Conservation Status of Salmo River Rainbow Trout: Radio Telemetry Investigations of Habitat Use and Abundance

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EXECUTIVE SUMMARY

- Prior to 2001, biologists were unable to assess the conservation status of the rainbow trout (*Oncorhynchus mykiss*) population inhabiting the mainstem of the Salmo River due to limited information about trends in abundance, habitat use, and life history. To address these deficiencies, we initiated during 2001 a multi-year study of habitat use and population size for this population employing radio telemetry as a primary investigative tool.

- Three years of radio telemetry investigations of habitat use by adult and sub-adult trout (>300 mm) suggested that: (i) holding water during the summer low water period was limited to a few relatively large pools containing deep water and/or wood cover; (ii) overwintering habitat consisted of areas of deeper water and abundant wood or boulder cover; (iii) radio tagged fish utilized primarily mainstem areas (including sidechannel areas) for spawning, with only limited use of tributaries; and (iv) off-channel areas within the flood plain provided important refuge habitat during high water events. A channelized section of the mainstem river extending from the town of Salmo downstream to Hellroaring Creek was conspicuously avoided by radio tagged trout, which was likely due to an absence of pool habitat and cover. The close association of rainbow trout elsewhere in the mainstem Salmo with deep water and cover suggests that habitat restoration work in this section, to create more area with depth and cover, may be of benefit to the population.

- Although diver counts of trout in streams are commonly used to monitor trout abundance, few studies have directly investigated the relationships between diver count accuracy and watershed physical conditions. We utilized diver observations of radio tagged trout, made during periodic surveys of a counting area located downstream of the town of Salmo, to estimate diver observer efficiency and its relationship with horizontal underwater visibility and discharge during July of 2001, 2002, and 2003. Results from the three years of the study suggested that diver observations of radio tagged trout can be reliably used to estimate observer efficiency, but also that the relationships of observer efficiency to underwater visibility and discharge exhibit interannual variability. Changes in visibility and discharge, which were highly correlated with each other, were good predictors of observer efficiency observations during July 2002 and July 2003, but observer efficiency did not change with changes in these variables during July 2001, a year in which mid-summer levels of flow were reached earlier in the summer than in any other year within the last decade. Overall relationships of observer efficiency to visibility and discharge for all three years' combined data were significant. Because the overall observer efficiency/visibility relationship was more precise than that for observer efficiency and discharge, and because visibility can be more practically measured and varies from one stream reach to another, this relationship was chosen as the basis for adjusting diver counts of trout to generate population estimates in the Salmo River mainstem.

- Population estimates incorporating observer efficiency estimates and expectations for error were made for the mainstem Salmo River between the Hall Creek canyon and Seven Mile Reservoir. Estimated adult (>400 mm) populations were 233 ± 27, 166 ± 17, and 195 ± 36 for July 2001, July 2002, and July 2003, respectively. The estimates suggest that the population size may be approaching minimum levels considered adequate for conservation. Due to the small size of the Salmo River rainbow trout population and the possibility that it is to some degree demographically and genetically isolated, special management actions to ensure the population's future viability and to maintain the quality of the fishery may be warranted. A change to a catch-and-release regulation on a portion of the Salmo mainstem, arising from the above results, was implemented on an experimental basis beginning with the 2003 angling season. Continued abundance monitoring, especially if it is accompanied with a willingness to experiment with alternative harvest regulations, is the key to learning about the population's status relative to meaningful conservation and management targets.

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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 500 mm or more, provides the highest quality small- to medium-sized stream fishery in the Nelson area. Angler effort has not been measured for the Salmo River, but appears to have been of light to moderate intensity in recent years, and until 2003 an angler harvest had been permitted with a daily limit of two rainbow trout over 300 mm. However, snorkel surveys of the system conducted in 2000, to investigate movements and abundance of other species, suggested that the rainbow trout population of the Salmo was small and possibly depleted (Baxter and Nellestijn 2000). Concerned local residents and fisheries agency staff have also expressed the belief that the Salmo population was of small size, so we felt it possible that the population's status was of conservation concern.

Assessing the current status of the population from a data review was impossible, as no information existed about trends or current levels of adult trout abundance, critical habitats, or population spatial structure. This lack of information prevented regional fisheries staff at the BC Ministry of Water, Land and Air Protection (MWLAP) from making knowledgeable management decisions regarding the population. For this reason, MWLAP staff 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, former regional fisheries biologist, Nelson, B.C.; personal communication). During spring 2001, we initiated a study of the habitat use and conservation status of the Salmo River's rainbow trout population, which had the financial and/or in-kind support of MWLAP, BC Hydro, Beaumont Timber, the Columbia Basin Fish and Wildlife Compensation Program, the Columbia-Kootenay Fisheries Renewal Partnership/Columbia Basin Trust, the Salmo Watershed Streamkeepers Society, and the West Kootenay Fly Fishing Club.

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, which we have employed here out of convenience:

Abundance. Population dynamics processes, including demographic stochasticity, genetic process (severe inbreeding and long-term genetic losses/genetic drift), and the effects of environmental stochasticity and catastrophes, work differently in small populations. 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 an adult population size of $N < 50$ 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).

Population growth rate. The population growth rate is the trend in the population's abundance and is either positive (increasing population) or negative (declining). At small population sizes it appears that demographic and environmental stochasticity are more immediate and potent threats than are inbreeding and genetic drift. However, under a situation of negative population growth rate 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 (negative population growth rate) to these population sizes in the first place - often overharvest and habitat destruction in salmonid populations - are far more important than any of the above, and extinction is likely unless these agents are identified and corrected and the negative population growth rate reversed.

Population spatial structure. A salmonid population's spatial structure affects extinction risk through processes increasing resilience to environmental stochasticity (variability 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).

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). Conversely, stocking hatchery fish, which occurred in the Salmo River watershed between 1924 and 1953, can dilute important genetic adaptation of the population if a large degree of introgression (successful interbreeding) between the native and hatchery fish occurs.

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 poorly adapted 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 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 early summer 2001 and continued through to the spring of 2004 was designed to gather the natural history information - particularly habitat use, life history, and population abundance - required by regulatory agencies prior to undertaking adaptive management. This report presents results of the population monitoring studies conducted during July 2001, July 2002, and July 2003, and the adult rainbow trout habitat use study for rainbow trout radio tagged during the summer of these three years.

Study Design
Our principal objectives for this study of the Salmo River watershed's rainbow trout population were twofold:

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

2. To establish an index of abundance that could be related to the size of the adult rainbow trout population (and that incorporated estimates of uncertainty), and would be 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 during the first year of the study (2001) 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 and then habitat use could be quantified from the telemetry record rather than merely described. A smaller number of fish were also radio tagged during 2002 and 2003 and provided habitat use information, although all of these tags were distributed in one section of the river for use in the population estimation study.

The Salmo is typically clear enough in summer to permit the technique of diver counts for trout population census. We assumed that this would be the most desirable approach (if reliable), as diver counts are a quick, inexpensive, and non-destructive method that can be employed in relatively deep, swift water. Although underwater observation by divers has long been used as a research technique in behavioural studies of fish in streams (e.g. Keenleyside 1962; Fausch and White 1981; Campbell and Neuner 1985; Bonneau and Scarnecchia 1998), evaluations of the technique's reliability for salmonid population census have been mixed. In order to evaluate the reliability of diver counts for assessing population status on the Salmo River, therefore, we also conducted a multi-year program of research into their accuracy relative to watershed physical conditions.

Quantitative evaluation of underwater census techniques has been limited, and much of it has been focused on their suitability for enumeration of juvenile salmonids or stream residents of small body size (Griffith 1981; Hankin and Reeves 1988; Mullner and Hubert 1998; Roni and Fayram 2000). Relatively little is known about the accuracy of diver counts, or factors affecting it, for fluvial salmonid populations comprising larger individuals. Comparisons of subsequent passes by divers (Schill and Griffith 1984) give an indication of the replicability of counts, but a true test of their accuracy requires an independent method of population estimation. In a study designed to assess the accuracy of diver counts using a secondary method, Northcote and Wilkie (1963) poisoned a stream section with rotenone after underwater census to learn that divers had observed only 59% of the rainbow trout and 64% of the mountain whitefish (*Prosopium williamsoni*) present, even though counts at that location had been replicable. Mark-recapture studies employing underwater census as the recapture method have also been utilized to independently evaluate the accuracy of population estimates derived from diver counts. There are only a small number of published accounts, but from these it appears that system-to-system variability can be high, with species differences and the amount of instream cover being potential variables that can affect the accuracy of diver counts (Slaney and Martin 1987; Zubik and Fraley 1988; Young and Hayes 2001).

Quantitative descriptions of factors that affect accuracy of diver counts within a given river system and salmonid population could allow the development of models for population estimation that account for changes in these variables from year-to-year and within a season, thereby improving the precision of population estimates. Recently, in a study designed to parameterize an area-under-the-curve model for estimating adult steelhead abundance in the Cheakamus River, British Columbia, Korman et al. (2002) deployed radio tags in steelhead that had also received visual tags for a diver-based mark-recapture study. As the number of marked fish in the surveyed stream section could be known with certainty, multiple recapture surveys over a much longer time period and a range of watershed conditions were possible. In their study, discharge and horizontal underwater visibility explained between 69 and 78% of the variation in diver observer efficiency.

In our study, we wished to investigate the effects of changes in stream physical conditions such as underwater visibility and discharge on the accuracy of underwater counts of a fluvial rainbow trout population, as well as inter-annual variability in these effects. Divers obtained counts of trout in two size categories, >300 mm and >400 mm, in a stream section in which radio tagged fish that had also received a visual mark were present. We related the accuracy of the counts (number of tagged fish seen by divers as a proportion of the number known to be present – hereafter referred to as observer efficiency) to levels of horizontal underwater visibility and discharge on the survey dates, which took place over the three year period from 2001-2003 over the range of watershed conditions naturally occurring in July, when the annual population census occurs. The goal of the research was to parameterize a model if possible for expanding future dive counts into a population estimate and for estimating confidence intervals, which would preclude the need for costly annual mark-recapture studies.

METHODS

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 Salmo is a 5th order stream, and has a total drainage basin area of roughly 1,300 km^2. 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 is comprised of 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 (Krajina 1959).

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/s, with mean monthly minimum and maximum values of 7.5 and 128.5 m^3/s, 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 (anadromous *O. mykiss*) and chinook salmon (*O. tshawytscha*) have been extirpated from this system due to past hydroelectric development on the lower Columbia River.

Fish Capture and Tagging

For 2001, the design for the habitat use study specified that each taggable fish have an equal probability of receiving a tag, with the assumption being that movements of the radio tagged fish would be representative of the population as a whole. Of the 30 radio tags used for the study in 2001, 29 tags were initially available and were allocated to the various stream sections in proportion to the relative abundance of harvestable (>300 mm) 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, with the assumption being that observer efficiency was comparable along the length of the Salmo. The majority of the watershed thought to contain trout of adequate size for radio tagging (>350 mm) was surveyed (Baxter 1999, 2001), 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. The canyon reach itself was omitted

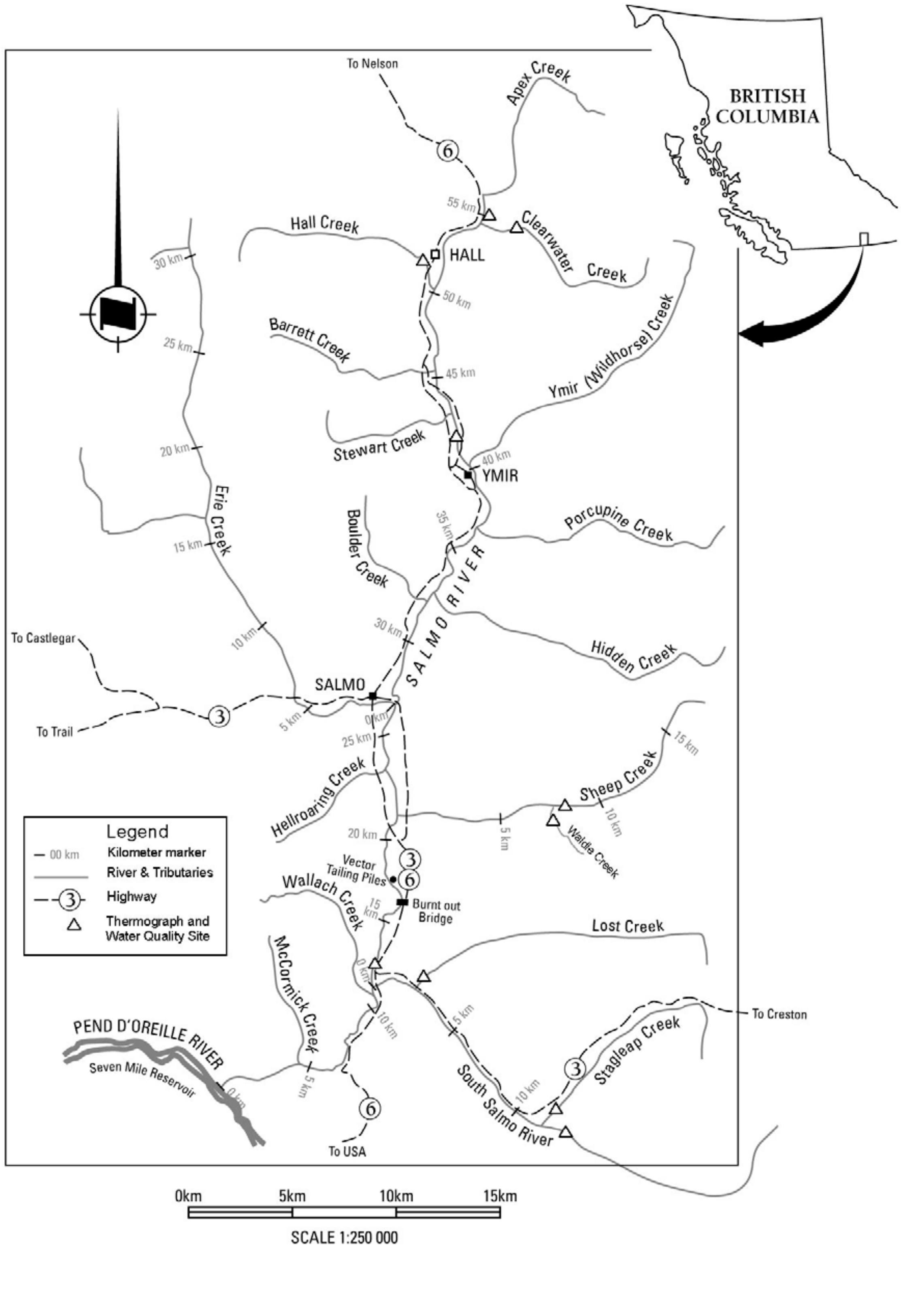

Figure 1. The Salmo River watershed study area.

because of safety concerns at that time. All rainbow trout captures during spring 2001 were made by angling in the mainstem Salmo River from June 1 to June 30 (one additional fish was captured and radio tagged on September 19). Angling therefore had been initiated prior to the diver counts, but effort and success were insufficient to exceed allocations for each stream section prior to their being established by the divers. Gear utilized included artificial lures and flies, as well as salmon egg bait.

In 2002 and 2003 resources were insufficient for the large number of radio tags required to replicate the habitat use study. However, in order to learn about interannual variability in the accuracy of diver counts a small number of radio tags were purchased in each year and deployed in the section used for the observer efficiency study, located downstream of the town of Salmo. Freshet conditions lasted longer in 2002, delaying the onset of tagging and diver counts. Rainbow trout captures were made between June 10 and July 4. In 2003 rainbow trout captures took place between June 13 and June 20.

Methods for surgically implanting tags in suitable rainbow trout were the same for all years. 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 in 2001 were a minimum of 350 mm in fork length and 0.50 kg in weight so that the weight of the radio tag did not exceed 2% of the fish weight. In 2002 and 2003 the threshold minimum size for radio tagged trout was increased to 400 mm, after considering life history data from scale analysis, and the larger size of radio tags used in 2002 and 2003. Sterile conditions were maintained at the surgery site with the operating biologist using surgical scrub to sterilize 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, B.C.) at a concentration of 75 PPM was sprayed on all handling nets, the surgery trough and added to the anaesthetic bath to reduce the loss of the slime coating of the fish.

Radio tags utilized for this study were manufactured by Lotek Wireless Inc. (Newmarket, Ontario). Tags used were model MCFT-3EM (11 mm diameter, 49 mm length, 4.3 g weight in water, operational life >598 days). The tags were programmed to be operational for a total of 8 hours a day, and were digitally coded tags transmitting at a 2.5 or 5 second burst rate on one of four frequencies.

Once it had been decided that a captured trout would receive a radio transmitter, the field surgery station was set up (Appendix I-Plate B) while the fish was allowed to recover from capture (typically for a minimum of 10 minutes). The fish was then anaesthetized in water containing diluted clove oil (emulsified in 95% ethanol) at a concentration of 100 PPM (Prince and Powell 2000). When the trout had reached the stage of anaesthesia where it had lost its equilibrium and no longer responded to external stimuli, it 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 C). A 3-4 cm 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 D).

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 antenna of the radio tag was then threaded through the needle and the needle was pulled out, leaving the antenna protruding from the abdominal cavity and laying along the side of the fish. 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 E). The antenna of the radio tag was then sutured to the body wall with one interrupted suture (Appendix I-Plate F) to prevent movement and irritation by the antenna at the exit point from the body wall. Finally the closed incision and exit point of the antennae were swabbed with Betadine (Syndel International, Inc., Vancouver, B.C.), and the fish was placed in a flow through tube for recovery for at least 10 minutes.

Biological sampling for rainbow trout captured in 2001 was more extensive than in 2002 and 2003. First, a small section of the adipose fin was removed and stored, along with a label, in a vial of 95% ethanol for genetic analysis (Taylor 2002). Following this a sample of at least 10 scales was removed for aging analysis, and two orange T-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. Biological sampling during spring 2002 and spring 2003 differed from 2001 in that fin and scale samples were not taken and fish mass was not measured. Radio tagged trout in 2002 and 2003 received white and blue Floy tags, respectively, to distinguish them from fish tagged during 2001.

Radio Telemetry

All of the telemetry information used for the study's analyses was collected by mobile tracking, either by: i) pontoon boat along the counting section on the same day as diver counts; ii) helicopter during surveys of most of the watershed, frequently concurrent with bull trout telemetry surveys (Baxter 2002); or iii) a combination of foot, boat, and vehicle surveys (according to stream navigability and proximity of roads to the channel) over the whole stream length used by radio tagged fish. Helicopter flights occurred on August 13 and September 8, 2001, January 11, April 22, May 2, May 31, and December 11, 2002, September 2, 2003, and March 3, 2004. Tracking took place approximately bi-monthly between the completion of diver counts in late July 2001 and the onset of the spawning period in April 2002, when tracking was approximately weekly until mid-June. A single over-winter tracking event (helicopter flight) in each year was the only tracking event after the completion of diver counts in summer 2002 and summer 2003, primarily to identify overwintering areas and determine which of the radio tagged fish were likely still alive. As it had been in spring 2002, spawning tracking was approximately weekly during the migration and spawning period extending from April to mid-June of 2003. In 2004, a total of seven tracking events occurred between May 4 and June 9.

