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Seasonal changes in abundance of brown trout (*Salmo trutta*) and rainbow trout (*S. gairdnerii*) assessed by drift diving in the Rangitikei River, New Zealand

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Abstract Numbers and approximate sizes of brown trout (*Salmo trutta* L.) and rainbow trout (*S. gairdnerii* Richardson) were estimated by snorkel divers at 6 sites in the middle reaches of the Rangitikei River, North Island, New Zealand, over 14 months. The results showed that different species and sizes of trout varied in abundance with time. The species of fingerling trout (6–12 cm FL) could not be identified because of their small size and shoaling behaviour. Rainbow trout abundance varied seasonally and was greatest in January and April (between 18 and 60 fish per kilometre) when fish between 23 and 38 cm FL were the most abundant size class. Brown trout abundance showed much less variation with time (between 5 and 36 fish per kilometre at most sites). Also in contrast to rainbow trout, the majority of brown trout were > 38 cm FL, and in June, when the greatest density was observed (56 fish per kilometre), 70 redds were seen at the same site. Two sites were dived within a 48 h period to test the variability of the method. Comparisons between the 3 dives at each site revealed no significant differences between the numbers of fish in different species and size classes.

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INTRODUCTION

Diving has been used to estimate fish populations in rivers for the past 20 years and, despite some shortcomings, it remains a powerful technique (Northcote & Wilkie 1963; Goldstein 1978). In New Zealand snorkel divers drifting with the current (drift diving) have counted brown trout (*Salmo trutta* L.) and rainbow trout (*S. gairdnerii* Richardson) in several rivers (Graynoth 1974a; Richardson & Teirney 1982; Cudby & Strickland in press), and have proved the value of the technique when underwater visibility is good.

Drift diving enables population estimates to be made rapidly, and without injury to the fish, and is not limited by deep water where electric fishing is ineffective. In small streams, estimates of fish size and abundance comparable to those made by electric fishing can be obtained (Griffith 1981). However, the relationship of drift diving fish counts to the actual population size may remain obscure because of the errors which can arise from the technique. Poor visibility, the width of the river bed in large rivers, and concealment of fish by substrate or turbulence can cause fish numbers to be underestimated.

Although we have not approached the problem of relating drift dive counts to actual population size directly, we have used drift diving to compare the numbers of brown and rainbow trout seen in different seasons at 6 sites, and to estimate the abundance of different size classes of trout. Dives were also repeated over a short time interval to test the variability between dives and hence the consistency of the counts.

Adequate documentation of the procedures and sites used is important to allow future studies to repeat the surveys and to obtain comparable results; some drift diving studies have not fulfilled this criterion (e.g., Graham & Bjornn 1976; Whitworth &

Table 1 Physical characteristics of drift dive sites in the middle reaches of the Rangitikei River.

Site	Length (m)	Mean width (m)	Area (m^2)	Habitat units Pools	Runs	Riffles	Rapids
1	1670	32	53 700	3	3	2	0
2	2010	40	79 800	1	6	3	0
3	1890	32	61 400	5	4	2	3
4	1510	31	47 500	4	6	4	1
5	1600	16	25 000	8	1	0	4
6	1100	34	37 000	6	1	0	2
Totals	9780	31	304 400	27	21	11	10

Schmidt 1980). Our study describes the methods and sites so that comparable counts can be made at a later date.

STUDY SITES AND METHODS

Study sites

Three reaches of the Rangitikei River were chosen in the upper middle reaches because of their accessibility by road and good water clarity. These reaches were divided into 6 sites between 1 and 2 km long for convenience of diving (Fig. 1). Sites 1 and 2 were contiguous, as were Sites 3, 4, and 5. The individual lengths, mean widths, and areas measured from aerial photographs (New Zealand Aerial Mapping Ltd, survey number 3792) taken in 1974 (Sites 3–6) and 1975 (Sites 1 and 2) are shown in Table 1. The river morphology did not appear to have changed between the time the aerial photographs were taken and the date of this survey.

