Salmo River Rainbow Trout (*Oncorhynchus mykiss*): Population Size and Habitat Use -Interim Report-

Report Prepared For:

The Columbia-Kootenay Fisheries Renewal Partnership and Columbia Basin Trust
BC Hydro
The Columbia Basin Fish and Wildlife Compensation Program
The BC Ministry of Water, Land and Air Protection
Beaumont Timber
The Salmo Watershed Streamkeepers Society

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EXECUTIVE SUMMARY

This interim report summarizes the initial field work and data collection of a project on the rainbow trout (*Oncorhynchus mykiss*) population of the Salmo River watershed. A total of 30 rainbow trout were radio tagged in the mainstem Salmo River in proportion to the abundance of rainbow trout >30 cm throughout the system. We used the radio tagged rainbow trout to derive a population estimate through a repetitive mark-recapture estimate in an index section over the summer, and have tracked the radio tagged fish to their summering and overwintering habitats.

ACKNOWLEDGEMENTS

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The successful completion of this study was made possible only as a result of the co-operation of a large number of organizations and individuals within the following organizations.

Columbia-Kootenay Fisheries Renewal Partnership and Columbia Basin Trust

Bill Green and Kenton Andreashuk provided comments on the project, while Jaime Christales provided administrative assistance.

BC Hydro

BC Hydro supplied the radio tags that were utilized for the study and provided equipment and personnel. Specifically Ric Olmsted, Gary Birch and Dave Wilson were instrumental in providing funds and expertise for the project, with Ric providing assistance with fish capture. Dean den Biesen and Clint Tarala also assisted in the field.

BC Ministry of Water, Land and Air Protection

The BC Ministry of Water, Land and Air Protection provided tracking equipment and personnel to aid in the completion of the project. Specifically John Bell assisted with swims, fish capture, and tracking. Murray Pearson assisted with swims. Albert Chirico ensured collection permits were put in place to allow fish capture. Jay Hammond provided insight into project requirements and management issues.

Salmo Watershed Streamkeepers Society

Community volunteers that are members of the Salmo Watershed Streamkeepers Society assisted with various components of the project. Brian Henderson and Gerry Nellestijn assisted with swims, fish capture, and tracking.

Baxter Environmental

Jeremy Baxter provided technical assistance with all aspects of this project. Scott Decker also assisted with the project during swims.

Columbia Basin Fish and Wildlife Compensation Program

Steve Arndt provided assistance in the field with fish capture and tagging.

Geosense Consulting Ltd.

Graham Smith provided mapping logistics.

Kokanee Helicopters

Duncan Wassick ensured aerial tracking could be undertaken.

Water Survey of Canada

Gordon Corcoran provided discharge data for the study period.

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INTRODUCTION

Background

Demand for quality trout stream fishing experiences is high in British Columbia, and this demand appears to be growing in the Kootenay Region particularly. The Salmo River, with its low flows, clear water, well-defined holding pools, and rainbow trout (*Oncorhynchus mykiss*) that can reach sizes of 50 cm, provides the highest quality small- to medium-sized stream fishery in the Nelson area. The fishery on the Salmo has been locally popular for years, and a kill fishery has traditionally been permitted with a current daily limit of two rainbow trout over 30 cm. However, the year 2000 snorkel surveys of the system, which were conducted to investigate movements and abundance of other species, suggested that the rainbow trout population of the Salmo is currently small and may be depleted (Baxter and Nellestijn 2000). Concerned local residents and fisheries agency staff have also expressed the belief that the Salmo population was low relative to historical levels, so we felt it possible that the population's status was potentially of a conservation concern.

Assessing the current status of the population was difficult, as no information existed about trends in abundance or current abundance levels. This lack of information was an obstacle for fisheries management staff at the BC Ministry of Water, Land and Air Protection (MWLAP) in Nelson in trying to make knowledgeable management decisions regarding the population. For this reason, staff of MWLAP believed that a population estimate for the Salmo River, or at least an index of relative abundance, should be established as soon as possible (J. Hammond, MWLAP, Nelson, B.C.; personal communication). During springtime, 2001, we initiated a study of the conservation status of the Salmo River's rainbow trout, which had the financial and in-kind support of the BC MWLAP, BC Hydro, Beaumont Timber, the Columbia Basin Fish and Wildlife Compensation Program, the Columbia-Kootenay Fisheries Renewal Partnership and Columbia Basin Trust, and the Salmo Watershed Streamkeepers Society.

Conservation Biology

McElhany et al. (2000) introduced the 'viable salmonid population' (VSP) concept and defined it as an "independent population that has a negligible risk of extinction due to threats from demographic variation (random or directional), local environmental variation, and genetic diversity changes over a 100-year time frame". They identified four parameters for determining a population's conservation status relative to this definition:

1. *Abundance.* Population dynamics processes work differently in small populations, including demographic stochasticity, genetic process (severe inbreeding and long-term genetic losses/genetic drift), and the effects of environmental stochasticity and catastrophes. It can be stated generally, however, that extinction risks posed by these forces are magnified greatly at very small population sizes (Simberloff 1988; Nunney and Campbell 1993). Empirical studies of extinction in mammals and birds have generally suggested that $N < 50$ is clearly insufficient for a population's long-term persistence, populations of $50 < N < 200$ are marginally secure, and those of $N > 200$ are secure at least over time frames as limited as those used in the studies (reviewed in Boyce 1992).

2. *Population growth rate.* At small population sizes it appears that demographic and environmental stochasticity are more immediate and potent threats than are inbreeding and genetic drift, but all of these can be likened to the final death throes of an organism that was already known to be dying (Caughley 1994). The anthropogenic external agents that forced the decline to these population sizes in the first place - typically overkill and habitat destruction in salmonid populations - are far more important than any of the above - extinction is likely unless these agents are identified and corrected and the negative population growth rate reversed.

3. *Population spatial structure*. A salmonid population's spatial structure affects extinction risk through processes increasing resilience to environmental stochasticity (heterogeneity in environmental conditions) and through evolutionary processes (genetic diversity) that affect a population's ability to respond to environmental change. A population consisting of multiple, connected sub-populations are generally thought to be more robust to extinction forces than is a single group (Simberloff 1988).

4. *Diversity*. Phenotypic and genetic diversity is an important part of salmonid population viability, for three general reasons. First, diversity allows a population to use a wider range of environmental conditions. Second, it protects a species against short-term spatial and temporal changes in the environment, and third it provides the raw

material for surviving long-term environmental changes (McElhany et al. 2000). Gene flow via strays from other populations and sub-populations is one potential source of diversity that can be cut off by human actions such as dams (which have affected the Salmo River population in the past). Conversely, stocking hatchery fish, which occurred in the Salmo River watershed between 1924 and 1953, can dilute important genetic adaptation of the population if introgression (successful interbreeding) between the native and hatchery fish takes place.

Genetic and demographic mechanisms of extinction at small population sizes have received much attention by workers in conservation biology (reviewed in Simberloff 1988; Caughley 1994), and generally accepted theory and population size guidelines are emerging. However, Caughley (1994) has pointed out that the anthropogenic agents that force negative growth rates, critically low population sizes, unconnected relict populations, and insufficient or maladapted genetic diversity are not as easily generalized and quantitative investigations usually must be on a situation-specific basis. The goal is to get these agents within the reach of powerful analytical methods. Towards this end Caughley (1994) recommended first studying the natural history of the population - ecology, context, and abundance - in order to identify putative agents of population decline, then confirming the causal linkage via carefully monitored management experiments. The program of study initiated in the Salmo River watershed during springtime, 2001 was designed to gather the natural history information - habitat use, life history, population structure, and status - required by regulatory agencies prior to undertaking adaptive management. This report presents preliminary results (mortality of tagged fish cannot yet be ruled out in all cases) mainly to do with the population monitoring study. A limited amount of information on habitat use is presented – migration timing and spawning habitat use cannot be investigated until springtime, 2002.

Study Design

Overkill and habitat destruction are typically the most important anthropogenic agents of salmonid population decline (McElhany et al. 2000). Thus, our principal objectives for the Salmo River watershed's rainbow trout population, therefore, were to:

1. establish the relative importance of habitats throughout the Salmo River watershed for the rainbow trout population, for evaluation of protection, restoration, and enhancement priorities.

2. establish an index of abundance that could be related to the size of the adult rainbow trout population and that incorporates uncertainty, and is sufficiently cost-effective for the long-term monitoring required to investigate population abundance and growth rate.

We chose radio telemetry as a method for investigating habitat use by Salmo River rainbow trout, a technique that has been utilized frequently in British Columbia for these purposes. Our goal was to distribute radio tags throughout the watershed in proportion to the relative abundance of taggable fish - if each fish had an equal chance of receiving a tag then habitat use could be quantified from the telemetry record rather than merely described.