Radio reception for surveys on foot or by boat along the river channel was through a whip antenna attached directly to a portable receiver. During helicopter surveys a two-element antenna was attached to the base of one of the helicopter's skids, and was oriented with the elements perpendicular to the water surface. The two-element antenna was attached to the roof rack of a truck during vehicle-based surveys. 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. During telemetry surveys along river channels in spring 2002, potential spawning areas were surveyed for redds if discharge and visibility conditions were suitable. Discharge and visibility conditions in spring 2003 and spring 2004 were not suitable for redd surveys.

During the observer efficiency study an observer with a receiver followed the diving team at a distance in a pontoon boat, and collected radio telemetry information about the number of tagged fish present in the study reach on each survey date. The telemetry information was not relayed to the divers prior to their surveying of the potential holding water. Conversely, the diving team would stop and relay information to the telemetry operator as soon as a radio tagged fish had been observed. The telemetry notes were then used to identify the individual fish that had been seen, so observations of tagged fish, along with movement data, were used to estimate how many fish had survived surgery and were alive at the time of the survey.

Diver Counts

The counting section of the Salmo River used for estimating observer efficiency extended from the end of Carney Mill Road (26.2 km), near the town of Salmo, downstream approximately 9 km to an access point along Highway 3 at a former bridge crossing ("burned out bridge" – 17.3 km). We conducted 4-7 underwater surveys of the study reach per year, which took place as water levels dropped from high, post-freshet conditions in early July to much lower, mid-summer levels as August approached. In 2001 surveys began upon the completion of radio tagging, but in 2002 and 2003 we waited approximately a week before beginning the counts, to allow fish to recover more fully from surgeries. We attempted to complete underwater enumeration within the time period between approximately 0900 and 1500 hours Pacific Standard Time, to ensure that lighting conditions were optimal. Four experienced divers were used on each survey of the study area, which was sufficient to cover the entire usable width for most of the surveyed distance. 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 in counts had occurred. In areas where the usable width was less than 20 m, one or more divers would walk around the constriction or drift through behind the line of observers. We considered methods described elsewhere for organizing divers across the stream, such as marked ropes (Northcote and Wilkie 1963) or polyvinyl chloride pipes (Schill and Griffith 1984) held between divers, to be impractical for the Salmo River due to the length of the study reach and the need to travel efficiently, and the steep, complex nature of some areas within the section.

Observed fish were described as to species, and rainbow trout were classified into one of 5 size categories: 0-200 mm, 200-300 mm, 300-400 mm, 400-500 mm, and 500+ mm. Radio tagged fish were identified by their orange (2001-tagged), white (2002-tagged), or blue (2003-tagged) Floy tags, and observations were noted for comparison with telemetry results from that survey date. Only radio tags deployed during the same year that each observer efficiency study was conducted in were used for estimates of observer efficiency, so that the estimate of the number of tags still functioning in live fish could be considered reliable. Size estimation was practiced on models suspended in the water column at the survey start point. Underwater visibility (horizontal secchi disk distance) was recorded three times during each diver survey, at the beginning and completion of the survey and once at midday. At each location where visibility was estimated the stream was oriented in a southward-flowing direction, meaning the secchi disk's face was sunlit. Although this was a measure meant to standardize horizontal visibility estimates, we assumed that fish were less visible than the sunlit secchi disk and the actual distance at which they could be identified was less than the measured horizontal visibility.

Data Analyses

Size and age at maturity

Estimating the abundance of adult rainbow trout in the Salmo River mainstem was a goal of the study, which required that the body size at maturity be reliably determined. To estimate the age and size that fish spawned for the first time, we recorded signs of recent spawning activity for rainbow trout captured in June of both years, and compared these to patterns of scale growth and resorption from scale samples taken from 2001 captures. As the first step in scale analysis one scale suitable for analysis was identified under 36X magnification on a microfiche reader-printer, and a photograph was made. Cleaning of scales was not usually required. Regions of closely spaced circuli were identified as annuli. Each photographed scale was measured along the focus-anterior axis, the radius of each annulus and the outer scale margin being recorded. Spawning at a given age was suggested by, in order of the reliability we assigned to each: (i) signs of recent spawning (worn tail, loose belly, dark coloration) recorded at time of capture (for last annulus); (ii) patterns of broken or resorbed circuli at the annulus; (iii) substantial reductions in the scale annual growth increment (signalling onset of maturity) following steady, large growth increments; and (iv) no plus growth since the most recent annulus.

We investigated the relationship between fish length and scale radius for 37 Salmo River rainbow trout using simple linear regression (Zar 1996). Lengths at age were then back-calculated using the Fraser-Lee equation (Duncan 1980):

$$l_k = c + (L - c)r_k/R$$

where: l_k is the length at age k,

c is the constant of proportionality from the fish length/scale diameter regression

L is the fish length at time of capture

r_k is the radius of the annulus at age k

R is the scale radius at the time of capture

Observer efficiency
We compared observer efficiency (radio tags seen / radio tags known to be present) with two variables representing physical conditions for the surveys, horizontal underwater visibility (m) and discharge (m^3/s), using simple linear regression for untransformed and log-transformed data, respectively. We also used regression analysis to evaluate the relationships between diver counts of untagged fish and physical conditions, and the relationships between discharge and visibility. Only radio tags deployed during the same year that each observer efficiency study was conducted in were used for estimates of observer efficiency, so that the estimate of the number of tags still functioning in live fish could be considered reliable. Regressions were compared among years by multiple analysis of covariance (MANCOVA - Tabachnick and Fidell 2001).

Population estimates
For 2001, we generated the population estimates for Salmo River rainbow trout greater than 300 mm (available for harvest) and 400 mm from the estimated parameters C (average count in index section), λ (average diver observer efficiency), and r (average relative distribution of radio tags to the index section) utilizing stochastic simulations (Hilborn and Mangel 1997) within a Microsoft Excel spreadsheet. Each population estimate N was the average of 1,000 calculations of:

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

where in every iteration each of the parameter values was generated stochastically from the error structure observed for that parameter during the 6 surveys of the counting section. The 95% confidence intervals for the population estimates were taken to be the 2.5% and 97.5% percentiles from the cumulative distribution of the stochastic simulations.

In 2002 we conducted diver surveys along the majority of the mainstem length known to be important for adult rainbow trout during the same time period covered by the 2002 observer efficiency study. A swift canyon reach extending from the Seven-Mile Reservoir upstream approximately 5 km was not surveyed. In 2003 this reach was included in the census, as was the mainstem river between the town of Ymir and Hall Creek. The population estimates for the surveyed mainstem length were then:

$$N = \sum_{i=1}^{k} C_i / \lambda_i$$

where N is the population estimate (>300 mm or > 400 mm), C_i is the diver count for section i, λ_i is the estimated observer efficiency for section i, derived from the observer efficiency study, and k is the total number of stream sections. We estimated confidence intervals from the cumulative distributions of 1000 estimates of N (for each of the two size distributions), where λ_i was simulated stochastically for each section based on the most reliable overall relationship of observer efficiency to physical conditions for the combined data set. Standard errors for individual predictions of observer efficiency were computed using formulae in Zar (1996, p. 332), and these formed the basis for the stochastic simulations. Population estimates for both 2001 and 2002 were expanded based on the 2003 survey data to account for the reaches that were unsurveyed in 2001 and 2002 but that do contain trout >400 mm or >300 mm.

RESULTS

Transmitter Distribution and Biological Sampling

In 2001 the diver counts of harvestable rainbow trout (>300 mm) along the length of the Salmo River that were the basis for radio transmitter allocation took place on June 18 and June 19, 2001, 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 harvestable rainbow trout were distributed upstream of the town of Ymir, located 43 stream kilometers from the mouth at the Wildhorse Creek confluence (Figure 1). Harvestable 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 km) and a former bridge crossing located 17.3 stream kilometers from the mouth (‘burned out bridge’). Harvestable rainbow trout were again less prevalent in habitats downstream, especially downstream of the South Salmo River confluence (12.1 km).

Tag allocations (of 29 available) were 1, 3, 2, 5, 13, 3, and 2 for the Hall Creek (53.4 km) to Wildhorse Creek (43 km), Wildhorse Creek to Hidden Creek (34.7 km), Hidden Creek to Erie Creek (28.4 km), Erie Creek to Sheep Creek (22.8 km), Sheep Creek to former bridge (17.3 km), former bridge to South Salmo River (12.1 km), and South Salmo River 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 (Figure 2; Appendix II). 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 Carney Mill 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).

In 2002 and 2003, all 10 radio tags available were deployed in the counting section between Carney Mill Road in Salmo and the former bridge site (Figure 2; Appendix II), as they were to be used primarily in the observer efficiency study.

Capture information and body size data for individual fish are presented in Appendix II, for all three years. Salmo River rainbow trout are large. Fish sampled from the catch ranged in size from 250 mm to 600 mm, averaging a robust 450 mm (n = 51; SE = 11 mm). Visual evidence of physical maturity or recent spawning was noted, as fish captures in June (all three years) and early July (2002) were presumed to have taken place shortly after the completion of spawning activities. Of the 20 fish that showed evidence of spawning in spring 2001, and the 7 that showed evidence of spawning in spring 2002 (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.

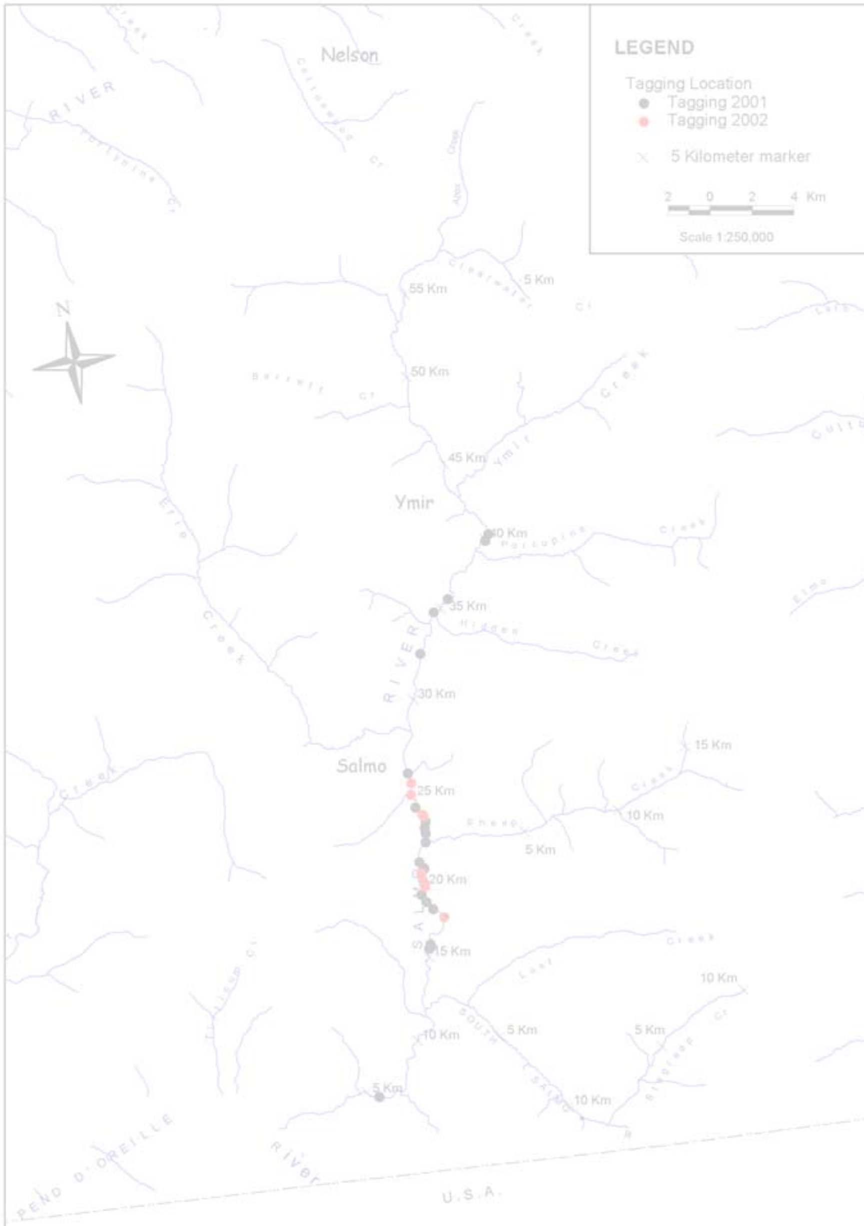

Figure 2. Capture locations of radio tagged rainbow trout in the Salmo River watershed, 2001-2003.

Of the 43 fish sampled for scales in 2001, readable scales were available for 37 fish ranging from 250 to 600 mm fork length (Appendix III). Scale diameter was a relatively good predictor of rainbow trout fork length (Figure 3; $r^2 = 0.77$), allowing back-calculation of lengths-at-age for a scale radius corresponding to a preceding annulus. Back-calculated average lengths-at-age were 310 mm (n = 37; SE = 7.2), 390 mm (n = 34; SE = 7.8), 440 mm (n = 29; SE = 9.1), 470 mm (n = 14; SE = 17), and 510 mm (n = 2; SE = 54) for ages 3 (end of third winter) to 7, respectively (Table 1). Of 37 readable scales, 27 were considered to have come from mature fish. Evidence of spawning on the scales was often subtle, so we employed as many indications as possible in assessing whether we should attribute a spawning event to a given annulus. Most Salmo River rainbow trout (70%, Table 1) appear to spawn for the first time at age 5s (after their fifth winter), with smaller numbers maturing at ages 4s (11%) and 6s (19%). Back-calculated lengths-at-first-maturity appear to agree well with the above visual observations of maturity status made during fish tagging, with the majority of fish appearing to have spawned for the first time at fork lengths between 375 and 475 mm (Figure 4). Back-calculated growth increments, which could only be estimated between ages covered by the regression equation, indicated growth in length is greatest in the fourth and fifth years of life and slows substantially after the fifth year (Table 1), supporting the notion that Salmo River rainbow trout begin spawning predominantly at age 5s.

Survival of Salmo River rainbow trout spawners appears to be high. Repeat spawners made up 48% of the sample of mature fish, 11% appeared to have spawned three or more times, and one fish in its eighth year appeared to have been a four-time repeat spawner based on a spawning checks at ages 4s and 5s (Appendix III). Their relatively good survival suggests that the angling exploitation rate for the population of adult fish, therefore, may be relatively low.

Genetic analyses were conducted by laboratory of Dr. E. B. Taylor, Dept. of Zoology, University of British Columbia, and were done concurrently with analyses of the genetic origins of wild-spawning rainbow trout in the Canadian portion of the Columbia River downstream of the Keenleyside Dam (Taylor 2002). Genetic samples from the Salmo watershed were available only from Clearwater Creek and the mainstem Salmo River. The Clearwater fish were the most divergent population in the study and exhibited a remarkable lack of genetic variation in the sample, which could be related to their headwater status or introduction with a small number of founders. Although the two populations (Clearwater and mainstem) were clearly genetically distinct from one another they did tend to share alleles to a large degree, but it was not clear that they were more closely related to each other than they were to other populations in the study (E.B. Taylor, fish geneticist, University of British Columbia, Vancouver, B.C.; personal communication). It should be noted that the Clearwater Creek sample was taken from upstream of a migration barrier, and genetic divergence between other tributary populations inhabiting reaches accessible to Salmo River spawners and the mainstem fish has not been investigated.

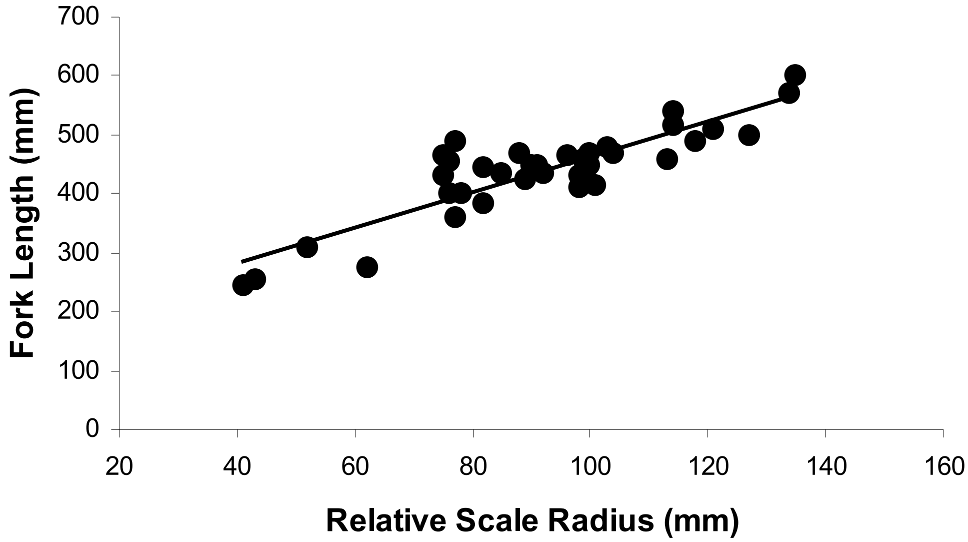

Figure 3. Relationship between fork length (mm) of sampled Salmo River rainbow trout and relative scale radius (mm) measured from scale photographs.

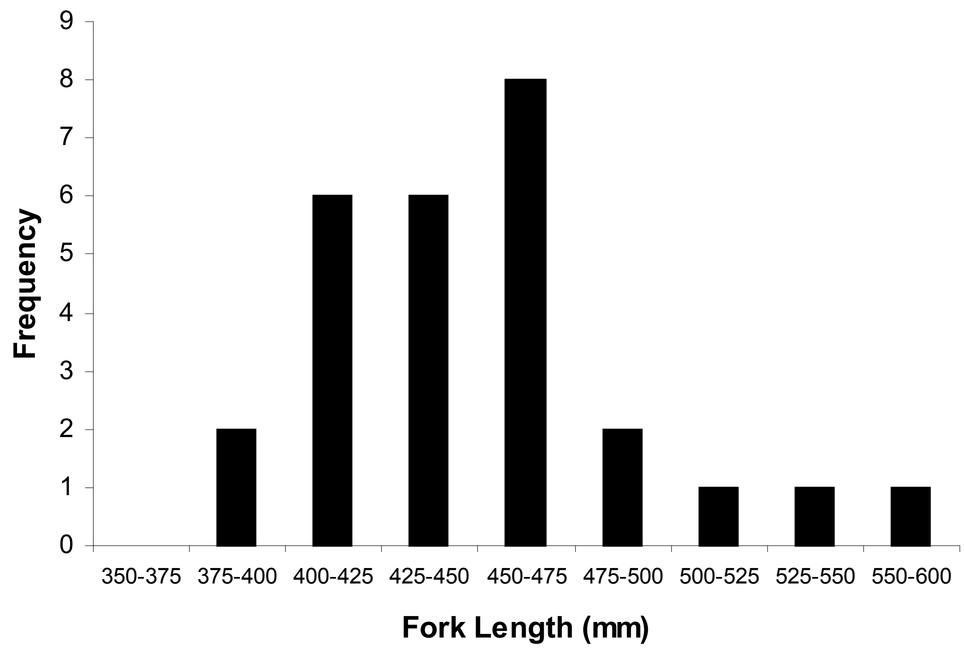

Figure 4. Fork length (mm) of Salmo River rainbow trout at first spawning, back-calculated according to the Fraser-Lee formula (Duncan 1980) from the scale radius (mm) at the annulus where evidence of spawning was suggested.

