
All	3	8	24	32	25	4	96

2.2.3 Drift diving and density estimates

Drift diving has been used in a number of studies both within New Zealand (Richardson and Teirney 1982, Bonnett and Docherty 1985, Hicks and Watson 1985, Cudby and Strickland 1986, Teirney and Jowett 1990) and overseas (e.g., Slaney and Martin 1987) to assess abundance of adult salmonids. The technique adopted for New Zealand conditions (Teirney and Jowett 1990) was used in the present study, with "small" trout defined as <20 cm, "medium" = 20-40 cm, and "large" being >40 cm. Sections of a number of the headwater rivers listed by fishery managers were dived during the 100-rivers programme (Jowett 1990). In addition to these, reaches of 10 highly regarded "A" list rivers were selected for diving. Access to rivers was by road, or helicopter in the case of the Mokihinui and Karamea Rivers. Data for the Oreti River were recorded during an ongoing study of the movements of tagged trout within the upper reaches of that river.

Abundance and biomass were calculated after the method of Teirney and Jowett 1990, i.e., abundance (kg/km) = (large brown trout (BT) × 1.16) + (medium BT × 0.31) + (small BT × 0.04)/km; biomass (g/m^2) = abundance (kg/km)/mean width (m). Such measures of abundance and biomass take into account fish size (both measures) and river size (biomass), and enable comparisons to be made between rivers where these parameters differ.

2.3 Benthic invertebrates

Samples of benthic invertebrates were collected from shallow riffles in several headwater rivers and analysed for the upper Wairau, upper Karamea and upper Oreti Rivers. Organisms were keyed out to species where possible. Biomass of functional groups of organisms (mayflies; stoneflies; etc.) was calculated after drying at 60°C for 24 hours. For this, caddis larvae were removed from their cases.

2.4 Trout movements and behaviour

Commencing in late 1989, movements of tagged trout in the upper Oreti River have been studied in a joint programme run by MAF Fisheries and the Southland Fish and Game Council. For this, large trout have been individually hand-netted by snorkel divers; fish length and coordinates of the capture point have been recorded, and the fish tagged with a Floy T-bar tag. Trout have been tagged in two upper reaches (2.8 km above Gibraltar Rock to Windy Point, a total distance of 5.5 km), and from 3.5 km above Rocky Point to 1 km below the Mossburn bridge (a total of 6.9 km). Different coloured tags have been used for both reaches. The area below Dipton constitutes a larger third reach where fish were caught by seine netting. Recaptures of tagged fish have come from both the diving programme and anglers.

To determine the effects of angling on trout behaviour, a simple questionnaire was sent to experienced guides and anglers, asking them for their opinions and observations on the behaviour of fish. Obviously such a technique can be subject to bias and subjective opinion, although it was hoped that there would be sufficiently consistent themes within the answers to allow some conclusions to be drawn. A copy of the questionnaire is presented in Appendix II.

3. RESULTS

3.1 Location of headwater rivers

3.1.1 Fishery managers' opinions

Responses to the questionnaire on identification of headwater rivers were received from all the Acclimatisation Society areas and both DOC conservancy areas. A list of the rivers which fish well all season (the "A" list rivers) is given in Table 3, together with information on the important reaches and the species present. Agreement with the "trophy" and "headwater" classification from the National Angling Survey (section 3.1.2), is also shown. Information on usage, management, and important qualities of the "A" list rivers are given in Appendix III. Equivalent data for rivers which fish well for early season only ("B" list rivers) are given in Table 4 and Appendix IV respectively.

From the information supplied by the fishery managers, a total of 18 "A" list rivers was identified in the North Island and 71 in the South Island. North Island rivers tended to be the upper reaches of rivers draining the central volcanic plateau and the Tararua Range, while South Island rivers were distributed throughout all Fish and Game Council districts. For the latter, there tended to be a concentration in the upland reaches of the northern districts (Nelson-Marlborough, West Coast, North Canterbury) and in the southern districts (Otago, Southland). Only one of the North Island rivers is associated with a lake (tributary or lake outlet river), compared with 22 South Island rivers.

Eleven of the 18 North Island "A" list rivers were considered important in their upper reaches, whereas upper and middle reaches of South Island rivers were of equal importance; 15 South Island rivers were considered important over their whole length. The species composition of rivers in both islands is given in Table 5. The number of rivers in Table 5 exceeds that in Tables 3 and 4 as several rivers are included twice in Table 5 if the dominant species changes between listed reaches. For example, in the Borland Burn, the lower reaches are a brown trout fishery, while the middle reaches are a mixed brown/rainbow fishery.

Attributes of the fish stocks for "all-season" rivers are given in Table 6. Predictably, the highest rating was for size of fish, with good condition being rated second for both islands. Apart from the species availability, there was little to distinguish between the remaining attributes. In addition to a list of attributes (see Appendix I), the survey also provided for "other" attributes to be given. Of the 17 "other" attributes given, 15 related to high scenic values, and the remaining two to good water clarity.

The South Island also dominated the "B" list of rivers with a total of 38 compared with three for the North Island (Table 4). Again, brown trout were the dominant species for South Island rivers (75%), although two of the three North Island rivers were "mostly rainbow".

3.1.2 Comparison with the National Angling Survey

Although anglers were not asked to classify rivers by type (e.g. headwater fisheries) in the National Angling Survey, it is possible to access the database by requesting a list of those rivers that conform to various criteria. For this exercise, two different sets of criteria were established. The first sought to determine "trophy" rivers. For this, a series of appropriate attributes was selected from those available, and frequencies of replies for those attributes were tabulated for a random group of rivers. From examination of these frequencies, appropriate ranges were then chosen for each attribute. Attributes and ranges selected were:

Attribute	**Range**
importance	4 or 5
distance from home	1 or 2
access	1 or 2
scenic beauty	3 - 5
feelings of solitude	4 or 5
method	exclude if only bait and/or spinners were used (but include if these were used in combination with flies or nymphs).

The second list of rivers extracted were "headwater rivers" as the criteria used were:

location	upper river
importance	4 or 5
method	as above.

TABLE 3. The "A" (all-season) headwater trout rivers, compiled from a survey of fishery managers in July 1989. Important reaches are indicated, together with the trout species. The "trophy" and "headwater" lists were generated from the National Angling Survey data (see text).

		Important reach			Trout species					Trophy		Headwater	
Fisheries district	River	Upper	Middle	Lower	B	R	50/50	R,<u>B</u>	<u>R</u>,B	a	b	a	b
Taupo	Manganuioteao River, middle		√				√						
	Manganuioteao River, upper	√							√	√	√		
	Waimarino Stream		√		√					√			
	Wanganui River	√						√		√	√	√	
	Whakapapa River		√	√					√	√		√	
Hawkes Bay	Esk River	√							√	√		√	
	Mohaka River, middle		√				√						
	Mohaka River, upper	√						√		√	√	√	√
	Ngaruroro River	√							√	√	√	√	√
	Taruarau River	√	√	√					√	√			
	Tukipo River		√	√					√	√			
	Waikoau River	√							√	√			
Wellington	Hautapu River	√	√		√					√		√	
	Otaki River	√			√					√		√	
	Rangitikei River	√					√			√	√	√	√
	Ruamahanga River	√			√					√		√	
	Tauherenikau River	√			√					√		√	
	Tokomaru River	√			√								
	Waingawa River	√			√					√		√	
	Waiohine River	√			√					√		√	
Nelson-Marlborough	D'Urville River	√	√	√				√		√	√		
	Deepdale River	√	√		√								
	Maruia River		√		√					√		√	
	Sabine River	√	√	√				√		√	√	√	

Fisheries district	River	Important reach			Trout species					Trophy		Headwater	
		Upper	Middle	Lower	B	R	50/50	R,<u>B</u>	<u>R</u>,B	a	b	a	b
Nelson-Marlborough	Tutaki River	✓			✓							✓	
	Rai River	✓	✓					✓		✓			
	Alma River	✓	✓		✓					✓			
	Saxton River	✓	✓		✓								
	Severn River	✓	✓		✓								
	Wairau River	✓			✓					✓		✓	
West Coast	Ahaura River	✓			✓					✓		✓	
	Awarua River	✓	✓		✓								
	Bruce River		✓	✓			✓						
	Crooked River		✓	✓			✓			✓			
	Grey River	✓			✓					✓		✓	
	Haupiri River		✓	✓	✓					✓		✓	
	Karamea River	✓	✓		✓					✓	✓	✓	
	Mokihinui River	✓	✓		✓					✓			
	Ohikanui River	✓	✓		✓					✓		✓	
	Otututu River	✓	✓		✓								
	Waitahu River	✓	✓		✓								
North Canterbury	Ashley River	✓			✓					✓		✓	
	Boyle River	✓						✓		✓		✓	
	Broken River		✓					✓		✓	✓	✓	
	Doubtful River	✓						✓					
	Glenariffe Stream		✓					✓		✓		✓	
	Hope River		✓		✓					✓	✓	✓	✓
	Hurunui River South Branch	✓	✓	✓	✓					✓	✓	✓	
	Hydra Waters		✓					✓		✓		✓	
	Lewis River	✓						✓		✓		✓	
	Mathias River		✓					✓					

Fisheries district	River	Important reach			Trout species					Trophy		Headwater	
		Upper	Middle	Lower	B	R	50/50	R,B̲	R̲,B	a	b	a	b
North Canterbury	Nina River	√						√		√		√	
	Poulter River		√					√		√		√	
	Waiau River	√						√		√	√	√	
	Wilberforce River		√					√		√	√	√	
	Winding Creek		√					√		√		√	
Central South	Cass River			√				√		√		√	
	Forks River	√	√					√					
	Grays River			√				√		√			
	Jollie River		√	√				√					
	Macaulay River		√	√				√		√			
	Tekapo River		√	√			√			√		√	
	Washdyke River			√				√					
	Ahuriri River	√	√	√			√			√	√	√	√
Otago	Dart River tributaries		√	√			√						
	Dingleburn	√	√	√					√	√			
	Caples River		√						√	√	√		
	Greenstone River	√	√	√					√	√	√	√	
	Hunter River	√	√	√					√	√			
	Lochy River	√	√	√					√	√			
	Fraser River	√			√								
	Pomahaka River	√			√					√	√	√	√
	Taieri River	√			√					√		√	
	Waikaia River	√			√					√		√	
	Nevis River lower			√				√		√	√	√	
	Nevis River middle and upper	√	√		√								
	Rees River		√					√					
	Von River	√	√	√					√	√		√	

		Important reach			Trout species					Trophy		Headwater	
Fisheries district	River	Upper	Middle	Lower	B	R	50/50	R,B̲	R̲,B	a	b	a	b
Southland	Aparima River	✓	✓	✓	✓					✓		✓	
	Borland Burn, lower			✓	✓					✓	✓		
	Borland Burn, middle		✓				✓						
	Mararoa River, lower and middle		✓	✓				✓		✓	✓	✓	✓
	Mararoa River, upper	✓			✓								
	Oreti River	✓	✓		✓					✓		✓	✓
	Wairaki River	✓	✓	✓			✓			✓			
	Whitestone River	✓	✓					✓		✓		✓	
	Arthur River		✓		✓								
	Wilkin River			✓					✓	✓			
	Worsley River		✓	✓					✓	✓	✓	✓	
	Young River		✓	✓					✓	✓			
	Neale Burn		✓	✓					✓				
	Glaisnock River		✓	✓					✓	✓		✓	
	Grebe River		✓	✓					✓	✓			
	Clinton River		✓	✓					✓	✓		✓	
	Clinton River, north branch	✓	✓	✓					✓				

B = brown trout.
R = rainbow trout.
50/50 = evenly mixed brown and rainbow trout.
R,B̲ = mixed but dominated by brown trout.
R̲,B = mixed but dominated by rainbow trout.
a = 1-4 replies.
b = >5 replies.

TABLE 4. The "B" (early-season) headwater trout rivers, compiled from a survey of fishery managers in July 1989. Important reaches are indicated, together with the trout species. The "trophy" and "headwater" lists were generated from the National Angling Survey data (see text).

		Important reach			Trout species					Trophy		Headwater	
Fisheries district	River	Upper	Middle	Lower	B	R	50/50	R,B̲	R̲,B	a	b	a	b
Hawkes Bay	Mangaonuku River		√	√					√				
	Maharakeke Stream		√	√				√					
Nelson-Marlborough	Travers River	√	√	√	√					√	√		
	Wangapeka River	√			√					√		√	
	Takaka River	√			√								
	Rainy River	√	√		√								
	Aorere River	√			√					√			
	Matakitaki River	√			√					√		√	
	Glenroy River	√	√		√					√	√		
	Owen River	√	√		√					√		√	
	Goulter River	√	√		√					√			
	Clarence River	√			√								
	Branch River	√	√		√								
	Leatham River	√	√		√			√		√		√	
	Pelorus River	√						√		√			
West Coast	Moonlight Creek		√	√	√								
	Big River		√	√	√								
	Robinson River	√	√	√	√								
	Clarke River	√	√	√	√								
	Te Wharau (Stony) River	√	√	√	√								
North Canterbury	Hurunui River, north branch		√					√		√	√	√	√
	Ryton River		√	√					√	√		√	
	Harper River		√	√					√			√	
	Selwyn River	√			√					√		√	√

Fisheries district	River	Important reach			Trout species					Trophy		Headwater	
		Upper	Middle	Lower	B	R	50/50	R,<u>B</u>	<u>R</u>,B	a	b	a	b
North Canterbury	Lake Stream	√	√					√				√	
Central South	Deep Creek		√	√			√						
	Deep Stream		√	√				√					
	Irishman Creek			√				√					
	Maryburn			√				√					
	Stony River			√	√					√			
	Mistake River			√				√					
	Otematata River	√	√				√			√			
	Maerewhenua River	√	√				√			√			
Otago	Timaru Creek			√		√							
	Makarora River, lower			√			√			√		√	
	Makarora River, middle		√				√			√			
	Matukituki River, upper	√			√					√			
	Matukituki River, middle and lower		√	√			√			√			
	Routeburn			√					√				
Southland	MacKenzie Burn			√				√					
	Iris Burn		√	√				√		√		√	
	Ettrick Burn		√	√			√						
	Electric Burn			√			√						

B = brown trout.
R = rainbow trout.
50/50 = evenly mixed brown and rainbow trout.
R,<u>B</u> = mixed but dominated by brown trout.
<u>R</u>,B = mixed but dominated by rainbow trout.
a = 1-4 replies.
b = >5 replies.

TABLE 5. Trout species of headwater rivers.

Species	"A" list rivers North Island	"A" list rivers South Island	"B" list rivers North Island	"B" list rivers South Island
Brown trout only	8	29	-	20
Rainbow trout only	-	-	-	1
50:50 brown:rainbow	3	8	-	6
Mostly brown trout	2	24	1	10
Mostly rainbow trout	7	13	2	3
n	20	74	3	40

TABLE 6. Characteristics of the fish stocks of all-season ("A" list) headwater rivers.

	North Island %	South Island %
Both species available	50	38
Medium-large average size	100	76
Chance to catch a trophy fish (>4.5 kg)	30	35
Good conditioned fish	50	53
Good catch rate	25	38
Hard fighting	30	33
Attractive fish (colour, shape)	30	32
Challenging, difficult to catch	25	39

The different approaches were tried in recognition that, firstly, headwater rivers should be afforded high "scores" for attributes associated with quality of angling experience, and, secondly, for some rivers the upper reaches are valued for their high quality fisheries, rather than the whole river. If the second approach had been the only one, then short rivers where fishing is important over the whole length would have been excluded, e.g., Greenstone, Waitahu (Larry's Creek).

The extraction of "trophy" rivers resulted in a list of 276 rivers of which 105 were in the North Island and 171 in the South Island. When only those rivers with more than five replies were considered, then the list was substantially reduced to 20 North Island and 29 South Island rivers (Appendix V). Table 3 shows which of these "trophy" rivers were considered as all season headwater fisheries by the fishery managers - a total of five North Island and 17 South Island rivers. Four "trophy" rivers appeared on the "B" list of rivers supplied by the fishery managers, i.e., Ngaruroro (middle reach), Travers, Glenroy, and Hurunui (North Branch).

The list of "headwater" rivers comprised 97 North Island and 136 South Island rivers. Again, selecting rivers for which more than five replies were received, the list reduced to 13 North Island and 17 South Island rivers (Appendix VI). Of these 30 rivers, only eight were listed by fishery managers as all season headwater rivers (Table 3). A further three were regarded as early season rivers ("B" list) by the fishery managers, i.e., Ngaruroro (middle), Hurunui (North Branch), and Selwyn.

Thus, there was only a reasonable overall agreement between rivers nominated by the fishery managers and rivers extracted from the National Angling Survey. Of the 88 "A" list rivers, 70 appeared on the "trophy" list, although only 22 received more than five replies. Fifty of the "A" list rivers appeared on the "headwater" list, but only eight received five or more replies. Apart from these agreements, the "trophy" and "headwater" lists gave extensive lists of rivers not nominated by the fishery managers. However, as pointed out by Teirney *et al.* (1982), the information obtained on rivers by the National Angling Survey was proportional to their usage with the consequence that the amount of data received for many headwater rivers was small.

Of the nationally important angling rivers (Teirney *et al.* 1982), sections of the following rivers were considered to be wilderness fisheries: Ruakituri, Ngaruroro, Rangitikei, Sabine, D'Urville, Hunter, Greenstone, and Caples. In addition, rivers (or sections of them) which may be nationally important wilderness fisheries were: Karamea, Travers, upper Pomahaka, and upper Oreti. With the exception of the Ruakituri, all these rivers were nominated by the fishery managers.

Of the two lists generated from the National Angling Survey, the "trophy" list was in closer agreement to the fishery managers list than was the "headwater" list. The "headwater" list tended to exclude a number of short South Island rivers where the whole river is a recognised headwater fishery. Also, it included rivers like the Kaituna which drains Lakes Rotorua and Rotoiti; while this is a very popular fishery in its upper reaches (Richardson *et al.* 1987), it is characterised by high usage and relatively small fish and therefore is definitely not a true headwater fishery. Even though it relied upon subjective assessment for inclusion of rivers, the managers' list was assumed to be the most reliable list of headwater rivers.

3.2 Characteristics of the fish stocks

3.2.1 Species distribution

Brown trout dominate "A" list rivers throughout the country, especially in the South Island (Table 3). Nationally, 37% of all rivers are considered brown trout only, while there are no rainbow trout only rivers. Again, the importance of brown trout is shown by their dominance of 64% of national rivers, and being equal with rainbows in a further 12%. Virtually all the headwater rivers in Wellington, Nelson/Marlborough, West Coast, and Otago are brown trout only fisheries.

Rainbow trout are often associated with lakes or tributaries of lakes. Certainly, for South Island "A" list rivers where rainbows were either the dominant species or co-dominant with browns, then 17 of the 19 rivers are lake tributaries. In contrast, a similar breakdown for North Island rivers shows that none of the nine rivers are associated with lakes.

Of scale samples received (n = 2712), 89% of all fish were brown trout, and 11% rainbows. Rainbows were recorded from 40 catchments, with browns from 139 (total catchments = 153). The catchments where the number of rainbow samples received was 10 or more are listed in Table 7. Although the sample size was small, rainbows were the only species provided by anglers from the Ngaruroro River and they dominated samples from the upper Rangitikei and upper Clutha tributaries.

TABLE 7. Distribution of rainbow trout among angler catches, for those catchments where the number of rainbow was ten or greater.

Catchment	% brown trout	% rainbow trout	Total
North Island			
Mohaka	85	15	91
Ngaruroro	0	100	11
Rangitikei	14	86	83
South Island			
Lochy	17	83	12
Von	14	86	14
Greenstone	6	94	68
Caples	26	74	19
Makarora	28	72	18
Upukerora	48	52	27

3.2.2 Sex distribution

For sexually mature fish of both species, the sexes are often easy to distinguish from external characters. Males have a relatively large head, and are often less deep in the body than females; male browns often have a prominent hook (kype) at the tip of the lower jaw, and a larger adipose fin than females, but these features are not so prominent in rainbows.

Most anglers supplying scale samples included their opinion of the sex of the fish with the information supplied. Of 2207 brown trout, 64% were males and 36% were females (Table 8). Equivalent figures for rainbows (n = 296) were 54% males and 46% females. Thus for brown trout, males exceed females almost 2:1, although the ratio for rainbows is almost 1:1.

TABLE 8. Proportions of male and female trout recorded by anglers per month.

	Brown trout			Rainbow trout		
Month	% male	% female	n	% male	% female	n
Jan	65	35	400	68	32	37
Feb	64	36	264	51	49	51
Mar	62	38	266	42	58	26
Apr	57	43	116	50	50	24
May	100	-	1	-	-	-
Jun	60	40	35	-	-	-
Jul	43	57	7	-	-	-
Aug	43	57	7	100	-	2
Sep	38	62	8	-	-	-
Oct	64	36	300	48	52	27
Nov	67	33	437	54	46	87
Dec	67	33	368	56	44	43
Total	64	36	2210	54	46	297

Table 9 gives the proportions of male and female trout recorded per month from the scale samples. At the general commencement of the angling season in October, males dominated brown trout catches, and continued to do so until autumn when the proportion of females increased, presumably as a result of more females moving into upstream areas. Trends within the smaller rainbow samples were less pronounced, but followed the same general pattern. (Seasonal movements are discussed further in section 3.3.1).

3.2.3 Size

The sizes of trout received from the scale sampling programme, are summarised in Table 9, with length and

TABLE 9. Sizes of brown and rainbow trout from scale samples. Mean, range, and standard deviation of length, weight, and condition for both sexes of both species.

	Male	Female	Total
BROWN TROUT			
Length (mm)			
No.	1417	790	2394
Mean	577	529	556
s.d.	65	81	80
Minimum	300	270	178
Maximum	884	898	898
Weight (g)			
No.	1089	528	1747
Mean	2324	1924	2185
s.d.	784	896	885
Minimum	300	200	200
Maximum	8618	9072	9500
Condition			
No.	1087	528	1745
Mean	1.17	1.18	1.17
s.d.	0.23	0.23	0.23
Minimum	0.48	0.52	0.48
Maximum	2.25	2.71	2.71
RAINBOW TROUT			
Length (mm)			
No.	160	136	311
Mean	542	553	545
s.d.	74	87	80
Minimum	305	350	305
Maximum	813	822	822
Weight (g)			
No.	94	102	205
Mean	2108	2260	2149
s.d.	1010	1276	1145
Minimum	350	450	350
Maximum	6318	6804	6804
Condition			
No.	94	101	204
Mean	1.14	1.17	1.15
s.d.	0.22	0.28	0.25
Minimum	0.71	0.68	0.67
Maximum	1.71	2.18	2.18

weight frequencies of the total samples of each species shown in Figures 2 and 3. For brown trout, males averaged almost 50 mm and 400 g larger than females, but female rainbows were slightly larger than males. For both species, the largest fish recorded were females. Overall, 1.7% and 3.5% of brown and rainbow trout respectively, exceeded 700 mm, while the proportion of "double figure" fish (i.e. fish of 10 lbs or greater) was 0.7% and 1.6% respectively.

