ESTIMATING THE ABUNDANCE OF ADULT STEELHEAD IN THE BABINE RIVER USING MARK RECAPTURE METHODS 1992-1993

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Abstract

A mark recapture study was conducted by angling on the upper 20 kilometers of the Babine River in an attempt to estimate the abundance of overwintering adult steelhead. The initial tagging was conducted by fisheries staff and volunteers during the 1992 fishing season. A total of 473 steelhead was considered to be the first sample of this mark recapture study. This total was used to develop a sampling strategy that would produce acceptable statistical precision. The sampling strategy was also designed to ensure as much accuracy as possible by minimizing the potential violation of mark recapture assumptions. Multiple census methods were expected to be better estimators than single census methods and therefore two subsequent recovery phases were conducted. Each of these two subsequent samples required eight angler days to complete and both were conducted in early April. Three Petersen estimates with 95% confidence limits were 4077 (3266-5396), 3623 (2688-5234), and 4660 (3072-7915). Three multiple census estimates were consistently lower than the Petersen estimates. These were the Schumacher at 3407 (2636-4817), the Original Schnabel at 3450 (2261-7273), and the Modified Schnabel at 3399 (2717-4381). Multiple census results suggested there may have been some violation of mark recapture assumptions. A corrective method applied to the data (Tanaka’s Model) produced an estimate of 2083 steelhead in the study area. Confidence limits could not be derived using this method because the number of sampling periods was too few. Nevertheless, the Tanaka estimate was considered to reflect the degree of possible inaccuracy in the other estimates. A number of possible violations of mark recapture assumptions were identified. However, from a stock monitoring perspective, the most serious problem in estimating the overwintering population of the Babine River was the uncertainty about annual variability in the distribution of the population. For this reason, an annual census of the overwintering population in the “Upper Babine” alone may be of limited use for stock monitoring purposes. It is recommended that an attempt be made to operate the Babine River fence during the spring. If a large and constant proportion of the total river spawning population does, as assumed, utilize the spawning area immediately upstream, fence operation should provide a useful index of abundance.

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Introduction

The interception of steelhead in the mix-stock commercial salmon fisheries near the Skeena River has become one of the most difficult and controversial fisheries management issues in British Columbia. From a management perspective, some of the difficulties could be alleviated if stock monitoring programs could be improved so that consensus could be reached with respect to the status of steelhead stocks. Presently, the most useful information on steelhead stock trends comes from the Department of Fisheries and Oceans' test fishery located at Tyee, however there is disagreement as to its relationship to steelhead abundance. Another shortcoming is that the Tyee test fishery samples the aggregate stock of steelhead and the means of identifying individual stocks has not been fully developed.

In general, accurate monitoring of *individual* Skeena steelhead stocks is very difficult because most of the tributary streams in which steelhead overwinter or spawn are either too large or too turbid and debris laden when steelhead occur in them. An exception is the upper Sustut River where a combination of fence counts and snorkel surveys has provided very accurate stock abundance information for the past two years (Bustard 1993; Saimoto 1993). Opportunities for weir or snorkel enumerations in other locations in the Skeena watershed are very limited. Therefore, past efforts of estimating stock abundance have been based on mark recapture methods using angling as a fish capture technique. Examples include studies on both the upper and lower Sustut rivers (Spence *et al.* 1990) and the upper Babine River (Pinsent 1971; Whately and Chudyk 1979). In 1992-1993, Fisheries Branch staff conducted another mark recapture experiment on the upper Babine River which is described in the following report. Recommendations regarding future stock monitoring attempts on the Babine population are included.

Methods

The Study Area

The Babine River is 97 kilometers in length from the outlet of Nilkitkwa Lake to the confluence with the Skeena River (Figure 1). The river is headed by Nilkitkwa and Babine lakes which together constitute an extremely large headwater catchment area. As in many other large lake outlets in British Columbia, the physical and chemical stream characteristics of the Babine River provide productive habitat for many species of salmonids and particularly steelhead. However, the productivity of the Babine likely decreases as it moves downstream because the three largest tributaries are glacial: the Nilkitkwa and Shelagyote rivers and Shedin Creek (Sebastian 1988). In general, the most important spawning and rearing habitats appear to be concentrated in the upper portion of the river. The most productive tributaries for steelhead rearing are two non-glacial streams located near the lake outlet: Nichyeskwa and Boucher creeks (Sebastian 1988). In addition, the most important spawning area for Babine steelhead is located at the outlet of Nilkitkwa Lake near the confluence of Boucher Creek (Beere 1991). The upper section of the river, which spans over a 20 kilometer distance from Nilkitkwa Lake, is also considered to be one of the main overwintering areas for adult steelhead. However, steelhead are also known to overwinter in downstream areas and some may even overwinter in Nilkitkwa Lake itself. The mark recapture study was conducted on overwintering steelhead in this upper section of river only (Figure 2).0