Table 1. Age, life history, and growth from scales of Salmo River rainbow trout sampled during springtime of 2001 (standard errors in parentheses).

	Age				
	III	IV	V	VI	VII
Sample size *n*	37	34	29	13	2
Avg. fork length (mm)	312 (6.5)	389 (7.8)	442 (9.1)	470 (17)	512 (54)
Preceding year growth (mm)	N/A	76 (4.3)	55 (4.6)	27 (4.1)	16 (1.5)
% mature	0	11	81	100	100

Habitat Use

The locations of radio tagged rainbow trout during each tracking event are presented in Appendix IV. For brevity, migration patterns of individual trout have not been included in this report.

Summer

As water levels dropped during the summer of 2001, most movements of radio tagged rainbow trout were small migrations of less than 2 km. Some fish (n = 9) made movements of 5-15 km, however, mainly upstream into deep-water pool habitat (Figure 5). In general, fewer locations were used by holding trout as the water dropped. In many cases several radio tagged fish moved into the same pool. Large, deeper pools with abundant overhead or wood cover were particularly important. During summer 2002, which had higher river discharge relative to 200l and 2003 (the two lowest levels of summer flow in the past decade), few longer migrations were observed (n = 2). Water temperature data collected during the summer, identified that water temperatures in the mainstem were well below upper limits of suitability for rainbow trout (21 ºC - Scott and Crossman 1973). In the summer of 2003 only one long migration was observed, a trout that moved downstream 4 km into deep pool habitat. In all years, tributary streams were not used by radio tagged trout during the summer. For the most part as water temperatures increased, fish moved into pools and areas of cover along the entire length of the mainstem Salmo River downstream of Ymir where these habitats were available. There was, however, an obvious avoidance of the channelized section of low complexity extending from the town of Salmo downstream to Hellroaring Creek (28.3-25.4 km; Appendix IV; Figure 5). Fish that migrated during the summer frequently moved through this section, but only one fish ever held in this area for an extended period, during July of 2002 (Appendix IV).

Winter

By the onset of winter in 2001 some redistribution of trout had taken place. In most cases these movements were small or non-existent from summer holding locations, but several fish did make downstream migrations of more than 10 km (Appendix IV; Figure 6). Suitable overwintering locations appeared to consist of mainstem areas of reduced flow

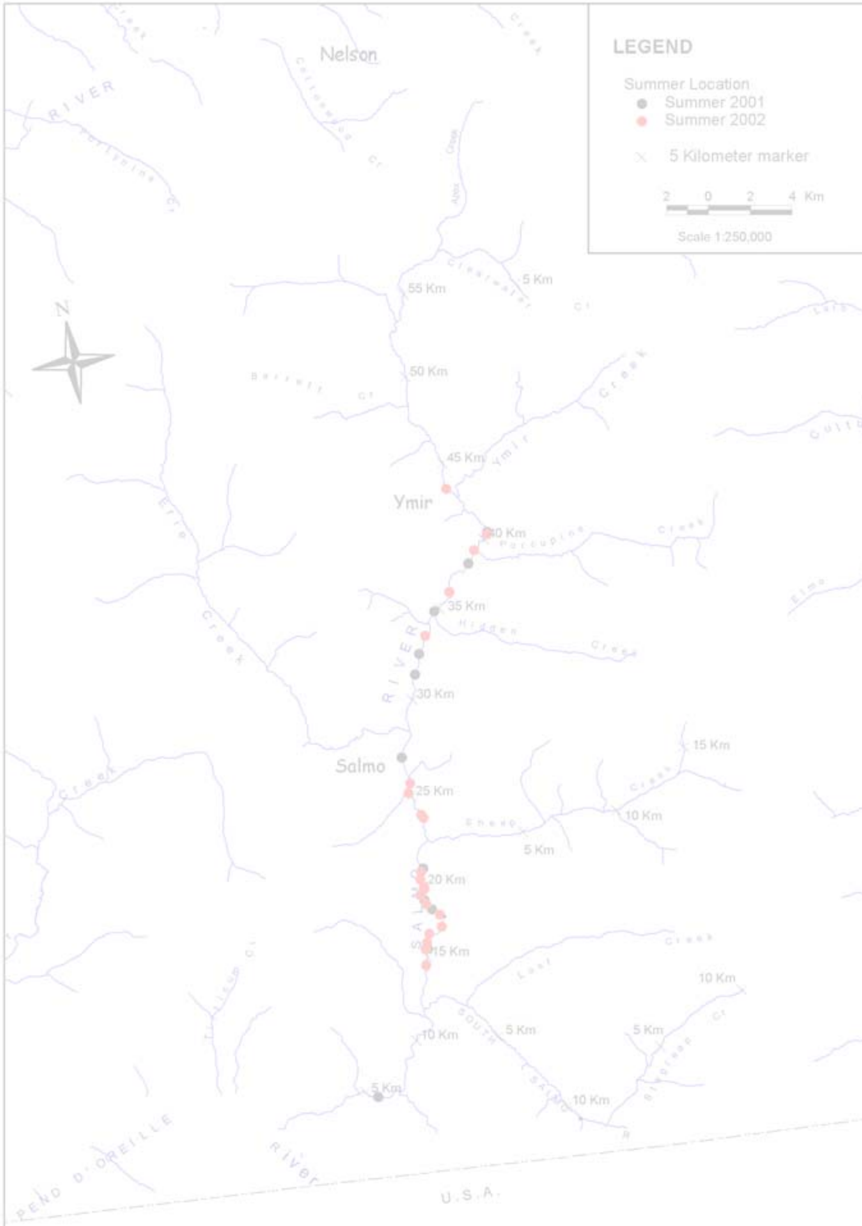

Figure 5. Summer locations of radio tagged rainbow trout in the Salmo River watershed, 2001-2003.

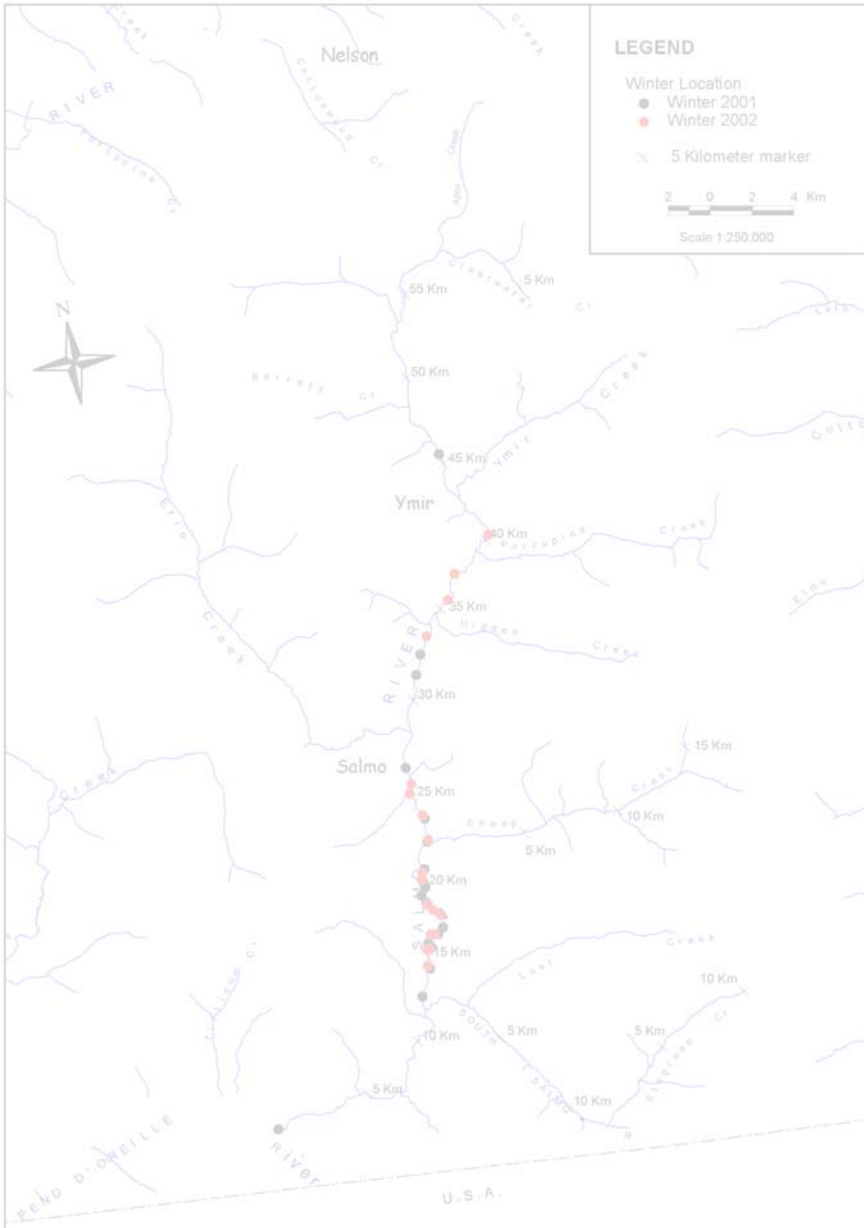

Figure 6. Winter locations of radio tagged rainbow trout in the Salmo River watershed, 2001-2003.

having an abundance of cover in the form of woody debris, deep pool areas, or boulder substrates (Appendix I-Plates G and H). The mainstem river from Salmo to Hellroaring Creek was again conspicuously avoided. One fish of note did migrate downstream to overwinter at the mouth of the Salmo River, and other significant overwintering areas were located at kms 16.0, 19.0, 19.9, 20.2, 32.3, and 35.7. Similar overwintering habitat use was observed on the only tracking event of winter 2002/2003, in December 2002, with some fish using the same pool in both years for overwintering (Appendix IV; Figure 6). During the winter tracking event of 2003/2004, only the ten radio tags deployed in trout in early summer of 2003 were still functioning. These trout tracked in March 2004, were found in the same general areas and habitat types that overwintering occurred in previous years (Appendix IV).

Spawning locations

Of the original rainbow trout radio tagged in the summer of 2001 (*n*=30), we did not receive signals from six tags after January of 2002. One of these tags is one known to have malfunctioned (fish recaptured with radio tag in place), and one fish was assumed dead before the tag signal was lost. It is unknown what the fates of the additional four tags were. In addition, two tags are known to have been either expelled or removed from live fish (angling recaptures), and one fish was assumed to have died soon after capture based on a complete lack of movement after tag implantation. The remaining 21 radio tagged rainbow trout from 2001 provide data for spawning movements and locations.

During the spring of 2002, weekly tracking events in May and June covered as much of the watershed as was feasible and that was thought to provide at least some opportunity for spawning. An initial tracking survey in the first week of March 2002, identified that no radio tagged trout had begun spawning migrations. Following this, three tracking events occurred in April, five tracking events occurred in May, and four tracking events occurred in June. The weekly tracking schedule was an attempt to ensure that the entire potential spawning period was surveyed, and that the resolution of the surveys was sufficient to detect spawning movements and locations.

The first movement that appeared to be associated with spawning took place in the third week of April, when two radio tagged trout began upstream migrations (Appendix IV). These movements occurred during an abrupt increase in discharge in early spring. It appears that the spawning period in 2002 extended from early May to mid-June (Appendix IV), with peak spawning occurring between the third week of May and early June (Appendix IV). This period corresponded approximately with mainstem water temperatures of 5°C or greater, and with the ascending limb of the hydrograph. Redds were identified during tracking surveys (Appendix I-Plates I and J) as early as May 9 (Table 2; Figure 7) but after mid-May it was virtually impossible to enumerate redds due to high water and poor visibility.

In spring of 2002, radio tagged Salmo River rainbow trout appeared to use primarily mainstem areas for spawning. Suspected spawning locations were distributed along the length of the mainstem Salmo River where there was suitable habitat, with concentrations being noted at km 18-21, 23-26, 31-32, and 34-37 (Figure 7). Within the mainstem Salmo River, redds visually identified during tracking were located in sidechannel areas and the near the margins of the mainstem channel. The only use of the channelized section downstream of Erie Creek that we observed was a redd constructed in a small sidechannel area near km 26.2. Spawning migrations were suspected in the telemetry record when a period of migration of radio tagged fish was followed by relatively brief period of holding at a new location that was followed by relatively rapid migration back in the direction from where the fish had come.

Table 2. Known rainbow trout redd locations in the Salmo River, 2002.

Date	Mainstem Location (km)	Habitat	Number of Redds	Radio Tagged Fish Present in Area
05/09/02	26.2	Sidechannel	1	Y
	23.8	Mainstem	2-3	Y
	20.7	Sidechannel	2	Y
05/15/02	43-45	Mainstem	2	Y
	37	Mainstem	1	Y
	30.9	Mainstem	1	Y
	17.6	Mainstem	1	Y

Of the 21 fish that were available to provide spawning data, nine (44%) made spawning migrations of greater than 5 km (Appendix IV), with three of these nine fish (33%) making movements into the lower reaches of tributaries (Sheep Creek and Erie Creek). No redds were identified in tributaries, but it appears likely that these fish spawned there. The greatest distance that a radio tagged fish was found upstream in a tributary was 1.9 km upstream in Sheep Creek, on May 24 (Appendix IV). We could not determine whether the remaining 12 trout did spawn, so the actual proportion of the adult population using tributaries for spawning is unknown. It is also possible that spawning movements are too limited for some fish to clearly be identified in the telemetry record. All of the 21 fish either made small migrations (0-2 km) within the suspected spawning period, made downstream migrations after the spawning period, or were located in proximity to known redd locations (Appendix IV; Figure 7).

Radio tagged trout also appeared to make non-spawning migrations into off-channel areas of refuge during high water runoff. From May 25-29, 2002 water discharge increased rapidly in the river from 122 to 273 m^3/s, and during this period we observed movements into sidechannel and off-channel habitats (Appendix I-Plates K and L). One off-channel area in particular, located near the Salmo golf course (km 23.5-24.1), was used by five radio tagged trout.

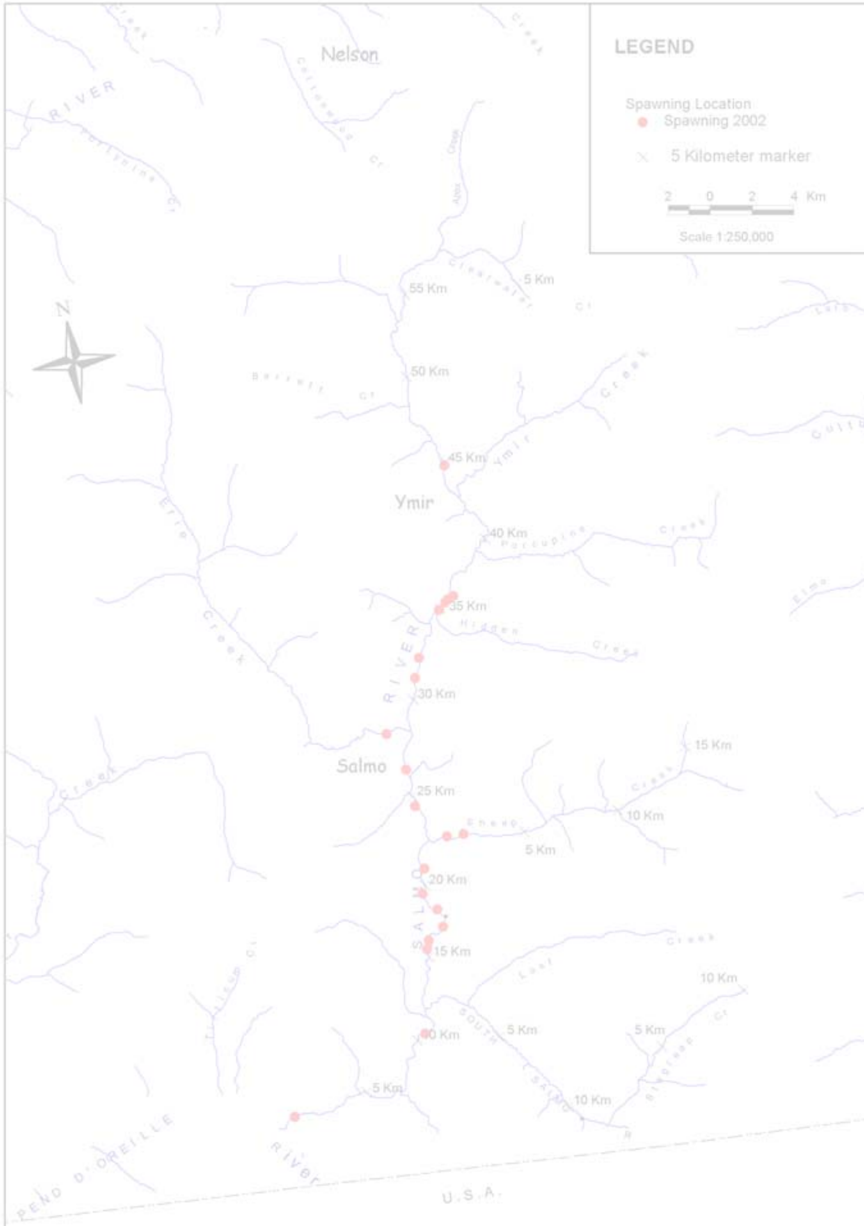

Figure 7. Spawning locations of radio tagged rainbow trout in the Salmo River watershed, 2002-2004.

During the spring of 2003, an initial tracking event was conducted in early April, and monitoring of the same areas surveyed in spring 2002 was then carried out weekly from late April to mid-June. Six tracking events took place in May, and two tracking events in June of 2003 (Appendix IV).

A total of 12 trout provided data on spawning movements and habitat in spring 2003, three trout that had been initially tagged in 2001 (one of which was retagged in 2002 as the radio tag had been expelled) and an additional nine that were radio tagged in 2002. In 2003, only one trout made an extensive upstream migration of greater than 10 km to spawn, with the majority of trout making small upstream or downstream migrations of less than 2 km to suspected spawning areas (Appendix IV; Figure 7). One trout did not migrate during the spawning period but was assumed to have spawned as it had moved upstream from its overwintering site. Spawning was concentrated in the last two weeks of May (Appendix IV) and occurred quickly as water temperatures rose above 5°C and on the ascending limb of the hydrograph (as in 2002).

