94-07

SKAGIT RIVER RAINBOW TROUT POPULATION TRENDS: UNDERWATER CENSUS FROM 1982 TO 1994

by
Jeff A. Burrows
Ross Neuman

British Columbia Ministry of Environment, Lands and Parks
Fish and Wildlife Management
Surrey, B.C.

Regional Fisheries Report No. LM253
1995

ABSTRACT

Burrows, Jeff A. and Ross Neuman. 1995. Skagit River rainbow trout population trends: underwater census from 1982 to 1994. B.C. Ministry of Environment, Lands and Parks Regional Fish. Rep. No. LM253, 22p.

The B.C. Fisheries Branch has had a team of snorkelers survey the trout population of the Skagit River
every year since 1982. Evaluation of the survey method indicated that snorkel surveyors may overestimate the size of individual fish by 2–3cm, that counts are relatively repeatable (less than 2-fold range in repeated counts of catchable fish), and that expansion factors to estimate absolute trout densities ranged from 2.09 to 4.59. Because of skepticism about using dubious expansion factors, we developed a robust abundance index that adjusted direct counts for survey section length and the number of floaters, and used it (trout per km per floater equivalent) to examine patterns of rainbow trout abundance. Rainbow trout abundance indices increase from upstream to downstream in the Skagit mainstem, and all size classes (except perhaps 40+cm) have shown large (2.7 to 4.9 times depending on size class) increases in abundance since a 1992 regulation change to catch-and-release angling. These observations are credible because float survey results agree well with independent research angling results. We recommend that the survey continue as a monitoring tool because it produces reliable and useful information about rainbow trout population trends in the Skagit River. Even at reduced intensity (fewer sections) the survey could produce similarly useful information.

ACKNOWLEDGEMENTS

Thanks for:

- funding: Skagit Environmental Endowment Commission
- swimming: employees and volunteers of the B.C. Fisheries Branch
- discussing Ross Reservoir and Skagit River rainbow trout: Alan Looff

TABLE OF CONTENTS

LIST OF TABLES

List of Figures

List of Appendices

INTRODUCTION

The B.C. Skagit River is an accessible, low gradient, 5th order stream approximately 150km east of Vancouver, which supports a vibrant sport fishery for rainbow trout. Detailed descriptions of its physical attributes and recreational appeal and use exist elsewhere (e.g. Perry 1981, Neuman 1988).

Because the Skagit River is "the only quality non-anadromous trout stream in the Lower Mainland" (Neuman 1988) the B.C. Fisheries Branch has focused considerable management attention on it over the last decade and a half, in part to demonstrate and in part to maintain that quality.

Part of this effort to manage the Skagit River as a quality angling destination has been an annual underwater snorkel survey of trout and char since 1982. Its aim has been to quantify trout and char abundance and size distribution in time and space. In this report we analyse and summarize rainbow trout population trends evident from this annual underwater survey.

Fisheries biologists have recognized the underwater snorkel survey as a practical method for assessing stream fish populations, in particular because it can quickly cover long stretches of stream (Northcote and Wilkie 1963, Goldstein 1978, Zubik and Fraley 1988), counts are typically consistent (Northcote and Wilkie 1963, Schill and Griffith 1984), and with practice snorkelers can estimate approximate lengths (Slaney and Martin 1987a) and identify species (Whitworth and Schmidt 1980). Although snorkel counts may be repeatable, they may (Zubik and Fraley 1988) or may not (Slaney and Martin 1987a) be accurate.

In the first part of this report we discuss an evaluation of trout length estimation, count precision, and count accuracy of the underwater survey method in the Skagit. Following this evaluation and incorporating its implications in our analysis, we present the methods and results of the survey from 1982-1994. We describe quantitative patterns of spatial distribution of trout within the Skagit River, and then consider the annual trend in abundance which we compare to recent angling regulation changes.

Finally, we summarize the knowledge about rainbow trout in the Skagit River that the survey has provided, and comment on survey design and utility.

EVALUATION OF SKAGIT RIVER UNDERWATER CENSUS

Slaney and Martin's (1987b) manuscript describes an evaluation of underwater census in the Skagit River (and two other large streams); because of limited distribution of the manuscript we outline the methods and discuss the results here. The purpose of the evaluation was to quantify the precision and accuracy of underwater survey in the Skagit River.

EVALUATION METHODS

In a 2.0km study section in the Skagit River, approximately 14km upstream of Ross Reservoir (the confluence with Shawatum Creek formed the downstream boundary, Fig.1), anglers caught and tagged (coloured Floy spaghetti tag) fish larger than 20cm from July 23–26, 1985. Anglers tried to tag as many fish as possible to optimize a mark-recapture estimate of the section population size; a further half day of tagging after the first underwater census on July 29 added several marked fish to the population. Fish 20–30cm received a different coloured tag than fish >30cm.

Initial attempts were to capture fish by fly casting. However, angling conditions were very poor (low water, bright sunshine and an absence of emerging insects) and it was necessary to use roe and barbless hooks. In the spring of 1986, hooking mortality was examined during a major tagging program on the Skagit River. Twenty-five randomly selected fish were held in the river in brood collection tubes for 48 hours after capture by angling with either roe and single barbless hook (14 fish) or artificial lure (11 fish). No mortalities were observed and fish did not appear stressed when checked at 24 hours or when released at 48 hours (Scott, 1986).

The river was legally open to public angling during the study. However, due to extreme fire hazard the Ministry of Forests and Lands declared a forest closure between July 23 and August 7. Since this closure precluded public access to the river, public angling during the study period was negligible.

The following list describes the test section and snorkelling conditions:

- flow was stable ($8m^3/s$)
- visibility was 2.5–3.5m
- mean wetted width was 27.5m (SD = 6.7m)
- mean and maximum depths were 0.5m and 2m, respectively
- habitat types were riffle (63%), glide (26%), and pool (11%)
- substrate was mostly gravel with some areas of cobble and boulder
- fish cover consisted mainly of large organic debris (often associated with pools), overhanging vegetation, boulders, and surface turbulence

A team of four floaters equipped with wet or dry suits and mask and snorkel conducted the underwater census over three days (July 29–31), repeating it five times. The river was divided into four lanes. Lane width was dependent on underwater visual distance (the distance at which a snorkeller could easily distinguish the adipose fin on a trout greater than 20 cm fork length). Each floater stayed within his lane and maintained one visual distance from the adjacent floater. Six experienced floaters rotated between the four lanes and five replicates. Floaters in the mid-stream lanes tended to travel faster than those on each bank and regularly waited to ensure that the float team traveled down the river as a unit to minimize duplicate counts.

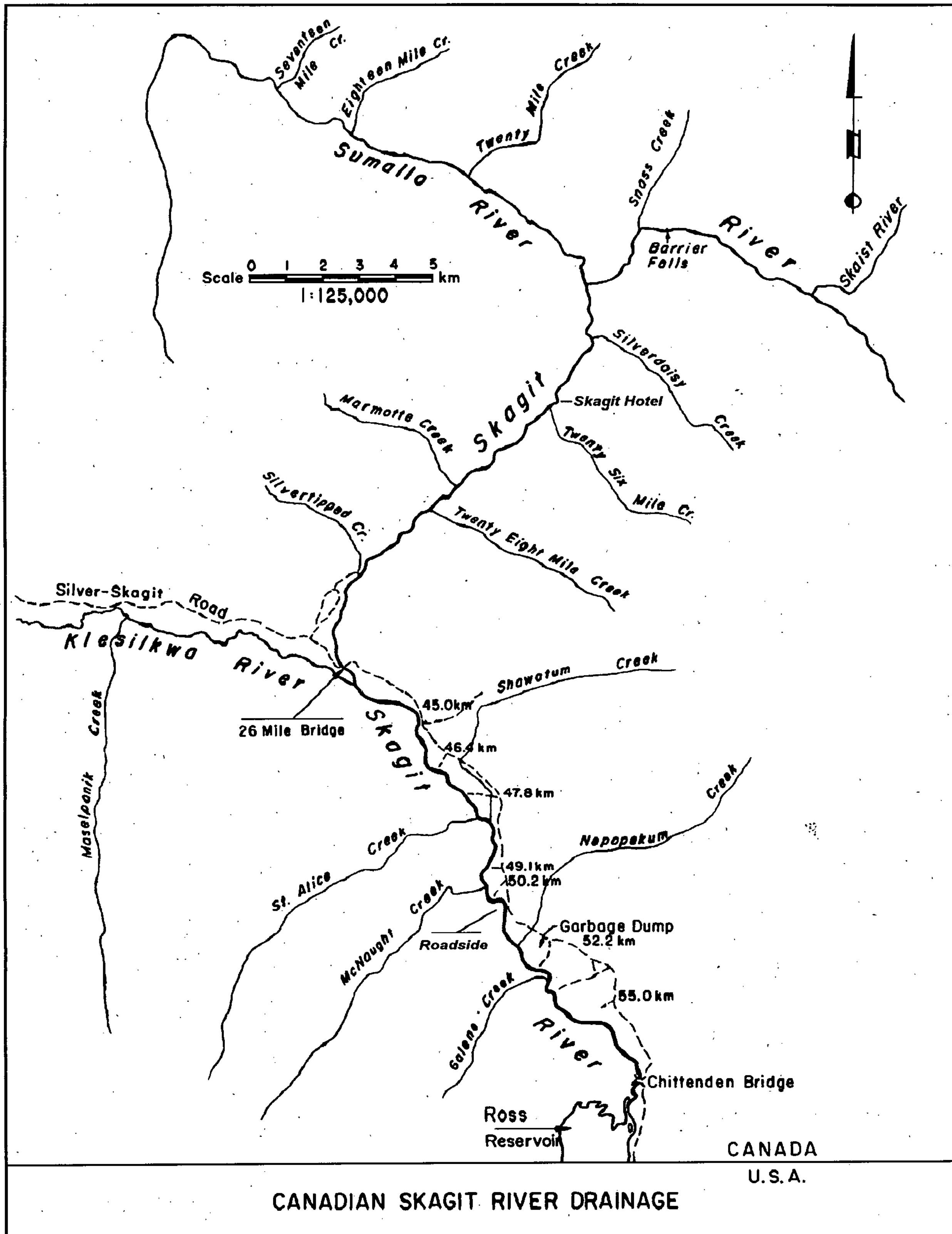


Fig 1. Skagit River Map. The map shows locations of confluences with tributaries and other landmarks that the snorkel evaluation and survey used as section boundaries. For detailed

descriptions of the location and physical attributes of the Skagit River and watershed see Neuman (1988) and Perry (1981).
Snorkellers recorded fish in size classes: 10–20cm, 20–30cm, and greater than 30cm, and also recorded tag color for all tagged fish. Before the first float, swimmers practiced estimating fish length by floating past (at one visual distance) frozen fish suspended underwater on a small stick, which provided data to estimate biases in length estimation.