The sites were surveyed by diving, and were visually assigned to habitat units (pools, runs, riffles, and rapids) on the basis of the dominant characteristics of water velocity, depth, substrate, and surface turbulence according to the criteria listed in Table 2. In addition, runs with gravel bars or riffles in them were subdivided for the purposes of this study into two or more units.

At Sites 1 to 4 the river flowed through a wide valley of pasture land. The bed was predominantly greywacke gravel, with greywacke bedrock outcrops in rapids and at river bends, where most pools occurred, and occasionally in the middle of the river channel in runs and pools. Boulders occurred in some runs, riffles, and rapids. Run and pool habitats occupied a larger area than riffles and rapids at these sites.

At Site 5 the river flowed through a sheer-sided greywacke gorge, with a bed of greywacke outcrops and boulders. There was less gravel substrate than at Sites 1–4, and pools and rapids were the dominant habitat types. The river was wider at Site 6 than at Site 5, but in contrast to Sites 1–4, the valley walls were either steep scrub and bush covered slopes, or high cliffs. Although pools were common at Site 6, one distinctive habitat feature was a run 170 m long. Maximum pool depths at all sites were visually estimated, and ranged from 2–5 m.

Table 2 Classification of riverine habitats for drift diving fish counts.

Habitat unit	Depth (m)	Appearance of water surface	Substrate
Pool	> 1.5	Slow current, unbroken water	All types possible
Run	0.5–1.5	Moderate current, unbroken water	All types possible
Riffle	< 0.5	Swift current, turbulent, broken water	Generally cobbles
Rapid	0–2.0	Swift current, very turbulent, broken water	Large boulders or bedrock, often breaking water surface

The mean annual flow of the river at Site 2 was 20 $m^3 s^{-1}$ (Tonkin & Taylor Consulting Engineers 1980), and there were no known substantial flow additions to the river between Site 1 and Site 6, 23 km downstream.

Dive methods

The divers were instructed in identification of fish species and size classes, and though their ability was not tested, all divers had previous experience in fish identification. The presence of dark spots which occur on the caudal fin of rainbow trout, but not on the caudal fin of brown trout, was used as the definitive character to distinguish between the two species.

Six divers equipped with wetsuits, face masks, snorkels, fins, and weight belts aligned themselves parallel to the water flow spaced equidistantly across the river. They floated with the current at the surface, scanning the river bed and water in front of them through an arc of c. 120° as they drifted downstream. Trout were visually assigned to size classes as fingerling (6–12 cm FL), small (12–23 cm FL), medium (23–38 cm FL), or large fish (> 38 cm FL). The length of each fish was estimated visually and was therefore approximate.

The species of trout > 12 cm FL could be readily identified in most instances, but where shoals of more than about 6 fish occurred, identifying all individuals was sometimes difficult. With salmonids < 12 cm FL, it was particularly difficult to distinguish between species, and this was further complicated by the unexpected capture of a quinnat salmon (*Oncorhynchus tshawytscha*) smolt at Site 2 in February 1981 amongst shoals of fingerling brown trout (Hicks & Watson 1983).

A method for recording trout observed by divers was developed, and this was consistently applied. Divers counted fish passing under them or laterally in front of them, but included in their personal tallies only those fish seen from the centre to the left of their vision. The diver on the extreme right noted the count for an entire 120° scan. Where the true left bank of a pool was sheer-sided, the diver on the extreme left noted the count for his or her entire scan.

Fish were not routinely counted in riffles and rapids because of the difficulty of maintaining the line of divers in these areas, and because shallow water (< 30 cm) in riffles and turbulence in rapids meant that a diver's attention was concentrated on moving through the section.