Again in 2003, the majority of radio tagged trout (91.7%) were detected only in the mainstem Salmo River during the spawning period, with areas associated with sidechannels being important. One fish spawned in Erie Creek approximately 2.7 km upstream from the mouth. A female trout that moved into Sheep Creek during the 2002 spawning period was detected only in the mainstem Salmo River in 2003 (Appendix IV). Important areas for spawning appeared to be located at km16-24, 26.2, 30.5, and 35.

Spawning period radio telemetry observations in the spring of 2004 (for the 10 trout radio tagged in the summer of 2003) were generally consistent with previous years. During the seven tracking events that occurred in May and June all ten trout were tracked on the majority of occasions, and all ten appeared to be alive during the spawning period (Appendix IV; Figure 7). The telemetry data suggested that the spawning period extended from early May to early June in 2004, with a peak in activity occurring from mid to late May (Appendix IV). Most trout exhibited behaviour consistent with spawning in this two-week period, indicated by relatively rapid migration (predominantly upstream in 2004) away from overwintering areas, holding at a potential spawning location for a period of time, and a subsequent migration in the direction from which it had come (Appendix IV).

Only one of the ten trout moved into a tributary during the spawning period. This trout moved into Sheep Creek, a previously identified spawning tributary, but travelled substantially further upstream than had been previously recorded, being found as much as 5 km upstream from the mouth during its two-week residence. The overlap in spawning areas for mainstem Salmo River rainbow trout and suspected tributary resident populations suggests that there may be a spawning interaction between the fluvial and resident populations. It may also be possible that discharge conditions in the spring of 2004 were more suitable for upstream migrations in tributaries relative to the two previous years, as the run off during the spawning period was relatively low and sustained.

Of the nine trout that did not leave mainstem areas during the spawning period (Appendix IV), three are suspected to have spawned in sidechannel areas parallel to the mainstem channel. A redd was observed in a sidechannel at km 35.0 used by a radio tagged fish during the spawning period. In general these areas provide ideal habitat characteristics for spawning (lower flows, abundance of gravel, abundance of cover). Other areas where trout were found during the spawning period in the mainstem channel of the Salmo River were predominantly areas where redds have been observed in previous years. These locations were typically areas where there was an abundance of gravel in proximity to cover that provided a velocity refuge and/or overhead protection.

Again in 2004, during high discharge events associated with intense precipitation, some radio tagged trout moved into off-channel habitat that provided a velocity refuge. These specific areas were surveyed and do not provide any spawning habitat, but were used during high flow events in both 2002 and 2004.

The life history observations of one female trout in particular are worth noting because of this fish's exceptional longevity. On June 20, 2001 the fish was captured, measured at 600 mm and implanted with a radio transmitter. At the time of initial capture the female was a kelt (Appendix II) and a double repeat spawner, spawning first at age 5 and being six years old (Appendix III). In the summer of 2002, this fish was recaptured again as a kelt, still 600 mm in length, but had lost its radio tag. This would make it a triple repeat spawner and seven years of age. The trout was implanted with another radio tag in 2002 and was seen several times by divers in July of 2002. The fish had reconditioned nicely during that summer, and the spawning tracking data suggested that she spawned again in the spring of 2003. If this was the case, the fish was a four time repeat spawner in her ninth year in the spring of 2003.

Observer Efficiency

During the first year of the radio telemetry study in 2001 a primary goal was to identify habitat use patterns in the watershed, so radio transmitters were deployed in adult rainbow trout along the entire length of the mainstem Salmo River. Eighteen transmitters were distributed to our 9.0 km observer efficiency study section in spring 2001, and during surveys between June 28 and July 30 the number of radio tagged trout that appeared to be alive and were present in the counting section ranged from 11 to 15. One radio tagged fish did not move from the surgery site and was never seen by divers, and was therefore considered dead and not included in the observer efficiency estimates. Ten radio transmitters were deployed in adult trout in 2002, all in the study section. During seven surveys of the counting section between July 9 and August 1, the number of transmitters that were functioning in live fish in the section ranged from 8 to 10. All tagged fish were visually identified at least once by divers and showed movement in the telemetry record consistent with their being alive during the entire study period. In 2003 we again deployed 10 radio transmitters in the study section, and similar to 2002 all fish were seen at least once and considered alive for the four surveys between July 2 and July 18.

Whether an observed rainbow trout was tagged or not was readily apparent to divers in 2001 and 2002, when pairs of anchor tags inserted into each fish's back were orange and white, respectively. In contrast, divers considered the blue tags used in 2003 to be less visible, and suggested that experience in looking for tagged fish (the antenna trailing behind the fish and profile of the fish's back were also clues) was essential to reliably determine whether fish seen at a distance were tagged or not. During the annual population census, three of four divers that surveyed our study section on July 10, 2003 did not have experience searching for radio tagged fish in fast water, which had not been the case for any other survey. Although we used counts of untagged trout from this survey in our analyses we did not use the observer efficiency data, which required reliable determination of whether fish were tagged or not.

Observer efficiency estimates made from observations of radio tagged trout were positively related to levels of horizontal underwater visibility in our study reach (Figure 8), but the strength of correlation among the variables was inconsistent among years (see Table 3 for regression data summary). During 2001, the range of visibility conditions over which observer efficiency estimates were made was limited relative to 2002 and 2003, and four of seven estimates were clustered between 10.1 and 11.2 m visibility. Variability in horizontal visibility explained only 4.3% of the variability in observer efficiency for 2001, and the regression was not significant ($P = 0.65$). In contrast, observer efficiency was significantly related to horizontal visibility in both 2002 ($P < 0.001$) and 2003 ($P < 0.001$), with 76% and 99.8%, respectively, of the variability in observer efficiency being explained by visibility changes.

The same patterns in observer efficiency were evident with respect to the three years' discharge data (Figure 9). Variability in log-transformed discharge explained only 3.5% of the variability in observer efficiency for that year, and the regression was not significant ($P = 0.69$). Observer efficiency was significantly and linearly related to log-transformed discharge in both 2002 ($P = 0.003$) and 2003 ($P = 0.018$), with 85% and 96%, respectively, of the variability in observer efficiency being explained by discharge changes.

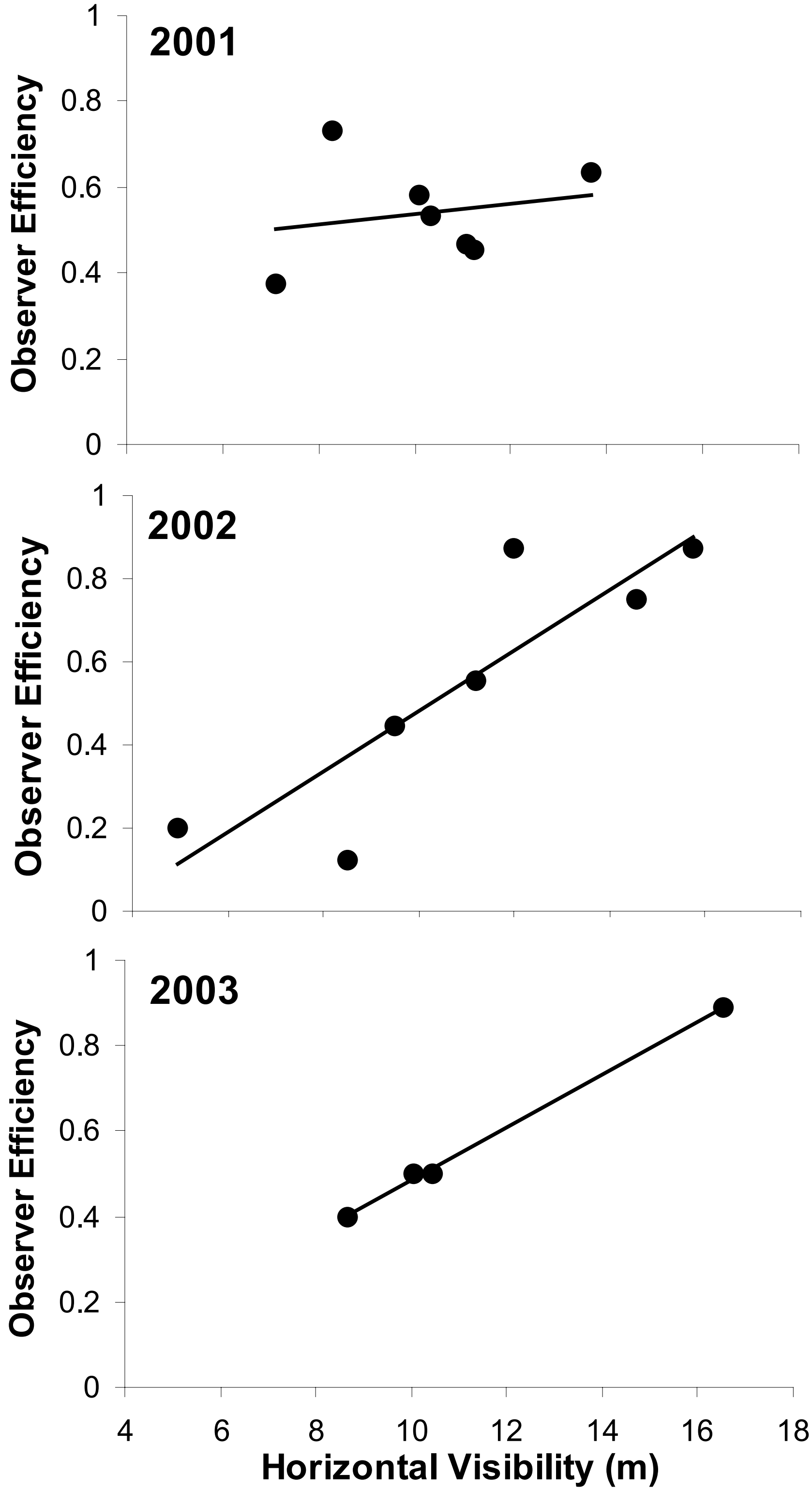

Figure 8. Observer efficiency estimates (number of tagged fish seen relative to the number known to be present) versus horizontal underwater visibility for three years (2001-2003) of periodic surveys in the Salmo River, British Columbia.

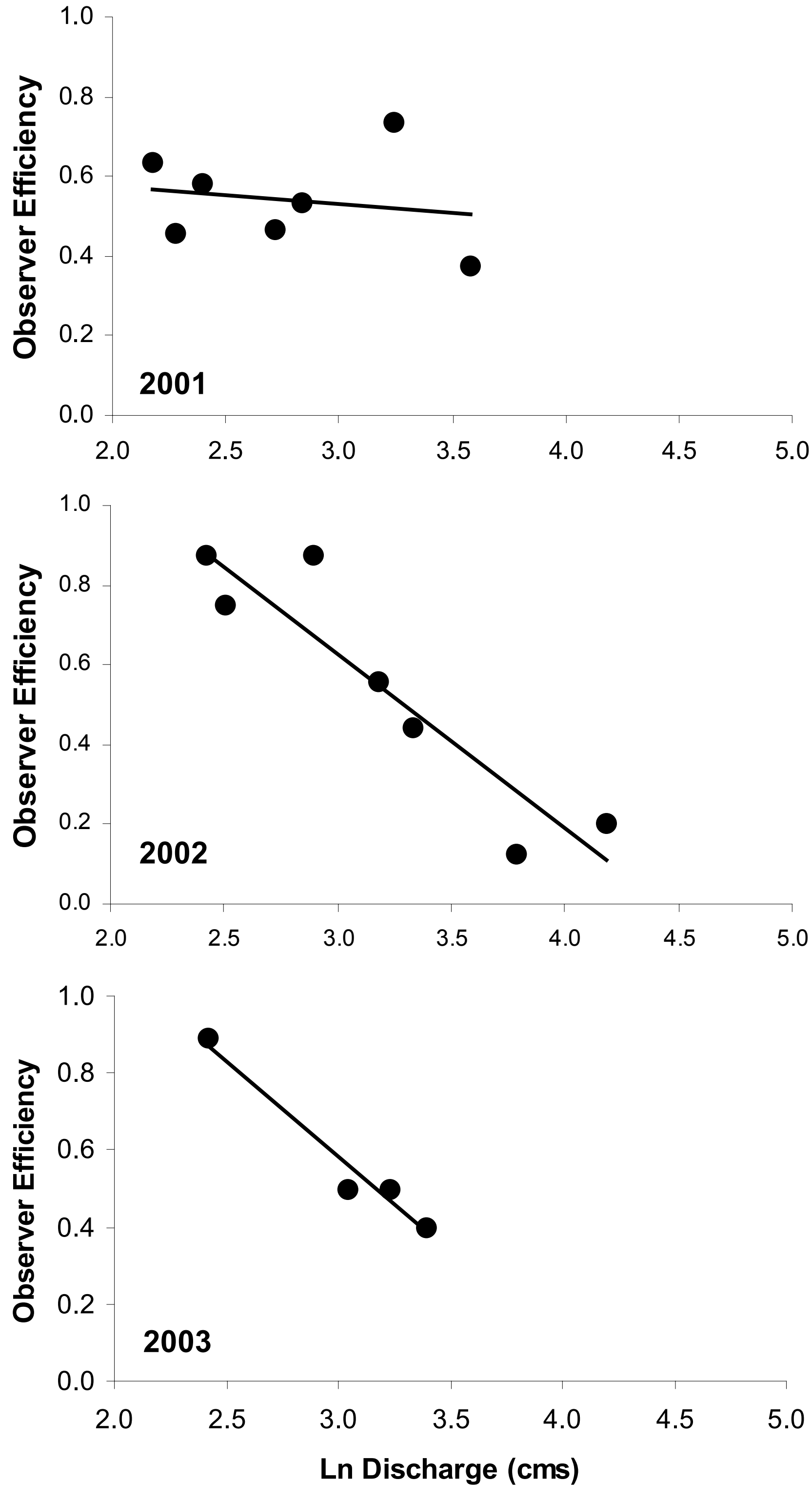

Figure 9. Observer efficiency estimates (number of tagged fish seen relative to the number known to be present) versus log-transformed discharge past the Water Survey of Canada station for three years (2001-2003) of periodic surveys in the Salmo River, British Columbia.

Table 3. Regression analysis summary, Salmo River rainbow trout observer efficiency study.

Year	Regression equation	r^2	P	n
2001	$Obs = 0.0119Vis + 0.419$	0.043	0.66	7
	$Obs = -0.0437LnDis + 0.661$	0.035	0.69	7
	$>300 = 3.56Vis + 97.0$	0.153	0.083	7
	$>400 = 0.475Vis + 46.9$	0.0096	0.85	7
2002	$Obs = 0.0729Vis + 0.249$	0.76	0.01	7
	$Obs = -0.437LnDis + 1.94$	0.85	0.003	7
	$>300 = 9.24Vis - 36.1$	0.94	<0.001	7
	$>400 = 4.15Vis - 13.5$	0.93	<0.001	7
2003	$Obs = 0.0618Vis - 0.134$	0.998	<0.001	4
	$Obs = -0.498LnDis + 2.08$	0.96	0.018	4
	$>300 = 11.6Vis - 23.7$	0.94	0.007	5
	$>400 = 4.82Vis - 9.56$	0.87	0.021	5
Combined*	$Obs = 0.0638Vis - 0.158$	0.76	<0.001	17
	$Obs = -0.267LnDis + 1.35$	0.48	0.001	18

* Note: outlier from June 28, 2001 removed for *Obs* vs. *Vis* regression

Because correlation values for observer efficiency regressions with such few data points should not be considered realistic (Thompson 2003), and because we were interested in whether general relationships between the variables could be described for population estimation purposes, we investigated whether combining the three years' data was feasible. We were not able to detect differences statistically among the annual observer efficiency regressions for either visibility (MANCOVA; $P = 0.98$) or log-transformed discharge ($P = 0.29$). A visual inspection of the observer efficiency versus visibility regression for the combined data set (Figure 10) indicated that the annual data overlapped, suggesting that pooling the data was reasonable. For the combined, three-year data set horizontal visibility, which ranged from 5.0 to 16.5 m (average = 10.9 m), was a significant predictor of diver observer efficiency ($r^2 = 0.62$, $P < 0.001$), which ranged from a minimum 0.13 to a maximum of 0.89 (average = 0.54). We created a general relationship of observer efficiency to underwater visibility for use in Salmo River population enumeration by removing the outlier from June 28, 2001 (Figure 10; studentized residual = 3.67), after which variation in visibility explained 76% of the variation in observer efficiency.

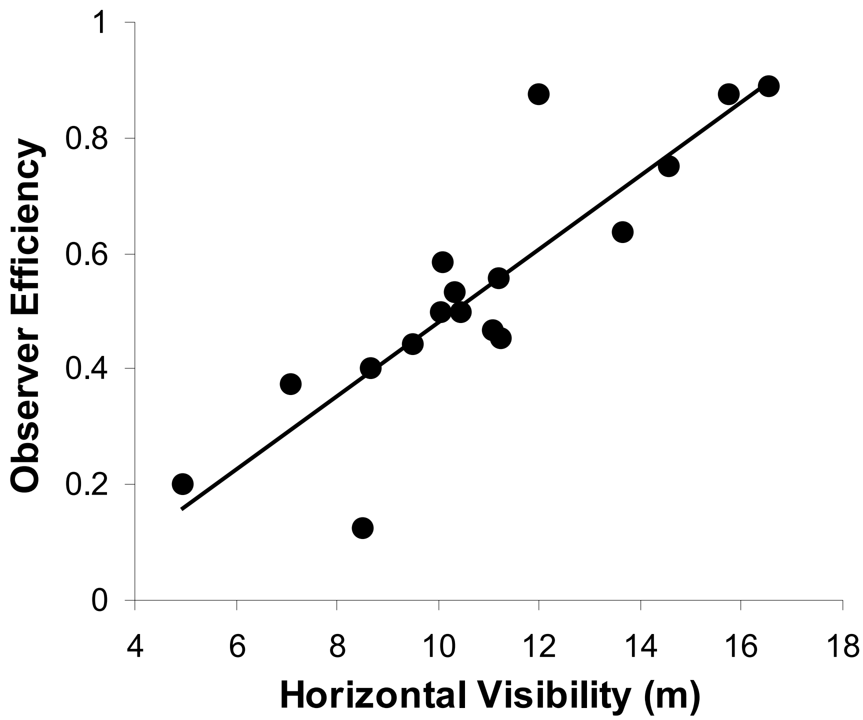

Figure 10. Observer efficiency estimates (number of tagged fish seen relative to the number known to be present) versus horizontal underwater visibility for three years' combined data (2001-2003) from periodic diver surveys in the Salmo River, British Columbia.

