The Duncan Bull Trout Telemetry Project
(1995 - 1997)

A report submitted to the Columbia Basin Fish & Wildlife Compensation Program by

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July 1999

ABSTRACT

Radio telemetry was used to identify spawning sites and gather migration timing data for bull trout (*Salvelinus confluentus*) in the Duncan River system in southeastern British Columbia. A total of 98 radio-tags were surgically implanted into adult bull trout over the three year project (1995 - 1997). Bull trout were collected at Duncan Dam on their spawning migrations from Kootenay Lake to sites in the upper Duncan River (upstream of the dam). Manipulation of discharge from the dam allowed migrant bull trout access to the reservoir and river upstream. Movement both upstream and downstream through the discharge structures at the dam was confirmed. Bull trout spawning sites were identified throughout the Duncan River system. Primary spawning sites in the upper Duncan River system were Houston Creek and Westfall River. Spawning was confirmed by ground surveys. Juvenile bull trout aggregations were identified in these two tributaries of the upper Duncan River. Migration timing was found to be the same over a range of migratory destinations regardless of minor environmental fluctuations. Migrations into the upper Duncan River system involved immigration to a spawning destination (mean = 51 days; from 8 July to 29 August), residence at the destination (mean = 32 days), and a rapid emigration back to the Duncan Reservoir (mean = 9 days; from 28 September to 8 October). There was no temporal variation in proportion of radio-tagged bull trout migrating to destinations in the upper Duncan River system. Two thirds of consecutive year migrants changed their migratory destination by more than 10 km, and one third changed destination tributary. Mitochondrial DNA RFLP analysis of both migrant and resident bull trout populations in the Duncan River system suggest that most molecular genetic variation exists in bull trout populations resident above barriers to upstream migration. Microsatellite markers used to compare juvenile bull trout sampled from Houston Creek and Westfall River in the upper Duncan River system revealed low levels of molecular genetic variation. Molecular and telemetry results combined, suggest that migration (gene flow *via* spawning stream switching) tends to drive observed low genetic variation between spawning sites in the upper Duncan River system.

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ACKNOWLEDGMENTS

This project would not have been possible without the contribution of many people, and their assistance is gratefully acknowledged. Dr. Don McPhail (UBC), Dr. Eric Taylor (UBC), Ric Olmsted (BCHydro), Colin Spence (B.C. MoELP), John Bell (B.C. MoELP), Harald Manson (CBFWCP), Steve Arndt (CBFWCP) and Maureen DeHaan (CBFWCP) provided a wealth of experience, ideas and encouragement that was vital to the success of the project. Additional thanks to: Ric Olmsted, Janelle Curtis, Steve Arndt and Harald Manson for thorough editing of draft reports. Rayanne McKay and Mark Phillpotts provided excellent assistance in the field; Murray Pearson, Peter Mylechreest, Gordon Haas, James Baxter, Ernest Keeley, Jason Ladell, Lynda Ritchie, Ian Kusabs, Steve Latham, Mike Stamford, Abraham bij de Vaate, Gary Birch, Dean den Biesen and Mark Hamilton for technical help, advice, and always an interesting new angle; Ken Ashley for getting the ball rolling; and the Staff at Duncan Dam, especially Len Wiens, Ray Wheldon and the late Dan Burt. Finally, 'Dutchy' Wageningen, for having the foresight to let bull trout through the dam in the first place.

The Columbia Basin Fish & Wildlife Compensation Program provided project funding and field equipment.
NSERC, through grants to D. J. McPhail and E. B. Taylor, supported a portion of operating costs in the lab.
BCHydro provided safety equipment and training for Duncan Dam work, and a jet boat used to access the Duncan River.
The Ministry of Environment, Lands and Parks provided staff housing, fence material, and fixed receiver stations.

1. INTRODUCTION

The Duncan River system, located in the southeast corner of British Columbia, is bounded by the Selkirk and Purcell mountains and drains into Kootenay Lake and ultimately into the Columbia River (Fig. 1, Fig. 2). On 31 July 1967, Duncan River was impounded by the completion of Duncan Dam, located approximately 10 kilometers upstream of the river's confluence with Kootenay Lake. Duncan Dam is 40 m high and creates a 72 km^2 reservoir. The dam provides water storage (1.73 billion m^3), but has no power generation facilities (Anon. 1986).

The migration route of bull trout (*Salvelinus confluentus*) to and from Kootenay Lake to spawning sites in the upper Duncan River requires passage through Duncan Dam. Studies prior to 1967 predicted that the migration route would be blocked by impoundment (Peterson and Withler 1965). In 1968, the first senior operator at the dam, 'Dutchy' Wageningen, altered spring and summer discharge at Duncan Dam to allow bull trout access to the upper river. Currently, the fish transfer procedure continues under the supervision of BCHydro, the B.C. Ministry of Environment, Lands and Parks - Fisheries Section (MELP), and Len Wiens, the present senior operator. Tag recapture information prior to this study suggested that bull trout are able to ascend the dam (J. Bell, *pers. comm.*, Fleck 1977), but in 1994, helicopter surveys of the upper Duncan River system failed to locate evidence of spawning (C. Spence, *pers. comm.*). Tagging studies of bull trout from the Duncan River system report evidence of migrations throughout the larger Kootenay River system, with tag returns ranging from Trout Lake in the north to the Kootenay River at the Moyie River confluence in the south (Fleck 1977).

The Columbia Basin Fish & Wildlife Compensation Program (CBFWCP) is a joint initiative of BCHydro and MELP to compensate for the impacts of impoundment of the Columbia River and tributaries on fish and wildlife populations. Bull trout utilizing the upper Duncan River were identified as candidates for CBFWCP attention. This radio-telemetry project was initiated in 1995 by the CBFWCP to achieve two objectives. The main objective was to quantify migratory timing and identify key migratory and spawning habitats of bull trout captured at the dam. The second objective was to evaluate interactions of bull trout with Duncan Dam, with the intent to modify, if necessary, dam operations to facilitate bull trout movements.

I was contracted to undertake this project within the context of a MSc. thesis at the University of British Columbia under the supervision of Dr. J. D. McPhail. In addition to the two primary objectives outlined above, the requirements of a MSc. thesis included an additional objective. McPhail and Murray (1979) hypothesized that as bull trout age and grow, they require sites with larger substrate for spawning and thus change spawning location through life. I used the data collected in this project to address this hypothesis and briefly outline the results in this report.

We located sites in the upper Duncan River that are likely spawning locations for bull trout. The spatial distribution of putative spawning sites suggested bull trout in the upper Duncan River system may be structured into sub-populations. Semi-isolated sub-populations, or demes, within a larger population may show genetic differentiation (Harrison and Hastings 1996, Hartl and Clark 1989). Two molecular genetic components were added to initial project goals to evaluate the contribution of hypothesized sub-populations to the bull trout interacting with Duncan Dam. If bull trout from different spawning sites have detectable genetic differences, it would be possible to identify the origin of bull trout sampled at the Dam. By knowing the origin of bull trout at Duncan Dam, the importance of different spawning sites could be evaluated. The first genetic component (1996) was a system wide survey of mitochondrial DNA (mtDNA) diversity, comparing bull trout captured at Duncan Dam with bull trout collected in both the upper Duncan River system and resident populations existing above migration barriers. The second genetic component (1997), using higher resolution microsatellite DNA markers, compared two confirmed spawning tributaries to determine if there was molecular genetic evidence of isolation between spawning sites in the upper Duncan River.

For convenience, this report is divided into four primary components, presented in order, in the methods, and in turn results and discussion:

1. *Telemetry* - addresses all aspects of radio telemetry including capture, surgery, tracking, and data analysis.
2. *Population Surveys* - describes the collection and analysis of tagging data on adult bull trout, electroshocking survey data from juvenile aggregations and above-barrier resident populations, as well as methods used to estimate spawning numbers.
3. *Molecular* - details mitochondrial and microsatellite DNA analyses.
4. *Temperature and Discharge* - outlines the collection and analysis of environmental data.

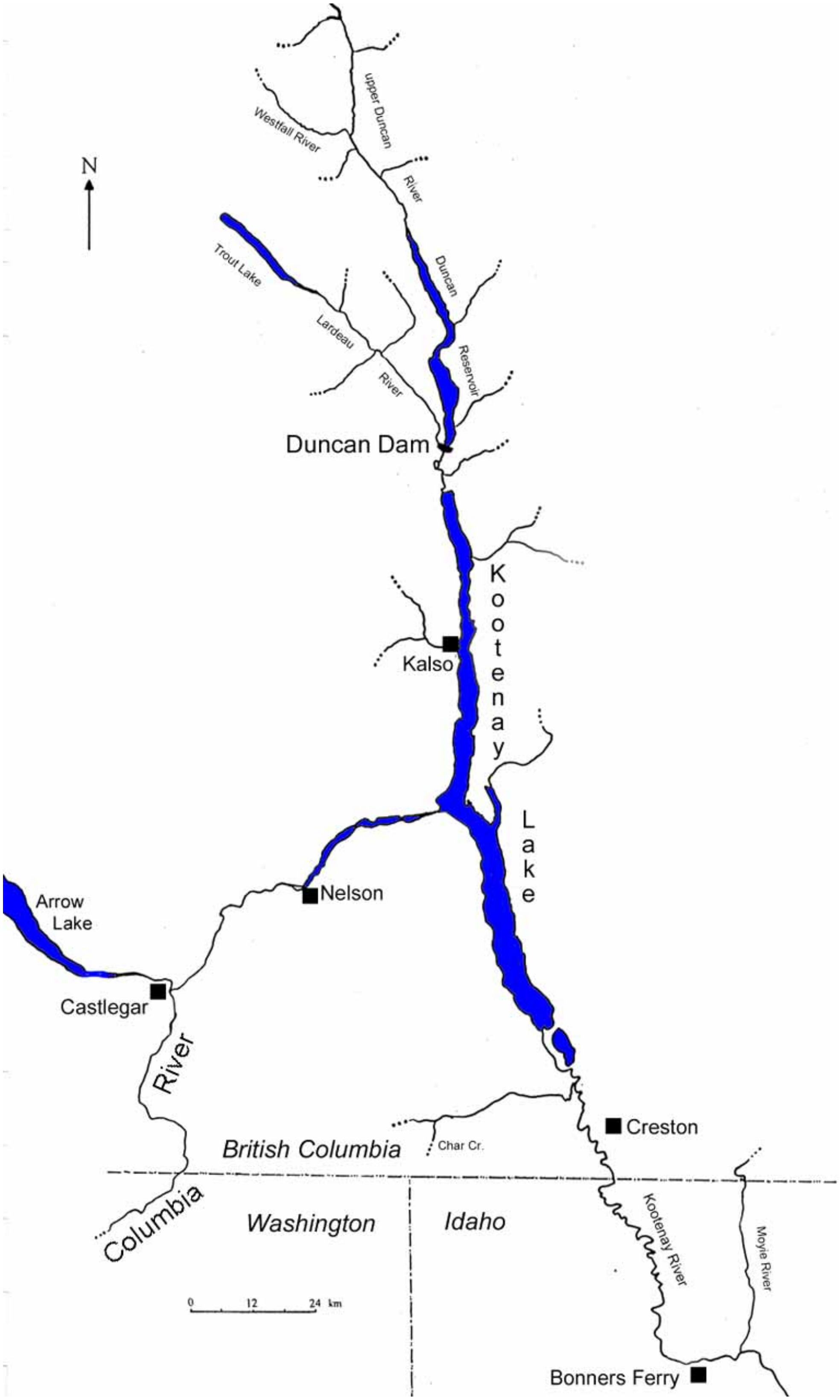

Figure 1. Map of the study area.

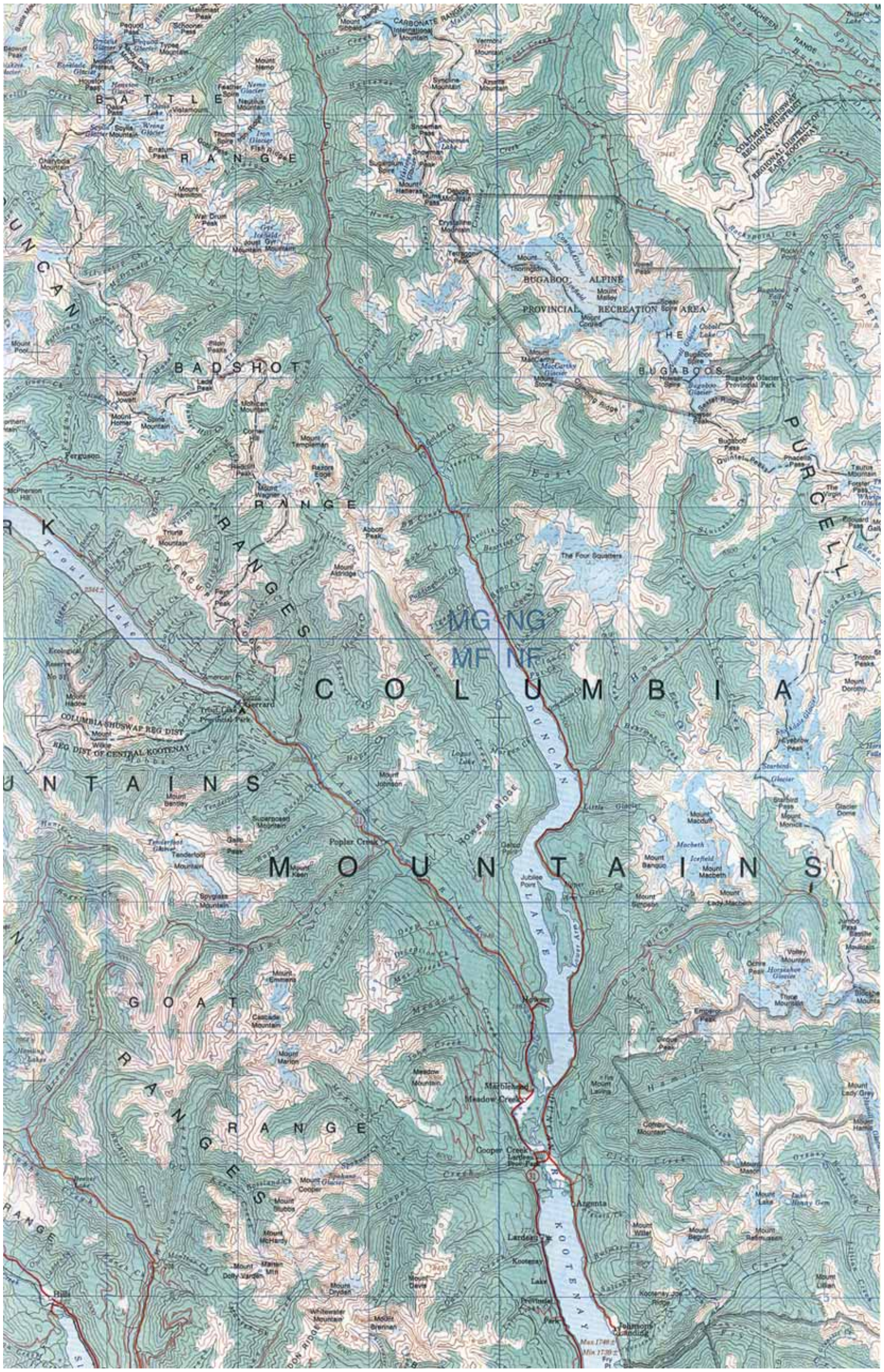

Figure 2. Regional topographic map of the Duncan River system. Scale is 1:250,000 (1 cm = 2.5 km)

2. METHODS

2.1. TELEMETRY

We used several different radio-tags, which varied in size, emission duration and frequency, during the project (Table 1). All radio-tags were digitally encoded, allowing reception equipment to distinguish individual signals. The radio-tags and reception equipment were manufactured by Lotek Engineering, Newmarket, Ontario.

Table 1. Characteristics of radio-tags employed in the study.

Channel	Frequency (MHz)	Number deployed	Duration (months)	Diameter (mm)	Length (mm)	Antenna length (mm)	Mass (g)
5	149.400	31	12	11	50	400	8.2
15	148.400	16	6	11	45	370	7.1
20	149.700	15	24	15	50	400	15.5
22	149.740	16	12	11	50	400	8.2
31	150.120	18	12	11	50	400	8.2

2.1.1. CAPTURE

We obtained bull trout for radio tagging from four locations: the discharge structure at Duncan Dam, the tailrace immediately downstream of the dam, the lower Duncan River (between the dam and Kootenay Lake), and the upper Duncan River. Bull trout were captured by angling with spoons at locations other than the Duncan Dam. Those captured at the discharge structure were fish that had actively moved into the weir or flip bucket. To obtain fish at the dam, discharge was blocked and fish netted out of the flip bucket or weir. Access to the discharge structure to capture bull trout required a dam operating procedure called a flip bucket drain. The drain procedure and capture of bull trout is described in more detail in the Population Survey section.

2.1.2. SURGERY

We did not select bull trout randomly for transmitter application. The weight (in water) of surgically implanted tags should not exceed 2% of the weight (in air) of the fish destined to carry it, and ideally this ratio should not exceed 1% (McLeod and Clayton 1993, Marty and Summerfelt 1986). By selecting bull trout that exceeded 500 mm fork length (FL), we kept the weight ratio below 1% in all cases. We attempted to radio-tag only male bull trout; however, sex determination prior to surgery was difficult, as few secondary sexual characteristics were evident. We targeted males for two reasons: primarily to limit effects of tagging on reproduction, and secondly because we thought it likely that male bull trout would remain at spawning locations longer than females. Although no specific character was informative in all cases, our sex estimates were based primarily on head and body shape. Generally, male bull trout have a larger head and more robust lower jaw than a female of similar size. We found the sex estimate technique suggested by McPhail and Murray (1979), involving adipose fin size and shape (males distinguished by their larger, more rounded adipose fins) was not reliable, although it was helpful when used with other observed characteristics. When possible during surgery, we determined sex by internal examination of the gonads.

We anaesthetized selected fish in a cooler containing 30 L of water with tricane methane sulfonate (MS222) at 100 ppm. Whenever possible, we used the anesthetic bath on two or three fish that did not undergo surgery prior to anaesthetizing a surgical candidate, to lower the stress of reduced pH brought about by the addition of MS222 (Bidgood 1980). We anaesthetized bull trout to stage 4 for surgery. Stage 4 anesthesia is characterized by loss of both equilibrium and reactivity to external stimuli as well as a slow but regular opercular rate (McKinley *et al*. 1992).

We measured FL, standard length (SL), and post orbital - hypural length (POHL) with a flexible tape (± 5 mm). Mass was measured using a spring scale (± 200 g) with the bull trout supported in either a collapsible fish tube or weigh bag of known mass. Scale samples were collected from an area between the insertion of the dorsal fin and origin of the anal fin immediately above and/or below the lateral line. We collected between three and five scales from either side of a sampled bull trout. In addition, we cut approximately 1 cm^2 of the upper lobe of the caudal fin from all radio-tagged fish as a tissue sample for molecular analyses. Both scales and fin tissue were preserved and stored in individually labeled centrifuge tubes containing 95% ethanol.

Subsequent to measuring lengths and mass, a radio-tag was inserted into the abdominal cavity, as described in McLeod and Clayton (1993). Briefly, we placed the anaesthetized fish on its back in a wet neoprene lined wooden ‘V’-trough and covered it, except the region of incision, with moist towels. In 1995, we made a 2.5 cm long incision into the abdominal cavity immediately anterior of the pelvic girdle and approximately 1 cm off and parallel to the mid-ventral line. In 1996, the incision was made directly on the mid-ventral line to reduce perceived damage to the ventral musculature. We then inserted a stainless steel needle (16 gauge, 5 cm long) through the body wall from posterior to the pelvic girdle into the incision. We threaded the whip antenna of the radio-tag through the needle, removed the needle, and inserted the tag into the abdominal cavity. We closed the incision with three or four interrupted sutures and applied betadine to the closed incision and antenna exit wound. We recovered the fish by holding it directly in a stream of flowing water. When the fish was capable of maintaining equilibrium (stage 2 anesthesia - McKinley *et al*. 1992), it was placed a collapsible fish tube and allowed to further recover (30 - 180 min.) before release.

Prior to 28 June 1995, all radio-tagged bull trout caught at Duncan Dam were released in the flip bucket. We anticipated that the majority of these fish would be tracked ascending through the discharge structure; however, we did not track any of these initial releases in the upper Duncan River. Subsequent to 28 June 1995, we released all bull trout radio-tagged at Duncan Dam into Duncan Reservoir. In 1996, we released 34 bull trout radio-tagged at the dam into the reservoir to ensure a large sample size of migrants to the upper Duncan River system. Six bull trout radio-tagged at the dam in 1996 were released back to the flip bucket. All bull trout that we angled and radio-tagged away from the dam were released at the point of capture.

In 1996, we recaptured seven bull trout carrying radio-tags from 1995. As these tags would have stopped functioning before the end of the migration period in 1996, we attempted (in six of the seven fish) to surgically remove the 1995 radio-tag and replace it with at new one. In two of the replacement attempts, we could not remove the old tag and so clipped its’ antenna close to the body to minimize drag before inserting the new tag. In the other four replacements we removed the initial tag without incident. We recaptured nine radio-tagged fish in the flip bucket in 1997, and removed (but did not replace) one of the tags.

2.1.3. TRACKING

We used a Lotek SRX-400A version 4.01/W5 receiver to track radio-tagged bull trout by truck, boat and aircraft. While tracking on the ground or by boat, we used either a hand held three element antenna or a short range whip antenna. A Cessna 172 aircraft was used for the majority of aerial tracking, but we used a Eurocopter AS 350B helicopter on two occasions, and a Cessna 337 aircraft once. Antenna setup differed by aircraft: the Cessna 172 had a single forward pointing four element antenna attached to the port side wing strut, the AS 350B had a single three element antenna attached to the nose of the aircraft, and the Cessna 337 had a downward-pointing two element antenna attached to each wing strut. In the Cessna 337, a switch-box allowed the receiver to ‘listen’ to both antennae simultaneously or either individually during tracking to help resolve the direction of receptions. When tracking from aircraft, we recorded location of receptions with both written descriptions and UTM coordinates from an onboard GPS unit (Magellan - Flight mate Pro).

Generally, we maintained a bi-weekly schedule of tracking flights during the immigration and spawning phase in 1995 and 1996. As the first radio-tagged fish began to leave their spawning sites, flight frequency was increased. In 1997 and 1998, we flew once in September to identify number and location of spawning bull trout.

We also used two Lotek SRX-400A version 4.01/W17T receivers - loaned for use by MELP (Nelson) - as data logging fixed stations during 1996. Fixed station sites consisted of a battery-powered (1 deep-cycle 12V RV battery) receiver connected to two antennae oriented upstream and downstream to resolve direction of travel. Fixed station sites were located 6.4 km downstream of the Duncan Dam on the lower Duncan River and 42.5 km upstream of the dam on the upper Duncan River ((UTM 5561050N 503340E and UTM 5609345N 496650E respectively, Fig. 3). We programmed fixed receivers to continuously scan each frequency in sequence for a five second interval on each antenna, and record any reception in memory. With this scan cycle, each frequency was scanned for a minimum of 12 min each hour. We downloaded reception information to a portable computer when the receiver battery was replaced (bi-monthly).

At the end of October in 1996, we dismantled one fixed station receiver and moved the other to the discharge structure at Duncan Dam. The dam site consisted of an adapter-powered receiver connected to a single antenna pointed directly into the tailrace, immediately downstream of Duncan Dam. We used the Continuous Record Time-Out (CRTO) data reduction routine (present in the receivers firmware) to prevent filling the receivers’ small built-in memory (512K) between data retrievals. We downloaded the dam receiver site monthly through the summer of 1997. BCHydro arranged for two downloads and the dismantling of the dam site in August 1998.

2.1.4. DATA ANALYSIS

Where necessary, I distinguish between two years of tracking data for a single fish. I converted raw aerial, ground, and remote reception data to UTM coordinates and distance upstream (+) or downstream (-) of the Duncan Dam. Figure 3 illustrates the kilometer designations used throughout the study.

To begin analysis of the telemetry data, I plotted the reception locations for each tagged individual as date vs. distance from Duncan Dam. Two patterns of movement were evident. First, a directed movement into a tributary stream, and second, a lack of directed movement. Since evidence of spawning was found in some tributary streams targeted by radio-tagged bull trout, I termed the directed movements ‘migratory’ and the less directed ones ‘non-migratory’. I divided the data into two groups based on this criteria for all further analyses. Many bull trout were tracked for multiple years, and often both patterns of movement were evident within a single individual across years. In these cases, I separated the two types of yearly movements and analyzed the data separately. In addition, I describe and compare the complete multiple year movement patterns of individuals.