The Application of Mark Recapture Methodology using Angling as a Fish Capture Technique

Tagging data collected by angling guides, their clients, volunteer anglers, and Fisheries staff during the fall fishing season (September-November, 1992) was used as the first sample of the mark recapture experiment. This tagging phase was not specifically designed for a mark recapture study but was instead part of an ongoing tagging program aimed at refining the understanding of stock specific run timing. It was assumed that tagged

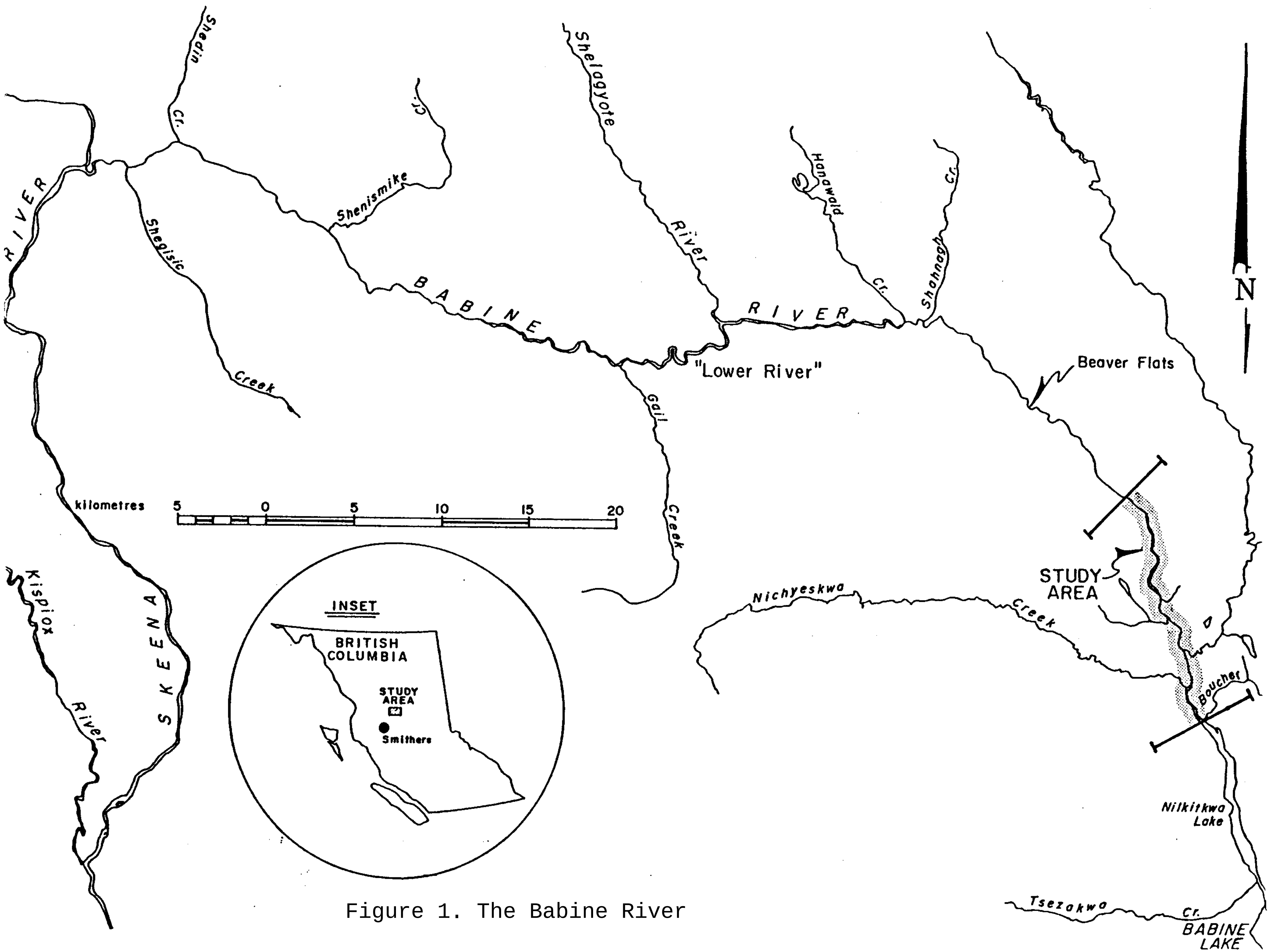


Figure 1. The Babine River