Incorporating radio telemetry as an investigative tool also allowed us to improve on typical methods for population estimation, via procedures that have only recently seen application in British Columbia. The Salmo River is typically clear enough to permit the highly efficient technique of diver-based counts of larger trout (Slaney and Martin 1987). However, it must not be assumed that all fish present are seen or counted accurately during snorkel surveys. Individuals are missed because of imperfect visibility, fish behaviour, stream channel complexity, and observer error (Cousens et al. 1982; Slaney and Martin 1987; Perrin and Irvine 1990), and furthermore a portion of the population will inevitably not be included in the index section (Irvine et al. 1992). Mark and recapture techniques (Ricker 1975; Slaney and Martin 1987) in combination with visual surveys are commonly used to address the problem of unseen individuals. However, annual mark and recapture surveys (at the required level of precision) are probably too costly to be practical over the longer term required to investigate population growth rate, as fish must be captured before they can be marked. Mark-recapture studies employing radio tags and periodic surveys (Webb et al. 2000; Korman and Ahrens 2000; Hagen 2001) provide an alternative that is more cost-effective over the longer term: a direct, quantitative investigation of the observer efficiency (radio fish seen / radio fish present) of standard snorkel survey practices and its relationship to variability in viewing conditions. Observer efficiency can be quantified only if it is known how many tags are in the counting area, information available from radio tagged fish but not from standard mark-recapture studies unless the entire population is surveyed. Using radio tagged fish that are also marked, therefore, allows observer efficiency to be estimated from a counting area that is much smaller, meaning that the number of replicate surveys (and therefore relative precision of the estimate) can be much higher for a given survey budget. If the observer efficiency relationship can be described accurately and with reasonable precision, then future population estimates and attendant uncertainty can be acquired in a highly cost-effective manner merely from standard snorkel survey observations.

We also wished to develop a model for the relationship between observer efficiency and watershed conditions in order to reduce future error due to interannual variability in these conditions, so stream discharge (Water Survey of Canada data on file), turbidity, visibility and temperature were to be recorded for each of the survey dates.

Because the study design specified that each of the taggable fish in the population was to have an equal chance of receiving a tag, diver counts in the counting area could be expanded to arrive at the population estimate according to:

$$N = C / (\lambda * r)$$

In this case N is the population estimate, C is observed fish derived from the diver counts in the counting area and their uncertainty, λ is derived from the observer efficiency in the counting area and its uncertainty, and r is derived from the relative distribution of tags to the counting area and its uncertainty.

Study Area

The Salmo River rises from the Selkirk Mountains 12 km southeast of Nelson, B.C. (Figure 1). The river flows in a southerly direction for approximately 60 km from its origin to the confluence with the Pend d'Oreille River (Seven Mile Reservoir). The system is a 5th order stream, and has a total drainage basin area of roughly 123,000 ha. Elevation in the basin ranges from 564 meters at its confluence to 2,343 meters at the height of land. Within this elevation range, the system comprises two biogeoclimatic zones. At lower elevations, the valley lies within the Interior Cedar-Hemlock zone, while areas in the higher elevations are found within the Englemann Spruce-Subalpine Fir zone. The Salmo River has a total of eight 2nd and 3rd order tributaries (including Apex Creek, Clearwater Creek, Hall Creek, Barrett Creek, Ymir Creek, Porcupine Creek, Erie Creek, and Hidden Creek) and two 4th order tributaries (Sheep Creek and the South Salmo River) (Figure 1). The Water Survey of Canada maintains a gauging station on the Salmo River downstream of the town of Salmo. Mean annual discharge in the Salmo River (1949-1976) was 32.5 $m^3 \cdot sec^{-1}$, with mean monthly minimum and maximum values of 7.5 and 128.5 $m^3 \cdot sec^{-1}$, respectively. Runoff reaches a peak in May, with the highest flows between April and July each year. In addition to rainbow trout, many other fish species are distributed in the watershed. These include bull trout (*Salvelinus confluentus*), eastern brook trout (*S. fontinalis*), mountain whitefish (*Prosopium williamsoni*), largescale sucker (*Catostomus macrocheilus*), longnose sucker (*C. catastomus*), northern pikeminnow (*Ptychocheilus oregonensis*), longnose dace (*Rhinicthys cataractae*), redside shiner (*Richardsonius balteatus*), and slimy sculpin (*Cottus cognatus*). Natural populations of steelhead trout (*O. mykiss*) and chinook salmon (*O. tshawytscha*) have been extirpated from this system due to past hydroelectric development on the lower Columbia and Pend d'Oreille rivers.

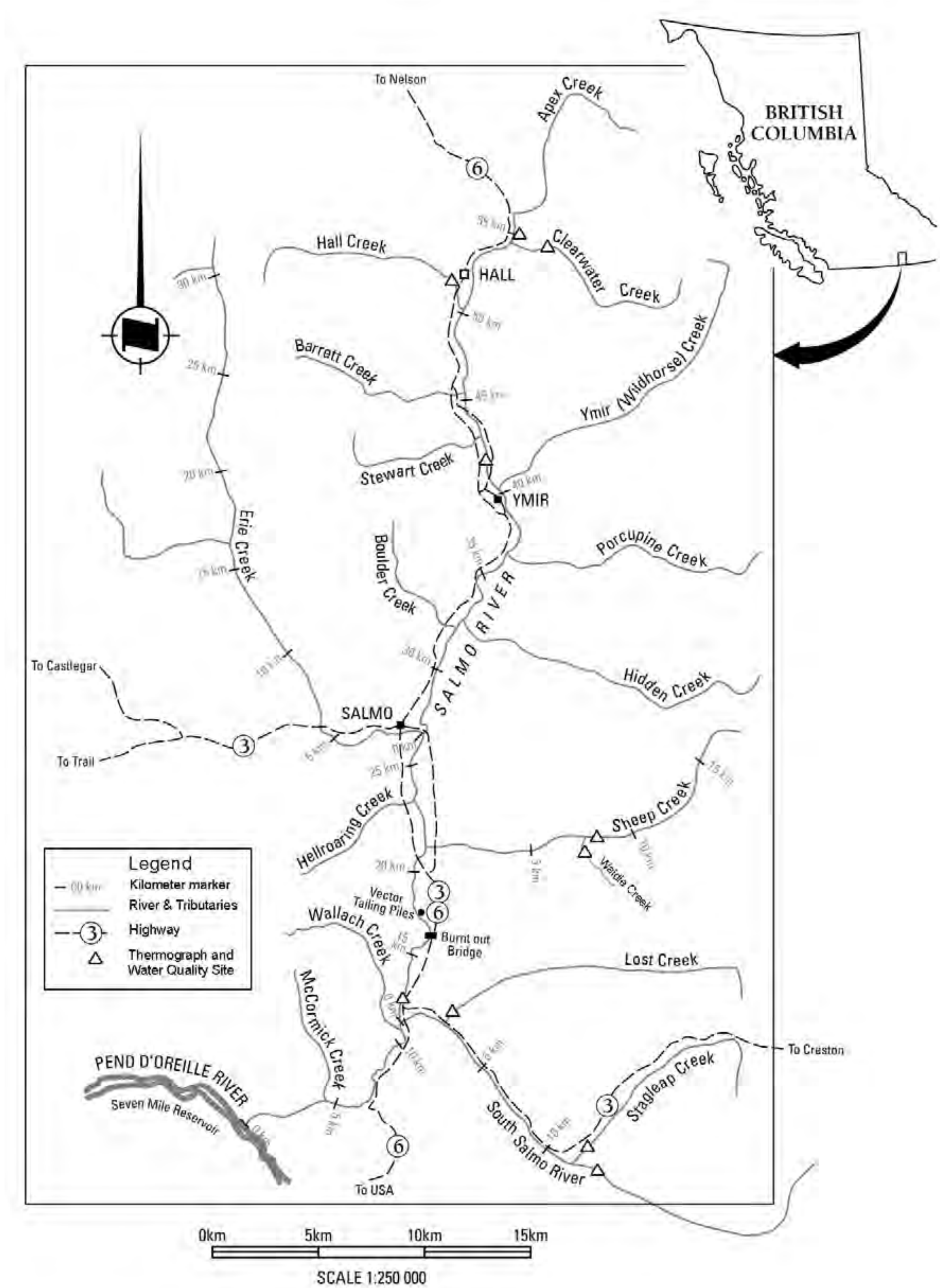

Figure 1. The Salmo River watershed study area.

METHODS

Fish Capture and Tagging

Of the 30 radio tags used for the study, 29 tags were initially available and were allocated to the various stream sections in proportion to the relative abundance of catchable (>30 cm) rainbow trout in each section. This was determined at the outset of the project by diver counts conducted by two teams of divers on June 18 and June 19, 2001. The entirety of the swimable watershed that was thought to contain taggable fish (Baxter 1999 and 2001) was surveyed, a section extending from the Hall Creek confluence downstream approximately 40 km to a point located 5.7 km from the Seven Mile Reservoir at the top of a steep canyon reach.