Length frequencies of some of the larger samples for each species, are also given in Figure 2. All samples appear to show some measurement bias due mainly to the conversion of imperial measurements (given to one-quarter inch) to the nearest metric equivalent (mm). While the shape of the length frequency distribution of the upper Wairau sample is generally similar to that for the total brown trout sample, the upper Oreti brown trout average slightly larger. The Greenstone-Caples rainbows represent a rather "average" size distribution for that species, but the upper Rangitikei rainbows are substantially larger.

The distribution of the weight of angler-caught trout for the largest samples, is given in Figure 3. As the measure of fish size of most relevance to anglers is still imperial weight (lbs), this was the statistic used. Only 1% of all brown trout exceeded 10 lbs, compared with 2.4% of rainbows. However, the figure for rainbows is strongly influenced by the sample of generally large trout from the upper Rangitikei River. The average weight of brown trout was 4.82 lb (2.19 kg); the largest average weight came from the upper Oreti River (6.03 lb), followed by the upper Karamea River (5.20 lb) and the upper Wairau River (5.10 lb). Rainbows averaged 4.74 lb (2.15 kg), with the upper Rangitikei River fish averaging 6.50 lb, compared with 2.79 lb from the Greenstone/Caples Rivers.

Although the scale collection programme concentrated on samples from upper river reaches, an effort was made to collect scales from two complete river systems, the Wairau and Oreti Rivers. Table 10 shows that for the Wairau, there is a small decline in average length

TABLE 10. Comparison of sizes (length, mm) of brown trout from upper, middle, and lower reaches of the Wairau and Oreti Rivers.

	Wairau	Oreti
Upper reach		
n	121	165
Mean length (s.d.)	562 (62)	604 (61)
Middle reach		
n	13	136
Mean length (s.d.)	529 (59)	488 (91)
Lower reach		
n	26	11
Mean length (s.d.)	516 (74)	523 (77)

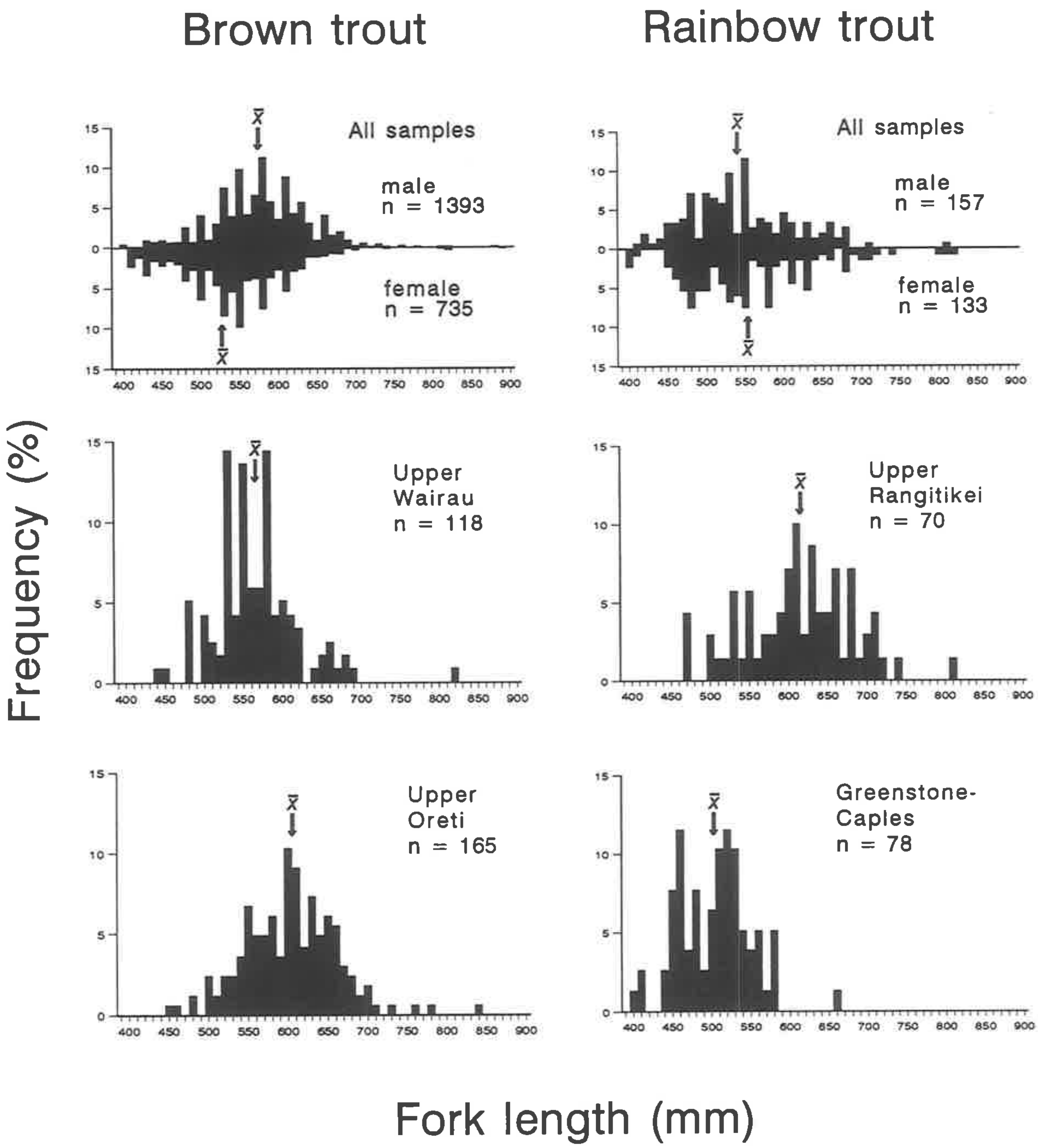

FIGURE 2. Length frequencies of all brown and rainbow trout samples and selected catchments. The mean sample length is indicated by $\bar{X}$.

with progress downstream, while for the Oreti there is a marked decline in length from the upper to the middle river, but an increase in the lower river.

Within a single catchment, some tributaries are more highly regarded as headwater rivers then others. Also, anglers recognise different characteristics associated with the fish stocks of different tributaries (Entwhistle 1989). The Buller catchment is extensive (6484 km^2), and contains a number of important fishing rivers; the National Angling Survey (Teirney *et al.* 1982) listed three and two rivers respectively within the Buller catchment as nationally important or possibly nationally important fisheries. The average lengths of brown trout from the main river and some of the major tributaries are given in Table 11. A Tukey test of the mean lengths indicated no significant differences ($P > 0.05$) between trout from the upper Buller, Ohikanui, Waitahu, Maruia, Owen, and D'Urville Rivers. Trout from the middle Buller and Mangles were significantly smaller than trout from elsewhere in the catchment, while the Stoney trout were significantly larger than those from

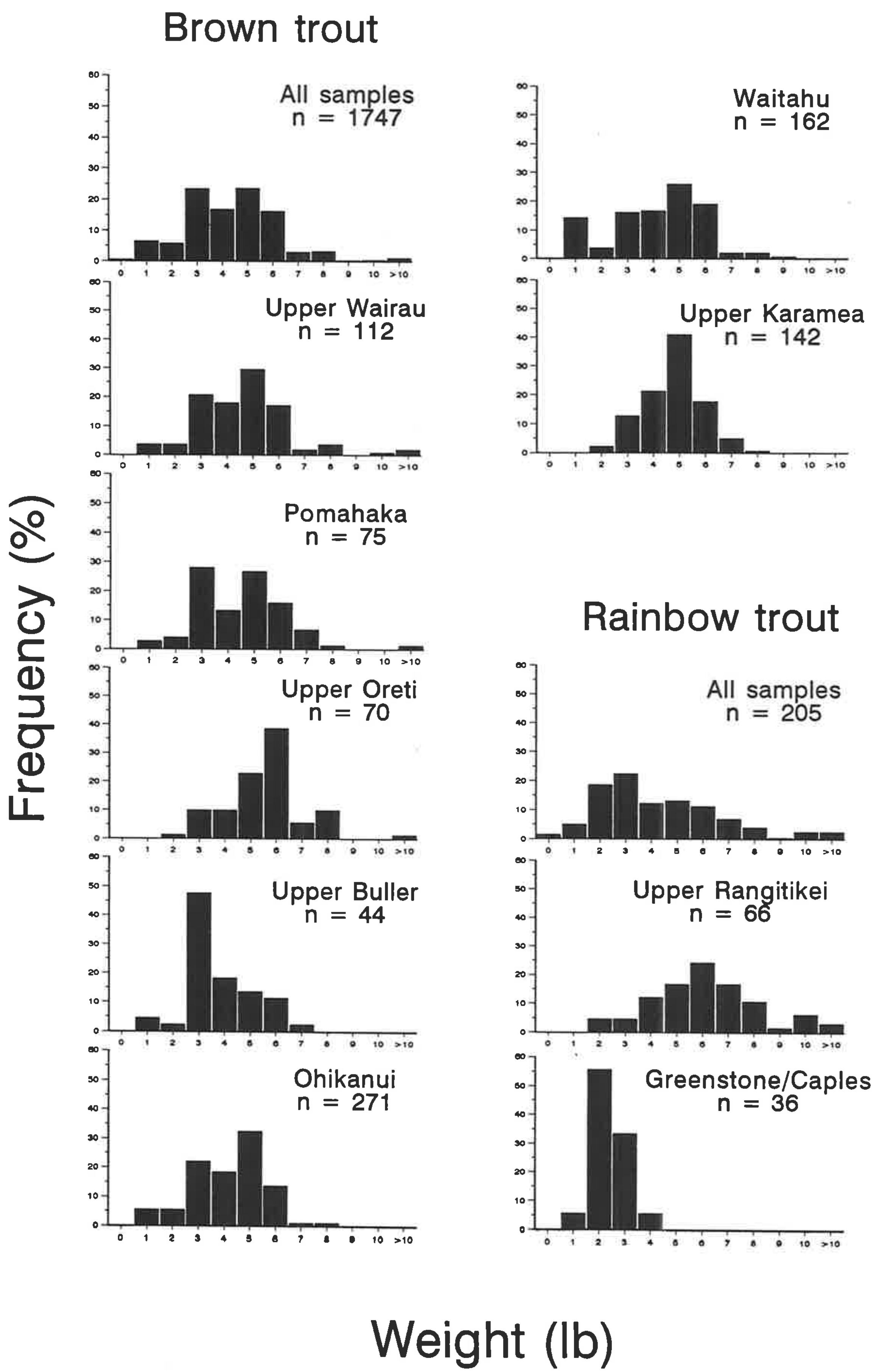

FIGURE 3. Distribution of weight (in lbs) of angler caught brown and rainbow trout from selected catchments.

TABLE 11. Variation in size of brown trout from the Buller catchment.

River	*n*	Mean length (mm)	s.d.
Buller River, middle	8	531	59
Buller River, upper	46	543	43
Ohikanui	320	558	67
Waitahu	171	552	103
Te Wharau (Stoney)	54	599	51
Maruia	29	568	44
Mangles	34	518	46
Owen	48	564	42
D'Urville	38	565	28
Travers	52	571	64

any other tributary; fish from the Travers were of similar size to those from the Ohikanui, Maruia, Owen, and D'Urville Rivers.

Average lengths of male and female brown trout from throughout the angling season (Table 12) show little variation except for the month of March which a Tukey test showed as significantly different ($P < 0.05$) to all other months. However, the decrease in length for this month was apparently due to the influence of a large sample of trout from the middle Oreti River (n = 72) rather than to any overall influx of smaller fish.

The availability of a set of detailed diaries kept by one angler (Ian McLellan, Westport) who fished the Ohikanui River from 1957 to 1986 provided an opportunity to look at trends in average length over time for this river. Further material obtained from the West Coast Fish and Game Council and the scale collection programme, meant that information was available for this river for a period of 25 years. Average length data for years with the largest samples (Table 13) show variations of up to 57 mm between adjacent years but no consistent trends.

The length–weight relationship was established for both species. The log-transformed equations are given in Table 14. The plots of weight on length for both species showed considerable scatter, which is reflected in the relatively low "*r*" value of the respective regressions. Such "scatter" would be partly attributable to anglers estimates of weights (from the data supplied by anglers, it was not known when a fish had been weighed or

TABLE 12. Average length and condition of male brown trout, October-April, all sites and years combined.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Total
MALES								
Length								
n	190	293	245	259	169	164	66	1420
Mean (mm)	574	581	575	589	583	558	576	577
s.d. (mm)	64	59	53	58	75	72	68	65
Condition								
n	180	175	198	207	145	104	62	1087
Mean	1.13	1.13	1.19	1.16	1.20	1.22	1.16	1.17
s.d.	0.22	0.22	0.21	0.25	0.23	0.23	0.19	0.23
FEMALES								
Length								
n	109	143	123	141	94	102	50	790
Mean (mm)	534	536	537	541	541	483	531	529
s.d. (mm)	69	80	70	71	97	82	85	81
Condition								
n	93	84	89	100	69	38	41	528
Mean	1.17	1.19	1.19	1.20	1.17	1.21	1.20	1.18
s.d.	0.28	0.27	0.22	0.20	0.18	0.23	0.15	0.23

TABLE 13. Average length and condition of brown trout from the Ohikanui River for years from 1957-1992. Data for 1957-1986 are from one angler; data from 1989-1992 are from various anglers.

Year	1957	1960	1961	1962	1963	1969	1971	1984	1985	1986	1989	1990	1991	1992	Total
Length (mm)															
n	10	19	16	21	23	16	13	23	12	14	16	17	12	13	320
Mean	506	537	590	600	556	559	564	603	546	544	514	523	543	601	558
s.d.	132	75	41	41	57	52	41	21	69	42	66	85	72	64	67
Condition															
n	9	19	16	21	22	16	13	11	10	14	1	12	10	13	271
Mean	1.00	1.25	1.22	1.12	1.22	1.18	1.26	1.00	1.08	1.09	0.90	1.28	1.15	1.23	1.17
s.d.	0.08	0.08	0.09	0.13	0.12	0.15	0.16	0.12	0.22	0.12	-	0.26	0.12	0.14	0.17

when weight had been estimated). However, anglers had sometimes noted "slab" or "fish in poor condition" on an envelope, so it was apparent that a proportion of headwater fish, especially males, can be in relatively poor condition.

TABLE 14. Length-weight relationships for brown and rainbow trout.

Brown trout	
Males	$\ln W = 2.532 \ln L - 8.403$ (n = 1087, r = 0.83)
Females	$\ln W = 2.745 \ln L - 9.760$ (n = 528, r = 0.92)
All fish	$\ln W = 2.686 \ln L - 9.387$ (n = 1745, r = 0.89)
Rainbow trout	
Males	$\ln W = 3.009 \ln L - 11.451$ (n = 94, r = 0.93)
Females	$\ln W = 2.933 \ln L - 10.964$ (n = 101, r = 0.90)
All fish	$\ln W = 2.950 \ln L - 11.076$ (n = 204, r = 0.91)

W = weight in g.
L = length in mm.

It was of interest that most anglers still recorded weight in imperial rather than metric units; for example, from a random sample of 200 scale packets, 117 (59%) had length and weight recorded in inches and pounds, 51 (25%) were in cm and pounds, 30 (15%) were in cm and kg, and two (1%) in inches and kg. Certainly, the legendary "10 pounder" sounds a more impressive statistic than a "4.5 kg" fish.

From the length-weight equations it can be shown that, for lengths <600 mm, brown trout of a given length are heavier than rainbows. Further, brown trout males are heavier than females, but rainbow females are heavier than males. At about 600 mm, both species are of similar weight, but above this length the descending order of weight for a given length is rainbow females, rainbow males, brown females, brown males.

3.2.4 Condition

Average condition factors of both brown and rainbow trout (Table 9) are practically identical. The ranges in condition are extensive and will be due to both anglers "guesstimates" of size, as well as real measures of variation; the former would be the most likely explanation for the range in weight of 770 - 4010 g for female brown trout (for the mean length of 529 mm).

In the questionnaire asking about perceived changes in the behaviour of headwater trout stocks (section 2.3), experienced anglers were also asked whether they thought changes in the condition of fish had occurred during the years that they had been fishing particular waters. Of the 29 responses to this question, 16 anglers recorded "no change", while 13 others considered that condition was related to seasonal and annual events, rather than to fish numbers. From information on the length-weight database there is little evidence of changes in condition during the season (Table 12), except that for males there is a suggestion of increasing condition during summer.

The Ohikanui River data (Table 13) provided an opportunity to examine variation in condition over an extended period. Although the average (1.17) was similar to that for all male and female brown trout (Table 9), there was a considerable range (1.0 - 1.28). This variation from year to year was consistent with the above comments from anglers.

An examination of the mean condition of brown trout by length groups (Table 15) showed that there was a tendency for condition to decline with increasing length, especially in males. Part of this apparent decline in condition would be attributable to the development of

TABLE 15. Mean condition per size group for male and female brown trout.

Size group (mm)	Males *n*	Males Mean CF	Males s.d.	Females *n*	Females Mean CF	Females s.d.
<500	83	1.26	0.29	138	1.26	0.28
500-549	216	1.24	0.22	143	1.19	0.22
550-599	393	1.18	0.22	139	1.15	0.19
600-649	261	1.11	0.19	79	1.12	0.18
650-699	108	1.08	0.21	21	1.13	0.18
>700	26	0.96	0.27	8	1.13	0.19

CF = condition factor.

the extended lower jaw (kype) in large male fish, although most of the decline will reflect the typical "leanness" of large males.

3.2.5 Age composition

3.2.5.1 Brown trout

A total of 1119 brown trout was aged. Scale erosion made it difficult to age old fish accurately, so fish older than eight years were simply recorded as 9+. The age composition of the largest samples (Table 16) shows that most fish were between three and seven years old, with the mean age being 5.8 years (s.d. = 1.7). Modal ages were five and six, and these age classes constituted 46% of all trout.

Males were on average 0.78 years older than females (n = 17, s.d. = 0.48). There were significant differences between rivers in the mean age of fish. The youngest fish were from the Motueka River and tributaries of Lake Te Anau (4.8 years), Hautapu and Ohikanui (4.9) and the oldest from the Rough (6.4), Pomahaka (6.5), Owen (6.6), Mokihinui (6.7) and Karamea tributaries (6.7). Note that, although the Motueka River itself is not regarded as a true headwater river (but two of its tributaries are), it was included for comparative purposes, as an example of a lowland river.

3.2.5.2 Rainbow trout

Most rainbow trout ranged from four to seven years of age (Table 17) and only a few exceeded nine years old. The mean age of samples in Table 17 was 5.6 years (s.d. = 1.5), with the modal age being five years. Together, age classes five and six made up 55% of the total age distribution. Males were on average slightly older than females. The youngest fish were caught in tributaries of Lake Te Anau (mean age 5.1 years) and in the Greenstone (5.1) and the oldest in the upper Rangitikei (6.7 years).

3.2.6 Growth rates and length at age

3.2.6.1 Brown trout

Growth rates and mean lengths at age were similar in most rivers (Table 18). For all brown trout combined, although males were longer than females in all age classes, the growth rates of both sexes were essentially similar. Fish grew relatively rapidly in the Ohikanui (mean length at age 5 = 504 mm), Roaring Lion (507 mm) and Hautapu (510 mm) and slowest in the lower Wairau (468 mm), and Motueka (444 mm).

Growth rates varied substantially among fish in the same river. For example, nine fish taken from the Pomahaka averaged 325 mm in length (s.d. = 31.7) at age two while the remaining fish only averaged 218 mm (n = 51, s.d. = 28.4). From the relative widths of the annuli, it is very likely that the latter fish had spent part of their lives at sea. For both the Wairau and Oreti Rivers, samples from both the upper and lower river (Wairau), and upper and middle river (Oreti), were available to compare growth rates. In the Wairau, females in the upper and lower river grew at similar rates until age 6, while for males, growth appeared slightly more rapid on the upper river. For the Oreti River, there were smaller differences in growth rates between the two locations. The theoretical maximum length of fish ranged from 600 mm in the Motueka and 650 mm in the Hautapu up to 780 mm in the Glenariffe.

From recaptures of 22 tagged trout in the upper Oreti River, a relationship between annual growth increment (I) (mm/year) and length at tagging (L) was determined. The relationship was

$$I = -0.384\ (L) + 239.446\ (r = 0.79)$$

Thus, annual growth declined with increased length, until growth became theoretically zero at a length of 625 mm. This growth rate was then used to compare with the rate established from the scale reading (Figure 4). Given that there is considerable variability within each set of data and the restricted range in length of the recaptured fish, the two sets complement each other reasonably well, thus providing some validity for the scale ageing technique used.

TABLE 16. Age composition of brown trout from selected catchments.

		Age (years)											
River	Sex	1	2	3	4	5	6	7	8	9+	Total	Mean age	s.d.
Mohaka, upper	F			2	5	5	4	3		1	20	5.2	1.5
	M			1	1	8	6	2	1	2	21	5.9	1.5
Hautapu, upper	U		5		2	1	3	1	1	2	15	4.9	2.6
Motueka	F		1	3	6	6	3			1	20	4.6	1.7
	M			1	8	6	6			1	20	5.0	1.5
	U	1		1	2	1					5	3.4	1.5
Wairau, lower	F			1	5	4	1	2	2		15	5.3	1.6
	M				1	2	1	2	1	2	9	7.2	2.8
Wairau, middle	F				2		2	2			6	5.6	1.4
	M					2	1				3	5.3	0.6
Wairau, upper	F		3	1	4	6	2		4	1	21	5.2	2.2
	M				3	11	8	11	3	5	41	6.4	1.6
	U					1		1	1	1	4	7.3	1.7
Glenariffe	F		1	3	4	6	4				18	4.5	1.2
	M			1	4	6	6	5	1		23	5.6	1.3
	U					2					2	5	
Pomahaka, upper	F				1	9	4	6	1	3	24	6.3	1.6
	M				3	2	13	6	2	6	32	6.7	1.8
Oreti, middle	F		2	10	18	12	5	2	1		50	4.4	1.3
	M			3	4	6	7	6	3		29	5.6	1.5
Oreti, upper	F				6	4	6	5	3	2	26	6.2	2.1
	M					4	13	3	4	8	32	7.1	1.6
Lake Te Anau tributaries	F			2	2	1	1	1			7	4.6	1.5
	M			1	4	2	5	1	1		14	5.3	1.4
Rough	F			1	2	5	1	2	1	2	14	6.0	2.1
	M			1	1	3	3	3	2	4	17	6.8	2.0
Buller, upper	F					3	2		1	1	7	6.3	1.6
	M					5	6	8	2		21	6.3	1.0
Ohikanui	F		1	5	9	5	5	4			29	4.7	1.4
	M			1	4	4	1	1		1	12	5.2	1.8
Mangles	F			1	3	5	2	1			12	4.9	1.1
	M				1	9	3	4	1		18	5.7	1.1
Owen	F					2	3	2	2		9	6.4	1.1
	M					1	6	4	3	1	15	6.8	1.1
D'Urville	F				2	1	1		1		5	5.4	1.7
	M				1	5	10	2		3	21	6.2	1.4
Travers	F				1		1				2	5.0	1.4
	M				2	5	8	8		1	28	6.9	2.2
Mokihinui	F			1		3	6	2	2	1	15	6.2	1.5
	M				1	2	3	11	3	3	23	7.2	1.9
Karamea	F					1					1	-	-
	M			1	1	5	7	6	4	2	26	6.4	1.6
Roaring Lion	F					3	1	3	3		10	6.6	1.3
	M				1	1	4	3	1	3	13	6.8	1.6
Crow	F				1	4	3	2	1	1	12	6.1	1.4
	M				1	2	5	4	4	6	22	7.5	2.3

M = male.
F = female.
U = sex unknown.