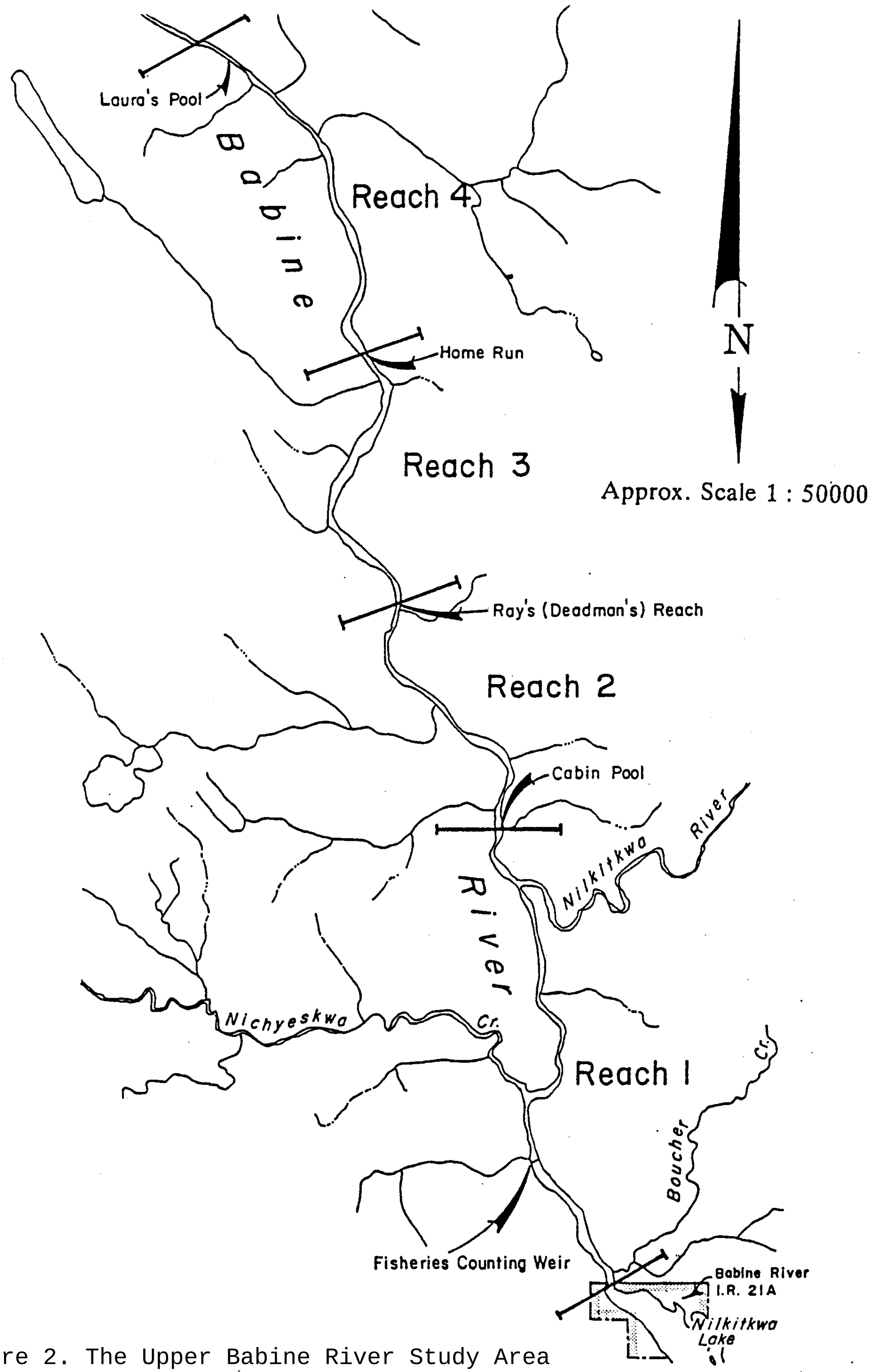


Figure 2. The Upper Babine River Study Area

steelhead were well dispersed in the study area because angling effort was roughly distributed throughout the entire area and because some degree of in-stream fish movement was expected. It was also assumed that tagged steelhead remained in the study area to overwinter and that the population was closed after the completion of the initial marking phase (ie. upon completion of steelhead immigration to overwintering areas). Numbered anchor tags were used in order to identify individual fish upon recapture.