Log-transformed discharge was also a significant predictor of observer efficiency for the combined data set ($P = 0.001$), but explained less of the variation in observer efficiency ($r^2 = 0.56$). Overlap in the annual data (Figure 11) appeared to be less than for the observer efficiency/visibility plot, suggesting the possibility that the relationship between discharge and visibility was not consistent from year to year, but that the observer efficiency/discharge relationships were not precise enough annually to detect it statistically. We were in fact able to detect a significant difference among the annual relationships between the discharge and visibility variables (MANCOVA, $P = 0.001$), although each of these relationships was highly precise on its own. We did not, therefore, make any further use of the overall relationship of observer efficiency to log-transformed discharge in estimating the population of rainbow trout in the Salmo watershed, as discharge appeared to be a less reliable as well as a less direct (i.e. cannot be determined at the time of the survey or specifically in individual stream sections) index of diver count accuracy relative to underwater visibility.

In order to corroborate the relationships of observer efficiency of radio tagged trout to visibility (Figures 8 and 10), we also examined counts of untagged rainbow trout in the study reach (Figure 12). The notion that a positive, linear relationship exists between observer efficiency and horizontal visibility was supported by precise, significant relationships between counts of trout and visibility for both 2002 (>300 mm: $r^2 = 0.94$, $P < 0.001$; >400 mm: $r^2 = 0.93$, $P < 0.001$) and 2003 (>300 mm: $r^2 = 0.94$, $P = 0.007$; >400 mm: $r^2 = 0.87$, $P = 0.021$). The *P*–value for the 2003 regression of counts of trout >400 mm was not significant after the sequential Bonferroni adjustment of the critical value (Holm 1979, as cited in Rice 1989). The poor quality, non-significant relationship between counts of untagged trout and visibility in 2001 (>300 mm: $r^2 = 0.48$, $P = 0.083$; >400 mm: $r^2 = 0.010$, $P = 0.85$) was consistent with the relatively poor observer efficiency relationship for that year.

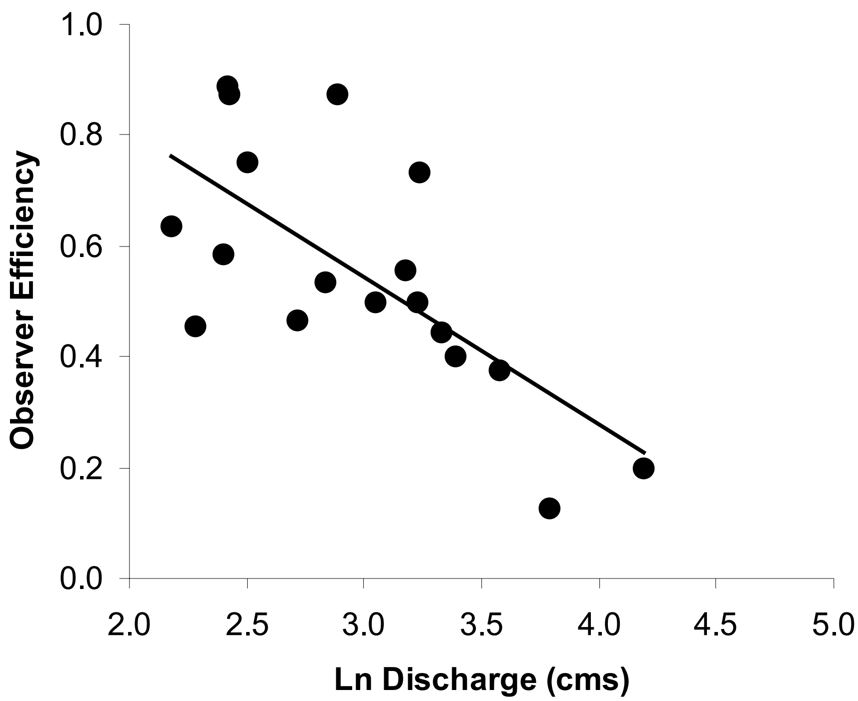

Figure 11. Observer efficiency estimates (number of tagged fish seen relative to the number known to be present) versus log-transformed discharge past the Water Survey of Canada station for three years' combined data (2001-2003) from periodic diver surveys in the Salmo River, British Columbia.

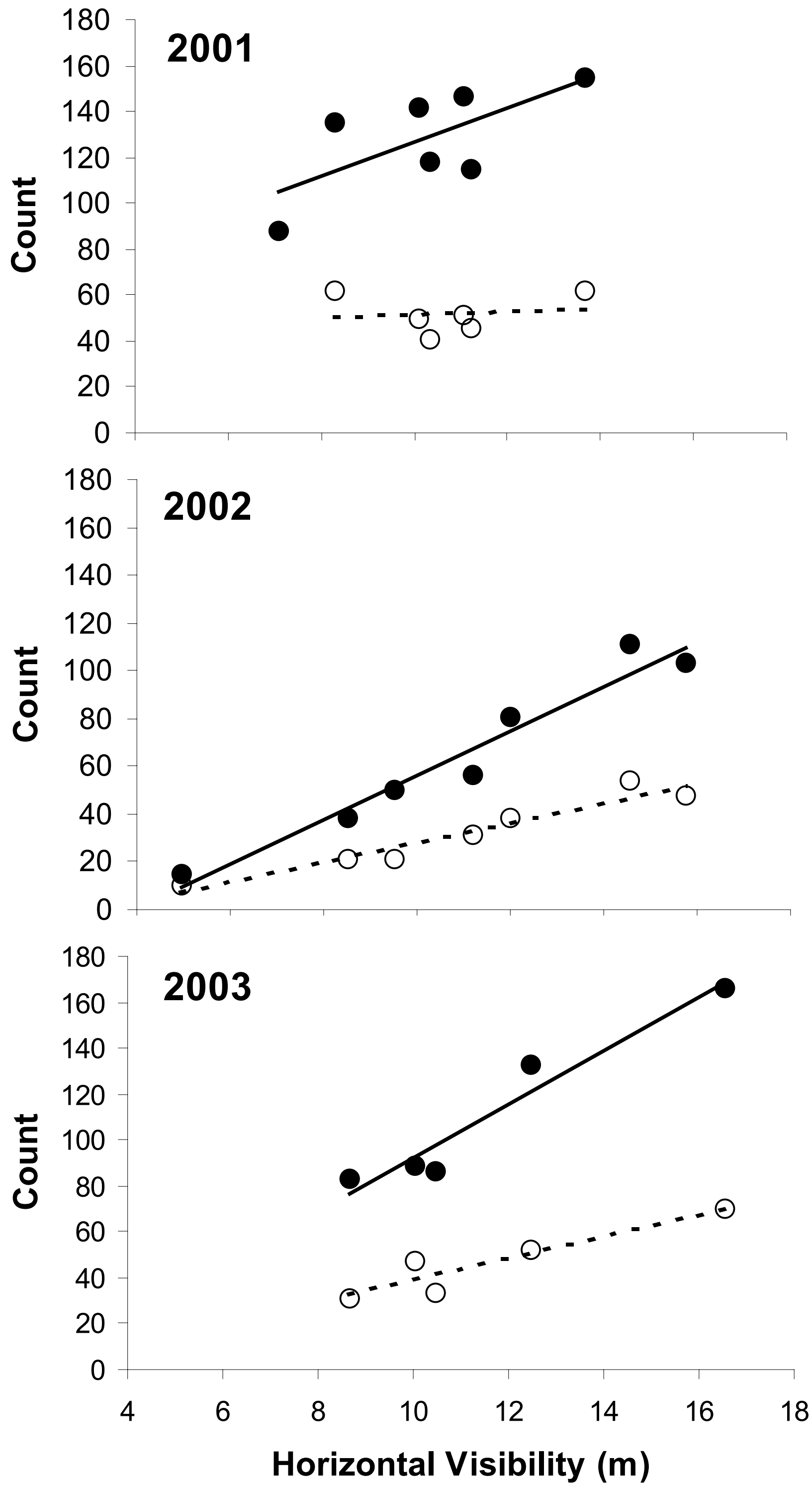

Figure 12. Counts of untagged rainbow trout >300 mm (solid circles) and >400 mm (open circles) versus horizontal underwater visibility for three years (2001-2003) of periodic surveys in the Salmo River, British Columbia.

2001 Population Size Estimates
Parameter estimation
Average diver counts (C) of rainbow trout in the index section between June 28 and July 30 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 0-200 mm, 200-300 mm, 300-400 mm, 400-500 mm, and >500 mm, respectively (Table 4; Appendix V). It is important to note that these estimates do not include the diver counts for June 18, which were made during the surveys along the surveyed length of the Salmo mainstem. Counts on that date were only for the size category >300 mm in order to increase the distance divers could cover each day, and furthermore we were interested in the population estimate for July specifically, for comparison with future surveys. Either strong recruitment to the mainstem Salmo, marked behavioural shifts, or increased observer efficiency relative to larger fish was documented for parr less than 200 mm over the course of the study (Table 4; Appendix V). Strong patterns were not obvious for other size classes with the possible exception of the 200-300 cm fish, which increased to stable levels after a low initial count on June 30 (possibly indicating recruitment or observer efficiency changes). It is important to note, however, that the above comments are only speculative, as these topics were not investigated directly.

Table 4. Diver counts of rainbow trout in the index section of the Salmo River, 2001.

Date	0-200 mm	200-300 mm	300-400 mm	400-500 mm	500+ mm
28-Jun-01	161	64	73	55	7
04-Jul-01	287	147	77	35	6
06-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

Observer efficiency (λ, radio tags seen/radio tags known to be present) for radio tagged, Salmo River rainbow trout averaged 0.57 and was relatively stable (SE = 0.043) over the counting period as described above. Again, this estimate does not include the observer efficiency estimate for June 18 because counts of rainbow trout on this date were not made for the size category >400 mm, and we were interested in population estimates for July for comparative purposes. It is also important to note the study's assumption that observer efficiency for all rainbow trout greater than 300 mm in length can be described by observations of tagged fish that were necessarily greater than 350 mm (minimum size requirement for the size of the implanted transmitter).

The relative distribution (r) of radio tagged fish to the counting area was relatively stable between June 28 and July 30, averaging 47% (SE = 3.0%) of the total. Because the allocation of radio tags was based on the relative distribution of fish >300 mm 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. One of these tagged fish was assumed to have died shortly after tagging, as it never showed any movement from the tagging location and was never seen by divers. It was removed, therefore, from the calculation of the observer efficiency and relative distribution estimates.

Population estimates

The population estimates for Salmo River rainbow trout greater than 300 mm (available for harvest) and 400 mm (estimated breeding population) were made utilizing the average values for the parameters and were not based on the regressions with watershed physical conditions, which were not significant during 2001 as described above. The relative consistency and good precision of each, however, suggested that reliable population estimates based on average values were feasible. Average diver count, observer efficiency, and relative distribution parameters were stochastically simulated 1000 times and combined to generate an estimate of 496 (SE = 54.2; 95% CI: $401 < N < 606$) for rainbow trout >300 mm for the surveyed section of the mainstem Salmo River. Because rearing habitats in the canyon comprising the lower 5.7 km of the Salmo were not taken into account in this estimate, the estimate was expanded by a factor equal to the relative proportion of the 2003 population residing in the unrepresented reaches, or 18%. The resulting population estimate of rainbow trout >300 mm in the mainstem of the Salmo River for 2001 was 605 (SE = 66.1; 95% CE: $489 < N < 739$). The relative precision of this estimate, expressed as the average confidence interval as a proportion of the mean, was 0.21, within the 0.25 target recommended by Robson and Regier (1964) for management experiments. The estimated size of the population of rainbow trout >400 mm for the mainstem Salmo was 233 (SE = 27.3; 95% CI: $184 < N < 289$). The relative precision of this estimate was 0.23, also within the 0.25 threshold. We expect the accuracy of this latter estimate to be relatively high, as fish >400 mm were disproportionately represented in the radio tagged group.

2002, 2003 Population Size Estimates

Parameter estimation

To estimate the size of the Salmo River rainbow trout population in July 2002 we swam the mainstem from the town of Ymir (lower Porto Rico Rd. bridge) downstream to the top of the canyon over a four-day period between July 22 and July 25 inclusive. Rainbow trout observations in all size categories were recorded, unlike the survey of the mainstem Salmo in June 2001 (Table 5; Appendix V). Over five days in July 2003 (July 7-July 17), we swam the same stream reaches but with additional swims to include habitats upstream of Ymir to Hall Creek, and to include the previously-unsurveyed 5.7 km canyon reach above Seven Mile Reservoir (Table 6; Appendix V).

Table 5. Diver counts of rainbow trout in the Salmo River watershed, July 22-25, 2002.

Section	Date	Counts				
		<200 mm	200-300 mm	300-400 mm	400-500 mm	>500 mm
Ymir-Porcupine C	25-Jul	135	26	7	6	0
Porcupine C-Hidden C	25-Jul	128	15	7	5	1
Hidden C-Erie C (Salmo)	24-Jul	39	27	14	7	2
Erie C to Carney Mill Rd.	24-Jul	21	4	1	1	0
Carney Mill-Sheep C	22-Jul	110	41	16	8	5
Sheep C-Burned Out Bridge	22-Jul	177	98	27	19	6
Burned Out Bridge-Swift C	23-Jul	166	48	29	18	4
Swift C-Canyon	23-Jul	478	135	23	6	0
Total		**1254**	**394**	**124**	**70**	**18**

Table 6. Diver counts of rainbow trout in the Salmo River watershed, July 07-17, 2003.

Section	Date	Counts				
		<200 mm	200-300 mm	300-400 mm	400-500 mm	>500 mm
Hall C-Ymir	07,08-Jul	51	17	5	0	0
Ymir-Porcupine C	08-Jul	17	14	13	3	0
Porcupine C-Hidden C	08-Jul	12	39	9	5	0
Hidden C-Erie C (Salmo)	10-Jul	55	31	7	3	2
Erie C to Carney Mill Rd.	10-Jul	26	3	0	1	0
Carney Mill-Sheep C	10-Jul	66	38	18	12	3
Sheep C-Burned Out Bridge	10-Jul	102	76	63	28	9
Burned Out Bridge-Swift C	09-Jul	105	89	22	8	2
Swift C to WSC station	09-Jul	53	68	15	6	0
WSC station to top of canyon	17-Jul	246	90	40	5	1
Top of canyon to Reservoir	17-Jul	853	254	50	8	0
Total		**1586**	**719**	**242**	**79**	**17**

Counts among sections may not be directly comparable for smaller fish, as observer efficiencies are unknown, but apparently intensive use of the lowermost reaches of the mainstem by juvenile trout (<200 mm) are noteworthy.

Because the time periods of the two years of the watershed census were within that covered by the observer efficiency study, and observer efficiency during 2002 and 2003 appeared to be strongly related to underwater visibility, we were able to estimate observer efficiency for each stream section surveyed from the overall regression of observer efficiency on visibility (Figure 10). Horizontal underwater visibility was recorded for each day, and that visibility measure was used to estimate observer efficiency using the overall regression equation (Table 3).

Population estimates
Population estimates for each section and their uncertainty (2002: Table 7; 2003: Table 8) were generated by factoring counts together with stochastically simulated observer efficiency values, which were generated from the standard errors for each predicted value of observer efficiency from the regression relationship (Zar 1996). The overall population estimate for 2003 (Table 8) was derived by summing the stochastically simulated section estimates. The Hall Creek to Ymir section that was omitted in 2002 was not important for larger rainbow trout in 2003, containing only 1% of the total >300 mm and no fish >400 mm (Table 8). However, in 2003 substantial use by larger rainbow trout occurred in the previously unsurveyed 5.7 km canyon above Seven Mile Reservoir, where 9% of trout >400 mm and 18% of trout >300 mm were found.

Table 7. Population estimates for rainbow trout in the Salmo River watershed, July 22-25, 2002.

Section	Date	Average visibility	Observer efficiency	Estimate >300mm *N*	LCI	UCI	Estimate >400mm *N*	LCI	UCI
Hall Creek-Ymir*	na			5			0		
Ymir-Porcupine C	25-Jul	13.8	0.72	18	14	26	8	6	12
Porcupine C-Hidden C	25-Jul	13.8	0.72	18	14	26	8	6	12
Hidden C-Erie C (Salmo)	24-Jul	11.7	0.55	42	30	71	16	12	28
Erie C to Carney Mill Rd.	24-Jul	11.7	0.62	3	2	5	2	1	2
Carney Mill-Sheep C	22-Jul	12.1	0.61	48	35	74	21	16	33
Sheep C-Burned Out Bridge	22-Jul	12.1	0.61	86	63	141	41	30	68
Burned Out Bridge-Swift C	23-Jul	10.7	0.51	99	70	171	43	30	74
Swift C-Canyon	23-Jul	10.7	0.54	54	39	94	11	8	19
Canyon-Reservoir*	na			82			15		
Total				**454**	**399**	**586**	**166**	**145**	**216**

***Note: not surveyed - estimate derived from the proportions of the total count in 2003 found in these sections**

The pattern of trout abundance along the mainstem of the Salmo River was roughly similar for 2002 and 2003 (Tables 7 and 8). Habitats upstream of the town of Ymir do not appear to be utilized intensively by larger trout, and abundances are relatively low between Ymir and Salmo. Larger trout are almost completely absent from the channelized section extending downstream of the town of Salmo to Hellroaring Creek (Carney Mill Rd. in Tables 7 and 8). Abundances increase in habitats downstream reaching a peak for both years in the stream section downstream of Sheep Creek. Trout >300 mm in length are abundant along the entire stream length between Hellroaring Creek and Seven Mile reservoir, but adult trout >400 mm show a much stronger peak in abundance in the stream section between Sheep Creek and Swift Creek. In 2003 the stream section immediately below Sheep Creek (Table 8: Sheep C-Burned Out Bridge) was particularly important, accounting for almost four times as many >400 mm fish as any other section.

Table 8. Population estimates for rainbow trout in the Salmo River watershed, July 07-17, 2003.

