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MAF

Trout Abundance in New Zealand Rivers: An Assessment by Drift Diving

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Trout Abundance in New Zealand Rivers: An Assessment by Drift Diving

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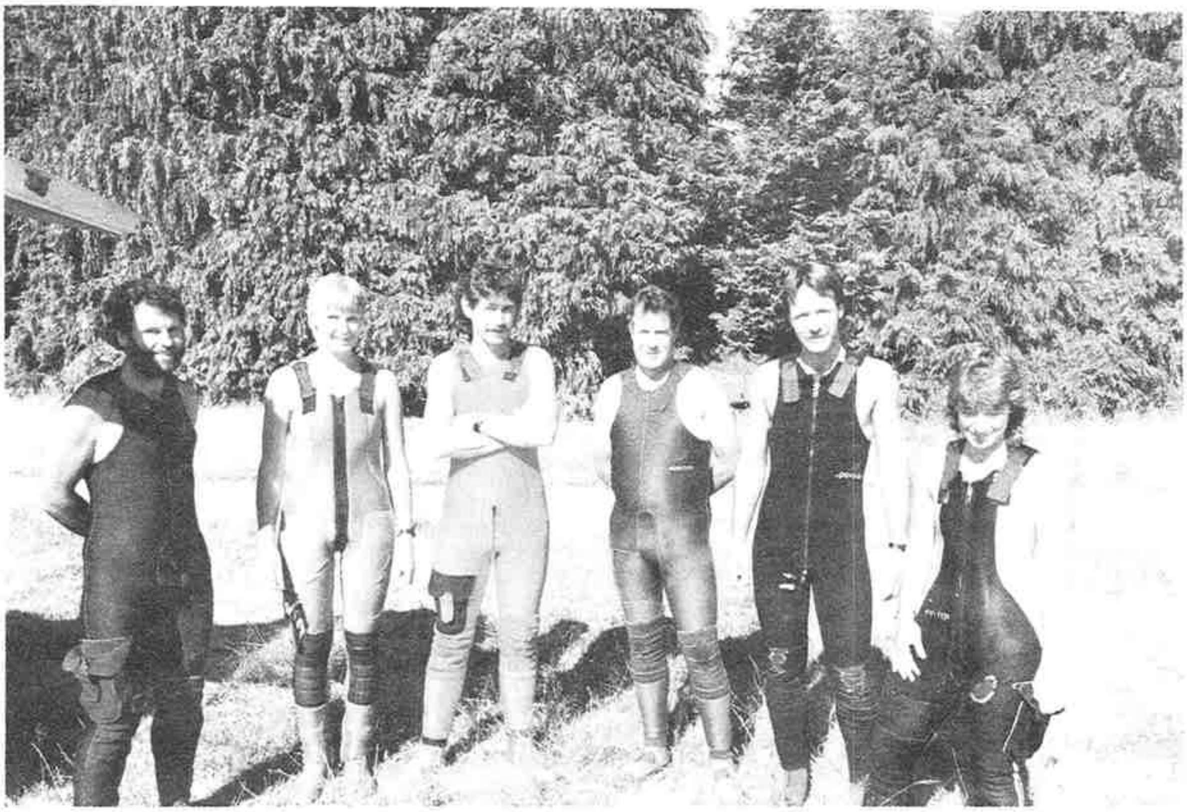

Frontispiece: The drift diving team. From left to right: Ian Jowett, Laurel Teirney, Rowan Strickland, Errol Cudby, Greg Kelly, Jody Richardson.

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SUMMARY

This report:

- describes drift diving methods used to assess trout stocks at 158 drift diving locations in 93 rivers throughout New Zealand;
- considers the accuracy of drift diving by reviewing ratification studies and comparing the precision of repeated drift dives with the variability of trout counts in different reaches of the same river and in different rivers;
- compares the characteristics of the rivers containing high numbers of trout with those of rivers containing few trout.

Drift diving is a technique which is as good as, or better than, other standard fisheries techniques used to assess adult salmonid abundance in larger rivers, provided that proper procedures are adopted and conditions are suitable. It is quick and efficient, requires fewer resources than other methods, and for many rivers is the only practical way of determining trout abundance.

For these reasons, drift diving was adopted as the most appropriate method to evaluate trout abundance in over 700 km of river throughout New Zealand. Data collected included measurements of selected fish habitat features, as well as observations on trout behaviour.

The known geographical distribution of brown and rainbow trout was confirmed by this survey. Rainbow trout predominated north of a line from southern Hawke's Bay to northern Taranaki, and brown trout were predominant to the south. The occurrence of rainbow trout in the South Island was associated with lakes, with the exception of some Marlborough rivers. The distribution of the two species did not appear to have altered in the past 20-25 years.

Classification based on species and abundance showed some clear divisions based on geography and river type. Lake outlets were outstanding in the numbers of trout they held and were closely matched by spring-fed rivers. The same characteristics were important both for brown and rainbow trout. Stable flows and large substrate were common factors in rivers containing large numbers of trout, whereas fine substrate in rivers with little instream cover was a characteristic of rivers with few brown trout. Brown trout commonly were observed in association with instream physical cover, whereas rainbow trout were only rarely observed associated with instream cover.

1. INTRODUCTION

Drift diving is a technique used increasingly overseas to estimate salmonid stocks in rivers. First reported in the literature by Northcote and Wilkie (1963), it is now included in texts on standard fisheries techniques (e.g., Nielsen and Johnson 1983).

In New Zealand, drift diving was used initially to collect data on trout stocks in rivers where other sampling techniques could not be applied (Graynoth 1974, Richardson and Teirney 1982, Bonnett and Docherty 1985, Hicks and Watson 1985a, Cudby and Strickland 1986). After these studies of individual rivers, drift diving was adopted as the most appropriate method to obtain a comparative measure of trout abundance in rivers nationwide.

Trout stock assessment by drift diving requires a team of divers equipped with snorkel gear to swim downstream, equally spaced across the river, and to locate and count all trout that they pass. This activity requires a high degree of teamwork to maintain formation and to coordinate searching and counting, and the experience to know where to search and how fish will react. For consistency, we used the same core group of MAF Fisheries divers throughout this study. The development of the drift diving technique and collection of data presented in this report represent the co-operative efforts of this team.

1.1 Background

In New Zealand, drift diving was first applied in response to the need for a method to assess trout abundance in medium to large rivers. It became an important tool for evaluating the potential impacts of proposed hydro-development on fish stocks in the Manganuioteao River. With a mean flow of 18.3 m^3/s in the middle section, a steep gradient, boulder rapids and runs, and deep pools, none of the commonly used fisheries methods, such as electric fishing, trapping, seine or gill netting, could be used. Initial trials showed that drift diving was practical, and that the results of repetitive dives through selected reaches were consistent. During the summers of 1979-1981, trout were counted throughout 24 km of the upper and middle sections (Cudby and Strickland 1986).

A similar drift diving exercise was undertaken during 1980 and 1981 on the neighbouring Whakapapa River, where the study sought to evaluate the effects of an 80% flow diversion from the upper section of the Whakapapa River (mean flow 16.5 m^3/s) to the Tongariro power development scheme. Trout counts were made in six reaches throughout the length of the river (Richardson and Teirney 1982).

One further investigation was undertaken by the drift diving team during this period. In the upper/middle reaches of the Rangitikei River (mean flow 20 m^3/s), six 1-2 km reaches were drift dived each season from April 1979 to May 1980 (Hicks and Watson 1985a). Data gathered have been used primarily to support an application to protect the river by a national water conservation order, under the 1981 amendment to the Water and Soil Conservation Act 1967 (Hicks and Watson 1985b).

Drift diving results revealed several trends common to all three rivers. Firstly, there was a change in predominance from rainbow to brown trout with increasing distance downstream. Secondly, during winter, rainbow trout numbers in the mainstems dropped dramatically and accumulations of spawning brown trout were encountered in suitable mainstem habitat. Similarities in the size and form of the Whakapapa and Manganuioteao Rivers, and in their trout stocks, were used to infer that trout numbers had been reduced by up to 90% in a 7 km section of the Whakapapa immediately below the intake. However, as the contribution from downstream tributaries increased the flow in the Whakapapa, trout numbers increased, until in the lower reaches, numbers were comparable with those in the Manganuioteao River.

Drift diving these rivers was not limited entirely to measuring relative trout abundance. Underwater observations of river form and trout behaviour provided valuable insights into trout habitat and how it was used. Understanding habitat was basic to the implementation of good drift diving techniques, and helped to identify the factors which determine trout abundance in rivers. However, the possibility of identifying critical habitat features from these three rivers was confounded by similarities in flow, habitat types, and mixed brown and rainbow trout stocks. A larger database was required, with measurements from rivers with widely varying flow characteristics, geomorphology, and trout stocks.

With increasing pressure on our freshwater resources, questions about the flow requirements of fish were becoming persistent and urgent. As the flow regime determines many aspects of instream habitat, a list of rivers with more than five years of flow record was compiled. A pilot survey, conducted between January and March 1985, established the feasibility of drift diving rivers of widely differing sizes and types (Jowett and Hicks 1985). For the following three years, between December and March, rivers from the list were drift dived.

Altogether, since 1979, trout abundance (as well as instream features such as cover and substrate) has been assessed by drift diving over 700 km, comprising some 300 reaches on a total of 93 rivers throughout the country (Fig. 1). In all, over 30 000 trout have been counted, and it is from this experience, and notes made at the time, that we comment on the relationships between instream features and trout abundance, and on behavioral differences between the two trout species.

The information provided by this survey is the primary database for a further study which seeks to identify factors which govern trout abundance in New Zealand rivers, and to incorporate them into a predictive model. It is part of a larger, interdepartmental, riverine study of biological, physical, and chemical modelling (Division of Water Sciences 1989).

1.2 Objectives

The objectives of this report are:

- to describe the development and application of the drift diving technique in New Zealand rivers in sufficient detail to enable divers with no previous experience of counting trout to achieve an acceptable standard when applying the method;
- to specify the conditions required for counting trout underwater and to provide a standardised set of criteria to be adhered to by those applying the method in New Zealand;
- to outline the advantages and limitations of the technique based on experience of drift diving a range of river sizes and types in New Zealand;

FIGURE 1. Location of drift diving reaches. (Numbers refer to the sites listed in Appendix II.)

- to consider trout count variability between repeat dives at one site at one time, between seasons, and from year to year;
- to make available data collected by the MAF Fisheries drift diving team and acclimatisation society field officers between 1979 and 1988;
- to review the literature which compares the results of drift diving with other techniques of assessing fish abundance in rivers;
- to outline the types of water and fisheries management issues where drift diving could be applied usefully.

2. THE DRIFT DIVING METHOD

The following standard criteria and procedures have been developed in response to the need for consistency when applying the drift diving technique. It is recommended that the drift diving and data recording methods described here be adopted nationwide.

2.1 Selection of Reaches

Drift diving reaches must be pre-selected to achieve the objectives of a particular investigation. Our drift diving reaches were located within sections of the river where flows had been recorded for at least five years. This was so that relative trout abundance could be related to the flow regime in that part of the river. We surveyed reaches of 1- 2 km in length. Over this distance, characteristic features of a given stretch of river, such as pools, runs, and riffles, were repeated several times. For this reason, trout counts from reaches of this length are likely to reflect abundance over a longer section of the river. However, it is unlikely that the results from a single reach will adequately reflect relative trout abundance throughout the entire length of a river, unless the river is short or particularly homogeneous.

Diving speed varied with water velocity, channel shape, and the amount of searching required to count all fish. If rivers were large, clear, and fast, speeds of over 4 km/h were possible. On average, divers covered 1-2 km/h. Therefore, reaches of 1-2 km in length, requiring divers to be submerged for 1-2 hours, maximised the accuracy of trout counts while minimising the possibility of hypothermia, loss of concentration, or injury to divers.

2.2 Pre-dive Reconnaissance

Topographical maps were used to identify suitable diving reaches and river access points. Ideally, road access was available at either end of the reach so that a vehicle could be placed at the downstream end. If the river could not be viewed beforehand, local knowledge was sought, if available, about the presence of diving hazards such as dangerous rapids, waterfalls, or log jams. Permission to cross private property was sought where possible.

2.3 Teamwork

Each member of the team held a recognised diving qualification, was physically fit, and confident in water. At times, less experienced divers were used to increase team numbers for large rivers, but were assigned to less arduous and less critical positions in line across the river, such as between the bank and centre positions. An experienced diver was assigned the position of dive leader. This person was responsible for the operation, performance, and safety of the team. Specifically, the functions of the dive leader included:

- assigning each team member a position in line across the river;
- deciding where data recording stops were to be made;
- recording trout counts made by the team;
- checking diver formation and maintaining the line;
- deciding appropriate strategies if major channel changes occurred.