When the line of divers was disrupted by a riffle or rapid, the line was reformed as soon as the channel morphology and water velocity allowed. Where overhangs and crannies in the bank or bedrock outcrops might have obscured fish, they were inspected closely. Bottoms of pools which could not be seen from the surface were inspected by diving, and a procedure was adopted in which divers worked in pairs to ensure coverage of the entire bottom. One of the pair dived while the other floated on the surface, and then the divers changed positions, allowing the first diver time to recover at the surface. This procedure was repeated until the pool became sufficiently shallow for the bottom to be seen from the surface. Although this necessitated breaking the search line, pools were generally narrower than runs and riffles and thus effective coverage of the pool was still maintained. The divers also had to modify their scans in deep pools to search through a hemisphere in front of them rather than to simply scan horizontally which was sufficient in shallow water.

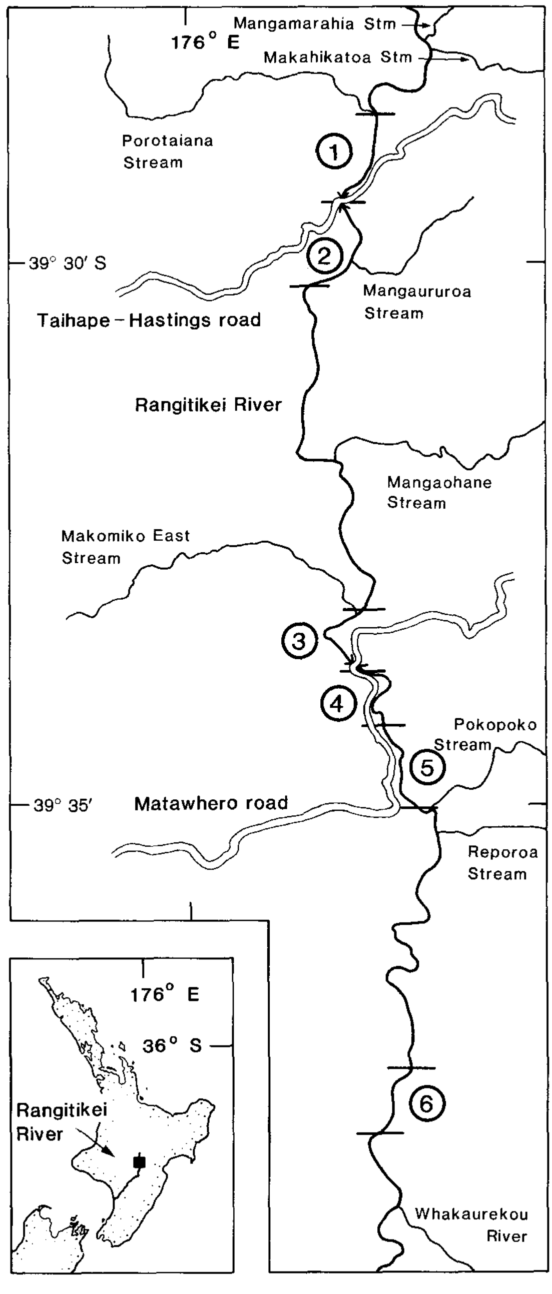

Fig. 1 Location of drift diving sites on the Rangitikei River, North Island, New Zealand.

At the end of each run or pool through which a count had been made, the divers were halted, and their tallies were recorded on a waterproof pad.

Table 3 Seasonal changes in the observed abundance of brown and rainbow trout and unidentified fingerlings at 6 sites in the Rangitikei River (estimated maximum numbers in brackets). Large = > 38 cm FL, medium = 23–38 cm FL, small = 12–23 cm FL, fingerling = 6–12 cm FL.