Floaters surveyed the river once, using the study methods (four floaters in lanes), for approximately two kilometers immediately upstream and one kilometer immediately downstream of the test section to determine if any tagged fish had left the test section, and they observed none; therefore we assumed that the trout population was closed during the evaluation.

These methods to evaluate the accuracy and precision of Skagit snorkelling were more intensive than the typical annual snorkel survey, which commonly used 2 or 3 snorkellers and rarely repeated surveying a particular section. Therefore 2 snorkellers made an additional 3 floats starting 10 minutes before three of the five more intensive section surveys, in order to evaluate typical survey methods.

EVALUATION RESULTS

Length Estimation

In Fig. 2 we compare the true length of the frozen fish to the lengths that floaters recorded. Panel A shows that almost all (89%) estimates were in the correct 100mm size class. In panel B we see that 22 estimates were too high, 4 were low, and 1 was correct (at 1cm resolution). In general floaters overestimate fish length, and this may be more pronounced at lower fish lengths; nevertheless for the remainder of this analysis we refer to counts according to their nominal size class (e.g. 20–30cm, not 17–28cm). Further research into length estimation especially at size class edges would give a more useful picture of bias in estimated length and how bias may change with size.

Count Accuracy

We used the following mark-recapture estimator (Krebs 1989) to compute an estimate of rainbow trout population size in the study section:

$$N = \frac{(M + 1)(C + 1)}{(R + 1)} - 1$$

where N = estimated number of rainbow trout >20cm in the study section, M = number of trout marked with floy tags, C = total number of trout>20cm observed in a float survey, and R = number of tagged fish observed in a float survey. Table 1 summarizes the results for the five intensive 4-person surveys. The numbers of marked fish that floaters observed in each size class were too low (<4) to make separate estimates so we pooled the observed marks to make estimates of the section's population of trout >20cm. Even so, the 95% confidence intervals are so wide that we believe that we can place little confidence in the point estimates of section trout numbers.

Table 2 compares the trout counts accumulated by the 2-person float teams and the respective mark-recapture estimate from table 1: estimated expansion factors are higher than for 4-person float teams.

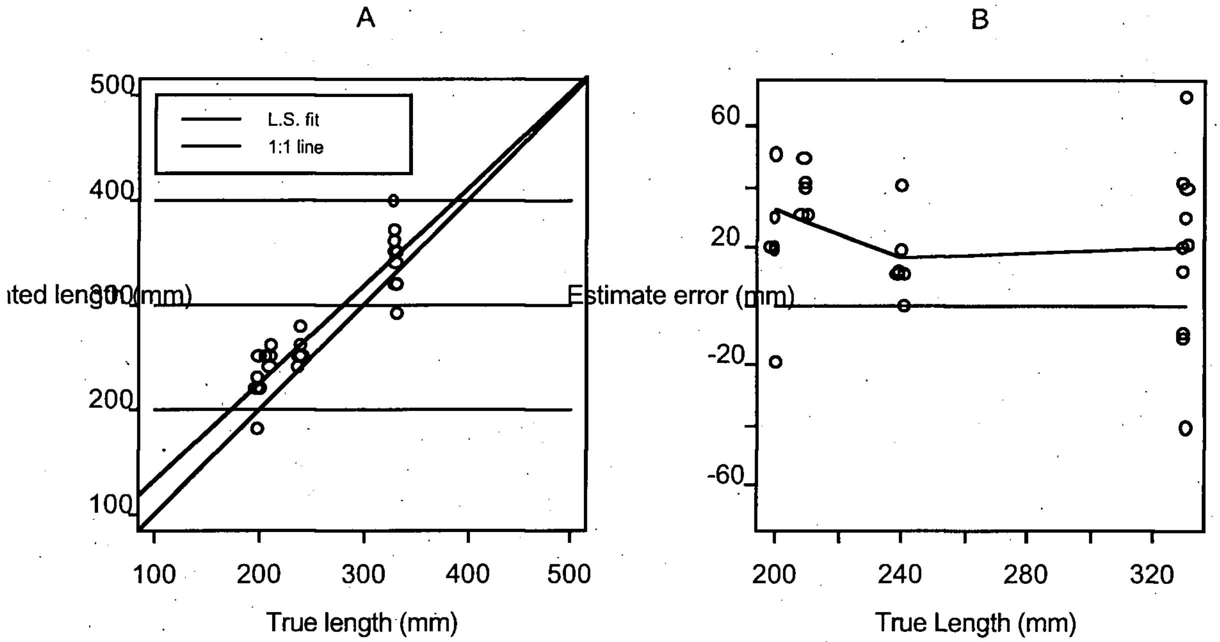


Fig. 2. Length Estimation. Panel A: Estimated length vs. true length of frozen trout under simulated survey conditions (true lengths have a small amount of random jitter added to reveal overlapping estimate values). The least squares fit is almost parallel to the 1:1 line (slope=0.93) but is high (y-intercept=40mm). Note that only three of 27 (11%) observations were not in the correct 100mm size class. Panel B: Examining the actual errors vs. true length more clearly reveals the positive bias of estimates. The locally weighted regression line suggests that the average bias is higher at shorter lengths (roughly 30mm error at 200mm in length in contrast to roughly 20mm at >240mm). Of 27 observations, 22 were high, 4 low, and 1 correct. We note that 26 (96%) were within 50mm of the actual size.

Because of the lack of confidence (wide 95% confidence intervals) and lack of information about differences in accuracy between different size classes, in the following analysis of 1982-1994 survey results we will not expand the counts to give a total estimate of abundance, but instead treat actual counts as an index of abundance. However, tables 1 and 2 do list expansion factors for 4-person and 2-person float teams respectively, should any investigator elsewhere wish to contrast Skagit trout densities (trout/km) to another stream.

Count Precision

Repeatability of snorkel survey counts lends credence to their use as an index of trout abundance, independent of bias estimation and subsequent expansion to some dubious point estimate of absolute abundance. Table 3 summarizes some measures of count repeatability for the Skagit float survey evaluation: precision appears to increase with size class, and for the larger size classes there is less than 2-fold variation in the range of counts. Two floaters reproduce counts as reliably as four floaters.

Table 1: Accuracy of 4-person float team counts. Population estimate of number of rainbow trout >20cm present in the study section determined via mark-recapture. Confidence interval based on *R*

distributed as a random Poisson variable (Krebs 1989). 4-person float team counts. Note the very wide confidence intervals, and low mark recovery.

Float #	Marked	Marks seen	Total seen	Estimated population	95% C.I.	Expansion Factor
1	20	7	81	214	116–401	2.65
2	26	6	66	257	130–500	3.90
3	26	7	86	293	158–547	3.40
4	26	7	81	276	149–516	3.40
5	26	12	103	215	131–364	2.09
					Average:	**3.09**

Table 2: Accuracy of 2-person float team counts. Counts compared with mark recapture estimates (table 1). Note that expansion factors are higher than for 4-person float team counts.

Float #	Trout observed	Estimate (table 1)	Expansion Factor
1	49	214	4.37
2	56	257	4.59
3	70	293	4.19
		Average:	**4.38**

Table 3: Count repeatability. The table summarizes several repeatability parameters for both 4- and 2-person float team trout counts (s.d.=standard deviation, c.v.=coefficient of variation). Precision increases with size class, and is of a reasonable magnitude (range <2 fold) to use as a reliable index for trout 20cm and larger, less reliably for trout <20cm. 4-person float teams do not appear to produce more reliable counts than 2-person float teams.

size class	no. floaters	no. floats	mean	s.d.	c.v. (%)	min	max	max/min
10-20cm	4	5	48.6	26	53	19	89	4.7
20-30cm	4	5	51.6	11.8	23	34	66	1.9
30+ cm	4	5	31.8	3.3	10	29	37	1.3
10-20 cm	2	3	21	14	67	11	37	3.4
20-30 cm	2	3	33.3	6.5	20	27	40	1.5
30+ cm	2	3	25	4.4	17	22	30	1.4