Co-operation and team work were basic to the success of the technique. Inexperienced divers have a tendency to become distracted watching fish, and do not always restrict themselves to their allotted area of channel, thereby counting other divers' fish. Failing to check their position in the line often means that inexperienced divers move ahead of, or fall behind, the rest of the team.

2.4 Measurements Prior to Diving

Before a drift dive commenced, the underwater visibility was measured using a secchi disc. A 20-cm black and white disc was held vertically under the water in the direction of the maximum amount of light. A second diver, holding a measuring tape, backed away until the disc was just visible underwater. If the secchi disc measurement was less than 3 m in a slowly flowing river, or less than 4 m in a swift river, the dive did not proceed. These visibilities were considered to be the minimum required to achieve a satisfactory survey. If there was uncertainty about visibility, the team did not gear up until the measurement was made. In retrospect, we would recommend that a black secchi disc be used for measurement of underwater visibility, as measurements using this kind of disc are less affected by light (Davies-Colley 1988).

Water temperature and water quality parameters also were measured, either before or after the dive. Immediately prior to entering the water, the dive leader recorded the names of those taking part in the dive and the starting time.

2.5 Counting Trout

The team, equipped with wet suits (including hoods, hard-soled booties, and gloves if required), face masks, snorkels, fins, and weight belts, spaced themselves evenly across the river in a line perpendicular to the river's banks. Floating with the current, each diver maintained visual contact with adjacent divers, as well as scanning the river bed and water ahead through an arc of about 120°. After several sweeps, each diver checked that line formation was being maintained.

Trout were counted only as they passed underneath or around a diver. If there was any question of adjacent divers counting the same fish, hand signals were used to decide who was to include the fish in their tally. When trout were abundant and visibility was good, the possibility of double counting or of missing a school was minimised by divers counting only those fish which passed between them and the adjacent diver to the left. This required the diver on the right bank to maintain 120° coverage. When banks required a lot of searching, edge divers restricted themselves to a sweep from the bank to directly ahead, leaving the diver immediately adjacent to cover the extra area. The form of the river and features of the channel dictated the most appropriate searching strategy, and the dive leader instructed accordingly.

2.6 Identification and Size Classes of Trout

Trout were identified first as either brown or rainbow trout. The definitive characteristic most easily seen underwater was the presence of spots on the tails of rainbow trout. Fish with a red flush down the lateral line were usually, but not always, rainbows, and those with prominent spots along the sides, especially below the lateral line, were browns. However, markings could vary greatly between individual fish. Usually, larger trout were identified more easily.

After identification, trout were assigned to one of three size categories: small (<20 cm), medium (20-40 cm), and large (>40 cm). With experience, fish sizes can be estimated underwater (Griffith 1981; Bell *et al.* 1985). Trout smaller than 10 cm often were seen in slow, shallow water at the channel margins, or amongst boulders in faster water. Although we recorded these fish in a juvenile category, we considered that drift diving did not adequately cover juvenile habitat and that the method is inappropriate to estimate juvenile trout abundance.

2.7 Recording Trout Counts

Periodically, the dive leader stopped the team and took a tally of the numbers of trout counted in each category. Distance across a river, together with the noise of the water, often meant that divers were out of earshot of the recorder and a standard procedure for taking counts was adopted. Rainbows, large, medium, small, and juvenile were tallied first, followed by browns, large, medium, small, and juvenile, with divers responding using hand signals.

The dive leader noted the results on a pre-ruled underwater pad or slate carried in a wetsuit pocket. A pencil was attached to the pad and the lead was protected. A spare pencil was carried.

Recording stops were made where distinct habitat changes occurred and where the water depth and velocity allowed divers to stand up; the tails of pools often provided such conditions. When the water was deep and velocities high, the team moved across to shallow water, or divided, with half the divers going to each bank. In rivers with significant sediment deposition or algal growth, stopping markedly reduced subsequent visibility. Turbulence around each stationary diver dislodged fine sediment and algae, which then floated in suspension down the river with the divers. This problem was reduced by standing for the counts rather than kneeling or lying in the water. If the problem was severe, divers swam to the bank and avoided contact with the river bed. When trout numbers were high, recording stops were made more frequently to avoid divers losing count.

2.8 Diving Strategies

A variety of diving strategies was required to provide effective diver coverage in rivers of varying size, channel complexity, and habitat features.

2.8.1 Number of Divers

Too few divers in a team may result in poor coverage, whereas too many can make team operation difficult, increase the possibility of double counting, and increase the likelihood of schooling behaviour and fast movement by the fish. Underwater visibility determines the optimum number of divers, because visual contact must be maintained between adjacent team members. However, divers are not seen as easily underwater as the secchi disc is. Measuring secchi disc and diver visibilities at the same time in 20 different situations ranging from 3-15 m secchi disc visibility, revealed that diver visibility was equivalent to 0.75 secchi disc visibility. Therefore, for each dive, the number of divers required could be calculated once visibility and river width were known. For example, at an underwater visibility of 8 m, a diver can be seen 6 m away and four divers can cover a 30-m-wide river.

The number of divers required to achieve good coverage also can be affected by water velocity, channel characteristics, and substrate size. In general, we used more divers when water velocities were higher, channels were more complex, and substrate was larger.

2.8.2 Line Maintenance

Maintaining a straight line during drift diving is critical if trout are not to be missed or double counted. Fish which swim back and forth in front of the line, or dart diagonally across the river can cause problems if line formation is not maintained.

We adopted the following strategies for maintaining line formation when channel width, shape, or depth changed:

- channel narrowed: in deep runs, the channel can narrow resulting in divers being crowded. In this situation, those at the edges moved back and behind the line, and rejoined when the channel widened;

- channel widened: the whole team spread out to maintain even spacing across the river. Occasionally, when channel widening was extreme, the team concentrated on areas containing the best habitat rather than leaving large spaces between divers;

- depth decreased: at the tails of pools or along river edges, the water may become too shallow for drifting. As depths approach 0.3 m, drift diving becomes difficult, but is still possible, especially without weight belts. When the water was too shallow, divers either stood up and walked or moved into deeper water behind the line;

- depth increased: usually, some diving was necessary to check bedrock, boulder, or instream debris cover. Divers worked in pairs, diving and searching alternately, until the depth decreased. Water exceeding 6 m in depth could not be searched adequately;

- high velocity, shallow water: in fast, shallow water, divers stood, removed fins, and walked along the river edge or bank, as walking within the stream bed dislodged sediment and periphyton, which reduced visibility. In rivers with sedimentary substrates, such as papa or mudstone, all riffles were avoided;

- high velocity, deeper water: water velocities often were higher in the centre of the channel. Such conditions made line maintenance difficult, as divers in the middle were carried along more quickly than those at the edges. To prevent such arrowhead formations, the outside divers were required to swim strongly, while the centre divers attempted to slow down;

- rapids: the danger of negotiating steep, white water rapids was assessed carefully beforehand. If there was any doubt, we walked. In difficult sections, divers proceeded one at a time, allowing sufficient space between each person to avoid collisions and possible injuries. Usually, the main flow and deepest part of the rapid was followed and divers re-formed into line as soon as possible. Inflated inner tubes were used rarely, as they were often a hindrance, especially in pools.

2.9 Trout Behaviour

Knowing where the trout are likely to be, is as basic to the success of drift diving as having the right number of divers or good line maintenance strategies. An understanding of how trout respond to drift divers was gained by observing fish of different sizes, at different levels of abundance, in a variety of river sizes and types. Throughout the survey we noted where trout were encountered in each river and how they reacted as we moved downstream. These observations were recorded at the end of each dive and form the basis of our comments on trout behaviour.

There is no doubt that trout were disturbed by our presence. We observed responses ranging from individual trout curled tightly around the base of boulders, to actively swimming schools of up to 60 fish. Brown trout tended to use physical cover more than rainbow trout. In pools, large brown trout commonly were observed facing into the current, lying stationary against bedrock, banks, boulders, logs, or amongst willow roots and weed beds. Unless approached closely or touched, they did not move from these positions. Rainbow trout rarely used this type of cover.

In run habitat, where cover was limited, large and medium brown trout often lay motionless on the bed facing upstream into the current. As in pools, they tended to remain completely still, only darting upstream if closely approached by a diver. When brown trout were very abundant, either in runs or in pools, we observed schooling, especially with medium and small fish.

In contrast, rainbow trout of all sizes were more likely to be encountered actively swimming in the water column. Schools of large and medium rainbow trout often gathered at the tail of pools, and darted back upstream en masse, underneath and around approaching divers.

The response of undisturbed trout to the presence of drift divers was observed from banks and bridges above several rivers. In pools, trout ceased feeding as divers entered the pool upstream. As the team approached, trout darted into physical cover or to the tail of the pool. Rather than moving downstream into runs or riffles, trout at the tail of the pool darted back upstream under the divers. In runs, trout began moving laterally as the divers entered the water upstream. A number of trout swam 20-30 m downstream, turned, and swam back to their original position, remaining stationary on the substrate or seeking bank cover as the divers approached. Our observations in these situations, together with the consistent observation of schools ahead darting back upstream from the tails of pools, suggest that trout are not driven significant distances downstream in front of drift divers.

2.10 Underwater Evaluation of Habitat

In the course of counting trout and observing their behaviour, we also observed and evaluated instream habitat.

2.10.1 Physical Cover

Underwater observations of medium and large trout lying in bedrock fissures, pressed against undercut banks, and curled under boulders confirmed that cover provided by physical objects was used often by disturbed fish. The amount of physical cover available (although not necessarily used) within each reach was assessed on a 10-point scale (0-9).

Low cover ratings, such as 2 or 3, were given to rivers with indistinct banks, no bankside vegetation, relatively straight open channels, and predominantly run/riffle habitat with fine, uniform substrate. Rivers with high cover ratings (7 - 9) tended to have undercut banks, overhanging willows, complex channels containing pools, submerged logs, and possibly weedbeds, or to have substrates composed of large boulders. Intermediate between these were rivers featuring coarse substrate and complex channels, which provided a moderate amount of cover for trout. For each reach, the cover rating was accompanied by a description of the type and amount of each cover type available. The cover utilised by trout also was recorded, and ranked in order of use by fish.

2.10.2 Pool, Run, and Riffle Composition

Initially, the proportion of deep pool, shallow (less than 1 m) pool, run, and riffle/rapid throughout a reach was assessed by paced measurement alongside the reach. After comparing these measurements with divers' estimates made while drifting, we decided to use a consensus estimate. The habitats were defined primarily by characteristics of the water surface. Shallow and deep pools were identified by their smooth surfaces. Water with a rippling, but unbroken, surface was classified as run, whereas riffles and rapids featured broken and white water surfaces.

2.10.3 Substrate Composition

Within each of the water types described above, divers noted the percentage of the following six substrate types: bedrock, boulder (>264 mm), cobbles (64 - 264 mm), gravel (10 - 64 mm), fine gravel and sand (0.06 - 10 mm), and mud/silt (<0.06 mm). At the end of the dive, individual evaluations were discussed and a consensus was reached.

2.10.4 Invertebrate Fauna

It is possible to gain an impression of invertebrate abundance while drift diving. River reaches were classified broadly into low, medium, or high invertebrate abundance categories. Furthermore, the predominant invertebrate groups, such as mayflies, caddisflies, or snails, were recorded.

2.11 Post-dive Records

At the end of the drift dive, the time was noted and the final trout counts were recorded. Two divers measured the average river width using a tape. Before the team departed from the site, a standard drift diving form was completed (Appendix I). Cover rating, cover types available, and how the cover was used by trout were decided by discussion. Pool, run, and riffle composition, substrate composition, invertebrate abundance, and the dominant invertebrate groups similarly were recorded. Sightings of native fish species, and any other comments relating to the survey were recorded immediately after the dive.

On returning from a drift diving trip, data from the standard form were transcribed onto the drift diving database at the Freshwater Fisheries Centre in Christchurch. Information can be made available from this database on request.

2.12 Converting Trout Counts to Abundance and Biomass

The total number of trout/km incorporates neither fish size nor river size and therefore can be misleading when comparing rivers of different sizes, or trout populations with different size structures. For convenience, we converted our observations to abundance and biomass, where abundance was the measure for a unit length of river and biomass was the measure for a unit area. To convert large, medium, and small trout counts to a single measurement, fish numbers were converted using the following formula, based on the mean weights (kg) of brown and rainbow trout derived from average condition factors (E. Graynoth, pers. comm.) in each size class:

abundance = (large bt + large rt) x 1.16
+ medium rt x 0.343 + small rt x 0.043
+ medium bt x 0.31 + small bt x 0.04 (kg/km)

where bt = brown trout and rt = rainbow trout.