		Abundance (fish km^{-1})									
					Rainbow trout			Brown trout			
Date	Dive site†	Total both species, all sizes	Total rainbow trout	Total brown trout	Large	Medium	Small	Large	Medium	Small	Fingerlings
April 1979	1	58 (87)	45 (63)	13 (24)	12 (18)	29 (35)	4 (10)	9 (14)	2 (5)	2 (5)	0
	2	35 (56)	27 (43)	8 (13)	3 (7)	24 (36)	0	8 (13)	0	0	0
	3	51 (74)	49 (66)	2 (8)	14 (21)	34 (41)	1 (4)	2 (8)	0	0	0
	4	38 (58)	28 (41)	10 (17)	11 (16)	17 (25)	0	8 (12)	2 (5)	0	0
	5	50 (72)	29 (34)	21 (38)	12 (18)	17 (26)	0	19 (29)	1 (6)	1 (3)	0
	6	49 (79)	37 (55)	12 (24)	4 (8)	18 (27)	15 (22)	10 (15)	2 (9)	0	0
June 1979	1	59 (75)	3 (7)	56 (68)	3 (7)	0	0	53 (58)	1 (6)	2 (4)	0
	2	17 (32)	3 (7)	14 (25)	3 (7)	0	0	11 (16)	3 (9)	0	0
	3	21 (37)	3 (10)	18 (27)	2 (5)	1 (5)	0	18 (27)	0	0	0
	4	11 (22)	1 (7)	10 (15)	0	1 (7)	0	10 (15)	0	0	0
	5	–	–	–	–	–	–	–	–	–	–
	6	8 (16)	0	8 (16)	0	0	0	7 (11)	1 (5)	0	0
October 1979	1	16 (33)	4 (13)	12 (20)	1 (6)	2 (4)	1 (3)	8 (12)	2 (4)	2 (4)	0
	2	10 (23)	2 (6)	8 (17)	1 (3)	1 (3)	0	7 (10)	* (2)	1 (5)	0
	3	15 (29)	3 (10)	12 (19)	2 (5)	1 (5)	0	11 (16)	1 (3)	0	0
	4	11 (23)	2 (10)	9 (13)	1 (7)	1 (3)	0	9 (13)	0	0	0
	5	11 (29)	3 (15)	8 (14)	1 (6)	1 (3)	1 (6)	7 (11)	0	1 (3)	0
	6	14 (33)	9 (22)	5 (11)	1 (5)	3 (6)	5 (11)	5 (11)	0	0	0
January 1980	1	56 (86)	20 (32)	36 (54)	5 (8)	7 (11)	8 (13)	14 (21)	9 (14)	13 (19)	99 (119)
	2	32 (55)	20 (32)	12 (23)	5 (7)	12 (17)	3 (8)	10 (15)	2 (6)	* (2)	67 (80)
	3	49 (71)	32 (44)	17 (27)	5 (8)	23 (28)	4 (8)	16 (24)	1 (3)	0	105 (126)
	4	65 (87)	56 (72)	9 (15)	3 (8)	27 (32)	26 (32)	8 (12)	1 (3)	0	64 (77)
	5	25 (39)	18 (28)	7 (11)	6 (9)	7 (11)	5 (8)	7 (11)	0	0	1 (5)
	6	73 (111)	60 (83)	13 (28)	5 (11)	39 (47)	16 (25)	7 (11)	2 (9)	4 (8)	147 (176)
May 1980	1	43 (55)	8 (13)	35 (42)	6 (9)	2 (4)	0	32 (35)	3 (7)	0	0
	2	14 (26)	1 (5)	13 (21)	0	1 (5)	0	11 (17)	2 (4)	0	0
	3	25 (45)	6 (14)	19 (31)	3 (6)	2 (5)	1 (3)	16 (24)	3 (7)	0	0
	4	14 (28)	6 (14)	8 (14)	4 (9)	2 (5)	0	7 (11)	1 (3)	0	0
	5	–	–	–	–	–	–	–	–	–	–
	6	43 (91)	24 (46)	19 (45)	7 (11)	15 (24)	2 (11)	13 (19)	6 (15)	0	0

* Abundance > 0, < 0.05 fish km^{-1}.
† Refers to Fig. 1.

Divers were asked to compare fish seen in their scans which were not in their count zones with the observations of the diver next to them. This minimised the chance of the same fish being counted by more than 1 diver.