Section	Date	Average visibility	Observer efficiency	Estimate >300mm			Estimate >400mm		
				N	LCI	UCI	*N*	LCI	UCI
Hall Creek-Ymir	07,08-Jul	12.9-13.8	0.67-0.72	8	6	12	0		
Ymir-Porcupine C	08-Jul	12.2	0.62	26	19	41	5	4	8
Porcupine C-Hidden C	08-Jul	12.2	0.62	22	17	36	8	6	13
Hidden C-Erie C (Salmo)	10-Jul	13.5	0.70	17	13	27	7	5	11
Erie C to Carney Mill Rd.	10-Jul	9.5	0.45	2	1	4	2	1	4
Carney Mill-Sheep C	10-Jul	12.8	0.66	50	38	77	23	17	35
Sheep C-Burned Out Bridge	10-Jul	9.8	0.46	215	148	429	80	55	159
Burned Out Bridge-Swift C	09-Jul	9.3	0.44	73	49	149	23	15	47
Swift C to WSC station	09-Jul	7.9	0.34	61	36	213	17	10	61
WSC station to top of canyon	17-Jul	9.7	0.46	99	67	198	13	9	26
Top of canyon to Reservoir	17-Jul	9.7	0.46	125	84	256	17	12	35
Total				**700**	**613**	**1040**	**195**	**169**	**297**

The overall population estimates for 2002 (Table 7) were expanded to account for the 19% of rainbow trout >300 mm in unsurveyed sections, and the 9% of trout >400 mm in these same sections as suggested by the 2003 surveys. In 2002 the estimated size of the population of Salmo River rainbow trout >300 mm was 454 (SE = 40.8; limits of 95% confidence: 399-586), and the estimated size of the population >400 mm was 166 (SE = 17.3; limits of 95% confidence: 145-216) at the time of the census. Average confidence intervals calculated in this manner as proportions of the estimates for 2002 were 0.206 and 0.214 for the >300 mm and >400 mm size categories, respectively, within the 0.25 threshold recommended by Robson and Regier (1964) for management experiments. Estimates were less precise for 2003 relative to 2002, because of lower values of observer efficiency in important stream reaches (Table 8 vs. Table 7). The estimated size of the 2003 population of Salmo River rainbow trout >300 mm was 700 (SE = 120; limits of 95% confidence: 613-1040), and the estimated size of the population >400 mm was 195 (SE = 35.9; limits of 95% confidence: 169-297) in July. Average confidence intervals as proportions of the estimates for 2003 were 0.305 and 0.328 for the >300 mm and >400 mm size categories, respectively. An index based on only one stream section could have shown substantially more variability between the two years than the overall population estimate.

No clear trend in abundance is evident in the three years' data (Table 9), although 2002 appears to represent a low point in abundance for both >300 mm and >400 mm trout. Abundance estimates of rainbow trout >300 mm range from 454-700 over the three years, and abundance estimates of >400 mm fish range from 166-233.

Table 9. Overall population estimates for the mainstem Salmo River in July, 2001-2003.

Year	>300mm	SE	95% confidence Interval	>400mm	SE	95% confidence Interval
2001	605	66.1	489-739	233	27.3	184-289
2002	454	40.8	399-586	166	17.3	145-216
2003	700	120	613-1040	195	35.9	169-297

DISCUSSION

Critical Habitats, Population Spatial Structure, and Diversity

Larger trout inhabit deeper pools of the Salmo mainstem with abundant overhead or wood cover year-round. Such habitat is relatively limited in the Salmo River watershed, especially after discharge through the mainstem has dropped to low levels by mid-summer. Where it is found it is intensively used - we frequently observed several radio tagged fish within the same pool. Stream sections upstream of the town of Ymir lack deeper pools and few larger rainbow trout were found there. There is a critical lack of such habitat in the stream section between Erie Creek and Hellroaring Creek (28.3-25.4 km; Appendix IV), where the stream has been channelized and straightened. Anecdotal reports suggest that this section of the Salmo once contained abundant deep pools and cover, and was the site of 'good' rainbow trout fishing. The section now is nearly devoid of larger trout (Tables 7 and 8), illustrating the effects of stream channelization and suggesting that a potentially serious net loss of trout habitat has occurred in the watershed.

The discovery that off-channel areas of the floodplain can be extensively used by larger trout, and not just juveniles, during high flows is noteworthy, and suggests that these areas may form critical habitats during freshet or flood events. Channelization of the mainstem river also eliminates access to these off-channel habitats, and may seriously limit the amount of sidechannel spawning habitat as well. Preserving fish habitat in the Salmo River watershed will therefore require that watershed and riparian processes that create fish habitat in the mainstem are maintained, through limiting channelization activities, maintaining mature riparian vegetation as sources of instream cover, and regulating upstream forestry management to ensure sediment transport and pool in-filling along the mainstem is limited to acceptable levels. Because a substantial net loss of rainbow trout habitat has occurred along the Salmo mainstem due to channelization activities, stream restoration activities may be warranted. The building of periodic constrictions in channelized areas to cause scour and increased pool depth, especially if associated with cover structures, may be an appropriate remedial action. Calibrated diver counts will be an effective way to monitor the effects of any such restoration activities on trout distribution and overall abundance, and can even be conducted at restored areas during the population census program.

Three years' telemetry data suggests that rainbow trout spawners in the Salmo watershed use mainstem channel margins and sidechannels, as well as the lower reaches (up to at least 5 km) of larger tributaries such as Sheep and Erie creeks. The lower reach of the South Salmo River appears to have comparable habitats and access, and it appears likely that it, too, is utilized to some degree. Little spawning by fluvial rainbow trout occurs in mainstem sections upstream of the town of Ymir. Spawning timing appears to be from approximately early May to mid-June, with our best estimate of the peak of spawning being late-May.

Diver count data for juvenile rainbow trout (Tables 5 and 6) is of unknown reliability, but will certainly be an underestimate. Nonetheless, intensive use of the lower reaches of the

Salmo mainstem is indicated, which is of higher gradient and larger bed material, implying that many juvenile rainbow trout will swim upstream to inhabit deeper holding water as they grow.

The estimated percentage of all living radio tagged rainbow trout appearing to have entered tributaries during the spawning period was never more than 15%, and none were detected more than 5.0 km upstream of the tributary's mouth (Appendix IV). It may be, therefore, that tributary populations of smaller rainbow trout are primarily of the stream resident life history. Samples of rainbow trout from the South Salmo River and Sheep Creek include individuals up to age 4, also supporting the notion that these fish are residents (Decker 2003). However, it should be noted that the estimate of tributary use may be low if not all of the radio tagged rainbow trout spawned. For example, during the springtime 2002 spawning period three of the nine radio tagged fish that made migrations during the spawning period of greater than 5 km, or 33%, entered tributaries. Tracking in 2004 of a fish 5 km upstream in Sheep Creek also suggested there may be some interaction during the spawning period between resident and fluvial forms.

The spatial structure (limits of genetic interactions and rates of gene flow) of populations of rainbow trout in the Salmo River watershed likely cannot be inferred without additional study, which would require at a minimum tissue sampling and genetic analysis for tributary populations for comparison with results from mainstem samples (Taylor 2002). Gene flow and migrants from tributary populations are likely, but whether these significantly increase genetic and demographic resilience (sensu Simberloff 1988) for the mainstem population would be difficult to infer. Hybrids could reasonably be produced from 'sneak' matings of resident males with fluvial females, but selection in alternative tributary and mainstem niches against intermediate hybrid phenotypes is possible. Residents make limited downstream movements and mature at smaller body sizes and younger ages than migrants (Elliott 1987). Northcote (1981) found substantial differences in spawning timing for resident and migratory rainbow trout in a steep tributary to Kootenay Lake, and attributed them to strong selection in resident fish for emergence after freshet had abated so that they would not be swept downstream. The fluvial trout of the Salmo River mainstem appear to mature at an exceptionally large body size and advanced age, which may reflect adaptations to physical conditions during spawning in mainstem habitats. In Elliott's (1987) study he suggested adaptations by residents in 'fringe' habitats would be in response to density-independent mortality factors, whereas in highly suitable habitats inhabited by fluvial and migratory fish adaptations would reflect density-dependent population regulation. If selection for adaptations to alternative niches in the Salmo watershed is strong relative to gene flow (few hybrids and they fair poorly), tributary and mainstem populations may be genetically distinct and tributary phenotypes will not be able to replace mainstem phenotypes in habitats left open in a situation of severe population decline.

The genetic origins or relationships of Salmo watershed rainbow trout have not been determined (Taylor 2002). Stocking of rainbow trout into the Salmo River watershed took place sporadically between 1924 and 1953 (BC MWLAP data on file), but it cannot be assumed that widespread introgression of wild and hatchery genotypes occurred.

Wild-spawning, apparently native rainbow trout in the free-flowing portion of the Columbia River below the Keenlyside Dam in Canada show little genetic impact from Roosevelt Reservoir hatchery stocking programs (Taylor 2002), a result which is consistent with a growing number of studies addressing this issue (e.g. Moran et al. 1994; Hansen et al. 1995). Until it is established otherwise, we consider it prudent to manage the Salmo mainstem population as if it were genetically unique and native. With respect to other fluvial forms of rainbow trout, the Salmo watershed is now genetically isolated, by the continuous impoundment of the Columbia and lower Pend d'Oreille Rivers, from populations downstream. Connectivity with populations upstream, each of which is separated from the Salmo River by at least one dam, is currently unknown.

Abundance and Population Growth Rate

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 or severe depletion. Predicting the persistence or extinction of small populations has been a primary focus of the growing 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 risk to a particular population is inexact at best. 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. The importance of genetic drift in fixing deleterious alleles in a population is related to N_e, 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 N_e 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 N_e into an equivalent N (number of adults in the population) is not straightforward, because N will increase relative to N_e with increases in the magnitude of population fluctuations. A recommended minimum adult population size of at least five times the minimum N_e (N = 250) therefore, has been suggested if populations fluctuate significantly (Nunney and Campbell 1993). It is important to note, however, that the importance of genetics in extinction has not been demonstrated sufficiently well 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 are subject to a relatively high degree of environmental stochasticity. 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 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). There is a clear need for a review of empirical data with respect to N and long-term persistence among fish populations and taxa.

Aging analysis and visual observations of maturity status for captured fish (Table 1; Appendix III) suggested that the large majority of Salmo River rainbow trout spawn for the first time when they are five years old and greater than 400 mm in length. The estimates of the size of the Salmo River population that is >400 mm fork length, therefore, is the best estimate of the adult population size N. Estimates of rainbow trout N for the mainstem Salmo River between the Hall Creek canyon and Seven Mile Reservoir were 233 $\pm$ 27, 166 $\pm$ 17, and 195 $\pm$ 36 for July 2001, July 2002, and July 2003, respectively. According to the above criteria, the current abundance levels of Salmo River adult rainbow trout may therefore be close to minimum levels considered adequate for long-term conservation.

Three years of population estimates is not enough of a time series to investigate the population growth rate (population increasing or declining) for the rainbow trout of the Salmo River mainstem, especially considering that the estimates were by two different methods and natural variability in the adult population size N is unknown. Anthropogenic factors forcing negative population growth rates are far more serious threats to a population's long-term persistence than are genetic and demographic factors associated with small population sizes (Caughley 1994). Although other anthropogenic agents capable of forcing decline in the Salmo population may exist, angling harvest is the most obvious and immediate threat. Given the current population size, even a small number of skilled anglers regularly harvesting one adult fish per day from the Salmo River could rapidly drive adult rainbow trout abundance to potentially dangerous levels. It is possible, of course, that the Salmo River rainbow trout population is stable under the management scenario in place to this point in time, and it may even be at the watershed's carrying capacity and therefore buffered to some extent from annual variability in recruitment and harvest. As mentioned, the relatively high incidence of repeat spawning suggests that exploitation of adult rainbow trout in the Salmo may currently be low. Regular abundance monitoring, especially if it is accompanied with a willingness to experiment with alternative harvest regulations, is the key to learning about the population's status relative to meaningful conservation and management targets.

Accuracy of Diver Counts of Trout

Although it is intuitively obvious that good underwater visibility is required for divers to be able to accurately census fluvial salmonid populations, rarely have the effects of variation in visibility on accuracy of diver counts been described quantitatively. In our study, variation in underwater visibility and discharge had significant effects overall on the accuracy of diver counts of adult rainbow trout in our study reach (Figures 10 and 11). Visibility and discharge were highly correlated, and of the two we chose visibility as the best index of diver count accuracy because of its higher correlation value with observer efficiency and how practical it is in application: diver count accuracy can be predicted from a simple measure that can be made prior to initiating the annual census effort. The linear regression equation (Table 3) we used to describe the overall relationship of observer efficiency to visibility provides a basis for adjusting future counts of adult trout in the system, in order to generate population estimates, and also for estimating confidence intervals for these estimates. Provided horizontal underwater visibility is sufficient at the time of the annual population census in July, rainbow trout population abundance estimates should be relatively precise. Average 95% confidence intervals for the population estimates will be close to target suggested by Robson and Regier (1964) for management purposes provided horizontal visibility is sufficiently high. The comparison of precision for the population estimates for 2002 and 2003 is instructive. In 2002, when percent relative error (average confidence interval as a percentage of the estimate) was within the 25% target, average visibility in important stream sections (downstream of Carney Mill Rd.) was 10.7-12.1 m, while in 2003 when percent relative error for adult trout was 33%, average visibility in these sections was 7.9-12.8 m but always below 10 m downstream of Sheep Creek. We recommend a lower threshold of horizontal secchi disk visibility of 10 m in important stream sections during the basin-wide population census. Although there are other sources of variation that adversely affect the ability of a population estimate time series to detect real changes in abundance, such as natural recruitment variation caused by environmental and biological influences, precise abundance estimates appear to be crucial for the rapid, sensitive detection of population impacts from such potential causes as habitat alterations, population enhancements, or harvest management changes (Korman and Higgins 1997; Ham and Pearsons 2000).

Counts of untagged trout in our study provided important corroboration for the observer efficiency relationships derived from observations of radio tagged fish, as their relationships to levels of horizontal visibility for each year of the study showed much the same pattern as did the corresponding observer efficiency relationships (Figures 10 and 12). The consistently good precision of the 2002 and 2003 relationships of counts to visibility, in particular, provided strong support for the notion that the accuracy of diver counts and levels of visibility can be linearly and closely related, but also suggested that the quality of the underlying relationship between observer efficiency and visibility had been underestimated by the observations of radio tagged trout. Extreme points in the 2002 observer efficiency regression are not reflected in the counts of trout on those dates, and their occurrence may therefore be due mainly to the small sample of radio transmitters in the study area. There were 8-10 transmitters present for each survey made during July 2002 and July 2003, a relatively small fraction of the number of untagged trout of the same size.

The 2001 observations of radio tagged and untagged trout are more problematic to interpret, as both show insignificant, poor quality relationships with visibility. The relationships of counts of trout, in particular, are in contrast to the precise, significant relationships of counts to visibility in 2002 and 2003, suggesting that the poor relationships could not easily be attributed to sampling error alone. The poor range of visibility conditions over which the observations were made, along with the fact that these data are from the first year of the study, may have affected the results. Behavioural differences may also have contributed - flows reached mid-summer low levels earlier in the year than in any other year over the fourteen-year period between 1993 and 2003 (Figure 13). Although we did not find the interannual variability in the observer efficiency relationships to be statistically significant, the 2001 results do suggest a potential importance in conducting behavioural studies over a multi-year time frame. For ensuring that variability in the relationships between the accuracy of diver counts and factors that affect it are realistic, and that relationships can be extrapolated across years, the three-year time period of our study may represent a minimum level of commitment. With respect to fluvial salmonid populations, we are not aware of any studies that have investigated interannual variability in factors that affect the accuracy of underwater census methods.

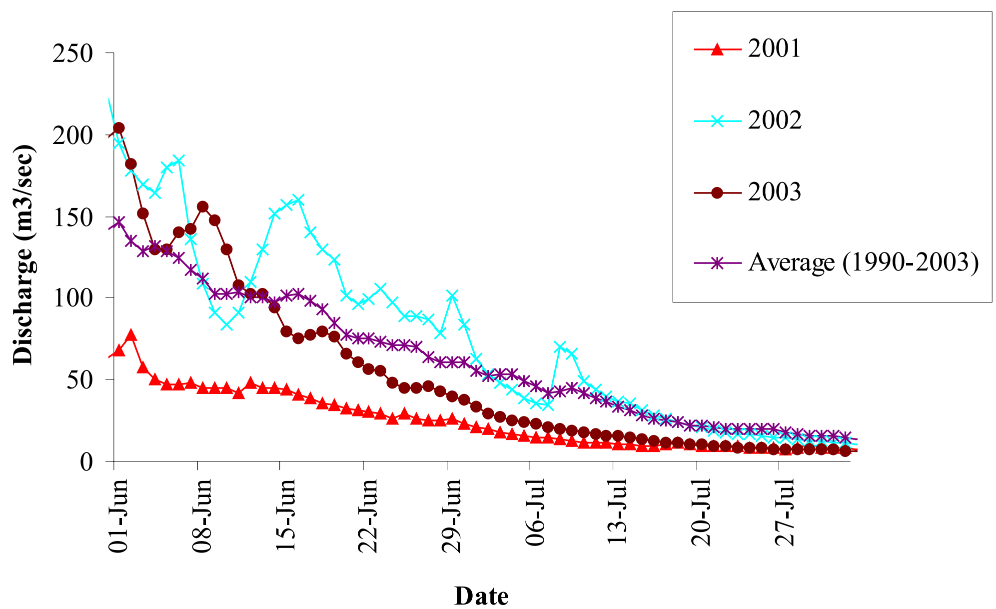

Figure 13. Water discharge (m^3/sec) in the Salmo River over the June 1 to August 1 period in 2001, 2002, and 2003 and the fourteen-year average for that period.

There are only a small number of published accounts of the accuracy of underwater census techniques for fluvial salmonid populations, but from these studies it appears that system-to-system variability can be high. During their study in which a surveyed reach was poisoned with rotenone after underwater census, Northcote and Wilkie (1963) estimated the observer efficiency of a team of divers counting rainbow trout and mountain whitefish. Although their estimate of horizontal visibility ("at least 25 feet") does not allow a direct comparison with our results, their estimate of 59% observer efficiency for rainbow trout and 64% for mountain whitefish are not greatly different for the overall average observer efficiency in this study of 54%. Consistently high levels of observer efficiency have been reported for westslope cutthroat trout (*Oncorhynchus clarki lewisi*) in larger rivers with relatively sparse cover. In a mark-recapture study Slaney and Martin (1987) estimated the observer efficiency for underwater counts of westslope cutthroat trout of greater than 200 mm length to be 74% despite underwater visibility of only 3 m, while Zubik and Fraley (1988) found that diver counts were in good agreement with the mark-recapture estimates at 'good' levels of water clarity. Estimates of visibility were made for the latter study and ranged from 4-4.6 m, but because they were estimated as the distance at which the species and size class of observed fish could no longer be determined they are not directly comparable with our results. More recently, observer efficiency estimates for diver counts of westslope cutthroat trout in the Wigwam and Bull rivers in southeastern British Columbia were 79% at 12.9 m and 81% at 12.2 m average horizontal secchi disk visibility, respectively (J. Baxter and J. Hagen; unpublished data). Diver counts of brown trout (*Salmo trutta*) were between 57-66% of the mark-recapture estimates at approximately 7 m horizontal visibility in one of two New Zealand rivers studied by Young and Hayes (2001), and 21-43% in the other at approximately 10 m visibility. The lower levels of accuracy were found in the system with more instream cover despite a better level of visibility.