TABLE 17. Age composition of rainbow trout from selected catchments.

		Age (years)										Mean	
River	Sex	1	2	3	4	5	6	7	8	9+	Total	age	s.d.
Rangitikei, upper	F				1	1	1	2		2	7	6.9	2.1
	M						3	2	1	2	8	7.6	1.9
Greenstone	F			1	2	7	5				15	5.1	0.9
	M			1	4	8	1	4			18	5.2	1.2
Caples	both				1	2	4	3	1		11	6.1	1.1
Lochy and Von	both				4	5	7	3		2	21	5.9	1.7
Lake Te Anau	F			1	3	3	2				9	4.7	1.0
tributaries	M			4	1	7	2		1	2	17	5.5	2.6

M = male.
F = female.

3.2.6.2 Rainbow trout

As with brown trout, growth rates and mean lengths at age were similar in most rivers (Table 19). The largest and fastest growing fish came from the Rangitikei River where they averaged 127 mm at age one and 532 mm at age 5. The smallest and slowest growing fish came from the Caples River, averaging 110 mm at age one and 433 mm at age 5. Overall, rainbow and brown trout were almost identical in growth rates and length at age.

3.2.7 Densities

Results of drift dives are given in Table 20. All rivers dived contained only brown trout, and the numbers observed ranged from three to 55 large trout/km. Using the classification of Teirney and Jowett (1990) of low abundance (<15 kg/km), medium (15-35 kg/km), and high (>35 kg/km), then seven of the river reaches in Table 20 had "low abundance", five "medium", and nine "high". Similarly, using Jowett's (1990) categories of biomass (low = <0.5 g/m^2, moderate = 0.5-2.0 g/m^2, high = >2.0 g/m^2), then most (14) of these reaches had moderate biomass, four had high biomass, and the remaining three had low biomass.

A characteristic of headwater rivers is their high proportion of large trout relative to other size categories. The percentage distribution of the three size classes of trout recorded for the headwater rivers dived are given in Table 21. More than two-thirds of all trout seen were "large". Counts for the lower reaches of the Mokihinui and Karamea Rivers (data from Teirney and Jowett 1990) show a relatively low proportion of "large" fish, but much higher proportions of "medium" and "small" fish. To provide a comparison with a wider range of rivers, data for lowland reaches of rivers (sites <20 km from the sea) were extracted from Appendix II in Teirney and Jowett (1990). For the resulting 28 rivers, the distribution of the three size classes are shown in Table 21 as "various rivers". Here also, medium sized trout are the dominant group; also, the mean density and mean biomass of these rivers are less than the equivalent information for all headwater rivers. Similarly, both mean density and mean biomass in the lower reaches of the Mokihinui and Karamea Rivers are less than in the upper reaches.

3.2.8 Benthic invertebrates

Feeding studies were not carried out, and, although some old angler diaries contained comments on the stomach contents of large trout, these were too subjective to warrant detailed analysis. Nevertheless, the observations did indicate that the primary source of food for trout in some Buller tributaries was aquatic invertebrates, although terrestrial insects could sometimes be important. As anglers who participated in the scale collection programme killed very few trout, no further feeding data were obtained. Previous studies on the diet and feeding of large trout in New Zealand (McLennan and MacMillan 1984, Hayes 1991), have shown that most food comes from invertebrate drift, and therefore benthic samples would indicate both the range and density of food available. Also, it was considered important to establish whether headwater rivers were characterised by particularly high density of benthos, as this could be an important factor in understanding why these areas often contain a high percentage of large trout.

TABLE 18. Mean length (mm) at age of brown trout from selected catchments.

		Age (years)										
River	Sex	1	2	3	4	5	6	7	8	9+	Max.	*n*
Mohaka, upper	F	119	249	346	413	475	501	549			670	20
	M	114	235	341	440	495	531	568	594		670	21
Hautapu, upper	U	148	307	414	474	512	545	575	591	617	650	15
Motueka	F	113	223	332	388	428	460	537			600	20
	M	115	235	347	411	460	498	508			600	20
Wairau, lower	F	105	212	315	408	489	515	565	582		700	15
	M	105	200	294	370	434	486	516	548	577	700	9
Wairau, upper	F	114	240	356	441	493	538	591	615	678	700	21
	M	119	231	340	432	489	531	576	612	651	700	40
Glenariffe	F	119	232	329	413	462	532				780	18
	M	122	231	337	409	473	512	569	606		780	23
Pomahaka, upper	F	117	225	319	407	479	525	583	635	671	750	24
	M	115	245	348	439	493	540	569	614	631	750	32
Oreti, middle	F	123	242	328	409	478	503				750	50
	M	120	252	349	414	481	529	575			750	29
Oreti, upper	F	123	247	352	430	489	531	535	553		750	26
	M	119	231	339	421	489	546	583	614	633	750	32
Lake Te Anau	F	97	197	371	500	507					700	7
tributaries	M	98	209	341	443	500	542				700	14
Rough	F	139	271	375	455	493	522	553			700	14
	M	125	242	363	433	487	524	557	568	582	700	17
Buller, upper	F	100	206	330	398	443	455				700	7
	M	114	233	343	426	479	513	547	591		700	21
Ohikanui	F	137	292	387	450	493	532	540			700	29
	M	138	305	447	509	530	540	577	638		700	12
Mangles	F	112	218	317	409	468	484	511			700	12
	M	116	231	344	432	487	528	573	570		700	18
Owen	F	114	212	315	414	474	508	531	552		700	9
	M	106	218	329	415	478	511	546	582	591	700	15
D'Urville	M	117	229	349	436	490	532	552	572	596	700	21
Travers	M	117	237	343	421	477	519	546	575	598	700	28
Mokihinui	F	114	226	355	427	494	542	577			750	15
	M	119	211	347	429	495	539	571	603	643	750	23
Karamea	M	125	257	366	444	497	536	565	594		720	26
Roaring Lion	F	128	259	359	443	515	539	557			720	10
	M	131	244	360	447	501	552	598			720	13
Crow	F	112	260	378	436	490	520	558			720	12
	M	123	274	376	446	492	532	563	587	618	720	22
Total	F	117	236	345	426	481	513	553	577			17
	M	118	237	350	431	486	527	561	592	611		20
	All	118	239	349	430	484	521	558	591	621		38

M = male.
F = female.
U = sex unknown.

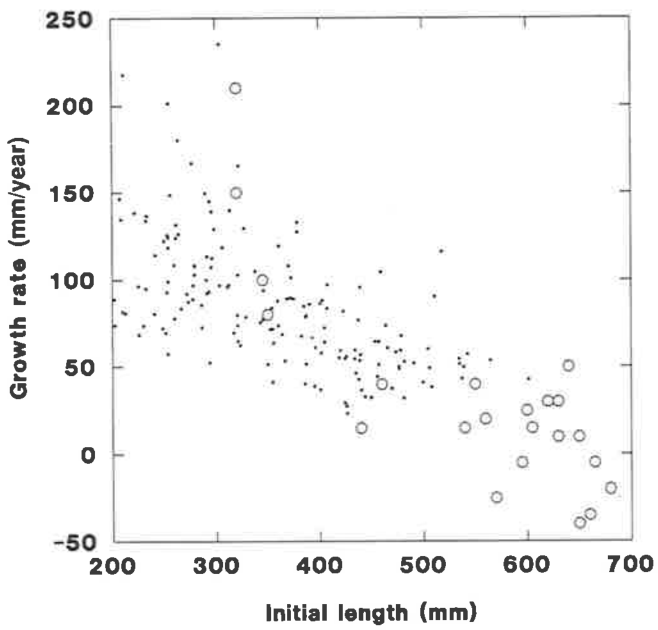

FIGURE 4. Relationship between initial length at beginning of each year's growth and annual growth rate (mm/year), and annual growth rate calculated from length increments (large circles) for upper Oreti brown trout.

During the present survey, benthic invertebrate samples were collected from shallow riffles in several headwater rivers. Unfortunately, owing to the amount of time involved in processing samples, not all could be analysed. Accordingly, samples from three recognised headwater rivers were chosen for analysis: the upper Wairau, upper Karamea, and upper Oreti Rivers. Invertebrate densities (Table 22) ranged from 2805 to 5957/m². The Wairau and Karamea samples were rather similar and the Oreti sample had greater density, number of taxa, and biomass. The numerical and gravimetric dominance of mayflies, stoneflies, and caddis varies between the samples (Appendix VII), although *Deleatidium* are 27-53% by number of each sample.

3.3 Behaviour of the fish

3.3.1 Seasonal movements

Some understanding of the life history strategy of headwater trout is of importance in considering management options. For instance, are these fish simply larger individuals of a single homogeneous riverine population, or are they a separate sub-population resident in the upper reaches of rivers? Electrophoretic analysis was outside the scope of the present study, so the question of any genetic demarcation of stock could not be investigated. Further, discussion with P.J.Smith (MAF Fisheries, Wellington) confirmed that small genetic differences are difficult to interpret; sample sizes must be sufficient to measure genetic variability within a stock so that comparisons between stocks may be made. Smith suggested that liver and muscle samples from a minimum of 70 trout of each stock would be needed for this.

TABLE 19. Mean length (mm) at age of rainbow trout from selected catchments.

		Age (years)										
River	Sex	1	2	3	4	5	6	7	8	9+	Max.	*n*
Rangitikei, upper	F	120	241	374	479	547	583	614			730	7
	M	135	265	412	481	518	560	579	581		730	8
Greenstone	F	111	206	320	418	490	520				670	15
	M	111	219	329	412	457	461	483			670	18
Caples	Both	110	202	291	377	433	494	543			670	11
Lochy and Von	Both	109	214	322	433	500	541	600			850?	21
Lake Te Anau tributaries	F	109	239	354	416	479	537				700	9
	M	112	225	338	436	495	520				700	17
Total	F	113	229	349	438	505	547					3
	M	119	236	360	443	490	514					3
	All	115	226	342	431	490	527	563				8

F = female.
M = male.

TABLE 20. Results of drift dives of headwater rivers carried out during present study.

River and access	Date	Grid reference (start)	Reach length (m)	Width (m)	Visibility (m)	Brown trout/km L	Brown trout/km M	Brown trout/km S	Abundance (kg/km)	Biomass (g/m^2)
Wairau River at Dip Flat	08.03.90	S33 272492	5500	15	8.5	5	3	2	6.8	0.45
Clarence River	08.03.90	S47 263858	1400	10	4.8	5	7	3	8.1	0.81
Larrys Creek	05.03.90	L30 198097	2500	15	8.2	5	2	2	6.5	0.43
Waitahu River	06.03.90	L30 259951	1200	20	8.5	13	14	0	19.4	0.97
Waitahu River	05.03.90	L30 203022	1000	20	7.4	3	6	37	6.8	0.34
Stoney at Inangahua confluence	06.03.90	L30 176114	1000	10	10.9	4	1	1	5.0	0.50
Mokihinui River, north branch	26.02.87	L28 432632	2050	25	10.8	31	1	1	35.9	1.44
Mokihinui River, north branch	07.03.90	L28 444634	2350	25	9.5	21	1	0	24.7	0.99
Mokihinui River, south branch	26.02.87	L28 433555	1950	30	12.0	38	3	12	45.9	1.53
Mokihinui River, south branch	07.03.90	L28 433555	1950	30	10.0	55	3	1	64.8	2.16
Karamea River at Crow River	26.02.87	M27 635896	2050	30	12.6	41	3	18	49.3	1.64
Karamea River at Crow River	07.03.90	M27 635896	2020	30	13.4	35	2	1	41.3	1.38
Karamea River at bend	26.02.87	M27 681951	1850	50	14.0	52	17	26	66.4	1.33
Karamea River at bend	07.03.90	M27 682951	2000	45	13.5	44	11	1	54.5	1.21
Ugly River	07.03.90	M27 497105	1700	10	10.0	25	4	5	30.4	3.04
Crow River, lower	07.03.90	M27 662902	1000	10	10.0	26	1	5	30.7	3.07
Crow River, upper	07.03.90	M27 684894	1100	15	10.0	6	2	28	8.7	0.58
Oreti River above Gibraltar Rock*	1989-92 $n = 3$	S141 127212	2800	10	8-12	16	1	1	18.9	1.89
Oreti River below Gibraltar Rock*	1989-92 $n = 6$	S150 122178	2900	15	8-12	30	2	1	35.5	2.36
Oreti River at Rocky Point*	1989-92 $n = 6$	S150 172950	3500	30	4-10	33	3	4	39.4	1.31
Oreti River below Rocky Point*	1989-92 $n = 5$	S150 202925	3400	30	4-10	24	3	11	29.2	0.97

*Multiple dives, indicated by *n*, were undertaken at these sites. Visibility is given as the range for all dives; brown trout/km, abundance and biomass are the means for all dives.

TABLE 21. Percentages of size classes of fish recorded during drift dives of headwater brown trout rivers (present study) and lower reaches of rivers (Teirney and Jowett 1990).

River	No. trout	Percentage L	M	S
Headwaters				
All	760	67	12	21
Mokihinui	167	87	5	8
Karamea	353	65	11	24
Lower reaches				
Various rivers	1389	31	46	23
Mokihinui	130	16	32	52
Karamea	103	20	60	20

L = >40 cm.
M = 20-40 cm.
S = <20 cm.

It was recognised that while it is likely that there will be some genetic differentiation of fish from different rivers, this would not necessarily imply differences in behaviour. The alternative investigation, that of studying behaviour, was therefore initiated. For this, the hypothesis was proposed that there would be a tendency for most trout as they grew, to migrate progressively to the upper reaches of rivers. For many fish, this upstream migration would take place during the spawning season, and having arrived in upper reaches and finding suitable vacant habitat (or creating this through displacing other fish), they would choose to remain there. The presence of large fish in the lower reaches of rivers means that such a strategy is by no means universal, but such annual recruitment would explain why headwater areas can remain relatively productive fisheries while sustaining an ongoing harvest.

3.3.1.1 Movement within fresh water

A summary of results to date from the recaptures of tagged trout in the Oreti River is given in Table 23. In the Gibraltar Rock reach, most recaptured fish had not moved; of those that had moved, only five had moved >1 km (four upstream, one downstream). In the reach near Mossburn, most recaptured fish had moved downstream some distance, an average 775 m. Only one fish moved more than 1 km. From the most downstream reach (below Dipton), none of the seven recaptures had moved further than 1 km. Overall, of the 46 recaptures, 19 had not moved at all, and only eight had moved more than 1 km. Upon release after tagging, fish normally swam rapidly downstream, sometimes leaving the pool and being recorded in the next pool downstream. Despite this initial downstream movement, the average distance moved upstream by recaptured fish in all three reaches exceeded the average distance moved downstream. Only four fish were at large for a year or more, and three of these were recaptured at the site where they were tagged, while the fourth had moved downstream 800 m.

Tentative conclusions from these results were that most fish were sedentary, presumably because they had established a territory, which, in some instances, they

TABLE 22. Summary of benthic invertebrate samples (means of three replicates) from the upper Wairau, Karamea, and Oreti Rivers.

Taxa	Wairau % *n*	Wairau % wt	Karamea % *n*	Karamea % wt	Oreti % *n*	Oreti % wt
Mayflies	32	42	36	50	54	37
Stoneflies	34	15	8	28	8	7
Caddis	18	31	41	17	24	16
Other aquatic organisms	15	12	13	4	13	40
Terrestrial organisms	1	<	2	1	1	<
Average density (no./m^2)	2805		2974		5957	
No. of taxa	23		22		27	
Mean biomass (g/m^2)	1.19		1.02		3.53	

< = <1%.

TABLE 23. Movement of tagged brown trout in the Oreti River, 1989 to 1992.

Site	Recaptures Upstream	Same site	Downstream
Gibraltar Rock reach (mean length 602 mm ± 65)			
(a) all movement			
n	8	11	7
average distance moved (m)	1425	0	629
(b) movement > = 1 km			
n	4	21	1
average distance moved (m)	2275	0	1500
Mossburn reach (mean length 575 mm ± 28)			
(a) all movement			
n	4	3	6
average distance moved (m)	9325	0	775
(b) movement > = 1 km			
n	2	10	1
average distance moved (m)	18 400	0	2900
Below Dipton (mean length 354 mm ± 36)			
(a) all movement			
n	1	5	1
average distance moved (m)	700	0	200
(b) movement > = 1 km			
n	0	7	0
average distance moved (m)	0	0	0
Total			
(a) all movement			
n	13	19	14
average distance moved (m)	3033	0	661
(b) movement > = 1 km			
n	6	38	2
average distance moved (m)	7650	0	2200

continued to occupy year after year. There was no real evidence that large fish from downstream areas tended to move upstream; however, for those fish that did move, there was a greater likelihood of upstream movement rather than downstream movement.

3.3.1.2 Anadromous movement

It is widely acknowledged that a proportion of brown trout in New Zealand rivers spend part of their lives at sea, or at least in estuarine areas. Life at sea is generally assumed from interpretation of scale patterns, with sea growth showing as wide and evenly spaced annuli (Scott 1986) consistent with a period of accelerated growth. Surprisingly, only 16% of the Pomahaka trout samples received had scales clearly of this type, although data in Scott (1981) indicate that 48% of trout arriving at a fish trap in the upper Pomahaka were considered to be sea-run.

Sea-run fish are keenly sought by anglers. Analysis of diaries from 1960 to 1989 from an experienced upper Pomahaka River angler, Bert Harvey of Gore, gave a wide annual range in average weight, from 2 to 6.7 lb (0.9 to 3.0 kg), with an average of 3.6 lb (1.6 kg; n = 432 trout). The catch rate was comparatively low, at 1.3 fish/day, probably indicative of the challenge that the capture of these fish represents.

3.3.2 Effect of angling on trout behaviour

While it is apparent that catch-and-release is gaining in popularity as a means of conserving headwater trout stocks (section 3.4.1), it is possible that released fish learn from their experience and become more difficult to catch subsequently. An allied concern to this is whether the amount of fishing pressure and general disturbance to which fish are subject also reduces their vulnerability to capture. To carry out a field experiment on these subjects would have been both time consuming and expensive, and beyond the scope of the present study.

Instead, a questionnaire (see Appendix VII) was sent to experienced guides and anglers. Results from the survey have been reported in Jellyman (1991), but the most important are repeated here. Thirty replies came from South Island anglers (and guides), and five from North Island anglers. Respondents averaged 21 years of angling experience.

The first question on behaviour asked whether anglers had noticed any changes during the years they had been fishing, and if so to describe these changes. For example "do fish still occupy the same or similar positions in the river(s) as they did previously?"; if had there been any overall change in the "lies" occupied by fish, were they as "accessible" to anglers today as previously?; had the feeding strategy of fish changed noticeably? Of the replies, 23 respondents had noticed changes in behaviour, while five had not. Seven did not reply to this question.

In relation to positions now occupied by fish, 11 anglers had noted "some changes" which were related to seasonal or physical changes in the river; two further anglers commented that reduced numbers of fish meant that "good lies" were now often unoccupied, while eight other anglers replied that they had noticed definite changes which were generally that fewer fish now resided in shallow "exposed" areas like the tails of pools, or even in the "eye" of a pool. One Nelson/West Coast guide stated "Due to more disturbance, trout occupy traditional feeding lies less frequently and mainly at prime feeding times (when the risk of disturbance or capture is worthwhile due to the availability of abundant food)". He also maintained that there were fewer "edgewater" but more midstream fish these days; with continuing disturbance or low flows, he noted that trout tended to move downstream or live in deeper pools, runs or undercuts, and feed more at night.

Most respondents considered that fish had changed the positions they occupied, and that this generally made them less accessible to fly fishers. This was because fish, especially in "high traffic" areas, tended to sit more often in deeper and faster water with less time spent in more open and exposed positions. Most anglers (16) recorded "no change" in the feeding habits of fish while a further 14 recorded changes of varying sorts. The most common changes noted were that fish feed less during the day, take surface food less frequently (and so feed less on insect hatches), and are increasingly selective. Nine anglers regarded trout as becoming increasingly "spooky" during the season, and often increasingly selective too. While such changes in feeding can be associated with disturbance by humans, they can also be brought about or exacerbated by low flows and warm water temperatures.

The last set of questions related to the "settling down" period. The first question asked how long it took until for a fish to again be vulnerable to capture once it had been disturbed by anglers. The wide range of replies to this question reflected the types of rivers fished and the amount of angling pressure these waters received. Four anglers considered that one-half to two hours were needed, although this was qualified by one of these to refer to scared fish only, whereas a fish caught and released would take a minimum of one-half day. Nine anglers considered "most of the day" but qualified this according to the type and extent of the disturbance. Six anglers thought that 1-2 days were necessary, while four anglers thought 1-4 days; the observation was made by several people that while fish may resume feeding within 3-4 hours, their behaviour would not return to a fully undisturbed state for several days. The final group of anglers thought that 5-7 days were needed, especially in remote waters, and at times of low flows. One angler commented that rainbows settled more rapidly than browns.

The second question in this set asked whether anglers considered the length of the settling down period changed during a season. Eleven anglers said "no" but 21 said "yes" with a variety of qualifying comments. In general, both angling pressure and reduced flows during summer were considered to make fish increasingly wary during the season.

The final question asked whether anglers had noticed any change in the length of this settling down period during the years that they had been fishing. Eighteen anglers reported no observed change, while 10 considered that the period had definitely increased; for instance, one angler who had fished the Karamea River for 10 years considered that the settling period had increased from four to 48 hours over this time.

3.4 Characteristics of the fishery

Summaries of the 1989 and 1991 angling regulations for the nominated headwater rivers are contained in Appendices II and III. Comparisons of the bag limits, permitted methods, and length of season for "A" list rivers are shown in Figures 5-7.

3.4.1 Bag limits

Bag limits vary considerably between districts, and ranged from 0 to 12 (1989) and 0 to 10 (1991). In both years, South Island limits were smaller than North Island limits (Figure 5), but both islands showed a trend towards smaller bags between 1989 and 1991. Thus, North Island averages were 7.8 and 5.0 fish/day for 1989 and 1991 respectively, while equivalent South Island averages were 4.9 and 4.0.

Although there are overall trends to reducing bag limits, the only zero bag (catch and release only) is on the upper Lochy River (Lake Wakatipu), although it is understood that the Routeburn River will also become a catch-and-release river in the 1992/93 season. Similarly, the six one-bag limits are also on rivers entering Lake Wakatipu. A one-bag limit will also commence in the upper Rangitikei River in the 1992/93 season (Taylor 1992).