The initial tagging phase was completed prior to the design of the mark recapture study and therefore these data were used to estimate subsequent sampling requirements. A total of 473 tagged steelhead were assumed to be present in the upper river area prior to commencement of the spring sampling. This marked population originated mainly from applying tags in the study area although some fish had been tagged further downstream. Based on this, predictions were made about the subsequent sampling required to achieve a 95% confidence limit that would deviate no more than +-25 % of the true population size using the Petersen mark recapture method (Ricker 1975; Robson and Regier 1964; Table 1).

Table 1. Subsequent sample sizes needed to achieve 95% confidence limits that are +-25% of the population size given that 473 steelhead were initially marked (Petersen method).

Number in population	Number examined for marks
1000	65
2000	190
5000	550

Two previous population estimates of upper Babine steelhead (Pinsent 1971; Whately and Chudyk 1979) indicated that the overwintering populations consisted of approximately 2000 individuals. Therefore, subsequent sampling was designed so that at least 190 steelhead were examined for a Petersen estimate. In addition, field sampling methods were designed so that it would be possible to apply multiple census methods to a closed population as well as single census methods. This was considered important because multiple census methods tend to produce more accurate estimates of population size, it allows for some insight as to the violation of assumptions, and provide for more comparisons between different mark recapture estimates. The multiple census methods used included the Original Schnabel, Modified Schnabel (Chapman's), and Schumacher (Ricker 1975; Krebs 1989;).

In the spring, there was a short period prior to spring freshet (late March to mid April) when air temperatures were at least near zero and water conditions were still low and clear. Such early spring conditions typically occur throughout the inland tributaries of the Skeena and provide an excellent opportunity to sample overwintering fish by angling. It was at this time that Fisheries staff conducted the two subsequent samples of the mark recapture study. The sampling effort for the two recapture phases was conducted systematically in order to minimize the potential for violation of mark recapture assumptions (i.e. that the population size is constant without recruitment or losses, that marking individuals does not affect their catchability, that animals do not lose marks between sampling periods, that the sampling is random, and that all individuals have an equal chance of capture in any given sample).

In order to achieve the desired distribution of effort, the upper river was divided into four sections that contained about equal amounts of holding water; each section containing enough holding water to occupy two anglers over a long days' effort (Figure 2). Drifting the river with rubber rafts or drift boats was considered the best mode of transportation for this application. Based on past experience by regional staff, each participant was expected to capture approximately 30 steelhead per day. Given that it would require 8 angler days to cover all four sections of river, it was expected that approximately 240 steelhead would be examined in each of the subsequent samples. This was more than adequate to achieve the appropriate statistical accuracy (Table 1).

Another assumption of particular concern was that angling and tagging may affect the vulnerability of those fish to recapture. Although a few fish seem to exhibit a remarkable susceptibility to angling, it was assumed that fish were generally less vulnerable to capture immediately following release. Therefore, a rest period between sampling periods was necessary to minimize this effect. The rest period between the first sampling period (September to November) and second sampling period (early April) was considered to be more than adequate especially since sport angling was closed from January 1 to June 15. The rest period between the second and third sample was much shorter in duration because both samples had to be taken prior to the onset of freshet (late April). In order to maximize the rest period between the second and third sample and at the same time minimize the risk of an early freshet, the samples were conducted on April 6-8 and April 14-16.

Results and Discussion

Sampling Effort

The sampling methods for the two spring sampling periods were intended to minimize the potential violation of mark recapture assumptions. Even though the designed precautions were conceptually sound, there were some shortcomings in practice. The most apparent was when four anglers (using more than one boat) were fishing at the same time (Table 2). Anglers that continued to drift downstream ahead of other anglers created difficulties for those following because the followers were unable to determine whether certain runs were sampled. Improvements to address this could be easily be made by either leap frogging or assigning certain areas to each angling party before starting.