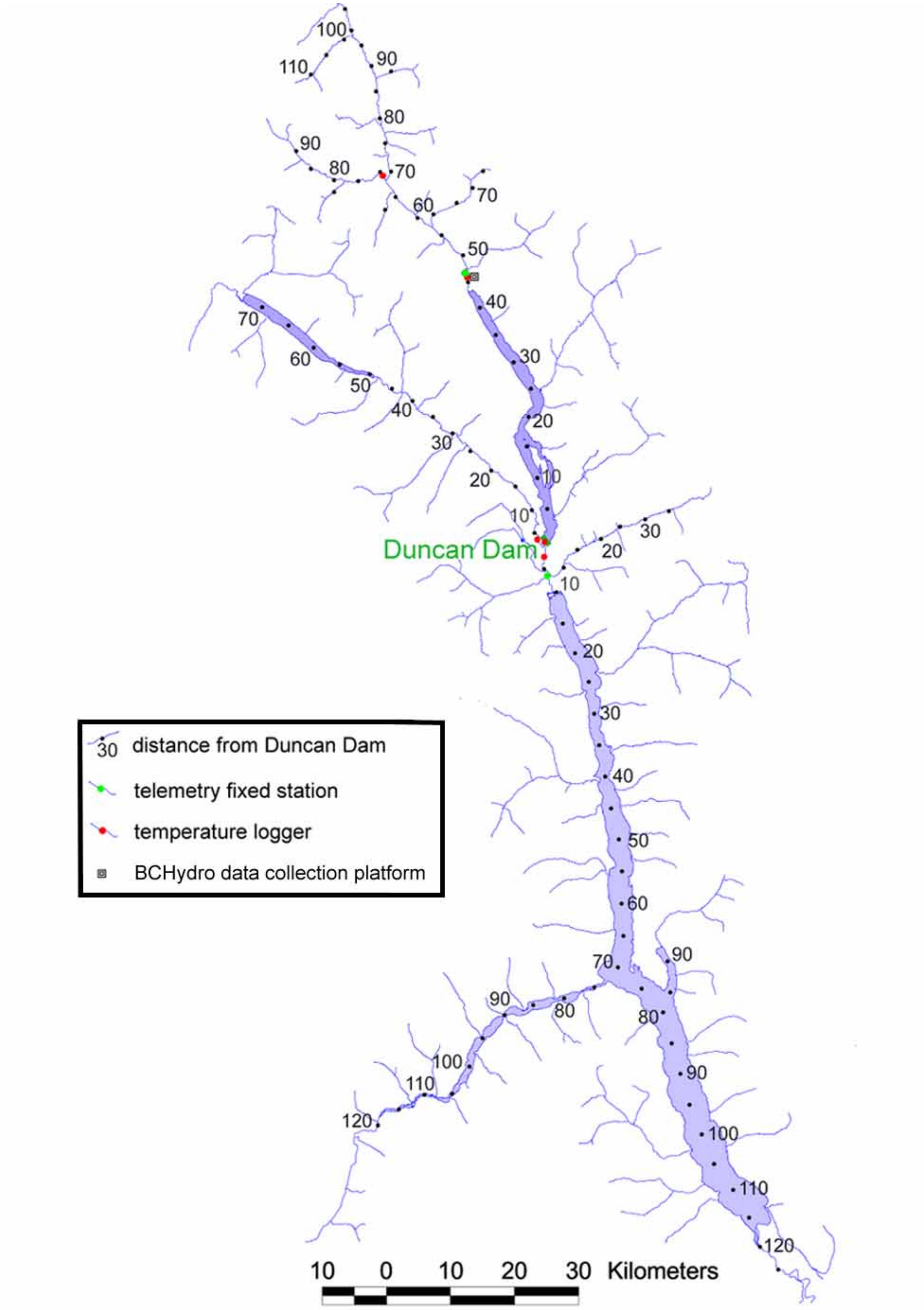

Figure 3. Kilometer designations in Kootenay Lake and the Duncan River system.

Bull trout movements that did not involve a directed migration were analyzed by calculating the total amount of time tracked in each of three zones: (i) within 1 km of the dam, (ii) in the lower Duncan River or Kootenay Lake, and (iii) in the Lardeau River or Trout Lake. I averaged these calculated times over all individuals to allow for a descriptive analysis of time spent in these locations. I also calculated the mean date for changes in position between these three zones to identify the timing of occupancy. Secondly, I plotted the frequency of reception (unique codes per day) within one km of Duncan Dam to show temporal changes in relative use of this area by bull trout.

I divided bull trout movements that reflected a distinct migration pattern into three phases: the immigration, spawning site residence, and emigration. I considered the immigration phase underway when a radio tagged individual was released or directed movement began, and it continued until directed upstream movement ended. The spawning site residence phase continued from the end of the immigration phase until a directed downstream movement began. For migrants to the upper Duncan River system, I considered the emigration phase complete when a tag was first detected in the Duncan Reservoir (1995) or when it had passed below the fixed station receiver at East Creek (1996). For migrants downstream of Duncan Dam, I considered the emigration complete when they had returned to Kootenay lake.

To simplify these data, I categorized bull trout migrating to similar locations, and for each destination, an arbitrary distance from Duncan Dam was used to distinguish between the three migration phases. The arbitrary residency mark was positioned to include all similar migrants to a particular location and was based on cessation of directed upstream movement by those migrants. For example, when a radio-tagged bull trout immigrating to Houston Creek (a tributary of the upper Duncan River) crossed a mark 100 km upstream of the Duncan Dam, I considered the immigration phase to have ended and the spawning site residency phase to have begun. Similarly, when the 100 km residency mark was crossed in the downstream direction by bull trout in Houston Creek the spawning site residence ended and the emigration phase started. Most often, we did not locate radio-tagged bull trout as they crossed the residency mark; the date was inferred from the closest receptions immediately upstream and downstream.

By dividing movement patterns into these three phases (Fig. 4), I was able to calculate 9 migration statistics for comparison:

- immigration start date / time (days) / rate (km•day^{-1})
- residency start date / time (days),
- emigration start date / time (days) / rate (km•day^{-1}) / end date.

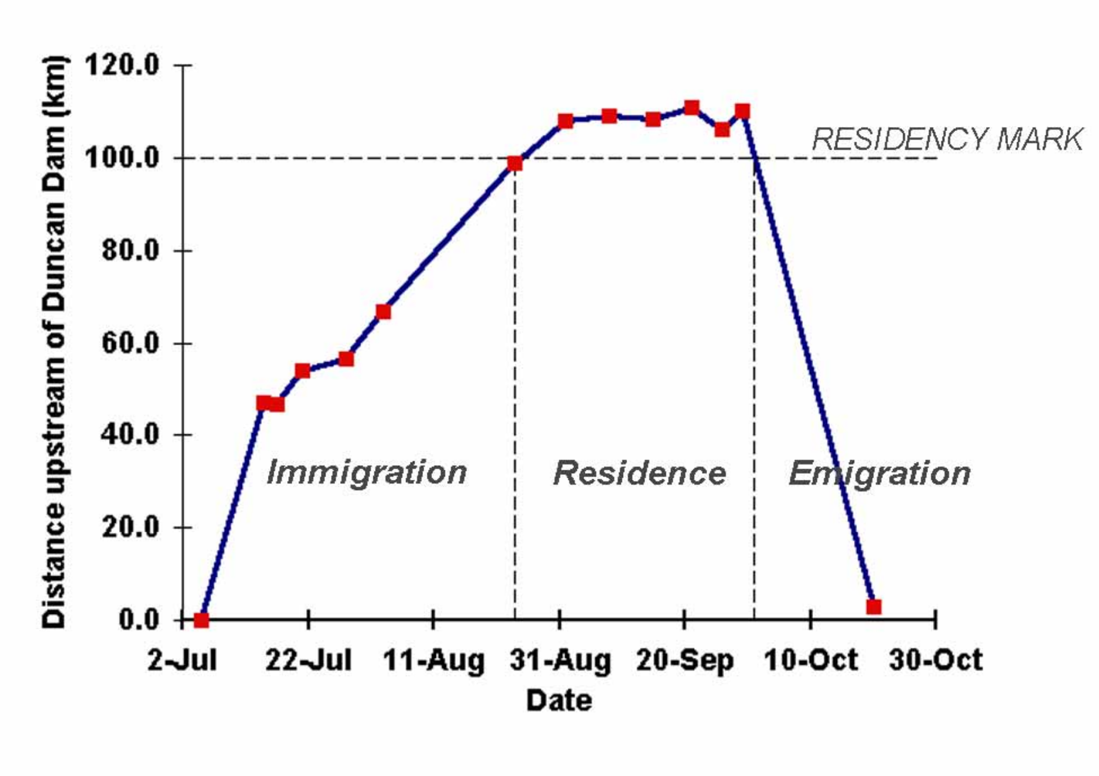

Figure 4. Example migration pattern showing the function of the residency mark in defining the boundaries between the three migration phases.

I compared the nine migration statistics, along with fork length and weight, over the two years of intensive tracking (1995 and 1996) using two-factor analysis of variance (ANOVA). The telemetry project was not designed to fit the ANOVA model and, as such, I used it only as an exploratory analysis tool. The first factor in the ANOVA analysis was the year of migration. For bull trout with two years of migration data in the upper Duncan River, I considered each migration year as independent in terms of the ANOVA analysis. The second factor in the analysis was destination. Because of small sample sizes to some destinations, I grouped low-use destinations into more broad categories for analysis. Where no differences were found by the two-factor ANOVA analysis, I pooled migration statistics.

A brief description of all destinations of radio-tagged bull trout are included in the results. Destination category descriptions and basic section-break data were developed from aerial observations and measurements on 1:50,000 and 1:20,000 regional topographic maps.

2.2. POPULATION SURVEYS

In addition to the collection of migration data and spawning site locations through telemetry, we gathered data to characterize bull trout biology in the Duncan River system. All adult bull trout we captured were Floy-tagged (T-anchor type) and measured (FL) to allow inferences on harvest rates, movement, and growth of fish recaptured by project sampling or recreational anglers. We enumerated bull trout emigrating from one of the primary spawning tributaries in the upper Duncan River with a fish trap, and recorded physical characteristics of redd sites. Via electrofishing, we verified the presence bull trout fry at several of the telemetry identified spawning locations. We compared qualitatively, and in two locations quantitatively, the juvenile distributions in two tributaries of the upper Duncan River. While collecting tissue for genetic analyses, we also sampled a large number of small tributaries within the Duncan River system - often above natural migration barriers - locating resident bull trout populations in many. To better describe these data, I divided them into four sections: adults, spawning, juveniles, and resident populations.

2.2.1 ADULTS

We captured the majority of bull trout adults at Duncan Dam. We captured all bull trout at the dam using the same methods described for radio tagging. The ascent of bull trout into the discharge structure and passage through to the reservoir is facilitated by dam operations. To better describe this process, the fish transfer and flip bucket drain procedures are described in detail.

2.2.1.1. Fish Transfers

Throughout the spring and summer, a 'fish attracting' flow is created by maintaining a minimal discharge of approximately 3 $m^3 \cdot s^{-1}$ (Fig. 5). This discharge fills the flip bucket and pours over the front edge in a 1.5 to 2 m waterfall. The flip bucket is a concrete basin with a concave floor at the downstream end of the discharge tunnel designed to disperse the force of discharged water. The discharge is controlled by adjusting the opening of the Low Level Operating Gate (LLOG) located at the downstream end of the discharge tunnel. The LLOG opening to achieve this flow depends on reservoir levels. Migrant bull trout ascend the waterfall and gather in the flip bucket. Once bull trout accumulate in the flip bucket, they are given access to the reservoir through the discharge tunnel in a fish transfer procedure. In 1994, BCHydro constructed a fish-weir at the base of the flip bucket to both ease access to the flip bucket and increase the size range of bull trout able to ascend. The weir serves as a fish ladder, cutting the height of the waterfall from the flip bucket in half. The dates of fish transfers over the duration of the project are summarized in Table 2.

The transfer procedure is essentially the use of two gates, the LLOG and the Lower Level Maintenance Gate (LLMG) at the reservoir (upstream) end of the discharge tunnel to create a 'lock' like mechanism (Fig. 5). To initiate a fish transfer procedure the LLMG is closed, isolating the discharge tunnel from the reservoir. The water level in the discharge tunnel is allowed to lower to that of the water level in the flip bucket (3 m, taking approximately 1 hour). When the water levels in both the discharge tunnel and flip bucket have equilibrated, the LLOG is fully opened (3m). Because of the shallow slope of the discharge tunnel (length = 300 meters, inside diameter = 6.7 meters, 1% grade), a large volume of water remains inside when the LLOG is opened. Bull trout are allowed to actively move into the tunnel and then the LLOG is closed, trapping the fish in the discharge tunnel. The LLMG is then opened, allowing the fish in the tunnel access to the reservoir. The fish transfer procedure is terminated by re-opening the LLOG to resume the 'fish attracting' flow.

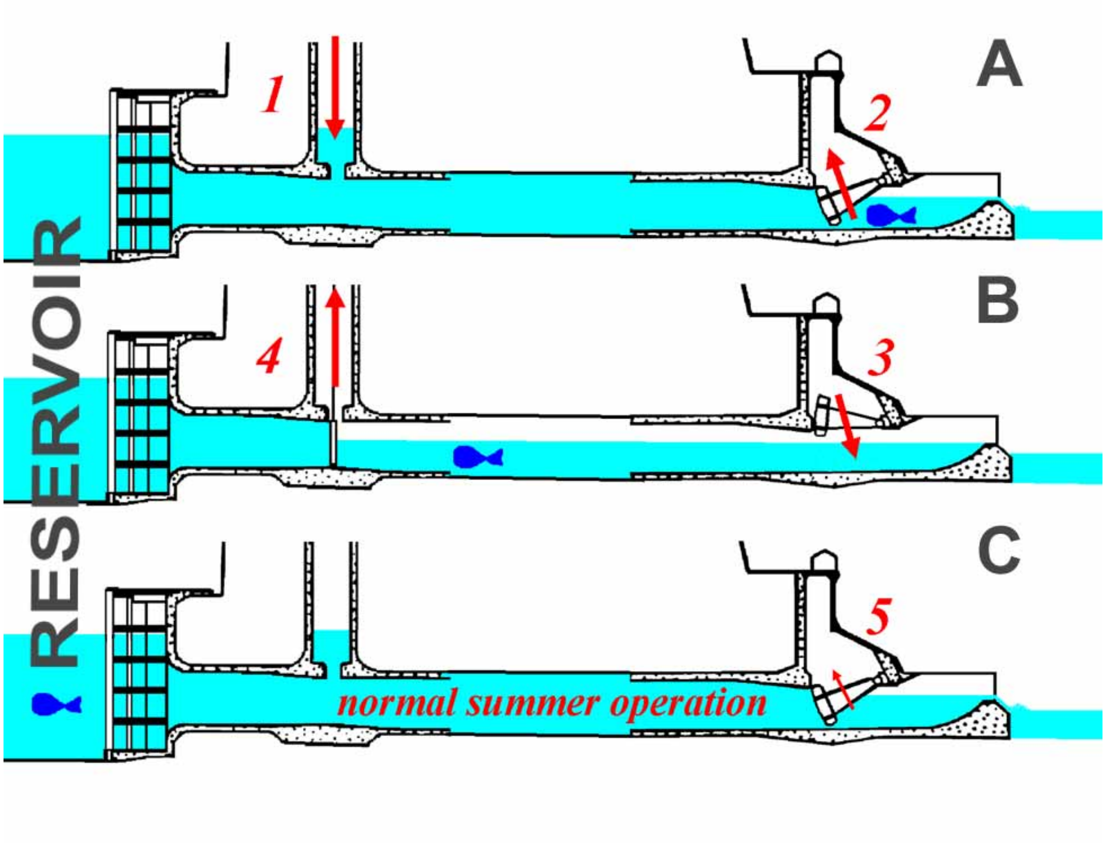

Figure 5 Fish transfer procedure at Duncan Dam illustrated using perspective views (A - C) of the discharge structure. 1.) Maintenance gate (LLMG) lowered to isolate Duncan Reservoir from discharge structure. 2.) Operating gate (LLOG) opened to allow fish access to tunnel from the flip bucket. 3.) LLOG closed, trapping fish in tunnel. 4.) LLMG opened allowing fish access to the reservoir. 5.) LLOG re-opened to allow fish attracting flow through the flip bucket (see text for more details).

The timing of gate movements involved in the transfer procedure changed during the project. The timing we found most effective was opening the tunnel to fish on the afternoon of the first day (approx. 1600h - day 1; steps 1 and 2, Fig. 5), and closing access the next morning (approx. 0830h - day 2; step 3, Fig. 5). The tunnel fills slowly over the second day before raising the LLMG (between 1400 and 1630h - day 2; step 4, Fig. 5) and opening the tunnel to the reservoir. On the morning of the third day of the transfer, the LLOG is raised (approx. 0830h - day 3; step 5, Fig. 5) to re-establish the fish attracting flow. This three day timing of the transfer procedure gives bull trout time to enter the tunnel and assures ample time to vacate the tunnel before flow is re-established. Interestingly, this is a return to the original timing developed by ‘Dutchy’ Wageningen.

Table 2 Dates of fish transfer and flip bucket drain procedures at Duncan Dam.

Number	1995		1996		1997	
	Transfer	Drain	Transfer	Drain	Transfer	Drain
1	May 17	June 8	May 31	June 6	*missing*	June 12
2	May 25	June 22	June 6	June 14	*some*	June 25
3	June 1	July 6	June 14	June 18	June 12	July 4
4	June 8	July 19	July 4	July 3	June 25	July 9
5	June 15	July 27	July 10	July 10	July 4	July 23
6	June 22		July 16	July 11	July 9	July 24
7	June 28		July 24	July 15	July 23	Aug. 13
8	July 6		Aug. 7	Aug. 14	Aug.13	Aug. 14
9	July 14		Aug. 14		Aug. 25	Aug. 25
10	July 19		Aug. 22			Sept. 4*
11	July 27					Sept. 25*
12	Aug. 28					
13	Aug. 31					

* data collected by BCHydro, Castlegar office

2.2.1.2 Flip Bucket Drains

The majority of flip bucket drains occurred immediately before fish transfer procedures (Table 2). To begin a flip bucket drain, the LLOG was lowered to block the fish attracting flow. A high volume submersible pump was used to lower the water level to approximately 0.5m. Bull trout were crowded with a seine net and captured for tagging with a large rectangular landing net. Flip bucket drains required, at minimum, three persons. A BCHydro employee (Duncan Dam staff member) controlled the LLOG and was responsible for all related safety procedures. Two additional personnel were required for the lowering and setup of all equipment, crowding and netting the bull trout, and tagging. In all but one flip bucket drain, additional BCHydro staff assisted with the lowering, setup and removal of the submersible pump and additional staff (CBFWCP, MELP, and BCHydro) and volunteers assisted with bull trout tagging. We measured bull trout not selected for radio tagging to the nearest 5 mm (FL) using flexible tapes, Floy-tagged (T-anchor type), and released them back to the flip bucket. The tagging method involved the passive maneuvering of a bull trout between the legs of the kneeling tagger where it could by tagged and measured without strain. We injected Floy-tags into the musculature between the dorsal pterigophores. We completed the entire Floy-tagging and measuring procedure without removing fish from the water.

Bull trout Floy-tagged away from the dam were either angled, netted from behind the Kokanee enumeration fence at the Meadow Creek Spawning channel, or trapped in the Houston Creek emigrant fence (1996 only). The majority of angling occurred from shore. On one occasion in 1995 and twice in 1996, a jet boat was used to access the lower Duncan River. We tagged and measured bull trout captured away from Duncan Dam in the same manner as those at the dam. Data describing tag numbers, colour, application date and location are appended.

We recaptured Floy-tagged bull trout in flip bucket drains. I calculated estimates of variance in length measurement by repeated measures of the same animal within the same summer. Where time to recapture exceeded one year, I calculated growth rates. I estimated the number of bull trout present downstream of Duncan Dam from the ratio of tagged to untagged fish (the Petersen method, as described by Greenwood 1996) in the flip bucket using:

$$N = (n_1 + 1)(n_2 + 1)/(m_2 + 1) - 1$$

where N = number of bull trout present downstream of Duncan Dam
n_1 = number of fish captured and marked in sample 1
n_2 = number of fish captured in sample 2
m_2 = number of marked fish in sample 2

To allow for comparison of estimates of population size over multiple years, I did not incorporate multiple year recapture information when calculating the Peterson estimates. For example, a bull trout tagged in 1995 would be tallied in calculating the m_2 parameter if subsequently recaptured in 1995 - if the same fish was captured in 1996, it would be considered unmarked in terms of 1996 population estimates.

In addition to the Petersen estimate, I calculated within year population estimates and numbers of bull trout immigrating and emigrating from immediately below Duncan Dam using a Jolly-Seber open model methodology as described by Greenwood (1996). The Jolly-Seber estimates, like the Peterson estimates above, did not incorporate multiple year recapture information. The Jolly-Seber method requires sample specific marks and uses the following information, where an individual “sample” refers to a single flip bucket drain:

n_i = number of fish captured in the i th sample
R_i = number of fish released after the i th sample
m_i = number of fish in the i th sample that carry marks from previous captures
r_i = number of fish released from the sample previous to the i th sample that are ever recaptured in subsequent sampling.
z_i = number of fish captured both before and after the i th sample but not in the i th sample itself

This information is used to calculate the following parameters:

M_i = number of marked animals in the population when the i th sample is taken.
$= m_i + (R_i + 1)/(r_i + 1)$

N_i = population size at the time of the i th sample
$= M_i(n_i + 1)/(m_i + 1)$

Φ_i = proportion of the population remaining in the study area from the i th sampling occasion to the $(i+1)$th sampling event
$= M_{i+1}/(M_i - m_i + R_i)$

B_i = number of animals that enter the population between the i th and $(i+1)$th sample events
$= N_{i+1} - \Phi_i(N_i - n_i + R_i)$

On three occasions the flip bucket was drained immediately before a fish transfer procedure and then drained again the following day to estimate the proportion of bull trout which ascended the dam. In each case, individuals not recaptured in the drain following the fish transfer were assumed to have passed successfully through the discharge structure.

I determined the age of bull trout by counting annuli on collected scale and otolith samples. I cleared Sagital otoliths in a 50% glycerin and water solution prior to viewing. I viewed the otoliths in glycerin on a dark background under a Leitz and Wetzlar dissecting microscope (32X magnification) as described by Kristoffersen and Klemetsen (1991). I cleaned and pressed scales between two microscope slides and viewed them either under a Leitz and Wetzlar dissecting microscope (32X magnification) or projected using a microfiche reader (30X magnification).

2.2.2. SPAWNING

Where access permitted, we conducted foot surveys in telemetry residency areas to locate evidence of spawning. We measured water depth and the excavation length and width at identified redd sites. We also measured water velocity at the surface and mid-column (60% depth) over redds using a Marsh-McBirney Flowmate 2000 Portable Flow Meter. In 1995, we estimated substrate D90 in the final excavation and egg deposition site from photographs of redd sites. In 1996, we made redd substrate D90 measurements in the field.

In 1996, we built a fish fence to determine the number of bull trout present in Houston Creek during the spawning period. The fence was located 1 km upstream of the confluence of Houston Creek with the upper Duncan River (UTM 5648275N 483700E). We first erected the fence using an aluminum sectional panel fence and 2.5 cm wire mesh supported by iron ‘T-bar’ fence posts pounded into the substrate. The first fence was broken by high water 20 h after setup. The fish fence was re-erected substituting 7.6 cm plastic coated wire mesh fence material for the aluminum sections. This second fence trapped emigrant bull trout for 70 h before it too was broken by high water. In total, the Houston Creek fence was functional for 91 h between 27 September and 4 October 1996.

We Floy-tagged bull trout captured at the fence as described previously, with the addition of sex determination by gently squeezing the abdomen to express gametes. All bull trout trapped had a small portion of the left pelvic fin clipped (perpendicular to and across all finrays) to both identify them as trapped in Houston Creek and to serve as a tissue sample for molecular genetic analyses (see below).

2.2.3. JUVENILES

We sampled streams in the Duncan River system for the presence of juvenile bull trout through electrofishing and minnow (Gee) trapping. We focused our search efforts on vehicle accessible areas identified by telemetry as likely spawning locations. In 1995, we used electrofishing (without stop nets or accurate measurements of site length) to look for the presence of bull trout juveniles - particularly fry, in order to confirm spawning at these sites. In 1996, we used electrofishing to quantitatively assess juvenile numbers at two locations in Houston Creek. We isolated channel sections of known length with nets (5 mm stretched mesh) and a three person team (one carrying the electrofisher and two with long handled strainer nets) made three electrofishing passes. All bull trout captured were counted, measured and released. In 1997, we completed single pass electrofishing at sites within Houston Creek (11) and Westfall River (14) specifically for the collection of tissue samples for genetic analyses. At these sites, we did not use stop nets, and site lengths were estimated by pacing. Our methodology was consistent at all 1997 electrofishing sites, allowing for qualitative comparison. In all locations where juvenile bull trout were found, we collected samples for molecular genetic and age analysis.

2.2.4. RESIDENT POPULATIONS

In addition to sampling of migratory bull trout below barriers to migration, we sampled above barrier resident populations throughout the Duncan River system to collect samples for molecular analysis. All above barriers sites were sampled using single pass electrofishing without stop nets.