Measures of abundance enable comparisons to be made between rivers which differed markedly in the size structure of the trout stocks. For example, the majority of fish counted in Spring Creek (Marlborough) were large brown trout, whereas in the Tarawera River at the lake outlet, small rainbow trout were very abundant. Despite such differences in trout size, trout abundance, expressed in kg/km, was almost identical (Appendix II).

To compare rivers of differing widths, we converted abundance to biomass:

abundance (kg/km)/mean river width (m)
= biomass (g/m^2).

Using the example above, Spring Creek is only half the width of the Tarawera River and therefore supports twice the trout biomass per m^2.

3. RESULTS

3.1 Trout Abundance and Biomass

Comparative trout abundance, assessed by drift diving 158 reaches in 93 rivers throughout New Zealand (Fig. 1), is presented in Appendix II. Where repeat dives were carried out, only the highest trout count is listed, and for 27 rivers drift dived at more than one site, results have been listed serially, from the headwaters to the lower reaches.

The availability of sites was limited in certain areas by the absence of adequate flow records, poor underwater visibility, or frequent extended periods of discolouration from snow melt and/or rain.

Despite these limitations, trout were counted in more than 700 kilometres of river.

Measures of mean river width, secchi disc visibility, and cover (Fig. 2) indicate the wide variety of rivers which were evaluated by drift diving. Mean river widths ranged from 5 m to 130 m, but over half were between 10 m and 30 m wide.

During the development of our drift diving techniques (1979-1982), counts were made in visibilities as low as 1.5 m. However, more recent dives have all been in visibilities greater than 3-4 m. Thus the distribution of underwater visibility was not uniform. Secchi disc readings of between 3 m and 6 m were recorded for 50% of all river reaches (Fig. 2), with higher readings (up to 19 m) in rivers flowing from unmodified catchments.

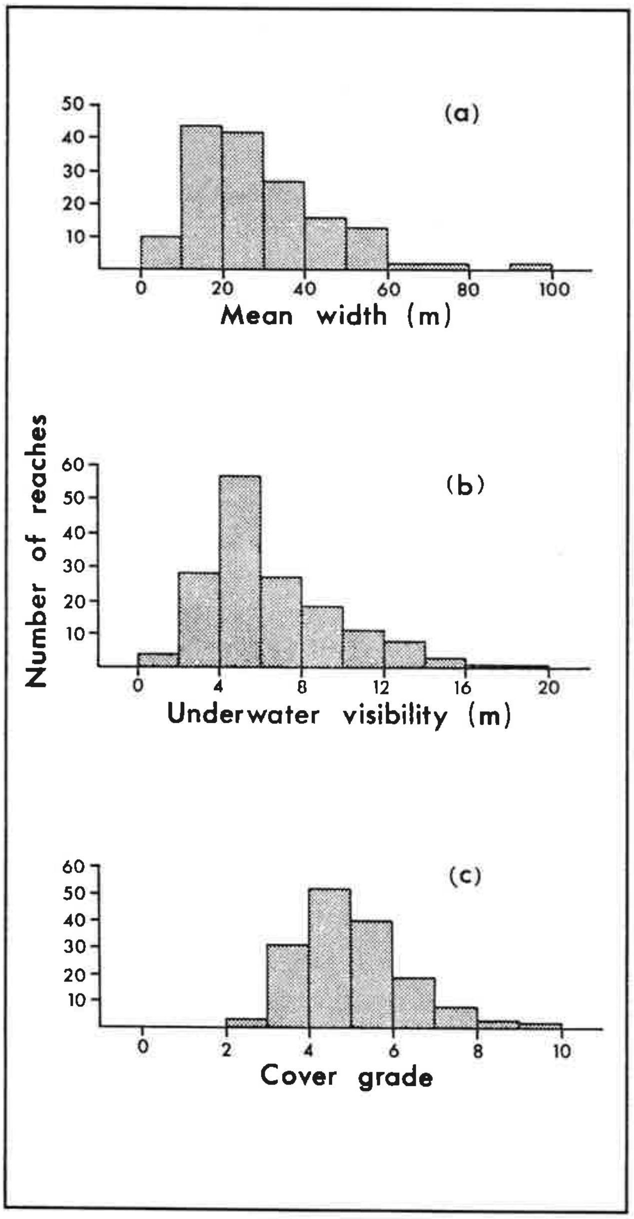

FIGURE 2. Distributions of (a) mean river width, (b) underwater visibility (secchi disc readings), and (c) cover grades in 158 drift diving reaches throughout New Zealand.

Cover grades of between 4 and 6 were assigned to the majority of river reaches evaluated in the survey (Fig. 2). Grades as low as 2 were recorded for rivers with open gravel channels, such as the Waimakariri. In contrast, rivers with boulder substrate, steep banks, and instream vegetation (such as willow branches and roots) earned the highest cover ratings. Particularly notable was the amount of cover provided by the large, rounded boulder streambeds of Taranaki rivers.

Trout counts varied widely, from none to 582 small, medium, and large trout/km, reflecting the variety of river sizes and types included in the survey. As with measures of habitat, the distribution of trout abundance was skewed, with the majority of rivers falling in the lower end of the range (Fig. 3). Trout abundance was less than 25 kg/km in 50% of the reaches surveyed.

Allowing for river width made no obvious difference to the pattern of trout abundance, although the relative position of individual river reaches was altered. In the majority of reaches, biomass was between 0 and 1 g/m^2 (Fig. 3), but ranged up to 8.32 g/m^2, excluding the exceptionally high density recorded in a short (300 m) reach at the outlet of Lake Rotoiti, where biomass was 16.14 g/m^2.

3.2 Observations on Trout Habitat, Use of Cover, and Response to Divers

During our surveys, more than 20 000 brown trout and 10 000 rainbow trout were observed. We noticed that there were broad similarities in trout response, cover preference, and habitat use, and have summarised the commonly repeated patterns.

We observed trout of different size classes in different habitats. Small and medium sized trout, particularly browns, often were found in shallow boulder/cobble runs or riffles, whereas large trout were in deeper runs or pools. We noted that run habitat with boulder/cobble substrate could contain high densities of large trout and that there was an almost complete absence of trout in rivers, or sections of a river, with fine substrate and slower water velocities.

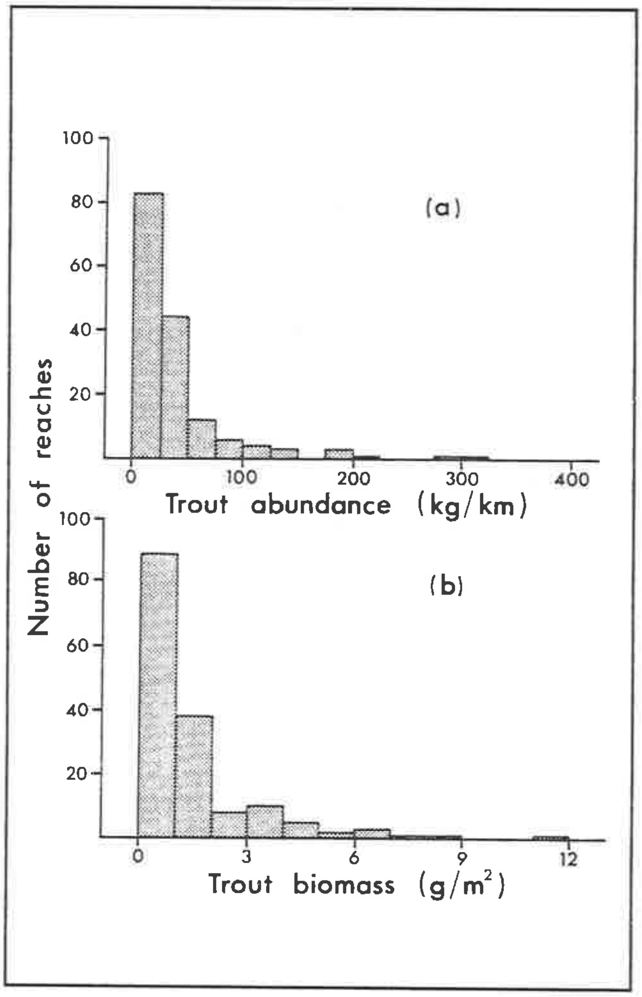

FIGURE 3. Trout abundance (a) and biomass (b) in 158 drift diving reaches throughout New Zealand.

Divers frequently observed trout under or alongside physical objects (bedrock, boulders, banks, instream debris, and aquatic vegetation). Rainbow trout were observed in association with physical cover in only six of the 17 rainbow trout rivers, and in three cases these comprised juvenile and small fish amongst aquatic vegetation. Brown trout were observed in association with cover in 127 of 132 rivers, with the proportion associated with cover varying from river to river. Brown trout were encountered most often in association with bedrock and boulders, although banks and instream debris were also likely locations. However, particularly when densities were high, many brown trout exhibited responses unrelated to physical cover. Within run habitat, large and medium trout often were seen lying stationary on the river bed facing into the current. At times, this position was maintained as divers swam past, but more often the fish would swim upstream as a diver approached, sometimes almost within touching distance. In rivers with high densities of small and medium trout (such as the Mohaka, part of the Gowan, Grey, and Hurunui), fish would move as a school in front of the divers until, at some stage, the whole group turned and fled upstream. All size classes of rainbow trout exhibited a similar form of behaviour, often schooling in front of the divers before swimming quickly upstream past the divers.

3.3 Classification of River Reaches by Abundance

By ranking the trout abundance data, reaches have been divided into three approximately equal groups: low (<15 kg/km), medium (15-35 kg/km), and high (>35 kg/km) abundance. Lake outlets, such as the Clutha, Buller, Gowan, and Hurunui Rivers, supported the most impressive trout stocks encountered in the survey, and rivers associated with lakes, such as the Tongariro, Tauranga-Taupo, Tekapo, Mararoa, Arnold, and Haupiri Rivers, also were among the top 10% of rivers surveyed. The Mohaka, Rai, Motueka, Grey, Aparima, Inangahua, Maruia, Mangles, Hutt, Mohikinui, and Karamea formed another group of rivers with high abundance, all of which featured a high percentage of boulder or cobble runs. Yet another group which supported good trout stocks comprised stable flow rivers, either spring-fed or draining pumice catchments, such as the Rangitaiki, Waihou, and Riwaka Rivers, and Spring Creek. Rivers which supported low numbers of trout also could be classified into several groups. Rivers with a combination of fine substrate, little cover, and low water velocities, such as Kaueranga, Oroua, Tukituki, and Tutaekuri Rivers, contained low trout numbers, as did a number of headwaters and gorges, such as Waimana, Mangorewa, Taipo, Orari, Kakanui, and Pomohaka. Similarities in trout stocks were evident within groups of rivers in the same geographical area, such as those originating on the slopes of Mt Taranaki or draining the Tararua Ranges.

3.4 Agreement between Trout Counts from Repeat Dives

Assuming that trout numbers, species composition, and size distribution will not alter significantly in a river reach over a 1-2 day period during summer, variation in trout counts between repeat dives provides a measure of diver performance and precision. Little variation indicates that divers are seeing a consistent proportion of the fish present, whereas large between-dive differences suggest that counts may be unreliable. Possible reasons for poor repetition are that there may be insufficient divers for the width of the channel, the channel was too complex, or the current was too fast and varied for effective counting. Alternatively, trout may move deeper into cover on successive dives, as occurred during an upstream diving survey on the Hautapu River, where trout became more difficult to detect (Barker 1988).

The degree to which trout counts can be repeated was evaluated by repeating dives in six rivers (Table 1) with a range of drift diving conditions and channel types. Mean annual flows ranged from 5.5-25.0 m^3/s, mean river widths from

TABLE 1. Trout numbers observed during nine sets of repeated drift dives, and coefficients of variation in total numbers (CV in %).