All rainbow trout captures during springtime, 2001 were made by angling in the Salmo River itself from June 1 to June 30 (one additional fish was captured and radio tagged on September 19). Gear utilized included artificial lures and flies, as well as salmon egg bait. To facilitate handling and reduce stress on the fish, trout were held prior to and after tagging in zippered tubes made from black, rubberized fabric with flow-through ends (Appendix I-Plate A). Fish selected for radio tagging were a minimum of 35 cm in fork length and 0.50 kg in weight so as the weight of the radio tag did not exceed 2% of the fish weight. Sterile conditions were maintained at the surgery site with the biologist using surgical scrub to sterile his hands and donning sterile latex gloves. All operating instruments and radio tags were sterilized and disinfected in a container filled with 50% benzylkonium chloride diluted in distilled water at a concentration of 1000 PPM. A solution of Vidalife (Syndel International Inc., Vancouver, BC) at a concentration of 75 PPM was sprayed on all handling nets, the surgery trough and added to the anaesthetic bath to prevent the loss of the slime coating of the fish.

Once a fish was selected as a candidate for a radio transmitter, the field surgery station was set up (Appendix I-Plate B) and the fish was allowed to recover from capture for a minimum of 10 minutes. The fish were then anaesthetized in water diluted with clove oil (emulsified in 95% ethanol) at a concentration of 100 PPM (Prince and Powell 2000). When the rainbow trout had reached stage of IV of anaesthesia (equilibrium lost, no response to external stimuli), the fish was removed from the anaesthetic bath and placed on its back in a V trough lined with foam (Appendix I-Plate C). Irrigation of the gills of the fish was started immediately upon removal from the bath (Appendix I-Plate D). A

1.0 to 1.5 inch incision was then made into the abdominal cavity (left hand body side wall about 3-5 cm anterior of the pelvic fins) using a scalpel fitted with a curved (No. 12) blade (Appendix I-Plate E). After the incision was complete, a 16 gauge stainless steel needle was inserted through the abdominal wall posterior to the incision and back out the incision. The antennae of the radio tag was then threaded through the needle and the needle was pulled out, leaving the antennae coming out the side wall of the fish (Appendix I-Plate F). The radio tag was then inserted into the abdominal cavity, and the incision was closed with three interrupted sutures of braided silk on a cutting needle (Appendix I-Plate G). The antennae of the radio tag was then sutured to the body wall with one interrupted suture (Appendix I-Plate H) to prevent movement and irritation by the antennae at the exit point from the body wall. Finally the closed incision and exit point of the antennae were swabbed with Betadine, and the fish was placed in a flow through tube for recovery for at least 10 minutes. During each surgery, the time in the anaesthetic, the time in surgery, and the recovery time were all recorded for each fish.

Biological sampling for all fish captured was standardized. First, a small section of the adipose fin was removed and stored, along with a label, in a vial of 95% ethanol for future genetic analysis (population structure analysis has been designed by E.B. Taylor, UBC Dept. of Zoology, but has not yet been budgeted for). Following this a sample of at least 10 scales was removed for future aging analysis, and two orange anchor tags (Floy Tag, Seattle, WA) were inserted into punctures on either side of the fish's back at the posterior insertion of the dorsal fin. Sex (if mature), fork length (mm), girth (mm), mass (g) Floy tag numbers, radio tag frequency and code, genetic sample number, condition at time of release, and tagging location were recorded.

Radio Telemetry

All of the telemetry information used for the study's analyses was collected by mobile tracking, either by: i) boat along the counting section on the same day as diver counts, ii) helicopter during surveys of the entire watershed for a separate telemetry study of bull trout habitat use (Baxter 2002), or iii) a combination of foot and boat surveys (according to stream navigability) over the whole stream length used by radio tagged fish. Tracking has taken place approximately once monthly since the completion of diver counts in late

July, and will be increased in frequency during the spawning and migration periods of springtime, 2002.

Radio reception for surveys on foot or by boat along the river channel was through a whip antenna attached directly to the receiver. During helicopter surveys a two-element antenna was attached to the base of the helicopter's high frequency radio antenna, and was oriented with the elements perpendicular to the water surface. During all surveys positions of tagged fish were recorded on prepared, 1:20,000 maps that showed distances from the mouth as marks located every 0.1 km.

Diver Counts

The counting section of the Salmo River used for estimating observer efficiency extended from the end of Lagoon Road, near the town of Salmo, downstream approximately 8 km to an access point along Highway 3 at a former bridge crossing. Four divers were utilized for each survey, which was sufficient to cover the entire usable width for most of the surveyed length on each of the survey dates. Where possible a diver's 'lane' extended approximately 5 m toward shore from his swimming position, with the two offshore divers positioned back-to-back in the middle of the stream. When the usable wetted width exceeded 20 m one or more of the divers would extend his lane width and look both ways, with frequent stops required to discuss whether duplication had occurred. Observed fish were described as to species, and rainbow trout were classified into one of 5 size categories: 0-20 cm, 20-30 cm, 30-40 cm, 40-50 cm, and 50+ cm. Radio tagged fish were identified by their orange Floy tags, and observations were noted for comparison with telemetry results from that survey date. Size estimation was practiced on models suspended in the water column at the survey start point. At the completion of each survey visibility (horizontal secchi disk distance) was recorded for each diver for averaging, as was turbidity and water temperature.

RESULTS AND DISCUSSION

Transmitter Distribution and Biological Sampling

The diver counts of catchable rainbow trout (>30 cm) along the length of the Salmo River that were the basis for radio transmitter allocation took place on June 18 and June 19, after tagging had already been initiated. Our goal was for tagging to be completed as shortly as possible after the distribution swims so that the relative distribution of tags was still representative. Very low densities of catchable rainbow trout were distributed upstream of the town of Ymir, located at 43 stream kilometers from the mouth at the Wildhorse Creek confluence (Figure 1). Catchable fish were more prevalent between Ymir and the town of Salmo (located at 28.4 stream kilometers at the Erie Creek confluence), with abundances increasing downstream of Salmo until the sharp peak of relative abundance was reached between Sheep Creek (22.8 stream km) and a former bridge crossing located 17.3 stream kilometers from the mouth. Catchable rainbow trout were again less prevalent in habitats downstream, and were relatively rare downstream of the South Salmo River confluence (12.1 stream km). Tag allocations (of 29 available) were 1, 3, 2, 5, 13, 3, and 2 for the Hall C. (53.4 km) to Wildhorse C. (43 km), Wildhorse C. to Hidden C. (34.7 km), Hidden C. to Erie C. (28.4 km), Erie C. to Sheep C. (22.8 km), Sheep C. to former bridge (17.3 km), former bridge to South Salmo R. (12.1 km), and South Salmo R. to canyon (5.7 km) stream sections, respectively.

Radio transmitters were distributed to rainbow trout angled over the period from June 1 to June 30, the earliest period suitable for both the distribution swims and relatively efficient fish capture (because of prior freshet conditions). Angling was terminated when the above goals for tag allocation were approximately met, with 0, 4, 2, 5, 13, 4, and 1 transmitters deployed respectively for the same stream sections mentioned above (Hall to Wildhorse, Wildhorse to Hidden, Hidden to Erie, Erie to Sheep, Sheep to former bridge, former bridge to South Salmo, and South Salmo to canyon (Figure 2)). It is important to note that some care was taken to ensure that the allocation goals were met exactly for the counting section, located between Lagoon Rd. in Salmo (26.2 km) and the former bridge site (18 tags total - Erie C. to Sheep C. and Sheep C. to former bridge sections).

Because it would be the required method for marking during mark-recapture studies (which we wish to evaluate as a future population monitoring alternative), it is important to make note of the relative efficiency of angling as a fish capture technique for Salmo