2.3. MOLECULAR

2.3.1. MITOCHONDRIAL

I used restriction fragment analysis of portions of the mitochondrial chromosome (mtDNA) to describe genetic diversity within the Duncan River System. We collected tissue samples from: adult bull trout captured at Duncan Dam, juveniles from the upper Duncan and Lardeau river systems, residents existing above migration barriers in the Duncan River System and from Char Creek - a tributary of Summit Creek draining into the South Arm of Kootenay Lake. (Fig. 1). The type of tissue collected from each fish varied as a function of FL. Tissue samples of small juvenile (< 50 mm FL) and young of the year bull trout consisted of the entire animal. For juveniles > 50 mm FL, the adipose fin was removed. Caudal fin clips were taken from individuals exceeding 300 mm FL. In all cases, the sample was placed in an individually numbered snap top centrifuge tube containing 95% ethyl alcohol and refrigerated until processing in the laboratory.

Total DNA was extracted from tissue samples as described by Taggart *et al*. (1992) and Taylor *et al*. (1996). Briefly, I first suspended tissue in 2 mM EDTA and digested with Pronase (24 h at 37 ^{o}C with rotation) and then RNAase (1 h at 37 ^{o}C). The DNA was extracted using standard protocols followed by ethanol precipitation. I resuspended the extracted DNA in TE buffer and quantified the concentration by spectrophotometry. I stored extracted DNA samples at -20 ^{o}C.

I separately amplified two flanking regions, ND 5/6 and Cyt. B/d-loop, of the mtDNA using the Polymerase Chain Reaction (PCR) from each total DNA extraction. I then digested a sample of each amplified mtDNA region with eleven restriction enzymes (*Hae* III, *Dpn* II, *Hin*f I, *Sty* I, *Rsa* I, *Taq* I, *Ava* II, *Nci* I, *Pvu* II, *Bam* HI, *Eco* RI) following the directions of the manufacturer (New England Biolabs). I size fractionated restriction enzyme digest products using gel electrophoresis (2% agarose - horizontal slab gels) with ethidium bromide staining. Each restriction gel was illuminated by U.V. and photographed. Restriction fragment length polymorphism's (RFLP's), and resulting differences in gel banding patterns, are indicative of DNA sequence divergence between samples. I screened 20 to 40 samples (including a small number of samples (2-4) from dispersed sample sites) for RFLP's with each restriction enzyme. For enzymes where RFLP's were located, I increased the number of samples digested. Different patterns of RFLP's over a number of restriction enzymes are termed haplotypes. I tested for independence between the locations of sampling (tributaries) and associated mtDNA haplotype frequencies using a chi-square randomization procedure (Roff and Bentzen 1989) within the Restriction Enzyme Analysis software Package (REAP, McElroy *et al*. 1992). The data set I used for analysis with REAP included only those restriction enzymes which cut both amplified fragments (seven of the initial eleven) and those samples for which the majority of enzymes where used.

2.3.2. MICROSATELLITE

I used microsatellites markers to assess bull trout genetic population structure in two tributaries of the upper Duncan River. The microsatellite loci used came from three sources: two loci were isolated from other species (*Omy* 77; Morris *et al.* 1996 and *Sfo* 18; Angers *et al.* 1995) and three were isolated from a bull trout genomic library (Sco 1, Sco 2 and Sco 19; E.B. Taylor, unpubl. data). Three of these loci are currently being used to assess bull trout genetic variation at a watershed scale in B.C. (Taylor and Costello 1999) and four are being used within the Arrow Lakes (S. Latham *in prep*). Different alleles represent different copies of the same region of DNA in an individual (called a 'locus'). Microsatellites are nuclear loci that show high levels of allelic variation, and as such are useful for differentiating closely related species, populations, or even individuals (Jarne and Lagoda 1996).

In order to score microsatellite alleles in bull trout juveniles sampled from Houston Creek and the Westfall River, we gathered tissue samples from 1997 electrofishing sites as described previously. I separated collected bull trout tissue into three age classes from each stream based on length frequency, and grouped samples in this way for all further analysis. In order to reduce the likelihood of sampling families, I used no more than three young-of-the-year (0+) bull trout from each sampling site (Hansen *et al.* 1997). I extracted total genomic DNA from tissue samples as described for mtDNA analyses. Five microsatellite loci were separately amplified with PCR, using 32-P end-labeled primers, from extracted DNA samples. Products were size fractionated on 6% denaturing polyacrylamide gels and autoradiographed. This procedure allows for the resolution of as slight as single base pair differences in size between alleles. Alleles were scored using a standard M13 sequence.

I examined the hierarchical structuring of genetic variation first within age classes, then between age classes in a stream, and finally between the two streams using the analysis of molecular variance (AMOVA) test within ARLEQUIN version 1 (Schneider *et al.* 1997). I also calculated pairwise comparisons of allele frequency differentiation between all age/stream groupings using ARLEQUIN. From analysis of pairwise Fst values across age classes, I estimated the number of migrants between age classes using ARLEQUIN.

2.4. TEMPERATURE AND DISCHARGE

For the evaluation of bull trout migration patterns in relation to environmental variables, we gathered data on both water temperature and discharge at various locations in the study area. We copied discharge information for Duncan Dam directly from the operation log. Upper Duncan River discharge is estimated hourly from river height at a BCHydro Data Collection Platform (DCP) located just below the confluence of the upper Duncan River and East Creek (Fig. 3). We transcribed DCP data from daily flow information records downloaded to Duncan Dam from BCHydro offices in Burnaby, B.C. I also obtained a long term data set of monthly snowpack recordings from Mt. Templeman in the upper Duncan River system (Ministry of Environment Snow Survey DCP 2DO9 - 1880 m elevation) for evaluation of long term flow trends. We placed Ryan RTM 2000 remote temperature loggers in the system in 1995 and 1996 (Fig. 3). In 1995, temperature loggers recorded water temperature at 6 h intervals: 0600h, 1200h, 1800h, and 2400h. In 1996, temperature loggers recorded water temperature every 24 h (1200h). The hours of daylight per day during the migration period were obtained from the web page of the U.S. Naval

Observatory Astronomical Applications Department (http://aa.usno.navy.mil/AA/data/docs/RS_OneDay.html).

3. RESULTS

3.1. TELEMETRY

We surgically implanted radio-tags into 94 bull trout over the duration of the project. In 1996, we recaptured seven and re-tagged six bull trout initially radio-tagged in 1995 which brought the total number of surgeries to 100. In 1995, two fish died within one hour of the surgical procedure: one during experimentation with another anesthetic (CO_2), the other of hemorrhaging from the incision wound. In 1996, no radio-tagged bull trout died prior to release. Surgery and release locations are presented in Table 3.

Table 3 Location of surgery and release of radio-tagged bull trout

Location	Surgeries		Releases	
	1995	1996	1995	1996
Discharge Structure (Duncan Dam)	49	40**	22	6
Duncan Reservoir			25	34
Upper Duncan R.	2		2	
Tailrace (Duncan Dam)		3		3
Lower Duncan R.		6		6
TOTALS	51*	49	49*	49

* two bull trout died before release as a result of surgery
** six surgeries were replacements of 1995 tags

We attempted to radio-tag male bull trout only. Sex determination of bull trout prior to surgery proved difficult due to lack of secondary sexual characteristics at the time of tagging. Upon internal examination of the gonads during surgery in 1995, we found 21 (41%) female bull trout had been radio-tagged. Sex determination prior to surgery improved in 1996, with only 3 of 49 radio-tags (6.1%) implanted into female bull trout.

The anesthetic concentration of 100 ppm MS222 was lower than the 150 ppm suggested by McLeod and Clayton (1993), but brought bull trout to stage 4 anesthesia within an average of 361 sec (min 93 sec / max 691 sec, n = 89). Surgery time, measured as the total time on the surgical table, averaged 627 sec (min 330 sec / max 1035 sec, n = 89). Post surgery recovery, from removal of the radio-tagged bull trout from the surgical trough until equilibrium and reactivity was regained, averaged 341 sec (min 125 sec / max 1146 sec, n = 85).

I found no significant difference in fork length and weight distributions of radio-tagged bull trout from across years (two sample t-tests, P = 0.882 and 0.468, respectively) and pooled these data (Fig. 6). Fork lengths and weights of all radio-tagged bull trout averaged 691.6 mm and 3460 g.

I separated tracking data into two sections for presentation: radio-tagged bull trout showing clear directed migrations and those that did not. The ‘migratory movements’ section is further divided: I present fish migrating to the upper Duncan River first, movements in the lower Duncan and Lardeau rivers second, multi-year migrations third, and finally overwinter movements. Table 4 briefly summarizes the destinations or areas frequented of all radio-tagged fish by year.

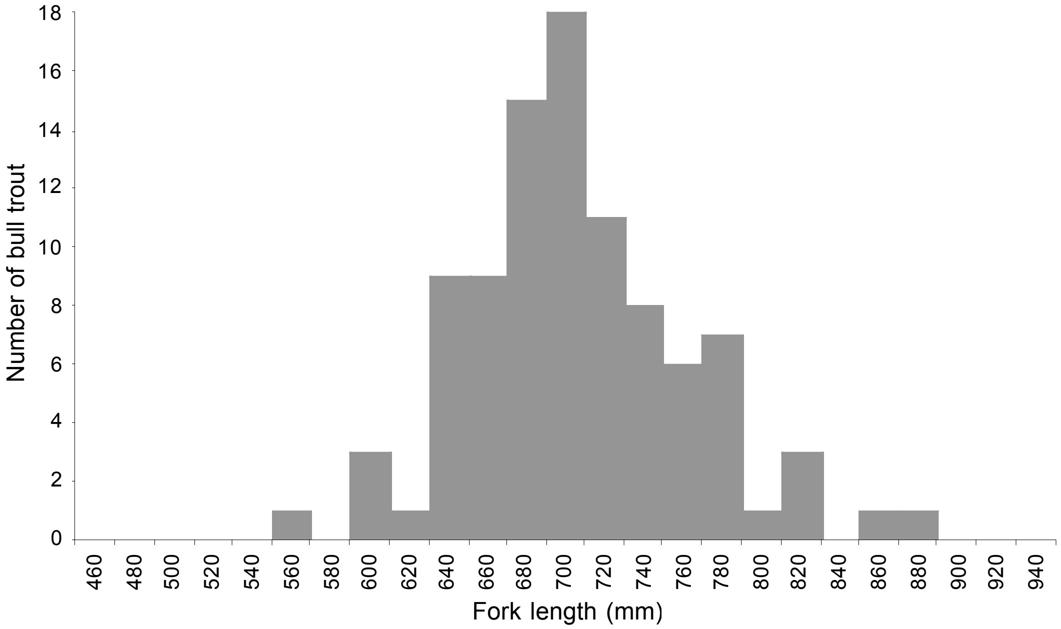

Figure 6 Length frequency histogram of bull trout radio-tagged during the project

Table 4 The destination of all radio-tagged bull trout by year.

Radio-Tag	1995	1996	1997	1998
1	Died @ Dam	n/a	n/a	n/a
2	Lost **U**	?	n/a	n/a
3	Died @ Dam	n/a	n/a	n/a
4	L.D.R. - Trout L.	U.D.R. - Giegerich Cr. *****	@ Dam **D**	@ Dam
5	L.D.R.	?	n/a	n/a
6	Died @ dam	n/a	n/a	n/a
7	Died @ dam	n/a	n/a	n/a
8	L.D.R.	?	n/a	n/a
9	L.D.R. - Healy Cr. **CR**	L.D.R. - mainstem *****	n/a	n/a
10	L.D.R.	U.D.R. - Westfall R. *****	@ Dam	@ Dam
11	Died @ dam	n/a	n/a	n/a
12	L.D.R. - Poplar Cr.	Kootenay L. **H**	n/a	n/a
13	Lost	?	n/a	n/a
14	L.D.R. - mainstem	?	n/a	n/a
15	L.D.R. - mainstem	?	n/a	n/a
16	Lost	?	n/a	n/a
17	L.D.R. - Hamill Cr.	?	n/a	n/a
18	L.D.R. - mainstem	L.D.R. -mainstem (dead?)	n/a	n/a
19	L.D.R. - Poplar Cr.	?	n/a	n/a
20	L.D.R. - mainstem	U.D.R. - Westfall R. *****	@ Dam	?
21	L.D.R. - mainstem	U.D.R. - Houston Cr. **U**	n/a	n/a
22	U.D.R. - Westfall R.	U.D.R. - Stevens Cr.	n/a	n/a
23	U.D.R. - Westfall R. **H**	n/a	n/a	n/a
24	U.D.R. - mainstem **D**	Kootenay L.	n/a	n/a
25	U.D.R. - Westfall R.	L.D.R. - mainstem	n/a	n/a
26	U.D.R. - Houston Cr.	L.D.R. - mainstem	n/a	n/a
27	U.D.R. - Houston Cr.	?	n/a	n/a
28	U.D.R. - Houston Cr.	Kootenay L.	n/a	n/a
29	U.D.R. - Houston Cr. **H**	n/a	n/a	n/a
30	U.D.R. - mainstem **D**	U.D.R. - mainstem **U**	Kootenay L. **H**	n/a
31	U.D.R. - Houston Cr.	L.D.R. - mainstem	n/a	n/a
32	U.D.R. - Giegerich Cr. **D**	L.D.R. - mainstem	n/a	n/a
33	U.D.R. - Westfall R.	L.D.R. - mainstem	n/a	n/a
34	U.D.R. - Houston Cr.	Kootenay R. - USA	n/a	n/a
35	U.D.R. - Stevens Cr. **D**	U.D.R. - Marsh Adams Cr. *****	@ Dam **D**	n/a
36	U.D.R. - Westfall R.	L.D.R. - mainstem	n/a	n/a
37	U.D.R. - mainstem	L.D.R. - mainstem	n/a	n/a

Radio-Tag	1995	1996	1997	1998
38	U.D.R. - Houston Cr.	Duncan Res. - Kootenay L. **D**	n/a	n/a
39	U.D.R. - mainstem	U.D.R. - mainstem *	?	?
40	U.D.R. - mainstem	U.D.R. - mainstem	n/a	n/a
41	U.D.R. - mainstem	Kootenay L. **H**	n/a	n/a
42	U.D.R. - mainstem **H**	n/a	n/a	n/a
43	U.D.R. - Houston Cr.	Kootenay L. **H**	n/a	n/a
44	U.D.R. - mainstem	Duncan Res.	n/a	n/a
45	U.D.R. - Giegerich Cr.	Duncan Res.	n/a	n/a
46	U.D.R. - mainstem **D**	Kootenay L. - South Arm	n/a	n/a
47	L.D.R. - mainstem	?	n/a	n/a
48	Duncan Res.	n/a	n/a	n/a
49	U.D.R. - Westfall R.	n/a	n/a	n/a
50	n/a	L.D.R. - mainstem	@ Dam	n/a
51	n/a	U.D.R. - Giegerich Cr. **U**	?	n/a
52	n/a	L.D.R. - mainstem	@ Dam	n/a
53	n/a	U.D.R. - Giegerich Cr.	@ Dam **D**	n/a
54	n/a	U.D.R. - Giegerich Cr. **D**	@ Dam	n/a
55	n/a	U.D.R. - Houston Cr.	@ Dam	n/a
56	n/a	U.D.R. - Houston Cr.	@ Dam	n/a
57	n/a	U.D.R. - Westfall R. **U**	?	n/a
58	n/a	U.D.R. - mainstem	@ Dam	n/a
59	n/a	U.D.R. - Westfall R.	@ Dam **D**	n/a
60	n/a	U.D.R. - mainstem	?	n/a
61	n/a	U.D.R. - Westfall R. **D**	?	n/a
62	n/a	U.D.R. - Hatteras Cr.	@ Dam **D**	n/a
63	n/a	U.D.R. - Stevens	@ Dam **D**	n/a
64	n/a	U.D.R. - Houston Cr.	U.D.R. - Houston Cr. **DU**	**D**
65	n/a	U.D.R. - Westfall R.	@ Dam **D**	?
66	n/a	U.D.R. - mainstem (dead?)	U.D.R. - mainstem (dead?)	U.D.R. - mainstem (dead?)
67	n/a	U.D.R. - Houston Cr.	?	n/a
68	n/a	U.D.R. - Houston Cr.	?	n/a
69	n/a	U.D.R. - mainstem	?	n/a
70	n/a	L.D.R. - mainstem **D**	L.D.R. mainstem	@ Dam
71	n/a	U.D.R. - Houston Cr.	@ Dam	@ Dam
72	n/a	U.D.R. - Westfall R.	@ Dam	@ Dam
73	n/a	U.D.R. - Houston Cr.	@ Dam - Kootenay L. **DH**	n/a
74	n/a	U.D.R. - Westfall R.	@ Dam **D**	?
75	n/a	U.D.R. - Houston Cr.	?	n/a
76	n/a	U.D.R. - Houston Cr.	?	n/a
77	n/a	U.D.R. - Westfall R.	?	n/a
78	n/a	U.D.R. - Westfall R.	?	n/a
79	n/a	U.D.R. - Westfall R. **D**	?	n/a
80	n/a	U.D.R. - Houston Cr.	?	n/a
81	n/a	U.D.R. - Houston Cr.	@ Dam - Kootenay L.	@ Dam
82	n/a	U.D.R. - Giegerich Cr. (dead?)	?	?
83	n/a	U.D.R. - mainstem **U**	@ Dam	n/a
84	n/a	L.D.R. - mainstem	@ Dam	n/a
85	n/a	L.D.R. - mainstem	@ Dam	n/a
86	n/a	L.D.R. - mainstem	@ Dam	@ Dam
87	n/a	L.D.R. - mainstem	U.D.R. Westfall R. **U**	n/a
88	n/a	L.D.R. - mainstem	?	n/a
89	n/a	L.D.R. - mainstem	?	n/a
90	n/a	L.D.R. - mainstem	?	n/a
91	n/a	L.D.R. - mainstem	?	n/a
92	n/a	L.D.R. - mainstem - lost	?	n/a

L.D.R. and U.D.R. are the lower and upper Duncan River respectively.
‘n/a’ indicates a non-functional transmitter.
* replacement surgery
D moved downstream through Duncan Dam during tracking periods
U moved upstream through Duncan Dam during tracking periods
H known angling harvest
CR known angling catch and release

3.1.1. MIGRATORY MOVEMENTS

3.1.1.1. Upper Duncan River Migrants

I categorized the destinations of radio-tagged bull trout in the upper Duncan River by tributary or section of the mainstem (Table 5). I found no significant difference in the number of migrants targeting each destination between the two years of intensive telemetry (1995 and 1996) using a Fisher's exact test (two tailed, *P* = 0.91).

Table 5 Migratory destinations and analytical groupings of radio-tagged bull trout in the upper Duncan River. Destination 3, mainstem upper Duncan River, is broken into it's five sub-categories (3.a. - 3.e., *italics*)

Migratory Destination	1995		1996		Analytical Group
	Migrants	% of Total	Migrants	% of Total	
1.) Houston Cr.	8	30.8	13	32.5	1
2.) Westfall R.	6	23.1	10	25	2
3.) mainstem upper Duncan River	9	34.6	8	20	3
3.a.) above Houston Cr.	*2*	*7.7*	*3*	*7.5*	*3*
3.b.) Hatteras Cr. to Houston Cr.	*4*	*15.4*	*2*	*5*	*3*
3.c.) Laidlaw Cr. to Hatteras Cr.	*1*	*3.8*	*1*	*2.5*	*3*
3.d.) Westfall R. to Laidlaw Cr.	*2*	*7.7*	*1*	*2.5*	*3*
3.e.) Giegerich Cr. to Westfall R.	*0*	*0*	*1*	*2.5*	*3*
4.) Giegerich Cr.	2	7.7	5	12.5	4
5.) Stevens Cr.	1	3.8	2	5.0	4
6.) Hatteras Cr.	0	0	1	2.5	4
7.) Marsh Adams Cr.	0	0	1	2.5	4
TOTALS	26	100	40	100	

Due to sample size constraints, I grouped the four least utilized destinations into a single category for further analysis (Table 5). Two factor ANOVA results are presented (Table 6). There was a significant relationship to destination for FL, mass and emigration time, but not between years or in terms of the interaction between year and destination. As emigration time was not significantly correlated (Pearsons correlation coefficient, r = 0.236, *P* = 0.09) with emigration distance I pooled the emigration time data. I plotted fork length data for each destination (Fig. 7) to show the relationship between length and destination suggested by the two factor ANOVA result. Two of the migration statistics used in this analysis are confounded. Migration rate statistics, immigration and emigration rate, are calculated as distance by time. The destination factor of the ANOVA model is also related to distance. As a result, the migration rate calculations are confounded due to the relationship between the distance inherent in both rate and the destination factor of the ANOVA. The ANOVA calculations involving rate are included because they do give insights into influence of the year of migration on migration rates. A table presenting all migration data used in the ANOVA analysis, by radio-tag number and destination category, is appended.

Nearly 80% of individual bull trout tracked into the upper Duncan River system migrated to one of the first three destination categories (Table 5). The pooled number of bull trout migrating to these three destinations was sufficient to calculate average locations over the migration period. I divided the migration period into ten day blocks, and plotted means and 95% confidence intervals of distance upstream of Duncan Dam (Fig. 8.a. - 8.k.) for fish migrating to these three destinations.

I have included a brief description of each of the destinations within the upper Duncan River system. These descriptions give basic information on physical characteristics (gradient and general stream morphology), the specific locations of spawning site residency, the residency mark I used for determination of migration statistics, as well as access and industrial development status.

Table 6 Two factor ANOVA comparisons of migration data for radio-tagged bull trout migrating to the upper Duncan River by destination (analysis group) and year of the project.

Migration Statistic	*P*-value Destination	*P*-value Year	*P* - value Interaction (Dest.*Year)	Pooled Mean ± 95 % C.I. (n)
Immigration Start Date	0.280	0.357	0.833	8 July ± 4.4 days (64)
Immigration Rate *	0.010*	0.332	0.825*	1.80 ± 0.17 km/d (64)
Immigration Time	0.247	0.754	0.981	51.4 ± 4.2 days (64)
Residency Start Date (Immigration End Date)	0.630	0.358	0.482	29 Aug. ± 2.9 days (64)
Residency Time	0.489	0.650	0.533	31.7 ± 3.4 days (53)
Emigration Start Date (Residency End Date)	0.084	0.154	0.733	28 Sept. ± 2.0 days (53)
Emigration Rate *	0.350*	0.102	0.711*	9.93 ± 2.78 km/d (52)
Emigration Time	**0.017**	0.655	0.561	8.99 ± 2.69 days (52)
Emigration End Date	0.849	0.574	0.619	8 Oct. ± 2.68 days (52)
Fork Length (mm)	**0.043**	0.351	0.360	significant differences
Mass (g)	**0.019**	0.471	0.257	significant differences

* comparison is confounded by similarity between factor variable and data variable (see text).

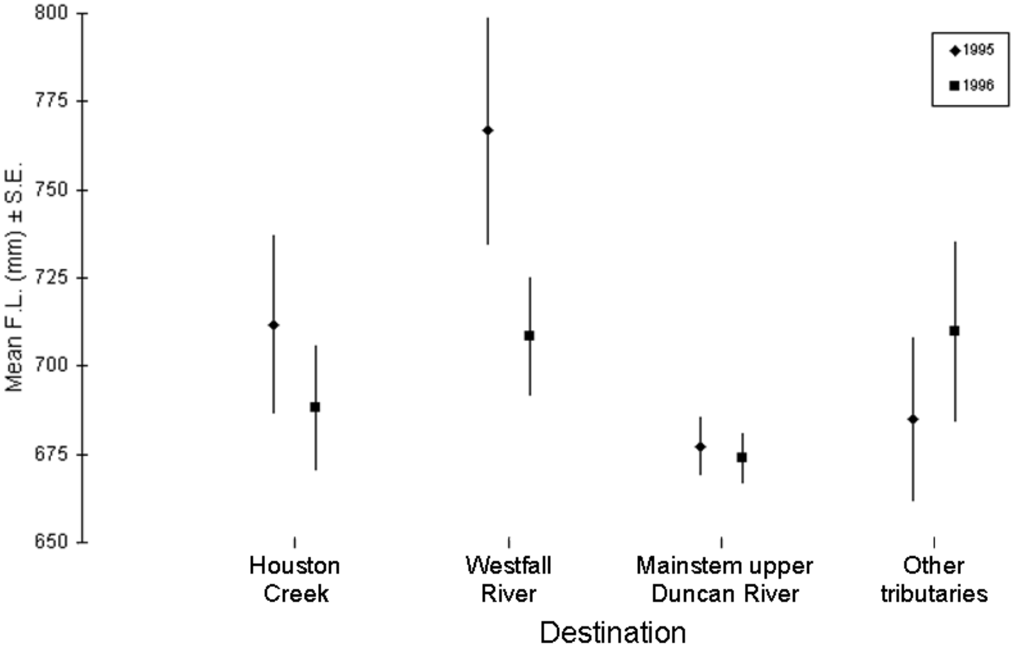

Figure 7 Data used in calculation of bull trout fork length (by destination and year) two factor ANOVA.