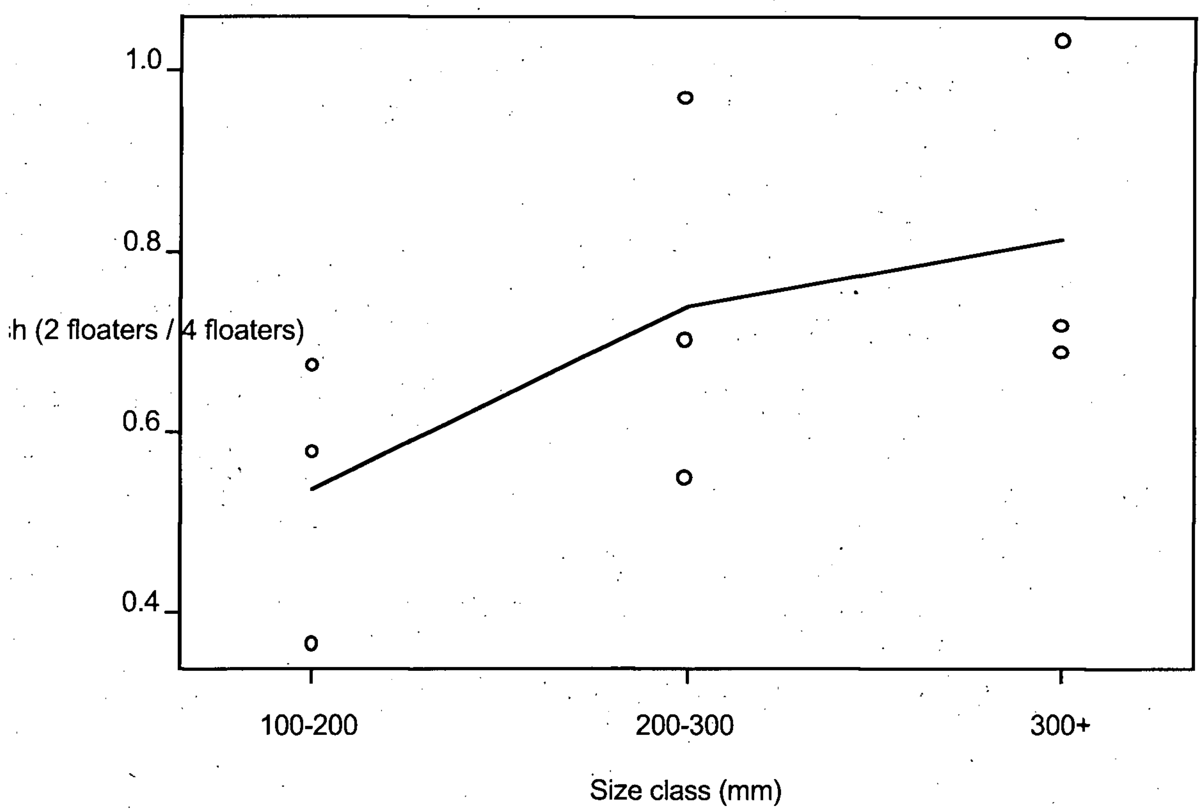


Fig. 3. Efficiency of two floaters relative to four floaters for 3 size classes of fish (number of fish 2 floaters saw divided by the number of fish 4 floaters saw). The line connects the mean fraction for each size class, which increases from 0.5 to 0.8 as size increases. These data suggest that in the 100-200mm size range 4 floaters see twice as many trout as 2 floaters, but as the size of fish increases 2 floaters see almost as many as four floaters. The number of floaters has varied in the underwater survey over the years, and the relationship we show above suggests that simply dividing the number of trout by the number of floaters to account for the fact that more floaters see more fish will not give the best abundance index; there are diminishing returns to adding more floaters, when considering catchable trout especially. In this analysis we assume the number of observable trout did not change in the 10 minute interval between passage of 2-person and 4-person float teams.

Effect of the Number of Floaters

Two possible ways to report observed fish densities from snorkel surveys are: fish observed per kilometre, and fish observed per kilometre per floater. The former isn't overwhelmingly useful as an index of abundance since it is a function of both fish present and number of floaters; although the latter attempts to control for the additional fish additional floaters see (since adding a floater doesn't change the number of fish in a section but does allow greater habitat coverage and therefore observation of more fish), it ignores possible diminishing returns to adding additional floaters, as they saturate the available area to survey. Fig. 3 shows that indeed two floaters see more than half the number of trout that 4 floaters see (trout >20cm), and that adding floaters increased the number of smaller fish floaters observed more than the number of larger fish. We developed a "floater equivalent" index to use in estimating the trout/km/floater value; this corrects for diminishing returns of adding floaters, for each size class separately (table 4). Coverage of available habitat for a given number of floaters would itself change as the team moved downstream and tributary inputs increased flow, stream width, and habitat. We have only these measurements, however, and though it would be more accurate to correct for stream width, there is no calibration available. This correction to '2-person equivalents' (table 4) we base on data collected from section 7 and therefore it best applies in that part of the river, but without similar information from elsewhere we can do no better than apply it upstream (where the correction should be stronger since additional floaters can rapidly saturate available trout habitat) and downstream (where the correction should be weaker, since the point at which adding floaters no longer increases the number of trout in the count is larger). For any of the data we portray in Fig. 3 or table 4 to be credible, the 10 minute interval between the time that the 2-floater team and the 4-floater team started a float must have been short enough to make the trout population closed to immigration and emigration (see above for claims that this is true), and yet long enough for trout to resume normal behaviour after the first team (2-floaters) had startled them.

Table 4: Conversion to two-person float team equivalents for larger teams. This is necessary in order to compute trout observed/km/floater as an abundance index, because diminishing trout count returns as additional floaters participate mean that floaters after 2 do not count proportionally as many of the fish that are present as do the first two floaters. Based on data reported in Fig. 3. The last three columns list the effective number of surveyors to use (as denominator) in computing the abundance index. We calculated four floaters in two floater equivalents from the observed ratio and three floaters in two floater equivalents by linear interpolation between two and four floaters (the average).

size class	ratio 4:2 floaters	2 floaters	3 floaters	4 floaters
10-20cm	1.98	2	3.0	4.0
20-30cm	1.42	2	2.4	2.8
30cm+	1.27	2	2.3	2.5

EVALUATION CONCLUSIONS

- *Length estimation*: At fine trout length resolution (i.e. 1cm) floaters apparently overestimate lengths by 2-3cm; we need to examine estimation at length interval boundaries to be sure corrections are necessary (almost 90% of these data were in the true 10cm wide size class). In the analysis of underwater survey data to follow, we make no corrections.

- *Count accuracy*: counts were obviously biased low compared to the mark-recapture estimates of the sections population of trout >20cm; in order to compare the Skagit counts to other streams investigators could use the expansion factor means we report in tables 1 and 2 (or an interpolation for 3 person teams). However, we could not estimate expansion factors for different size classes, and the fraction of trout floaters see is strongly dependent on the size class. We recommend not relying on expanded counts of Skagit trout <20cm. Because of the large uncertainty in the mark-recapture estimates (very wide confidence intervals) and effect of size on expansion factor we decided to use direct counts as an index of abundance.

- *Count precision*: we can justify using counts as an index of abundance because, at least for >20cm (catchable) trout, the counts are reasonably repeatable. Precision increases with increasing size class (table 3), and two floaters reproduce counts as reliably as 4 floaters.

- *Computing abundance index*: to compute an index of trout abundance it is necessary to divide the number observed per kilometre by the number of floaters, where the number of floaters is somewhat modified for >2 floaters in a survey team (table 4). This 2-person floater equivalent index loses accuracy up- and downstream from section 7 but without additional information it remains the best choice, e.g., better than simply reporting the absolute trout count, which is a function of both trout present, and number of floaters.

SKAGIT RIVER FLOAT SURVEY

FLOAT SURVEY METHODS

General

Two or three person (once a four person team, in 1982) teams swam consistent sections of the mainstem Skagit River, downstream, from 1982–1994. Table 5 provides some summary information about the sections. Floaters kept to a lane and looked only straight ahead or to the nearest bank, and maintained one visual distance from their respective bank. When present, the center floater kept one visual distance away from either the left or right floater. Each floater recorded counts of rainbow trout (and Dolly Varden char—bull trout; data on file) in 10cm size classes (<10cm, 10-20cm, 20-30cm, 30-40cm, and 40cm+) and regularly reported these numbers to a data recorder who walked the bank of the river and compiled the data as floaters reported it. For the purposes of this report, we considered only commonly surveyed Skagit River sections (count data in appendix A) and excluded both infrequently surveyed Skagit sections and the few surveys of sections in the Klesilkwa and Sumallo Rivers (although we provide these data in appendix B).

Floaters

Eighteen different people have floated river sections in this survey at one time or another. However, there has been a stable core of floaters that have surveyed each or most years: 3 have floated >50% of all Skagit sections we analyse in this report, and 10 have floated almost 90%. We therefore discount learning as playing an important role in biasing or reducing precision of counts.

River Conditions

Floaters encountered underwater visibilities ranging from <1m to 6m. We excluded counts from two sections with visibility <2m as unreliable; of visibilities ranging from 2–6m the mean was 3.5m (n=112). Water temperatures ranged from 7.5–13°C, with a mean of 9.9°C (n=70). These temperatures presumably had negligible effect on trout behaviour for the purposes of counting. Float speeds varied from 6–72 m/min (0.36–4.32km/hr) with a mean of 38m/min (or 2.3km/hr; n=59). These speeds include resting and reporting counts to the data recorder.

Table 5: Commonly surveyed Skagit River sections. See Fig. 1 for the geographic location of sections based on the description of section boundaries. Personnel surveyed above Skagit Falls in the first two years only of the annual survey, section "1" (Chittenden Bridge downstream to Ross Reservoir full pool contour) only one year, and rarely surveyed reaches of the Sumallo and Klesilkwa Rivers.

Section	Description	Length (m)
15	Sumallo River confluence to Silverdaisy Creek	1900
14	Silverdaisy Creek to Skagit Hotel	2570
13	Skagit Hotel to Twentyeight Mile Creek	6010
12	Twentyeight Mile Creek to Silvertipped Creek	3480
11	Silvertipped Creek to 26 Mile Bridge	3310
10	26 Mile Bridge to Klesilkwa River	740
9	Klesilkwa River to 45km	2490
	45km to 46.4km	1980
7	46.4km to Shawatum Creek	2510

6	Shawatum Creek to Fuel Dump	960
5	Fuel Dump to Roadside	2490
4	Roadside to Garbage Dump	2860
3	Garbage Dump to 56km	2920
2	56km to Chittenden Bridge	2630
	Total	**36850**

Coverage

Fig. 4 shows the Skagit River 1982–1994 float survey in time and space. All years have had representative coverage of upper-, mid-, and lower Skagit reaches, and the survey counted trout from the Sumallo confluence to Chittenden Bridge (36.9km) in the four most comprehensive survey years (top panel, Fig. 4). Surveys have occurred in late July to late September with the bulk of them in August (bottom panel Fig. 4). While a ten week span might imply difficulty in comparing between years, we note that even the same week in different years might not represent the same set of environmental conditions for trout in the river, and that tagging studies have indicated stable populations of trout in the river until autumn, when they move down into Ross Reservoir (Usher 1986). Thus it remains reasonable to compare float surveys from summer months (including September), without time controls.