Sites 1–4 and 6 were dived on 5 occasions between April 1979 and May 1980 at 2–4 monthly intervals, and Site 5 was dived on 3 occasions during this time. Site 4 was dived 3 times in January 1980, with a 16 h interval between the first 2 dives, and a 2 h interval between the second and third dive. Site 1 was dived 3 times in May 1980 with a 5 h interval between the first 2 dives, and a 42 h interval between the second and third dive. Underwater visibility varied from 3–10 m, and was between 4 and 5 m for most dives.

Actual abundance

Errors in fish population estimates made by divers arise from fish escaping observation (Northcote & Wilkie 1963; Goldstein 1978).

We have assumed that observed abundance was equal to or lower than actual abundance because of this. Regier & Robson (1967) proposed a correction termed the "bounded counts method" to compensate for fish that escape observation. This correction uses the formula:

$$\hat{N} = 2N_m - N_{m-1}$$

where N_m is the highest count obtained, and N_{m-1} is the second highest count, to estimate $\hat{N}$, the actual number of fish present.

The effect of this correction is to give a population estimate equal to or larger than the maximum number of fish counted, based on the assumptions that no fish have been counted twice, and that the counts are independent. The larger the difference between the highest and the next highest count is, the larger $\hat{N}$ will be compared to N_m.

RESULTS

Seasonal abundance

A cumulative total of 44 km of river was surveyed by drift diving, during which 733 rainbow trout > 12 cm FL, 670 brown trout > 12 cm FL, and 758 unidentified salmonid fingerlings between 6 and 12 cm FL were seen. However, species composition, size class, and abundance varied considerably with site and season (Table 3). A two-way analysis of variance (Sokal & Rohlf 1981) was used to test whether the variation in trout abundance was associated primarily with site or with season. Species and size classes were tested together and individually, and a summary of the F-statistics derived from these tests and their significance is presented in Table 4.

The variation in total abundance of brown and rainbow trout > 12 cm FL (Table 3) showed significant association with both site and season, although the association with season was stronger than that with site (Table 4). Brown and rainbow trout abundance tested separately, however, showed differences in variation with site and season.

Rainbow trout were most abundant in January and April, and were much less abundant in May, June, and October (Table 3). The total abundance of all rainbow trout > 12 cm FL showed a highly significant association with season, but an insignificant association with site (Table 4). Large, medium, and small rainbow trout abundance tested individually also showed significant association with season, but not with site (Table 4). Despite the fact that there was no significant association of rainbow trout abundance with site, at Site 6, medium rainbow trout were particularly abundant in January and May, and small rainbow trout were abundant in April compared to their abundance at other sites at the same time (Table 3). This was notable during diving because the medium and small rainbow trout were largely confined to the only run at Site 6 (Table 1).

Brown trout, in contrast to rainbow trout, were observed to be relatively constant in their abundance throughout the study, showing more site specificity than seasonal association (Table 3). The total abundance of brown trout > 12 cm FL was found to be significantly associated with site, but not with season (Table 4). However, large, medium, and small brown trout tested individually showed no significant association with either site or season (Table 4). Despite this lack of statistically significant association of individual size classes of brown trout with site, notable increases in the number of large brown trout occurred at Sites 1 and 3 in June, and at Site 1 in May (Table 3). That these were spawning aggregations of brown trout was shown by a high abundance of redds at Site 1 in June. Seventy redds occurred in an area 290 m long by 34 m wide, in which 35 large brown trout were also seen, many in pairs. The low number of small brown trout observed (Table 3) probably compromised the validity of the analysis of variance for these fish.

Fingerlings showed clear seasonal variation in abundance (Table 3), but were absent from Site 5 in January when they were abundant at other sites. This association of fingerling abundance with season

Table 4 Significance of the association between brown and rainbow trout abundance and site and season tested by two-way analysis of variance. Data for analysis was taken from Table 3, with the results from Site 5 excluded because of missing data. The F-statistic for each test has 4 degrees of freedom for the numerator mean square, and 16 degrees of freedom for the denominator mean square. Large = > 38 cm FL, medium = 23–38 cm FL, small = 12–23 cm FL, fingerling = 6–12 cm FL. Significance: * $0.05 \geqslant P > 0.01$, ** $0.01 \geqslant P > 0.001$, *** $P < 0.001$, ns = not significant.