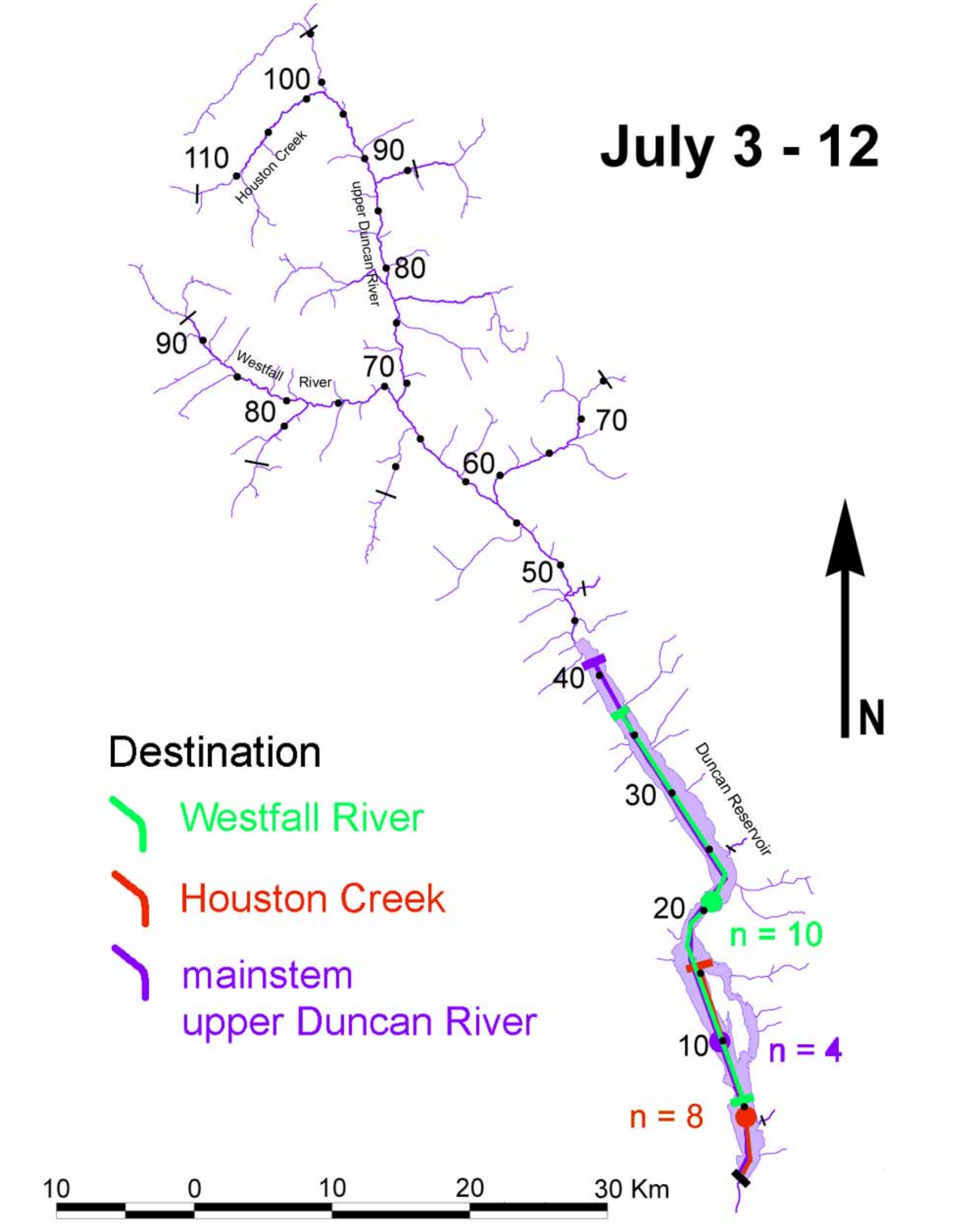

Figure 8a Mean and 95% C.I. of distance upstream of Duncan Dam for radio-tagged bull trout migrating to three destinations in the upper Duncan River System over the period July 3 to July 12.

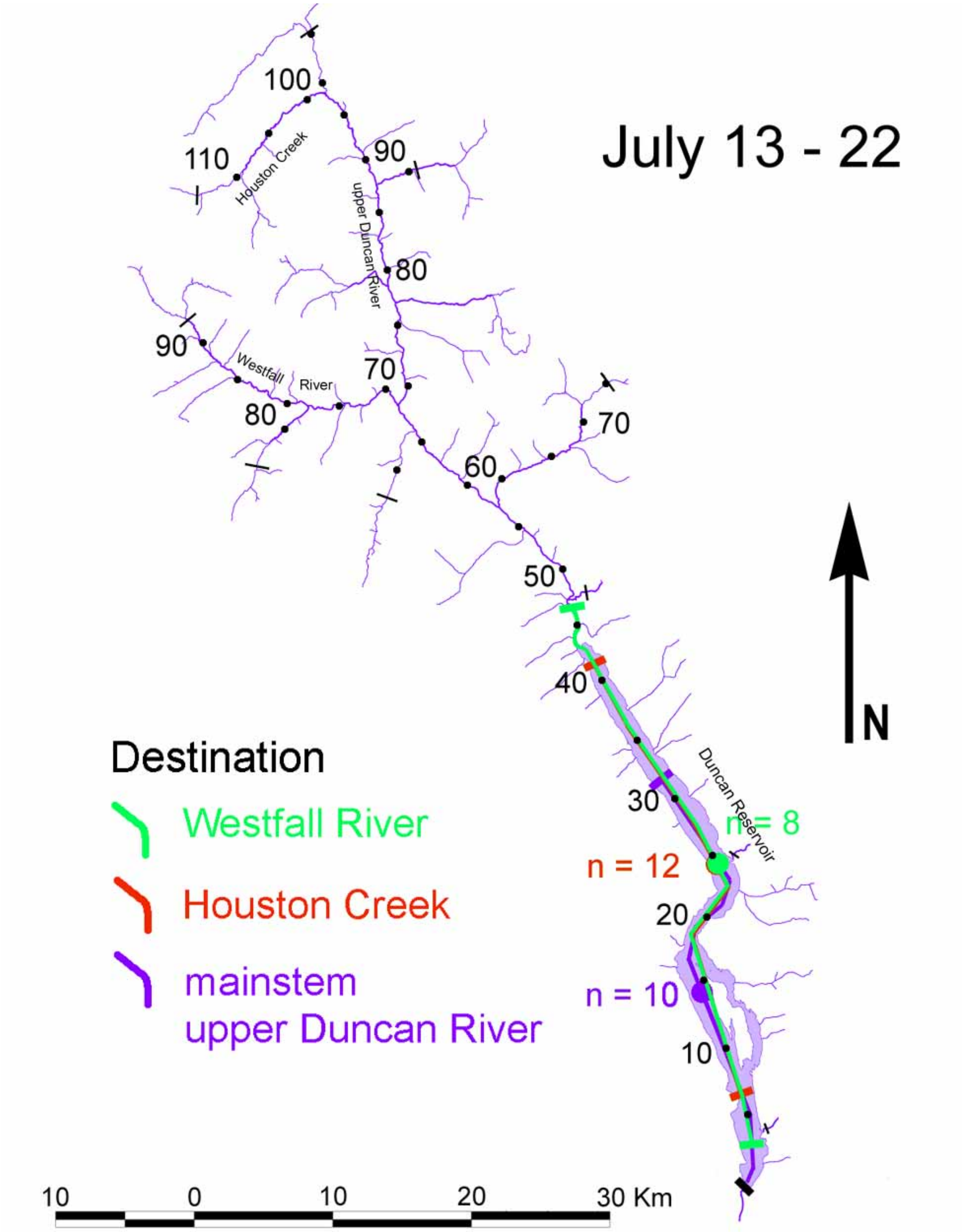

Figure 8b Mean and 95% C.I. of distance upstream of Duncan Dam for radio-tagged bull trout migrating to three destinations in the upper Duncan River System over the period July 13 to July 22.

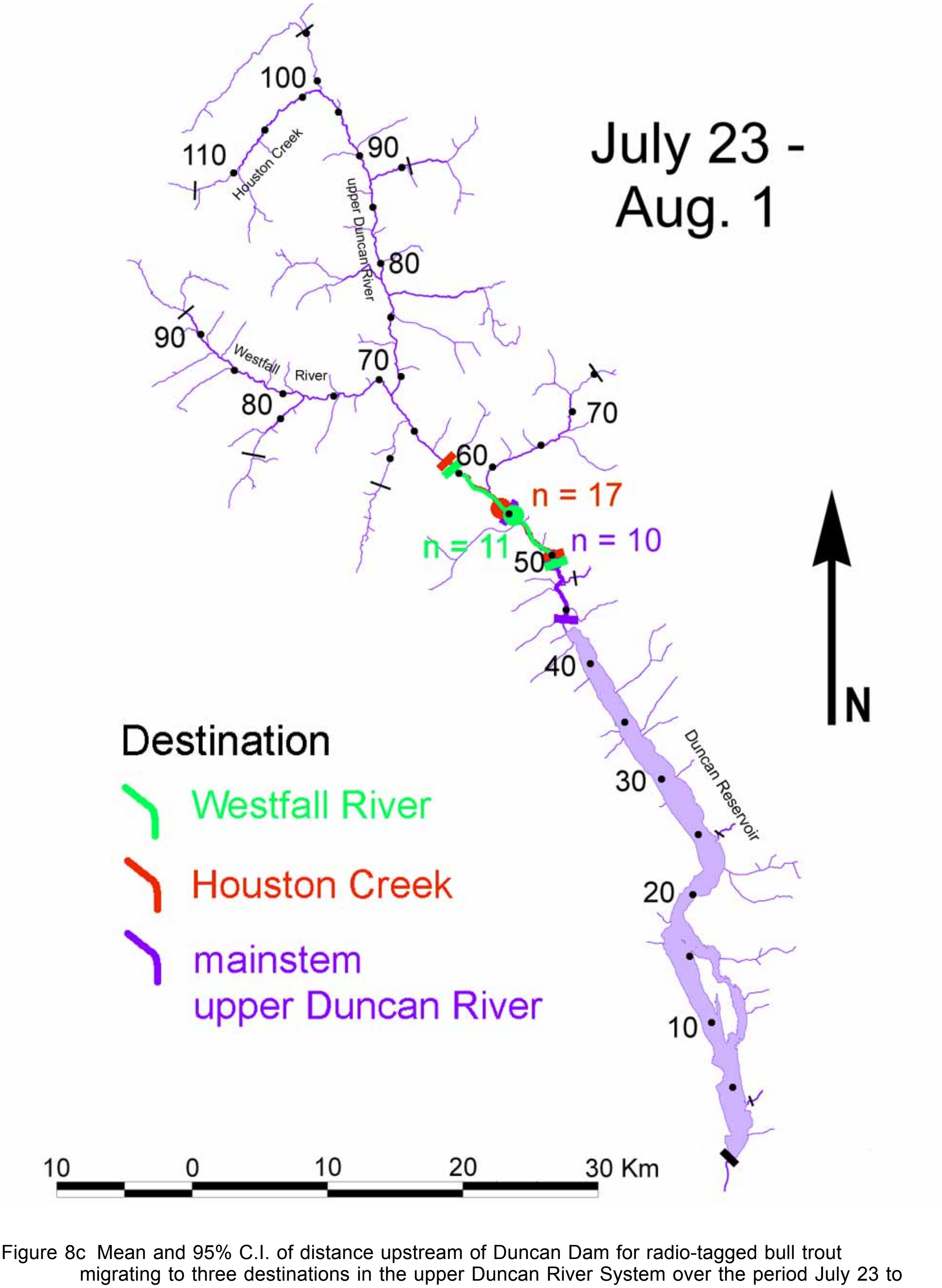

Figure 8c Mean and 95% C.I. of distance upstream of Duncan Dam for radio-tagged bull trout migrating to three destinations in the upper Duncan River System over the period July 23 to Aug. 1.

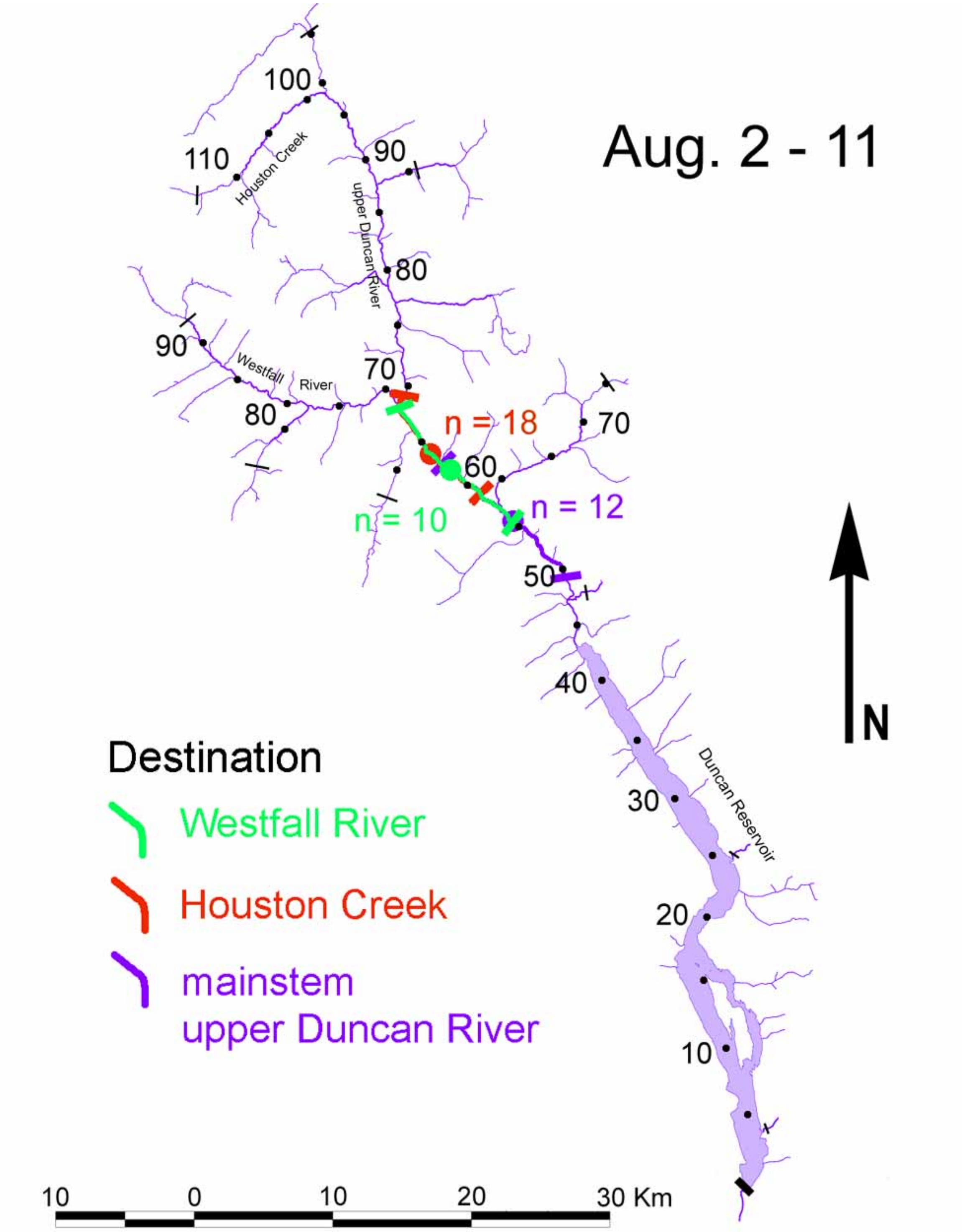

Figure 8d Mean and 95% C.I. of distance upstream of Duncan Dam for radio-tagged bull trout migrating to three destinations in the upper Duncan River System over the period Aug. 2 to Aug. 11.

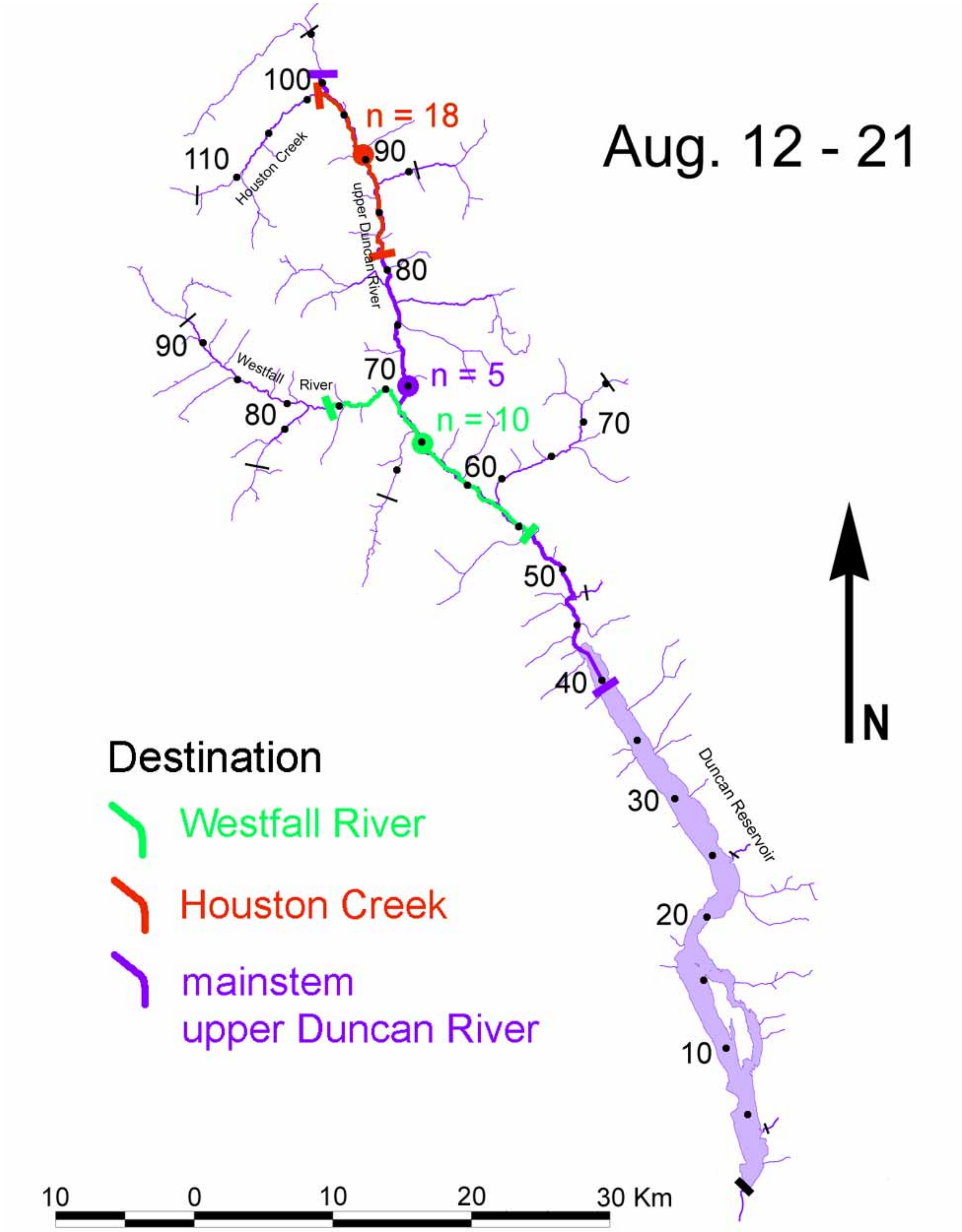

Figure 8e Mean and 95% C.I. of distance upstream of Duncan Dam for radio-tagged bull trout migrating to three destinations in the upper Duncan River System over the period Aug. 13 to Aug. 21.

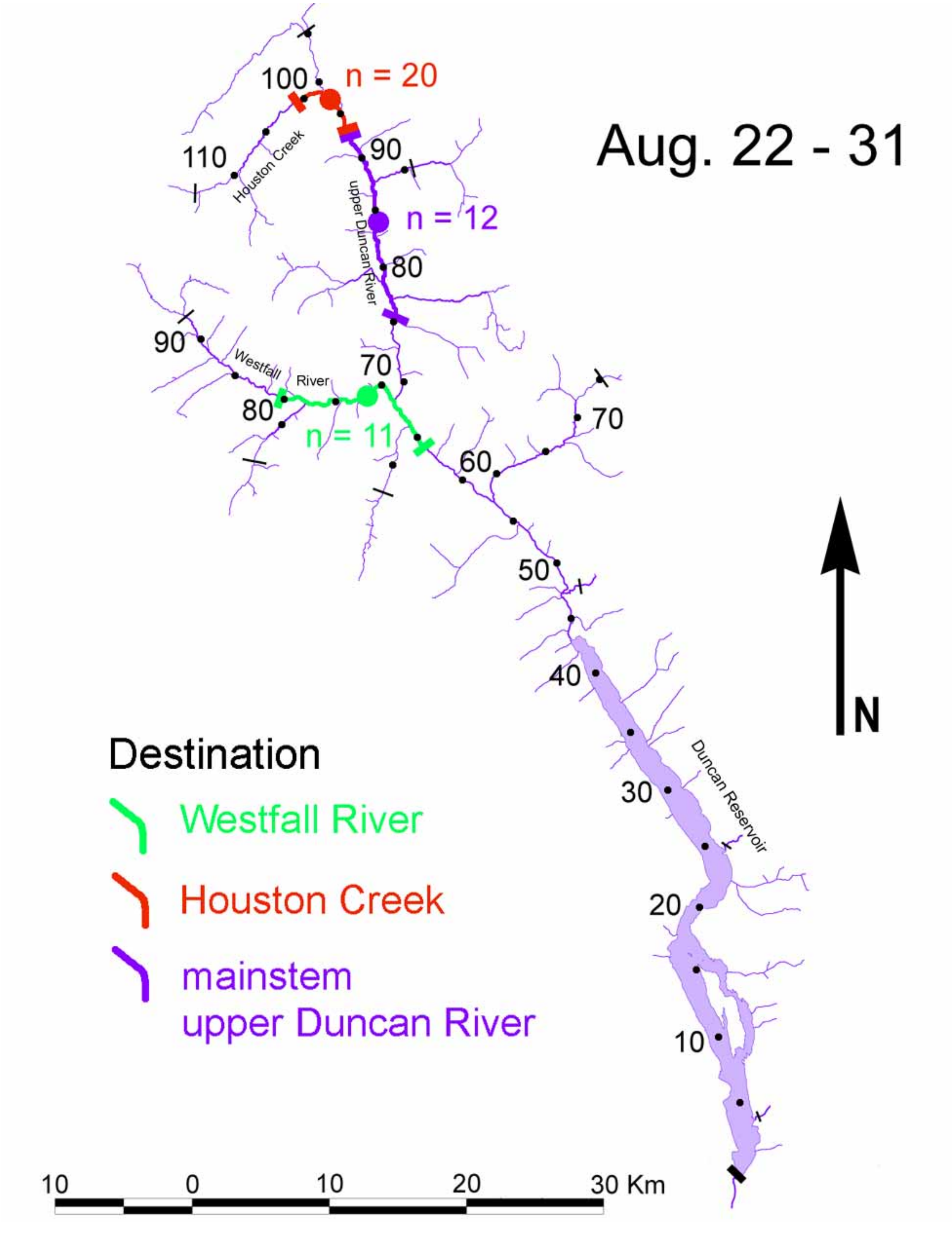

Figure 8f Mean and 95% C.I. of distance upstream of Duncan Dam for radio-tagged bull trout migrating to three destinations in the upper Duncan River System over the period Aug. 22 to Aug. 31.

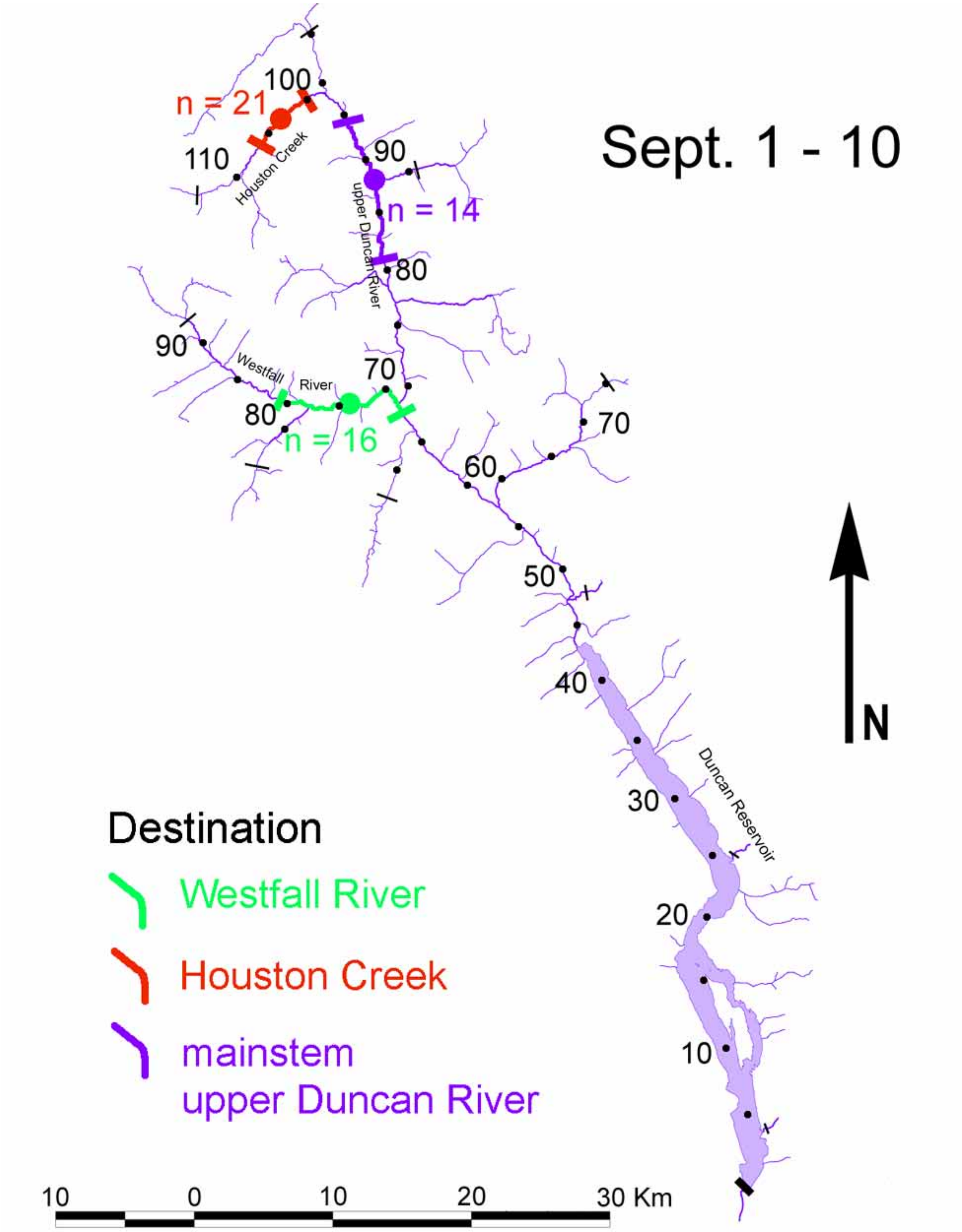

Figure 8g Mean and 95% C.I. of distance upstream of Duncan Dam for radio-tagged bull trout migrating to three destinations in the upper Duncan River System over the period Sept. 1 to Sept. 10.