River	Date	Dive no.	Brown trout L	Brown trout M	Brown trout S	Brown trout Total	Rainbow trout L	Rainbow trout M	Rainbow trout S	Rainbow trout Total	Total trout
Rangitikei (Springvale A)	05.80	1	50	2	0	52	7	2	0	9	61
		2	49	6	0	55	10	3	0	13	68
		3	54	2	1	57	9	5	0	14	71
		CV									7.7
Rangitikei (Mangaohane B)	01.80	1	13	9	0	22	15	35	29	79	101
		2	14	1	0	15	7	43	41	91	106
		3	13	1	0	14	14	34	39	87	101
		CV									2.8
Wanganui (Kakahi)	02.88	1	33	39	24	96	23	31	12	66	162
		2	27	30	5	62	28	36	13	77	139
		CV									10.8
Rai (above the falls)	01.88	1	24	33	17	74	12	7	1	20	94
		2	27	17	5	49	14	17	0	31	80
		3	28	21	7	56	11	21	1	33	89
		CV									8.1
Hutt (below Akatarawa forks)	01.85	1	58	156	21	235	-	-	-	-	-
		2	58	147	38	243	-	-	-	-	-
		CV				2.4	-	-	-	-	-
	02.85	1	38	180	35	252	-	-	-	-	-
		2	39	203	45	287	-	-	-	-	-
		CV				9.2	-	-	-	-	-
	03.85	1	50	138	42	230	-	-	-	-	-
		2	46	96	66	208	-	-	-	-	-
		CV				7.1	-	-	-	-	-
Hurunui (below Lake Sumner)	05.82	1	91	203	23	317	-	-	-	-	-
		2	56	159	22	237	-	-	-	-	-
		CV				20.4	-	-	-	-	-
Kakanui (at Pringles)	02.85	1	8	87	63	158	-	-	-	-	-
		2	7	42	91	140	-	-	-	-	-
		CV				8.5	-	-	-	-	-

L = large (>40 cm).
M = medium (20-40 cm).
S = small (<20 cm).

22-38 m, cover grade from 3-7, and underwater visibility from 4-10 m. Apart from the Hurunui River, total trout counts from successive dives were very close, with the coefficients of variation ranging from 0.024 to 0.108. There were no apparent relationships between variability in trout counts and river size, channel morphology, physical cover, or underwater visibility. The variability on the Hurunui River was most probably the result of reducing the number of divers between dives (from four to three), as well as insufficient divers for the width of river and visibility. Twenty-five per cent fewer trout were seen during the second dive, although trout distribution among the size classes remained the same (Bonnett and Docherty 1985).

Generally, there was good agreement between counts of large trout, but more variation between counts of medium and small trout. Results from the Kakanui and Hutt River (January and March dives) indicate that divers may have difficulty discriminating between medium and small size classes when fish sizes are borderline.

Results from mixed brown and rainbow trout rivers (Rai, Wanganui, and Rangitikei River at Mangaohane B) indicate that species identification in the small and medium size classes can pose problems, particularly if trout are abundant and actively swimming when seen. In these rivers, the total numbers in each class remained about the same, but the numbers of each species differed between dives. In most cases, rainbow trout counts increased with successive dives and brown trout numbers decreased. This may be due to trout, especially small and medium trout, being more mobile on the second dive and a tendency for divers to associate mobility with rainbow trout. Otherwise, given adequate diver coverage, repeat counts can be expected to show a high degree of agreement.

3.5 Year-to-Year Variation in Trout Counts

Year-to-year variation in relative trout abundance was assessed at 36 reaches on 27 rivers by repeat surveying once or twice over the course of six summers (Table 2). Most rivers were represented by a single reach, but data were available from three sites on the Rangitikei, four sites on the Whakapapa, and seven sites on the Manganuioteao. Thirty of the reaches were surveyed in consecutive summers and the remaining six were surveyed at an interval of 2-5 years.

Some counts from consecutive summers showed wide variation, but a large number showed little change. Rivers which showed less than 30% change in trout abundance or biomass from one year to another included the Tutaekuri, Tauherenikau, Waiohine, Hutt (over the summers 1981/82, 1984/85, and 1985/86), Ohau, Rangitikei, Motueka, both reaches of the Gowan, Mangles, Ahaura, and Kakanui (1985, late 1986, and 1988).

In a number of rivers there were significant changes in trout abundance and biomass. In the Waihou River, counts in 1987 and 1988 were similar, but 70% lower than those recorded in 1985. Numbers of large and medium trout had both declined dramatically, leaving a stock dominated by small fish. Although not as obvious, a similar trend was apparent in the adjacent Waimakariri Stream. Trout numbers observed in the Kakanui River in 1986 were much lower than those observed earlier and subsequently. Jowett and Richardson (1989) speculated that the decline was real and that a subsequent flood improved trout habitat and increased trout numbers. Another decline in trout stocks occurred in the Oreti, where trout abundance and biomass almost halved between 1985 and 1988. Between surveys, the channel had altered considerably, becoming wider, shallower, and more braided. In 1985, most trout were seen in fast runs with coarse substrate. Three years later, there was little of this type of habitat and trout were found sheltering in backwaters.

Floods can modify not only instream habitat but also the age structure of trout stocks (Jowett and Richardson 1989). These effects, together with variable recruitment, mean that numbers of small and medium fish are less stable from year to year than numbers of large fish. In the Selwyn River, between 1986 and 1988, numbers of small trout declined by over 90%, medium trout by almost 80%, and large trout by 50%. In the Rai River, a similar pattern was evident, with medium and small brown and rainbow trout exhibiting relatively greater declines than large fish.

Substantial increases in trout abundance and biomass were recorded on other rivers. Those recorded in the Waimana, Mohaka, Waipawa, and Tutaekuri Rivers probably can be attributed to an improvement in visibility. These surveys were repeated because we considered the visibility on the previous dive to be unsatisfactory. On each occasion, higher numbers were observed in conditions of improved visibility. Rainbow trout are generally more active swimmers than brown trout, and are more difficult to see at reduced visibility. This could be a partial explanation for

TABLE 2. Year-to-year variation in trout numbers, abundance, and biomass obtained by drift diving in the same reach in different years. (L = >40 cm; M = 20-40 cm; S = <20 cm.)

River	Grid reference (start)	Date	Visibility (m)	Brown trout/km L	M	S	Rainbow trout/km L	M	S	Biomass kg/km	g/m^2
Waihou	N75:301189	11/12/85	6.7	-	-	-	15	150	157	76.0	6.98
		06/04/87	9.0	-	-	-	5	33	119	22.8	2.10
		19/01/88	8.3	-	-	-	6	23	181	22.9	2.10
Waimakariri	N66:328206	15/12/85	3.5	-	-	-	0	36	193	20.7	1.85
		19/01/88	3.8	-	-	-	0	8	299	15.4	1.38
Tarawera (outlet)	N77:959984	13/12/85	6.5	0	0	0	14	37	38	30.6	1.53
		21/01/87	7.4	0	2	0	5	66	200	37.2	1.86
		20/01/88	3.2	0	0	0	1	21	87	11.9	0.60
Waimana	N78:478071	20/01/87	3.0	2	8	4	-	-	-	4.6	0.19
		15/01/88	3.6	8	3	4	-	-	-	9.6	0.39
Mohaka	N114:050756	26/03/86	5.0	9	5	5	2	2	0	15.1	0.38
		01/02/88	7.5	12	21	23	10	11	22	36.8	0.92
Tutaekuri	N134:210368	16/12/85	3.0	2	3	0	0	3	0	3.9	0.17
		26/03/86	4.0	0	0	0	2	2	22	4.4	0.22
Waipawa	N140:750985	16/12/85	6.8	1	1	0	0	0	0	1.1	0.07
		25/03/86	9.0	1	0	4	4	1	4	6.0	0.37
Ruamahanga	N162:167574	27/03/85	7.4	10	5	0	-	-	-	13.6	0.45
		18/12/85	5.5	18	4	0	-	-	-	22.2	0.74
Tauherenikau	N161:860493	27/03/85	11.6	3	0	10	-	-	-	4.1	0.29
		19/12/85	18.0	2	4	0	-	-	-	3.8	0.27
Waiohine	N161:903557	27/03/85	11.6	1	4	6	-	-	-	2.5	0.07
		19/12/85	16.0	2	0	1	-	-	-	2.2	0.06
Hutt	N161:632458	07/01/82	4.8	30	82	19	-	-	-	61.4	2.82
		22/04/82	3.5	39	18	9	-	-	-	50.7	2.33
		17/01/85	4.0	40	108	14	-	-	-	80.3	3.69
		13/02/85	4.8	27	140	31	-	-	-	75.8	3.48
		18/03/85	5.1	34	95	29	-	-	-	70.6	3.23
		20/12/85	6.0	23	46	32	-	-	-	41.7	1.92
Otaki	N157:727781	21/03/85	12.0	10	12	2	-	-	-	15.9	0.66
		19/12/85	14.0	7	3	1	-	-	-	8.7	0.36
Ohau	N152:858984	21/03/85	14.8	5	2	10	-	-	-	6.3	0.36
		19/12/85	6.4	2	10	6	-	-	-	5.7	0.33
Rangitikei (Springvale A)	N123:508420	24/04/79	10.0	9	2	2	12	29	4	35.1	1.33
		15/01/80	3.5	14	9	13	5	7	8	28.3	1.07
		23/03/86	13.0	16	11	2	0	8	34	26.0	0.98
(Springvale B)	N123:503404	24/04/79	10.0	8	0	0	3	24	0	21.3	0.53
		15/01/80	3.5	10	2	1	5	12	3	22.3	0.56
(Pukeokahu)	N133:514245	26/04/79	3.0	10	2	0	4	18	5	23.2	0.68
		14/01/80	3.5	7	2	4	5	39	16	28.5	0.84
Wanganui	N101:910083	08/03/80	1.5	5	6	2	1	6	2	11.6	0.31
		21/03/86	6.0	11	11	4	1	1	0	17.6	0.47
		02/02/88	4.9	16	18	3	16	21	8	50.7	1.34
Manganuioteao (Mangaturuturu)	N121:860666	23/01/79	3.0	2	0	0	4	3	0	7.3	0.15
		02/02/80	3.0	2	1	0	6	4	2	11.7	0.24
		03/02/81	3.0	5	0	0	9	2	1	16.2	0.32
(Possum ridge)	N121:790614	18/01/79	3.0	5	1	0	4	6	0	13.2	0.27
		31/01/80	3.0	6	2	1	5	5	3	14.3	0.27
		30/01/81	3.5	16	2	0	4	3	1	24.7	0.49

TABLE 2. (Contd.)

River	Grid reference (start)	Date	Visibility (m)	Brown trout/km L	M	S	Rainbow trout/km L	M	S	Biomass kg/km	g/m^2
(Mangamingi)	N121:789633	18/01/79	3.0	3	0	0	5	2	3	10.4	0.21
		31/01/80	3.0	6	0	0	12	7	3	22.9	0.46
		30/01/81	3.5	15	0	0	7	1	0	25.8	0.52
(Hoihenga)	N121:772619	19/01/79	4.0	7	7	0	3	8	1	16.3	0.33
		31/01/80	3.0	8	2	1	4	5	1	15.4	0.31
		30/01/81	3.0	14	4	2	6	8	3	27.7	0.56
(Olivers swing bridge)	N121:743615	17/01/79	3.0	8	4	0	4	9	0	18.6	0.37
		30/01/80	2.0	6	2	0	2	2	1	10.7	0.21
		29/01/81	2.5	22	8	1	4	2	4	33.5	0.67
(Training pool)	N121:743609	18/01/79	3.0	7	7	0	13	15	0	30.4	0.61
		30/01/80	2.0	6	2	0	2	2	1	10.7	0.21
		29/01/81	2.5	17	8	0	3	4	1	27.2	0.54
(Ram paddock)	N121:731621	20/01/79	3.0	8	7	0	5	10	0	20.8	0.42
		30/01/80	2.0	7	0	0	1	0	1	9.8	0.20
		21/01/81	2.5	12	7	2	4	4	5	22.2	0.45
Whakapapa (intake)	N111:967856	12/03/80	4.0	0	0	0	1	0	0	1.1	0.06
		07/01/81	3.0	1	0	0	3	0	0	4.8	0.24
		06/04/81	3.0	0	0	0	2	0	0	2.2	0.11
(Otamawairua)	N111:926895	06/03/80	1.5	7	1	0	4	1	0	12.6	0.36
		25/03/81	1.0	5	1	0	1	0	0	7.8	0.22
(Oio)	N111:898943	09/03/80	2.0	13	4	2	1	0	0	17.3	0.38
		11/02/81	1.5	16	10	1	3	5	8	27.1	0.60
(Owhango)	N101:904002	07/03/80	1.5	4	3	1	1	1	1	7.2	0.16
		10/02/81	1.5	9	9	5	5	5	27	21.4	0.48
Waiwakaiho	N109:713809	20/03/85	4.2	7	3	7	-	-	-	9.3	0.57
		20/03/86	12.4	3	2	0	-	-	-	4.1	0.25
Motueka	S19:203298	26/02/85	7.2	94	123	58	-	-	-	149.6	3.67
		24/02/87	6.2	67	129	34	-	-	-	119.3	2.93
Rai	S15:902304	23/02/87	5.0	45	55	23	11	60	7	103.8	4.55
		08/01/88	5.7	31	21	8	11	21	1	62.5	2.74
Selwyn	S74:350656	11/12/86	3.6	8	29	41	-	-	-	19.3	1.35
		10/02/88	6.6	4	6	2	-	-	-	6.7	0.47
Kakanui	S136:451582	04/02/85	4.5	7	76	55	-	-	-	34.0	1.53
		12/02/86	3.8	4	11	18	-	-	-	9.3	0.42
		24/04/86	7.3	17	57	33	-	-	-	38.3	1.72
		12/03/88	6.5	15	39	28	-	-	-	30.6	1.37
Oreti	S150:168958	05/02/85	5.0	27	12	24	-	-	-	36.4	1.21
		09/03/88	10.2	19	4	1	-	-	-	23.4	0.78
Mararoa	S149:764980	06/02/85	4.6	22	3	2	4	4	2	32.0	1.19
		09/03/88	7.0	24	4	2	20	29	10	61.8	2.30
Ahaura	S52:297783	15/02/86	19.0	33	5	0	1	1	0	40.4	1.01
		01/03/87	9.0	28	5	7	0	0	0	34.0	0.85
Mangles	S32:848644	28/02/87	3.2	40	46	106	-	-	-	64.8	3.95
		07/01/88	5.1	49	25	55	-	-	-	67.1	4.10
Gowan (lake outlet)	S33:993671	18/02/86	8.5	103	215	160	-	-	-	192.3	6.41
		27/02/87	12.2	85	158	173	-	-	-	154.3	5.14
Gowan	S33:989678	18/02/86	9.0	134	89	27	-	-	-	183.9	7.33
		27/02/87	12.2	144	125	79	-	-	-	208.8	8.32