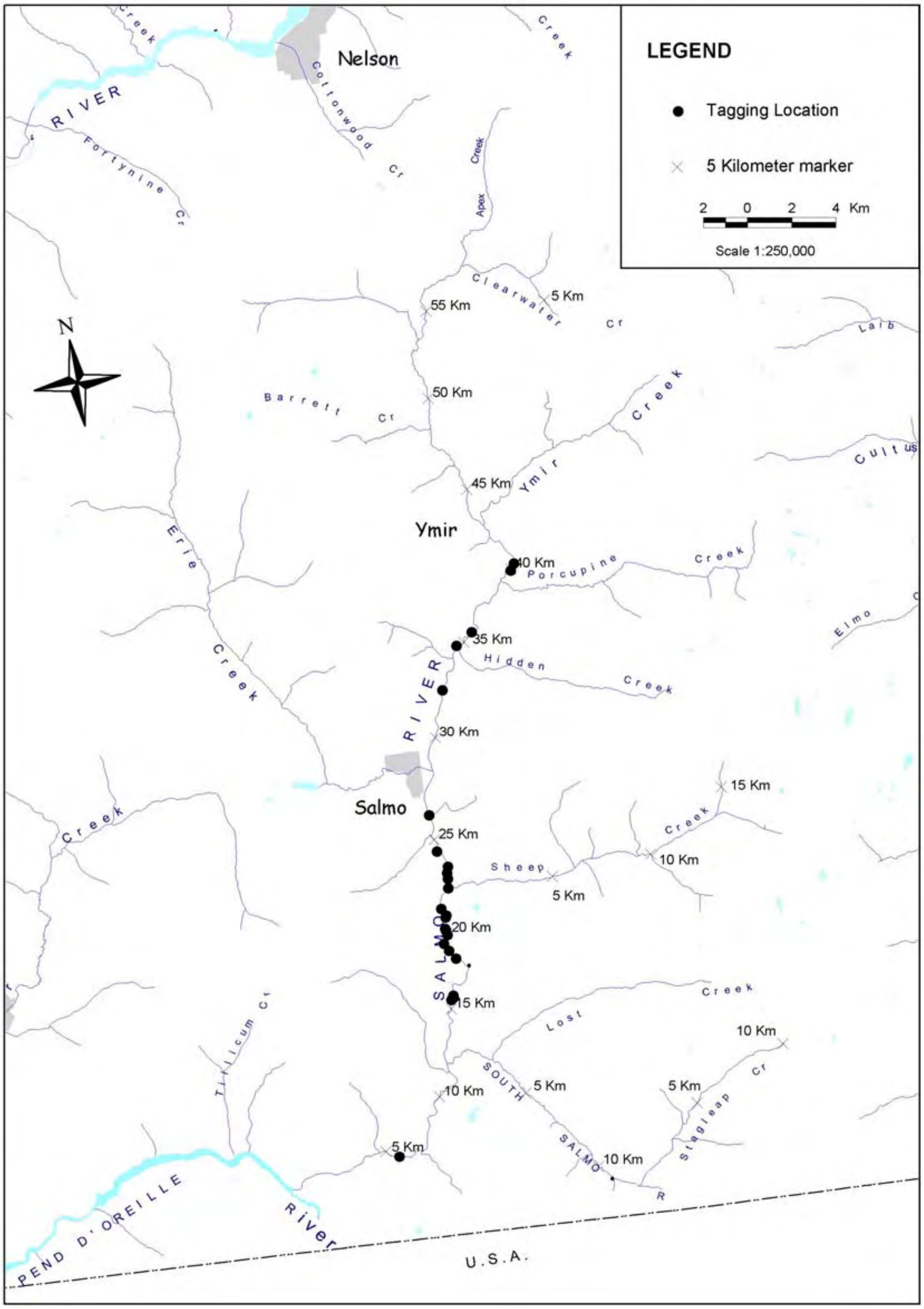

Figure 2. Tagging locations of radio tagged rainbow trout in the Salmo River watershed, 2001.

River rainbow trout. We expended 14 crew days (crew size 2-3) to capture 29 taggable fish (> 450 g approx.) distributed in a manner that ensured taggable fish had roughly equal probabilities of being selected. This approach would also be required for mark-recapture estimates unless the whole of the Salmo River mainstem (Hall C. to top of canyon) was surveyed for marks, a procedure that would greatly reduce the number of replicate swims possible.

Capture information and body size data for individual fish are presented in Appendix II. Salmo River rainbow trout are large. Fish sampled from the catch ranged in size from 245 mm to 600 mm, averaging an impressive 442 mm (n = 38, SE = 12 mm). Visual evidence of physical maturity or recent spawning was noted, as fish captured in June presumably took place shortly after the completion of spawning activities. Of the 20 fish that showed evidence of spawning that spring (others showed no evidence or there was uncertainty), none were smaller than 390 mm in length, suggesting that this length was the best estimate of the threshold body size for adulthood.

Scale and tissue samples were collected for aging and genetic analyses, respectively. Analyses have not been budgeted as part of the 2001/2002 study, but are required in order to learn: i) population spatial structure; ii) the effects on the native population of rainbow trout stocking, which was conducted between 1924 and 1953; and iii) age, life history, and growth. Life history information is particularly important for researchers wishing to confirm the size of maturity and thereby estimate the size of the breeding population for assessing population status. Also, growth and life history information combined with long term stock monitoring should allow the stock-recruitment analysis that would help managers investigate stock productivity and carrying capacity (Ricker 1975; Haddon 2001).

Habitat Use

Tracking of rainbow trout after initial tagging occurred at least weekly through June and July (2001), bi-weekly in August and September (2001), and monthly from October to March (2001 and 2002). In total 21 ground surveys and 3 aerial surveys were carried out during this period. The location of rainbow trout during each tracking event are summarized in Appendix III.

The tagging locations of all fish are summarized in Appendix III and Figure 2. Fish were sampled in runs and pools during the tagging period and were found throughout the entire survey area. As the water dropped in July and August there were some migrations to summering areas (Figure 3). Most of these migrations were small movements between 2-5 km, but there were several movements of greater than 10 km (Appendix III). In general there were movements and a constriction of distribution from areas where habitat was limited due to decreasing water levels and increasing water temperatures. Movements occurred to large pools where there was suitable depth and cover. In many cases several radio tagged fish moved into the same pool. At the onset of winter there was a redistribution of rainbow trout to suitable overwintering habitat where there was reduced flow and an abundance of cover in the form of woody debris or deep pool and boulder (Figure 4). As of the overwintering period, the location of 27 of the 30 tagged rainbow trout were accounted for (Appendix III), with one fish migrating to the reservoir.

This report summarizes the movements of radio tagged rainbow trout to mid-March, 2002. In the spring and early summer of 2002 a more intensive tracking schedule will be undertaken to identify migration periods and spawning areas in the Salmo River watershed. After that period a more detailed report summarizing migration timing and habitat use will be completed.

Population Enumeration

Population Estimation by Diver Counts

Given suitable watershed conditions, diver counts have been proven to be a reliable and efficient means of obtaining indices of relative abundance for salmonid populations in British Columbia streams (Northcote and Wilkie 1963; Slaney and Martin 1987; Oliver 1990; Korman and Ahrens 2000). In most instances, however, it is likely that diver counts will be underestimates of true abundance (provided that duplication is avoided successfully) because individuals are commonly missed due to imperfect visibility, fish behaviour, and stream channel complexity (Cousens et al. 1982; Slaney and Martin 1987; Korman and Ahrens 2000). The results we present in this report are from a mark-recapture study that employed radio tags and periodic surveys to address the problem of unseen individuals (see Webb et al. 2000; Korman and Ahrens 2000; Hagen 2001) during diver counts in the Salmo River. The July, 2001 population estimate N and its

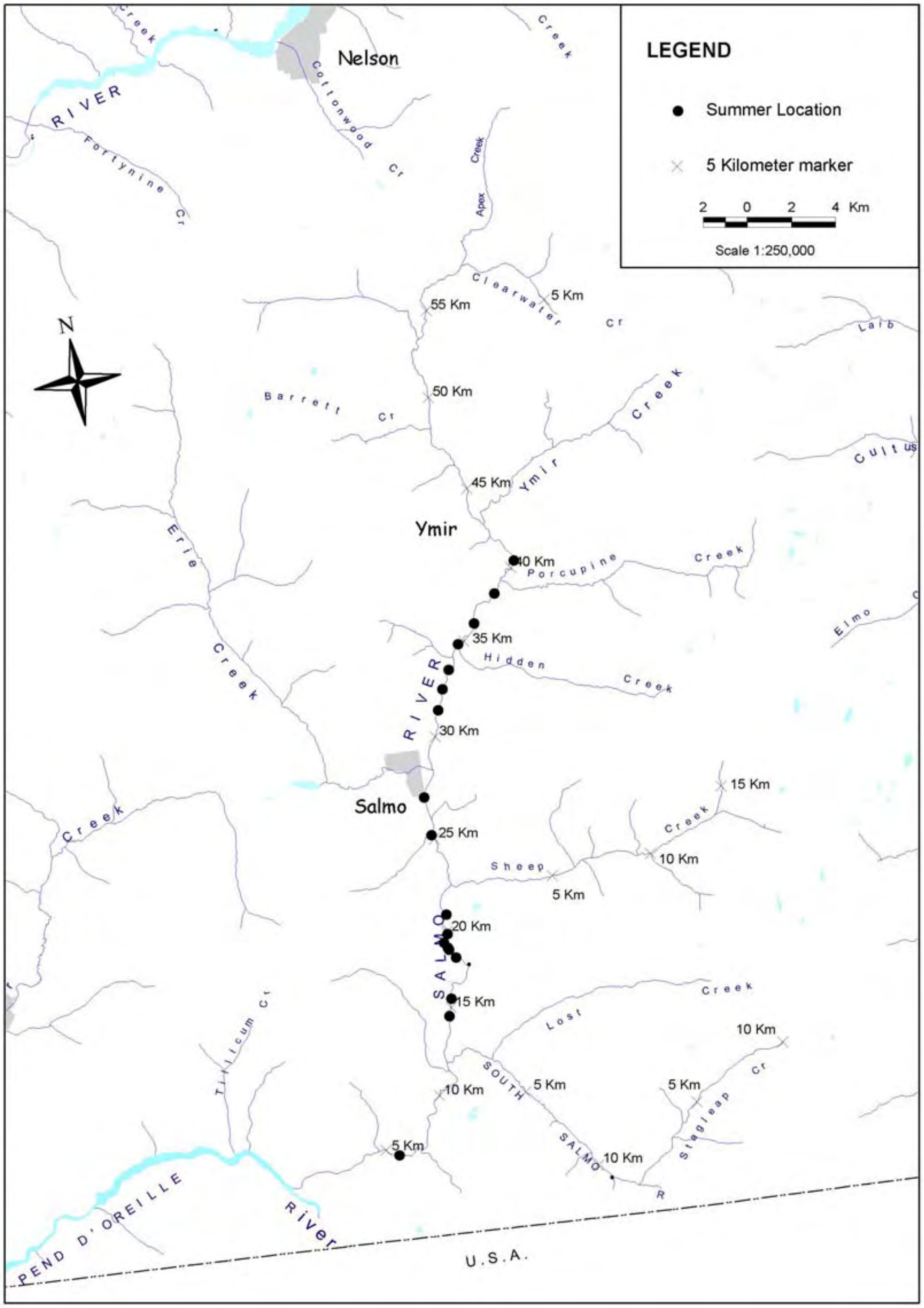

Figure 3. Summer locations of radio tagged rainbow trout in the Salmo River watershed, 2001.