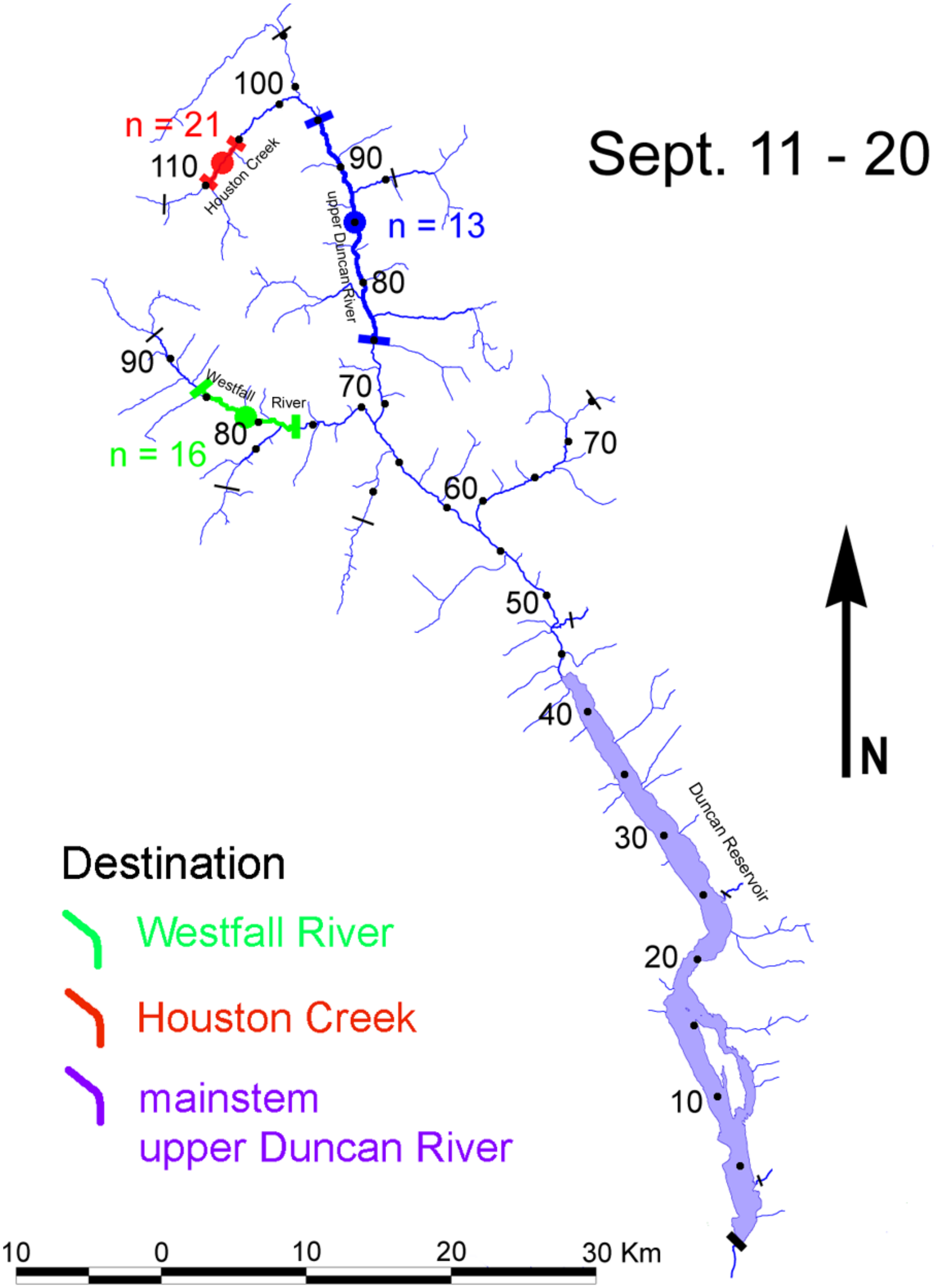

Figure 8h Mean and 95% C.I. of distance upstream of Duncan Dam for radio-tagged bull trout migrating to three destinations in the upper Duncan River System over the period Sept. 11 to Sept. 20.

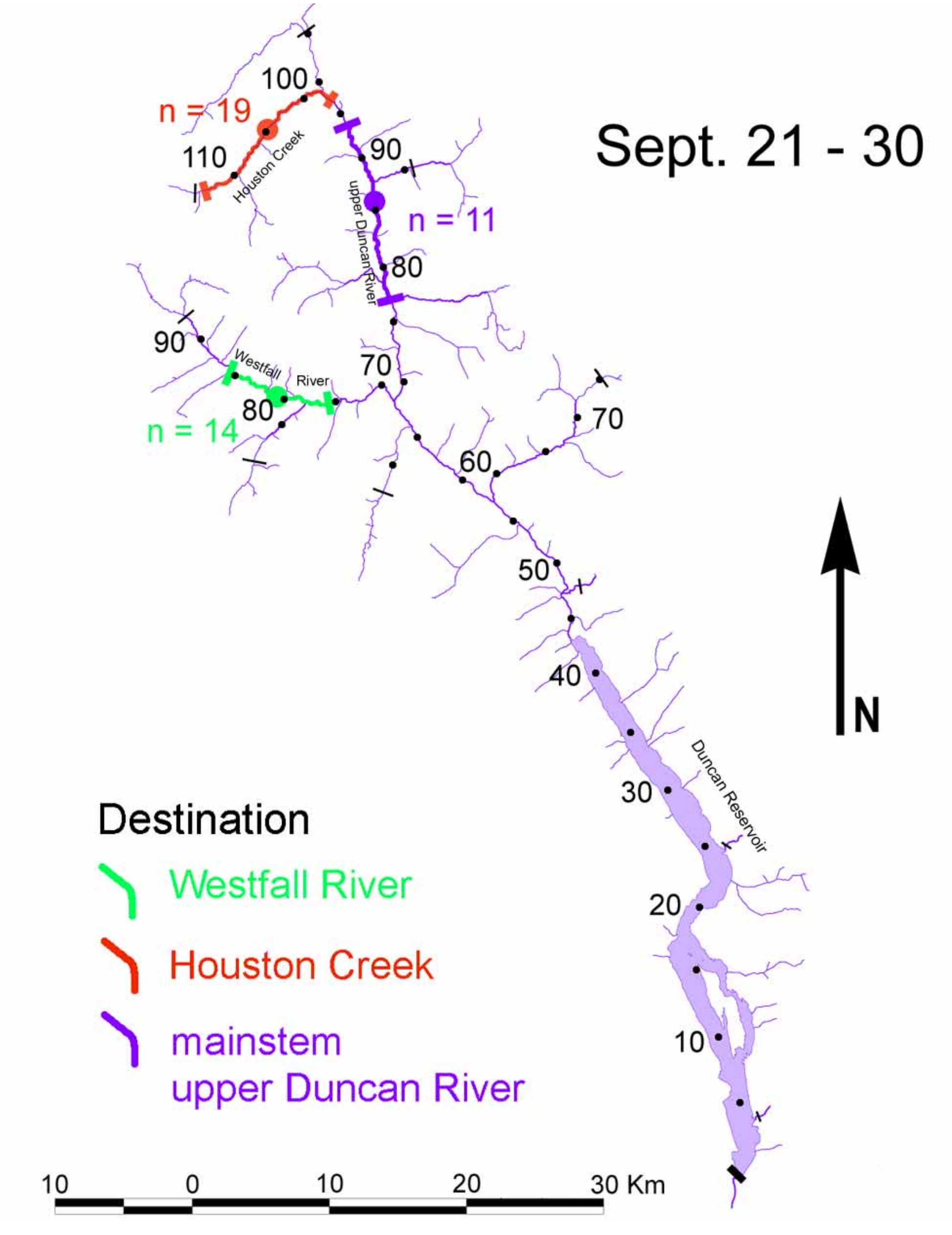

Figure 8i Mean and 95% C.I. of distance upstream of Duncan Dam for radio-tagged bull trout migrating to three destinations in the upper Duncan River System over the period Sept. 21 to Sept. 30.

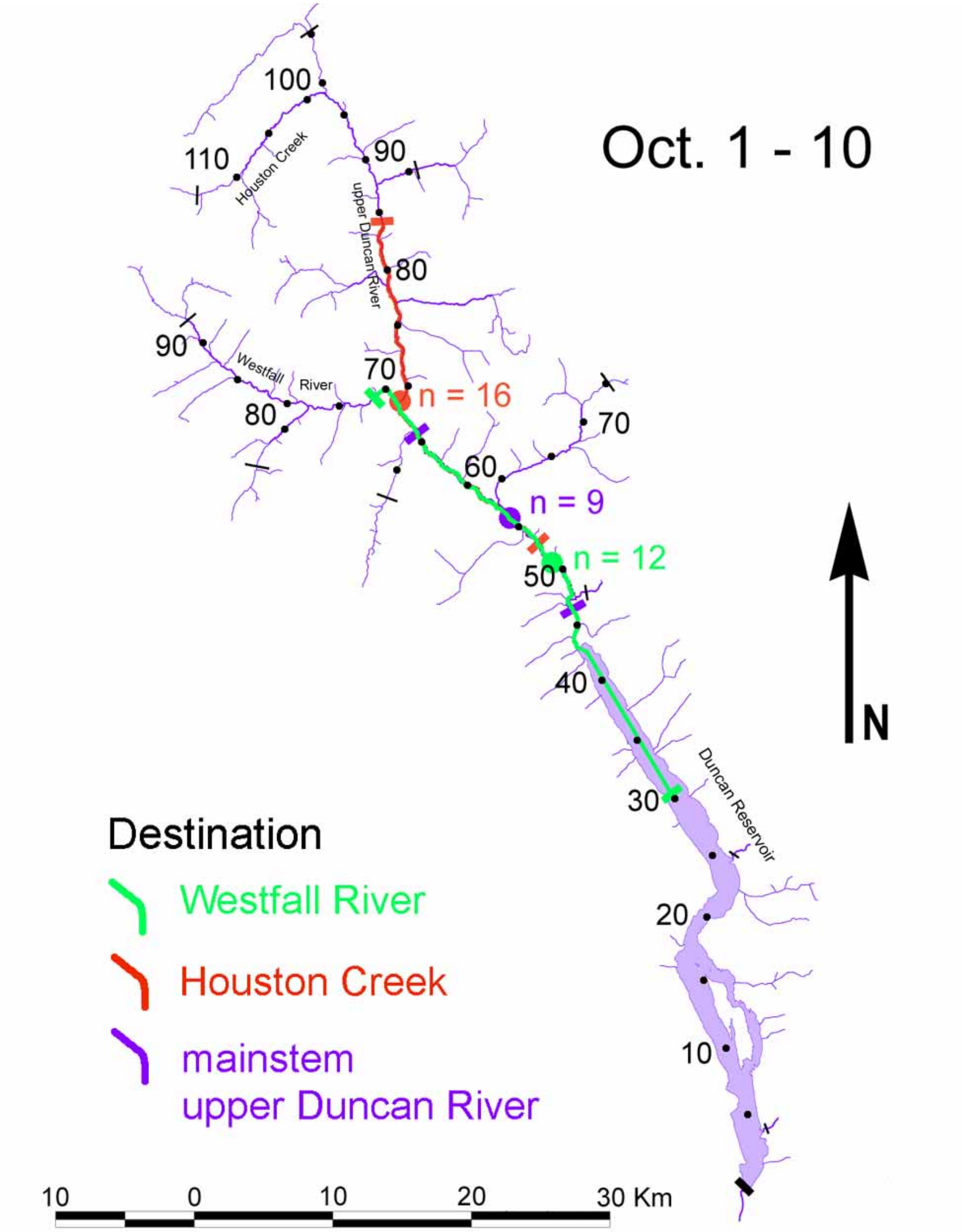

Figure 8j Mean and 95% C.I. of distance upstream of Duncan Dam for radio-tagged bull trout migrating to three destinations in the upper Duncan River System over the period Oct. 1 to Oct. 10.

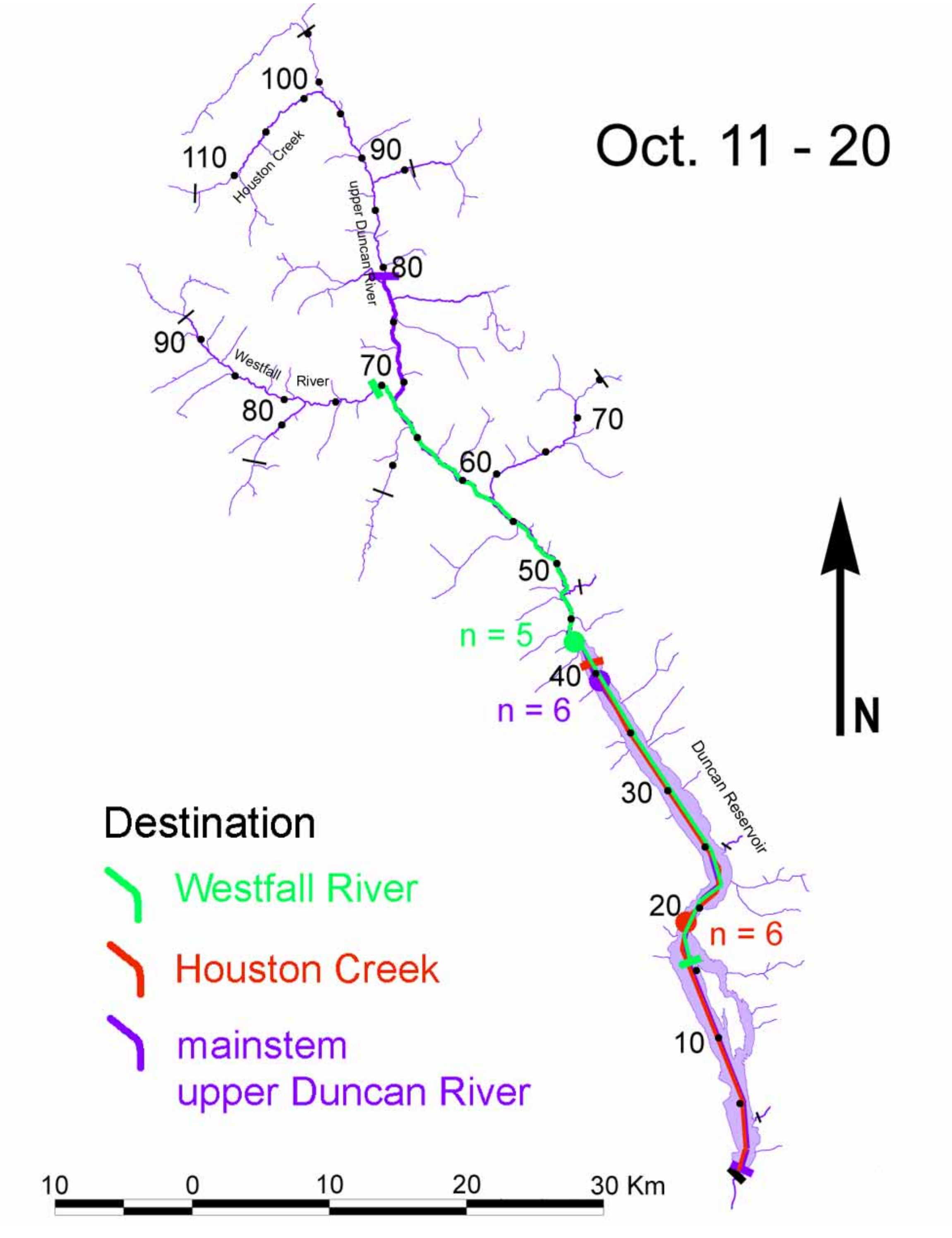

Figure 8k Mean and 95% C.I. of distance upstream of Duncan Dam for radio-tagged bull trout migrating to three destinations in the upper Duncan River System over the period Oct. 11 to Oct. 20.

Houston Creek

We tracked approximately one third of radio-tagged bull trout to Houston Creek (destination 1). Eight and 13 radio-tagged bull trout migrated into Houston Creek in 1995 and 1996, respectively. These numbers represent 30.8 and 32.5% of the total number of fish tracked to the upper Duncan River system in those years. Figure 9 illustrates example migration patterns of four bull trout migrating to Houston Creek. I considered a radio-tagged fish crossing the 100 km mark in Houston Creek resident in this area. One radio-tag (RT 38) clearly spent the spawning site residency period in this tributary but its residency mark was lowered to 95 km as it never crossed the 100 km mark.

Houston Creek, with a drainage area of 107 km^2, joins the upper Duncan River 97.5 km upstream of Duncan Dam (Fig. 10). The first 6.5 km of the creek, from 97.5 to 104 km upstream of the dam, is characterized by an occasionally confined channel with an average gradient of 1.6% (section I, Fig. 10). The next 6 km, from 104 to 110 km upstream of the dam (section II, Fig. 10), has both reduced gradient (to an average 1.3 %) and confinement relative to the first section. It is clear from vegetation pattern that this part of the creek is in a region of frequent avalanche activity. This second section of the creek has abundant side channel habitat and was the destination of the majority of radio-tagged bull trout migrating to this tributary. We identified bull trout redds during redd survey work and also conducted juvenile density estimates in this portion of Houston Creek. The third section (III, Fig. 10), from 110 to 114 km upstream of Duncan Dam, both confinement and gradient (6.8 %) rapidly increase. This third section ends at a series of impassable waterfalls, 16 km upstream of the confluence with the upper Duncan River.

There has been no recent industrial activity in the Houston Creek watershed and there is no road access, although logging activity is planned in a region of the creek frequented by radio-tagged bull trout (Shafthuizen, 1993).

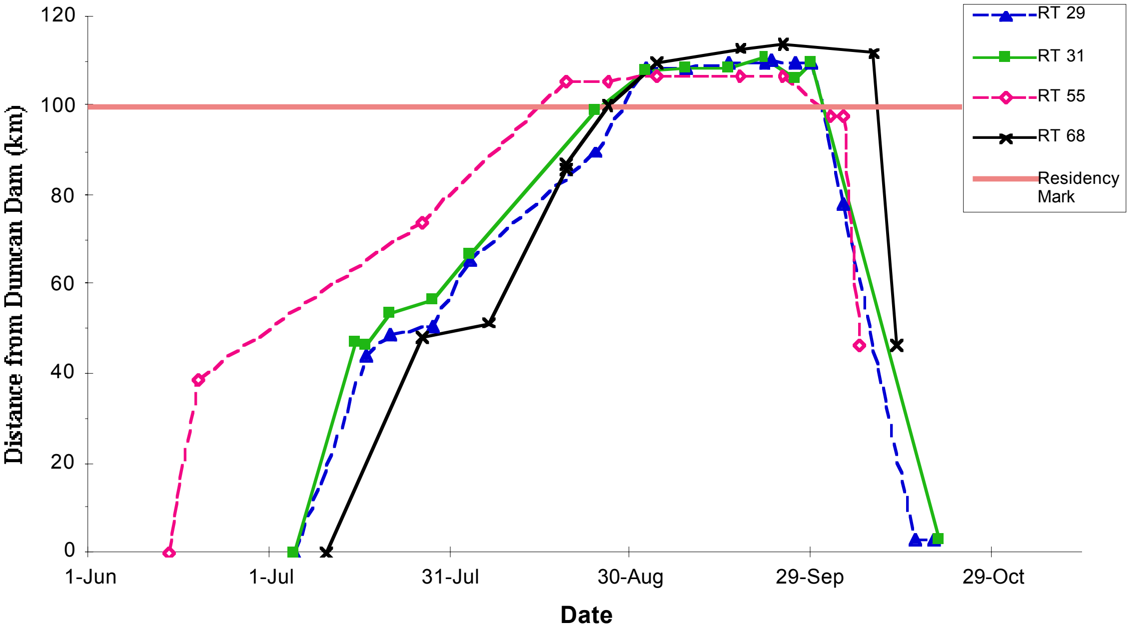

Figure 9 Example migration patterns of radio-tagged bull trout tracked to Houston Creek.

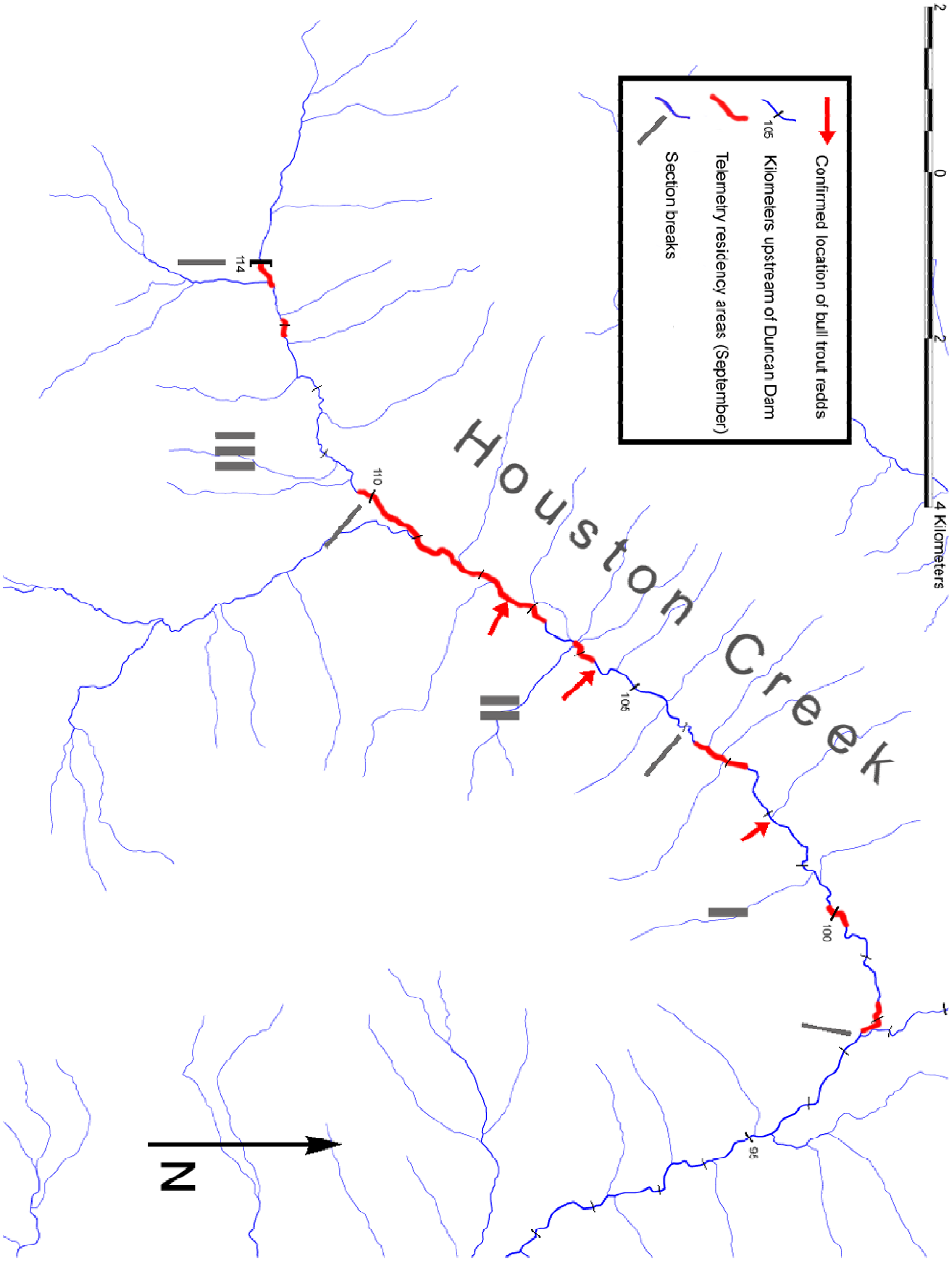

Figure 10 Houston Creek with distances upstream of Duncan Dam, section breaks, and telemetry residence areas (September) of radio-tagged bull trout.