Single Census Estimates

Steelhead recaptured during the same sampling period that they were tagged were not considered “recaptures” for population estimation. There were numerous instances where fish were recaptured in the same sampling period that they were tagged, however including these as “recaptures” would have biased the population estimates and the calculation of confidence limits.

Petersen estimates were calculated using three data set variations (Table 3). Since

Table 2. The distribution of sampling effort.

Sample	Dates	River Section	Effort (angler days)
1	Sept. 13 – Nov. 20	All	?(approx. 200-300)
2	April 6	1	2
	April 7	2 and 3	4
	April 8	4	2 (4 anglers over ½ day)
3	April 14	1	2
	April 15	2 and 3	4
	April 16	4	2 (4 anglers over ½ day)

Table 3. Single census, mark-recapture estimates for the Babine River, 1992-1993, using 3 data set variations.

	First sample	Second sample		
	(Sept.13-Nov.20)	April 6-16 samples	April 6-8 sample only	April 14-16 sample only
No. captured	473	412	236	176
No. recaptured	0	47	30	17
Petersen estimate	-	*4077*	*3623*	*4660*
95% C.L.	-	*3266-5396*	*2688-5234*	*3072-7915*

two recovery samples were taken in the spring, calculations were made using each sampling period separately as well as combining them. For the first recovery sample (April 6-8), the number of fish examined exceeded the predicted requirement that should have ensured that 95% confidence limits be approximately + -25% of the estimated population size. The number of steelhead captured in this sample was 236 which exceeded the predicted requirement of 190. However, because the population estimate was considerably greater than the expected 2000, the confidence limits that resulted were also greater than +-25% of the population estimate. The estimate calculated from the first recovery sample had confidence limits that were +44% and -26% of the estimate (3623 steelhead). The confidence limits for the estimate resulting from the combination of the two spring samples varied the least (+32% and -20%) because combining samples produced the largest sample size.

Robson and Regier (1964) recommended that the following be true in order be sure that Petersen estimates do not underestimate population size:

*No. captured in first sample * No. captured in second sample* **>** *4 * Population estimate*

This condition held true for all of the estimates and therefore they should be accurate if mark recapture assumptions were not violated.

Multiple Census Estimates and Inferences about the Violation Mark Recapture Assumptions

Multiple census estimates were consistently lower than the single census estimates and were all very similar (Table 4). Seber (1982) recommended the Schumacher estimate as the most robust and useful one for multiple censuses on closed populations.

In order to further investigate the possible violation of mark recapture assumptions, a regression of the proportion of recaptures in a given sample versus the number previously marked was plotted (Seber 1982; Krebs 1989; Figure 3). This regression must pass through

Table 4. Multiple census mark recapture data for the Original Schnabel, Modified Schnabel, and the Schumacher methods and the resulting estimates.

Dates	No. captured	No. tagged	No. recaptured
Sept.13-Nov.20	473	473	0
Apr. 6-8	236	206	30
Apr.14-16	176	139	37

Schumacher estimate:	*3407 (95% C.L. 2636-4817)*
Original Schnabel estimate:	*3450 (95% C.L. 2261-7273)*
Modified Schnabel (Chapman's) estimate:	*3399 (95% C.L. 2717-4381, Poisson distribution)*

Table *5.* Summary of mark recapture estimates for the upper Babine River, 1992-1993.

Method	Population estimate	95% confidence limits
$Petermen_1$	4077	3266-5396
$Petermen_2$	3623	2688-5234
$Petermen_3$	4660	3072-7915
Original Schnabel	3450	2261-7273
Modified Schnabel	3399	2717-4381
Schumacher	3407	2636-4817
Tanaka	2083	N/A

the origin and will be linear if mark recapture assumptions are not violated. Because only a minimum number of samples were collected for multiple census application, determining whether the regression was curved was difficult. The data available suggested a slight upward curve which could have easily resulted from sampling variability. However, assuming that the curved regression resulted from violation of mark recapture assumptions, a corrective method was applied to the data (Tanaka's model, Seber 1982; Figure 4). The resulting population estimate using Tanaka's model was 2083 which is considerably lower than any of the other estimates (Table 5). Confidence limits for this method could not be calculated because the sample size was too small (df=0) and therefore Tanaka's estimate was not considered to be very reliable. However, this result gives and indication as to the

Figure 3. The Schumacher and Eschmeyer regression. Slope estimates 1/N.