The trend towards reduced harvest from headwater rivers reflects the growing appreciation among managers that these resources are both valuable and vulnerable. Guides and anglers are also increasingly aware of the necessity to "husband" these stocks and it is of interest to note the extent to which "catch-and-release" is practised; Appendices III and IV give the results from the managers' survey, including the extent to which they perceived that catch-and-release was carried out during the 1989 season. Although the results are subjective, they do indicate that the practice is widespread.

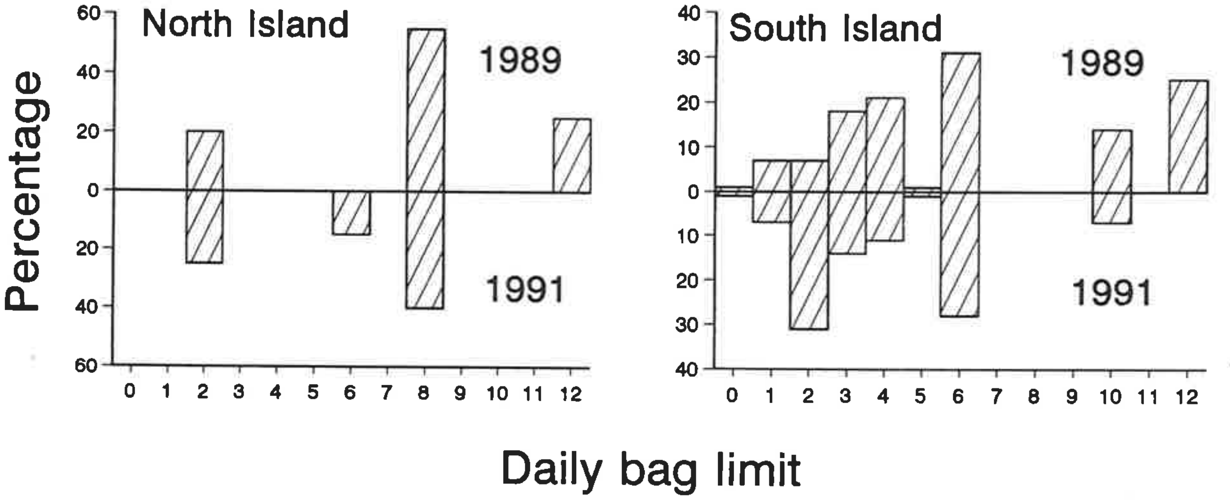

FIGURE 5. Comparison of daily bag limits for "A" list rivers, 1989 and 1991.

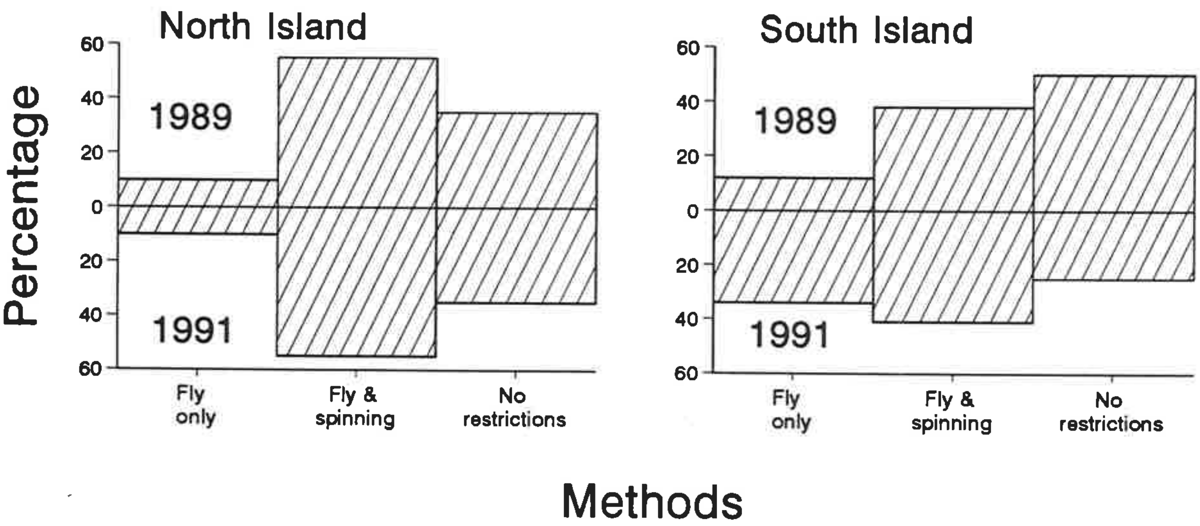

FIGURE 6. Comparison of fishing methods permitted in "A" list rivers, 1989 and 1991.

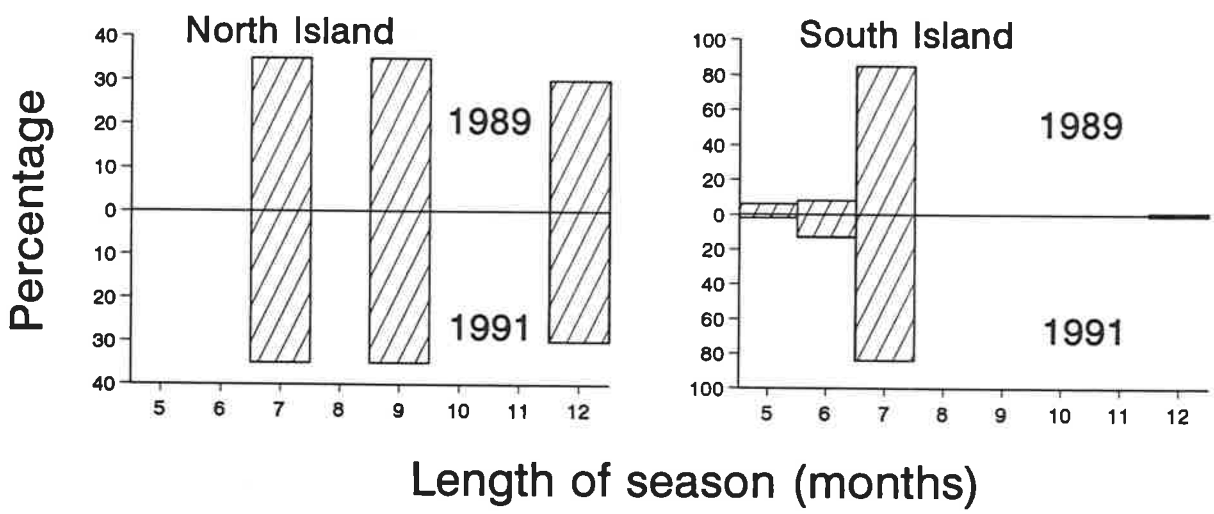

FIGURE 7. Comparison of season lengths for "A" list rivers, 1989 and 1991.

3.4.2 Angling methods

Although headwater rivers are usually considered the domain of experienced fly-fishers, the methods allowed in both islands are reasonably liberal. In the North Island, there were no net changes in permitted methods between 1989 and 1991 (Figure 6), with fly-fishing only confined to 10% of rivers. In contrast, methods permitted in South Island rivers had changed in favour of fly only rivers. Presumably this latter trend is directed towards reducing the overall fishing pressure on rivers. Historically, many Acclimatisation Societies have fielded vigorous debates about so-called incompatibility of fly fishing and spin fishing, and the alleged "exclusiveness" of reserving waters as "fly only". While it is outside the scope of this document to address current management philosophy, it is our understanding that fishery managers are moving towards liberalising method regulations where this is considered appropriate.

3.4.3 Length of season

Between 1989 and 1991, there had been little overall change in the distribution of the lengths of angling seasons for either island (Figure 7). Consequently the mean length of season remained virtually similar in both islands, while the North Island season averaged longer than the South Island season, i.e., North Island 1989 season averaged 9.2 months, and 1991 averaged 9.4 months; both the 1989 and 1991 South Island seasons averaged 6.9 months.

3.4.4 Catch rates

While catch rate is a useful statistic for comparing angler "success" between rivers, it must be interpreted with some caution. For instance, catch rate is often assumed to be directly proportional to population size; however, in a national review of angling diaries for 1947 - 1968, Graynoth (1974) found that a number of variables influenced catch rate, and catch rate was poorly correlated with fish density ($r = 0.45 - 0.73$). Previous to Graynoth's study, Allen and Cunningham (1957) had noted that variations in catch rate by up to a third may occur between seasons, without it being necessary to ascribe this to population fluctuations.

A major variable affecting catch rate is angler skill. Table 24 gives catch rates of a very experienced angler (Jim Ring, Nelson) for the lower Motueka River. It is apparent that catch rate has changed substantially as the angler has gained in both skill and experience. Catch rate can also vary during the angling season; this may be due to fish becoming increasingly wary as a result of fishing pressure, lower flows, and increased temperatures (section 3.3.2), but could also reflect declining stocks (as per the "B" list rivers of Table 4). Such a decline may not be due to excessive removal of fish, but rather to a seasonal movement of fish from smaller tributaries downstream to a lake or mainstem river. For example, diary information for the 1988/89 season from a guiding service operating in the upper Wanaka/Hawea catchments shows a steady decline in

TABLE 24. Variation in catch rate (and mean fish length and condition) for brown trout from the Motueka River below the Wangapeka River confluence. Data supplied by Jim Ring; excludes undersized fish.

Season	Fish caught	Fish per hour	Mean length (mm)	Mean condition
1965/66	164	0.91	414	1.33
1966/67	147	1.16	418	1.25
1967/68	274	1.34	408	1.13
1968/69	124	0.99	444	1.13
1969/70	166	0.93	455	1.44
1970/71	272	1.53	438	1.36
1971/72	178	1.37	422	1.27
1972/73	216	1.41	441	1.36
1973/74	155	1.37	443	1.44
1974/75	157	1.50	438	1.19
1975/76	173	1.52	421	1.27
1976/77	162	1.46	438	1.36
1977/78	157	1.67	443	1.41
1978/79	102	1.85	426	1.36
1979/80	49	1.26	427	1.30
1980/81	130	3.71	429	1.36
1981/82	113	2.35	412	1.41
1982/83	67	2.09	422	1.52
1983/84	157	4.03	424	1.44
1984/85	174	3.70	405	1.55
1985/86	193	5.36	405	1.49
1986/87	188	3.69	399	1.61
1987/88	275	6.88	396	1.30

fish/day during the season, i.e., November 4.6 fish/person/day; December 3.0; January 2.5; February 1.7; March 1.8. Likewise, creel census information for the Greenstone River (T.Kroos, Otago Fish and Game Council, pers. comm.) indicates an overall decline in catch rate during the season, i.e., November-December, mean = 0.80 fish/hr; January-February 0.76 fish/hr; March-April 0.29 fish/hr.

Catch rates in headwater rivers can be high, again depending upon angler skill, availability of fish, and environmental conditions. Results from 19 replies to an angler diary/questionnaire scheme run in the upper Karamea River (questionnaires, Appendix VIII, were left in several huts and completed ones forwarded by DOC staff) gave an average catch rate for the upper river and tributaries of 0.44 fish/hr, with a range of 0-2.1 fish/hr. Of the 620 fish seen, 136 were hooked, 91 landed, and 75 released. Brochures from guiding operations fishing Nelson and West Coast rivers indicate that a few skilled anglers are able to catch up to 25 fish/day (although 95%+ of all fish landed are reportedly released).

The Karamea River catch data referred to above gave a "success rate" of fish hooked:fish seen of 22%. For many anglers, especially those from overseas, use of a guide can enhance this rate. For instance, diary data for the 1987/88 and 1988/89 seasons were made available from a fishing guide also operating in the Nelson-West Coast region. Analysis showed that during this time, the guide and clients had "spotted" 2290 trout in fishable positions in 25 rivers, of which 1506 (66%) had been "touched or hooked" (i.e. had attempted to take a fly/nymph, whether or not they had actually become hooked); of these, 761 (50%) had been landed, and all but 17 released. The average weight of these fish was 1.93 kg (s.d.= 0.57 kg).

4. DISCUSSION

4.1 Characteristics of the fish stocks

4.1.1 Species distribution

Brown trout are widely distributed throughout New Zealand, being absent from only those waters where physical obstructions have prevented their invasion or where temperatures are too warm for natural reproduction to take place (McDowall 1990). In contrast, rainbows have a more limited distribution; in the South Island they are usually associated with large lakes and tributary rivers, while in the North Island they tend to be in the upper reaches of longer rivers like the Rangitikei, Mohaka, Ngaruroro, and Wanganui. Rainbows have a reputation for being the more "flamboyant" fighter and easier to catch; in waters where both species are present, proportionally more rainbows are caught than browns (e.g. Flain 1986, Pawson 1991). Browns are frequently described as "wary", requiring more skill and patience to catch.

4.1.2 Sex distribution

This is discussed in section 4.2.1 during consideration of seasonal movements of fish.

4.1.3 Size

Data on average sizes of angler caught trout for various water within New Zealand confirm that trout from headwater rivers are large compared with trout from lowland rivers in New Zealand (e.g., Allen and Cunningham 1957, Graynoth 1974, Scott 1987), and with overseas rivers (Scott 1987). From both the present study and a previous study of the Oreti River (Unwin 1980), there is evidence that average size increases with distance upstream. Although the definition of a "trophy" fish is open to interpretation, Mirfin (1991) records an experienced fishing guide from the Buller district, defining a trophy trout as 6 lb (2.7 kg) or greater (this would equate to an average length of 625 mm). In contrast, Graff (1984) defined a trophy wild trout in Missouri as exceeding 14 inches (355 mm).

4.1.4 Condition

Condition of trout was found to vary with both time (Table 13) and size (Table 15). However, while headwater trout are generally large fish, their average condition factor is not correspondingly high. For instance, NIWA data files contain length-weight relationships of trout from several studies within New Zealand; comparison of the regression coefficients (an index of condition) shows that headwater brown trout have a lower condition than fish from the other studies, while headwater rainbows were generally similar to fish from elsewhere.

Male brown trout have a comparatively low average coefficient of 2.53 (Table 14), indicating that they tend to be somewhat lean. This is not to imply that these fish are poorly conditioned, but rather that they are "trim". Certainly there is a proportion of poorly conditioned kelts (post-spawned fish) that are unlikely to regain condition (senior authors personal observation). Generally though, a post-spawning increase in condition would be anticipated for both sexes, especially males, as spawning is considered more debilitating for males than females (see section 4.2.1).

4.1.5 Age composition

There is little information available on the age of trout in other waters in New Zealand. Parrott (1936) gave the age composition of trout caught by anglers or trapped in 13 lowland rivers. Most of the fish caught ranged from two to seven years of age and the predominant age was three. Therefore headwater brown and rainbow trout, which have mean ages of 5.8 and 5.6 years, are, apparently, older than trout caught in lowland rivers.

In the low altitude Horokiwi Stream (Allen 1952), only 0.4% of yearling brown trout normally survived to age five and the last of these probably died at age seven. This assumes that about 80% of the yearling and older trout die each year. Therefore, unless mortality rates are very different, the brown trout caught by anglers in headwater rivers are the few, old surviving remnants of earlier year classes.

Differences between headwater rivers in age composition could be caused by actual differences in the trout population or possibly by the selection of certain sizes of fish by anglers. We suspect the presence of old trout in rivers such as the Owen, Mokihinui and Karamea is due to the lack of fishing pressure, and catch and release practices.

4.1.6 Growth rates

The methods developed for determining annuli and back-calculating growth rates from eroded trout scales, have not been independently tested and validated for New Zealand conditions. However there is some evidence that the results presented here are approximately correct.

Firstly, back-calculated growth rates of brown trout in the Oreti River (Table 18) are similar to those shown by trout tagged and later recaptured (Figure 4) in this river. Secondly the lengths of known age two- and three-year-old brown trout electric-fished from lowland Canterbury streams (Burnet 1968) and netted in the Horokiwi Stream (Allen 1951) are similar to those recorded in this study.

It is possible that the back-calculated lengths of trout at age one are too low. Brown and rainbow trout averaged 118 mm and 115 mm respectively, and there was little variation in length among rivers. Yearling brown trout caught by electric fishing are usually larger than these lengths and range from about 115 mm to 170 mm in mean length in August/September (Graynoth and Bloomberg 1990). It is possible some checks formed in the first summer of life have been misinterpreted as winter annuli (Burnet 1969)

Comparisons of growth rates from headwater rivers were made with rates recorded from trout in lakes (Hobbs 1948, Percival and Burnet 1963, Fish 1968, McCarter 1987, Graynoth *et al.* 1993a) and lowland rivers (Parrott 1932, 1936, Burnet 1968, Bloomberg *et al.* 1990, James and Bloomberg 1990). Three- to five-year old brown trout were larger than brown trout in five lowland rivers (South Branch, Hinds, Aparima, Hutt and Kakanui) but were smaller than trout in the Waitaki River. They were larger than trout from Lakes Brunner and Poerua, similar to trout from Benmore and Sumner but smaller than trout from Ellesmere and Coleridge.

Rainbow trout were larger at ages three to five than trout in Lakes Lyndon, Ngahewa, and Ngapouri, similar in size to fish in Lakes Roxburgh and Benmore but were smaller than fish in eight other lakes (Tarawera, Okataina, Rotoehu, Okaro, Alexandrina, Coleridge, Georgina and Ruataniwha) and the Waitaki River. Therefore, in headwater rivers, brown trout seem to grow slighter faster and rainbow trout slightly slower than trout in other waters in New Zealand.

Overall, there were few major differences in growth rates among headwater rivers and it is unwise to speculate on reasons for differences until the accuracy of the age and growth estimates is checked. Information is also needed on the movements and migrations of fish into these rivers, before the reasons for differences can be fully understood. For example, an exceptionally large (813 mm) rainbow trout was caught in the Lochy River during August 1989; as this fish was only five years old, it is likely that it was usually resident at the Queenstown wharf and had benefitted from the regular feeding that occurs there, but had entered the nearby Lochy River to spawn. Similarly the fast growing brown trout caught in the Pomahaka River may have lived in the lower Clutha or possibly the sea, while the slower growing fish remained resident in the Pomahaka.

4.1.7 Problems associated with estimation of age from scales

The use of scales to age trout in the present study has highlighted a number of problems. Firstly, a high proportion of scales are replacement scales, and are unreadable. Secondly, the marginal erosion that accompanies spawning can result in the loss of annuli, with a consequent under-estimate of total age and an over-estimate of back-calculated length at previous age. Thirdly, the scales are difficult to interpret.

Although the presence of replacement scales has been reported from previous aging studies of trout (e.g. Stokell 1955, Frost and Brown 1967), there do not appear to be any studies that discuss the incidence of scale loss. Accordingly, it is likely that scale loss is not much of a problem in most studies. Thus the levels recorded in the present study (48% and 14% of brown and rainbow samples) are considered to be high, probably reflecting the longevity of the fish, and the high rate of "wear and tear" associated with living in headwater reaches.

In the present study, the age read directly from the scales significantly under-estimated real age. As previously stated, it was not possible to reliably age fish older than nine years by the adjusted method. However, there is growing evidence from other studies that growth of large trout in New Zealand is slow, and ages of >10 years are possible.

For example, seven tagged brown trout from Lake Coleridge were found to be eight and 15 years old, whereas scale reading gave ages of 5-10 (Jellyman 1992b) growth rates for these fish averaged only 17 mm/year. James (1992) recorded two brown trout from Lake Pukaki that were a minimum of 11 years old and had only grown about 10 mm/year each. In March this year, drift divers in the upper Rangitikei River recorded four adipose-clipped brown trout (S.Smith, Wellington Fish and Game Council, pers. comm.) the latest that these fish could have been fin-clipped was 1984 when they were captured as at least 3-year-old fish on their spawning migration, meaning that they would be a minimum of 11 years old. Growth rates calculated for tagged brown trout from the upper Oreti River averaged 48 mm/year for 500 mm fish, but fell to 9 mm/year by 600 mm. Similarly, growth rates of tagged trout (mean 522 mm) from the Manganuioteao River were relatively slow, averaging 33 mm/year (Cudby and Strickland 1986).

The extent to which previous life-history information is lost from scales is of particular concern for age and growth studies. Trout are classically aged from scales (e.g., Frost and Brown 1967), although the subjective nature of scale aging is well known (Mann and Steinmetz 1985). As pointed out by Beamish and McFarlane (1983), true age validation studies have been performed for few freshwater or marine species. In such a validation study of scale aging for rainbow trout in Tasmania, Davies and Sloane (1986) reported the difficulty of aging trout beyond year four due to close spacing of annuli, and scale resorption; however, for a fast growing lake population (Davies and Sloane 1987), they were able to validate scale aging for fish to four years of age. Likewise Faragher (1992) validated scale aging for rainbow trout up to three years old in lake Eucumbene, New South Wales, but experienced difficulty beyond that age when growth became asymptotic.

Other researchers have reported difficulty in aging trout from scales. For example, Hesthagen (1985) experienced difficulty with aging brown trout beyond their fifth year as scale zonation became indistinct. Mature brown trout were found to have considerably fewer zones in their scales than were immature trout of the same age (Jonsson 1976). A recent study in a Norwegian lake extended the maximum recorded age for brown trout to 38 years (Svalastog 1991); this study used otoliths to age two large trout, and noted that with slow growth (less than 1-1.5 cm per year), no annuli are formed in brown trout scales. In the face of such adverse comment on the ability to successfully age large trout from scales, it is interesting that many studies, including the present one, have persisted with the use of scales. The reason is usually one of convenience of collection. Also, in the present case, the alternative technique is to use otoliths, which would have required killing large numbers of fish.

Research is planned to test methods of aging trout over the next few years. Additional unbiased samples of yearling and two-year-olds will be collected and the use of otoliths and other methods of aging trout examined.

4.1.8 Benthic invertebrates

As headwater rivers have relatively high proportions of large trout, it is of interest to compare the invertebrate densities with those of other rivers (Table 25). Large, unstable rivers (Rakaia, Rangitata) typically have low densities compared with stable streams (e.g., Glenariffe). Compared with other results for the Oreti, the density found during the present study was particularly high, and probably reflects the lengthy period of stable flows prior to collection of the samples. Densities for both the Wairau and Karamea are close to the average for the 88 rivers studied by Quinn and Hickey (1990). From these limited data, there is no suggestion that the invertebrate fauna of headwater rivers is especially abundant, certainly not to the extent that would provide enhanced growing conditions relative to the rest of the same river, or other rivers.

TABLE 25. Densities of benthic invertebrates recorded in New Zealand rivers. Brackets indicate number of sites as number of samples was not given.