Westfall River

The Westfall River (destination 2) was the migratory destination of 16 radio-tagged bull trout: 6 in 1995 (23.1%) and 10 in 1996 (25%). Migration patterns to the Westfall River, or ‘west fork’ as it was called (Chapman 1981), are shown in Fig. 11. I considered radio-tagged fish migrating beyond a point 75 km upstream of the dam within Westfall River to have started the residence portion of their migration. Two radio-tagged bull trout (RT 6, RT 74) targeting Westfall River did not proceed > 2 - 2.5 km upstream of the confluence with the upper Duncan River. Aerial views of this area (69 - 71 km upstream of Duncan Dam) suggest little suitable spawning habitat exists in this location in terms of gradient and substrate. As this residency area differs so much from those of the other radio-tagged fish using the Westfall River, I set the residency mark to 69 km upstream of Duncan Dam for these two bull trout and calculated all migration statistics using that mark.

With a watershed area of 230 km^2, the Westfall River is the largest tributary of the upper Duncan River (Fig. 12). The first 7.6 km (section I, Fig. 12) from its confluence with the upper Duncan River, from 68.4 to 76 km upstream of the dam, is bounded by a steep valley and has a high gradient (averaging 3.7 %). This first section has one significant waterfall, approximately 1 to 1.5 m high, that had been noted as a potential barrier to migration (C. Spence, *pers. comm*.). The small waterfall is over one of several avalanche and landslide paths in this area of the stream. The second section is characterized by a decrease in both gradient and confinement over the first (section II, Fig. 12). Section II is 11 km in length (76 to 87 km upstream of Duncan Dam) and has an average gradient of 1.9 %. The majority of radio-tagged bull trout in the Westfall River spent the spawning period in this portion of the stream, and this is where we identified redd sites (Fig. 12). The third section, 87 to 92 km upstream of the dam, is slightly more confined but of similar gradient to the section of river immediately below it (section III, Fig. 12). The portion of the Westfall River accessible to migratory bull trout ends 92 km upstream of Duncan Dam with a vertical fall of approximately six meters.

This watershed is an area of past and present timber harvest. Until very recently, road access had not extended to the area of bull trout spawning activity. However, road and bridge construction extending road access upstream of identified spawning sites and residency areas on both sides of the river was completed during the course of this project. Logging activities are planned directly adjacent to confirmed spawning locations (Jones 1994).

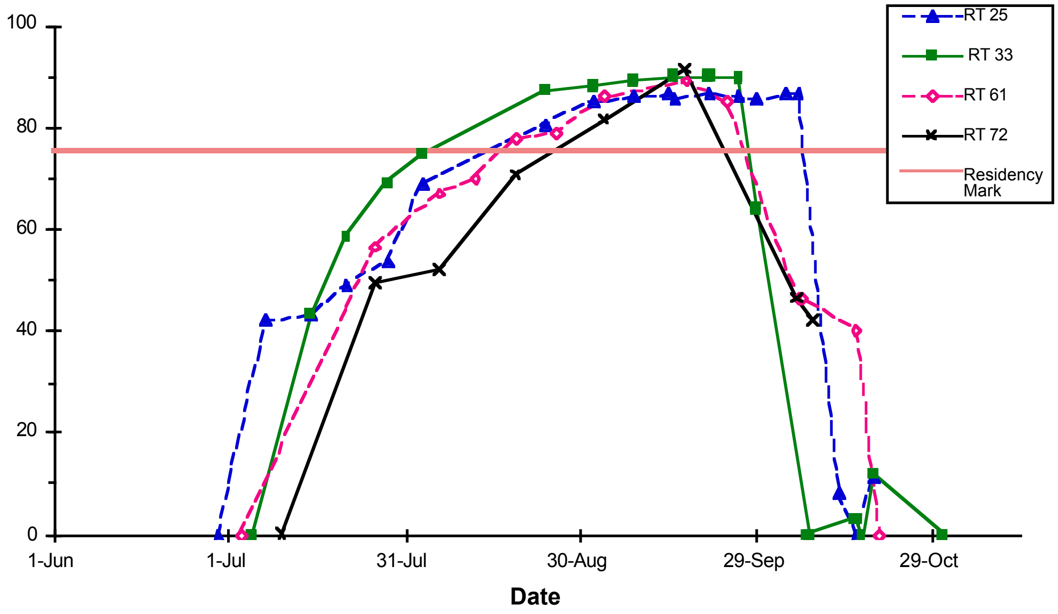

Figure 11 Example migration patterns of radio-tagged bull trout tracked to Westfall River

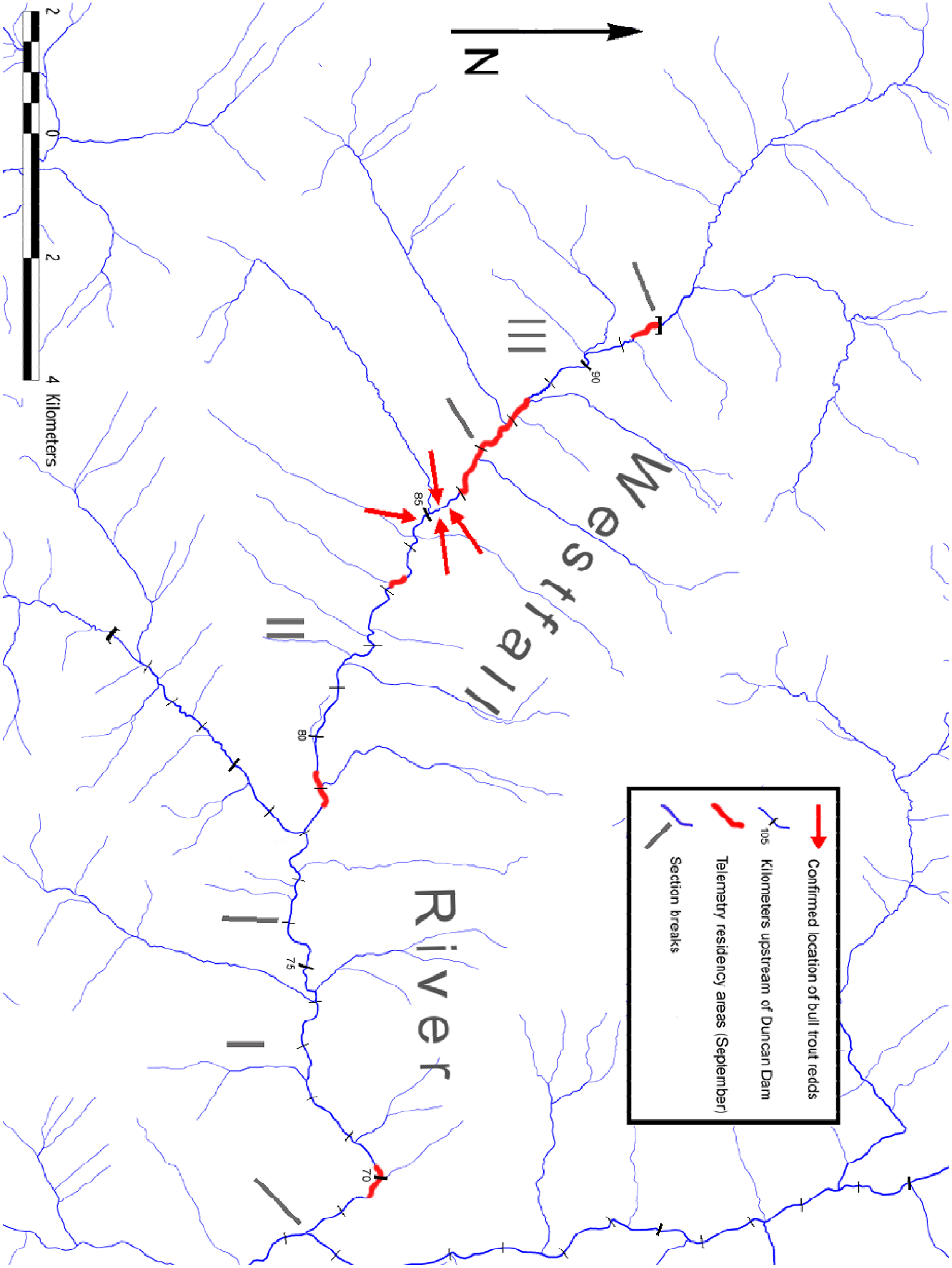

Figure 12 The Westfall River with distances upstream of Duncan Dam, section breaks, telemetry residence areas (September) of radio-tagged bull trout, and confirmed redd locations.

Mainstem Upper Duncan River

Seventeen radio-tagged bull trout migrated to destinations in the mainstem upper Duncan River, representing 34.6 % of the total tracked in 1995 (9 fish) and 20 % in 1996 (8 fish). We tracked bull trout to five distinct sections of the upper Duncan River (destination 3.a. to 3.e., Table 5). I describe each section separately below, but all were grouped for comparison to other destination categories. Figure 13 shows the location of each of the five sections of the mainstem upper Duncan River and the September residency locations. Note that each of the five sections has a separate residency mark(s) for calculation of migration statistics.

In total, we tracked five radio-tagged bull trout beyond the confluence of the upper Duncan River and Houston Creek (3.a.). Two fish migrated into this portion of the upper Duncan River in 1995 and three in 1996; these numbers represent 7.5 and 7.7 % of total tracked migrants in the respective years. For calculation of migration statistics, I considered these fish resident after crossing the 95 km mark. I plotted the migrations of RT 39-95 and RT 30-96 to this destination in Figure 14.

The river immediately above Houston Creek, 97.5 to 100 km upstream of the dam, has a gradient of 1.6 %. Above the 100 km mark, the river enters a canyon and gradient rises to an average of 3.7 % to a large waterfall, approximately 6 m high, in Butters Creek (106 km upstream of the dam). The upper Duncan River is inaccessible beyond the Butters Creek confluence, 104.5 km upstream of the dam, due to waterfalls. We had difficulty getting aerial views of this destination due to the steep canyon walls; however, when compared to confirmed spawning locations it would appear to have much less available spawning habitat. The Duncan forest service road crosses this portion of the river but there has been no recent (within approximately 10 years) forest harvesting near the spawning period residence area.

A short section of the upper Duncan River between Hatteras Creek and Houston Creek (3.b.) was the destination of six radio-tagged bull trout: four in 1995 (15.4 % of total) and 2 in 1996 (5.0 % of total). For calculation of migration statistics, fish were considered resident in this area after crossing a mark 85 km upstream of Duncan Dam. I plotted the migrations of RTs 30-95, 40-95, 40-96 and 39-96 to this destination in Figure 14.

The residency location was the section of river between 87 and 92 km upstream of the Duncan Dam, and the area most similar to redd locations in other destination areas was located in the upstream portion of this focal area (km 90 to 92, average gradient 1.2 %). The river below this point has a confined channel and the gradient averages 2.3 %. Above this destination area, the river gradient and confinement increase slightly to its confluence with Houston Creek. Aerial observation suggests that suitable spawning habitat relative to both gradient and gravel is available; however, foot surveys failed to locate evidence of spawning. The Duncan forest service road allows access to this entire section of the river. There is no active logging in this area, but there has been forest harvest activity in the past.

The upper Duncan River between Laidlaw Creek and Hatteras Creek (3.c.) was the destination of two radio-tagged bull trout, one in 1995 (3.8 %) and one in 1996 (2.5 %). One bull trout targeted a portion of this section closer to Laidlaw Creek and its residency mark was set 80 km upstream of the dam. The other fish remained 86.5 km upstream of the dam and I set its residency mark at 85 km.

Upstream of Laidlaw Creek, the gradient in the upper Duncan River averages approximately 1% until 85.2 km upstream of the dam (2 km below Hatteras Creek) where the gradient increases to 2.3 %. Despite the low gradient between these two tributaries, steep valley walls confine the river. When compared to spawning sites in other targeted areas, quantity of spawning habitat appears low; however, this section was not surveyed for spawning activity.

Three radio-tagged bull trout targeted the portion of the upper Duncan River lying between the Westfall River and Laidlaw Creek (3.d.). RT 83, the only bull trout in 1996 to migrate to this portion of the river (2.5 %) was not successfully tracked out of the system by 30 October 1996, perhaps due to mortality. I did not include the migration statistics for RT 83 in ANOVA comparisons for this reason. The two other fish, representing 7.7 % of upper Duncan River migrants in 1995, targeted a short section immediately downstream of Laidlaw Creek. I set the residency mark at 75 km upstream of the dam for the fish migrating to this portion of the upper Duncan River.

Gradient in this section (72 - 77 km upstream of the dam) of the upper Duncan River averages approximately 0.9 %. The river is confined at this point and difficult access prevented redd surveys.

One radio-tagged bull trout (2.5% of radio-tagged migrants in 1996) ended the immigration phase in the mainstem upper Duncan River between Giegerich Creek and the Westfall River (3.e.). I considered this fish resident after it crossing a mark 60 km upstream of the dam. The gradient in this section of the river is below 1 % but high flow makes it difficult to compare to other destinations. This portion of the valley was extensively logged in the past, but there has been no recent forest harvest activity.

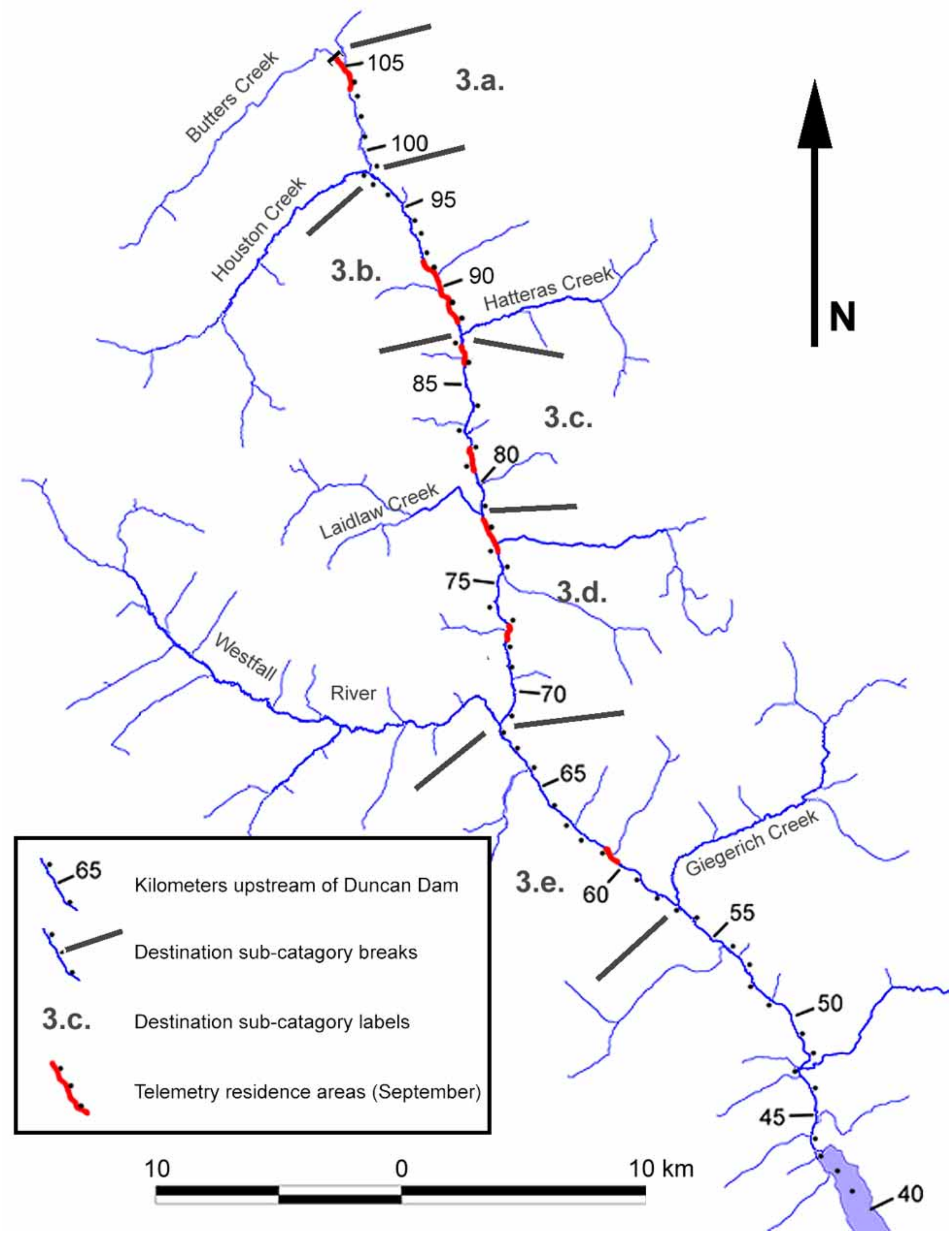

Figure 13 The mainstem upper Duncan River with distances upstream of Duncan Dam, the location of the five destination sub-categories (see text and Table 5), and telemetry residence areas (September) of radio-tagged bull trout.

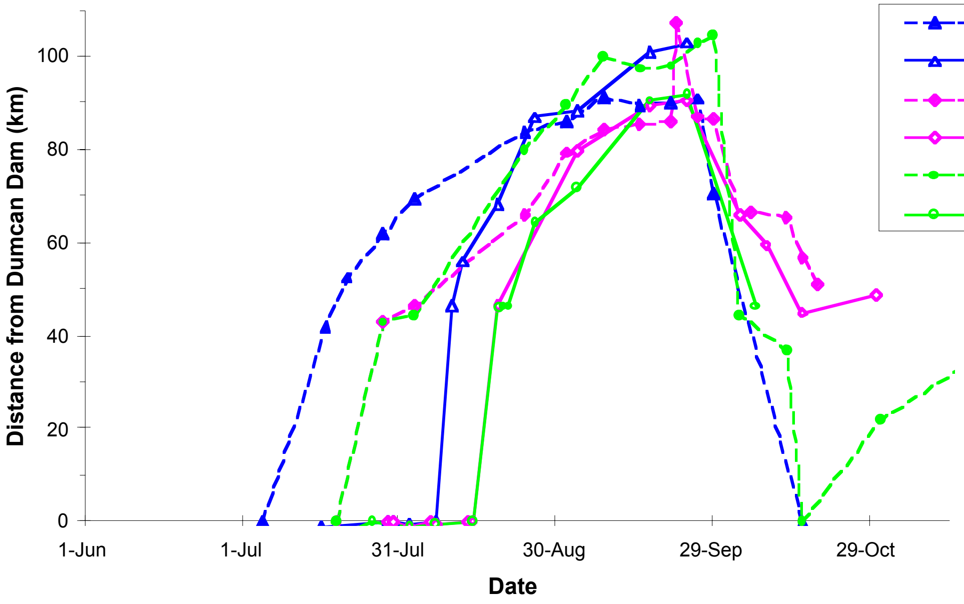

Figure 14 Example migration patterns of radio-tagged bull trout tracked to destinations in the mainstem upper Duncan River.

Giegerich Creek

Two (7.7 %) and 5 (12.5 %) radio-tagged fish targeted Giegerich Creek (destination 4) in 1995 and 1996, respectively. For calculation of migration statistics, I considered bull trout resident after they crossed a mark 60 km upstream of Duncan Dam. In 1996, one bull trout did not emigrate from the creek (suggesting mortality) and I did not use its movement data for ANOVA analysis. Figure 15 gives four example movement patterns to Giegerich Creek.

Giegerich Creek is characterized by a confined channel and a high gradient relative to the majority of tributaries targeted by other radio-tagged fish. This tributary has a watershed area of 113 km^2 and joins the upper Duncan River 57 km upstream of the Duncan Dam (Fig. 16). The creek rises approximately 275 m in the first 6 km section (7.2 % average gradient), from 57 to 63 km upstream of the dam (section I, Fig 16). From 63 to 72 km upstream of Duncan Dam, gradient decreases to just over 2.4 % and the creek becomes less confined. This second section (section II, Fig. 16) is where the majority of spawning period residence was situated. Habitat similar to that found in confirmed areas of spawning was only apparent in the third section of stream, from 72 to 75 km upstream of the dam (section III, Fig. 16), but only one bull trout migrated this far upstream. A large waterfall 18 km upstream of the upper Duncan River confluence marks the upward limit of migration and the end of the third section. Giegerich Creek has had no recent forestry activity and there is no road access. The upper portion of the creek lies within the Bugaboo Alpine Recreation Area.

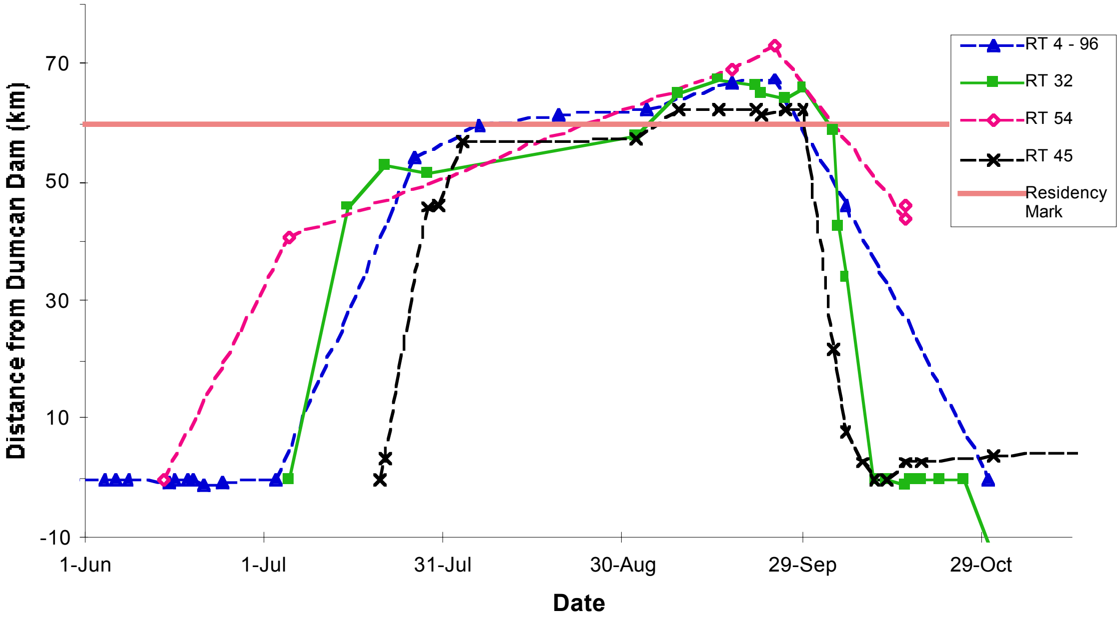

Figure 15 Example migration patterns of radio-tagged bull trout tracked to Giegerich Creek.

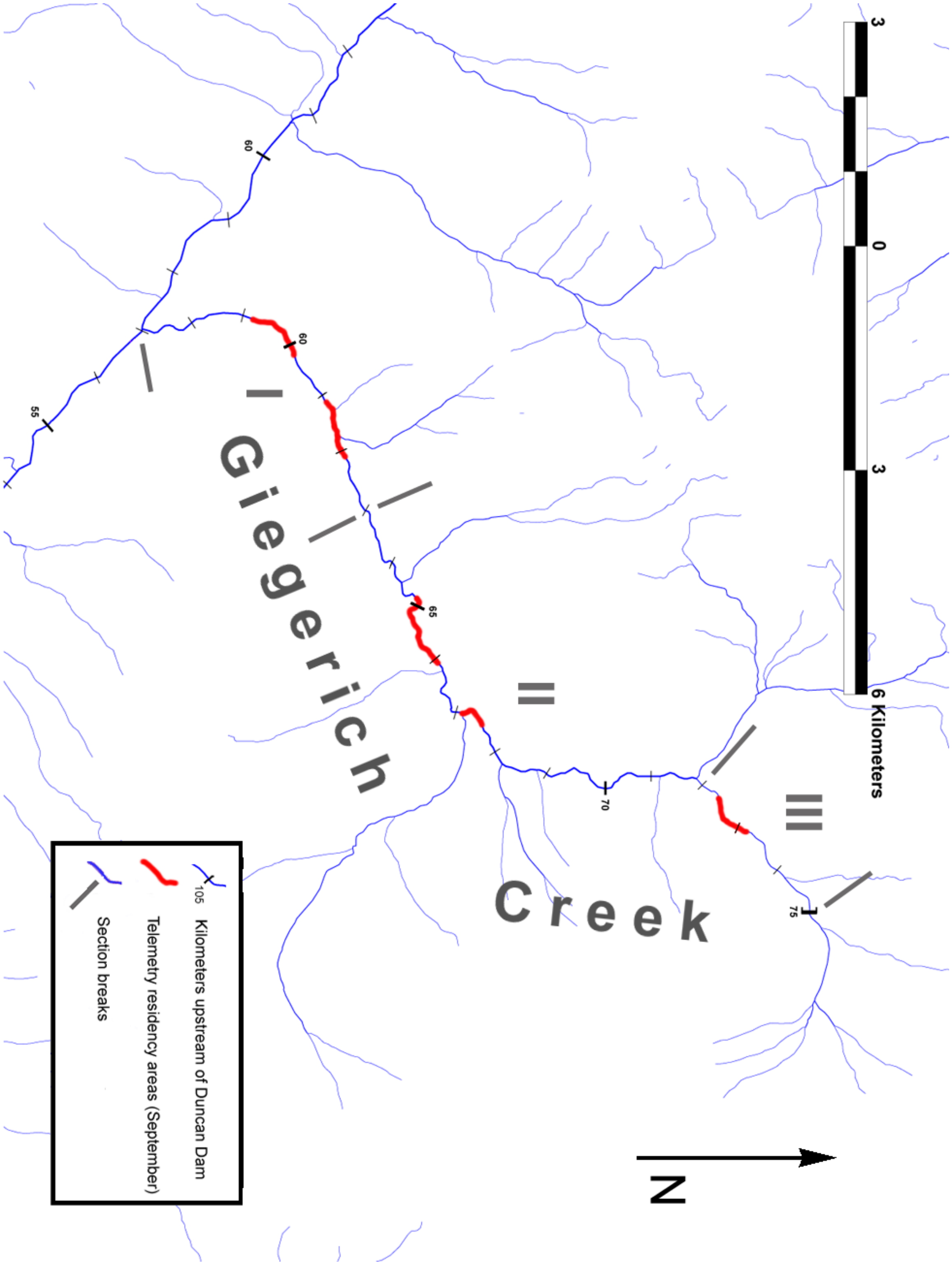

Figure 16 Giegerich Creek with distances upstream of Duncan Dam, section breaks, and telemetry residence areas (September) of radio-tagged bull trout.