TABLE 3. Trout survey results from river reaches with similar mean flows and morphology, surveyed at similar times. (L = >40 cm; M = 20-40 cm; S = < 20 cm.)

River and access	Date	Reach length (m)	Width (m)	Cover grade	Vis. (m)	Brown trout/km L	Brown trout/km M	Brown trout/km S	Rainbow trout/km L	Rainbow trout/km M	Rainbow trout/km S	Biomass kg/km	Biomass g/m²
Hutt River													
Silverstream	07/01/82	610	40.0	3.0	4.0	31	20	8	0	0	0	42.5	1.06
Silverstream bridge	07/01/82	272	35.0	3.0	3.6	18	48	26	0	0	0	37.1	1.06
Rangitikei River													
headwaters A	01/04/85	1600	30.0	5.0	17.5	10	0	1	39	1	0	56.8	1.89
headwaters B	01/04/85	1600	32.0	4.0	14.8	5	0	1	21	0	1	29.8	0.93
Rangitikei River													
Springvale A	15/01/80	1670	26.5	4.0	3.5	14	9	13	5	7	8	28.3	0.89
Springvale B	15/01/80	2010	40.0	3.0	3.5	10	2	1	5	12	3	22.3	0.56
Rangitikei River													
Mangaohane A	15/01/80	1890	32.0	4.0	3.5	16	1	0	5	23	4	32.8	1.03
Mangaohane B	15/01/80	1750	31.0	3.5	3.5	7	5	0	9	20	17	27.7	0.89
Pukeokahu	14/01/80	1100	34.0	4.0	3.5	7	2	4	5	39	16	28.5	0.84
Rangitikei River													
Mangaohane A	22/04/79	1280	32.0	4.0	6.0	2	0	0	14	34	1	29.6	0.93
Mangaohane B	25/04/79	1510	31.0	3.5	5.0	8	2	0	11	17	0	27.8	0.90
Manganuioteao River													
Mangamingi	30/01/81	2300	50.0	6.0	3.5	15	0	0	7	1	0	25.8	0.52
Possum Ridge	30/01/81	4900	50.0	6.0	3.5	16	2	0	4	3	1	24.7	0.49
Mangaturuturu	03/02/81	8200	50.0	5.0	3.0	5	0	0	9	2	1	16.2	0.32
Hoihenga bridge	30/01/81	4000	50.0	6.0	3.0	14	4	2	6	8	3	27.7	0.56
Olivers swing bridge	29/01/81	1700	50.0	6.0	2.5	22	8	1	4	2	4	33.5	0.67
Training pool	29/01/81	1200	50.0	6.0	2.5	17	8	0	3	4	1	27.2	0.54
Ram paddock	29/01/81	2200	50.0	6.0	2.5	12	7	2	4	4	5	22.2	0.45
Whakapapa River													
Owhango	07/03/80	7500	45.0	5.5	1.5	4	3	1	1	1	1	7.2	0.16
Otamawairua	06/03/80	5700	35.0	5.5	1.5	7	1	0	4	1	0	12.6	0.36
Oio	09/03/80	7800	45.0	5.5	2.0	13	4	2	1	0	0	17.3	0.38
Kakahi	08/03/80	1200	55.0	5.0	1.5	3	3	7	8	1	7	15.1	0.28
Spring Creek													
Odwyers Road	19/02/86	3100	9.6	8.0	7.0	27	16	2	0	0	0	36.8	3.84
Spring Creek	19/02/86	2500	10.0	8.0	5.0	23	12	2	0	0	0	30.1	3.01
Tekapo River													
below Forks River	24/02/89	700	15.0	4.0	3.0	1	6	7	0	30	17	14.7	0.98
above Grays River	24/02/89	1000	25.0	4.0	5.0	6	1	1	2	29	39	21.2	0.85
Tekapo River													
below Maryburn	24/02/89	1300	40.0	4.0	5.0	38	88	155	7	106	186	129.5	3.24
above Lake Benmore	23/02/89	1000	40.0	4.0	5.0	55	32	51	6	24	285	103.2	2.58
above steel bridge	23/02/89	1100	40.0	4.0	5.0	21	22	22	10	41	99	61.7	1.54
Buller River													
below Lake Rotoiti	24/02/87	1500	20.0	4.0	6.8	19	9	5	0	0	0	25.5	1.28
above Hope River	28/02/85	1865	25.0	4.0	7.1	29	14	4	0	0	0	38.6	1.55
Gowan River													
at Lake Rotoroa	18/02/86	800	30.0	5.5	8.5	103	215	160	0	1	0	192.3	6.41
below lake outlet	27/02/87	1800	25.1	5.0	12.2	144	125	79	0	0	0	208.8	8.32
Mokihinui River													
South branch	26/02/87	1950	30.0	6.0	12.0	38	3	12	0	0	0	45.9	1.53
North branch	26/02/87	2050	25.0	5.0	10.8	31	1	1	0	0	0	35.9	1.44
Karamea River													
above Crow hut	26/02/87	2050	30.0	7.0	12.6	41	3	18	0	0	0	49.3	1.64
above Karamea bend	26/02/87	1850	50.0	6.0	14.0	52	17	26	0	0	0	66.4	1.33

the observed increases in the Mararoa and Mohaka rivers. However in some rivers, the increase in trout abundance can be attributed to actual events. Over three consecutive summers, trout abundance and biomass from five of the seven drift diving reaches in the Manganuioteao River showed a consistent increase. The lower reaches of the neighbouring Whakapapa River exhibited a similar trend. Trout populations in both rivers had been destroyed by the 1975 lahar from Mount Ruapehu, and the stocks were considered to still be recovering (Cudby and Strickland 1986).

3.6 Comparison of Trout Count Variation Between and Within Rivers

A number of rivers were surveyed at more than one reach. Counts made in different reaches at similar times were compared for sections of the river considered to be similar in flow and gradient (Table 3). Thus, headwaters were not compared with downstream reaches where flows were greater and gradients less.

The average coefficient of variation in trout abundance between different reaches within the same river was 0.204 ± 0.118 (Table 1), whereas the coefficient of variation of abundance for all rivers was 0.986. Results for biomass were similar. The fact that abundance varied less along a river than between rivers indicates that drift diving survey results can be used to distinguish broadly between rivers, provided that the results for a reach are not extrapolated beyond sections of the river with similar flow and gradient.

4. DISCUSSION

4.1 Drift Diving Ratification

Drift diving provides a technique for evaluating comparative trout abundance in rivers throughout New Zealand when other methods cannot be applied. Like most other fish stock assessment methods, such as netting and electric fishing, drift diving does not account for every trout in a section of river. However, the degree of agreement between our repeat dives, and the large differences in trout abundance between rivers, support our view that changes in relative trout abundance can be monitored effectively by drift diving.

While some investigators have used drift diving to study salmonid behaviour and habitat preferences (Keenleyside 1962, Fausch and White 1981, Stradmeyer and Thorpe 1987), most reported studies have compared drift diving counts with the results of other sampling methods. Both Goldstein (1978) and Whitworth and Schmidt (1980) found that the number of fish species and the number of fish seen by drift divers exceeded those captured by seine netting. Similarly, underwater counts of spawning rainbow trout were higher than those made from a helicopter or the bank (Northcote and Wilkie 1963). Campbell and Neuner (1985) found that drift diving censused large trout better than electric fishing, but that the reverse was true for juvenile trout. Griffith (1981) reported similar age frequency distributions of one year and older trout from electric fishing and drift diving.

Mark and recapture methods have been used to compare population estimates derived from angling and drift diving (Slaney and Martin 1987). Although the species composition and size distribution of the fish were comparable between the two methods, drift diving estimates were lower. After a similar mark and recapture angling/diving comparison, Zubik and Fraley (1988) concluded that in large clear streams with little cover, drift diving provides a quick, reliable, relatively low cost method for estimating fish density.

Working on steelhead trout densities in small streams, Hankin and Reeves (1988) noted that bias in underwater visual estimates of fish has rarely been determined because of a lack of suitable methods which give true estimates of fish stocks. Poisoning is one of the only methods which enables all the fish within a river channel to be censused accurately. Following 12 replicate dives, Northcote and Wilkie (1963) poisoned a side channel of one river. Although they recovered more trout than the average drift count, the total number of fish was close to the maximum number counted in any of the trials.

Another method of making a total fish count was tried in selected braids of the lower Waitaki River (Palmer and Graybill 1986), where the flow to five side channels, of varying size, was able to be controlled artificially. A team of five divers spent one day counting trout in the three smaller braids in sub-optimal diving conditions, caused by a combination of high water velocity and poor underwater visibility (3 m). Following the diving evaluation, the braids were stop-netted and the flow lowered, allowing sampling by alternative techniques. Electric fishing, seine, trap, gill, and hand nets were used by a team of 15 for a week. Assuming that the intensive effort captured a high proportion of the trout in the channels, the diving team, in poor diving conditions, had counted about 40% of the trout.

Less rigorous than these studies were our own observations on the performance of the team and our ability to observe trout under the prevailing conditions. In some rivers, trout observation was easy, with good clarity, good team formation, and trout stationary rather than in cover or schooling. However, at times, conditions were below the minimum required and dives were abandoned or not recorded. Such circumstances included poor visibility, especially in fast water, poor team formation, or large amounts of cover. The effect on the trout count depended upon trout behaviour. For instance, when fish were in high numbers and schooling, poor visibility was sufficient reason to repeat the dive when visibility improved. In contrast, some dives in slower rivers with poor visibility and a large amount of cover were considered good because of the thoroughness with which cover was searched, and the tendency of the trout to remain stationary rather than to school or flee.

This review of drift diving ratification studies suggests that the technique is as good as, or better than, other standard fisheries techniques used to assess adult salmonid abundance in larger rivers. Furthermore, it is quick and efficient, requiring few resources compared with other methods. For large, clear rivers, drift diving is the only practical way to evaluate relative trout abundance.

4.2 Factors Determining Distribution and Abundance

The trout rivers of New Zealand fell into some very clear geographical and river-type groupings. There was a broad north to south grouping based on trout species, with rainbow trout dominating in the north and brown trout in the south. The presence of lakes within a river system influenced this overall pattern, and when southern catchments were connected to lakes, there were similarities with their northern counterparts. Lake outlets and spring-fed rivers provided some of the best conditions for high densities of trout. Using angler catch information collected between 1947 and 1952, Allen and Cunningham (1957) grouped trout rivers geographically. They noted that rainbow trout were predominant north of a line from southern Hawke's Bay to north Taranaki, and that brown trout predominated to the south. They also associated the occurrence of rainbow trout in the South Island with lakes, and noted the exception of some rivers in Marlborough. This distribution of brown and rainbow trout is the same as shown by our surveys, indicating that there has been no change in trout distribution in the past 20-25 years, and suggesting that the factors controlling distribution are ecological rather than historical.