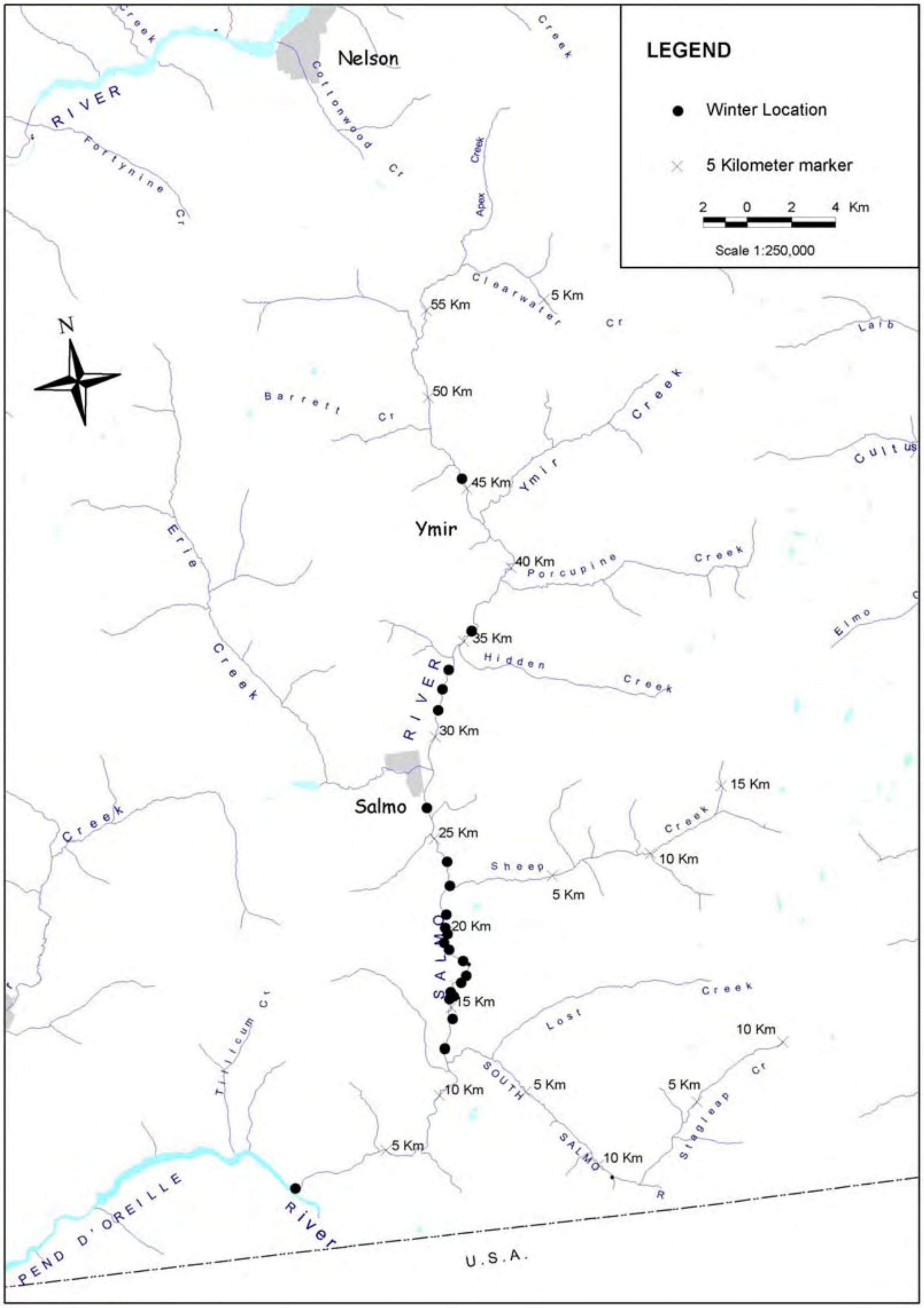

Figure 4. Winter locations of radio tagged rainbow trout in the Salmo River watershed, 2001/2002.

uncertainty were based on the parameters *C*, the mean July count in the index section, λ, the observer efficiency in the counting area, and *r* the relative distribution of radio tags to the counting area according to:

$$N = C / (\lambda * r)$$

where each parameter value and its associated variance was derived from empirical observations of radio tagged fish.

Parameter Estimation (preliminary)

Average diver counts (*C*) of rainbow trout in the index section were 306 (*SE* = 54.9), 130 (*SE* = 13.8), 83 (*SE* = 4.8), 43 (*SE* = 3.0), and 9 (*SE* = 0.99), for the size classes 0-20 cm, 20-30 cm, 30-40 cm, 40-50 cm, and >50 cm, respectively (Table 1). Either strong recruitment to the mainstem Salmo or marked behavioural shifts were documented for parr less than 20 cm over the course of the study (Table 1; Appendix IV). Strong patterns were not obvious for other size classes with the possible exception of the 20-30 cm fish, which increased to stable levels after a low initial count on June 30 (possibly indicating recruitment from other areas). It is important to note, however, that speculations about the relative effects of recruitment and observer efficiency changes on counts of fish in size categories less than 30 cm are just that, as they were not investigated directly. If the count of rainbow trout of less than 20 cm is disregarded, then the proportions of the other size classes in the total count (of fish > 20 cm) averaged 0.48, 0.32, 0.17, and 0.033 for the size classes 20-30 cm, 30-40 cm, 40-50 cm, and >50 cm, respectively, and these were relatively stable (Table 2). The focus of the 2001 study was on two groups - fish greater than 30 cm (inclusive), and fish greater than 40 cm (inclusive). The first category is made up of those fish available for harvest by the angling public, the latter group is an approximation of the breeding population (see 'Distribution of Transmitters and Biological Sampling') that is to be compared with conservation guidelines of effective population size. Of the counted fish that were of catchable size (>30 cm), a remarkable 38% on average (*SE* = 1.8%) were greater than 40 cm, indicating the potential quality of a well-managed sport fishery.

Table 1. Diver counts of rainbow trout in the index section of the Salmo River during July. 2001.

Date	0-20cm	20-30cm	30-40cm	40-50cm	50+cm
28-Jun-01	161	64	73	55	7
4-Jul-01	287	147	77	35	6
6-Jul-01	195	135	96	42	9
16-Jul-01	388	135	69	38	8
18-Jul-01	277	136	92	41	9
30-Jul-01	528	161	93	49	13
Average	**306**	**130**	**83**	**43**	**9**
SE	54.9	13.8	4.8	3.0	1.0

Table 2. Relative proportions of rainbow trout >20 cm in diver counts in the index section of the Salmo River during July, 2001.

Date	20-30cm	30-40cm	40-50cm	50+cm
28-Jun-01	0.322	0.367	0.276	0.035
4-Jul-01	0.555	0.291	0.132	0.023
6-Jul-01	0.479	0.340	0.149	0.032
16-Jul-01	0.540	0.276	0.152	0.032
18-Jul-01	0.489	0.331	0.147	0.032
30-Jul-01	0.509	0.294	0.155	0.041
Average	**0.482**	**0.317**	**0.169**	**0.033**

Observer efficiency (λ - radio tags seen/radio tags known to be present) for radio tagged, Salmo River rainbow trout averaged 0.53 (*SE* = 0.041), a surprisingly low figure considering that all surveys were conducted during conditions of relatively low flow and relatively good visibility (Appendix IV). Cover in forms including submerged woody debris, interstitial spaces of rip rap embankments, and turbulence in riffle areas appeared to be sufficient to obscure a large number of fish from sight. Our original goal was to relate changes in observer efficiency to changes in watershed conditions, and we expected changes in stream discharge and visibility to be particularly relevant. The ranges of these variables across the July study period were likely anomalous because of the atypically low runoff of springtime, 2001 (although discharge data is not available for analysis at the time of this report). Visibility averaged 10.8 m (*SE* = 0.72 m) and did not fall below 8.3 m, which is highly suitable for viewing. The trends of observer efficiency and visibility over the period of the survey, however, appears to suggest a negative relationship between the variables (Figures 5 and 6). The regression of observer efficiency on visibility (Figures 5 and 6) was not significant (t = -0.75, P = 0.50), but the negative pattern remains an interesting hypothesis that awaits further analysis using 2002 data. It is possible that the low observer efficiencies that occurred during July, 2001 reflect behavioural responses to low, clear water, pointing to the importance of conducting further study across a broader range of watershed conditions during springtime, 2002.