Stevens Creek

Stevens Creek (destination 5) is the steepest tributary of the upper Duncan River targeted by radio-tagged fish. Three bull trout were tracked to this stream: one in 1995 and two in 1996 (3.8% and 5.0% of the total tracked in each respective year). I considered bull trout resident once they crossed a mark 65 km upstream of the dam. The migration patterns of the three radio-tagged bull trout are presented in Figure 17.

Stevens Creek has a watershed area of 51 km^2 (Fig. 18). The gradient over the confined first seven kilometer section (66 - 73 km above the dam) averages 8.9%. Stevens Creek then opens into a considerably wider valley and the gradient drops to 4.2%. We classified the area upstream of the steep first section as containing relatively good spawning and rearing habitat. In aerial surveys, we could not identify a particular waterfall as being impassable to migrating fish, but we did not monitor radio-tagged bull trout proceeding through the high gradient first section. There is no road access or recent industrial activity in the Stevens Creek valley.

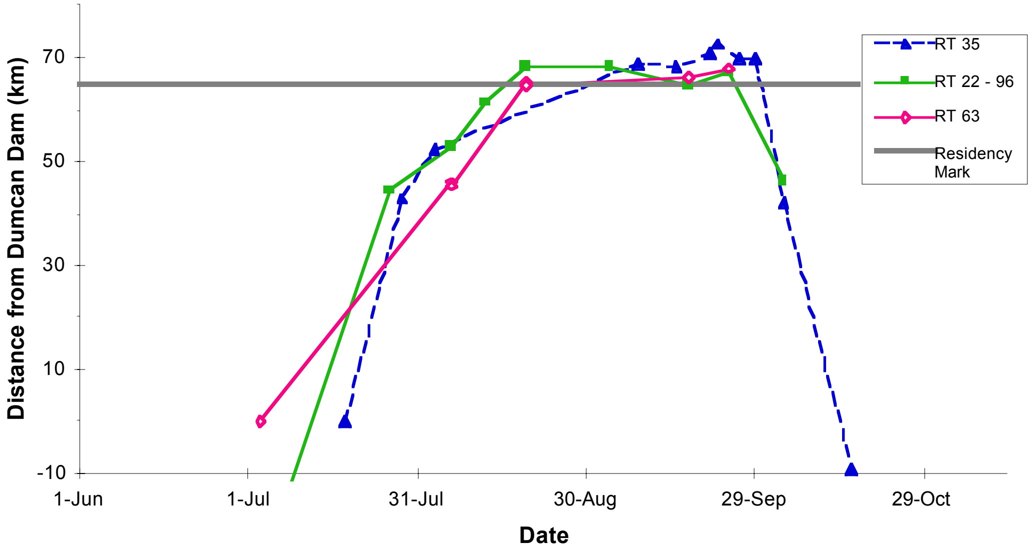

Figure 17 The migration patterns of radio-tagged bull trout tracked to Stevens Creek.

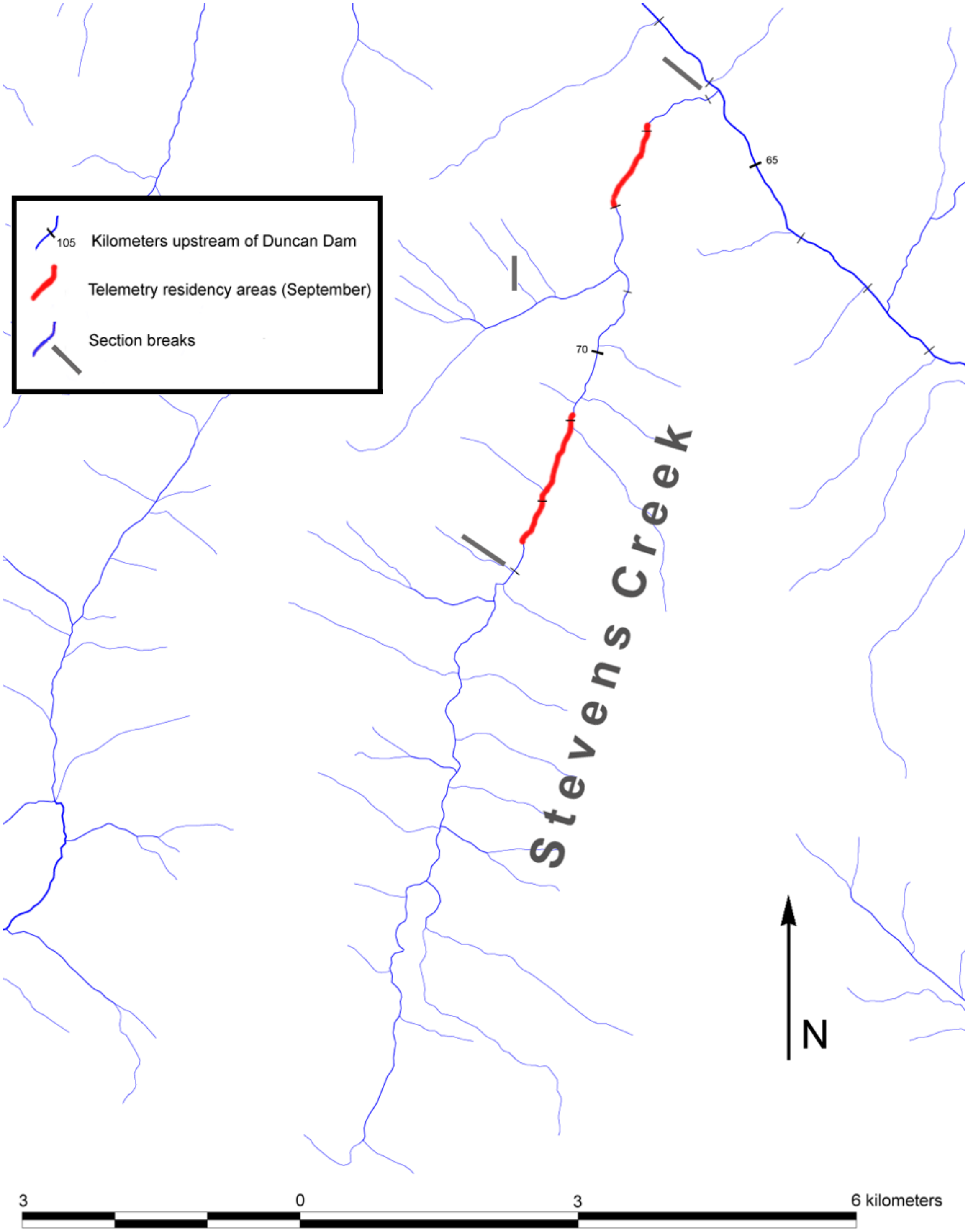

Figure 18 Stevens Creek with distances upstream of Duncan Dam, section breaks, and telemetry residence areas (September) of radio-tagged bull trout.

Hatteras Creek

We tracked a single bull trout into Hatteras Creek (destination 6) in 1996, representing 2.5% of the total tracked that year. I considered this fish resident in the creek after it had left the mainstem upper Duncan River, 88 km upstream of the dam. The migration pattern of this bull trout is presented in Figure 19. This bull trout spent the September residence period of its migration 2 km upstream of the upper Duncan River confluence, 90 km upstream of Duncan Dam.

Hatteras Creek has a watershed area of 65 km^2. From aerial views, we felt an avalanche caused debris jam less than one km upstream of the upper Duncan River confluence (approximately 88.5 km upstream of the dam) would prevent migration into this creek, and did not expect to locate a bull trout above this point. The limit of migration in the creek is a waterfall three kilometers upstream of its confluence with the upper Duncan River (91 km upstream of the Duncan Dam). There is no road access to this tributary.

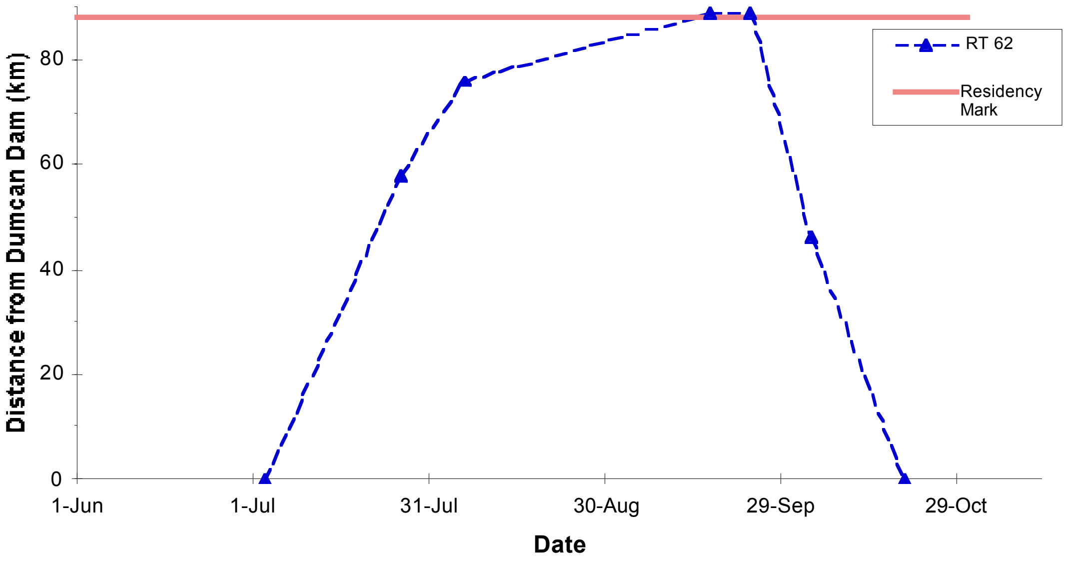

Figure 19 The migration pattern of the radio-tagged bull trout tracked to Hatteras Creek

Marsh Adams Creek

Marsh Adams Creek (destination 7) is tributary to the Westfall River. In 1996, we tracked a single radio-tagged bull trout into this creek (2.5% of the total tracked that year). The migration pattern of this bull trout is presented in Figure 20. I used the confluence of Marsh Adams Creek and the Westfall River (78 km upstream of the dam) as the residency mark for the calculation of migration statistics. September residency was focused in a area between 5 and 6 km upstream of the Westfall River confluence, 83 to 84 km upstream of Duncan Dam.

Marsh Adams Creek has a watershed area of 46 km^2. The limit of migration is 8 km upstream of the Westfall River confluence (86 km upstream of the dam), where the creek passes through a short (450 m) entrenched canyon with a series of impassable waterfalls. Below the barrier, gradient averages 3.5% although there are short stretches with abundant side channels and seemingly suitable spawning habitat. There is no road access to Marsh Adams Creek, although there has been considerable mining activity in this area in the past (Chapman 1981).

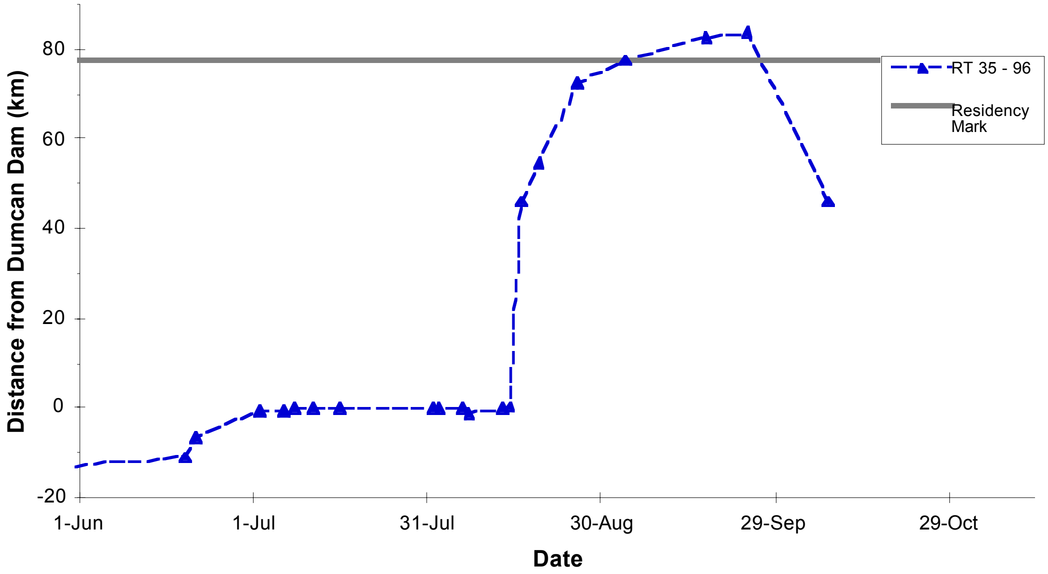

Figure 20 The migration pattern of the radio-tagged bull trout tracked to Marsh Adams Creek

3.1.1.2. Lower Duncan and Lardeau River migrants

We tracked four radio-tagged bull trout to tributaries of the lower Duncan and Lardeau rivers in 1995, but none in subsequent years of telemetry. This number represents 18.2 % of the radio-tagged bull trout we tracked downstream of the dam over the migration period in 1995.

I treated the bull trout migrating to tributaries of the lower Duncan and Lardeau rivers in the same manner as the above dam releases for calculation of migration statistics. A residency mark was determined for Hamill, Poplar, and Healy creeks (28, 33 and 42 km from Duncan Dam, respectively). The low number of bull trout migrating to these tributaries precludes meaningful comparisons with the migration statistics calculated for bull trout migrating to destinations in the upper Duncan River. I averaged the migration statistics for these bull trout for presentation (Table 7).

Table 7 Migration statistics calculated from radio-tagged bull trout migrating to tributaries of the lower Duncan River and the Lardeau River.

Migration Statistic	Mean ± 95% C.I. (n)
Immigration Start Date	18 June ± 9.31 days (4)
Immigration Rate	0.73 ± 0.5 km/d (4)
Immigration Time	50 ± 20.58 days (4)
Residency Start Date (Immigration End Date)	7 Aug. ± 21 days (4)
Residency Time	52 ± 15.25 days (4)
Emigration Start Date (Residency End Date)	29 Sept. ± 2.0 days (3)
Emigration Rate	22.56 ± 40.7 km/d (3)
Emigration time	6.25 ± 14.7 days (3)
Emigration End date	5 Oct. ± 7.28 days (3)

Hamill Creek

Hamill Creek drains the northern edge of the Purcell Wilderness Conservancy into the lower Duncan River 6.2 km downstream of the dam (Fig. 3). The first 10.8 kilometers of Hamill Creek from its confluence with the lower Duncan River (6.2 to 17 km from Duncan Dam) is characterized by a steep and confined channel (gradient averages 5.0 %). This first section gives way to a wider valley and gradient drops to approximately 1.9 % over the next 7.5 km (17 to 24.5 km from the dam). At 18.3 km upstream of its confluence with the lower Duncan River (24.5 km from the dam), Hamill Creek resumes a high gradient (4.9 %) to a series of impassable waterfalls 30 km from Duncan Dam.

The single radio-tagged fish in this tributary bypassed the moderate grade section of the river and proceeded to the higher gradient section immediately below the falls (Fig. 21). We did not track this fish for the entire emigration, and did not calculate emigration statistics. The residency mark in Hamill Creek was 28 km from the dam (21.8 km upstream of the lower Duncan River confluence). A recreational hiking trail gives access to this watershed, and the upper portion of the river is within the Purcell Wilderness Conservancy.

Healy Creek

Healy Creek flows south to join the Lardeau River 6 km downstream of Trout Lake (Fig. 3). Near Lardeau River, the creek enters a high gradient (> 7 %) canyon, and migration is blocked by a series of high velocity drops at a point < 2 km from the confluence. We walked the lower 2 km with the telemetry receiver on 4 September 1995 in an attempt to locate the one radio-tagged bull trout migrating to Healy Creek. The bull trout remained just inside Healy Creek for the duration of the residency phase (Fig. 21). It is possible that the radio-tagged bull trout migrating to Healy Creek spawned in this lower section, but we did not survey it for the presence of redds.

Poplar Creek

We located two radio-tagged bull trout in Poplar Creek approximately 5 km upstream of the confluence of Lardeau River (Fig. 3). Upstream migration was blocked at this point by a 2.5 m waterfall. The two radio-tagged individuals remained immediately downstream of the falls for the entire residence portion of their migration, 35 km from Duncan Dam (Fig 21). Poplar Creek is steep and confined below the waterfall, with an average gradient of 4 % from the confluence with the Lardeau River. Above the migration barrier, gradient drops and the creek continues westward into the mountains for well over 20 km. We estimated that 20 non-tagged adult bull trout migrated to Poplar Creek. During a one hour period, bull trout were seen attempting to jump above the barrier 26 times. We observed two bull trout spawning groups and examined redds in the creek immediately below the falls in 1995 and 1996. It is important to note that we would have classed the habitat used here, directly below a barrier, as poor based on aerial comparisons to confirmed spawning locations observed in the upper Duncan system.

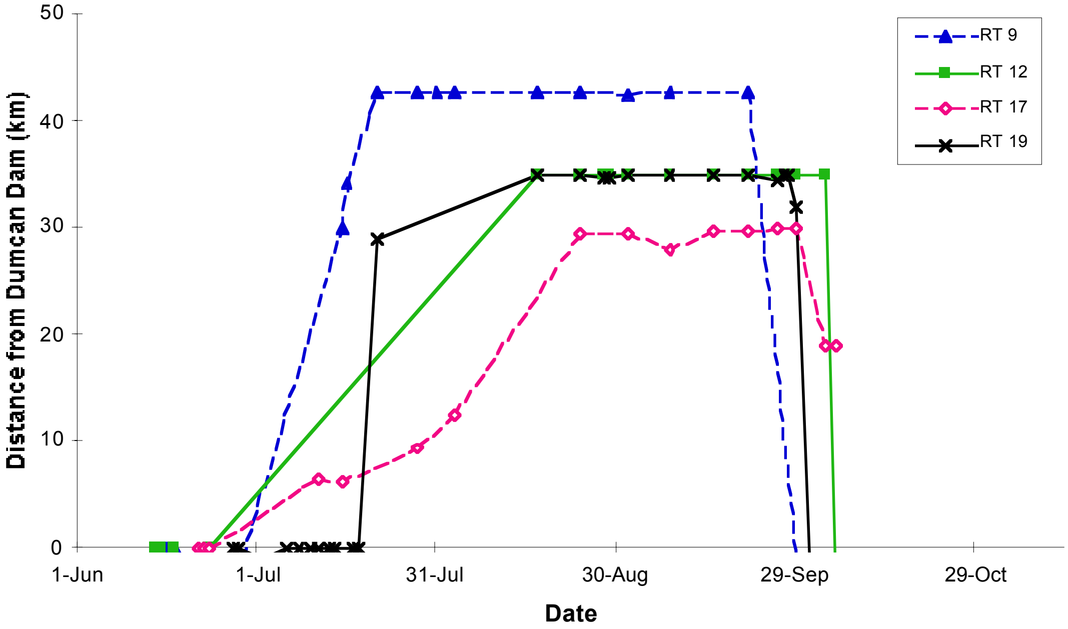

Figure 21 The migration patterns of radio-tagged bull trout tracked to tributaries of the lower Duncan and Lardeau rivers.

3.1.1.3 Overwinter Movements

In calculating migration statistics, I considered the migration complete when a radio-tagged bull trout was about to, or did, enter the Duncan Reservoir or Kootenay Lake. This method of calculation ignores the timing of exit from the reservoir for those bull trout that migrated into the upper Duncan River. If radio-tagged bull trout were subsequently located (via telemetry or capture) downstream of the dam, they had obviously emigrated. Over the winter of 1995/96, 86.4 % (19 of 22) radio-tagged bull trout left the reservoir through the discharge structure. I excluded three confirmed angler mortalities and one tag not functional in 1996 from the calculation. Over the winter of 1996/97, 74.3 % (26 of 35) of radio-tagged bull trout were confirmed to have left the reservoir; this excludes two fish whose movement suggested mortality at the residency site and three expired transmitters. Over the winter of 1997/98, the single migrant with a functional transmitter post residency was confirmed to have left the reservoir.

In addition to simply looking at subsequent locations, we tracked a portion of the bull trout known to have emigrated through the dam using both manual (1995 + 1996) and data logging (1997 + 1998) reception equipment (Table 8). Over the winter of 1996/97, we had both good remote reception coverage (late September 1996 through May 1997) and 13 radio-tagged bull trout emigrating through the discharge structure. The mean date of emigration over this period was 23 January ± 30 days (± 95% C.I.).

Table 8 Overwinter emigration dates through the discharge structure at Duncan Dam by year of migration to the upper Duncan River.

Number of bull trout	1995 migration	1996 migration	1997 migration
1	16-Oct-95*	8-Oct-96*	18-Feb-98
2	16-Oct-95*	20-Oct-96*	
3	16-Oct-95*	26-Dec-96	
4	31-Oct-95*	25-Jan-97	
5	25-Nov-95*	1-Feb-97	
6	13-Aug-96*	7-Feb-97	
7		10-Feb-97	
8		13-Feb-97	
9		16-Feb-97	
10		19-Feb-97	
11		24-Feb-97	
12		10-Mar-97	
13		11-Mar-97	

*approximate only - first reception downstream of the dam using manual receiver

3.1.1.4. *Multiple-year Data*

We followed six radio-tagged bull trout to destinations within the upper Duncan River system in two consecutive years. Four of these migrants changed their residence locations by more than 10 km and two changed the destination tributary (Table 9). We tracked no alternate year migrations to the upper Duncan River; however, this is likely because only two bull trout migrating to the upper Duncan River in 1995 carried an active transmitter over the subsequent two monitored migration periods.

Table 9 Destinations of radio-tagged bull trout migrating to the upper Duncan River in two consecutive years

Radio-Tag Number	F.L. (mm) at Tagging	Sex	Destination year 1	Destination year 2	Distance (km) between destinations
22	675	F	Westfall R.	Stevens Cr.	11.7
30	655	F	Mainstem (b)	Mainstem (a)	11.5
35	755	M	Stevens Cr.	Marsh Adams Cr.	18.7
39	655	M	Mainstem (a)	Mainstem (b)	12.5
40	690	F	Mainstem (b)	Mainstem (b)	3.5
64	685	M	Houston Cr.	Houston Cr.	4.0

3.1.2. NON-MIGRATORY MOVEMENTS

In total, we tracked summertime movements of 69 radio-tagged bull trout that did not exhibit an obvious migratory pattern (Table 10). Excluding those with only rare receptions (less than 3 days), on average we tracked each over 76.9 ± 11.1 days (n=61, ± 95% C.I.). Mean time at the dam was 57.7 ± 10.9 days. To look at the overall timing of bull trout movements at Duncan dam, I plotted the number of unique radio-tag codes present at the dam by date (Fig. 22) and then divided these into the year of origin (Fig. 23). Tracking away from the dam located radio-tagged bull trout in the Lardeau River or Trout Lake (mean = 1.1 ± 1.3 d) or in the lower Duncan River or Kootenay Lake (mean = 18.0 ± 9.1 d). Of the bull trout not exhibiting obvious migratory movements in 1995, nine returned to Kootenay Lake (90 %) and one to Trout Lake (10 %) by the end of tracking in that year (25 December). One bull trout (RT 18) did not leave the lower Duncan River by the end of 1995, and was presumed dead when we detected no movement from the last monitored location in 1996. By the end of the tracking period in 1996 (30 October), 17 bull trout (89.5 %) had returned to Kootenay lake, and none remained in the area when we began tracking in 1997. We focused tracking effort on the dam in 1997 and 1998, and as such do not know the fate of bull trout in these years except that none remained below the dam all winter. I plotted examples of the movements of bull trout that we tracked both at the dam and in the lower Duncan River within one summer in Figure 24. For convenience, I plotted distance downstream of Duncan Dam as negative numbers in Figure 24.