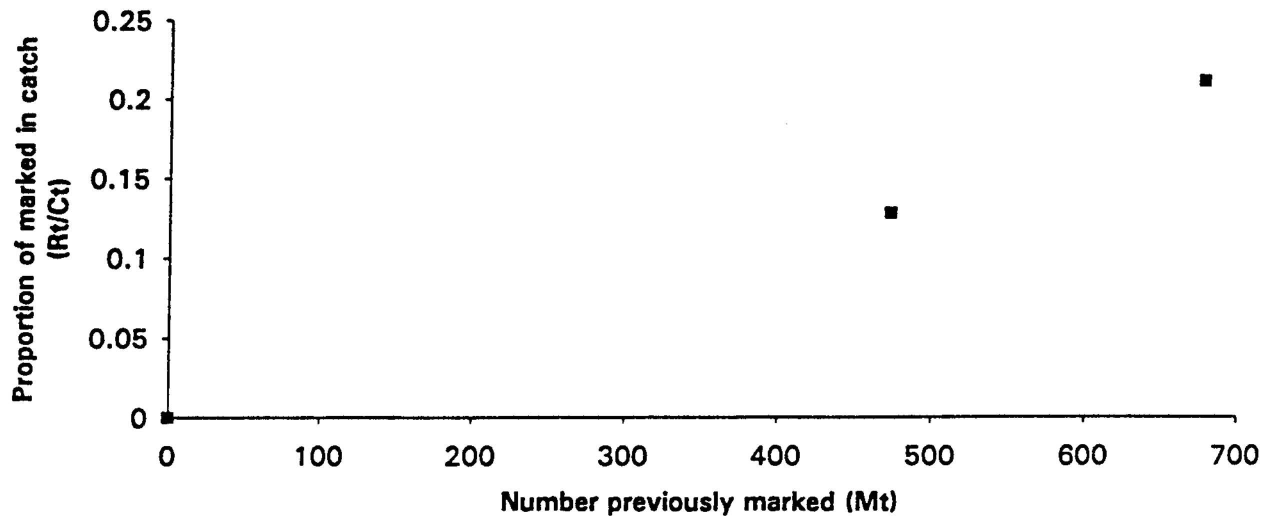
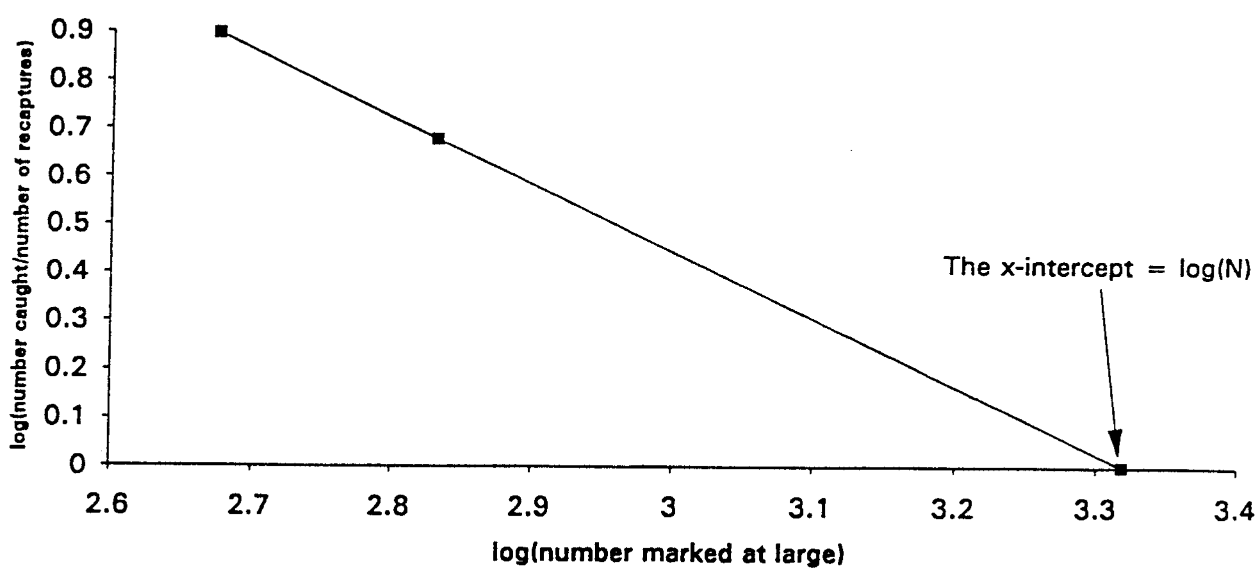


Figure 4. Tanaka's model.



potential inaccuracy of single census mark recapture estimates and multiple census estimates that are derived from a very few number of sampling periods.