Abundance Index Computation

We chose to analyse rainbow trout counts from the Skagit River float survey using the following abundance index for each size class *s* in a given section:

$$\text{Index}_s = \text{Count}_s / (\text{Length} \times \text{Floater Equivalents})$$

where 'Count$_s$' is the count for a particular size class *s* in a section, 'Length' is the section length, and 'Floater Equivalents' is the value from table 4 corresponding to the number of floaters that accumulated the count. Index units are trout per km per floater equivalent. As we indicate above this index is the least

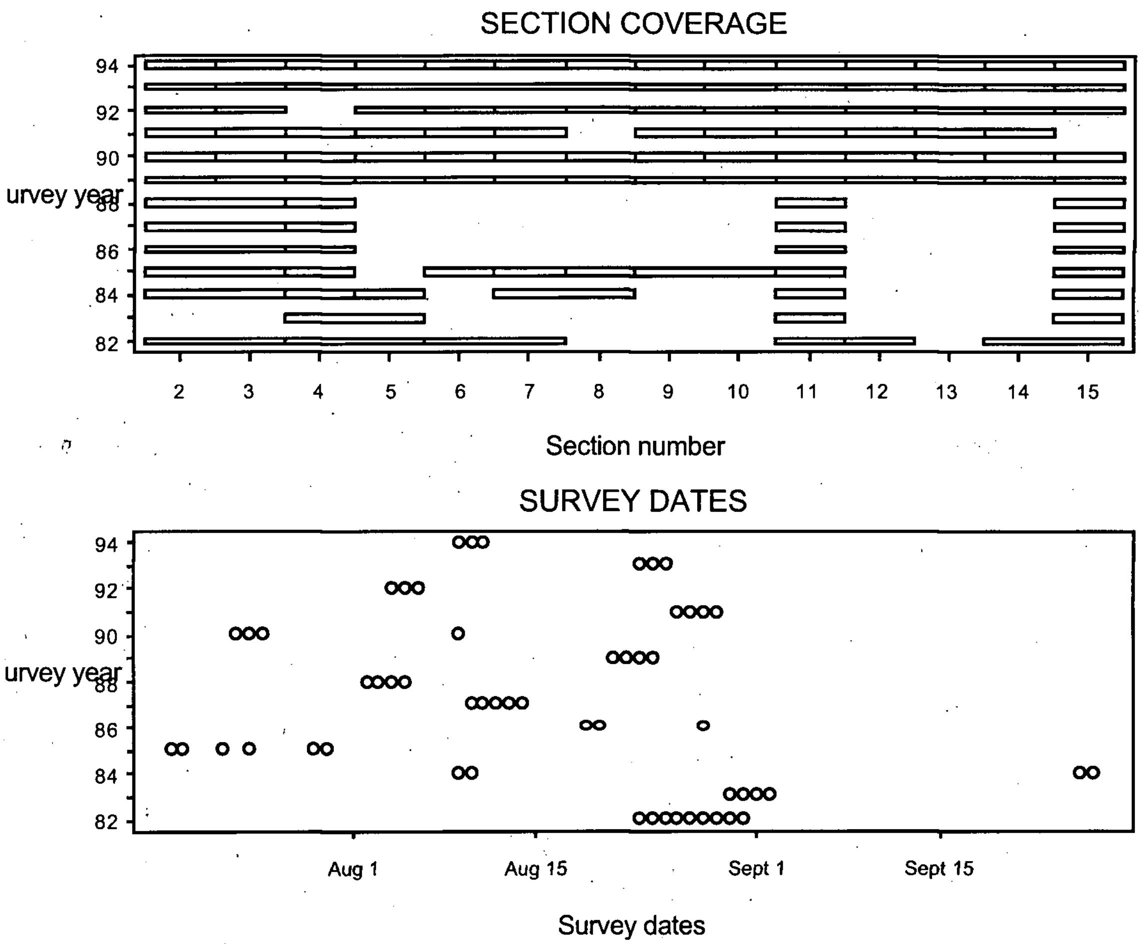


Fig. 4. Float survey coverage for the main Skagit River survey sections when visibility was 2m or more. The top panel shows the sections surveyed each year; we show sections for which floaters pooled counts as unbroken horizontal segments (occasionally surveys pooled the counts from 2 or more sections). The survey has covered sections 2–3, 4, 11, and 15 most frequently. The bottom panel shows survey dates for the data we interpret in this report; points show each survey day (except for 1982 and 1983 where only a date range was available).

biased of several possible indices (e.g. raw counts, or counts/km, or counts/km per person, without correction). Although Fig. 5 shows that the survey has used larger teams in the 3 downstream sections (2–4) more often than smaller teams, in order to cover more of the larger stream habitat available to trout, in the rest of the river there has been a roughly even mix of float team size. The correction to '2-person equivalents' (table 4 and text) we based on data collected from section 7 and therefore it best applies in that part of the river, but without similar information for other sections we can do no better than apply it upstream (where the correction should be stronger) and downstream (where the correction should be weaker). There have been 2 person float teams in both the upper and lower Skagit, as well as 3 person float teams.

Where there was more than one count of trout for a given section in a year, we computed the mean abundance index for each size class.

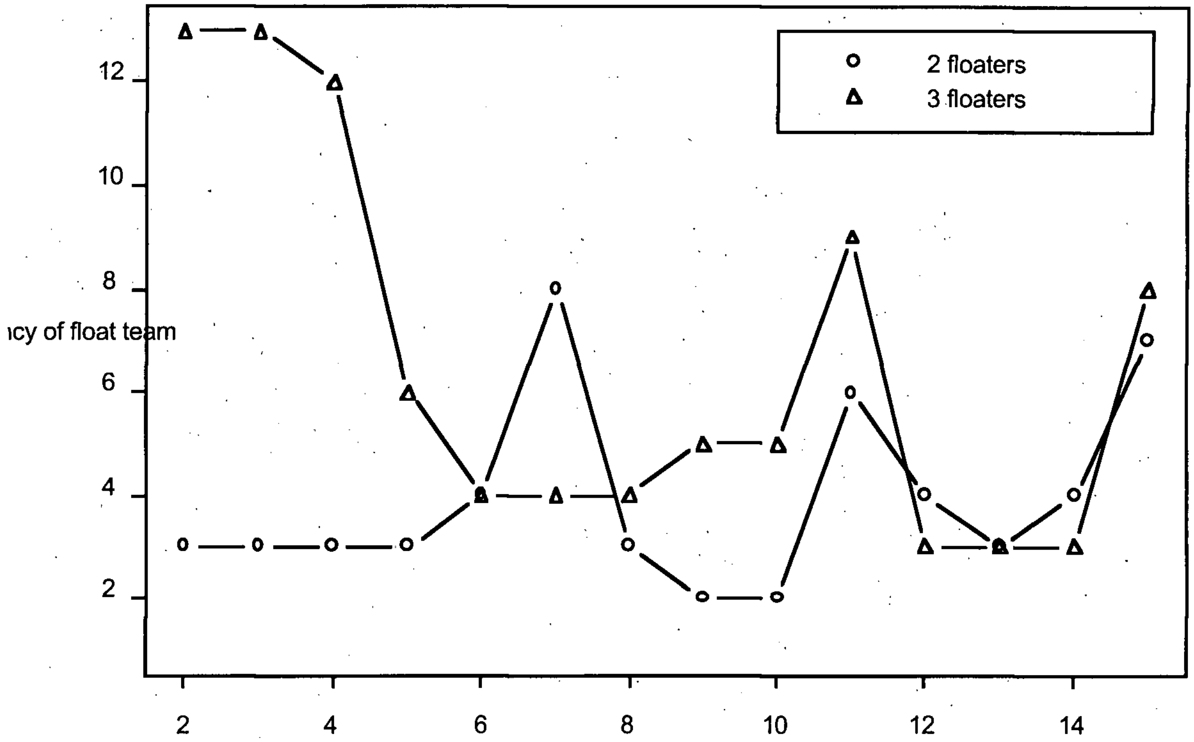


Fig. 5. Frequency of use of two- and three-person float teams versus section. The survey has used larger teams in the 3 downstream sections (2–4) more often than smaller teams whereas in the rest of the river there has been a roughly even mix of float team size. The correction to '2-person equivalents' (table 4 and text) we based on data collected from section 7 and therefore best applies in that part of the river, but without similar information from elsewhere we can do no better than apply it upstream (where the correction should be stronger) and downstream (where the correction should be weaker).

FLOAT SURVEY RESULTS

Some summarizing facts convey the magnitude of the Skagit River float survey. During the years 1982–1994, and including tributaries and infrequently surveyed sections (though excluding one count from October of 1983 and spawner counts from 1985 and 1986) summer float surveys covered 418km of stream length, and snorkellers floated a total of 1095km and counted 19058 rainbow trout (4543 <20cm and 14515 >20cm). We present a summary of the data we analyse for this report in table 6. Raw counts of trout per kilometre have increased with time, as has the survey intensity. We also list expanded counts/km of catchable fish based on the lowest and highest expansion factors that the float evaluation revealed (tables 1 and 2), duly emphasizing the dubious accuracy of these numbers. Recent sport fishing quality, at least as measured by the number of catchable fish available, has increased.

Table 6: Overall summary of survey effort and results, excluding tributaries, infrequently surveyed sections, and sections the survey did not cover during summer (spawner surveys 1985, 1986, and one autumn survey in 1983). Pooled sections (table 5) count as one here; the table includes sections the survey covered more than once in a year. In general the intensity of the survey has increased with time, as have the raw fish counts, which we report here in 2 size categories. Of interest to anglers: expanded counts/km of catchable trout (>20cm) for the lowest and highest expansion factors (e) of tables 1 and 2. Recent years ought to have been excellent fishing, particularly 1994. Note the skepticism we attach to estimated expansion factors in the text, however.

Year	No. sections	Stream-km	Person-km	<20cm	20+cm	Catchables/km low (e=2.09)	Catchables/km high (e=4.59)
82	6	21.6	49.8	240	203	20	43
83	3	9.3	27.9	18	187	42	92
84	9	33.2	79.2	198	595	37	82
85	11	33.3	66.6	189	433	27	60
86	4	13.6	40.9	74	767	118	258
87	8	27.2	81.7	187	1168	90	197
88	8	27.2	81.7	138	915	70	154
89	14	36.9	110.6	113	926	53	115
90	16	42.4	125.3	303	720	35	78
91	12	33.0	77.6	153	349	22	49
92	13	34.0	84.7	836	1909	117	258
93	11	36.9	82.1	184	1247	71	155
94	14	36.9	108.7	1027	4696	266	585
totals	129	385.4	1016.7	3660	14115		

Rainbow Trout Distribution in the Skagit River

In Fig. 6 we plot the average abundance index versus river section for three size classes of rainbow trout: sub-catchables (<20cm), and two catchable size-classes (20–30cm and 30cm+). There appears to be a trend towards lower abundances of the larger size classes as one moves upstream, a pattern consistent with research angling CPUE results (Burrows and Neuman 1995). Sub-catchables have a more uniform distribution in the river, with one higher mean count in section 10. Section 10 borders on the Klesilkwa River, in which at least one survey counted very high juvenile densities (appendix B). In a similar plot with more detailed size gradations (Fig. 7), we see the same trends as in Fig. 6 except for 40cm+ trout which appear to show no trend or even increase in abundance farther upstream, although the earlier surveys (pre-1991) which covered sections 2 and 3 as one unit show higher downstream abundances of the 40cm+ category.