River	No. samples	Mean	Range	Reference
Wairau	3	2805	1610-4430	this study
Wairau	(1)	1592	270-3980	Stark 1991
Motueka	(23)	3611	187-11430	Stark 1991
Whakapapa	15	1928	623-3540	Richardson and Teirney 1982
Horokiwi Stream	162	4151	514-8449	Allen 1951
Rakaia at gorge	12	647	90-2840	Sagar 1983
Glenariffe Stream, upper	13	4175	2030-8973	Sagar 1983
Glenariffe Stream, lower	13	3452	1543-5950	Sagar 1983
Rangitata above gorge	7	1917	733-6047	Bonnett 1986
Ahuriri River	19	2036	352-5988	Jellyman *et al.* 1982
Ahuriri River tributaries	4	3564	1577-5398	Jellyman *et al.* 1982
Karamea	3	2974	1800-4430	this study
Clutha	21	1451	61-7982	Biggs and Shand 1987
Mataura	147	3533	528-9952	Witherow and Scott 1984
Mataura	83	2858	2110-3520	Boud and Cudby 1965
Oreti	3	5957	4840-7370	this study
Oreti above Mossburn	20	1148	-	MacDonald 1960
Oreti above Gibraltar Rock	3	2400	-	MacDonald 1960
Oreti above Rocky Point	20	2196	-	Boud *et al.* 1962
88 New Zealand rivers	616	2874	10-29796	Quinn and Hickey 1990, in Stark 1991

It is generally acknowledged that in North American flowing water habitats, trout predation is unlikely to impact on invertebrate prey to the extent that this could limit growth or survival of the trout themselves (Fausch 1992). Evidence from New Zealand waterways does not support this. For instance Allen (1952) concluded that competition for food limited the growth of trout in the Horokiwi Stream. More recently, Jowett (1992) found that the biomass of benthic invertebrates was the single most important factor in determining abundance of brown trout in New Zealand rivers; invertebrate biomass alone accounted for 45% of the variation in trout abundance, and in combination with adult drift-feeding habitat, accounted for 64%.

4.1.9 Feeding

Diet of headwater trout was not studied during the present survey. The only specific study on diet in headwater trout (McLennan and MacMillan 1984) stated that both brown and rainbow trout feed primarily from the invertebrate drift. These authors considered that browse-feeding was probably particularly important in rivers with poor visibility and/or little current. Observations on feeding habitat occupied by trout in New Zealand rivers (Shirvell and Dungey 1983, Hayes 1991) have shown that habitat occupied is consistent with drift feeding. Further, Hayes and Jowett (in press) record that all the trout he observed in the Travers and Mohaka Rivers, and 84% of those in the Mataura River, were drift feeding; of these Mataura trout, 37% were feeding on surface drift (mayfly and caddis adults, and scarab beetles) with the remainder feeding on drift within the water column.

Trout spend most of their time during daylight, in a position sheltered from the main current, from where they can move out into faster water to intercept drift fauna (Hayes 1991). Brown trout seem especially adept at taking advantage of low velocity areas both in front of and behind boulders, and at the "eye" of a pool (an area of reduced current adjacent to the main flow at the top of a pool) (Hill and Marshall 1985), which allows them to maximise the amount of food they intercept for the least amount of energy expended.

While trout in some back-country rivers are known to take such large prey items as mice (Dixon-Didier 1983), and Paradise Duck ducklings (J.Ring, pers. comm.) the supply of such food will be intermittent. Brown trout especially have a reputation for being opportunist feeders, and will take advantage of such food sources, although their primary food will still be drifting benthic invertebrates (McLennan and MacMillan 1984). This is not to downgrade the importance of terrestrial food, which can be extremely important in some catchments, especially towards the end of summer when increased condition is advantageous to trout prior to spawning. Such terrestrial foods as wasps, cicadas, brown beetles, Manuka beetles, and willow grubs are important seasonally-available food. Although caddis larvae and mayfly nymphs were the main prey items of both brown and rainbow trout in the Mohaka River (McLennan and MacMillan 1984), terrestrial insects increased in importance during summer.

Confirmation of the importance of column drift comes from the variety of angling books about trout fishing in New Zealand, where nymph fishing which mimics column drift, is the primary technique advocated (e.g., Orman 1974, Marsh 1983, Hill and Marshall 1985). That headwater trout will also take larger prey items like small fish, crickets, beetles, and even mice, is well known; threadline fishing using lures that imitate small fish can be a very effective angling technique (Hill and Marshall 1985). However, as mentioned previously and in the following quote, such food is taken on an opportunistic basis - more an entree than a main course "..while trout may sometimes take crayfish, small fish or terrestrial food, the opportunity for such morsels is not always available. The chance to take nymphal larvae is." (Orman 1974).

In a theoretical approach to trout feeding in North America, Bachman (1981) proposed that larger trout were forced to adopt a piscivorous diet, simply because they could not derive sufficient energy from invertebrate drift. In reviewing several diet studies of brown trout in North America, Clapp *et al.* (1990) noted that "brown trout tend to shift their primary food source from insects to fish at about... 350 - 400 mm". Seemingly then, in North American rivers, the presence of larger piscivorous trout is a factor which could influence the availability of juvenile trout, although there is also a wide range of other "forage fish" species potentially available.

New Zealand headwater rivers are typified by low numbers of sub-adult and juvenile trout. While it is assumed that this is primarily a reflection of a comparative lack of suitable cover and the hydraulic "robustness" of headwater areas, it may also be due to the predatory nature of large trout. During daylight, large trout in New Zealand rivers will normally occupy drift-feeding habitat, but at night, like their North American counterparts (Clapp *et al.* 1990) they are likely to be more mobile, including moving to shallower water in search of any juvenile fish. Trout are adept at night-time feeding as their eyes are adapted to function in very low light levels; and brown trout have been found to feed at levels equivalent to starlight (Behnke 1987). In contrast to North America where there is much richer freshwater fish fauna, opportunities for piscivory in upland reaches of New Zealand rivers would be very limited, as the few native species of these areas are small and cryptic (McDowall 1990). The presence of large predatory trout would be an added incentive for juvenile trout to vacate upstream areas.

New Zealand headwater trout are able to derive a livelihood by feeding on invertebrate drift, something that large North American trout seem unable to do. Why this should be is not obvious, but may have to do with such factors as the density of drift, the relative proportions of large items in the drift, availability of many of our common invertebrates throughout the year, the high proportion of gravel habitat in New Zealand river-beds, general steepness with a consequent high proportion of riffles, the length of the growing season, and genetic selection in favour of more rapid growth. For example, although Scott (1987) considered that invertebrate production in New Zealand freshwaters was similar to that recorded from Britain and North America, a comparison of drift rates of aquatic macroinvertebrates between New Zealand (Collier and Wakelin 1992) and overseas rivers (Cellot 1989), indicates that rates in New Zealand are substantially higher; further, New Zealand aquatic invertebrates have poorly synchronised life-histories, meaning that most life-history stages of most species are available all year round (Towns 1985). Comparing growth rates of Horokiwi brown trout with those raised under experimental conditions in Britain, Allen (1985) concluded that "It is possible that there has been genetic selection for more rapid growth and a higher temperature limit in the Horokiwi trout". Whatever the reason(s), while large headwater trout in New Zealand can exist on an invertebrate diet, their growth rates are not fast relative to smaller fish.

Size-hierarchy feeding strategies are common among trout stocks (e.g., Bachman 1984, McLennan and

McMillan 1984). Thus a large fish will occupy the prime feeding position in a pool (Hill and Marshall 1985) with subordinate fish relegated to progressively less desirable sites. However, during a substantial emergence of invertebrates, territory boundaries become less vigorously defended, and trout feed in much closer proximity than normal. This strategy enables a much more efficient utilisation of available food, with virtually no expenditure of energy spent in defence of territory. When trout are actively feeding on a "hatch", they appear less wary than normal, and are thus more vulnerable to anglers. It has been the observation of the senior author that large trout will often move to much shallower positions in a pool under cover of darkness; presumably such positions, notably at the tail of a pool, are too "exposed" to occupy during the day, but darkness engenders a greater sense of security. Bachman (1984) refers to the likelihood of such behaviour, although he did not observe it in the small stream he monitored.

4.1.10 Differentiation of stocks

Within a particular river system, there is evidence that headwater trout are large fish from a single riverine population. Thus, growth rates of headwater fish are similar to rates elsewhere in the same river, and headwater reaches have low proportions of small and medium sized fish, meaning that extensive within-river movements are probable.

There have been no meristic or biochemical studies of New Zealand trout stocks to see whether separate strains have differentiated during the one hundred or so years that both species have been present. Given the findings of Krueger and May (1987) that brown trout introduced into Lake Superior in the early 1900s have since differentiated into genetically and behaviourally distinct populations, then it is highly likely that a similar process has taken place within New Zealand. However, given their ability for anadromous migration and inter-catchment movement (Cudby and Strickland 1986, Davis *et al.* 1983), brown trout will be less likely to show formation of genetically discrete stocks, except for populations that have been established in locations where they are physically isolated, e.g., stocks in some inland lakes, and above non-negotiable waterfalls.

Because of their more disjunct distribution and apparent inability to migrate via the sea, rainbow trout are more liable to show genetic differences between populations, with some differences exhibiting as behavioural ones. For instance, although rainbow trout are autumn-winter spawners, summer spawning runs of rainbows are known (McDowall 1990). Also, in a study of natal stream rearing of juvenile rainbow trout in tributaries of Lake Taupo, Rosenau (1991) found differences in age and size at emigration, although it seems he considered that these were a explicable in terms of physical differences in rearing habitat. If there are genetic differences between rainbow trout populations for such features as age at first spawning, longevity, and migratory movements, then this has implications for management, because extensive stocking by hatchery reared juveniles could "swamp" or at least dilute such locally adapted characteristics.

4.2 Behaviour of the fish

4.2.1 Seasonal movements

4.2.1.1 Movements within freshwater

A number of New Zealand studies have shown that brown trout, especially, show restricted movements outside the spawning season. For example, a high incidence of non-movement of large brown trout has been recorded from the Wairaki River, Southland, where all 10 recaptures of tagged trout were within 100 m of the tagging site (Southland Fish and Game Council 1991). Similarly, recaptures of tagged brown trout in the Waitaki River were made close to the tagging site (Palmer 1987).

Such persistence of home range is also known from overseas studies (e.g., Solomon and Templeton 1976) but appears at variance with the observations of Clapp *et al.* (1990) that large radio-tagged brown trout in Michigan appeared to have separate summer and winter ranges, often many kilometres apart; however, their observations are explicable in terms of trout avoiding seasonal temperature extremes.

Of course, there may be unobserved short-term movements between recaptures. Thus Clapp *et al.* (1990) noted diurnal differences in habitats occupied by large (437-635 mm) brown trout in a Michigan stream, with fish moving to midstream to forage at night, but returning to cover at specific sites during the day. Bachman (1984) found that the home range of brown trout in a stable spring-fed stream, became established within the first two years of life, and changed little thereafter; within their home range, trout used both foraging and refuge sites, often for year after year. Foraging sites were occupied very precisely, indicating the importance of choosing sites where swimming energy was minimised. Such precise positioning meant that only one fish could occupy such a site at any one time, although more than one fish might flee to the same refuge site when disturbed. Considerable overlap existed in the home ranges of neighbouring fish.

Results to date for recaptured tagged brown trout from the Oreti River, indicate that most large fish establish a home range which they may occupy from year to year. For the proportion of fish that had moved significantly (>1 km) from their tagging site (17%), most had moved upstream, and the average distance moved upstream exceeded that moved downstream. Thus, while the majority of adult trout are sedentary, there is limited evidence that a small proportion are more mobile and show net upstream movement. It is postulated that most substantial movement occurs during spawning migrations, and that, having arrived and taken up residence in upstream areas, trout may retain this territory for a number of years. As well as such periods of extensive movement, the Oreti data suggest that there is a gradual upstream movement going on at times other than the spawning season. Of course, the passage of a substantial flood could alter the configuration of the river, with consequent redistribution of fish, although largest fish will be least affected (Allen 1951, Jowett and Richardson 1989).

The onset of the spawning season may require some headwater trout to move upstream to suitable spawning water. For unstable East Coast braided rivers, there would be a strong selection pressure for trout to migrate from the mainstem river to stable spring-fed tributaries like the Glenariffe Stream. However, it is generally accepted that brown trout do not undergo extensive spawning migrations if suitable water is available locally (Hicks and Watson 1985, Mense 1975, Jackson 1980, Harcup *et al.* 1984). Also, as spawning migrations of trout are almost invariably upstream, there is often limited distance available for such movements anyway. Rainbows however, are a more migratory species, and in a study in the Rangitikei River (Hicks and Watson 1985), it was suggested that rainbows moved greater distances on spawning migrations than did brown trout. A similar observation has been made in the Yellowstone River, Montana (Swedberg 1980).

Movements of trout during the spawning season represent a directed upstream movement as opposed to the more individual movements of fish outside of the spawning season. As spawning migrations have been hypothesised as the primary time of recruitment of large fish to upstream areas, some consideration of the arrival patterns of the sexes at the spawning grounds, and the subsequent dispersal and recapture of these fish is of considerable interest.

Overseas studies show that spawning migrations of both species of trout are typically dominated by females (e.g., Davies and Sloane 1987), although there are some exceptions (e.g., Maisse and Bagliniere 1990). A review of New Zealand data shows a similar trend (Table 26), with the exception of the Waitaki catchment where lower river tributaries and the Tekapo River show a 1:1 sex ratio, but tributaries of the Tekapo River itself show a dominance of males. Why the Waitaki Catchment should be so different to elsewhere is not known. In comparison, in the Glenariffe Stream, the sex ratio of spawning chinook salmon, (*Oncorhynchus tshawytscha*), a species often coexisting with trout, is exactly 1:1 (data from Flain, 1982).

Two reasons are put forward to explain why spawning runs typically contain fewer males. Firstly, in most upstream areas, there will already be more males than females present. Secondly, males probably experience a higher post-spawning mortality than females. Several factors may contribute to this. From trapping of spawning runs of trout in New Zealand, it is known that males precede females onto spawning grounds, (e.g., Frost 1985, Webb *et al.* 1991), and stay longer. Although females lose proportionately more of their body weight at spawning, they do so over a shorter period, and are then able to leave the spawning grounds, migrate downstream, and commence regaining condition. Males however, remain on the spawning grounds, where they are often involved in disputes over both territory and pairing with females; this aggressive behaviour, combined with the fact that they do not feed much during spawning, means that the process is a particularly debilitating one for males, with the likelihood of significant post-spawning mortality.

As the present survey has shown that males dominate headwater populations of brown trout, it follows that more females than males must migrate downstream after spawning. Some indication of this comes from the number of spawned trout recovered from the upstream side of a trap in the Tekapo River (S. Bloomberg pers. comm.) where twice as many females as males were caught although numbers of both sexes moving upstream were almost equal. Unfortunately, there is little published information on migrations of spent fish in New Zealand rivers.

There are some records of post-spawning distribution of brown trout in New Zealand. Davis *et al.* (1983) reported on the recapture of 101 brown trout tagged at the Glenariffe salmon trap; 71 fish were recaptured at the trap on a subsequent spawning occasion, seven were recaptured in another catchment, six were recaptured in the Rakaia mainstem, and 16 were recaptured in the Rakaia lagoon. Since then, other fish have been

TABLE 26. Sex composition of trout recorded during spawning migrations.

River	Year	Brown trout % male	Brown trout *n*	Rainbow trout % male	Rainbow trout *n*	Reference
Mill Creek, Lake Hayes	1958-61	34	10419	-	-	Ulberg 1961
Pigeon Creek, Lake Brunner	1963	34	199	-	-	Cudby and Moore 1965
Evans River, Lake Brunner	1987-89	47	1642	-	-	West Coast Acclimatisation Society 1989
Orawia River, Waiau River	1964	35	1022	-	-	Galloway and Cudby 1965
Lake Alexandrina	1962	38	214	37	3372	Moore *et al.* n.d.
Scotts Ck, L. Alexandrina	1980	32	62	35	2860	Hayes 1987
Selwyn River	1941-85	31	65352	-	-	Hardy 1989
Ngongotaha St., L. Rotorua	1985-89	35	9993	35	19442	Cudby and Strickland 1986
Wairehu St., L. Rotoaira	1974	-	-	37	7294	Cudby and Strickland 1986
Tokaanu River, Lake Taupo	1976-78	-	-	36	5988	Cudby and Strickland 1986
Waihukahuka St., L. Taupo	1976-78	-	-	33	6944	Cudby and Strickland 1986
Orautoha, Manganuioteao	1980	35	152	42	64	Cudby and Strickland 1986
Mary Burn, Tekapo River	1980-82	71	583	63	292	NIWA unpublished data
Grays River, Tekapo River	1983	75	94	75	4	NIWA unpublished data
Tekapo River	1981-83	52	2010	55	521	NIWA unpublished data
Ohau River	1984	31	400	34	89	Graynoth 1993a
Hakataramea R., Waitaki R.	1981-83	48	657	48	456	Webb *et al.* 1991
Maerewhenua R., Waitaki R.	1981-82	47	315	52	117	Webb *et al.* 1991
Welcome Stream Waitaki R.	1981-82	52	197	-	-	Webb *et al.* 1991
Awakino River, Waitaki R.	1987-89	-	-	39	1556	Bloomberg *et al.* 1990
Glenariffe Stream, Rakaia R.	1965-91	48	3942	46	95	MAF Fisheries unpubl. data

captured from the Glenariffe Stream upstream of the trap itself. So, although the bulk of spawning fish later leave this stream, some do stay and take up residence. Further analysis of these data would be of interest to see whether a higher proportion of females than males have been recaptured from downstream areas.

Similar results were obtained from recaptures of large brown trout caught and tagged while on their spawning migration in the upper Wairau River (Frost 1985). Of 72 trout tagged (mean length approximately 590 mm), a total of 16 were recaptured. Of these, 11 males were caught upstream of the trap, and the remaining five (four males, one female) were caught at distances up to 48 km downstream.

Post-spawning migration is particularly significant in some of the shorter tributaries of some southern high country lakes. Rainbow trout especially are known to drop downstream and re-enter the lake. Kroos (1992) records that the number of rainbow trout in a 12 km reach of the upper and middle Greenstone River declined 55% between October and December as fish migrated downstream to Lake Wakatipu, and this migration continued during the summer.

4.2.1.2 Anadromous movement

Since New Zealand rainbow trout originated in California (although the actual source is in doubt, McDowall 1990), it was a reasonable expectation that sea-run rainbows, "steelhead", would establish in New Zealand. Although there have been periodic reports of such fish, mainly from Hawkes Bay rivers (McDowall 1990), there has been no compelling evidence that steelhead stocks ever established within New Zealand. Scott (1985) hypothesised that the probability of salmonids becoming established within New Zealand was inversely proportional to the migration distance undertaken by the parent stock. In their native range, steelhead move extensive distances offshore (Hartt 1980) meaning that the likelihood of this species establishing in New Zealand could be considered to be low.

However, New Zealand does have stocks of brown trout that go to sea and there are several accounts of tagged fish being recaptured considerable distances from their original tagging site. Thus, Burnet *et al.* (1969) record a brown trout tagged in the Selwyn River being recaptured in the Mataura River, a distance of some 500 km; similar out-of-catchment movement has been noted by Davis *et al.* (1983), and Cudby and Strickland (1986). Although South Island anglers catch considerable numbers of brown trout at river mouths and estuaries, the extent to which these fish actually go to sea as opposed to living within the estuary is unknown. Fisheries investigations of South Island lagoons/estuaries have shown considerable numbers of brown trout to be present (Rakaia River, Eldon and Greager 1983; Waimakariri River, Eldon and Kelly 1985; Waitaki River, Deverall 1986), and growth rates of trout in these areas can be rapid (e.g., brown trout in the Rakaia lagoon averaged about 100 mm/year; Eldon and Greager, 1983), as they exploit seasonally available species such as Stokell's Smelt.

In addition to such apparently estuarine dwelling trout, there are other stocks of brown trout in New Zealand that spend varying portions of their lives at sea. Among freshwater fish, adoption of a sea-going (anadromous) life-history tends to increase with increasing latitude (McDowall 1988) as fish leave the colder freshwater and take advantage of the warmer water and longer growing season provided by the sea. Consistent with this trend, the best-known populations of sea-trout in New Zealand come from the south of the South Island, from rivers such as the Pomahaka and Shag.

The annual spawning run of trout into the Pomahaka River was trapped by the Otago Acclimatisation Society from 1977 to 1981. Scott (1981) indicated that it was possible to distinguish between the two groups of fish using colour and body shape, sea-run fish having a smaller head and mouth, and silvery flanks. The average size of sea-run fish, 585 mm, exceeded that of resident fish, 457 mm (Scott 1981). The scales of fresh sea-run fish are very deciduous and easily dislodged, whereas those of riverine fish, especially males, are much more embedded and difficult to detach.

As well as being distinguishable from riverine trout on descriptive grounds, sea-run trout appear to behave differently. They show a marked tendency to shoal; they also migrate upstream earlier than resident trout. Figure 8 shows a shoal of about 65 large brown trout (1.8 - 4.1 kg) photographed in the upper Pomahaka River by Neil McDonald, Tapanui on 25 May 1992. Shoal formation seems characteristic of sea-run fish, and Petrie (1987) describes how the schools often mill around with a circular motion; when disturbed, the fish disperse rapidly, but unlike riverine fish, they then slowly reform their school. Newly arrived fish are described as "extremely shy" and invariably have empty stomachs (Petrie 1987). From the Pomahaka trap data (Scott 1981), there appear to be two migration periods, November-December, and April. This timing is confirmed by Petrie (1987).

While it is possible to distinguish between riverine and anadromous fish from the chemical composition of their otoliths (Kalish 1990), a detailed study has not been carried out for New Zealand stocks to date. Preliminary work by Knowles (1979) showed that there was a discernible difference in the amount of strontium in scales of the two groups, but he was unable to find a relationship between the amount of this element and the length of time assumed spent at sea (as determined from scale reading). From a previous study of trout in the lower Clutha River (Pack and Jellyman 1988), no consistent pattern was found for the age at which sea-run brown trout went to sea, or the length of time that they spent there.

Based on the proportional width of scale annuli, only 1% of scales examined appeared to be from sea-run trout, and all of these came from the Pomahaka River. From this preliminary observation, it does not appear that sea-run trout make a substantial contribution to headwater stocks, although there are obviously exceptions to this statement, like the upper Pomahaka River.