		Site		Season	
Species	Size	F-statistic	Significance	F-statistic	Significance
Rainbow and brown trout	All sizes > 12 cm FL	3.3	*	10.9	***
Rainbow trout	All sizes > 12 cm FL	1.5	ns	15.9	***
Rainbow trout	Large	1.2	ns	6.7	**
Rainbow trout	Medium	1.0	ns	13.3	***
Rainbow trout	Small	1.8	ns	4.6	*
Brown trout	All sizes > 12 cm FL	5.7	**	2.4	ns
Brown trout	Large	2.8	ns	2.0	ns
Brown trout	Medium	1.8	ns	2.1	ns
Brown trout	Small	2.5	ns	1.8	ns
Unidentified salmonid	Fingerlings	1.0	ns	40.8	***

was highly significant (Table 4), but the association with site was not significant either with Site 5 data included, assuming that the missing data points were zero, or without Site 5 data.

Repeated dives

Dives repeated at Site 4 in January 1980 (Table 5A) showed good agreement for (a) total number of fish large enough to be identifiable to species (101, 106, and 101); (b) number of fingerlings; (c) total number of fish identifiable as brown trout; (d) brown trout classed as large. Less agreement was found between dive totals for large, medium, and small rainbow trout, and for medium brown trout. The shoaling behaviour observed in medium and small rainbow trout may have caused the differences between dives by leading to errors in estimation of numbers and in species identification, or fish may have moved, or simply have escaped observation in some dives.

The coefficient of variation of all fish observed in 3 dives at Site 4 was 10%, similar to that for dives at Site 1, which was 8%. However, many more fish were observed at Site 4 because fingerlings, the most common size class, were absent from Site 1 in May (Table 5B). At this time a combined total of 61, 68, and 71 brown and rainbow trout were observed in each of 3 dives, and large brown trout again showed the least variation in numbers of any individual species or size class present.

Chi-square tests (Siegel 1956) of the numbers of fish observed in each of 3 dives at Site 4 (size and species classes tested separately, Table 5A) showed no significant difference between dives. However, the small numbers of medium and small brown trout compromised the validity of the test for these size classes. The species and size classes seen at Site 1 (Table 5B) tested separately between dives using Chi-square also showed no significant difference between the 3 dives, although low numbers of medium and small rainbow and brown trout compromised the validity of tests for these size classes.

Actual abundance

Although it is not possible to know what proportion of the total number of trout present are seen on the basis of only a single dive, a correction can be derived from the difference between the largest and next largest trout count from two or more successive dives (bounded counts method). This correction can be applied to the trout count from a single dive to estimate the maximum possible abundance of trout.

The bounded counts method was used to estimate the actual abundance ($\hat{N}$) from multiple drift dive counts. These estimates for each species and size class are shown in Table 5A and B. From the plot of $\hat{N}$ against the observed count (N) for that estimate a regression line was calculated, ignoring $\hat{N}$ values derived from N values of 0 or 1. The line equation was:

Table 5 Numbers of brown and rainbow trout and fingerlings observed by drift diving at 2 sites in the Rangitikei River. Large = > 38 cm FL, medium = 23–38 cm FL, small = 12–23 cm FL, fingerling = 6–12 cm FL, *N̂ = bounded counts estimate of actual number of trout in pools and runs (Regier & Robson 1967).