It is not possible to determine whether mark recapture assumptions were violated or if the results as displayed in Figure 3 were simply due to sampling variability. Intuitively, the possible violations that would cause the regression in Figure 3 to curve upward include the following:

(1) Marked fish emigrated from the study area into Nilkitkwa Lake to overwinter.

(2) Marked fish were harvested from the study area between the first and second sampling period. There were two reports of Natives harvesting Babine steelhead over the winter months (R.S Hooton, pers. comm.). One of the reports estimated the harvest to be 500 while the other estimated 300. According to Figure 3, the removal of approximately 60 tagged fish between the first and second sampling period would account for the curved relationship. The ratio of 60 tagged fish in a catch of 300 or 500 is realistic according to the catch ratios experienced in samples two and three.

(3) Total mortality resulting from predation or disease was greater in the interval between the first and second sample as compared to the interval between the second and third sample. This could be attributed to the long interval between the first and second sample compared to the second and third sample.

(4) Tag loss was proportionately higher between the first and second sample compared to the second and third sample. Assuming that tag loss between the second and third samples was negligible, a 12% tag loss in the first sample of 473 would account for the curved relationship in Figure 3. Tag loss would be relatively easy to assess in future tagging exercises by using two marking methods simultaneously. An opercular punch in combination with a floy tag would is one option that has worked well in other steelhead studies (R.S. Hooton, pers. comm.).

There was no indication that fish captured in the second sample were any less vulnerable to capture in the third sample. This was a concern which was addressed in the sampling design by allowing for a maximum rest period. If this effect was a major factor, Figure 3 should have suggested a descending rather than an ascending curve.

With the exception of tag loss, all of the above possibilities would be very difficult to assess in any future tagging exercises. Redesigning the sampling scheme so that all samples were collected in the spring would address some of the other possible problems namely Native harvest, predation, disease, and migration into Nilkitkwa Lake. However, conducting all of the samples in the spring is unrealistic because of the narrow window between unsuitable air temperatures and unsuitable stream flows.

Future Stock Monitoring Considerations

The most serious problem in estimating the overwintering Babine River steelhead population is not necessarily the accuracy of the mark recapture estimate(s) but the uncertainty about the year to year variability in the distribution of adults. It is known that the upper river consistently attracts adult steelhead, however it appears that a variable proportion of the population overwinters in downstream areas. Beere (1991) confirmed that steelhead destined to spawn in the mainstem outlet near the Boucher Creek confluence overwintered in areas downstream of upper river area. It is believed that the annual variability in distribution can be attributed to annual variation in stream flows (R. Tetreau and R.S. Hooton, pers. comm.). For instance, angling guide reports from 1992 suggested that a relatively larger proportion of the steelhead population overwintered in the upper reaches whereas in 1990 and 1991, steelhead appeared to be more evenly distributed between upper and lower river areas (unpublished data). Also, it is not known whether a significant proportion of the population overwinters in Nilkitkwa Lake or if there is any annual variability in this proportion. Intuitively, it seems likely that the proportion of the Babine population that overwinters in the upper 20 kilometers of the river may vary from year to year. Therefore, an annual census of this portion of the population alone would be of limited use for stock monitoring purposes.

Broadening the geographical scope of the survey would correct for the variable distribution problem, however this is not considered to be logistically feasible since the Babine is 97 kilometers in length and access is extremely difficult. Much of this work would have to be conducted by helicopter and would therefore be extremely costly. The additional man days associated with tagging and recovering tags over such an extensive area would also be prohibitive.

Beere (1991) indicated that a large percentage of the Babine population spawns in the mainstem outlet near the Boucher Creek confluence. This spawning area is located upstream of the fish counting fence which is used primarily for sockeye enumeration during the summer. There is a reasonable possibility that the fence could be operated during the early portion of spring freshet when steelhead migrate from overwintering to spawning areas. If the fence captures steelhead effectively without deterring upstream movement and if a relatively constant proportion of the total Babine River steelhead spawners do utilize the area immediately upstream, enumeration could provide a useful index of the population.

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