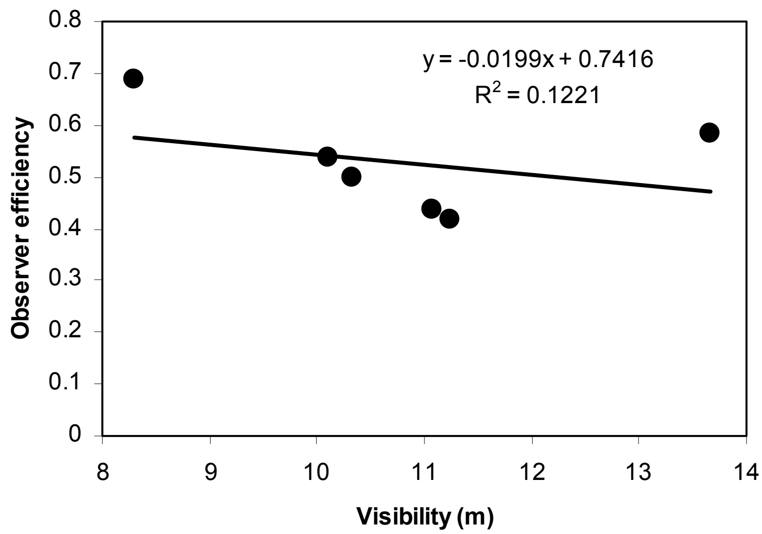

Figure 5. Observer efficiency (radio tags seen/radio tags present) and underwater visibility in the Salmo River during the late June/July counting period, 2001

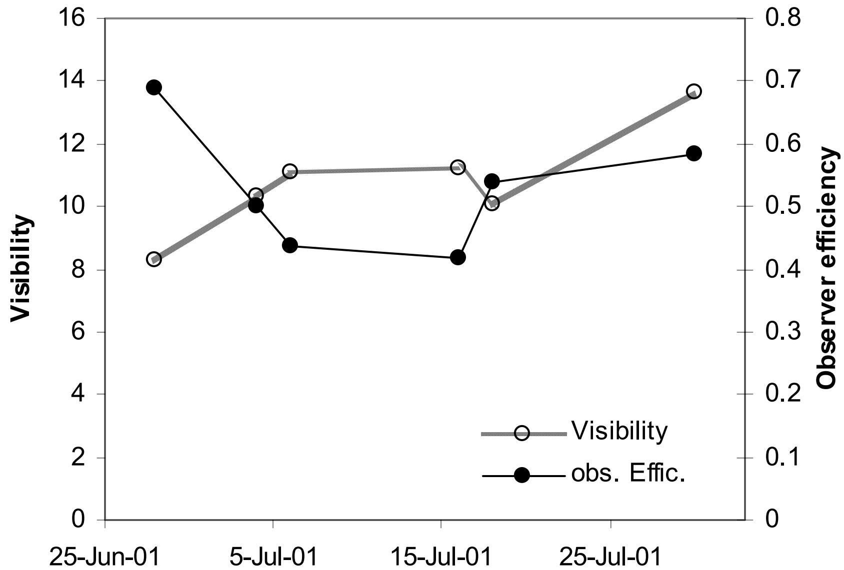

Figure 6. Relationship between observer efficiency (radio tags seen/radio tags present) and visibility in the Salmo River during the late June/July counting period, 2001 ($Y = -0.020X + 0.74$; $R^2 = 0.12$).

It is important to note the study's assumption that observer efficiency for all rainbow trout greater than 30 cm in length can be described by observations of tagged fish that were necessarily greater than 35 cm. There were two reasons for the disproportionate representation of larger fish in the radio tag sample. The first was our simultaneous need to learn about spawning habitat use, which appeared to require us to tag fish greater than 39 cm, and second we wished to use radio tags large enough to allow us a second year of observation, which specified a minimum fish size of 450 g (approximately 35 cm). It is also important at this juncture to realize that the radio telemetry data is preliminary. Almost all fish have shown some movement since they were tagged, indicating that they were alive during the July diver counts. However, a complete analysis of tagged fish mortality must wait until the expected spawning migrations of springtime, 2002 have taken place.

The relative distribution (r) of radio tagged fish to the counting area was relatively stable over the observation period, averaging 49% (SE = 2.9%) of the total. Because the allocation of radio tags was based on the relative distribution of fish >30 cm observed during the distribution swims, we assumed movements of radio tagged fish were representative of the untagged population as well. After the June distribution swims, 17 of 29 radio tags were allocated to the counting area - during the July diver counts 12-16 radio tagged rainbow trout were present depending on the survey.

2001 Population Estimates (preliminary)

Because parameter estimates are preliminary, pending the outcome of analyses to determine whether all tags were alive during the summer, 2001 study period, the 2001 population estimates are of course subject to change.

The population estimates for Salmo River rainbow trout greater than 30 cm (available for harvest) and 40 cm (estimated breeding population) were generated from the estimated parameters C, λ, and r according to the technique of stochastic (Monte Carlo) simulation (Hilborn and Mangel 1997). Each population estimate N was the average of 1,000 calculations of:

$$N = C / (\lambda * r)$$

where in every simulation each of the parameter values were generated stochastically from the observed error structure. By this technique, then, the preliminary estimate for catchable rainbow trout (>30 cm) for the mainstem Salmo River during July, 2001 was 532 (SE = 59; 95% CI: $426 < N < 656$). The relative precision of this estimate, expressed as the average confidence interval as a proportion of the mean, was 0.22, within the 0.25 target recommended by Robson and Regier (1964) for management experiments. The estimated size of the population of rainbow trout >40 cm for the mainstem Salmo river during July, 2001 was 203 (SE = 16; 95% CI: $174 < N < 241$). The relative precision of this estimate was 0.16, well within the study's goal. This latter estimate, because it is an approximate estimate of the breeding population, is the best for comparison with guidelines for minimum population size that are based on the effective population size N_e (Boyce 1992; Nunney and Campbell 1993). We also expect the accuracy of this estimate to be high, as fish > 40 cm were disproportionately represented in the radio tagged group.

Population Estimation Procedure - Future Years

We suggest that future population estimates be based on diver counts across as much of the watershed as possible. The reason for this is that if the population is spatially structured then the relative distribution parameter would not necessarily be expected to be stable over the longer term. Our recommendation is for diver counts extending from the Wildhorse Creek confluence at Ymir to the top of the unswimmable canyon 5.7 stream kilometers from the mouth, a total distance of 37.3 km that covers an estimated 96% of the Salmo River rainbow trout population >30 cm. To cover this whole section requires 4 crew days, with crew sizes of 2 for the Wildhorse Creek to Hidden Creek section (8.3 km), 3 for the Hidden Creek to Lagoon Road section (8.5 km), and 4 for the Lagoon Rd to former bridge and former bridge to top of canyon sections (8.9 and 11.6 km), respectively. Under this scenario population estimation is simplified, and N is equal to the diver counts factored together with the observer efficiency (λ) derived from the current study. We presume that replicating the entire diver survey for multiple time periods will not be feasible, and the estimate will be for a point in time that is ideally consistent year to year. The diver counts in the estimation procedure will be a point in time and therefore held to be unvarying, with uncertainty in the estimate determined by the uncertainty in the observer efficiency relationship. Pending the outcome of quantitative attempts to determine the relationship of observer efficiency to watershed conditions in 2002, the calculation of July observer efficiency in future may require measurements of visibility and discharge that reduce the effects of these sources of error. If these efforts to expand the range of watershed conditions over which diver counts can be calibrated are not undertaken, then the only defensible method of estimating observer efficiency in the future is to wait until the low, clear water conditions we observed during July, 2001 are in place. This is probably not the ideal approach, as the early summer water conditions of 2001 were atypical.

Management Implications

The conservation in perpetuity of wild fish populations is the top management priority for the BC Ministry of Water, Land and Air Protection (MWLAP). The agency needs assurance that small populations, in particular, do not face an unacceptably high probability of extinction. Predicting the persistence or extinction of small populations has been a primary focus of the growing academic discipline of conservation biology.

Because there are many causes of extinction for small populations in addition to anthropogenic agents forcing negative growth rates (those with some theoretical support include demographic stochasticity, environmental stochasticity, severe inbreeding, and long-term genetic losses - Simberloff 1988; Caughley 1994), predicting the extinction of a particular population is very difficult. Speculation about the minimum population sizes necessary to reduce extinction risks to acceptable levels (MVP - minimum viable population size) has been primarily from two perspectives, one based on genetic processes and the other on stochastic population dynamics. In the genetics-based approach the conservation minimum is generally set by i) the risk of fixation of deleterious alleles (genetic drift), and/or ii) the requirement for some minimum amount of genetic variation that allows the population to evolve, which from this perspective is an essential buffer against environmental change. Conversely, from the perspective of the population dynamics-based approach the conservation minimum is determined according to the extinction probabilities set by stochastic demographic processes.