A. Site 4 (1750 m long) dived in January 1980.

	Rainbow trout				Brown trout					
	Large	Medium	Small	Total	Large	Medium	Small	Total	Fingerlings	Total
Dive 1	15	35	29	79	13	9	0	22	226	307
Dive 2	7	43	41	91	14	1	0	15	255	371
Dive 3	14	34	39	87	13	1	0	14	266	367
*N̂	16	51	43	95	15	17	0	29	277	375

B. Site 1 (1370 m long) dived in May 1980.

	Rainbow trout				Brown trout					
	Large	Medium	Small	Total	Large	Medium	Small	Total	Fingerlings	Total
Dive 1	7	2	0	9	50	2	0	52	0	61
Dive 2	10	3	0	13	49	6	0	55	0	68
Dive 3	9	5	0	14	54	2	1	57	0	71
*N̂	11	7	0	15	59	10	2	59	0	74

$$\hat{N} = 4.1 + 1.1\ N.$$

The correlation coefficient (r) was 0.995, and the probability that r = 0 was $P < 0.001$.

The variability of the bounded counts estimate (N̂) as a proportion of the observed counts (N) showed a hyperbolic decrease as the observed count increased (Table 6). Counts of ⩽ 7 fish were unreliable compared to greater counts.

It is therefore possible, using the trout count from a single dive and the relationship between the bounded count estimate of the total number of trout present and the actual count (Table 6), to estimate the maximum possible number of trout present at each site. The maximum possible number of trout was calculated by multiplying the number of trout seen (N) by the appropriate N̂/N value from Table 6, then dividing by the station length. All fingerling counts were multiplied by 1.2 on the basis of the N̂/N value from Table 6, except for those at Site 5, to which the correction for very small numbers (⩽ 2) was applied. These estimates are the bracketed figures in Table 3.

Fish reactions to divers

Different size classes of the 2 trout species showed different and consistent reactions to divers. Large and medium brown trout were often observed close to the river bed, banks, or other solid objects. Large and medium rainbow trout, and small brown and rainbow trout were usually seen in mid-water, and often at the downstream end of pools. Medium rainbow, and small brown and rainbow trout were observed in shoals of similar sized fish, as were fingerlings, though fingerlings were usually seen in shallow margins over gravel substrate, or in sheltered margins of riffles and rapids.

Brown and rainbow trout and salmonid fingerlings were the only fish seen during drift diving despite the fact that trout fry (< 6 cm FL), longfinned eels (*Anguilla dieffenbachii*), Cran's bullies (*Gobiomorphus basalis*), and upland bullies (*G. breviceps*) had been caught previously at the margins of these sites by electric fishing (Hicks & Watson in press). This was probably because of the naturally cryptic habits of these fish combined with their reaction to hide in the presence of divers. It could also be attributable to their occupation of habitats that were generally too shallow to dive.

DISCUSSION

Changes in abundance

The value of drift diving in the Rangitikei River was primarily to estimate the size and abundance of brown and rainbow trout relative to their abundance at other sites and seasons. The cause of the low relative abundance of rainbow trout in winter observed during the survey can only be speculated on, but it is likely that adult rainbow trout migrate

Table 6 Maximum variation in the number of brown and rainbow trout estimated by the bounded counts method as a proportion of the number of trout observed by drift diving.

Number observed (N)	Maximum bounded counts estimate/number observed ($\hat{N}$/N)
≤ 2	5.0
3–7	2.3
8–35	1.5
36–49	1.2
50–54	1.1
226*	1.2

* Fish between 6 and 12 cm FL.

upstream from the study area to spawn. Smaller juvenile fish may migrate or be displaced downstream, to return to the area after recruitment into the adult population. Adult brown trout on the other hand appear to find adequate spawning in the main river channel in the study area, and to stay close to their summer habitat, perhaps redistributing themselves within this area with respect to the most-favoured spawning gravels in winter.

Few studies exist which document the comparative spawning migrations of brown and rainbow trout in the same river system, but evidence that rainbow trout move further upstream than brown trout to spawn in the same river system in New Zealand comes from studies of trout in Post Office Stream, a tributary of Lake Mahinurangi in the South Island, where rainbow trout move further upstream than brown trout to spawn (D. Scott pers. comm.). In addition, rainbow trout moved further than brown trout in the Yellowstone River, Montana (Swedburg 1980). This is consistent with our theory of adult trout movement in the Rangitikei River.