4.2.2 Effects of angling on fish behaviour

From the replies to the questionnaire on behaviour, it was possible to distinguish two different responses by fish to being disturbed. The first was that fish in remote and seldom-fished locations take longer to settle than do fish subject to more frequent disturbances in more heavily fished rivers. Similarly, Bachman (1989) recorded that trout in heavily fished catch and release areas were much less affected by the presence of anglers than were fish in areas subject to less angling. The second response noted was that, with repeated disturbance, fish may resume feeding at progressively

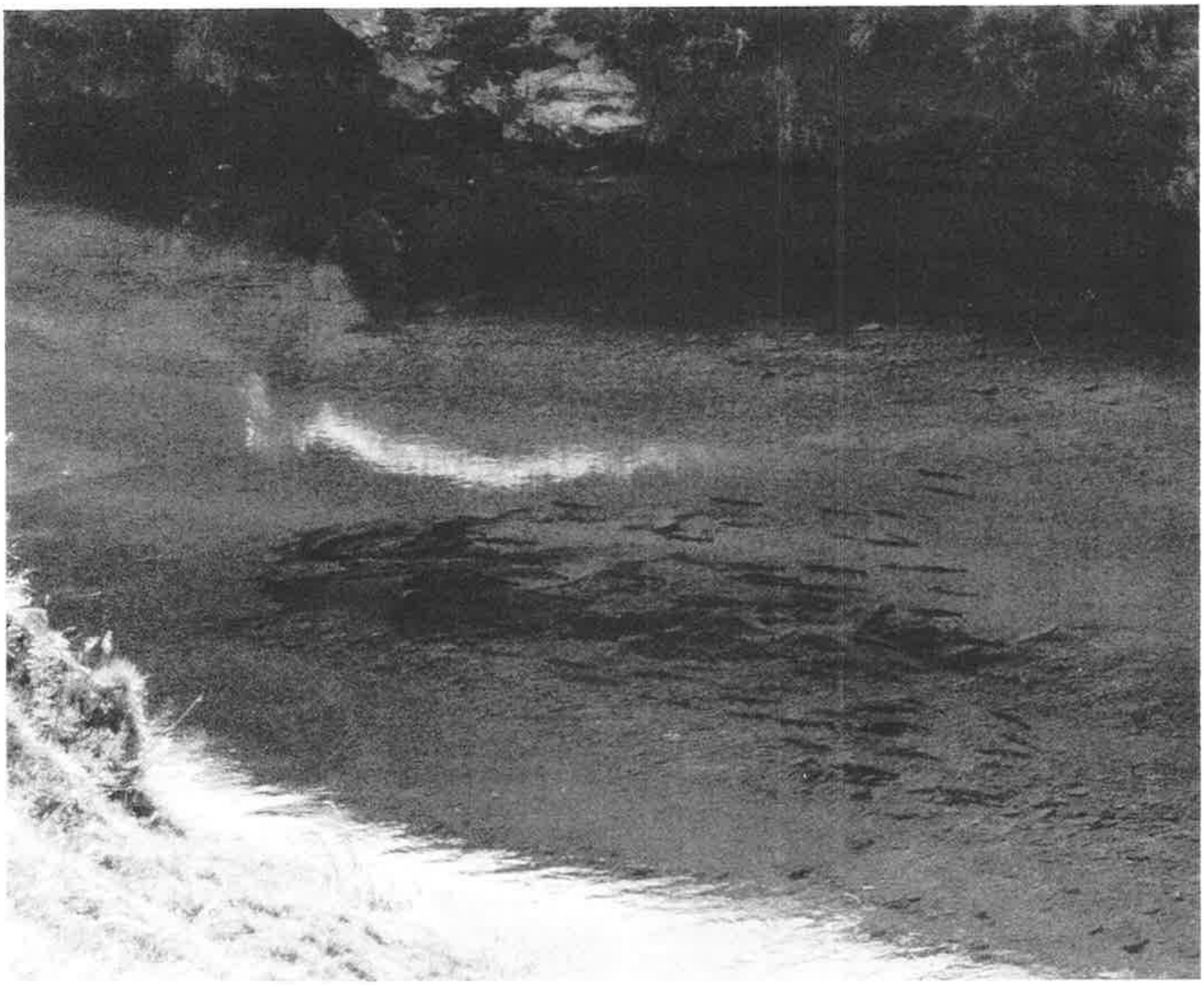

FIGURE 8. A school of about 65 large brown trout (1.8-4.1 kg) in the upper Pomahaka River, 25 May 1991. (Photo: Neil McDonald, Tapanui)

shorter intervals during the season, but the net result is that they become increasingly wary and more difficult to catch. In a comparison of the relative catchability of brown and rainbow trout in a put-and-take lake fishery in England, Pawson (1991) concluded that brown trout were less catchable than rainbows, and browns became less vulnerable to fly fishing with increased residence in the fishery.

Questionnaire respondents indicated that catch rates also declined as flows decreased and water temperatures increased during summer. Support for this statement comes from a study of the effect of temperature on catch rates of both brown and rainbow trout (McMichael and Kaya 1991) where it was found that catch rates tended to decrease with increasing temperature (range 8-25°C), but at temperatures of 19°C and above, catch rates were considered unsatisfactory. Given the influence of temperature, it would be interesting to observe seasonal "catchability" of trout in a stable, spring-fed system, with relatively constant flow and temperature.

There was a strong suggestion in the replies that fish today take longer to settle than in former times. This in turn implies some learning over a fish's lifetime, as suggested by Hill (1987, 1990a). At the beginning of a new angling season, an individual fish will be more "catchable" than at the end of the previous season; however, that fish may become progressively more wary each season. There is little scientific information available about the length of time that trout can retain learned behaviour, but in reviewing experiments on feeding behaviour, Fausch (1991) noted that trout could "remember" for at least three weeks, but apparently "forgot" within three months.

4.3 Characteristics of the fishery

4.3.1 Bag limits

The effectiveness of daily bag limits as a means of stock conservation was extensively reviewed by Allen (1955), and Allen and Cunningham (1957). To quote from the latter study "In general, existing bag limits have no significant effect on angler's catches or on the conservation of fish stocks". However, these studies were primarily concerned with lowland rivers, and bag limits were high by today's standards (mean 13.2; range 5-20). It can be reasonably argued that conservative bag limits on headwater rivers have the effect of conserving stocks (as per the example in section 4.3.4) and, in the case of smaller rivers ("B" list rivers), ensuring that the available fish are available over a longer period. The comparison of regulations between 1989 and 1991 indicated that bag limits for headwater rivers were becoming more conservative.

It seems that the opportunity to catch a trophy-sized fish is a significant part of the attraction of headwater fisheries. However, growth rate data in the present report indicate that most trophy fish will be relatively old, say 10 years or more. If it is decided to manage a fishery to ensure the availability of trophy fish, then very conservative bag limits need to be imposed. Rivers without a lake in the catchment would seem to be particularly vulnerable, as lakes can act as a "reservoir" of large fish which can contribute to headwater stocks.

Catch and release is widely practised in North America (Graff 1987) and is gaining in popularity within New Zealand, especially among guides. Although McDowall (1984) considers much of the advocacy for catch and release is based on "sheer snobbery", he also concedes that there are situations, like headwater fisheries, where it is a useful management strategy. Like the age-old controversy of whether fly fishing and spin fishing are incompatible, catch and release is an issue that similarly polarises anglers: "Perhaps no other issue in trout fishing is more clouded by controversy, prejudice, emotionalism and truth-obscuring myth than the concept of catch-and-release" (Harris, 1987).

From diaries of guides fishing in Nelson-West Coast rivers during the 1987/88-1988/89 seasons, Mirfin (1991) found that of 2223 trout landed by clients, 96.4% were released. Similarly, Orman (1991) quotes catch and release figures of 96.9-98% for the Lake Rotorua Lodge, for the 1984/85-1989/90 seasons. In a survey of angler use and opinion in the Wellington Acclimatisation Society district, Smith (1989), participants were asked whether they were in favour of restricted areas being set aside for catch and release. Of the replies (227), 52% were in favour, 45% were against, and 3% had no opinion. Smith commented that while support was clearly inconclusive, the support for the concept was "quite surprising".

The increasing popularity of catch and release has prompted some research into the well-being of released fish. A recent study (Ferguson and Tufts 1992) has implications for the way that fish are handled prior to release. In this study, exhausted rainbow trout were exposed to the air for 30-60 seconds, being equivalent to the times that captured trout are often exposed to the air for photography (in the case of angling) or for identification and sorting, in the case of North American commercial fisheries. Results showed that 12 hours after release, survival of fish was 62% and 28% for fish exposed to the air for 30 seconds and 60 seconds respectively. Seemingly, the critical period for the fish to start metabolising some of the waste products that have accumulated due to exercise, is the period immediately following capture; however, if the fish is removed from the water at this stage, the delicate lamellae of the gills collapse, meaning that gaseous exchange is seriously inhibited. Obviously then, to ensure a high survival rate for released trout, the time that fish are held out of water should be minimised. This would especially apply to rainbows which are usually exhausted when landed, but would also apply to large brown trout that have been played for a long time on light tackle.

Catch and release is obviously a useful technique in maintaining fish stocks in areas where populations are low and/or harvest is potentially high; given the difference in catchability between the two species, it is more effective in rainbow trout fisheries than in brown trout fisheries (Varley 1980). However, it is wrong to assume that any harvest is detrimental to a population. Ideally, the rate of harvest should be set at the rate of natural mortality; in practice this is seldom achievable as rates of natural mortality are not static.

If it is considered desirable from a management viewpoint to maximise numbers of trout, then some culling of larger trout is advantageous; a given amount of food might support two medium sized fish but only one large fish. Also, with increasing size, trout become less efficient users of food (Bachman 1989); with growth it takes more energy to capture the same piece of food, and the maintenance requirements of larger fish exceed those of smaller fish. Therefore, unless a fish can compensate by collecting more food or food of higher energy content, then its growth rate will decline. So, catch and release can be used as a technique to manage trout numbers. Interestingly though, it might be expected that growth rates of trout could be changed by altering population densities. In practice, growth rates of trout in given streams and rivers have remained remarkably constant over time, even in heavily exploited stocks (e.g., McFadden *et al.* 1967); exceptions would be the rapid growth that usually occurs when trout are first introduced into a catchment.

It is sometimes assumed that no-harvest fisheries are also warranted from the viewpoint of genetics - that if size and growth rates are genetically influenced, then killing the biggest and presumably fastest growing fish will result in a breeding population of "runts". However, as pointed out by Behnke (1989), the biggest and oldest trout in any population will probably have already spawned at least once, and so passed on any fast-growing hereditary characters to their progeny. The situation would be different for species like Pacific salmon though, as these spawn only once and size-selective mortality could result in an earlier age and smaller size at maturity.

A consequence of catch and release is that fish that have been caught will be more difficult to catch subsequently (Hill 1990a). An experiment to determine avoidance of recapture in rainbow trout (Lewynsky and Bjornn 1987) concluded that the fish showed definite hook avoidance, although the length of memory may have been only 3-4 weeks. In a comparison of recapture rates of fly-caught brown and rainbow trout, Favro *et al.* 1986 found that the probability of recapture for both species decreased with increasing time in the fishery, but the recapture rate of brown trout increased rapidly with increasing length, while the rate for rainbows was independent of length. Given the reputation that large brown trout have for being "wily" and difficult to catch, it would have been expected that the recapture rate would have declined with increasing length.

4.3.2 Angling methods

One argument often put forward for excluding spin fishing from some areas is that multiple hooks result in far greater damage to fish than single hooks; consequently, if such fish are released after capture, they will be subject to a higher mortality than would fish caught on single hooks. Although this sounds a plausible argument, it is not supported from research (Wydoski 1977). However, it is true that fish caught on single hooks can often be released more rapidly than fish caught on multiple hooks, while the use of barbless hooks facilitates even quicker release and is gaining wider acceptance among serious anglers.

4.3.3 Length of season

Important factors in determining the appropriate length of the fishing season is the timing of the spawning season, and the amount of time required for post-spawned fish (kelts) to recover condition. The spawning season is more a problem associated with rainbow trout fisheries as this species spawns later than browns, often over a very extended period. While the main spawning season is June-July, rainbows are known to spawn in summer also (McDowall 1990), and it seems that the South Island season is less clearly defined than the North Island season. Even with a 1 November opening to the season in some of tributaries of the southern lakes, anglers still catch some pre-spawned rainbows (T.Kroos, Otago Fish and Game Council, pers. comm.).

4.3.4 Catch rates

Overall catch rates for headwater rivers appear comparable to rates from other rivers around New Zealand (Allen and Cunningham 1957, Graynoth 1974, Scott 1987). For example, Allen and Cunningham showed that catch rates for most of New Zealand ranged from 0.5-0.8 fish/hr, while catch rates for the nine headwater rivers listed in Graynoth (those "A" or "B" list rivers from the present report where the whole river was considered a headwater fishery) averaged 0.55 fish/hr. From 531 angler interviews conducted over five consecutive seasons, Kroos (1992) calculated a high catch rate of 0.76 takeable trout/hr for the Greenstone River; an even higher rate of one fish/hr was recorded from the Von River (52 interviews) although Kroos expected this would decrease during the season. A comparison of catch rates from some headwater rivers from 1947 to the present (Table 27) shows no evidence of an overall decline in catch rates, but rather considerable variation between years.

To illustrate the impact of potential angler harvest, catch rates and trout densities from the Crow and Karamea Rivers may be used. For the Crow River there is approximately 10 km of fishable water, where conservative densities of large trout would range between six and 26 fish/km (Table 20). Assuming an average density of, say, 20 fish/km, then the river would normally hold a population of about 200 large trout. Two "average" anglers with a mean catch rate of 0.44 fish/hr and fishing for 5 h per day for five days could take 22 fish over this period (while disturbing 4-5 times that number). Two expert anglers averaging 10 fish/day each could theoretically take half the stock over the same time. Being larger, the comparable impact on the Karamea River itself would obviously be less. Using

TABLE 27. Comparison of average length and catch rate of trout from headwater rivers, 1947-1992.

River	Years	No. measured	Mean length	Catch rate	% BT	Reference
Manganuioteao	1947-52	138	478	0.54	21	Allen and Cunningham 1957
	1962-63	56	478	0.36	50	Graynoth 1974
	1967-68	5	549	1.00	67	Graynoth 1974
	1979-81	472	505	-	81	Cudby and Strickland 1986
Whakapapa	1947-52	198	453	0.81	34	Allen and Cunningham 1957
	1962-63	165	506	0.53	32	Graynoth 1974
	1967-68	84	469	1.35	72	Graynoth 1974
	1979-80	85	500	0.35	25	Richardson and Teirney 1982
	1980-81	76	499	0.50	31	Richardson and Teirney 1982
Hautapu	1947-52	244	428	0.85	100	Allen and Cunningham 1957
	1957-58	30	461	0.87	100	Graynoth 1974
	1962-63	216	417	0.57	100	Graynoth 1974
	1967-68	73	483	1.13	100	Graynoth 1974
	1979-88	81	509	-	100	Barker and Smith 1989
	1989-92	16	510	-	100	present study
Wangapeka	1947-52	460	497	0.51	100	Allen and Cunningham 1957
	1957-58	28	533	0.09	100	Graynoth 1974
	1962-63	9	541	0.16	100	Graynoth 1974
	1967-68	68	475	0.40	100	Graynoth 1974
	1990-92	8	530	-	100	present study
Travers	1947-52	225	533	0.59	100	Allen and Cunningham 1957
	1957-58	50	620	0.39	100	Graynoth 1974
	1962-63	52	561	0.38	100	Graynoth 1974
	1967-68	58	528	0.66	100	Graynoth 1974
	1989-92	52	571	-	100	present study
Owen	1947-52	94	547	0.44	100	Allen and Cunningham 1957
	1957-58	9	550	0.29	100	Graynoth 1974
	1962-63	1	584	-	100	Graynoth 1974
	1967-68	10	564	0.54	100	Graynoth 1974
	1969-92	48	564	-	100	present study
Gowan	1947-52	97	507	0.59	100	Allen and Cunningham 1957
	1957-58	87	508	0.46	99	Graynoth 1974
	1962-63	110	564	0.60	100	Graynoth 1974
	1967-68	38	521	0.52	100	Graynoth 1974
	1989-91	3	538	-	100	present study
Mangles	1947-52	81	546	0.56	100	Allen and Cunningham 1957
	1957-58	3	559	0.22	100	Graynoth 1974
	1962-63	32	526	0.30	100	Graynoth 1974
	1967-68	80	485	0.98	100	Graynoth 1974
	1969-92	34	518	-	100	present study
Ohikanui	1947-52	60	565	0.50	100	Allen and Cunningham 1957
	1957-58	19	535	0.38	100	Graynoth 1974
	1962-63	25	594	0.33	100	Graynoth 1974
	1964-92	213	558	-	100	present study
Crooked	1947-52	77	439	0.83	100	Allen and Cunningham 1957
	1962-63	54	531	0.57	100	Graynoth 1974
	1987-89	1642	482*	-	100	West Coast Acclimatisation Society 1989
Mararoa	1947-52	111	556	0.48	81	Allen and Cunningham 1957
	1957-58	40	522	0.24	77	Graynoth 1974
	1962-63	65	503	0.32	80	Graynoth 1974
	1967-68	155	452	0.45	83	Graynoth 1974
	1990-91	15	551	-	60	present study

* = spawning trout caught in fish trap.

the above scenario for 25 km of mainstem Karamea (the distance from the Ugly River to the Crow River) at an average density of 43 large trout/km), then the "average" anglers would take about 2% of the stock over five days, while the expert anglers would take 19%. Although such calculations contain several assumptions, they do serve to illustrate that it is theoretically possible for a few anglers to substantially deplete trout stocks should bag limits allow, and should they choose to keep all fish caught.

4.4 Management concerns

4.4.1 Reduction in numbers and size of fish

A question put to the expert anglers (Appendix II) asked whether they had noticed any changes in the size of fish during the time of their angling experience. Of the 33 replies, 11 anglers recorded no change in average size, 18 considered that the average had decreased, three thought it had increased, and one suggested that changes were probably cyclic. For those anglers recording a decline in size, many considered that this was due to loss of large "trophy" fish. This general agreement about overall decline in average size is evident from Hill (1991), who records that the size range of trout from an undisclosed river has fallen from 4-9 lbs to 3-6 lbs over 12 years of his observation. Other anglers report similar declines; for example, the average weight of brown trout from the Crow River in early 1980s ranged from 6 to 7 lb (2.7-3.2 kg), but this had declined to 5-6 lb (2.3-2.7 kg) by the late 1980s (Greg Caigou, Christchurch, pers. comm.).

In contrast to such claims, a comparison of average sizes of trout over a range of years (Table 27) does not show any consistent differences. However, it does seem reasonable to assume that with increased angling pressure, many of the largest trout from many populations have been caught and killed. Although such large trout are described as "ever vigilant, easily scared" (Hill 1990b), they do feed readily at times and are vulnerable to capture, especially early in season when they are recovering from the rigors of spawning.

Claims of reduced numbers of trout in headwater rivers seem less frequent. Certainly there is widespread acceptance that small and popular tributaries like the Dingle Burn, are "fragile....and...in danger of becoming overfished" (Turner 1983). Also, the population of large and old rainbows in the upper Rangitikei River would also seem susceptible to over-harvest; in view of this, a one-fish bag limit has recently been imposed (Taylor 1992). However, for most larger rivers, there seem to be few concerns that the actual numbers of trout are seriously diminished. For example, although Hill (1991) recorded a decline in the average size of trout in two back country rivers, he noted that numbers of fish seen were similar today to what they were in 1977-78.

4.4.2 Riparian access

Access issues are threefold: firstly, riparian access rights. Secondly, the issue of where and how aerial access should be permitted, and the associated practice of issuing concessions. Thirdly, the possible need to restrict the numbers of anglers able to fish some areas in order to maintain quality of fishing (in terms of both catch rates and the aesthetic features of peace and solitude). This latter point is not discussed, but simply "flagged" as a major issue for future management.

4.4.2.1 Riparian rights

The desire that waterways in New Zealand should not become privatised and hence the domain of an exclusive few, was one of the founding principles of the acclimatisation movement within this country. Hence, continued access to rivers for angling is of fundamental importance to both fishery managers and anglers. The widely held view that anglers have access to the "Queens Chain", a 20 m wide border along rivers, is untrue (MacKenzie 1992); this right of way apparently exists only where official maps show a "marginal strip", and all other private land titles have riparian rights which generally means ownership of the river bank. DOC are of the opinion that the key issue to river access is one of navigability, although this would obviously be subject to a range of interpretations.

Marginal strips can be of three kinds: the old "Section 58 strips" which were principally designed to provide river access for the purposes of stock watering; public road reserves ("paper roads") which were primarily intended to ensure that an area was designated for public access, even if a construction of a real road was highly unlikely; and Esplanade Reserves, a requirement under the Resource Management Act - these reserves are required along margins of the coast, lakes over 8 ha, and rivers and streams with an average width of 3 m or more. Should a landowner wish to subdivide land then he/she would be required to cede portions to the Crown to ensure public access. Local authorities have the right to decide whether or not the need for an esplanade strip can be waived.

The issue of Esplanade Reserves is currently being reviewed, as Federated Farmers have expressed concern about the amount of land that could be lost, and the survey costs to landowners. Proposed amendments to the Resource Management Act discuss access in terms of Esplanade Reserves, Esplanade Strips (to be negotiated on a covenant basis for access or conservation), and access strips.

Until legal precedents are set under both the Conservation Act (1987), and the Resource Management Act (1991), the issue of access remains largely unresolved.

4.4.3 Aerial access and use of concessions

Low usage is one of the prime prerequisites of a wilderness fishery (Teirney *et al.* 1982), yet the increased use of helicopters by fishing guides and parties of anglers means that some remote rivers are subject to increasing angling pressure. Fishery managers occasionally receive complaints from anglers who have spent hours or even days tramping into some remote river, only to have their sense of accomplishment diminished by the arrival of a party of air-borne anglers. The Dingle Burn, in Central Otago, typifies an area where increased usage, especially by guides, has lead to allegations of over-use, lack of angler ethics (e.g., guides depositing clients insufficient distances ahead of anglers already fishing; using helicopters to locate fish), and detraction of the angling experience by aircraft noise. Increasingly, fishery managers will be faced with the need to consider restrictions on the number of anglers allowed to fish particular waters, in order to maintain the quality of fishing.

In central Otago, the issue of aerial access is associated with DOC's and Landcorp's practice of issuing concessions to commercial fishing operators. Under the concession scheme, registered users are allowed to make flights into lands under the departments' control; a fee is charged and various restrictions are imposed on the operator. For example, an operator could be limited to a set number of flights per season, not permitted to operate in popular areas during most of January and February, and able to land in the lower reaches of valleys only. These concessions are seen as a way of providing a range of visitor opportunities, and not as a means of making money (DOC 1991). Thus, the fishery managers contend that the money should go towards maintaining the fisheries themselves, rather than simply go into DOC's general funds. Angling guides propose that a guide's licence be instituted instead of the present concessions.

4.4.4 Environmental impacts

The comparative remoteness of many headwater fishery rivers means that they have not been subject to a wide range of environmental developments. There are some site-specific problems, like the entry of coal fines into the Waitahu River from Garvies Creek coal mine (Tweed 1989). Also, the Crown has recently purchased the Greenstone and Elfin Bay Stations on the eastern shore of Lake Wakatipu with the objective of passing them to Ngai Tahu as part (*Christchurch Press*, 8 July 1992) settlement of the latter's land claims. Ngai Tahu have since revealed their proposal to install a gondola system to transport tourists up the Greenstone valley and so provide access to Milford Sound without having to go via Te Anau. Should such a development proceed, it would scarcely seem compatible with maintenance of the wilderness angling experience currently afforded by the Greenstone River.