Allen and Cunningham (1957) attempted to relate trout size and abundance to catchment characteristics. They described the variation in trout stocks in different zones of long rivers, and associated low trout numbers with schist catchments. However, they were generally unable to explain the distribution of trout, especially in the North Island which they described as irregular. Our surveys showed that there were different fish stocks in different zones of rivers, especially between headwaters and lower zones. However, we were unable to substantiate any relationship between low trout numbers and schist catchments, and recorded high fish densities in some of the West Coast rivers, and in the Shag and Manuherikia Rivers, all of which have schist catchments. Hydrological characteristics might be an important factor determining trout stocks. Stable flows and substrate were a common characteristic of the rivers containing high numbers both of brown and rainbow trout. Low numbers of trout were associated with headwater rivers with variable flows, or with shallow rivers flowing over a wide, gravel floodplain in which little instream cover existed.

4.3 Application of Drift Diving to Water and Fisheries Management Issues

Drift diving has provided a means of surveying trout stocks in a wide variety of rivers and reaches, and an opportunity to observe relationships between trout abundance and instream habitat which will be useful in further work such as "the 100 rivers project" (Division of Water Sciences 1989). The classification has identified some hydrological characteristics, such as lake outlets and spring-fed streams, which relate to high trout abundance, and more study may reveal factors which might be affecting trout abundance and species distribution.

Drift diving has been used to assess the effect of natural disturbances on trout stocks. A group of seven lowland rivers was drift dived before and after a major flood affected the area, which demonstrated a generally adverse effect of flooding on fish numbers (Jowett and Richardson 1989).

Drift diving also provides a means of evaluating the impacts of habitat manipulations on trout river fisheries. Before and after, up and downstream, and between-river comparisons, can all be useful when investigating the impacts of hydroelectric development, irrigation, water abstraction, or channel alterations associated with river control works. Despite less than optimal diving conditions at times, the technique was used to help evaluate trout habitat and fish stocks in a series of artificially controlled side-braids in the lower Waitaki River (Palmer 1987).

One of the most frequent concerns which anglers convey to fisheries' managers is a perceived long-term decline in trout stocks. Such claims cannot be validated unless comparative trout abundance has been assessed over a period of years. Commitment to a long-term drift diving programme, where trout counts are repeated in selected river reaches, would satisfy this requirement. These type of data are fundamental to successful negotiations with water managers over the effects of wetland drainage, changes in agricultural practices, riparian management, and river control works on trout stocks and habitat.

Concern about the perceived lack of trout in some angling waters, such as the Hutt and Riwaka Rivers, often has resulted in requests for stocking by acclimatisation societies. However, high trout numbers were observed in both rivers. An explanation may be that, although the trout are present, the anglers find it difficult to catch them. The converse was true in the headwaters of the Ahuriri River, where underwater trout counts were low, but anglers' perceptions of catch rate were high. These cases demonstrate the difficulties faced by fishery managers if they base their decisions solely on angler perceptions. However, apart from these unusual instances, a positive relationship between trout counts and anglers' catch rate perceptions has been demonstrated (Teirney 1987).

There are other specific issues where drift diving can be useful. For example, helicopter and fixed-wing aeroplane access into wilderness river fisheries has led to a growing concern about the effect of increased angling pressure on trophy headwater fisheries. Without some measure of relative trout abundance over time, there is no way of knowing whether perceived changes in trout stocks are real or are the result of changes in trout behaviour caused by increased angling pressure.

4.4 Future Use of Drift Diving

There is a wide variety of issues and problems where drift diving can be applied. The benefits are particularly clear both for fisheries and for water managers. For this reason, the existing data on the national drift diving database have been made available in this report. Results from future drift diving projects may be recorded on the standard drift diving form (see Appendix I) and sent to the second author, c/- MAF Fisheries, PO Box 8324, Riccarton, Christchurch. Regular drift diving of rivers throughout New Zealand to build up a long-term database is recommended, but, for the database to be reliable, it is essential that dive teams be experienced, use similar techniques, and record all pertinent data.

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6. LITERATURE CITED

Allen, K.R., and Cunningham, B.T. 1957. New Zealand angling, 1947-1952, results of the diary scheme. *N.Z. Marine Department, Fisheries Bulletin No. 12.* 153 p.

Barker, R. 1988. Crawl dives - a useful fish census method. *Freshwater Catch No. 38:* 22-23.

Bell, J.D., Craik, G.J.S., Pollard, D.A., and Russell, B.C. 1985. Estimating length frequency distributions of large reef fish underwater. *Coral Reefs 4:* 41-44.

Bonnett, M.L., and Docherty, C.R. 1985. An assessment of trout stocks in the upper Hurunui River. *N.Z. Ministry of Agriculture and Fisheries, Fisheries Environmental Report No. 57.* 34 p.

Campbell, R., and Neuner, J.H. 1985. Seasonal and diurnal shifts in habitat utilised by resident rainbow trout on Western Washington Cascade Mountain streams. pp. 39-48. *In:* Olson, F.W., White, R.G., and Hare, R.H. (Eds.), "Proceedings of the Symposium on Small Hydropower and Fisheries." *The American Fisheries Society.*

Cudby, E.J., and Strickland, R.R. 1986. The Manganuioteao River fishery. *N.Z. Ministry of Agriculture and Fisheries, Fisheries Environmental Report No. 14.* 226 p.

Davies-Colley, R. J. 1988. Measurement of water clarity using a black disk. *Limnology and Oceanography 32:* 416-425.

Division of Water Sciences. 1989. The 100 rivers project: Tools for river managers in New Zealand. *Streamland 71.* 4 p.

Fausch, K.D., and White, R.J. 1981. Competition between brook trout (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*) for positions in a Michigan stream. *Canadian Journal of Fisheries and Aquatic Sciences 38:* 1220-1227.

Goldstein, R.M. 1978. Quantitative comparison of seining and underwater observation for stream fishery surveys. *Progressive Fish Culturist 40(3):* 108-111.

Graynoth, E. 1974. The Wellington trout fishery. *N.Z. Ministry of Agriculture and Fisheries, Fisheries Technical Report No. 115.* 39 p.

Griffith, J. S. 1981. Estimation of the age-frequency distribution of stream-dwelling trout by underwater observation. *The Progressive Fish Culturist 43(1):* 51- 53.

Hankin, D.G., and Reeves, G.H. 1988. Estimating total fish abundance and total habitat area in small streams based on visual estimation methods. *Canadian Journal of Fisheries and Aquatic Sciences 45:* 834-844.

Hicks, B.J., and Watson, N.R.N. 1985a. Seasonal changes in abundance of brown trout (*Salmo trutta*) and rainbow trout (*S. gairdnerii*) assessed by drift diving in the Rangitikei River, New Zealand. *N.Z. Journal of Marine and Freshwater Research 19:* 1-10.

Hicks, B.J., and Watson, N.R.N. 1985b. Fish and fisheries of the Rangitikei River. *N.Z. Ministry of Agriculture and Fisheries, Fisheries Research Division Occasional Publication No. 48.* 32 p.

Jowett, I.G., and Hicks, B.J. 1985. Estimation of comparative trout abundance in New Zealand rivers by drift diving. *Freshwater Catch No. 28:* 8-10.

Jowett, I.G., and Richardson, J. 1989. Effects of a severe flood on instream habitat and trout populations in seven New Zealand rivers. *N.Z. Journal of Marine and Freshwater Research 23:* 11-17.

Keenleyside, M.H.A. 1962. Skin-diving observations of Atlantic salmon and brook trout in the Miramichi River, New Brunswick. *Journal of the Fisheries Research Board of Canada 19(4):* 625-635.

Nielsen, L.A., and Johnson, D.L. (Eds.). 1983. "Fisheries Techniques." American Fisheries Society, Bethesda, Maryland. 468 p.

Northcote, T.G., and Wilkie, D.W. 1963. Underwater census of stream fish populations. *Transactions of the American Fisheries Society 92(2):* 146-151.

Palmer, K.L. 1987. Adult trout in the demonstration channels, lower Waitaki River, 1982-85. *N.Z. Ministry of Agriculture and Fisheries, Fisheries Environmental Report No. 81.* 61 p.

Palmer, K.L., and Graybill, J. 1986. More observations on drift diving. *Freshwater Catch No. 30:* 22-23.

Richardson, J., and Teirney, L.D. 1982. The Whakapapa River: a study of a trout fishery under a modified flow regime. *N.Z. Ministry of Agriculture and Fisheries, Fisheries Environmental Report No. 22.* 71 p.

Slaney, P.A., and Martin, A.D. 1987. Accuracy of underwater census of trout populations in a large stream in British Columbia. *North American Journal of Fisheries Management 7:* 117-122.

Stadmeyer, L., and Thorpe, J.E. 1987. Feeding behaviour of wild Atlantic salmon *Salmo salar* L., parr in mid to late summer in a Scottish river. *Aquaculture and Fisheries Management 18:* 33-49.

Teirney, L.D. 1987. Angler perceptions. pp. 3-7. *In:* Jellyman, D.J. (Ed.), Factors affecting trout abundance in rivers: proceedings of a workshop held in May 1987. *Fisheries Research Centre Internal Report No. 76.* 44 p.

Whitworth, W.R., and Schmidt, R.E. 1980. Snorkelling as a means of evaluating fish populations in streams. *New York Fish and Game27:* 91-92.

Zubik, R.J., and Fraley, J.J. 1988. Comparison of snorkel and mark-recapture estimates for trout populations in large streams. *New American Journal of Fisheries Management 8:* 58-62.

APPENDIX I. Standard drift diving survey form.

DRIFT DIVE SURVEY

ACCESSION NUMBER

RIVER/STREAM DIVED
ACCESS

RIVER NUMBER

DATE

GRID REFERENCE (Map number, eastings, northings)

NZMS 1 1:63360 ☐ UPSTREAM START

NZMS 262 1:50000 ☐ DOWNSTREAM FINISH

STATION LENGTH m
METHOD

WIDTH max m
min m
average m

NUMBER OF DIVERS

DIVE LEADER

NAMES OF OTHER DIVERS

Temperature °C

UNDERWATER VISIBILITY

SECCHI DISTANCE m

DIVER DISTANCE m

FISH DISTANCE m

WEATHER CONDITIONS – FINE ☐ OVERCAST ☐

TIME : START h STOP h

NUMBER OF FISH OBSERVED –

SPECIES	☐				☐				☐				COMMENTS
	Size*				Size				Size				
REACH COUNT	F	S	M	L	F	S	M	L	F	S	M	L	
SUBTOTALS													
TOTAL													
FISH/KM													

* F = fry or fingerling (< 10 cm); S = small (10–20 cm); M = medium (20–40 cm); L = large (> 40 cm)

APPENDIX I. (Contd.)

DRIFT DIVE SURVEY

(continued)

DESCRIPTION AND RANKING OF INSTREAM COVER (Rank the importance of all COVER AVAILABLE to fish from 3 to 7. Describe principal types as undercut banks, rounded boulders, angular and fissured rocks, logs and debris, aquatic vegetation.

COVER RATING -

COVER AVAILABLE - TYPES -
(rank order)

COVER ACTUALLY USED - TYPES -
(rank order)

MAXIMUM POOL DEPTH
m

BANKSIDE VEGETATION/MATERIAL
(% of each)

ESTIMATED PROPORTION OF HABITAT TYPE IN REACH SURVEYED (%)	DEEP POOL	SHALLOW POOL	RUN	RIFFLE/RAPID
SUBSTRATE (%)				
BED ROCK				
BOULDER(> 300 mm)				
COBBLES(75-300 mm)				
GRAVEL(to 75 mm)				
FINE GRAVEL SAND(0.06-10mm				
MUD(<0.06 mm)				
OTHER				

COMMENTS (e.g. substrate covered with silt, presence of filamentous algae or aquatic macrophytes, riparian vegetation, water level if available)

APPENDIX II. Trout survey results from 158 reaches drift dived during summer (November to April inclusive) and listed in order of catchment number i.e., clockwise around each island. Numbers refer to localities shown on Figure 1. (L = <40 cm; M = 20-46 cm; S = <20 cm.)