Genetics- and population dynamics-based models of extinction tend to reach similar conclusions about minimum viable population sizes, which is perhaps surprising, given that the mechanisms of extinction are fundamentally different. The importance of genetic drift in fixing deleterious alleles in a population is related to Ne, the effective population size, which is a measure of how many individuals are contributing their genes to the next generation (Nunney and Campbell, 1993). Franklin (1981, as cited in Nunney and Campbell 1993) argued that Ne must remain > 50 to for a population to avoid suffering inbreeding depression, and probably greater still to maintain the genetic diversity required for adaptation to a changing environment. Turning this Ne into N (number of adults in the population) is not straightforward, because N will increase relative to Ne with increases in the magnitude of population fluctuations. A recommended minimum adult population size of at least five times Ne (N = 250) therefore, has been suggested if populations fluctuate significantly (Nunney and Campbell 1993), although it should be noted that the importance of genetics in extinction may not be sufficient to allow specific management predictions (Boyce 1992). Models of extinction due to demographic stochasticity alone (reviewed in Boyce 1992; Nunney and Campbell 1993) support a lower limit to the MVP of approximately N = 100, although the MVP can increase by up to an order of magnitude if populations have a relatively high degree of environmental stochasticity. The MVP's in these cases are typically described in terms of carrying capacity, so corresponding mean population sizes will be lower. Neither genetics- nor population dynamics-based models of minimum viable population size are uncontroversial. However, empirical evidence does suggest that the above guidelines may be of the appropriate magnitude. Studies of extinction in mammals and birds have generally suggested that $N < 50$ is clearly insufficient for a population's long-term persistence, populations of $50 < N < 200$ are marginally secure, and those of $N > 200$ are secure at least over time frames as limited as those used in the studies (reviewed in Boyce 1992).

The estimate of the Salmo River adult rainbow trout population size for July, 2001 was 203 ± 16.2, which according to the above criteria implies that the current population size is approaching minimum levels considered adequate for conservation. It appears, therefore, that the population should be considered one of conservation concern, especially if negative population growth is detected. Special management actions to ensure the population's future survival and health, therefore, may be warranted. The introduction of catch and release regulations for the rainbow trout fishery on the Salmo River is a management option that may be appropriate given the population's current level. However, we cannot be sure of the current need for such a step, as we have no information about the adult population size relative to the watershed capacity, the current harvest level, and the population growth rate. If continued population monitoring is possible for future years, then an opportunity exists to learn about population growth rate, which should indicate the urgency or need for regulatory change. In this scenario, because a number of years of pre-catch and release data would have been compiled, the effects of such a management experiment can be better quantified and the need for them, therefore, better understood. This is the science-based approach to conservation management recommended by recent authors (examples: Walters and Hilborn 1976; Lande 1988; Caughley 1994). Clearly, if the opportunity for monitoring does not exist, then a conservative approach to management and the earliest possible introduction of more stringent protective regulations than the current two fish per day limit appear warranted.

Efforts to increase rainbow trout habitat capability in the Salmo River watershed may be worth consideration, as extinction risk declines relatively rapidly with increases in carrying capacity (see Nunney and Campbell 1993 for review) provided anthropogenic agents forcing negative population growth rate have been addressed. However, the ability of any proposed habitat enhancement to increase rainbow trout habitat capability should be evaluated carefully, which likely would require additional study. Thorough monitoring, of course, is essential given the experimental nature of any such manipulation.

Conclusions

This report documents the preliminary results of our investigation of habitat use and population size of rainbow trout in the Salmo River, British Columbia. To date we have effectively tracked the majority of the radio tagged rainbow trout in the watershed and summering and overwintering habitat locations have been documented. Summering habitat in 2001 was limited to a few relatively large pools where large accumulations of fish were observed. Overwintering habitat in 2001 and 2002 was concentrated throughout the mainstem Salmo River and was found in areas of deeper water in association with cover. Future tracking during the spring and summer of 2002 will document migration timing and spawning areas.

The recognition that the Salmo River rainbow trout population size may be at or near the minimum considered adequate for conservation is an important result of this study, and suggests: i) that close monitoring of the future population status is required, and ii) that more stringent angling regulations may be warranted if negative population growth is detected or population assessments can not be carried out over the next several years.

Diver counts are an efficient means of estimating the size of rainbow trout populations of interior, British Columbia rivers (Slaney and Martin 1987), but calibrating these surveys for the inevitable missed individuals is required for accuracy in the estimate. In this study, the use of radio telemetry in combination with periodic visual counts has been proven to be an effective method for calibration in the Salmo River watershed. Importantly, the relative precision of the population estimate can be investigated with this method. Both the confidence intervals for the estimates of catchable and adult population sizes and the total effort expended to acquire them were reasonable given the importance of the information. It is important to note that the costs of acquiring a population estimate of this precision will decline in future. The parameters required for calculating the estimate will have been estimated from two years of telemetry information, meaning that the technique would no longer be required in the estimation procedure and diver counts could be calibrated merely from knowledge of watershed conditions at the time of the survey.

The habitat use and population size information for the Salmo River rainbow population will improve our ability to monitor the effects of management experiments in the watershed. Angling harvest of rainbow trout and habitat impacts from recent and past resource use patterns may be anthropogenic agents that are forcing negative growth rates, and future monitoring of habitat use and population size can address these speculations. The conservation of Salmo River rainbow trout forever is the principal goal of the British Columbia Ministry Water, Land and Air Protection, BC Hydro, Beaumont Timber, the Columbia Basin Fish and Wildlife Compensation Program, the Columbia-Kootenay Fisheries Renewal Partnership, the Columbia Basin Trust, and the Salmo Watershed Streamkeepers Society. Maintaining the habitat capability of the watershed and closely monitoring population sizes are important steps towards ensuring that this goal is achieved.

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Appendix I – Photographic Plates

Plate A. Rainbow trout in flow through fish tube prior to surgery.

Plate B. Field surgery station used during surgical radio tagging of rainbow trout.

Plate C. Anaesthetized rainbow trout on V trough prior to incision.

Plate D. Irrigation of gills of anaesthetized rainbow trout.

Plate E. Incision made into abdominal cavity through body wall of rainbow trout prior to insertion of radio tag.

Plate F. Radio tag antennae coming out body wall of rainbow trout.

Plate G. Sutures being used to close incision after radio tag is inserted into abdominal cavity of rainbow trout.

Plate H. Suture placed on antennae to prevent movement and irritation at exit point.

Appendix II – 2001 Salmo River Rainbow Trout Capture Information

Fish No.	Frequency	Code	Date	River Km	Length (mm)	Girth (mm)	Mass (g)	Sex	Scales	DNA	Floy Tag 1	Floy Tag 2	Maturity
A	380	9	06/06/2001	20.2	540	280	1700	F	A	A	6401	6402	Kelt
B			06/06/2001	19.1	415	230	800	F	B	B			?
C	420	4	06/06/2001	19	445	240	1000	F	C	C	6403	6404	Kelt
D	780	2	06/06/2001	15.5	475	245	1125	F	D	D	6405	6406	Kelt
E	380	2	06/06/2001	15.5	450	210	800	M	E	E	6407	6408	?
F	780	5	08/06/2001	40.5	450	230	1000	F	F	F	6449	6450	
G	780	10	08/06/2001	39.9	470	230	1100	M	G	G	6410	6411	Kelt
H	420	1	12/06/2001	32.3	570	275	1800	F	H	H	6391	6392	?
I			12/06/2001	24.4	245			?	I				IMM.
J			20/06/2001	23.9	310			F	J				IMM.
K	420	8	20/06/2001	23.5	400	195	600	F	K	K	6357	6358	Kelt
L	420	9	20/06/2001	23.2	400	200	650	?	L	L	6389	6390	Kelt
LO	780	1	19/09/2001	34.6	410	210	725	F	LO	LO	6301	6302	Kelt
M	420	10	20/06/2001	22.4	465	215	950	M	M	M	6359	6388	Kelt
N	380	5	20/06/2001	20.9	600	290	2100	F	N	N	6360	6361	Kelt
O			20/06/2001	20.9	370	180	550	?	O				?
P	380	4	21/06/2001	19.9	430	215	750	F	P	P	6424	6425	Kelt
Q			21/06/2001	19.9	490			M	Q	Q			?
R	380	6	22/06/2001	5.7	390	200		M	R	R	6362	6363	Kelt
U			21/06/2001	18.3	450			M	U	U			?
SARB-1	420	2	01/06/2001	26.2	465	250	1150	F	SARB-1	SARB-1	6351	6352	IMM.
SARB-10	420	3	12/06/2001	35.7	360	185	500	F	SARB-10	SARB-10	6414	6415	IMM.
SARB-11	420	7	20/06/2001	24.4	510	265	1450	F	SARB-11	SARB-11	6416	6417	?
SARB-12	780	7	20/06/2001	22.9	570	285	2000	F	SARB-12	SARB-12	6418	6419	?
SARB-13	780	9	20/06/2001	22.4	510	240	1300	M	SARB-13	SARB-13	6420	6421	?
SARB-14	380	8	20/06/2001	20.8	385	200	600	F	SARB-14	SARB-14	6422	6423	IMM.
SARB-15	380	1	21/06/2001	21.3	490	230	1100	F	SARB-15	SARB-15	6386	6387	Kelt
SARB-16	380	3	21/06/2001	19.4	445	195	700	M	SARB-16	SARB-16	6383	6385	Kelt
SARB-17			21/06/2001	19	435	220		F	SARB-17	SARB-17			?
SARB-18	380	10	30/06/2001	15.7	390	175	350	F	SARB-18	SARB-18	6381	6382	Kelt
Fish No.	**Frequency**	**Code**	**Date**	**River Km**	**Length (mm)**	**Girth (mm)**	**Mass (g)**	**Sex**	**Scales**	**DNA**	**Floy Tag 1**	**Floy Tag 2**	**Maturity**
SARB-2	780	3	06/06/2001	20.1	455	230	1100	F	SARB-2	SARB-2	6399	6400	Kelt