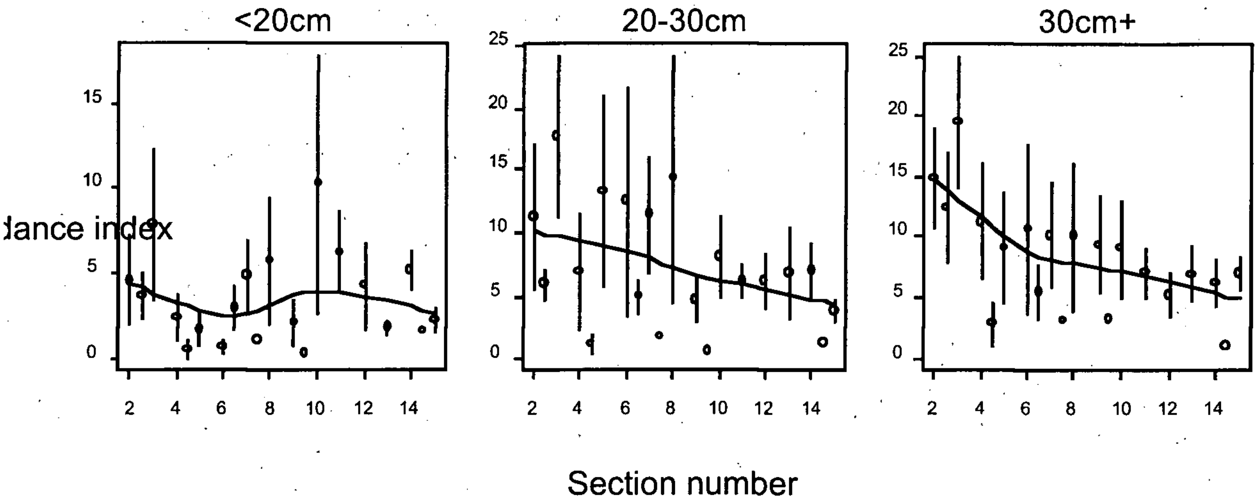


Fig. 6. Rainbow trout abundance by section and size class. The abundance index is trout per km per floater equivalent (see text), and here we show means for all years ± standard error for each section (or the midpoint of pooled sections; that these tend to be lower in value may be due to the annual trend we discuss in the next section. Pooling of multiple section counts occurred in earlier survey years, see Fig. 4). Lines are locally weighted regressions. The general trend for catchables tends to be to lower densities farther upstream, and higher densities closer to Ross Reservoir. Sub-catchable (<20cm) rainbow trout appear to distribute themselves uniformly except for the high section 10 abundance. The downstream boundary of section 10 is the Klesilkwa River.

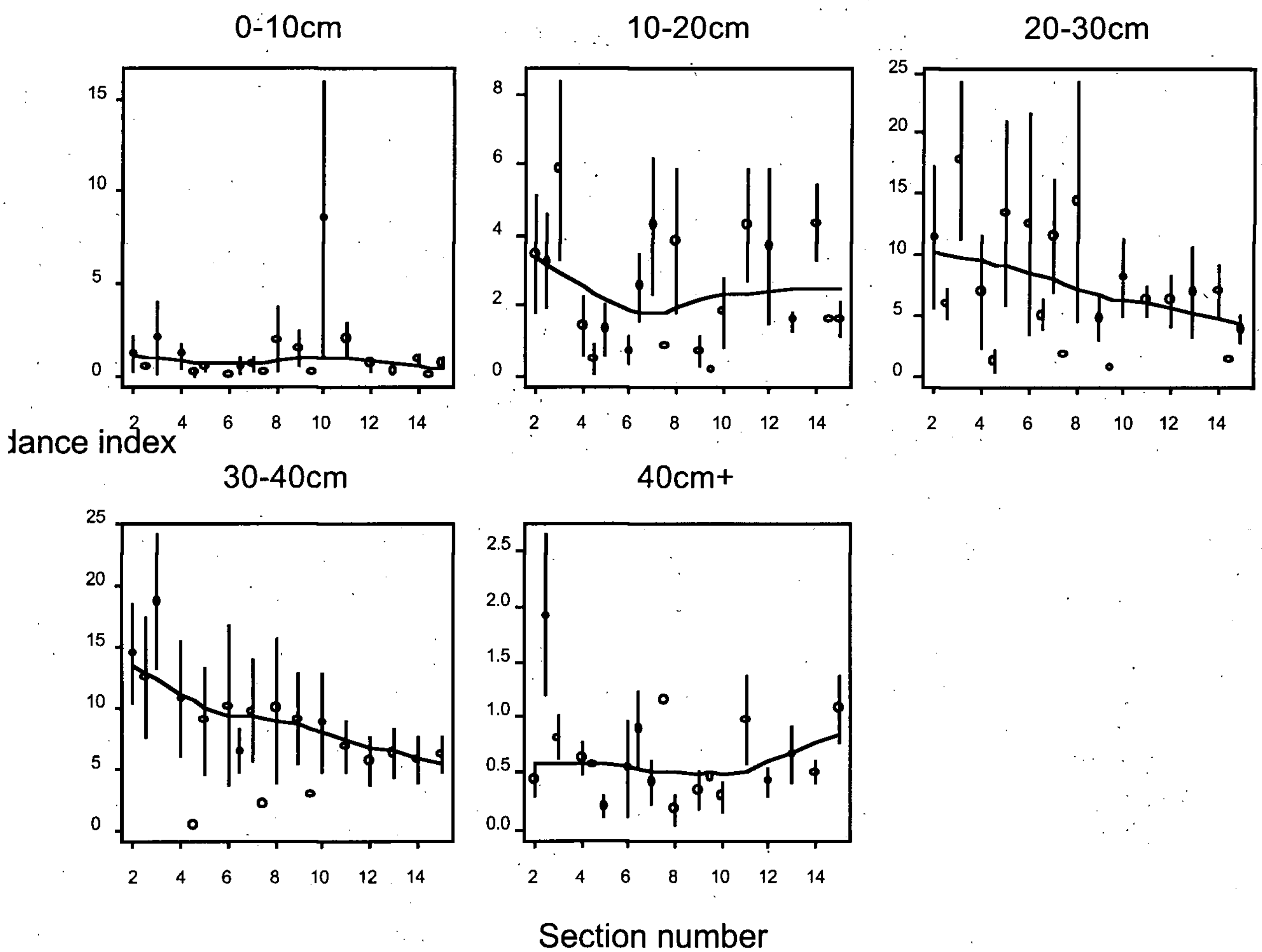


Fig. 7. Rainbow trout abundance by section and detailed size class. This more detailed view of trout abundance (mean index ± standard error) reveals additional information about their spatial distribution: while 20-40cm trout decline in abundance as we move upstream, large trout (40cm+, 1984 and later recorded this size class separately) show no decline and may increase (the high mean abundance of section 2–3 is from earlier survey years, and the lower mean abundance for each of 2 and 3 separately are from later survey years) . Trout in the 10-20cm size class may decrease in abundance farther upstream but this is not clear. The large value for section 10 for fish 0-10cm is the result of a very high 1994 count (10 times as high as the largest count in other years); if we treat it as an outlier then we see that these juvenile trout are evenly distributed in the Skagit mainstem.

Rainbow Trout Annual Abundance Trends

For management purposes, Skagit rainbow trout annual trends are more interesting than spatial trends because they reveal more about the effects of angling regulation changes, which typically apply to the whole river.

In Fig. 8 we show the overall trend in mean abundance for sub-catchables and 3 size classes of catchables, for the whole river (using the average of available section abundance indices in computing an annual mean). This portrait of abundance in time clearly reveals a recent increase in trout population size, for all size classes, though after what appears to be a lengthy decline in larger trout (40+cm) abundance this size class hasn't shown as strong an increase as have smaller size classes. Nevertheless if 30+cm fish show an increase so will 40+cm after a lag time dependent on growth. The mean index for 1992–1994 is 4.2, 4.9, and 2.7 times the mean index for previous years for <20cm, 20–30cm, and 30+cm size classes respectively. Unless float teams have made remarkable improvements in the proportion of trout present that they count, recent changes in Skagit River angling regulations are probably causing the increase in apparent trout densities. In particular, the Skagit River changed to 100% catch-and-release from a 2 fish>300mm limit per day in 1992 (appendix C). As well, in 1990 Ross Reservoir regulations changed to 3 fish per day (from 4), 330mm minimum size (from no minimum size), and a bait ban (from no previous gear restrictions). Both regulation changes might have immediate and delayed abundance effects. Average length at maturity of female rainbow trout in the 1994 Ross Reservoir harvest was 333mm (Looff 1995); if increases in spawning females from 1990 on occurred and resulted in increased recruitment, increases in abundance in larger size intervals would occur from 2–3 years later (age 3+ trout in the 1994 harvest ranged from 226mm to 314mm—Looff 1995). Note that in Fig. 8 rainbow trout <20cm may indeed show an earlier increase in abundance index than trout 20+cm.

The float survey has consistently covered 2 lower Skagit sections (2–3 and 4), one mid-Skagit section (11) and one upper Skagit section (15) from 1982–1994, and we show the annual abundance counts for all of these sections versus year in Fig. 9. These graphs confirm the increase in abundance throughout the river for all size classes, and also confirm that the 40+cm size class, after abundance decreases in the mid-to-late 1980s, has not consistently increased (yet) in abundance in recent survey years. It may not increase, if the northern Ross Reservoir harvest is efficient at cropping these largest trout.