River and access	Date	Grid reference (start)	Reach length (m)	Width (m)	Cover grade	Vis. (m)	Brown trout/km L	Brown trout/km M	Brown trout/km S	Rainbow trout/km L	Rainbow trout/km M	Rainbow trout/km S	Biomass kg/km	Biomass g/m²
1. Kaueranga River at water level recorder	15/12/85	N49:093244	1200	22.8	4.0	5.4	0	0	0	1	3	1	1.8	0.08
2. Tairua River above Broken Hills	14/12/85	N49:231275	2000	20.0	5.0	4.1	0	0	0	1	1	2	0.8	0.04
3. Waiari Stream at Muttons farm	10/12/85	N67:799428	2000	9.7	7.0	9.7	0	0	0	0	0	1	0.0	0.00
4. Mangorewa River at water level recorder	10/12/85	N67:816349	2000	12.0	7.0	12.6	0	0	0	2	0	0	2.3	0.19
5. Waihou River at Whites Road	11/12/85	N75:301189	2400	10.9	6.0	6.7	0	0	0	15	150	157	76.0	6.98
6. Waimakariri River at SH 5 bridge	15/12/85	N66:328206	1600	11.2	5.0	3.5	0	0	0	0	36	193	20.7	1.85
7. Tarawera River below falls	13/12/85	N77:976013	1600	10.0	5.0	6.8	0	0	0	8	7	0	11.7	1.18
8. Tarawera River at lake outlet	21/01/87	N77:959984	1100	20.0	5.5	7.4	0	2	0	5	66	200	37.2	1.86
9. Waimana River at Ogilvies Bridge	15/01/88	N87:551803	1300	18.4	5.5	5.3	2	0	0	2	2	2	5.3	0.29
10. Waioeka River at gorge	17/01/88	N78:737923	1500	30.0	3.5	9.0	0	0	0	3	8	3	6.7	0.22
11. Waimana River at gorge	15/01/88	N78:478071	1200	25.0	4.0	3.6	8	3	4	0	0	0	9.6	0.39
12. Rangitaiki River above Murapara	18/01/88	N95:107553	1300	25.0	5.0	4.7	2	9	5	32	98	54	78.1	3.13
13. Mohaka River headwaters	02/04/85	N113:793877	2250	23.0	6.0	3.9	77	37	58	1	0	0	103.9	4.52
14. Mohaka River at Glenfalls	01/02/88	N114:050756	1650	40.0	3.5	7.5	12	21	23	10	11	22	36.8	0.92
15. Esk River at Eskdale Park	26/03/86	N124:253518	1400	14.4	4.5	4.0	3	3	3	0	0	19	5.1	0.36
16. Tutaekuri River at Puketapu Bridge	26/03/86	N134:210368	1700	20.4	3.5	4.0	0	0	0	2	2	22	4.4	0.22
17. Ngaruroro River at Ngawapurua	02/04/85	N113:709710	1100	20.0	5.0	8.7	6	1	0	14	5	5	25.2	1.26
18. Ngaruroro River at Kuripapango	24/03/86	N123:784526	2900	20.1	5.0	9.0	2	3	1	2	7	14	8.6	0.43
19. Ngaruroro River at Whanawhana	24/03/86	N133:843318	1500	23.0	3.0	6.0	2	2	0	5	15	5	14.3	0.62
20. Taruarau River headwaters	01/04/85	N133:705386	1300	15.0	4.5	4.4	3	2	1	21	9	17	32.0	2.14
21. Taruarau River headwaters	01/04/85	N123:635505	1000	14.0	5.0	9.0	7	0	2	11	2	5	21.8	1.56
22. Taruarau River at Taihape Road	23/03/86	N123:678470	1400	12.0	4.0	10.2	4	1	1	1	6	81	10.9	0.91
23. Makaroro River at Makaroro Road	25/03/86	N140:746001	2100	12.0	3.5	3.3	0	0	1	3	1	0	4.4	0.37
24. Waipawa River at Fletchers Crossing	25/03/86	N140:750985	1340	15.0	3.5	6.8	1	0	4	4	1	4	6.0	0.40
25. Tukituki River at Fairfield Road	24/03/86	N140:860856	1000	9.0	4.0	5.0	0	0	0	0	0	0	0.0	0.00
26. Ruamahanga River at SH 2 bridge	18/12/85	N158:095869	2200	22.0	4.0	9.0	3	0	0	0	0	0	3.6	0.17
27. Ruamahanga River at Wardells	18/12/85	N162:167574	1270	30.1	4.0	5.5	18	4	0	0	0	0	22.2	0.74
28. Tauherenikau River at water level recorder	27/03/85	N161:860493	928	14.3	3.5	11.6	3	0	10	0	0	0	4.1	0.29
29. Waiohine River at gauge	27/03/85	N161:903557	2060	38.3	3.0	11.6	1	4	6	0	0	0	2.5	0.07
30. Waingawa River at water level recorder	18/12/85	N158:098711	1600	16.3	5.0	6.3	6	3	0	0	0	0	7.4	0.46
31. Akatarawa River at West Akatarawa Road	03/03/86	N161:641491	1500	13.2	5.5	6.7	17	3	1	0	0	0	20.2	1.53
32. Hutt River below Akatarawa forks	17/01/85	N161:632458	1450	21.8	5.0	4.0	40	108	14	0	0	0	80.3	3.68
33. Whakatiki River at Bulls Run Road	03/03/86	N161:570464	1060	9.5	5.0	4.1	4	1	5	0	0	0	4.8	0.51
34. Hutt River at Whakatiki Street	07/01/82	N161:586428	270	25.0	3.0	5.0	4	130	0	0	0	0	44.4	1.78
35. Hutt River at Silverstream cut	07/01/82	N160:547399	610	40.0	3.0	4.0	31	20	8	0	0	0	42.5	1.06
36. Hutt River at Silverstream bridge	07/01/82	N160:538392	272	35.0	3.0	3.6	18	48	26	0	0	0	37.1	1.06
37. Hutt River at Taita Rock	04/12/81	N160:509366	500	50.0	3.0	3.0	2	4	0	0	0	0	3.5	0.07
38. Waikanae River at treatment plant	19/12/85	N157:605703	1400	25.0	3.0	7.7	4	1	1	0	0	0	4.6	0.19
39. Otaki River at Swingbridge	21/03/85	N157:727781	1335	24.2	4.0	12.0	10	12	2	0	0	0	15.9	0.66
40. Ohau River at Gladstone Road	21/03/85	N152:858984	1910	17.5	3.5	14.8	5	2	10	0	0	0	6.3	0.36

APPENDIX II. (Contd.)

River and access	Date	Grid reference (start)	Reach length (m)	Width (m)	Cover grade	Vis. (m)	Brown trout/km L	M	S	Rainbow trout/km L	M	S	Biomass kg/km	g/m²
41. Oroua River at Feilding Road	18/03/86	N144:113529	1600	14.1	4.0	3.1	0	2	0	0	0	0	0.5	0.04
42. Pohangina River at Raumai	18/03/86	N144:269528	2250	22.6	4.5	4.6	5	4	5	0	0	0	6.9	0.31
43. Mangahao River at Ballance bridge	17/12/85	N149:274245	1400	27.1	4.0	4.8	8	6	1	0	0	0	11.1	0.41
44. Mangatainoka River at Tui brewery	17/12/85	N149:328259	1500	26.0	5.0	4.5	12	28	4	0	0	0	22.7	0.88
45. Rangitikei River headwaters A	01/04/85	N123:476655	1600	30.0	5.0	17.5	10	0	1	39	1	0	56.8	1.89
46. Rangitikei River headwaters B	01/04/85	N123:506569	1600	32.0	4.0	14.8	5	0	1	21	0	1	29.8	0.93
47. Rangitikei River headwaters C	01/04/85	N123:483460	1000	15.0	5.0	10.0	4	0	0	2	1	1	7.3	0.49
48. Rangitikei River at Springvale A	24/04/79	N123:508420	1670	26.5	4.0	10.0	9	2	2	12	29	4	35.1	1.33
49. Rangitikei River at Springvale B	15/01/80	N123:503404	2010	40.0	3.0	3.5	10	2	1	5	12	3	22.3	0.56
50. Rangitikei River at Mangaohane A	22/04/79	N133:502324	1280	32.0	4.0	6.0	2	0	0	14	34	1	29.6	0.93
51. Rangitikei River at Mangaohane A	15/01/80	N133:505326	1890	32.0	4.0	3.5	16	1	0	5	23	4	32.8	1.03
52. Rangitikei River at Mangaohane B	15/01/80	N133:504317	1750	31.0	3.5	3.5	7	5	0	9	20	17	27.7	0.89
53. Rangitikei River at Mangaohane B	25/04/79	N133:508314	1510	31.0	3.5	5.0	8	2	0	11	17	0	27.8	0.90
54. Rangitikei River at Mangaohane gorge	25/04/79	N133:509304	1600	16.0	4.5	5.0	19	1	1	12	17	0	42.4	2.65
55. Rangitikei River at Pukeokahu	14/01/80	N133:514245	1100	34.0	4.0	3.5	7	2	4	5	39	16	28.5	0.84
56. Rangitikei River at Mokai	27/04/79	N133:493183	2430	40.0	2.5	2.0	3	2	0	2	10	1	9.7	0.24
57. Hautapu River at Abattoir Road	29/01/88	N132:268195	1600	13.0	5.0	4.6	9	1	0	0	0	0	10.3	0.80
58. Moawhango River at Moawhango	23/03/86	N132:338288	1700	13.7	6.0	3.1	12	2	1	0	0	0	15.0	1.10
59. Wanganui River at SH 47	20/01/88	N112:080929	1700	4.5	4.0	10.5	4	0	0	1	0	2	4.8	1.08
60. Wanganui River at Kakahi	02/02/88	N101:910083	1700	37.9	4.0	4.9	16	18	3	16	21	8	50.7	1.34
61. Manganuioteao River at Mangaturuturu	03/02/81	N121:860666	8200	50.0	5.0	3.0	5	0	0	9	2	1	16.2	0.32
62. Manganuioteao River at Mangamingi	30/01/81	N121:789633	2300	50.0	6.0	3.5	15	0	0	7	1	0	25.8	0.52
63. Manganuioteao River at Possum Ridge	30/01/81	N121:790614	4900	50.0	6.0	3.5	16	2	0	4	3	1	24.7	0.49
64. Manganuioteao River at Hoihenga bridge	30/01/81	N121:772619	4000	50.0	6.0	3.0	14	4	2	6	8	3	27.7	0.56
65. Manganuioteao River at training pool	18/01/79	N121:743609	1200	50.0	6.0	3.0	7	7	0	13	15	0	30.4	0.61
66. Manganuioteao River at Olivers bridge	29/01/81	N121:743615	1700	50.0	6.0	2.5	22	8	1	4	2	4	33.5	0.67
67. Manganuioteao River at Ram paddock	29/01/81	N121:731621	2200	50.0	6.0	2.5	12	7	2	4	4	5	22.2	0.45
68. Manganuioteao River at Ruatiti Stream	21/01/79	N121:713621	6000	50.0	6.0	2.0	2	2	0	2	4	0	7.1	0.14
69. Whakapapa River at Whakapapanui	04/03/80	N111:988826	3700	20.0	6.0	4.0	0	0	0	2	2	3	2.8	0.14
70. Whakapapa River at intake	07/01/81	N111:967856	6500	20.0	5.5	3.0	1	0	0	3	0	0	4.8	0.24
71. Whakapapa River at Otamawairua	06/03/80	N111:926895	5700	35.0	5.5	1.5	7	1	0	4	1	0	12.6	0.36
72. Whakapapa River at Oio	11/02/81	N111:898943	7800	45.0	5.5	1.5	16	10	1	3	5	8	27.1	0.60
73. Whakapapa River at Owhango	10/02/81	N101:904002	7500	45.0	5.5	1.5	9	9	5	5	5	27	21.4	0.48
74. Whakapapa River at Kakahi	08/03/80	N101:913069	1200	55.0	5.0	1.5	3	3	7	8	1	7	15.1	0.28
75. Patea River above Stratford intake	19/03/85	N119:781593	1920	5.0	9.0	4.1	1	0	1	0	0	0	1.2	0.25
76. Patea River at King Edward Park	19/03/86	N119:847575	950	9.6	7.0	3.0	8	12	19	0	0	0	14.1	1.47
77. Waingongoro River at Eltham	20/03/85	N119:851497	1540	7.9	9.0	5.4	14	20	5	0	0	0	22.2	2.82
78. Kaupokonui River at Skeet Road	19/03/86	N129:711400	900	10.5	7.0	6.2	0	16	8	0	0	0	5.1	0.49
79. Stony River at Okato	20/03/86	N108:464743	1150	11.8	7.0	13.0	4	3	4	0	3	6	7.4	0.63
80. Waiwakaiho River at SH 3	20/03/85	N109:713809	1000	16.5	8.0	4.2	7	3	7	0	0	0	9.3	0.57

APPENDIX II. (Contd.)