Differences in behaviour among the species studied in the above accounts may contribute to the variation among the observer efficiency estimates. Northcote and Wilkie (1963) observed adult rainbow trout in the Lardeau River, British Columbia under conditions of >10 m underwater visibility, and noted that fish fled laterally as the line of divers approached, then burst upstream through it, behaviour that could affect counting accuracy in lower visibility conditions. When approached by the line of divers, adult rainbow trout in the Salmo River during this study reacted in the same manner. Young and Hayes (2001) suggested that brown trout in New Zealand rivers react to divers by moving into cover when it was available, behaviour which appeared to have a significant effect on observer efficiency. In contrast, Schill and Griffith (1984) and Zubik and Fraley (1988) both indicated that westslope cutthroat trout showed little reaction to the presence of divers, observations that appear to be true for the subspecies in southeastern British Columbia rivers as well. This behaviour must certainly be a factor in the relatively high levels of observer efficiency observed for the studied populations across a range of visibility levels. For westslope cutthroat trout, then, it is possible that observer efficiency estimates are less system-specific and more precise generally, and calibration relationships may be suitable for more general application across the subspecies' range.

In our study, the relatively good agreement between observations of tagged and untagged fish relative to underwater visibility changes is consistent with the assumption, implicit in our methods, that adult trout bearing surgically implanted radio transmitters behave in a manner representative of untagged trout in mark-recapture studies. Outfitting marked fish with radio transmitters is attractive because certain assumptions implicit in mark-recapture studies, such as (1) no emigration of marked individuals out of the study area, and (2) no mortality or harvest of tagged individuals, can usually be verified when the location of the radio transmitter is known with certainty. This is of obvious benefit in studies such as ours, where multiple recapture surveys are planned over longer time periods and over a range of viewing conditions in order to investigate factors that affect counting accuracy. Other factors than underwater visibility and discharge that may affect the observer efficiency of fluvial salmonid populations include temperature, availability of cover, and light intensity. Our study has suggested that observations of radio tagged individuals over a representative range of values for the potential factor can establish the value of and confidence level for the observer efficiency parameter estimate, and ideally permit the development of regression models that account for the effect of factor variation on observer efficiency, thereby improving the accuracy and precision of the abundance estimate.

A principal drawback of the use of radio telemetry in mark-recapture studies is the costly nature of the equipment and the tags themselves, as well as the commitment involved in doing repeated counts, especially if done over a multi-year time period. The cost may be justifiable in instances where long-term population dynamics monitoring of a fish population is desired, and variability in the observer efficiency of divers (or observers on foot in certain circumstances) is suspected to be an important component of sampling error. If relationships of diver observer efficiency to watershed conditions can be considered reliable, they can be applied to standard diver counts in future years to generate calibrated population estimates at a greatly reduced cost relative to annual mark-recapture studies. For example, the annual population census along the mainstem of the Salmo River, which includes virtually all of the habitats used by adult-sized rainbow trout, can be completed with an effort of only four days for a crew of four divers if annual tagging is not required. The technique of radio telemetry is commonly used in salmonid behavioural and habitat use studies. With some forethought, these studies may also yield information that is required for population census methods, such as the observer efficiency of diver counts, residence time in spawning areas, or population spatial structure, making their high cost more justifiable.

Conclusions and Recommendations

This report documents the results of our investigation by radio telemetry of rainbow trout habitat use of in the mainstem Salmo River. Summer rearing habitat was limited to a few relatively large pools where accumulations of fish were observed. Overwintering habitat consisted of areas of deeper water in association with cover, and was distributed along the length of the Salmo mainstem. Movements of radio tagged fish during the spawning period suggested that fluvial, mainstem-dwelling rainbow trout are not spatially segregated along the length of the Salmo River, and that spawning takes place in sidechannels, along the margins of the mainstem, and in the lower reaches of some tributaries. Off-channel areas appear to be important to Salmo River rainbow trout during spring freshet. A channelized section of the mainstem, which had limited areas of deeper water and cover, extending from the town of Salmo downstream to Hellroaring Creek was conspicuously avoided by radio tagged trout.

The above observations suggest a close association between the population of larger rainbow trout in the Salmo River and areas of deeper water and cover, and it is even possible that this habitat type limits the size of the adult population. Efforts to increase rainbow trout habitat capability in the Salmo River watershed, through habitat complexing, may be worth consideration, as a population's resilience to extinction threats increases with increases in carrying capacity (see Nunney and Campbell 1993 for review) provided anthropogenic agents forcing negative population growth rates 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. The channelized sections of the mainstem may provide the best opportunity to improve the habitat for larger rainbow trout, as a substantial net loss of fish habitat at these locations appears to have occurred.

The mainstem Salmo River adult rainbow trout population is relatively small, of unknown population growth rate, and isolated demographically from downstream fluvial rainbow trout populations. Special management actions to ensure the population's future viability and to maintain the quality of the fishery, therefore, may be warranted. Catch and release regulations may be effective at increasing population size (e.g. Oliver 1990). We have previously recommended to MWLAP that this step be taken for a portion of the Salmo River watershed, to be applied on an experimental basis. We recommended a catch-and-release zone that included all of the mainstem downstream of Sheep Creek to the South Salmo River, which encompassed 65% of the harvestable and adult trout, or an adult population of almost 100 individuals in July 2002 prior to implementing the change (Table 7), and a zone for the remainder of mainstem outside this section where a harvest of one trout >300 mm would be allowed. High quality angling experiences at numerous runs and pools, in locations with and without road access, are possible in both portions of the watershed. This recommendation was implemented beginning with the 2003 angling season.

We recommend that annual or at least periodic diver counts across all sections identified in Table 8 continue, so that the effects of the regulation change can be monitored closely. This is the science-based approach to conservation management recommended by recent authors (Walters and Hilborn 1976; Lande 1993; Caughley 1994), and that may generate research data that is of provincial significance. While a positive response to the regulation change is expected, population declines may signal the need for a basin-wide catch and release regulation. Declines of the adult population to levels approaching 50 adult individuals should be considered grounds for complete fishery closure, especially given the unknown genetic and demographic structure of the mainstem population relative to tributary populations and to other fluvial rainbow trout populations in the Pend d'Oreille basin.

Although diver counts of trout in streams are commonly used to monitor population status, few studies have directly investigated the relationships between diver observer efficiency and watershed physical conditions. The results of the three years' observer efficiency studies reported on here have suggested that underwater visibility can be reliably used to predict observer efficiency (Figure 10). The overall relationship of observer efficiency to underwater visibility, therefore, provides the basis for calibrating future diver counts in the watershed without the need for costly annual mark-recapture studies, meaning that population estimates can be acquired in a highly cost-effective manner.

It is worth considering whether it is feasible to investigate potential genetic and demographic relationships between rainbow trout in the Salmo mainstem and other locations, and whether the information would be of value in fishery management in the watershed. It may be possible to obtain this information from analyses of genetic samples from tributary or other lower Pend d'Oreille populations for comparison with the mainstem Salmo River sample, which has already been analyzed (Taylor 2002). A habitat use and life history study directed at the tributary residents would also benefit our understanding of their role in the overall rainbow trout population dynamics of the watershed, as well as point out potential conservation issues faced by these fish.

One final point of recommendation is for continued community involvement and education with regard to fisheries issues in the Salmo River watershed. We feel that student involvement (Appendix I-Plate M) and community education through a poster campaign increased community awareness in general of fisheries issues within the watershed. A workshop organized in the area to discuss rainbow trout biology and management, and oriented to the community, would also be of great benefit.

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Appendix I – Photographic Plates

Plate A. Rainbow trout in flow through fish tube following 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, and irrigation of gills.

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

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

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

Plate G. Pool used for overwintering by rainbow trout in the Salmo River.

Plate H. Pool used for overwintering by rainbow trout in the Salmo River.

Plate I. Rainbow trout redd location in side channel of Salmo River.

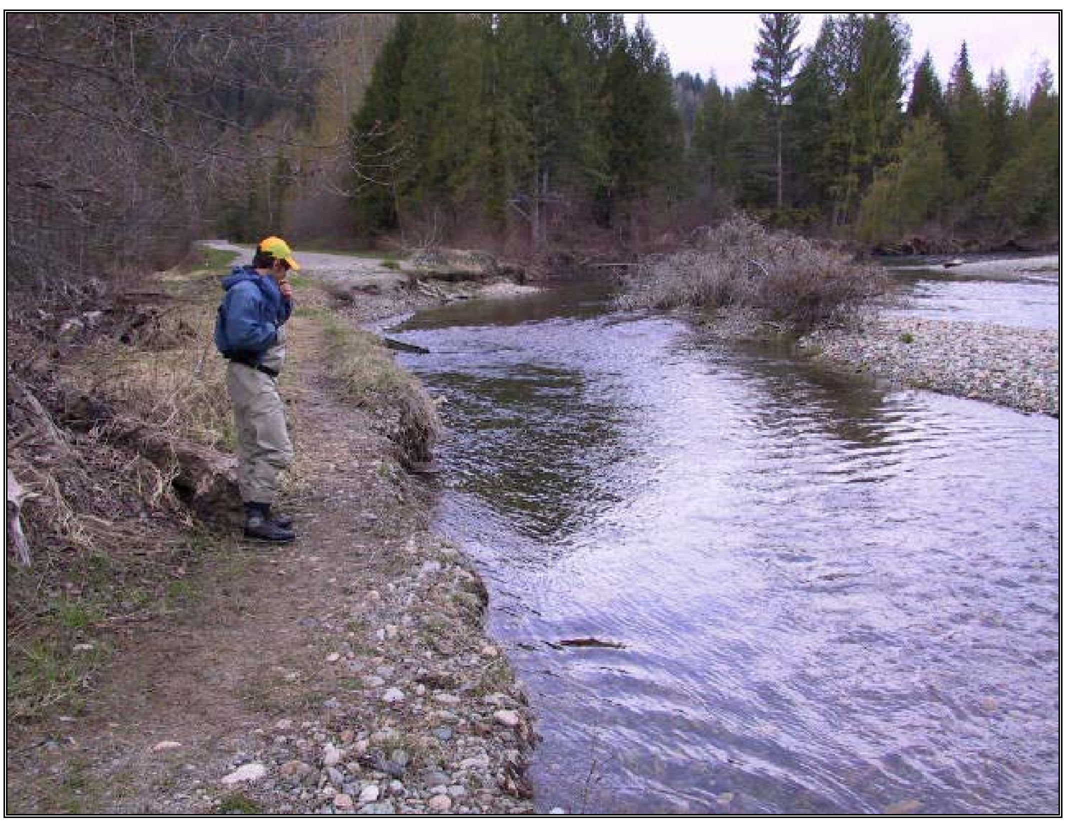

Plate J. Rainbow trout redd location in side channel of Salmo River.

Plate K. Off-channel habitat used by rainbow trout in high flow of May 2002.

Plate L. Off-channel habitat used by rainbow trout in high flow of May 2002.

Plate M. Students observing a radio tag implant into a rainbow trout.

Appendix II – 2001-2003 Salmo River Rainbow Trout Capture Data

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	06-08-2001	40.5	450	230	1000	F	F	F	6449	6450	
G	780	10	06-08-2001	39.9	470	230	1100	M	G	G	6410	6411	Kelt
H	420	1	06-12-2001	32.3	570	275	1800	F	H	H	6391	6392	?
I			06-12-2001	24.4	245			?	I				IMM.
J			06-20-2001	23.9	310			F	J				IMM.
K	420	8	06-20-2001	23.5	400	195	600	F	K	K	6357	6358	Kelt
L	420	9	06-20-2001	23.2	400	200	650	?	L	L	6389	6390	Kelt
LO	780	1	09-19-2001	34.6	410	210	725	F	LO	LO	6301	6302	Kelt
M	420	10	06-20-2001	22.4	465	215	950	M	M	M	6359	6388	Kelt
N	380	5	06-20-2001	20.9	600	290	2100	F	N	N	6360	6361	Kelt
O			06-20-2001	20.9	370	180	550	?	O				?
P	380	4	06-21-2001	19.9	430	215	750	F	P	P	6424	6425	Kelt
Q			06-21-2001	19.9	490			M	Q	Q			?
R	380	6	06-22-2001	5.7	390	200		M	R	R	6362	6363	Kelt
U			06-21-2001	18.3	450			M	U	U			?
SARB-1	420	2	06-01-2001	26.2	465	250	1150	F	SARB-1	SARB-1	6351	6352	IMM.
SARB-10	420	3	06-12-2001	35.7	360	185	500	F	SARB-10	SARB-10	6414	6415	IMM.
SARB-11	420	7	06-20-2001	24.4	510	265	1450	F	SARB-11	SARB-11	6416	6417	?
SARB-12	780	7	06-20-2001	22.9	570	285	2000	F	SARB-12	SARB-12	6418	6419	?
SARB-13	780	9	06-20-2001	22.4	510	240	1300	M	SARB-13	SARB-13	6420	6421	?
SARB-14	380	8	06-20-2001	20.8	385	200	600	F	SARB-14	SARB-14	6422	6423	IMM.
SARB-15	380	1	06-21-2001	21.3	490	230	1100	F	SARB-15	SARB-15	6386	6387	Kelt
SARB-16	380	3	06-21-2001	19.4	445	195	700	M	SARB-16	SARB-16	6383	6385	Kelt
SARB-17			06-21-2001	19	435	220		F	SARB-17	SARB-17			?
SARB-18	380	10	06-30-2001	15.7	390	175	350	F	SARB-18	SARB-18	6381	6382	Kelt
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.

Fish No.	Frequency	Code	Date	River Km	Length (mm)	Girth (mm)	Mass (g)	Sex	Scales	DNA	Floy Tag 1	Floy Tag 2	Maturity
SARB-4	380	7	06-06-2001	18.5	480	235	700	F	SARB-4	SARB-4	6397	6398	Kelt
SARB-5	420	6	06-08-2001	20.2	435	225	850	F	SARB-5	SARB-5	6395	6396	Kelt
SARB-6	780	6	06-08-2001	20.1	425	210	750	M	SARB-6	SARB-6	6353	6354	Kelt
SARB-7	780	8	06-08-2001	15.8	445	220	1000	F	SARB-7	SARB-7	6355	6356	Kelt
SARB-8	420	5	06-08-2001	34.6	470	235		F	SARB-8	SARB-8	6393	6394	Kelt
SARB-9	780	4	06-12-2001	35.7	460	235		F	SARB-9	SARB-9	6412	6413	IMM.
1	580	10	06-10-2002	20.6	470	230		M	1	No	W7851/W7853	W7854/W7855	Kelt
2	580	2	06-10-2002	17.8	480	220		F	/	No	W7923/W7922	W7921/W7920	Kelt
3	580	4	07-04-2002	25.7	490	260		F	/	No	W7919/W7918	W7917/W7916	Kelt
4	580	1	07-04-2002	25.1	430	225		F	4	No	W7915/W7914	W7913/W7912	
5	580	3	07-04-2002	23.9	515	255		F	5	No	W7911/W7910	W7907/W7908	
6			07-04-2002	25.2	350	180		F	6	No	no tags	no tags	Maturing
JH-1	580	7	07-02-2002	23.8	460	215		F	JH-1	No	W7950/W7949	W7948/W7947	Kelt
JH-2	580	9	07-02-2002	20.2	500	255		F	JH-2	No	W7946/W7945	W7944/W7943	Kelt
JH-3	580	8	07-04-2002	19.9	380	205		Imm	/	No	no tags	no tags	Immature
JH-4	580	5	07-04-2002	19.5	600	280		F	/	No	6360	6361	Kelt given new radio tag
JH-5	580	6	07-05-2002	19.9	460	225		F	/	No	W7935/W7936	W7937/W7938	Kelt
JH-6			07-02-2002	23.5	255			?	JH-6	No	6419		
JH-7			07-02-2002	22.9	570			?	/	No	6418		Kelt
J1-03	400	12	06-13-2003	17.0	430	230		M	No	No	952	955	Kelt
J2-03	400	18	06-16-2003	22.9	480	240		F	No	No	956	959	Kelt
J3-03	400	11	06-19-2003	22.9	545			F	No	No	960	963	
03-01	400	15	06-13-2003	22.3	530			F	No	No	901/902	903/904	Kelt
03-02	580	9	06-17-2003	19.4	500			F	No	No	905/906	907/908	Kelt
03-03	400	16	06-17-2003	19.4	580	27.5		F	No	No	909/910	911/912	Kelt
03-04	400	20	06-18-2003	22.9	540	28		F	No	No	913/914	915/916	na
03-05	400	19	06-18-2003	20.3	545	30		F	No	No	917/918	919/920	Kelt
03-06	400	14	06-18-2003	20.1	475	24		M	No	No	921/922	923/924	Kelt
03-07	400	17	06-20-2003	19.4	440			F	No	No	925/926	927/928	Kelt
03-08	400	13	06-20-2003	18.2	520			F	No	No	929/930	931/932	Kelt

Appendix III – Scale Measurements, Salmo River Rainbow Trout, June 2001

					Dia.				Annulus				Fraser-Lee	
Scale no.	**Fork l.**	**Sex**	**Maturity**	**Age**	**Scale**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**size-at-mat.**	**Comments**
jh-6	25.5	I	I	3+	43	8	22	38						Plus growth at scale margin
4	43	F	na	5sss?	98		26	35	57	85	92	98	59	Poss. 3-time repeat spawner?
5	51.5	F	na	5ss	114	9	28	43	80	108	114		57	
1	47	M	kelt	5ss	100	15	25	34	47	80	100		70	Poor resolution for first 2-3 years
jh-2	50	F	kelt	5ss	127	13	30	47	91	116	127		60	
jh-1	46	F	kelt	5s	99	14	29	58	81	99			46	
sarb-17	43.5	F	na	6s	85		29	42	57	67	84		45	Resorption at scale margin
sarb-16	44.5	M	kelt	5ss	82	10	20	30	62	75	82		55	Resorption and spawning check p2
sarb-15	49	F	kelt	5ss	77	14	22	32	55	71	77		58	Classic spawning check
sarb-14	38.5	F	I	4+	82	13	30	58	77					Plus growth - immature
sarb-13		M	na											regenerated - repeat spawner
sarb-12		F	na											regenerated - poor scales
sarb-11	51	F	na	5s+	121	14	34	63	91	115	107		57	Plus growth
sarb-10	36	F	I	4+	77	13	30	44	71					
sarb-9	46	F	Imm?	5s?	113	15	30	65	95	113			46	No resorption or plus growth
sarb-8	47	F	kelt	5ss	88	15	32	62	79	88			47	Classic spawning check
sarb-7														V. poor scales
sarb-6	42.5	M	kelt	5s	89	14	29	48	74	89			43	Resorption at scale margin
sarb-5	43.5	F	kelt	5s	92	14	32	64	79	92			44	No resorption or plus growth
sarb-4	48	F	kelt	5s+	103	11	26	45	69	99			53	Plus growth although a kelt
sarb-3	27.5	I	I	3+	62	19	34	57						
sarb-2	45.5	F	kelt	4ss	76	21	33	60	71	76			53	May have spawned at age 4 also.
sarb-1	46.5	F	I?	4+	96	14	31	54	89					Substatial plus growth. Immature?
U	45	M	na	5s	90	13	31	52	76	90			45	Resorption
R														V. poor scales
Q	49	M	na	5+	118	15	28	47	75	112				Substatial plus growth. Immature?
P	43	F	kelt	5ss	75		22	34	56	71	75		49	
O														V. poor scales
N	60	F	kelt	5ss	135	12	35	66	102	128	135		65	Spawned at 600mm, 5sss in 2002
M	46.5	M	kelt	5s	75	14	26	41	63	75			47	Resorption at scale margin
L	40	na	kelt	4+	76	11	26	43	65	76				Substatial plus growth. Kelt?
LO	41	F	kelt	5s	98	12	24	39	85	98			41	Resorption at scale margin
K	40	F	kelt	5s	78	11	25	37	57	78			40	No plus growth
J	31	I	I	4+	52	10	29	41	52					
I	24.5	I	I	3+	41	11	23	35						
H	57	F	na	4ssss?	134	16	43	93	112	122	129	134	75	4-time repeat? - checks at 4s, 5s
G	47	M	kelt	5ss	104	17	32	45	71	99	104		53	good 5s check