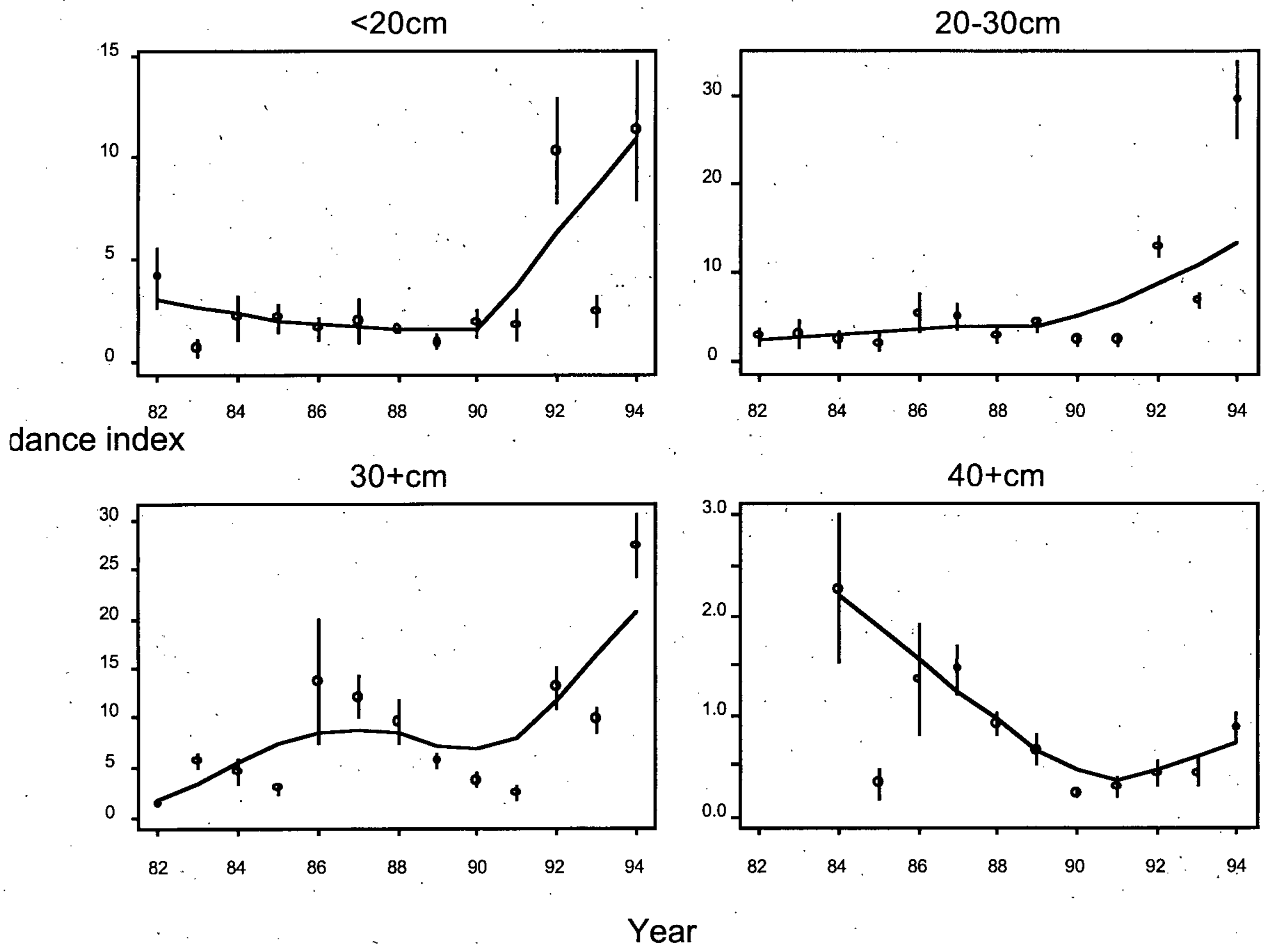


Fig. 8. Annual rainbow trout abundance for various size classes (40+cm data displayed alone and as part of the 30+cm panel). This graph shows the mean (for all sections available in a given year) abundance index (trout per km per floater equivalent) ± standard error. Lines are locally weighted regressions. It is clear that in recent years abundance has increased dramatically for trout <40cm and that after a long decline, the largest trout may be showing an increase in numbers as well. The mean index for 1992–1994 is 4.2, 4.9, and 2.7 times the mean index for previous years for <20cm, 20–30cm, and 30+cm size classes respectively. Skagit River and Ross Reservoir have had significant angling regulation changes in recent years which are the likely cause for this trend (see appendix C); in particular, in 1992 the Skagit River regulations changed to 100% catch-and-release from a 2 fish>300mm limit per day. Also, in 1990 Ross Reservoir regulations changed to 3 fish per day (from 4), 330mm minimum size (from no minimum size), and a bait ban (from no previous gear restrictions). Note that the abundance index scales differ.

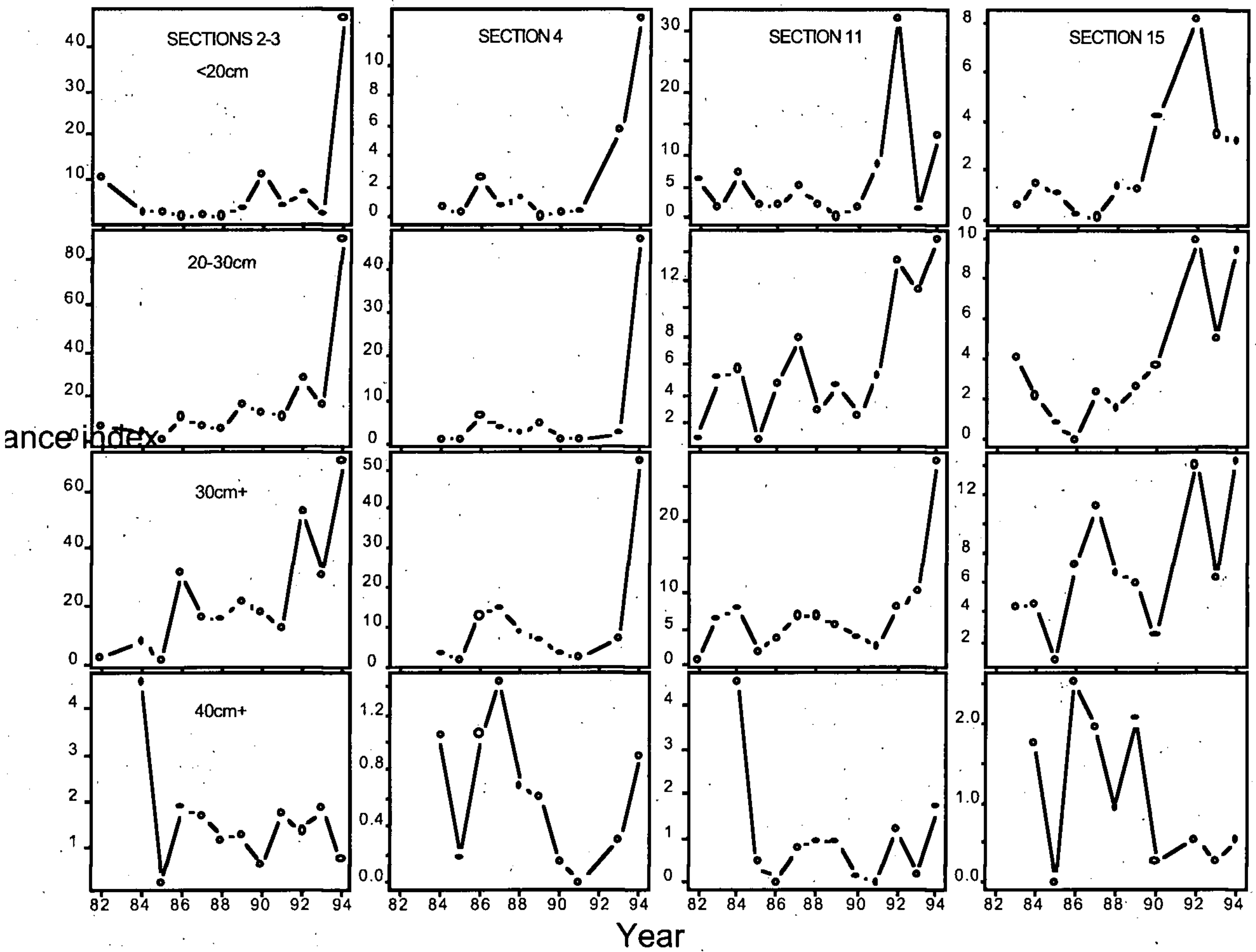


Fig. 9. Annual rainbow trout abundance for various size classes in the most frequently surveyed sections. This view of annual trend in trout abundance shows the abundance index (trout per km per floater equivalent) versus year for the 4 sections that the survey covered most frequently (see Fig. 4). Columns are the different sections, and each row is a different size class (note that in 1982-83 the survey did not record 40cm+ trout separately but instead as 30cm+). The last row, 40cm+ trout, we naturally graph as part of the 30cm+ row, but the size class also shows an interesting pattern alone. Abundance is increasing for all size classes, from near Ross Reservoir to the upper mainstem at the Sumallo confluence, although the indices for 40cm+ trout are ambiguous. They clearly experienced a strong decline in the mid- to late-1980s and may now be increasing, probably because of the new catch-and-release regulations, and in spite of the kill fishery in the northern Ross Reservoir (a small proportion of the harvest is composed of trout >40cm , Looff 1995).