SARB-3			06/06/2001	20.1	275			?	SARB-3	SARB-3			IMM.
SARB-4	380	7	06/06/2001	18.5	480	235	700	F	SARB-4	SARB-4	6397	6398	Kelt
SARB-5	420	6	08/06/2001	20.2	435	225	850	F	SARB-5	SARB-5	6395	6396	Kelt
SARB-6	780	6	08/06/2001	20.1	425	210	750	M	SARB-6	SARB-6	6353	6354	Kelt
SARB-7	780	8	08/06/2001	15.8	445	220	1000	F	SARB-7	SARB-7	6355	6356	Kelt
SARB-8	420	5	08/06/2001	34.6	470	235		F	SARB-8	SARB-8	6393	6394	Kelt
SARB-9	780	4	12/06/2001	35.7	460	235		F	SARB-9	SARB-9	6412	6413	IMM.

Appendix III – Locations (stream km from mouth) of Radio Tagged Salmo River Rainbow Trout, 2001/2002

Tag no.	01-Jun-01	06-Jun-01	08-Jun-01	12-Jun-01	19-Jun-01	20-Jun-01	21-Jun-01	22-Jun-01	28-Jun-01	30-Jun-01	04-Jul-01	06-Jul-01	11-Jul-01	16-Jul-01	17-Jul-01	18-Jul-01	19-Jul-01	30-Jul-01	31-Jul-01	02-Aug-01	13-Aug-01	08-Sep-01	19-Sep-01	10-Oct-01	07-Nov-01	16-Dec-01	15-Jan-02	15-Feb-02	06-Mar-02
380(1)							21.3		20.9		20.7	20.5					15.0			14.3	19.0			14.3	12.8		12.8	12.5	12.6
380(2)		15.5					15.5			15.5							15.3			15.4	15.5	36.3					45.5		
380(3)							19.4		19.4		19.3	19.4				18.5		19.6		19.5	19.4	19.4			19.4		19.4	19.4	19.4
380(4)							19.9		20.1		19.7	19.9		19.8		19.9	19.8			19.8	19.9	19.9			19.9		19.9	19.9	19.9
380(5)						20.9	20.9		19.4		19.7	19.9		19.4		19.4		21.2		21.2	19.9	19.4			19.9		19.9	19.9	19.9
380(6)								5.7									6.0			5.7	5.7	0.0			0.0		0.0		
380(7)		18.5					18.5		18.6		18.6	18.6		18.6		18.6		18.5		18.5		19.0			16.9				
380(8)						20.8	20.8		20.8		20.5	20.4		20.4		20.4		20.4		20.4	19.0	18.1			20.2		19.9	19.9	19.9
380(9)		20.2					19.0		19.0		19.0	19.0		19.0		19.0		19.1		19.0	19.0	19.0			21.8		20.9		20.9
380(10)										16.0							16.1			16.1	15.5	15.8		16.0	16.0		16.0	16.0	16.0
420(1)				32.3	32.3											32.3		32.3			32.3						14.3		
420(2)	26.2				26.0											32.3		32.3			32.3	32.3			32.3		32.3	32.3	32.3
420(3)				35.7	37.0								36.3		36.3			37.6			38.3	38.3	37.0		37.0	35.7	35.7	35.7	35.7
420(4)		19.0					19.0		19.0		19.0	18.9				33.5		33.3			33.3	33.3			33.3		33.3	33.3	33.3
420(5)			34.6		34.6								34.6		34.6			34.7			34.7		34.7		34.7		16.9	16.9	16.9
420(6)			20.2				20.2		20.2		20.3	20.2		25.2		25.2		25.2		25.2	25.2	25.2					15.4	15.4	15.4
420(7)						24.4	24.4		24.4		24.4	24.4		24.4		24.4		19.1		19.1					19.0		19.0	19.0	19.0
420(8)						23.5	23.5		23.6		23.4	22.9		22.9		22.9		24.1		23.8	27.0	21.6			22.5		23.7	23.7	23.7
420(9)						23.2	23.2		23.3		23.3	23.3			36.0			36.0			36.3	35.8	35.8		22.5		22.5	22.5	22.5
420(10)						22.4	22.0		22.0		22.0	22.0		18.5		18.5		18.5		18.5					18.1		18.1	18.1	18.1
780(1)																							34.7						
780(2)		15.5					14.5		15.5								15.0			14.4	14.5	14.5		17.3	19.0		15.4	15.4	15.4
780(3)		20.1					20.1		20.1		19.8	20.0				31.3		31.3			31.3	31.3			31.3		31.3	31.3	31.3

Tag no.	01-Jun-01	06-Jun-01	08-Jun-01	12-Jun-01	19-Jun-01	20-Jun-01	21-Jun-01	22-Jun-01	28-Jun-01	30-Jun-01	04-Jul-01	06-Jul-01	11-Jul-01	16-Jul-01	17-Jul-01	18-Jul-01	19-Jul-01	30-Jul-01	31-Jul-01	02-Aug-01	13-Aug-01	08-Sep-01	19-Sep-01	10-Oct-01	07-Nov-01	16-Dec-01	15-Jan-02	15-Feb-02	06-Mar-02
780(4)				35.7	35.7								36.3		36.3				36.3		36.3	36.3	36.3		36.3	35.7	35.7	35.7	35.7
780(5)			40.5	40.5									40.5		40.5				40.8		40.6	40.7	40.7		24.5		17.3		
780(6)			20.1	20.2			20.2				19.9	20.0			20.1	18.0		20.1		20.1	20.9	19.9			19.0		20.2	20.2	20.2
780(7)						22.9	22.9		25.2		25.1	25.2		25.2		25.2		25.2		25.2	25.2	25.2			25.2		19.9	19.9	19.9
780(8)			15.8				15.8		15.8								15.8			15.7	15.5	14.5		15.7	15.7		15.7	15.7	15.7
780(9)						22.4	26.2		26.2		26.2			18.5		18.5				14.4	14.5	25.2			26.5		26.5	26.5	26.5
780(10)			39.9		40.5								40.4		40.5				40.6		40.6								

Appendix IV – Diver Counts for Index Section on the Salmo River, 2001

Survey date	Section	RB tags observed	RB tags present	Observer efficiency	RB tags alive	Relative distribution	RB observed 0-20cm	20-30cm	30-40cm	40-50cm	50+cm	N >30	N >40	Pop >30	Pop >40	Average visibility	Discharge	Turbidity 1	Turbidity 2
	total	6	16	0.375	16	1				146		389.3333	na	389.3333		7.1			
28-Jun-01	upper	2	4	0.5		0.137931	15	14	14	14	0								
	lower	9	12	0.75		0.413793	146	50	59	41	7								
	total	11	16	0.6875	29	0.551724	161	64	73	55	7	135	62	355.9091	163.4545	8.3		-7.7	-82
04-Jul-01	upper	2	4	0.5		0.137931	51	32	30	12	3								
	lower	6	12	0.5		0.413793	236	115	47	23	3								
	total	8	16	0.5	29	0.551724	287	147	77	35	6	118	41	427.75	148.625	10.33333		-6.2	32
06-Jul-01	upper	3	4	0.75		0.137931	21	25	36	9	5								
	lower	4	12	0.333333		0.413793	174	110	60	33	4								
	total	7	16	0.4375	29	0.551724	195	135	96	42	9	147	51	609	211.2857	11.06667		-7.1	-73
16-Jul-01	upper	2	4	0.5		0.137931	150	47	15	13	4								
	lower	3	8	0.375		0.275862	238	88	54	25	4								
	total	5	12	0.416667	29	0.413793	388	135	69	38	8	115	46	667	266.8	11.23333		-0.4	-8
18-Jul-01	upper	4	4	1		0.137931	59	42	33	14	4								
	lower	3	9	0.333333		0.310345	218	94	59	27	5								
	total	7	13	0.538462	29	0.448276	277	136	92	41	9	142	50	588.2857	207.1429	10.1		-0.1	-6
30-Jul-01	upper	2	3	0.666667		0.103448	88	42	27	8	4								
	lower	5	9	0.555556		0.310345	440	119	66	41	9								
	total	7	12	0.583333	29	0.413793	528	161	93	49	13	155	62	642.1429	256.8571	13.66667		-7.3	-73