					Dia.				Annulus				Fraser-Lee	
Scale no.	**Fork l.**	**Sex**	**Maturity**	**Age**	**Scale**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**size-at-mat.**	**Comments**
F	45	F	na	5s?	100	14	32	62	87	100			45	No plus growth
E	45	M	na	5s	91	15	28	41	70	91			45	Resorption at scale margin
D														regenerated - poor scales
C	44.5	F	kelt	4sss	91	15	29	57	78	85	91		62	Based on spawning check at 4s p.2
B	41.5	F	na	4+	101	15	39	67	96					Substatial plus growth.Imm?
A	54	F	kelt	6s	114	16	29	43	78	101	114		54	Resorption at scale margin

Appendix IV – Locations (Stream Kilometer from Mouth) of Radio Tagged Salmo River Rainbow Trout, 2001-2004 (Blue = Tagging Location, Green = Summering Location, Grey = Overwintering Location; Red = Spawning Location)

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	04-Apr-02	16-Apr-02	22-Apr-02	02-May-02	09-May-02	15-May-02	23-May-02	24-May-02	30-May-02	31-May-02	05-Jun-02	06-Jun-02	10-Jun-02	12-Jun-02	13-Jun-02	18-Jun-02	19-Jun-02	26-Jun-02	27-Jun-02	02-Jul-02	04-Jul-02	05-Jul-02	09-Jul-02	11-Jul-02	14-Jul-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	12.8	14.3	14.3	19.9	21.4	21.5	21.5		1-SC	1-SC		1.9-		22.6			20.7		20.7			20.7	20.7	20.7	
380-2		15.5					15.5			15.5							15.3			15.4	15.5	36.3					45.5				44.9	44.9	44.9	44.9	44.9	44.9		44.9	44.9	44.9			44.6		43.7		43.7							
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	19.5	19.5	19.5	19.5	19.5	19.5	19.5		19.5	19.5	19.0			19.4			19.5		19.5			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	19.9	19.9	19.9	19.9	19.9	19.9	19.9		19.5	19.5		19.4		19.5			19.5		19.5		19.5	19.5	19.5	19.9	
380-6								5.7									6.0			5.7	5.7	0.0			0.0		0.0					0.0	0.0	0.9		1.1			1.1		2.2			2.2										
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	19.9		19.9	19.9	19.9	19.9	20.2		21.4	21.4		24.5		26.2			25.2		28.3			20.7	25.4	20.2	
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	20.9	20.9	28.3	35.7	35.5	23.1	23.5		23.5	23.5		23.5		23.5			23.5		20.7			20.7	23.0	20.2	20.2
380-10										16.0							16.1			16.1	15.5	15.8		16.0	16.0		16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0		15.4	15.4		16.0		15.4			15.4		15.4						
420-1				32.3	32.3											32.3		32.3			32.3						14.3													32.3							32.3							
420-2	26.2				26.0											32.3		32.3			32.3	32.3			32.3		32.3	32.3	32.3	32.3	32.3	32.3	32.3	32.3	32.3	32.1		32.3	32.3	32.1			31.9		31.9			31.9						
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	35.9	35.9	35.9	35.9	35.9	35.9	36.0		35.9	35.7	35.9			35.4		35.4		35.4							
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	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	16.9	16.9	16.9	16.9	16.9	23.9																			
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	15.4	15.4	15.4	15.4	15.3	25.2	25.2			31.1	31.1	23.5		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	19.0	19.0	19.0	19.0	19.0	19.0	18.5		17.3	16.6		16.6		16.6			16.6		16.5						
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	23.7	23.7	23.7	23.7	23.7	23.7	23.7		23.7	23.7		23.7		23.7			23.7		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	22.5	22.2	22.2	22.2	22.3	22.3	22.3		24.5	24.5	34.9			38.6		38.6									
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	18.1	18.1	18.1	18.1	18.1	18.1	18.1		18.1	18.1		18.3		18.0			18.0		18.0			18.0	18.0	18.0	
780-1																							34.7									15.4	17.3	17.3	24.4	24.4			25.2	34.9			36.3		30.7	24.4		24.4				24.4	24.4	
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	15.4	15.4	25.2	1.3-	26.2	26.2	23.5		23.5	23.5		23.5		23.5			23.5		14.5						
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	31.3	31.3	31.3	31.3	31.3	30.9	30.5		31.3	31.3	30.7			30.7		30.7		30.7							20.1
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	35.7	35.7	35.7	35.7	35.7	35.7	36.5		35.7	35.5	36.4			35.8		35.8		35.8							
780-5			40.5	40.5									40.5		40.5				40.8		40.6	40.7	40.7		24.5		17.3					5.7	5.7	5.7	5.7	5.7		10.6	10.6		16.0		15.5			15.5		15.5						
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	21.3	20.9	21.3	21.3	20.9	20.9	20.9		20.9			20.9		20.3			20.3		20.3			20.3	20.3	20.3	
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	19.9	19.9	19.9	19.9	19.9			1.9-	23.5	23.5		23.5		23.5			23.5		23.5				25.1	25.2	
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	15.7	15.4	15.4	15.4	15.7	15.7	16.0		16.1	16.1		16.4		17.7			15.5		15.5						
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	26.5	26.5	26.5	26.5	26.4	26.4	26.4		26.4	26.4		26.4		26.4			26.4		26.4						
780-10			39.9		40.5								40.4		40.5				40.6		40.6																																	
580-1																																																		25.1		23.1	22.9	
580-2																																										17.8									19	18.9	19	
580-3																																																		23.9		23.9	23.9	
580-4																																																		25.7		25.7	25.7	
580-5																																																						
580-6																																																		19.9	19.9	17.7	20.2	
580-7																																																	23.8			24		
580-8																																																		19.9	19.4	19.4	19.4	
580-9																																																	20.2		20.2	20.2	20.2	
580-10																																										20.6										20.6	20.6	
400-11																																																						
400-12																																																						
400-13																																																						
400-14																																																						
400-15																																																						
400-16																																																						
400-17																																																						
400-18																																																						
400-19																																																						
400-20																																																						

Tag no.	16-Jul-02	17-Jul-02	18-Jul-02	22-Jul-02	23-Jul-02	24-Jul-02	30-Jul-02	01-Aug-02	11-Dec-02	29-Mar-03	07-Apr-03	24-Apr-03	08-May-03	13-May-03	21-May-03	23-May-03	28-May-03	30-May-03	04-Jun-03	11-Jun-03	13-Jun-03	16-Jun-03	17-Jun-03	18-Jun-03	19-Jun-03	20-Jun-03	04-Jul-03	07-Jul-03	09-Jul-03	10-Jul-03	18-Jul-03	02-Sep-03	03-Mar-04	04-May-04	16-May-04	20-May-04	22-May-04	25-May-04	01-Jun-04	09-Jun-04
380-1	20.7		20.7	20.9			20.9	20.9																																
380-2		43.7																																						
380-3	19.4		19.4	19.4			19.4	19.4	19.4																															
380-4																																								
380-5	19.9		19.8	19.8			19.8	19.8	18.5	19.8	19.8	19.5	19.4	19.0	19.2	19.2	19.2	19.2	19.2	19.2																				
380-6																																								
380-7																																								
380-8	20.7		20.7	20.2			19.9	19.9																																
380-9	20.7		20.9	20.9			20.9	20.9																																
380-10					16.0																																			
420-1																																								
420-2									31.9																															
420-3		36.3							36.3	35.9	35.4	35.4	39.9	40.5																										
420-4																																								
420-5																																								
420-6					15.4				15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4									15.4											
420-7					16.5				16.5	16.5	16.5	16.5	16.5	16.5	16.5	16.5	16.5	16.5	16.5	16.5																				
420-8	23.7		23.7	23.7			23.7	23.7	23.7	23.7	23.7	23.7	23.7	23.7	23.7	23.7	23.7	23.7	23.7	23.7							23.9	23.9		23.9										
420-9		39.0							37.3	37.3	37.3	37.3	37.3	37.3	37.3	37.3	37.3	37.3	37.3	37.3																				
420-10	18.0		18.0	18.0			18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0							17.8	17.8		17.1	17.1									
780-1						33.3			33.3																															
780-2					14.5				14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5									14.5											
780-3						30.7			30.7	30.7	30.7	30.7																												
780-4		36.3							35.7	36.3	36.3	35.7	35.7	35.7	35.7	35.7	35.7	35.7	35.7	35.7																				
780-5		40.5							40.5	40.5	40.5	40.5	40.5	40.5	40.5	40.5	40.5	40.5	40.5	40.5																				
780-6	20.3		20.3	20.3			20.3	20.3	20.3	20.2	20.2	20.4	20.4	20.4	20.9	20.9	20.9	20.4	20.4	20.4							20.4	20.2		20.2	20.2									
780-7	25.2		25.2	25.2			25.2	25.2	25.2	25.2	25.2	25.7	25.0	25.0	25.0	23.5	23.5	23.5	23.5	23.5							25.2	25.2		25.2										
780-8					16.0				15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5																				
780-9						26.4			26.4	26.4	26.4	26.4	26.4	26.4	26.4	26.4	26.4	26.4	26.4	26.4																				
780-10																																								
580-1	22.9		24.4	25.2			25.2	25.2	22.6	22.9	22.9	22.9	22.9	22.9	22.9	22.9	22.9	22.9	22.9	22.9							22.9	22.9		22.9	22.9	22.9								
580-2	18.9		18.9	18.9			18.9	18.9	18.9	19.9	19.9	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8							19.0	19.0		19.0	19.0	19.0								
580-3	23.9		23.9	23.9			23.9	23.9	23.9	23.9	23.9	23.9	23.9	25.4	1.5-	1.5-	2.7-	2.7-	2.7-	23.9							23.9	23.9		23.9	23.9	23.9								
580-4			25.7	25.7			25.7	25.7	25.7	25.7	25.7	25.7	25.7	25.7	26.2	26.2	26.2	26.2	25.7	25.7							25.7	25.7		25.7	25.7	25.7								
580-5																											19.0	19.0		19.2	19.2	18.5								
580-6	19		19.8	19.8			19.8	19.8	18.5	18.5	19.0	18.8	19.0	16.1	16.1	18.3	18.3	18.3	18.3	18.3							19.0	19.0		19.0	19.9	15.5								
580-7						33.3			33.3	33.3	33.3	33.3	33.3	33.3	33.3	33.3	33.3	33.3	33.3	33.3												32.3								
580-8	19.4		19.4	19.4			19.4	19.4		19.9	19.4	19.5	19.0	19.8	19.5	19.5	19.5	19.5	19.5	19.5							19.4	19.9		19.9	19.4	19.9								
580-9	20.2		19.9	19.9			19.9	19.9	20.7	20.9	20.1	19.5	20.2	20.2	30.5	19.4	19.4	19.4	19.4	19.4							20.2	20.2		19.9	19.9									
580-10	20.6		20.7	17.1	17.3				16.7	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1							17.1		17.1		17.1	17.1								
400-11																									22.9							28.7	22.9	33.3	23.1			22.9	23.1	23.1
400-12																					17.0						17.6	17.6		17.6	18.5	19.8	18.2	17.8	17.8	17.8	17.8	17.8	17.8	17.8
400-13																										18.2	19.4	19.4		19.4	19.4	19.8	17.9		17.8	17.8	17.8	17.8	17.8	17.8
400-14																								20.1			20.2	20.2		19.9	20.4	20.4	20.4	19.9	19.4	19.0	19.0	19.0	19.0	19.0
400-15																					22.3						22.3	22.3		22.6	22.6	23.5	22.4	23.1	22.4	23.1	23.1	22.4	22.4	22.4
400-16																							19.4				19.9	19.9		19.9	19.9	19.9	19.4	19.4	16.9	SC-	SC-	SC-	16.4	16.4
400-17																										19.4	19.0	19.0		19.0	19.0	19.0		19.0	19.0	24.6	24.6	24.6		19.0
400-18																						22.9					22.9	22.9		22.9	22.9	22.9	22.9	24.4	33.0	33.0	33.0	33.0	35.0	25.2
400-19																								20.3			20.2	20.2		19.9	17.9	17.9	19.9	17.8	18.2	17.8	17.8	17.8	17.8	17.8
400-20																								22.9			19.9	19.9		19.9	19.9	19.9	19.9	19.4	19.4	19.4	19.4	19.5	19.4	19.4

Appendix V – Diver Survey Data from the Observer Efficiency Study Section of the Salmo River, 2001-2003

Survey date	Section	Observer efficiency	RB observed 0-20cm	20-30cm	30-40cm	40-50cm	50+cm	Count >30	Count >40	BT	EB	MW	SU	NPM
28-Jun-01	upper	0.5	15	14	14	14	0			7	1	0	0	0
	lower	0.75	146	50	59	41	7			9		4	47	5
	total	**0.6875**	**161**	**64**	**73**	**55**	**7**	**135**	**62**	**16**	**1**	**4**	**47**	**5**
04-Jul-01	upper	0.5	51	32	30	12	3			0	0	0	0	0
	lower	0.5	236	115	47	23	3			18	12	6	62	0
	total	**0.5**	**287**	**147**	**77**	**35**	**6**	**118**	**41**	**18**	**12**	**6**	**62**	**0**
06-Jul-01	upper	0.75	21	25	36	9	5			6	2	0	0	0
	lower	0.333333	174	110	60	33	4			20	2	4	181	0
	total	**0.4375**	**195**	**135**	**96**	**42**	**9**	**147**	**51**	**26**	**4**	**4**	**181**	**0**
16-Jul-01	upper	0.5	150	47	15	13	4			4	5	1	0	1
	lower	0.375	238	88	54	25	4			6	0	2	169	27
	total	**0.416667**	**388**	**135**	**69**	**38**	**8**	**115**	**46**	**10**	**5**	**3**	**169**	**28**
18-Jul-01	upper	1	59	42	33	14	4			1	3	1	0	1
	lower	0.333333	218	94	59	27	5			0	0	1	180	24
	total	**0.538462**	**277**	**136**	**92**	**41**	**9**	**142**	**50**	**1**	**3**	**2**	**180**	**25**
30-Jul-01	upper	0.666667	88	42	27	8	4			2	4	1	0	0
	lower	0.555556	440	119	66	41	9			8	10	3	135	32
	total	**0.583333**	**528**	**161**	**93**	**49**	**13**	**155**	**62**	**10**	**14**	**4**	**135**	**32**

Survey date	Section	Observer Efficiency	RB observed 0-20cm	20-30cm	30-40cm	40-50cm	50+cm	Count >30	Count >40	BT<30	BT>30	EBT	MW
09-Jul-02	upper	0.25	4	1	0	1	0	1	1	0	6	1	0
	lower	0.166667	11	13	5	8	1	14	9	0	3	0	1
	total	**0.2**	**15**	**14**	**5**	**9**	**1**	**15**	**10**	**0**	**9**	**1**	**1**
11-Jul-02	upper	0	9	5	6	5	2	13	7	0	2	0	0
	lower	0.2	22	9	11	13	1	25	14	1	5	0	0
	total	**0.125**	**31**	**14**	**17**	**18**	**3**	**38**	**21**	**1**	**7**	**0**	**0**
16-Jul-02	upper	0.333333	63	19	11	2	1	14	3	0	3	8	0
	lower	0.5	56	31	18	14	4	36	18	1	8	0	0
	total	**0.444444**	**119**	**50**	**29**	**16**	**5**	**50**	**21**	**1**	**11**	**8**	**0**
18-Jul-02	upper	0.333333	92	37	4	9	1	14	10	0	5	5	0
	lower	0.666667	184	75	21	17	4	42	21	0	11	7	2
	total	**0.555556**	**276**	**112**	**25**	**26**	**5**	**56**	**31**	**0**	**16**	**12**	**2**
22-Jul-02	upper	0.666667	110	41	16	8	5	29	13	1	2	16	0
	lower	1	177	98	27	19	6	52	25	0	5	2	5
	total	**0.875**	**287**	**139**	**43**	**27**	**11**	**81**	**38**	**1**	**7**	**18**	**5**
30-Jul-02	upper	1	254	90	15	20	2	37	22	0	1	9	0
	lower	0.6	416	177	42	24	8	74	32	1	4	0	2
	total	**0.75**	**670**	**267**	**57**	**44**	**10**	**111**	**54**	**1**	**5**	**9**	**2**
01-Aug-02	upper	0.666667	152	72	15	11	2	28	13	0	1	17	0
	lower	1	189	86	40	31	4	75	35	0	3	0	1
	total	**0.875**	**341**	**158**	**55**	**42**	**6**	**103**	**48**	**0**	**4**	**17**	**1**

Survey date	Section	Observer efficiency	RB observed 0-20cm	20-30cm	30-40cm	40-50cm	50+cm	Count >30	Count >40	BT<30	BT>30	EBT	MW
02-Jul-03	upper		19	29	19	5	2	26	7	0	6	0	0
	lower		21	65	33	14	10	57	24	0	2	0	0
	total	**0.40**	**40**	**94**	**52**	**19**	**12**	**83**	**31**	**0**	**8**	**0**	**0**
04-Jul-03	upper		9	24	13	11	7	31	18	1	2		
	lower		59	52	28	22	7	57	29	1	14		
	total	**0.50**	**68**	**76**	**41**	**33**	**14**	**89**	**47**	**2**	**16**	**0**	**0**
07-Jul-03	upper		72	37	21	11	6	38	17	0	10	1	
	lower		103	72	33	13	3	49	0	1	7	0	4
	total	**0.50**	**175**	**109**	**54**	**24**	**9**	**86**	**33**	**1**	**17**	**1**	**4**
10-Jul-03	upper		66	38	18	12	3	33	15	4	6	2	
	lower		102	76	63	28	9	100	37	1	13	7	3
	total	**na**	**168**	**114**	**81**	**40**	**12**	**133**	**52**	**5**	**19**	**9**	**3**
18-Jul-03	upper		55	72	23	7	10	40	17	0	4	0	0
	lower		236	153	73	38	15	126	53	7	11	4	3
	total	**0.89**	**291**	**225**	**96**	**45**	**25**	**166**	**70**	**7**	**15**	**4**	**3**