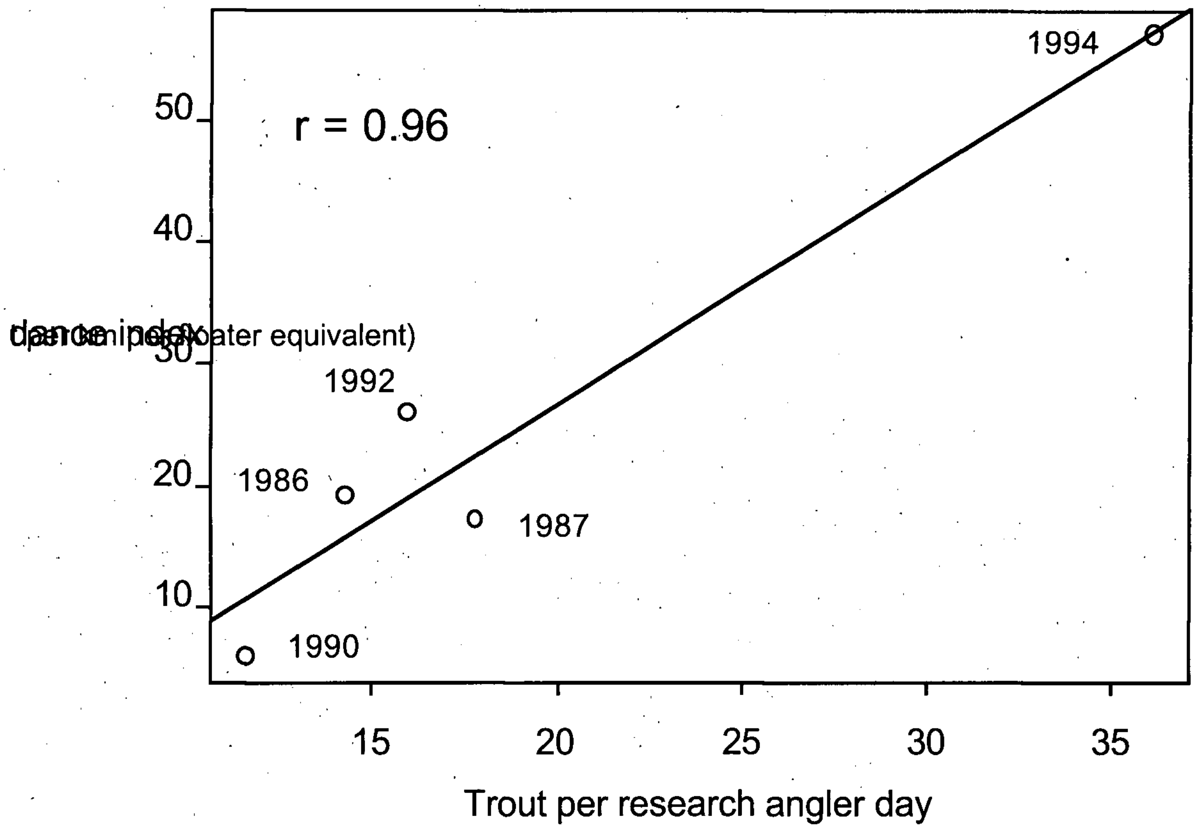


Fig. 10. Relationship between the Skagit River float survey abundance index and research angling catch per unit effort (Burrows and Neuman 1995). There is a clear correlation between these two indices of catchable (20+cm) trout abundance in the Skagit River. Without the 1994 data, however, the correlation is weaker (r=0.68).

Comparison of Research Angling to Underwater Census

We compare research angling CPUEs for years available (Burrows and Neuman 1995) to the mean abundance index for the same size class (20+cm pooled) that the float survey compiled for those years, in Fig. 10. The strong correlation validates a claim that both research angling and float survey results are responding to the same factor, presumably trout abundance. However, this correlation is weaker for smaller contrast ranges in either index (i.e., omitting the 1994 result), suggesting that while one index alone is possibly enough to make statements about trout population trends, together they increase each other's credibility.

DISCUSSION AND CONCLUSIONS

Wide confidence intervals in mark-recapture estimates of the evaluation reach's trout population preclude reliable estimation of expansion factors to use to expand snorkel counts to absolute abundances; a comparison of Skagit counts to other streams requires either real skepticism or a repeat of the evaluation with more initial marking effort.

The 1985 survey evaluation suggested that size estimates might be too high by 2–3cm but that at survey resolutions (10cm) such bias may not occur. Further calibration of length estimation at size interval edges would be useful. Counts are reasonably repeatable especially for catchable (>20cm) trout. The evaluation also provided some information we used to control for the effect of diminishing habitat coverage when adding extra floaters: we developed a robust abundance index to control for the number of floaters and section length. Improvements to this index are possible if further calibrations take place at other sites in the river, but we believe that it is useful as it stands.

Using this abundance index we established that Skagit rainbow trout population densities increase from upstream to downstream, and that after the 1992 change to catch-and-release regulations all size classes of the population have been increasing in abundance, by factors ranging from 2.7–4.9 times pre-1992 mean abundance indices. Inspection of 40+cm trout abundance indices suggests that this size class may not have increased, although it probably will over time (unless the northern Ross Reservoir kill fishery crops trout efficiently as they reach 40+cm). The increase in abundance after the change to catch-and-release is consistent with other stream trout population responses to such regulation changes (e.g. Jones 1987).

The strong correlation between float survey abundance estimates and research angling CPUE provides independent credibility to the trends we believe we see in these data; the ability to cross-validate both methods of evaluating trout abundance (angling and float survey) suggests that both should continue as management tools for the Skagit system.

Because the conclusions about abundance patterns that we draw from the most frequently surveyed subset of sections (2–3, 4, 11, and 15) do not greatly differ from those we draw from all sections combined, and because this subset provides reasonable spatial coverage of the Skagit River, future surveys can omit the other sections if logistical constraints force a minimized survey design.

The Klesilkwa River is a potential candidate for survey work because there are hints in the data that it may be a significant rearing tributary for juvenile Skagit system rainbow trout.

In conclusion, the Skagit River float survey should continue because it has revealed important changes in the status of the river's rainbow trout population, especially with respect to angling regulation changes.

REFERENCES

Burrows, J.A. and R. Neuman. 1995. Skagit River rainbow trout population trends: research angling from 1986 to 1994. B.C. Ministry of Environment, Lands and Parks Regional Fish. Rep. No. LM169, 15p.

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

Griffith, R.P. and D.L. Greiner. 1983. Assessment of existing and potential fisheries values of the Canadian Skagit River: I. Inventory of existing stream populations of catchable-sized fish and general assessment of enhancement potential, 1982. Unpublished MS B.C. Ministry of Environment, 88p.

Griffith, R.P. 1985. Assessment of existing and potential fisheries values in the Canadian Skagit River drainage: II. Inventory of juvenile fish populations and final management recommendations, 1983. Unpublished MS B.C. Ministry of Environment, 50p.

Jones, Ronald D. 1987. The Yellowstone experience: a decade of catch-and-release, p. 94-99 *In* R.A. Barnhart and T.D. Roelofs [eds.] Catch-And-Release Fishing: a Decade of Experience, Proceedings of a National Sport Fishing Symposium. Humboldt State University, Arcata

Krebs, C.J. 1989. Ecological Methodology. Harper and Row, New York.

Looff, A.C. 1995. Ross Lake rainbow trout study 1994-95 final report. Washington Department of Fish and Wildlife Fisheries Management Division, Skagit Environmental Endowment Commission Project Report No. 94-08, 95p.

Neuman, H.R. 1988. Skagit River and Ross Reservoir fisheries management plan. B.C. Ministry of Environment RFP No. LM150, 40p.

Northcote, T.G. and D.W. Wilkie. 1963. Underwater census of stream fish populations. Trans. Am. Fish. Soc. 92: 146–151

Perry, T.L. 1981. A citizen's guide to the Skagit Valley. Run Out Skagit Spoilers Committee, Vancouver B.C. 85p.

Schill, D.J. and J.S. Griffith. 1984. Use of underwater observations to estimate cutthroat trout abundance in the Yellowstone River. N. Am. J. Fish. Manage. 4: 479–487

Scott, K.J. 1986. A data report of rainbow trout tagging and test fishing studies in the Canadian Skagit River, 1986. B.C. Ministry of Environment Regional Fisheries Report No. LM114, 68p.

Slaney, P.A. and A.D. Martin. 1987a. Accuracy of underwater census of trout populations in a large stream in British Columbia. N. Am. J. Fish. Manage. 7: 117–122

Slaney, P.A. and A.D. Martin. 1987b. Further evaluations of underwater census as a method for estimating trout populations in large streams. B.C. Ministry of Environment Fisheries Research Branch unpublished MS, 20p.

Usher, J.B. 1986. Skagit River rainbow trout (*Salmo gairdneri*) tagging study, 1984. B.C. Ministry of Environment Regional Fisheries Report No. LM101, 28p.

Whitworth, W.R. and R.E. Schmidt. 1980. Snorkeling as a means of evaluating fish populations in streams. New York Fish and Game Journal 27: 91–94

Zubik, R.J. and J.J. Fraley. 1988. Comparison of snorkel and mark-recapture estimates for trout populations in large streams. N. Am. J. Fish. Manage. 8: 58–62

APPENDICES

A. Rainbow trout counts 1982–1994 for the main Skagit River

Rainbow trout counts 1982–1994 for the main Skagit River (tributary and least frequent Skagit reaches excluded) which we have analysed in this report. Section number is the modern label (see table 5) or best approximation, section length is in metres, date is in year-month-day format, and trout length intervals are in cm (1982 and 1983 surveys recorded trout 30-40cm and 40+ as a 30+ size class). We excluded counts from 2 sections due to poor visibility (<2m—sections 8 and 15, 1991), as well as the one survey downstream of Chittenden Bridge (1989) due to indeterminate length and a lack of samples for it any other year. There were also spawner surveys in 1985 and 1986, but they aren't the subject of this report (data on file). 1982–1983 data from Griffith and Greiner (1983) and Griffith (1985); other years, data on file.

section number	section length	date	no. floaters	0-10	10-20	20-30	30+
~2–3	5100	820823–0831	2	6	101	66	25
4, part of 5	4300	820823–0831	2	4	11	24	12
parts of 6 and 7	2700	820823–0831	2	1	16	22	9
11	3350	820823–0831	4	39	42	9	6
~12	2550	820823–0831	2	3	6	9	5
14–15	3550	820823–0831	2	0	11	9	7
4, part of 5	4300	830830–0902	3	0	0	1	63
11	3350	830830–0902	3	4	11	42	49
~15	1650	830830–0902	3	1	2	16	16

section number	section length	date	no. floaters	0-10	10-20	20-30	30-40	40+
2–3	5550	840809	3	10	59	76	41	38
4	2860	840809	2	2	1	5	13	6
8, part of 7	3470	840809	2	1	6	12	14	8
11	3310	840809	2	21	58	63	35	7
15	1900	840810	3	0	4	5	16	5
2–3	5550	840926	2	0	15	37	26	68
4–5	5350	840926	3	0	1	6	5	7
11	3310	840926	2	0	12	13	8	53
15	1900	840927	2	2	6	12	7	9
2–3	5550	850718	2	10	19	17	17	3
4	2860	850718	2	0	1	5	10	1
11	3310	850718	2	5	7	6	8	3
15	1900	850719	2	1	3	3	3	0
9–10	3230	850722	2	1	1	4	18	3
8	1980	850722	2	1	7	2	11	0
6–7	3470	850722	2	7	13	17	33	10
6–7	3470	850724	2	9	41	30	31	7
7	2510	850729	2	0	15	31	22	0
7	2510	850730	2	0	11	34	24	0
7	2510	850730	2	0	37	47	33	0
11	3310	860819	3	0	19	38	28	0
4	2860	860819	3	0	22	43	77	7
15	1900	860820	3	0	1	0	20	11
2–3	5550	860828	3	5	27	142	377	24
15	1900	870813	3	0	1	16	43	8