The single biggest development threat to headwater trout fisheries is their potential for hydro power. Both the upper Wairau and upper Hurunui Rivers have been threatened with hydro development, which could truncate the upstream migration of large fish. Prior to diversion of 80% of the mean annual flow, the Whakapapa River was regarded as the best river fishery in the Waimarino Acclimatisation District (Richardson and Teirney 1982), although it has since been replaced by the unmodified Manganui-a-te-Ao as the most highly ranked river in the district. The rivers of the MacKenzie Basin are extensively modified by the upper Waitaki power scheme, to the extent that Jellyman *et al.* (1982) claimed that the Ahuriri River was the last recognised fishery in the area that was "unmodified" by hydro. A scheme currently being investigated would dam the Ngakawau River (West Coast, South Island) and incorporate flows from the upper Buller, Matiri, Wangapeka, and Mokihinui Rivers.

Historically, predators of trout have come in for a lot of attention by fishery managers. Thus in the early 1930s the acclimatisation societies waged an extermination programme on eels (McDowall 1990). Although longfinned eels especially do catch and eat trout, there is evidence that this results in fewer but larger trout (Burnet 1968). Also, as pointed out by Orman (1991), some of New Zealand's classic back-country fisheries exist in the presence of substantial populations of large eels, so the two species are scarcely incompatible. The black shag was another trout predator that fishery managers actively culled. However, shags primarily take small and some medium sized trout, of which there will be a surplus in a healthy population (Allen 1952). McDowall (1990) considers that the shooting of shags to reduce their predation, or to control the infection of trout by shag worm (Eustrongylides), was probably quite unjustified.

4.4.5 Lack of co-ordinated management

A continuing problem for management of back-country wilderness fisheries is the respective management roles of the fishery managers (Fish and Game Councils) and the land and recreational resource managers (DOC, Landcorp, private owners). For example, within National Parks, the salmonid fisheries are managed through regulations of the respective Fish and Game Councils, although access, including the sensitive issue of aerial access, is administered by DOC.

DOC are currently considering charging commercial fishing guides a licence fee as a resource rental "as compensation for the guides' high impact on the resource" (*Otago Daily Times*, 17 March 1992). An earlier, similar, proposal foundered after the Professional Fishing Guides Association received a legal opinion which said that current legislation did not allow for charges to be made for freshwater fishing access. While the Fish and Game Councils appear to agree with the principle of resource rentals, they again maintain that such monies should be targeted for management of the resource, and so should be administered by the councils rather than by DOC.

The rationale is that guides should be paying some resource rental for deriving their livelihood from back-country rivers, although the N.Z. Professional Fishing Guides Association contends that the fishery managers already benefit from their activities in that their clients have to buy angling licences. For those guides currently paying concession fees to DOC or Landcorp, it is anticipated that the amount of that fee will be reduced when the new guiding licence fee is introduced. It seems likely that both DOC and the Fish and Game Councils will share such licence fees.

The extent to which a co-operative management approach is required is well illustrated by reference to Central Otago. The following headwater rivers are within DOC Otago Conservancy's stewardship estate or pastoral lease land: Hunter, Dingle Burn, Wilkin, Lochy, Von, Nevis, Timaru Creek, Matukituki, Rees, Greenstone, Caples, Makarora, Routeburn. In addition, the Young River is within Mount Aspiring National Park. Aerial access to the latter river is managed under the Mount Aspiring National Park Management Plan, while the other rivers are subject to a management plan for aircraft landings in the Otago Lakes Crown Land, currently being drawn up by DOC. The Otago Fish and Game Council are also pursuing the establishment of some aircraft-free back-country wilderness areas through a series of submissions on concession applications, DOC aerial access strategy, and a review of the Mount Aspiring National Park Management Plan.

As managers of a substantial part of the Crown's land, DOC have a philosophy to "see the back-country resource managed in way which will best accommodate the range of recreational opportunities sought by all the various user groups" (Draft Strategy for Aircraft Landings, Otago Lakes Crown Lands, DOC Otago Conservancy). In order to achieve this, DOC intends to institute a zoning approach to aerial access, which will allow unrestricted access in some areas, and restricted or no access in other areas. As part of the management plan for Northwest Nelson Forest Park, the Ugly and Beautiful Rivers, tributaries of the middle section of the Karamea River, are now within the "wilderness" area, meaning that "no aerial access" is permitted. Such zoning is generally in agreement with the management philosophy of the Fish and Game Councils (e.g., Otago Fish and Game Council, 1989), although it is recognised that exclusion of aerial access in one area will usually result in additional angling pressure elsewhere.

A fundamental criterion for management of trout angling in North America is maintenance of diversity of angling experiences. Thus salmonid stream fisheries in British Columbia are classified as "Wild Class A" (accessible, high use, limited kill fisheries), "Wild Class B" (inaccessible, low usage, more liberal regulations), "Trophy Class" (limited kill, or catch and release), and "Hatchery Supported" (reliant upon hatchery releases, liberal regulations) (Slaney *et al.* 1984). Fisheries agencies in a number of USA states have adopted a similar approach (e.g., Graff 1984, Seehorn 1984).

Trout waters within New Zealand are managed regionally, with virtually no attempt at national consistency. Adoption of an appropriate classification system of trout fisheries would be an significant step in commencing a nationally co-ordinated approach to management of these waters. High quality fisheries such as headwater trout fisheries would be better managed if there were better co-operation between the agencies that manage the fishery and the access, and if there were a more co-ordinated system of management between regions. Inter-regional co-ordination would be especially important if it were decided to manage some rivers more restrictively, such as limiting the total number of anglers that could fish in any one season. In such a case, it could be possible to allow a more liberal regulations on other rivers within that region or a within an adjoining region. Hopefully, the present compilation of headwater rivers will be a significant step in promoting such broader-scale management.

5. CONCLUSIONS

New Zealand's headwater trout rivers offer a unique angling opportunity - the chance to catch large, wild trout of one or even two species, in clear waters in remote and scenic conditions. Such outback angling experiences are highly valued by both New Zealand and increasing numbers of overseas anglers. To quote from a recent article on headwater trout fishing in New Zealand that appeared in the prestigious *Esquire* magazine: "The opaque oblongs in the pool are trout. That is when you learn, if you have any sense at all, that fishing in New Zealand demands adaptation. You realise that you have never seen clear water. Never seen trout this big or this wild" (Klinkenborg 1988).

Overseas anglers constitute a significant proportion of both guided and unguided fishing trips on New Zealand headwater rivers. During an angler survey of the Ahuriri River, Jellyman (1984) recorded that 6% of anglers responding to a questionnaire, and percentage of those interviewed were from overseas, mainly Australia. Kroos (1992) found that almost half (49.5%) of 531 anglers interviewed on the Greenstone River, were from overseas, coming from 14 different countries. Higher proportions of overseas anglers occur among statistics from guiding services; for example, Entwhistle (1989) recorded that overseas anglers accounted for 98.6% of the clients of a guiding service in North-West Nelson/West Coast from 1985-1987, while data for the same area for 1989-90 (Mirfin 1990) give 89.4% overseas clients. From both these latter references, anglers from the United States comprised about 70% of all overseas anglers.

Historically, fisheries management practices have concentrated on increasing yields. However, there is a growing realisation that other factors are very important ingredients of angler satisfaction. Results of the National Angling Survey showed the importance of qualities like peace, solitude, and scenic surrounding, to the angling experience. Similar attributes have been determined from other studies. For example, Wisconsin trout anglers ranked being in the outdoors, nature appreciation, opportunity to utilise skills, seeing trout feeding, solitude, and escape, ahead of catching trout in an evaluation of satisfaction (Jackson 1988); only 4% of Texan anglers rated catch more important than other aspects of their angling experience (Holland and Ditton 1992). The importance of having a fishery based on wild trout cannot be overstated. "..I never cease to give thanks for wild trout and the wild places they live.... these wonderful fish and streams have certainly expanded and enhanced my own enjoyment of life" (Abrams 1984).

Headwater trout are big because they are old. Their growth rates are typical of those of trout from elsewhere in the country, and there is no suggestion that they constitute a unique fast-growing stock. Most fish aged during this study were considered to be 5-6 years, which is comparatively old by New Zealand standards. However, it was found that aging from scale reading under-estimated maximum age, meaning that maximum ages of large trout could not be determined. Nevertheless, 8% of both species were considered to be in excess of eight years old although brown trout as old as 15 years have been reported from Lake Coleridge (Jellyman 1992b).

This situation, with large fish dominating upstream populations, is not known from other countries. While such factors contribute to provide a highly sought after angling experience, they also combine to make headwater fish vulnerable to over-exploitation. Given appropriate weather, these fish are readily spotted and fished for; being principally drift feeders, they will often readily accept the angler's nymph, although they do become increasingly cautious during the season.

Although there is some upstream movement of trout at times other than during the spawning season, spawning migrations are considered to be the primary period of recruitment for headwater populations. Hence any truncation of upstream migration will have deleterious impacts on headwater stocks.

In a review of factors associated with the distribution and abundance of trout in New Zealand rivers, Jowett (1990) found that climatic, geographic, and hydraulic factors affected species distribution, while fish abundance was related to flow variability, river gradient, in-stream habitat, and the presence of lakes in the catchment. While these results were determined for a wide range of rivers (157 sites in 93 rivers) and not specifically for headwater rivers, it is highly likely that the same factors are the principle ones governing headwater populations, as Jowett's survey contained a number of headwater sites.

As headwater rivers are often steep and prone to rapid floods, the overall composition of the fish stocks (large proportion of big fish, and low proportion of small and even medium-sized fish), may be more a consequence of floods than is apparent in other rivers, or the lower reaches of the same rivers. The relatively uniform density of trout over non-spawning periods (e.g., Cudby and Strickland 1986, Hicks and Watson 1985) suggests that fish density is determined more by the availability of suitable refuge areas from high flows, than by the availability of food. Further factors influencing the relative size distribution of fish could be an overall lack of extensive juvenile rearing areas, combined with the predatory pressure exerted by large resident trout.

To date, headwater trout stocks in larger rivers seem to be sustaining angling pressure, although there is some evidence that the average size of fish has declined (e.g., Hill 1991). Part of this decline will be due to a selective take of large "trophy" fish by anglers; realisation that 4-5 kg trout may be in excess of 10 years old gives good ground for cautious management in future if it is considered desirable to retain these large but generally slow growing fish. The well-being of stocks can be threatened by over-exploitation, and such catchment modifications as hydro development. While the ongoing vigilance of fishery managers is required to ensure that such modifications do not degrade fish habitats and hence fish stocks, the bigger management issue in future will be that of people management.

The appeal of back-country angling is principally that of catching large wild trout in scenic and remote surroundings. Both the likelihood of fishing success and the sense of solitude that accompanies remote locations, are influenced by the presence of people. While adoption of conservative bag limits or catch-and-release only can significantly benefit fish stocks, there is subjective evidence that the catchability of fish diminishes in response to fishing pressure; this is especially so for brown trout which are the basis for New Zealand's headwater trout fisheries. Ultimately, if feelings of peace and solitude and maintaining a reasonable likelihood of catching trout (as opposed to simply seeing trout) are considered important components of headwater trout fishing, then future management will need to include a greater emphasis on limiting access to some sensitive fisheries. The alternative is for anglers to accept that they are likely to encounter other anglers on such waters, and that the fish in those waters will be increasingly challenging to catch as the season progresses.

Recognition and planning for a diversity of experience is important. Thus some rivers should be managed as for their "wilderness" value which may mean exclusion of air-borne access, and even limits on the number of anglers permitted to fish both simultaneously and during the season. Adoption of such strategies will require more co-ordinated management by the agencies variously controlling the fish stocks and access to them, than is apparent at present.

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APPENDIX I. Headwater fisheries questionnaire and accompanying notes.

MAF

The Leading Edge

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11 July 1989

Marlborough Acclimatisation Society
Nelson Acclimatisation Society
North Canterbury Acclimatisation Society
Ashburton Acclimatisation Society
South Canterbury Acclimatisation Society
Waitaki Valley Acclimatisation Society
Otago Acclimatisation Society
Southland Acclimatisation Society
Department of Conservation, Queenstown
Westland Acclimatisation Society
West Coast Acclimatisation Society
Wellington Acclimatisation Society
Hawkes Bay Acclimatisation Society
Department of Conservation, Taupo
Taranaki Acclimatisation Society
Stratford Acclimatisation Society
Hawera Acclimatisation Society
Wanganui Acclimatisation Society
Auckland Acclimatisation Society
Northland Federation of Acclimatisation Societies
Tauranga Acclimatisation Society

Dear Sir

HEADWATER TROUT STUDIES

This financial year, MAFFish will be commencing a specific research programme on headwater trout fisheries. (The term "headwater" is not entirely appropriate, but is used in preference to "trophy", "backcountry", etc.) The programme will start in a modest way this year and it is hoped to obtain further funding in subsequent years to extend the scope and duration of studies. Initially the emphasis will be placed on identifying recognised headwater fisheries, studying the age composition and growth rates of trout stocks and gaining a knowledge of the management problems of these fisheries. Further developments could include studying the behaviourial response of fish to increasing (?) fishing pressure, growth rates in relation to food availability and dominance (by large fish) and annual recruitment rates of fish from downstream areas.

This letter is designed to do several things:

- inform you of the commencement of the programme
- ask your help in identifying recognised headwater fisheries

- ask your help in identifying recognised headwater fisheries
- obtain some information on the types of headwater fisheries and the management problems associated with them.

At this stage, I do not have an all-embracing definition of a headwater fishery, but recognise that there are different types, eg. associated (or not) with a lake. A working definition would be a fishery, normally in a scenic and often remote location, characterised by a reasonably high catch rate of large fish caught mainly by fly fishing. To be a recognised trophy fishery, a river should be capable of sustaining a reasonable degree of fishing effort throughout the season (= series 'A' of the questionnaire). However, some of the more sensitive fisheries from a management viewpoint, may be those which hold a few 'trophy' fish at the start of each season, but which are quickly 'fished out' and do not recover until the following spawning season. These rivers should also be listed (= series 'B' of the questionnaire).

Note: In general I would not anticipate lake outlet fisheries being listed (upper Clutha, Gowan, upper Waikato), although many lake tributaries will be listed.

On the following pages I have provided a simple questionnaire and ask that you fill it in as completely as possible. As the categories provided will not be good descriptions of all headwater fisheries, please add comments as appropriate, on a further sheet if necessary. When I have analysed the results of the questionnaire I will compare the list with one to be generated from a review of the National Angler Survey, but, as the national survey was principally related to angler use, some remote and little-used (but highly valued) rivers may not be listed - or have so few replies that the data are of limited use. Be assured that it is not my intention to publicise these fisheries in any way, but knowing where they are is an obviously necessary step in developing any biologically oriented management strategies.

Dr Donald Scott (Otago University/OAS) also has a particular interest in management problems of headwater fisheries. If you have any problems in filling in this questionnaire please contact Donald Scott (telephone (024) 797-981) or myself (telephone (03) 488-939). (I will be overseas from 19 July to 3 September)

I realise that a questionnaire of this type requires you to make some "educated guesses" about what qualifies and why. Inevitably, it will be inadequate to describe all types of headwater fisheries. So, do your best and make explanatory notes where needed.

Thanks in anticipation for your assistance.

Kind regards

(D J Jellyman, Dr)

EXPLANATORY NOTES AND KEY

Important reach(s) (of river listed)	U = upper M = middle L = lower
Trout species	B = brown trout R = rainbow trout M = mixed (50:50) M(B) = mixed but dominated by brown M(R) = mixed but dominated by rainbow
Access (to important reach(s)) (you may need to use various combinations of these)	M = road access for most of reach S = road access for some of reach L = road access very limited F = foot access only P = light plane access H = helicopter access R = access restricted (specify how eg. private property, National Park)
Usage - by unguided anglers	H = high M = moderate L = low
- by guides (and clients)	H = high M = moderate L = low
Present management	
Bag Limit	give present daily bag limit
Methods	F = fly only S = fly and spinner N = no restrictions
Season length	number of months open per season
Catch and release	C = catch and release widely practised D = catch and release sometimes practised ? = don't know
Importance/Qualities/ Reputation. (You may need to use various combinations. This is rather subjective so do your best.)	S = both species available L = medium-large average size T = chance to catch a trophy (>4.5 kg/10 lbs) C = good conditioned fish R = good catch rate H = hard fighting fish A = attractive fish (colour, shape) D = challenging, difficult to catch ? = don't know O = other (add, or specify in appended notes)

SERIES 'A'. RIVERS THAT FISH REASONABLY WELL ALL SEASON.

Name of river	Important reach(s)	Species	Access	Usage		Present management				Importance/ qualities/ reputation	Comments
				Unguided anglers	Guided	Bag limit	Methods	Season length	Catch and release		

SERIES 'B'. RIVERS THAT FISH REASONABLY WELL EARLY IN SEASON ONLY

Name of river	Important reach(s)	Species	Access	Usage		Present management				Importance/ qualities/ reputation	Comments
				Unguided anglers	Guided	Bag limit	Methods	Season length	Catch and release		

APPENDIX II. Questionnaire to trout angling guides and experienced anglers.

MAF

The Leading Edge

Freshwater Fisheries Centre
P.O. Box 8324
Riccarton
Christchurch, New Zealand

Location: Kyle Street
Riccarton
Christchurch
Telephone (03) 488-939
Fax (03) 485-548

6 November 1989

Dear

It is widely recognised that headwater (trophy) trout river fisheries are some of this country's most sensitive and important fisheries. Despite this, we have little biological knowledge of the trout stocks themselves, on which to base sensible management decisions. Recognising this the Acclimatisation Society Movement have asked MAF Fisheries to commence investigations of headwater fisheries throughout the country.

In an endeavour to contact experienced trout fishing guides I requested a list of members of the New Zealand Professional Fishing guides Association from Tony Entwhistle, the former secretary of the association. Hence this letter and the enclosed questionnaire.

Having read the questionnaire, you may feel not able to fill it in for whatever reason - however, you may still be interested in collecting scales or could forward the name of another angler who would probably also collect scales. If so, please contact me (note - it is possible to collect scales from fish and then release the fish alive and unharmed).

Good luck with the questionnaire. Thanks in the anticipation of your interests.

Kind regards

Don Jellyman

(D J Jellyman)

QUESTIONNAIRE TO TROUT ANGLING GUIDES AND EXPERIENCED ANGLERS

INTRODUCTION. MAFFish have been commissioned by the Acclimatisation Society Movement to carry out investigations into headwater / trophy trout fisheries .Although the primary emphasis of these investigations is biological,many management issues are beginning to surface. To obtain information on which rivers are regarded as important headwater fisheries, I have recently sent a questionnaire to staff of all Acclimatisation Society districts and the two D.O.C. areas . The information provided will make an interesting comparison with information from the National Angling Survey carried out in the early 1980's.

The following questionnaire is a different one and has 2 objectives:

-to obtain information on trout behaviour
-to ask for assistance in collecting scale samples

A number of experienced guides and anglers have suggested that the behaviour of trout in back-country areas can be affected by angling pressure. I am interested to know whether this is a widespread belief and, more importantly, whether people have made any observations to back up this suggestion.

Could you please assist me by answering the following questions. The questions can be answered for either a particular river that you are familiar with or for headwater rivers in general.

Please give your name__________________________________

PART 1. FISH BEHAVIOUR.

If you are filling in for a particular river, please give the name of the river:____________________________

- otherwise, please state the general area you are commenting on (e.g. West Coast, S.I.):____________________________

Question 1. About how many years have you been fishing this (these) rivers?____________

Question 2. Over this time, have you noticed much change in fishing pressure (indicate choice)

________fewer anglers

________about the same

________a few more anglers

________a lot more anglers

Question 3. Over this time, have you noticed any changes in fish behaviour ?....**YES / NO**. If " yes " can you describe the changes:

For example-
- do fish still occupy the same or similar positions in the river(s) today as they did previously?________________

____

____

- are fish as accessible to anglers today as they were previously?______________________________________

____

____

- have you noticed any changes in fish feeding behaviour during the time that you've been fishing this (these) river?________

____

____

- any other comments__________________________________

____

____

____

Question 4. Over this time have you noticed any changes in

- the average size of fish? (explain)____________________

____

- the average condition of fish? (explain)________________

____

- the catch rate? (explain)______________________________

____

- the total numbers of fish? (explain)____________________

____

- any other comments____

____

____

____

Question 5. Once fish in this (these) river(s) have been disturbed by anglers, about how long does it take them to "settle down" and become available to anglers again?____________________

____

- have you noticed any change in the length of this settling down period during the fishing season? (describe)____________________

____

- have you noticed any change in the length of this settling down period during the years that you have been fishing this (these) river(s)?____

____

PART 2. REQUEST FOR YOUR ASSISTANCE.

Question 1. If requested, would you be willing to collect scale samples from some fish? (this would require recording fish length, and scraping or plucking a few scales from the fish)....**YES / NO**

note: Further information/instructions and a supply of scale envelopes will be sent to those persons who indicate a willingness to assist. Participants will receive a summary of results of the scales they supply.

Question 2. Have you kept a fishing diary for the above river(s) ? ... **YES / NO.** If so, for how many years?__________ If "yes" then would you be willing to make it (or sections of it) available for analysis? ... **YES / NO** (this would be an examination of the size, condition and catch rates of fish over a number of years).
Confidentiality will be respected as requested.

Many thanks for your help.

Please return this questionnaire to:

Dr.Don Jellyman
Freshwater Fisheries Centre
MAFFish
P.O.Box 8324
Riccarton
Christchurch.

APPENDIX III. Information on access, usage, management, and attributes of "A" list rivers.