River and access	Date	Grid reference (start)	Reach length (m)	Width (m)	Cover grade	Vis. (m)	Brown trout/km L	M	S	Rainbow trout/km L	M	S	Biomass kg/km	g/m²
81. Manganui River at Croyden Road	20/03/86	N109:852700	1100	14.7	7.0	5.7	4	6	6	0	0	0	6.4	0.44
82. Waipapa River at water level recorder	16/01/88	N84:145815	1050	25.0	3.5	4.6	0	0	0	6	17	29	13.7	0.55
83. Tauranga-Taupo River at pump pool	22/03/86	N102:385078	1800	17.5	4.5	5.4	1	1	1	33	133	127	90.0	5.15
84. Tongariro River at Waipakahi River	22/03/86	N112:269719	1300	28.0	4.0	6.5	0	0	0	0	16	42	7.3	0.26
85. Tongariro River at Turangi	02/02/88	N102:286031	1900	37.7	4.5	4.9	40	5	4	36	68	99	117.1	3.11
86. Aorere River at Devils Boots	27/02/85	S3:032937	2100	50.0	5.0	5.5	20	23	14	0	0	0	31.5	0.63
87. Takaka River at Harwoods	06/01/88	S13:184596	1400	18.4	5.0	4.9	6	10	16	0	0	0	10.3	0.56
88. Takaka River at Kotinga bridge	27/02/85	S8:207777	1990	70.0	4.5	9.5	17	8	2	0	0	0	21.7	0.31
89. Riwaka River at Moss Bush	06/01/88	S13:307574	1750	12.5	5.0	9.2	70	26	15	0	0	0	89.4	7.16
90. Riwaka River at Moss Bush	26/02/85	S13:308573	1270	12.5	4.0	3.0	35	9	1	0	0	0	43.8	3.51
91. Motueka River at Woodstock	26/02/85	S19:203298	2040	40.8	5.0	7.2	94	123	58	0	0	0	149.6	3.67
92. Baton River above concrete ford	26/02/85	S19:175292	2000	18.2	6.0	4.5	16	24	17	0	0	0	26.5	1.46
93. Wairoa River at gorge	25/02/87	S20:491136	1300	21.4	4.0	10.0	16	29	22	0	0	0	28.6	1.34
94. Pelorus River at Maungatapu Road	25/02/87	S21:875248	1300	30.3	4.0	8.8	23	12	6	7	5	55	42.8	1.41
95. Rai River above falls	23/02/87	S15:902304	1000	22.8	6.0	5.0	45	55	23	11	60	7	103.8	4.55
96. Spring Creek at Odwyers Road	19/02/86	S21:218042	3100	9.6	8.0	7.0	27	16	2	0	0	0	36.8	3.84
97. Spring Creek at Spring Creek	19/02/86	S21:051249	2500	10.0	8.0	5.0	23	12	2	0	0	0	30.1	3.01
98. Hurunui River at Lake Sumner outlet	08/02/88	S53:700545	1600	33.1	3.5	6.5	86	243	79	0	0	0	178.5	5.40
99. Hurunui River below Lake Sumner (a)	09/03/83	S53:695547	4700	33.1	0.0	6.0	36	50	52	0	0	0	59.3	1.79
100. Hurunui River at Lake Taylor (b)	09/03/83	S60:748454	3300	28.0	0.0	5.0	13	9	8	0	0	0	18.6	0.67
101. Hurunui River at Lake Taylor (c)	09/03/83	S60:762424	2800	28.0	0.0	5.0	10	7	0	0	0	0	13.7	0.49
102. Waimakariri River at groyne 0	04/04/85	S75:754659	4500	30.0	2.0	5.0	1	3	1	0	0	0	2.6	0.09
103. Selwyn River at Whitecliffs	11/12/86	S74:350656	1200	14.3	5.5	3.6	8	29	41	0	0	0	19.3	1.35
104. Selwyn River at Coes Ford	11/12/86	M36:621235	1000	12.0	4.5	8.0	19	25	9	0	0	0	30.1	2.51
105. Orari River at gorge	10/02/86	S91:730087	1400	14.0	4.0	11.0	0	9	18	0	0	0	3.3	0.24
106. Opihi River at Rockwood bridge	10/02/86	S101:505794	1280	14.5	5.0	4.4	1	1	16	0	0	0	1.7	0.12
107. Opihi River at SH1 bridge	12/03/88	S111:781680	1300	24.2	2.5	10.2	15	9	3	0	0	0	20.8	0.86
108. Waitaki River 5 cumec channel	14/02/86	S127:265986	1500	18.6	6.0	5.0	7	11	7	0	0	0	12.2	0.66
109. Waitaki River 10 cumec channel	14/02/86	S127:272986	2350	21.3	5.0	5.2	5	7	10	0	0	0	8.5	0.40
110. Waitaki River 15 cumec channel	14/02/86	S127:275985	850	25.4	4.0	5.9	7	9	5	0	1	0	11.7	0.46
111. Waitaki River 20 cumec channel	14/11/85	S127:282985	1750	28.2	5.0	7.0	34	39	35	0	0	0	53.2	1.89
112. Waitaki River 30 cumec channel	14/11/85	S127:290983	2630	55.0	5.0	7.0	20	44	30	3	3	1	42.4	0.77
113. Maerewhenua River at Kellys Gully	12/02/86	S127:196845	1350	11.0	4.0	10.6	1	2	10	0	0	13	2.5	0.23
114. Hakataramea River at SH bridge	12/02/86	S118:128128	1450	13.0	3.5	9.5	16	16	110	0	1	77	31.5	2.42
115. Otematata River at pumphouse	12/02/86	S117:871234	1800	19.8	4.5	5.5	1	2	27	1	1	16	5.2	0.26
116. Ahuriri River above Birchwood	07/02/85	S108:351663	1940	30.0	3.0	9.0	2	0	0	0	0	0	1.7	0.06
117. Ahuriri River at Thomas's	11/02/86	S116:525363	1200	31.1	3.0	6.0	1	1	1	1	6	10	4.6	0.15
118. Ahuriri River at SH bridge	11/02/86	S109:685415	1100	43.0	3.0	4.0	8	19	17	5	34	7	33.2	0.77
119. Tekapo River above steel bridge	24/02/89	S109:917620	700	15.0	4.0	3.0	1	6	7	0	30	17	14.7	0.98
120. Tekapo River above Grays River	24/02/89	S100:966673	1000	25.0	4.0	5.0	6	1	1	2	29	39	21.2	0.85

APPENDIX II. (Contd.)

River and access	Date	Grid reference (start)	Reach length (m)	Width (m)	Cover grade	Vis. (m)	Brown trout/km L	M	S	Rainbow trout/km L	M	S	Biomass kg/km	g/m²
121. Tekapo River below Maryburn	24/02/89	S109:673966	1300	40.0	4.0	5.0	38	88	155	7	106	186	129.5	3.24
122. Tekapo River at willows	23/02/89	S109:873585	1000	40.0	4.0	5.0	55	32	51	6	24	285	103.2	2.58
123. Tekapo River above steel bridge	23/02/89	S109:910622	1100	40.0	4.0	5.0	21	22	22	10	41	99	61.7	1.54
124. Tekapo River above Pukaki River	11/02/86	S109:958626	1440	18.5	4.0	5.9	28	34	16	11	28	22	66.9	3.62
125. Kakanui River (upper)	04/02/85	S136:203729	1560	9.0	4.0	5.0	2	0	0	0	0	0	2.2	0.25
126. Kakanui River at Pringles	23/04/86	S136:451582	1140	22.3	6.0	7.3	17	57	33	0	0	0	38.3	1.72
127. Shag River at Dunbach	13/02/86	S146:260302	1600	6.6	6.0	6.3	31	13	6	0	0	0	40.5	6.15
128. Clutha River at Lake Wanaka outlet	06/02/85	S115:963163	3200	90.0	5.0	5.0	179	22	2	63	10	2	291.5	3.24
129. Pomahaka River at Hukarere	11/03/88	S161:987854	1300	15.0	3.0	9.0	2	2	2	0	0	0	2.5	0.17
130. Manuherikia River at Ophir	11/03/88	S134:364643	1250	25.0	4.5	3.0	12	40	26	0	0	0	27.3	1.09
131. Mataura River at Nokomai	10/03/88	S151:488063	950	25.5	4.0	3.0	16	11	9	0	0	0	21.9	0.86
132. Waikaia River at Piano Flat	10/03/88	S152:875061	1050	30.0	3.5	8.6	11	19	9	0	0	0	19.5	0.65
133. Oreti River above Mossburn	05/02/85	S150:168958	1825	30.2	3.0	5.0	27	12	24	0	0	0	36.4	1.21
134. Irthing Stream at water level recorder	09/03/88	S151:380907	1100	21.0	4.0	8.6	12	12	131	0	0	0	22.6	1.08
135. Aparima River above Otautau	07/03/88	S168:130449	2400	30.0	4.0	12.4	29	94	11	0	0	0	63.4	2.12
136. Mararoa River above water level recorder	09/03/88	S149:764980	2000	26.9	3.0	7.0	24	4	2	20	29	10	61.8	2.30
137. Taramakau River at Kumara	17/02/86	S51:728655	4000	100.0	4.0	4.2	14	20	5	1	1	3	23.0	0.23
138. Taipo River at gorge	16/02/86	S51:933500	3000	29.3	4.5	12.4	3	2	1	0	0	0	4.1	0.14
139. Grey River at Waipuna	17/02/86	S45:225029	1350	68.6	5.0	9.5	36	156	53	0	0	0	92.4	1.35
140. Arnold River at Kotuku	01/03/87	S51:963752	1400	41.2	6.0	4.0	133	70	42	0	0	0	177.5	4.31
141. Arnold River at Kokiri	17/02/86	S44:889841	1200	48.0	5.0	4.5	52	22	3	0	0	0	66.7	1.39
142. Ahaura River above Haupiri River	15/02/86	S52:297783	1970	40.0	3.0	19.0	33	5	0	1	1	0	40.4	1.01
143. Haupiri River downstream of lake	01/03/87	S52:200729	1400	30.0	4.5	8.0	103	63	53	0	0	0	140.9	4.70
144. Buller River at Lake Rotoiti outlet	05/01/89	S33:201659	300	18.7	4.0	7.0	117	290	1917	0	0	0	301.9	16.14
145. Buller River below Lake Rotoiti	24/02/87	S26:094749	1500	20.0	4.0	6.8	19	9	5	0	0	0	25.5	1.28
146. Buller River above Hope River	28/02/85	S26:037787	1865	25.0	4.0	7.1	29	14	4	0	0	0	38.6	1.55
147. Inangahua River at Blacks Point	18/02/86	S38:270344	1800	18.5	4.5	6.4	4	26	204	0	0	0	21.4	1.16
148. Inangahua River at landing	03/03/87	S31:368563	1250	60.0	4.0	5.1	30	29	16	0	0	0	44.8	0.75
149. Maruia River at Paenga	07/01/88	S32:628497	1400	40.0	4.0	7.2	42	32	21	0	0	0	59.7	1.49
150. Mangles River at gorge	07/01/88	S32:848644	850	16.4	7.0	5.1	49	25	55	0	0	0	67.1	4.10
151. Gowan River at Lake Rotoroa outlet	18/02/86	S33:993671	800	30.0	5.5	8.5	103	215	160	0	1	0	192.3	6.41
152. Gowan River below outlet	27/02/87	S33:989678	1800	25.1	5.0	12.2	144	125	79	0	0	0	208.8	8.32
153. Mokihinui River (South branch)	26/02/87	L28:433555	1950	30.0	6.0	12.0	38	3	12	0	0	0	45.9	1.53
154. Mokihinui River (North branch)	26/02/87	L28:432632	2050	25.0	5.0	10.8	31	1	1	0	0	0	35.9	1.44
155. Mokihinui River at cableway	02/03/87	S25:485966	2100	45.0	5.0	5.4	21	42	67	0	0	0	40.1	0.89
156. Karamea River above Crow hut	26/02/87	M27:635896	2050	30.0	7.0	12.6	41	3	18	0	0	0	49.3	1.64
157. Karamea River above bend	26/02/87	M27:681951	1850	50.0	6.0	14.0	52	17	26	0	0	0	66.4	1.33
158. Karamea River at Arapito	02/03/87	L27:446946	1400	70.0	5.0	5.3	21	61	21	0	0	0	44.5	0.64