section number	section length	date	no. floaters	0-10	10-20	20-30	30-40	40+
15	1900	870814	3	0	0	5	37	9
2–3	5550	870812	3	0	60	97	183	29
4	2860	870812	3	0	1	12	90	12
2–3	5550	870811	3	1	17	81	178	14
4	2860	870811	3	2	9	34	83	7
11	3310	870810	3	8	33	68	48	4
11	3310	870810	3	7	48	59	43	8
11	3310	880802	3	1	13	25	41	4
11	3310	880802	3	7	18	20	48	10
15	1900	880805	3	0	3	8	29	4
15	1900	880805	3	4	8	6	21	4
2–3	5550	880803	3	4	17	65	160	15
4	2860	880803	3	4	5	14		4
2–3	5550	880804	3	9	33	83	212	15
4	2860	880804	3	4	8	15	57	5
2	2630	890824	3	0	22	35	53	5
3	2920	890824	3	0	6	76	77	3
4	2860	890824	3	0	0	29	40	4
5	2490	890824	3	1	2	48	38	2
6	960	890823	3	0	1	2	4	0
7	2510	890823	3	3	6	39	26	0
8	1980	890823	3	1	0	14	23	1
9	2490	890823	3	0	0	9	29	1
10	740	890823	3	0	0	2	1	1
11	3310	890823	3	0	1	37	34	7
12	3480	890822	3	0	22	42	33	7
13	6010	890822	3	0	12	41	56	20
14	2570	890822	3	0	29	24	21	4
15	1900	890821	3	0	7	12	17	9
2	2630	900725	3	0	1	7	11	1
3	2920	900725	3	0	3	18	20	2
4	2860	900725	3	0	2	6	21	1
5	2490	900725	3	0	1	9	8	1
6	960	900725	3	0	1	2	1	1
7	2510	900725	3	0	7	21	23	2
8	1980	900725	3	0	2	4	6	0
9	2490	900725	3	0	0	5	9	1
10	740	900724	3	0	0	2	10	0
11	3310	900723	3	9	7	20	28	1
12	3480	900724	3	0	3	3	14	3
13	6010	900724	3	0	21	14	28	2
14	2570	900724	3	13	31	20	16	2
15	1900	900723	2	5	11	14	8	1
2	2630	900809	3	0	48	48	94	3
3	2920	900809	3	3	135	105	102	2
2	2630	910828	3	2	1	17	17	5
3	2920	910828	3	0	34	58	54	6
4	2860	910829	3	2	1	6	15	0

section number	section length	date	no. floaters	0-10	10-20	20-30	30-40	40+
5	2490	910828	2	0	0	5	9	0
6	960	910828	2	0	0	0	1	0
7	2510	910828	2	0	4	10	8	3
9	2490	910827	3	0	2	4	7	1
10	740	910827	3	2	2	8	3	1
11	3310	910826	2	2	53	35	17	0
12	3480	910827	2	5	16	13	5	2
13	6010	910827	2	4	18	20	8	0
14	2570	910827	2	3	2	8	2	1
2	2630	920806	3	0	12	51	112	1
3	2920	920806	3	0	50	142	224	8
5	2490	920806	3	10	25	85	51	0
6	960	920806	3	0	2	31	29	0
7	2510	920806	3	11	96	110	87	2
8	1980	920805	3	53	65	71	33	0
9	2490	920805	3	30	17	46	36	1
10	740	920805	3	10	15	28	10	1
11	3310	920804	2	71	141	89	44	8
12	3480	920805	2	17	118	81	88	1
13	6010	920805	2	3	17	73	126	8
14	2570	920805	2	5	37	75	63	3
15	1900	920804	2	10	21	38	51	2
15	1900	930823	2	5	8	19	23	1
14	2570	930824	2	3	37	42	27	4
13	6010	930824	2	3	23	54	79	6
12	3480	930824	2	2	14	51	33	1
11	3310	930825	2	3	5	74	68	1
10	740	930825	2	0	2	10	16	0
9	2490	930825	2	0	0	35	77	1
5–8	7940	930825	2	0	11	118	132	9
4	2860	930824	3	45	4	15	45	2
3	2920	930824	3	0	1	65	86	10
2	2630	930824	3	6	12	43	98	2
15	1900	940809	2	4	8	36	52	2
14	2570	940810	3	8	27	66	61	3
13	6010	940810	3	11	48	360	191	18
12	3480	940810	3	0	12	127	75	6
11	3310	940810	3	59	71	118	205	13
10	740	940810	3	101	4	35	47	0
9	2490	940810	3	34	12	62	141	7
8	1980	940811	3	0	37	249	151	3
7	2510	940811	3	11	47	188	162	7
6	960	940811	3	0	6	109	77	5
5	2490	940811	3	5	20	251	147	3
4	2860	940811	3	36	76	325	338	6
3	2920	940811	3	104	149	342	254	4
2	2630	940811	3		93	256	193	1

B. Rainbow trout counts 1982–1994 for other sites

Rainbow trout counts 1982–1994 for infrequently surveyed tributaries and the Skagit above the falls. Table lists the location, section length, date of float, and counts in 10cm size intervals. Data for 1982 and 1983 from Griffith and Greiner (1983) and Griffith (1985); other data on file.

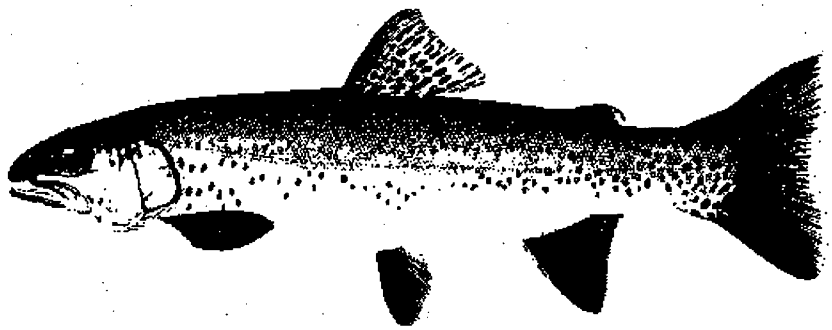
River	location	length (m)	date	no. floaters	0-10	10-20	20-30	30+	
Sumallo	2.2km above Skagit	2200	820823–820831	2	6	128	33	8	
Skagit above falls	0.8km above falls	800	820823–820831	2	11	68	72	5	
Skagit above falls	3.3km above falls	900	820823–820831	2	13	117	43	0	
Klesilkwa	2.6km above Skagit	1750	820823–820831	2	4	22	17	14	
Klesilkwa	10.3km above Skagit	2300	820823–820831	2	0	9	7	6	
Sumallo	6.2km above Skagit	6200	820823–820831	2	13	47	19	0	
Sumallo	13.5km above Skagit	1600	820823–820831	2	0	0	1	4	
Skagit above falls	3.3km above Skagit falls	900	830830–830902	3	2	82	72	4	
Klesilkwa	10.3km above Skagit	2300	830830–830902	3	195	150	24	1	
Sumallo	6.2km above Skagit	1270	830830–830902	3	4	3	1	1	
					0-10	10-20	20-30	30-40	40+
Sumallo	NA	2000	850719	2	0	0	0	1	0
Sumallo	Hwy turnoff	850	850719	2	0	0	0	0	0
Sumallo	d/s to 20 Mile Creek	2000	860820	3	1	0	0	0	1
Sumallo	d/s to 20 Mile Creek	2000	870813	3	0	0	0	1	0

C. Summary of B.C. Skagit River and Ross Reservoir Angling Regulations 1982–1995.

Note the recent regulation changes.

Year	Closure	Catch/day	Large fish limit	Possession	Min (mm)	Gear Restrictions
Skagit River[1]						
1982	Apr 1 - June 18	2	only 2 > 500mm	4	200	none
1983	Apr 1 - June 17	2	only 2 > 500mm	4	200	none
1984	Apr 1 - June 17	2	only 1 > 500mm	4	200	none
1985	Apr 1 - June 14	2	only 1 > 500mm	4	300	single barbless, bait ban
1986	Apr 1 - June 13	2	only 1 > 500mm	4	300	single barbless, bait ban
1987	Apr 1 - June 19	2	only 1 > 500mm	4	300	single barbless, bait ban
1988	Apr 1 - June 17	2	only 1 > 500mm	4	300	single barbless, bait ban
1989	Apr 1 - June 16	2	only 1 > 500mm	4	300	single barbless, bait ban
1990	Nov 1 - June 30	2	only 1 > 500mm	4	300	single barbless, bait ban
1991	Nov 1 - June 30	2	only 1 > 500mm	4	300	single barbless, bait ban
1992	Nov 1 - June 30	0	0	0	∞	single barbless, bait ban
1993	Nov 1 - June 30	0	0	0	∞	single barbless, bait ban
1994	Nov 1 - June 30	0	0	0	∞	single barbless, bait ban
1995	Nov 1 - June 30	0	0	0	∞	single barbless, bait ban
Ross Reservoir						
1982	Apr 1 - June 18	2	only 2 > 500mm	4	none	none
1983	Apr 1 - June 17	8	only 2 > 500mm	16	none	none
1984	Apr 1 - June 17	8	only 1 > 500mm	16	none	none
1985	Apr 1 - June 14	4	only 1 > 500mm	8	none	none
1986	Apr 1 - June 13	4	only 1 > 500mm	8	none	none
1987	Apr 1 - June 19	4	only 1 > 500mm	8	none	none
1988	Apr 1 - June 17	4	only 1 > 500mm	8	none	none
1989	Apr 1 - June 16	4	only 1 > 500mm	8	none	none
1990	Nov 1 - June 30	3	only 1 > 500mm	6	330	bait ban
1991	Nov 1 - June 30	3	only 1 > 500mm	6	330	bait ban
1992	Nov 1 - June 30	3	only 1 > 500mm	6	330	bait ban
1993	Nov 1 - June 30	3	only 1 > 500mm	6	330	bait ban
1994	Nov 1 - June 30	3	only 1 > 500mm	6	330	bait ban
1995	Nov 1 - June 30	3	only 1 > 500mm	6	330	bait ban

[1] Below Skaist Creek



Oncorhynchus mykiss
Rainbow Trout