River	Access								Usage		
	road	some road	limited road	foot	plane	helicopter	restricted	boat	unguided	guided	Catch and release
Manganuioteao, middle	✓								l	l	s
Manganuioteao, upper			✓	✓			✓		l	l	s
Waimarino		✓		✓					l	l	s
Wanganui			✓						l	l	s
Whakapapa			✓				✓		m	l	s
Esk		✓		✓					h	l	s
Mohaka, middle		✓							h	l	w
Mohaka, upper			✓						m	h	w
Ngaruroro, upper									h	h	s
Taruarau			✓						h	m	s
Tukipo		✓		✓					h	l	s
Waikoau		✓		✓					h	l	s
Hautapu	✓								m	l	?
Otaki				✓		✓			l	l	?
Rangitikei				✓		✓	✓		l	m	s
Ruamahanga				✓		✓			l	l	?
Tauherenikau				✓		✓			l	l	?
Tokomaru				✓		✓			l	l	?
Waingawa				✓		✓			l	l	?
Waiohine				✓		✓			l	l	?
D'Urville				✓			✓	✓	h	m	s
Deepdale				✓		✓			l	l	w
Maruia				✓		✓		✓	l	m	s
Sabine				✓			✓	✓	h	m	s
Tutaki		✓							m	m	w
Alma							✓		l	?	s

River	Access								Usage		
	road	some road	limited road	foot	plane	helicopter	restricted	boat	unguided	guided	Catch and release
Rai, middle	✓								h	?	s
Rai, upper	✓								h	?	s
Saxton	✓								l	?	s
Severn		✓							l	?	s
Wairau	✓						✓		h	m	s
Ahaura		✓		✓					m	l	s
Awarua				✓					m	m	?
Bruce		✓		✓					h	h	?
Crooked		✓		✓					h	m	?
Grey		✓		✓		✓			m	m	?
Haupiri		✓		✓					m	m	?
Karamea				✓		✓	✓		h	h	w
Mokihinui				✓		✓			m	m	w
Ohikanui				✓		✓	✓		m	m	s
Otututu				✓		✓			m	m	s
Waitahu		✓		✓					m	l	?
Ashley		✓							m	m	?
Boyle		✓		✓					l	l	s
Broken				✓					m	l	s
Doubtful				✓					l	l	s
Glenariffe Stream		✓							m	l	s
Hope				✓					m	l	s
Hurunui, South Branch	✓						✓		m	l	s
Hydra Waters		✓							l	l	s
Lewis				✓					l	l	s
Mathias		✓							l	l	s
Nina				✓					l	l	s
Poulter				✓					m	l	s

River	Access								Usage		
	road	some road	limited road	foot	plane	helicopter	restricted	boat	unguided	guided	Catch and release
Waiau							✓		l	l	s
Wilberforce		✓							l	l	s
Winding Creek				✓					m	l	s
Cass	✓								m	m	s
Forks				✓					m	m	w
Grays			✓						m	m	s
Jollie				✓		✓			m	m	w
Macaulay	✓								l	m	w
Tekapo	✓								h	m	s
Washdyke	✓								m	l	s
Ahuriri, middle and lower	✓								m	m	s
Ahuriri, upper	✓								m	m	s
Fraser	✓								m	?	s
Pomahaka		✓							m	l	s
Taieri	✓								m	l	s
Waikaia	✓								m	l	s
Aparima, lower	✓								h	l	s
Aparima, middle	✓								m	l	s
Aparima, upper		✓							l	l	s
Borland Burn				✓					m	m	s
Mararoa, lower			✓						l	l	s
Mararoa, middle	✓								h	h	s
Mararoa, upper			✓						m	m	s
Oreti, middle		✓							m	l	s
Oreti, upper		✓		✓			✓		h	m	s
Wairaki, lower			✓						m	l	s
Wairaki, middle and upper							✓		m	m	w
Whitestone, middle		✓							l	l	s

River	Access								Usage		
	road	some road	limited road	foot	plane	helicopter	restricted	boat	unguided	guided	Catch and release
Whitestone, upper			√						l	l	s
Arthur							√		m	l	s
Caples		√		√		√	√		m	l	w
Clinton							√	√	m	l	w
Clinton, North Branch				√			√		l	l	w
Dart River tributaries		√		√			√		l	l	w
Dingleburn, lower			√	√	√			√	m	m	w
Dingleburn, middle and upper				√	√	√	√		m	h	w
Glaisnock							√		m	l	w
Grebe							√		l	l	?
Greenstone, lower		√		√		√	√	√	m	m	s
Greenstone, middle				√					l	l	w
Greenstone, upper		√		√		√	√		m	l	w
Hunter		√		√	√	√	√	√	m	m	s
Lochy, middle and lower					√	√	√	√	m	m	w
Lochy, upper				√		√	√		l	m	w
Neale Burn							√		l	l	w
Nevis, lower			√	√		√			l	l	s
Nevis, middle		√		√					m	l	s
Nevis, upper	√			√					m	l	s
Rees		√		√					l	l	s
Von	√			√		√	√		m	m	s
Wilkin				√	√	√	√		h	m	?
Worsley							√		m	l	s
Young				√		√	√	√	m	m	s

APPENDIX III. (Contd.)

	Regulations						Attributes							
	1989			1991										
River	bag limit	methods	season	bag limit	methods	season	both species	large size	trophy	condition	catch rate	hard fighting	attractive	challenging
Manganuioteao, middle	8	s	9	6	s	9	√	√		√			√	√
Manganuioteao, upper	8	s	9	6	s	9	√	√		√			√	√
Waimarino	8	s	9	6	s	9		√		√				√
Wanganui	8	s	9	8	s	9	√	√						
Whakapapa	8	s	9	8	s	9	√	√						
Esk	8	s	7	8	s	7	√	√	√	√		√		
Mohaka, middle	8	s	12	8	s	12	√	√		√	√	√	√	
Mohaka, upper	8	s	9	8	s	9	√	√	√	√	√	√	√	
Ngaruroro, upper	2	s	7	2	s	7	√	√	√	√	√	√	√	
Taruarau	8	s	7	8	s	7	√	√	√	√	√	√	√	
Tukipo	8	f	7	8	f	7	√	√			√	√		
Waikoau	8	s	7	8	s	7		√	√	√		√		√
Hautapu	2	f	7	2	f	7	√	√						
Otaki	12	n	12	2	n	12		√						
Rangitikei	2	n	7	2	n	7		√	√					√
Ruamahanga	2	n	12	2	n	12		√						
Tauherenikau	2	n	12	2	n	12		√						
Tokomaru	12	n	7	2	n	12		√						
Waingawa	12	n	12	2	n	12		√						
Waiohine	12	n	12	2	n	12		√						
D'Urville	4	n	7	2	s	7	√	√		√			√	√
Deepdale	4	n	7	4	n	7		√		√				√
Maruia	4	n	7	4	n	7		√	√	√			√	√
Sabine	4	n	7	2	s	7		√	√	√			√	√
Tutaki	4	f	7	4	s	7		√		√	√	√	√	
Alma	2	s	7	2	s	7		√	√		√			
Rai, middle	4	s	7	4	s	7	√			√				√

River	Regulations 1989 bag limit	methods	season	1991 bag limit	methods	season	Attributes both species	large size	trophy	condition	catch rate	hard fighting	attractive	challenging
Rai, upper	4	s	7	4	s	7	√			√				√
Saxton	2	s	7	2	s	7		√	√		√			
Severn	2	s	7	2	s	7		√	√		√			
Wairau	2	s	7	2	s	7		√	√	√		√		
Ahaura	6	n	7	6	n	7		√	√	√		√		√
Awarua	6	n	7	2	n	7		√	√	√		√	√	√
Bruce	6	n	7	6	n	7		√	√	√	√	√		√
Crooked	6	n	7	6	n	7		√		√				√
Grey	6	n	7	6	n	7		√		√	√	√	√	
Haupiri	6	n	7	2	n	7		√	√	√	√			
Karamea	6	n	7	2	n	7		√	√	√	√	√	√	
Mokihinui	6	n	7	2	n	7		√	√	√	√	√	√	
Ohikanui	6	n	7	2	n	7		√		√	√	√	√	
Otututu	6	n	7	2	n	7		√	√	√	√	√	√	
Waitahu	6	n	7	2	n	7		√	√	√	√	√	√	
Ashley	6	n	7	6	n	7		√	√					
Boyle	6	n	7	6	n	7		√						√
Broken	6	n	7	6	n	7								√
Doubtful	6	n	7	6	n	7		√						√
Glenariffe Stream	6	n	5	6	n	7		√						√
Hope	6	n	7	6	n	7		√		√				
Hurunui, South Branch	6	n	7	6	n	7		√						√
Hydra Waters	6	n	5	6	n	7		√						
Lewis	6	n	7	6	n	7		√						√
Mathias	6	n	5	6	n	5		√						
Nina	6	n	7	6	n	7		√						√
Poulter	6	n	7	6	n	7		√			√			
Waiau	6	n	7	6	n	7			√					

	Regulations						Attributes							
	1989			1991										
River	bag limit	methods	season	bag limit	methods	season	both species	large size	trophy	condition	catch rate	hard fighting	attractive	challenging
Wilberforce	6	n	5	6	n	7		✓						
Winding Creek	6	n	7	6	n	7					✓			
Cass	10	n	7	10	n	6					✓			
Forks	10	n	6	4	s	6	✓							
Grays	4	s	6	4	s	6			✓					
Jollie	10	n	7	10	n	6			✓					
Macaulay	10	n	7	4	n	6			✓					
Tekapo	10	s	6	10	n	6				✓				
Washdyke	10	n	7	10	n	7								✓
Ahuriri, middle and lower	5	s	6	5	s	6		✓	✓		✓			
Ahuriri, upper	2	s	5	2	s	6		✓	✓		✓			
Fraser	10	n	7	6	n	7		✓						✓
Pomahaka	4	n	7	3	n	7			✓					✓
Taieri	10	n	7	10	n	7			✓					✓
Waikaia	10	n	7	10	n	7			✓					✓
Aparima, lower	10	n	7	6	n	7					✓			
Aparima, middle	10	n	7	6	n	7					✓			
Aparima, upper	4	s	7	2	s	7		✓						
Borland Burn	4	s	7	2	s	7	✓	✓						
Mararoa, lower	4	n	7	4	n	7	✓			✓		✓		✓
Mararoa, middle	4	s	7	2	s	7	✓	✓		✓		✓		
Mararoa, upper	4	s	7	2	s	7		✓						
Oreti, middle	10	n	7	6	s	7				✓	✓	✓	✓	
Oreti, upper	4	s	7	2	s	7		✓	✓	✓		✓	✓	✓
Wairaki, lower	4	n	7	4	n	7	✓	✓						
Wairaki, middle and upper	4	s	7	2	s	7	✓	✓						
Whitestone, middle	4	s	7	2	s	7	✓	✓						
Whitestone, upper	4	s	7	2	s	7	✓	✓						

	Regulations						Attributes							
	1989			1991										
River	bag limit	methods	season	bag limit	methods	season	both species	large size	trophy	condition	catch rate	hard fighting	attractive	challenging
Arthur	6	s	12	6	s	12		√		√	√			
Caples	1	f	7	1	f	7	√	√		√	√	√	√	√
Clinton	3	s	7	2	s	7	√	√		√	√	√	√	√
Clinton, North Branch	3	s	7	2	s	7	√	√		√	√	√	√	√
Dart River tributaries	3	s	7	3	s	7	√	√	√	√			√	
Dingleburn, lower	3	s	7	3	s	7	√	√		√			√	
Dingleburn, middle and upper	3	s	7	3	s	7	√	√		√	√		√	
Glaisnock	3	s	7	2	s	7	√	√		√	√	√		√
Grebe	3	s	7	2	s	7	√	√		√	√	√		
Greenstone, lower	1	f	7	1	f	7	√	√	√	√		√	√	√
Greenstone, middle	1	f	7	1	f	7	√	√	√	√		√	√	√
Greenstone, upper	1	f	7	1	f	7	√	√		√	√	√	√	√
Hunter	3	s	7	3	s	7	√	√		√				
Lochy, middle and lower	1	f	6	1	f	6	√	√			√	√	√	
Lochy, upper	0	f	6	0	f	6	√	√	√	√	√	√	√	√
Neale Burn	3	s	7	2	s	7	√	√		√	√	√	√	√
Nevis, lower	3	f	7	3	f	7		√	√	√			√	√
Nevis, middle	3	f	7	3	f	7		√	√	√			√	
Nevis, upper	3	f	7	3	f	7		√					√	
Rees	3	s	7	3	s	7	√	√				√		
Von	1	f	6	1	f	6	√	√	√	√	√	√	√	√
Wilkin	3	s	7	3	s	7	√	√		√				
Worsley	3	s	7	3	s	7	√	√	√	√	√	√		√
Young	3	s	7	3	s	7	√	√		√				

APPENDIX IV. Information on access, usage, management, and attributes of "B" list rivers.

River	Access								Usage		
	road	some road	limited road	foot	plane	helicopter	restricted	boat	unguided	guided	Catch and release
Mangaonuku	√			√					h	l	s
Maharakeke	√			√					h	l	s
Travers				√			√	√	m	m	w
Wangapeka		√		√			√		m	l	c
Takaka		√		√			√		l	l	c
Rainy			√	√					l	l	c
Aorere			√	√		√			l	l	c
Matakitaki			√	√			√		l	l	c
Glenroy			√	√		√			m	l	w
Owen	√								h	h	w
Goulter			√						h	l	w
Clarence	√								m	l	?
Branch		√		√					m	m	s
Leatham			√	√					m	l	s
Pelorus			√	√					l	?	?
Moonlight Creek		√		√					m	m	?
Big		√		√					m	l	?
Robinson				√					l	l	?
Clarke				√					m	l	?
Te Wharau				√		√			m	l	?
Hurunui, North Branch				√					m	l	s
Ryton				√					h	l	?
Harper				√					h	l	?
Selwyn				√					m	l	?
Deep Stream		√		√					m	l	s
Deep Creek		√		√					m	l	s
Lake Stream			√	√			√		l	l	?

	Access								Usage		
River	road	some road	limited road	foot	plane	helicopter	restricted	boat	unguided	guided	Catch and release
Irishman Creek		✓							l	l	w
Maryburn	✓								m	l	w
Stony	✓								m	l	s
Mistake		✓							l	m	s
Otematata, upper			✓				✓		l	l	s
Otematata, middle			✓				✓		l	l	s
Maerewhenua, upper			✓						l	l	s
Maerewhenua, middle			✓						l	l	s
Timaru Creek				✓				✓	m	l	s
Makarora, lower	✓			✓				✓	m	l	s
Makarora, middle	✓			✓					m	l	s
Matukituki, upper	✓			✓					l	l	s
Matukituki, middle and lower	✓			✓					l	l	s
Routeburn		✓		✓			✓	✓	l	l	s
MacKenzie Burn							✓	✓	l	l	?
Iris Burn						✓			l	l	s
Ettrick Burn							✓	✓	l	l	w
Electric Burn				✓				✓	l	l	?

APPENDIX IV. (Contd.)

River	Regulations						Attributes							
	1989			1991										
River	bag limit	methods	season	bag limit	methods	season	both species	large size	trophy	condition	catch rate	hard fighting	attractive	challenging
Mangaonuku	8	f	7	8	f	7	✓	✓	✓	✓				
Maharakeke	8	f	7	8	f	7	✓	✓	✓	✓				✓
Travers	4	n	7	2	s	7		✓	✓	✓			✓	✓
Wangapeka	4	n	7	4	n	7		✓	✓					✓
Takaka	4	n	7	4	n	7				✓			✓	✓
Rainy	4	n	7	2	s	7				✓		✓		✓
Aorere	4	n	7	4	n	7		✓	✓					✓
Matakitaki	4	n	7	4	n	7		✓	✓	✓				✓
Glenroy	4	n	7	4	n	7		✓	✓	✓			✓	
Owen	4	n	7	2	s	7		✓	✓	✓		✓	✓	✓
Goulter	2	s	7	2	s	7		✓	✓	✓				✓
Clarence	2	s	7	2	s	7		✓		✓	✓		✓	
Branch	2	s	7	2	s	7		✓		✓		✓		✓
Leatham	2	s	7	2	s	7		✓		✓			✓	✓
Pelorus	2	s	7	2	s	7	✓	✓						✓
Moonlight Creek	6	n	7	2	n	7	✓		✓					✓
Big	6	n	7	6	n	7		✓		✓				✓
Robinson	6	n	7	6	n	7		✓		✓		✓		✓
Clarke	6	n	7	6	n	7		✓		✓		✓		✓
Te Wharau	6	n	7	2	n	7		✓		✓		✓	✓	✓
Hurunui, North Branch	6	s	6	6	s	6		✓						
Ryton	6	s	6	6	s	6					✓			
Harper	6	s	6	6	n	7					✓			
Selwyn	6	n	7	6	n	7								
Deep Stream	4	s	5	4	s	5	✓	✓		✓		✓		✓
Deep Creek	4	s	5	4	s	5	✓	✓		✓		✓		✓

	Regulations						Attributes							
	1989			1991										
River	bag limit	methods	season	bag limit	methods	season	both species	large size	trophy	condition	catch rate	hard fighting	attractive	challenging
Lake Stream	4	s	5	4	s	5	√	√		√		√		√
Irishman Creek	4	s	6	4	s	6	√							
Maryburn	4	s	6	4	s	6	√							
Stony	10	n	7	10	n	7					√			
Mistake	10	n	7	10	n	7								√
Otematata, upper	2	s	6	2	s	6		√						
Otematata, middle	5	s	6	5	s	6		√			√			
Maerewhenua, upper	2	f	7	2	f	7		√						
Maerewhenua, middle	5	f	7	5	f	7		√						√
Timaru Creek	3	s	6	3	s	6		√						√
Makarora, lower	3	s	7	3	s	7	√	√		√				
Makarora, middle	3	s	7	3	s	7	√	√		√			√	√
Matukituki, upper	3	s	7	3	s	7		√		√				√
Matukituki, middle and lower	3	s	7	3	s	7	√	√		√		√		
Routeburn	3	s	7	3	s	7	√	√	√					
MacKenzie Burn	3	s	7	2	s	7					√			
Iris Burn	3	s	7	2	s	7	√				√			√
Ettrick Burn	3	s	7	2	s	7	√	√	√		√	√		
Electric Burn	3	s	7	2	s	7	√	√	√	√	√	√	√	

APPENDIX V. A list of "trophy" rivers, identified from the National Angling Survey, that received more than five replies.

Fisheries district	River	Replies
Eastern	Rangitaiki	8
	Otamatea	6
	Wheao	17
	Whirinaki	5
	Whakatane	6
	Tarawera outlet	6
	Ruakituri	7
	Oamaru	5
	Kaipo	5
	Ripia	6
	Waipunga	8
Taupo	Tongariro	13
	Whanganui	5
	Waihaha	10
	Tauranga-Taupo	14
Taranaki	Manganuioteao	10
Waikato	Waipapa	8
Hawkes Bay	Mohaka	18
	Ngaruroro	11
Wellington	Rangitikei	21
Nelson-Marlborough	Matakitaki	5
	D'Urville	11
	Sabine	13
	Travers	14
	Goulter	5
West Coast	Karamea	7
	Arnold	5
North Canterbury	Waiau	5
	Hope	6
	Hurunui	17
	Broken	6
	Wilberforce	5
Central South	Tekapo	9
	Waitaki	14
	Hakataramea	7
	Ahuriri	12
Otago	Upper Clutha	5
	Nevis	5
	Greenstone	9
	Caples	7
	Hunter	10
	Pomahaka	6
Southland	Mataura	7
	Waiau	17
	Borland Burn	6
	Mararoa	10
	Hollyford	5
	Worsley	9
	Upukerora	6

APPENDIX VI. A list of "headwater" rivers, identified from the National Angling Survey, that received more than five replies.

Fisheries district	River	Replies
Eastern	Rangitaiki	11
	Wheao	5
	Whirinaki	5
	Whakatane	5
	Ohau channel	13
	Tarawera outlet	23
	Hangaroa	5
Waikato	Awakino	9
	Waipa	6
	Kaituna	40
Hawkes Bay	Mohaka	18
	Ngaruroro	13
Wellington	Rangitikei	18
Nelson-Marlborough	Buller	19
	Clarence	14
North Canterbury	Hope	8
	Hurunui	18
	Waimakariri	8
	Selwyn	5
	Rakaia	6
Central South	Waitaki	10
	Ahuriri	5
Otago	Upper Clutha	27
	Lower Cluth	7
	Pomahaka	6
Southland	Mataura	17
	Oreti	9
	Waiau	23
	Mararoa	6
	Eglington	5

APPENDIX VII. Number of benthic invertebrates (mean of three replicate Surber samples) per 0.1 m² from the upper Wairau, Karamea, and Oreti Rivers.

Taxa	Wairau River Dip Flat	Karamea River Karamea Bend	Oreti River Gibraltar Rock
AQUATIC			
Ephemeroptera			
Nesameletus sp.	4.7	26.6	7.5
Coloburiscus humeralis	-	1.8	0.4
Deleatidium spp.	84.0	79.3	255.8
Atalophlebioides cromwelli	1.4	-	-
Plecoptera			
Stenoperla prasina	-	3.2	3.2
Zelandoperla decorata	94.7	14.0	29.8
Zelandobius furcillatus	-	6.1	6.5
Zelandobius sp.	1.1	-	-
Trichoptera			
Aoteapsyche sp. larva	37.7	36.6	33.7
Hydrobiosis sp. larva	-	1.4	7.9
Hydrobiosis sp. pupae	0.4	1.4	1.1
Hydrobiosis parumbripennis larva	0.4	0.7	2.9
Hydrobiosis parumbripennis pupae	0.4	-	0.7
Hydrobiosis clavigera larva	-	0.8	0.7
Hydrobiosis clavigera pupae	-	-	1.4
Psilochorema sp. larva	1.8	-	1.1
Costachorema sp. larva	1.8	-	-
Costachorema sp. pupae	-	-	0.4
Tiphobiosis sp. larva	1.4	1.8	-
Tiphobiosis sp. pupae	0.5	-	-
Oxyethira albiceps larva	0.4	-	0.7
Baraeoptera roria larva	3.6	5.0	0.4
Pycnocentrella eruensis larava	-	-	0.4
Pycnocentria sp. larva	-	0.4	1.4
Conuxia gunni sp.	-	-	38.0
Olinga feredayi larva	-	50.9	23.3
Olinga feredayi pupae	-	-	0.4
Helicopsyche poutini larva	-	19.7	-
Zealandoptila sp. larva	-	2.9	-
Unidentified pupae	0.7	-	0.7
Megaloptera			
Archichauliodes diversus	0.4	0.4	1.4
Coleoptera			
Hydora sp. larva	8.3	-	-
Hydraena zealandica	-	1.8	-

Taxa	Wairau River Dip Flat	Karamea River Karamea Bend	Oreti River Gibraltar Rock
Elmid sp. larva	-	2.5	-
Diptera			
Tipulidae larva	0.4	-	-
Aphrophila neozelandica larva	12.6	6.5	7.5
Aphrophila neozelandica pupae	0.4	-	0.4
Eriopterini sp. larva	0.4	-	3.6
Chironomus sp. larva	12.9	26.6	14.0
Chironomus sp. pupae	5.7	1.8	5.7
Austrosimulium sp. larva	-	-	2.5
Austrosimulium sp. pupae	-	-	1.8
Limnophora sp. larva	0.7	-	0.4
Neocurupira hudsoni larva	0.7	-	-
Empididae larva	1.1	-	-
Oligochaetae	-	0.4	25.1
Mollusca			
Potamopyrgus antipodarum	-	-	0.4
TERRESTRIAL			
Collembola	-	-	0.4
Aphididae	-	0.4	0.4
Thysanoptera	-	-	0.4
Chironomus adult	0.4	1.1	0.7
Unidentified diptera adult	-	-	0.4
Hymenoptera adult	0.4	0.4	0.4
Staphylinidae adult	-	0.4	-
Austrolsimulium adult	1.1	2.5	-
TOTALS			
Mean no./0.1 m²	280.5	297.4	595.7
Number of aquatic taxa	23	22	27
Dry weights			
Ephemeroptera	0.0499	0.0516	0.1288
Plecoptera	0.0181	0.0290	0.0246
Trichoptera	0.0369	0.0169	0.0570
Other aquatic organisms	0.0142	0.0036	0.1427
Terrestrial organisms	0.0003	0.0010	0.0001
Mean	0.1194	0.1021	0.3532
s.d. (three samples)	0.0914	0.0504	0.0875