Abundance in other rivers

Trout population at the drift dive sites was similar to other New Zealand rivers in which drift diving population estimates have been made. The maximum abundance of trout observed in the Manganuiateao River was 42 fish km^{-1} (E. Cudby pers. comm.), and was 59 fish km^{-1} in the Whakapapa River in February (Richardson & Teirney 1982). The mean annual flows of these rivers at the diving sites were 18 and 19 $m^3 s^{-1}$ respectively. In the Rangitikei River, the maximum abundance of brown and rainbow trout observed in January, excluding fingerlings, was 73 fish km^{-1} and the river had a mean flow at Site 1 of about 20 $m^3 s^{-1}$. A smaller proportion of the total trout population was probably counted in the Whakapapa and Manganuiateao Rivers than in the Rangitikei because of the bouldery nature of the bed and the considerable number of rapids in the Whakapapa and Manganuiateao, and thus abundance of fish was probably similar in the three rivers.

However, not all rivers of similar size have similar fish populations. Graynoth (1974a) estimated the trout population in a number of Wellington rivers in summer using bounded count estimates of drift diving counts, and estimated a brown trout population of fish > 23 cm FL of 110 fish km^{-1} for the Hutt River, and 35 fish km^{-1} in the Ruamahanga River. These rivers had mean annual flows of 21 and 26 $m^3 s^{-1}$ respectively, approximately the same as the Rangitikei at the dive sites. The maximum possible trout population of fish > 23 cm FL in the Rangitikei in January was 79 fish km^{-1} estimated by the correction factor in Table 6 applied to the number of trout observed at Site 6 (Table 3), which is greater than the estimated abundance in the Ruamahanga, but less than in the Hutt. Mean annual flow is therefore not necessarily a reliable predictor of trout abundance but can be useful in the absence of a detailed habitat description.

Counting efficiency

Underwater visibility was generally very good during the survey, and was always > 3 m. Whitworth & Schmidt (1980) felt that 2 m was the minimum visibility for effective drift diving, and Goldstein (1978) reported 1.5 m to be the limiting distance. Riffle and rapid areas, where counting was difficult because of shallow water or turbulence, were a relatively small proportion of most sites (between 6 and 15% by length) except at Site 5, where rapids were about 40% of the site length. However, the average river width at Site 5 was half that at other sites (Table 1), and this would have compensated for the decreased efficiency of counting caused by the rapids. We have no way of knowing how many fish may have eluded observation in rapids and riffles, but the proportional correction derived from the bounded counts method (Table 6) provides an estimate of the maximum possible number of fish present in pool and run habitats.

Behaviour

Our observations of brown and rainbow trout behaviour show similarities to those of Graynoth (1974b) for trout in New Zealand rivers; brown trout often remained motionless and close to cover, whereas rainbow trout "formed free swimming, actively moving shoals in midwater". Similar behaviour patterns in rainbow trout were also observed in a mixed trout population in Convict Creek, USA, and when disturbed, trout formed "fright-huddles" (Jenkins 1969), a midwater shoaling behaviour first reported in *Oncorhynchus kisutch* (Mason & Chapman 1965). However, when brown trout were disturbed they sought cover or attempted to dig holes in the substrate (Jenkins 1969). Shoals of rainbow trout in the Rangitikei often moved ahead of divers, eventually darting back upstream as the pool shallowed towards its downstream end. As long as brown trout cannot hide in the substrate, they are likely to be more readily and accurately counted than rainbow trout, which is consistent with the smaller proportional variation seen between counts from repeated dives (Table 5A and B).

Our survey has provided conclusive evidence that drift diving can be used to make consistent estimates of the relative abundance of different species and sizes of trout. Variations in seasonal patterns of relative abundance of brown and rainbow trout can also be determined. The bounded counts method offers a useful means to estimate the actual population in runs and pools, but 3 dives within 2 days or less is, in our opinion, the minimum effort needed to see the variation inherent in the drift diving method of estimating relative trout abundance in a particular river.

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