Table 10 The tracking category of non-migratory bull trout, 1995 - 1998.

Tracking category	Number of radio-tagged bull trout			
	1995	1996	1997	1998
Dam only	0	2	18	6
Dam and lower Duncan/Lardeau rivers	10	8	1	0
Lower Duncan/Lardeau rivers only	0	10	0	0
Mortalities	5	0	0	0
Rare (less than 3 days of receptions)	3	1	5	1
Totals	18	21	24	7

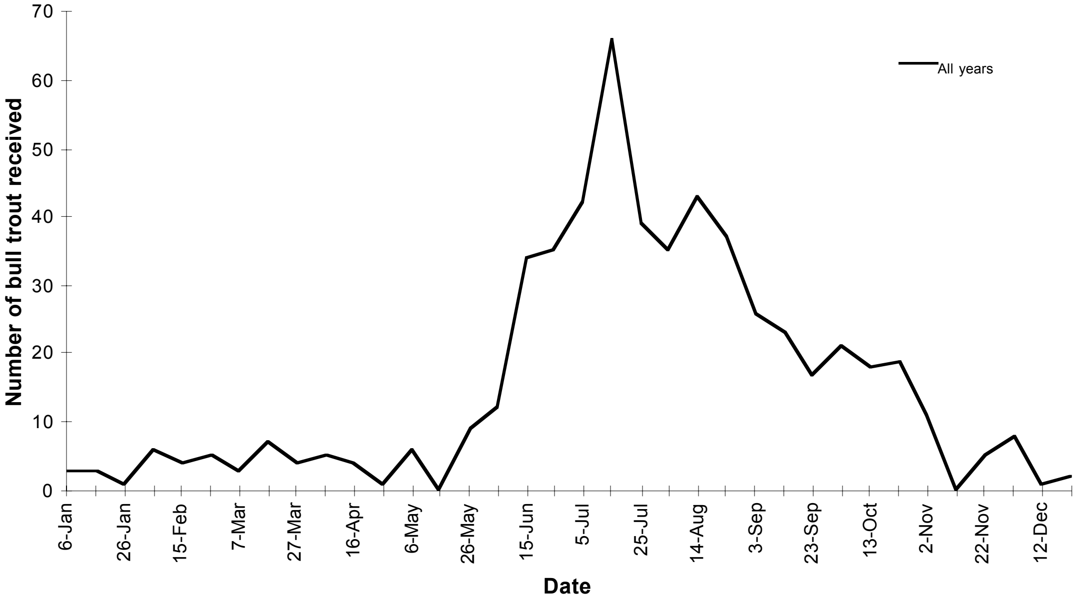

Figure 22 Number of unique radio-tags received by date at Duncan Dam over all years of the project.

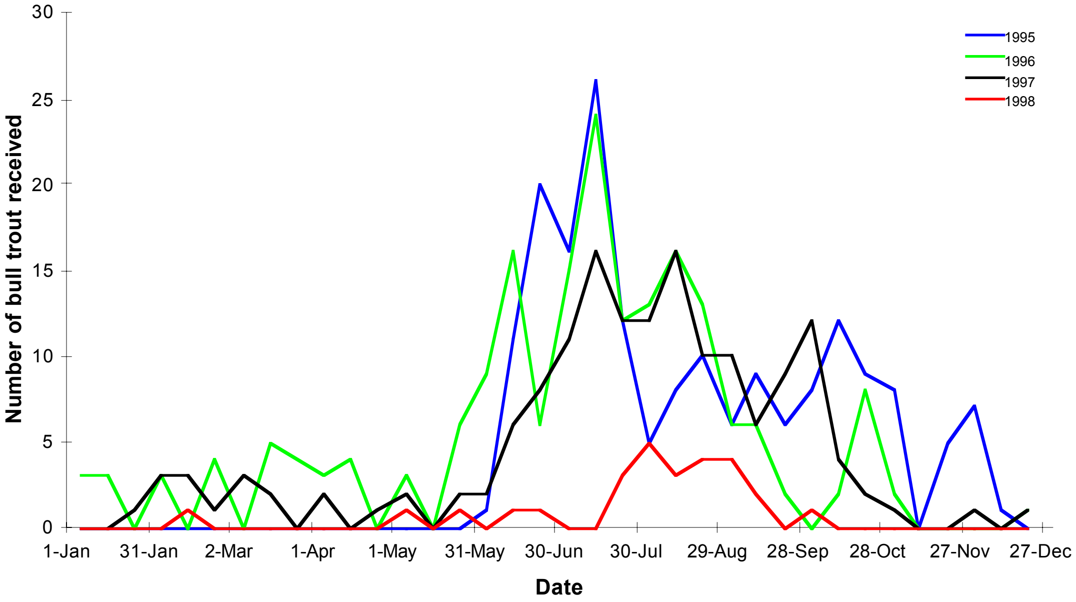

Figure 23 Number of unique radio-tags received by date at Duncan dam by year of the project.

Of particular interest are those bull trout that returned to the dam in a season subsequent to the year of radio-tagging. The first reception at the dam of a returning radio-tagged bull trout in a season reflects the actual arrival time at Duncan Dam, not the time of tagging. On average, we first received bull trout returning to Duncan Dam on July 7 ± 13.1 d (n = 28, ± 95% C.I.). Figure 25 presents the reception timing of all bull trout returning to the dam for which more than a single reception exists. For comparison, I included the dam receptions of the four bull trout that returned and ascended to migrate into the upper Duncan River system. The average reception time at the dam was 67 d ± 14.4 d (n=28, ± 95% C.I.) for the returning bull trout.

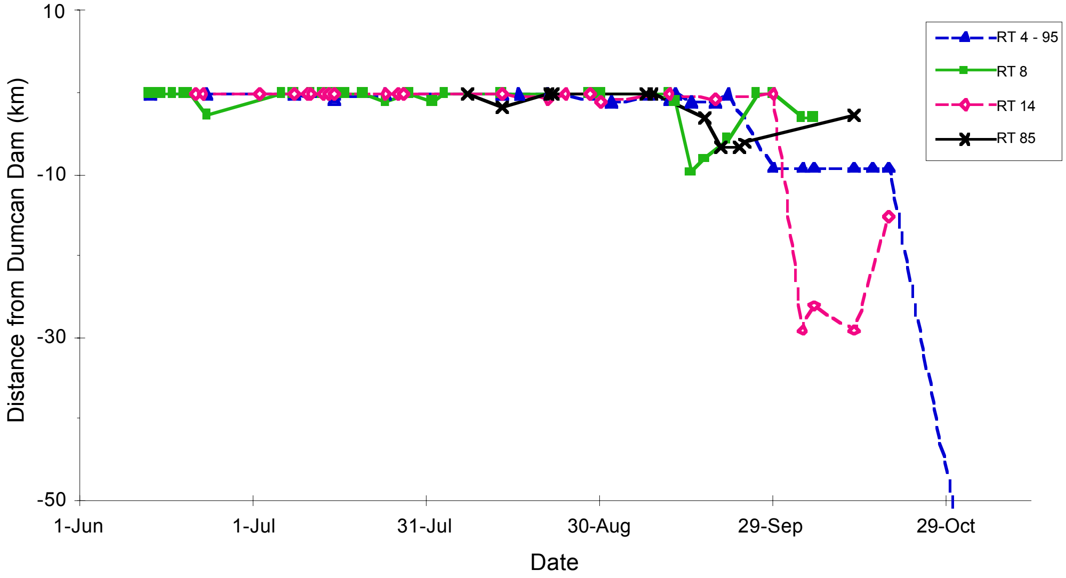

Figure 24 Example movements of radio-tagged bull trout tracked at both Duncan Dam and in the lower Duncan River which did not ascend the dam.

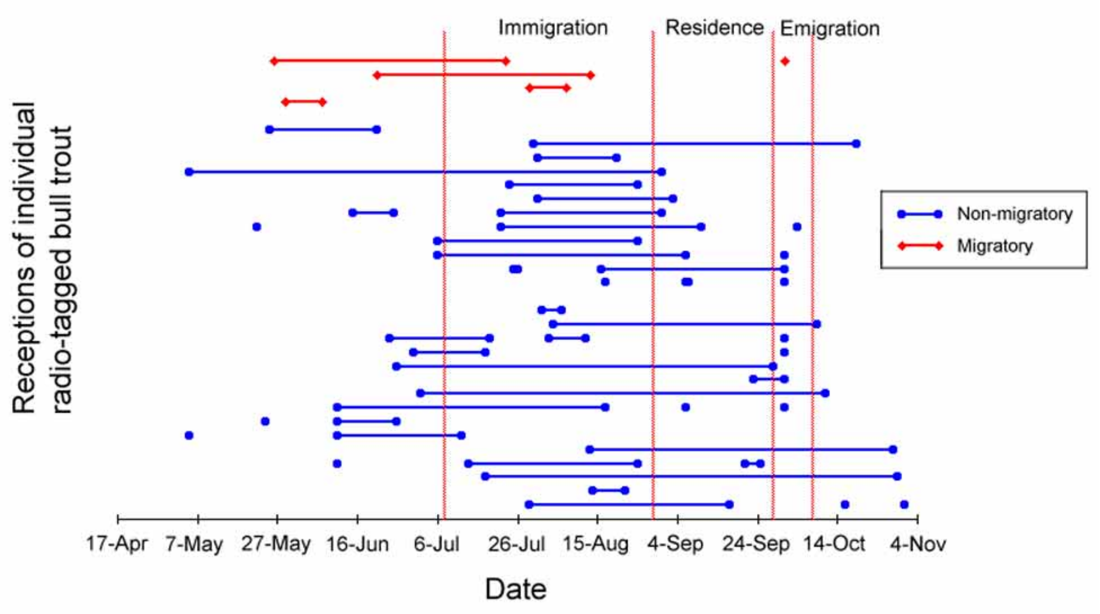

Figure 25 Tracking history of all bull trout returning to and only tracked at Duncan Dam subsequent to year of implant surgery (blue). The tracking history of the four bull trout ascending the discharge structure in a year subsequent to year of implant surgery are included (red) for comparison. The average timing of migratory immigration, residence, and emigration are indicated with vertical bars.

Movements of bull trout below the dam correspond well with the timing established for bull trout showing obvious migratory movements. This suggests that most of the bull trout tracked at the dam may have been attempting to ascend the discharge structure. Table 11 summarizes the number of radio-tagged bull trout successful in ascending the dam *versus* the number spending extended periods of time at the dam in each year of the project. I did not include any radio-tagged bull trout later found to have died, those for which less than three days of reception information existed, or those that were recaptured and released above the dam in the calculations summarized in Table 11.

Table 11 The number of radio-tagged bull trout present at the base of Duncan Dam and those ascending through the discharge structure (1995-1998)..

Year	Radio-tagged bull trout present	Ascending	% Ascending
1995	11	1	9.1
1996	15	5	33.3
1997	11	2	18.2
1998	6	0	0
All Years	43	8	18.6

In 1996, we radio-tagged six bull trout in the lower Duncan River more than 6 km downstream of Duncan Dam, expecting to track them upstream of the Dam over the summer. These bull trout did not move up to the dam, and with the increased tracking effort in the lower Duncan River, we tracked an additional four bull trout tagged in 1995 move upstream from Kootenay Lake without proceeding to the dam. I plotted examples of these movements in Fig. 26. As in Figure 24, I have plotted distances downstream of Duncan Dam in Figure 26 as negative numbers to indicate ‘downstream’.

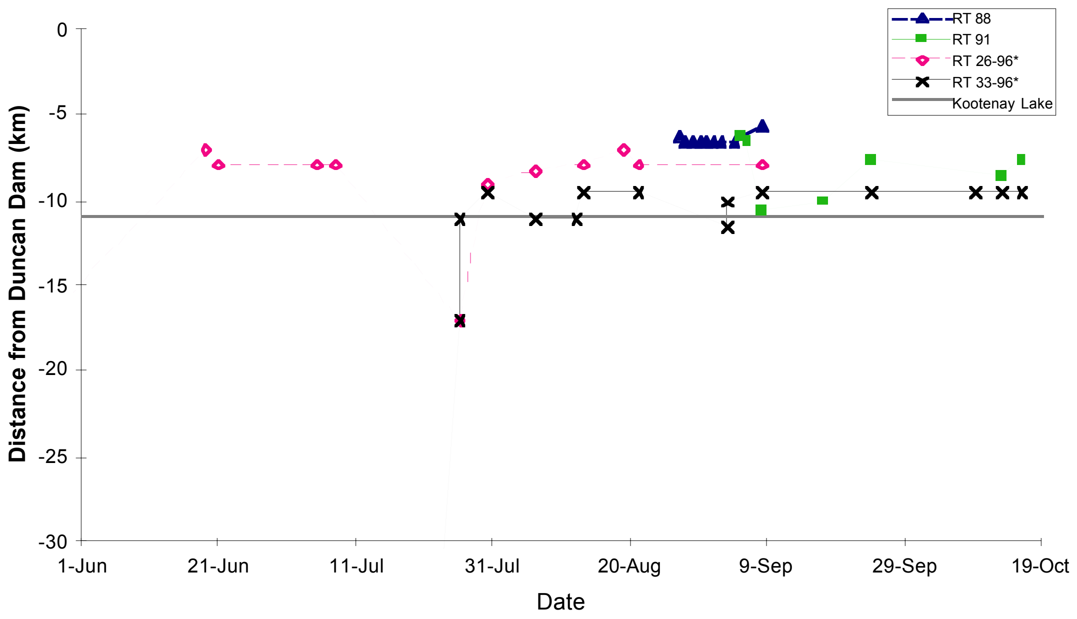

Figure 26 Example movements of bull trout tracked exclusively within the lower Duncan River within a single season. Starred radio-tags are examples of those that returned subsequent to the year of implant surgery.

On average, subsequent to 22 September ± 8.1 d (n=53, ± 95% C.I.) all bull trout had left the lower Duncan and Lardeau river systems for overwintering locations. It is assumed that this was almost exclusively Kootenay Lake, as only one radio-tagged bull trout was tracked to another location (Trout Lake). Unfortunately, not all radio-tagged bull trout were received in overwintering locations, due to low tracking effort and potential signal attenuation in deep water (Winter 1983).

3.1.3. MULTI-YEAR RECEPTIONS

I have presented results pertaining to multi-year migratory movements previously, but have not brought together patterns of return movements to Duncan Dam. By moving bull trout above Duncan Dam, it is difficult to determine what constitutes repeat spawning migrations or attempted migrations. As a surrogate for repeat spawning attempt, I used reception at Duncan Dam. I assumed that reception at the dam reflects an attempt at a spawning migration - regardless of whether it happened, was assisted with transport, or did not occur. Largely, this information is contained in Table 4, but it will be summarized here (Table 12). I have calculated percentages based on the number of tags still functioning through the year in question, excluding known mortalities or those radio-tags for which less than three days of reception data exists in a given year.

Table 12 Number of radio-tagged bull trout returning to Duncan Dam from 1996 - 1998.

Radio-tagging year	Number returning*		
	1996	1997	1998
1995	13 of 32 (40.6%)	4 of 5 (80%)	2 of 4 (50%)
1996	n/a	16 of 30 (53.3%)	5 of 9 (55.6%)

* of radio-tags still functioning, excluding known mortalities and rare reception

3.2. POPULATION SURVEYS

3.2.1. ADULTS

In total, we Floy-tagged 1029 adult bull trout, of which 792 (77%) were captured at the discharge structure (Table 13). Cumulative tagging totals of bull trout during flip bucket drain procedures, not including within year recaptures, are presented in Figure 27. Comparing the tagging totals presented in Table 13 with the cumulative catch at Duncan Dam (Fig. 27) is confusing. For presentation in Figure 27, I tallied all bull trout new to the flip bucket in a particular year, regardless if they had been Floy-tagged previously at another location. For example, in 1995, Table 13 indicates that the total number of bull trout receiving Floy-tags in the flip bucket was 349. In contrast, Figure 27 suggests that 371 bull trout were captured in the flip bucket. This discrepancy is largely due to fish Floy-tagged in the weir in 1995 (75 in total - Table 13) being subsequently recaptured in the flip bucket - thus adding to the cumulative total in Figure 27, but not to the total number captured in the flip bucket (Table 13). I included flip drain data collected by BCHydro in 1998 (den Biesen 1999) in Figure 27; however, I only included those data collected over a similar time period to the 1995 through 1997 data set to allow direct comparison. Differences in mean FL between those bull trout Floy-tagged at the discharge structure were not significant between 1995 and 1996 (1995: 654 ± 8.6 mm, n = 313, 1996: 650 ± 8.7 mm, n = 220; two tailed, two sample t-test, *P* = 0.558) and I pooled the data. Bull trout Floy-tagged at the dam in 1997 were significantly larger than the pooled 1995/96 data (pooled: 652 ± 5.0 mm, n = 533, 1997: 687 ± 10.6 mm; one tailed, two sample t-test, *P* << 0.001). I plotted the pooled 1995/96 and 1997 fork length histograms separately in Figure 28.

The fork length - weight relationship of all bull trout captured and weighed at the discharge structure at Duncan Dam is plotted in Figure 29. The regression (log weight = 2.941 * log fork length - 4.845, $r^2 = 0.837$, n = 123) was significant ($P << 0.001$).

There is similarity between ages I estimated from scales and a very small sample of otolith. I plotted otolith (n=6) and scale ages (n=47) together to allow comparison (Fig. 30).

Table 13 Number of bull trout Floy-tagged (T-anchor type) by location and year

Floy tagging location	Number of bull trout		
	1995	1996	1997
Discharge structure (Duncan Dam)	349	222	221
Weir (Duncan Dam)	75	0	0
Tailrace (Duncan Dam)	20	16	0
Houston Creek emigrant fence	0	41	0
Meadow Creek kokanee enumeration fence	11	16	0
Lower Duncan River	4	49	0
Upper Duncan River	3	0	0
Poplar Creek	2	0	0
Totals	464	344	221

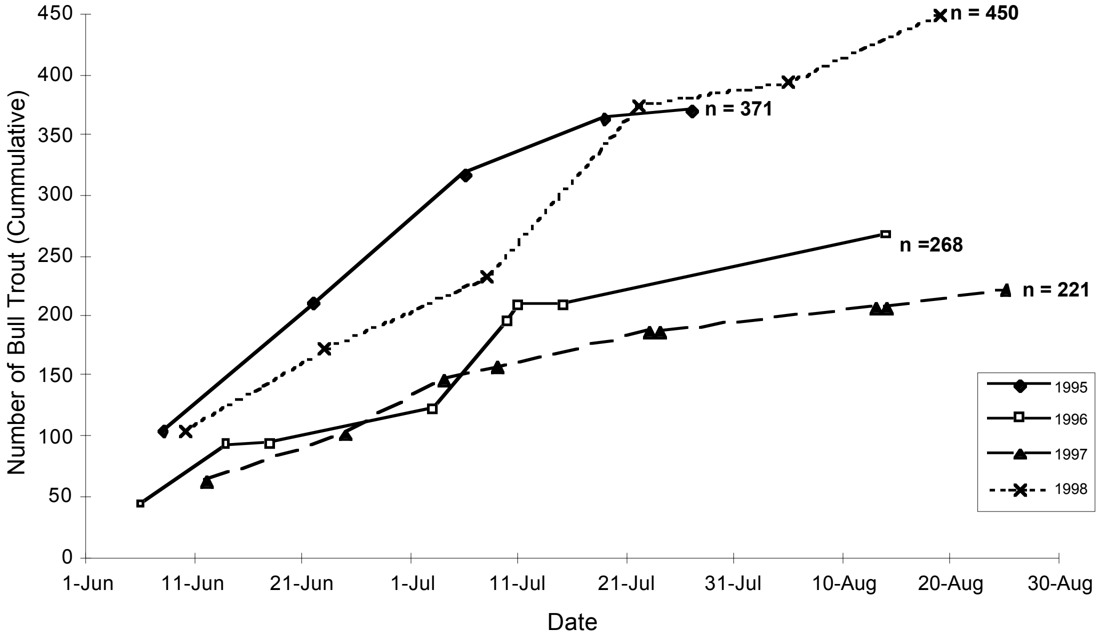

Figure 27 Cumulative bull trout capture at Duncan Dam by year of the project. The data include all bull trout new to the flip bucket each year, excluding within year recaptures. 1998 data after den Biesen 1999.

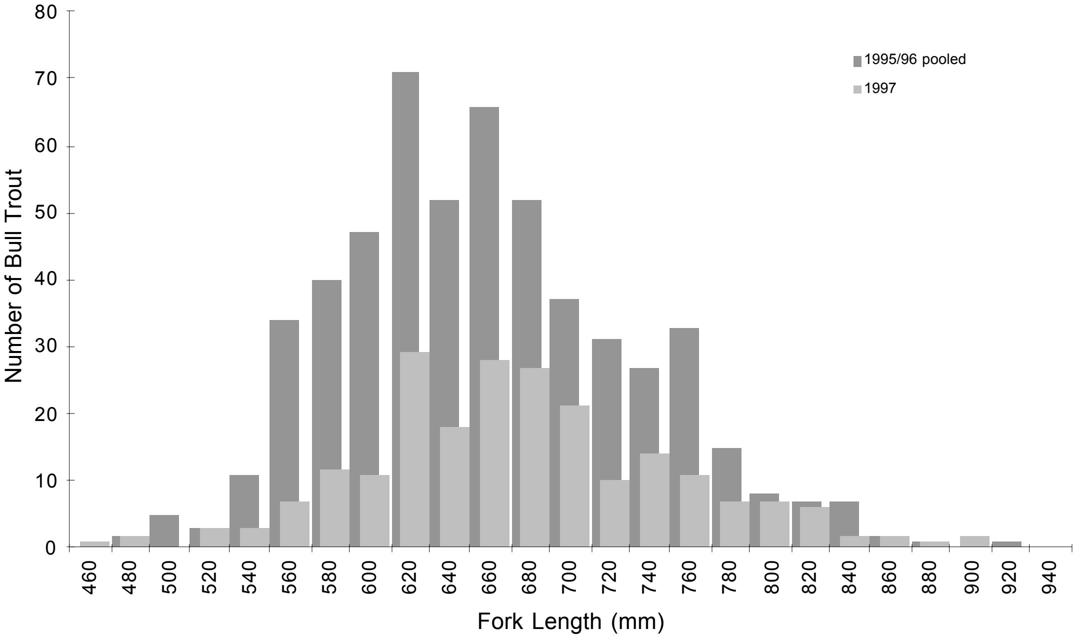

Figure 28 Fork length frequency histogram of bull trout tagged in the flip bucket at Duncan Dam in 1995/96 and 1997.

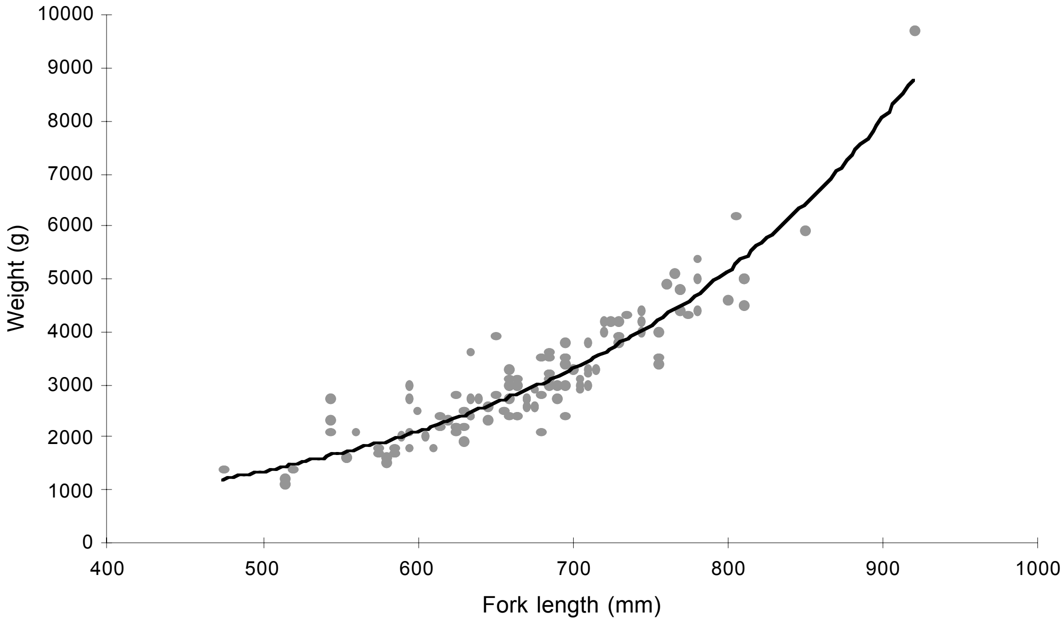

Figure 29 Fork length - weight relationship of bull trout captured in the flip bucket at Duncan Dam.

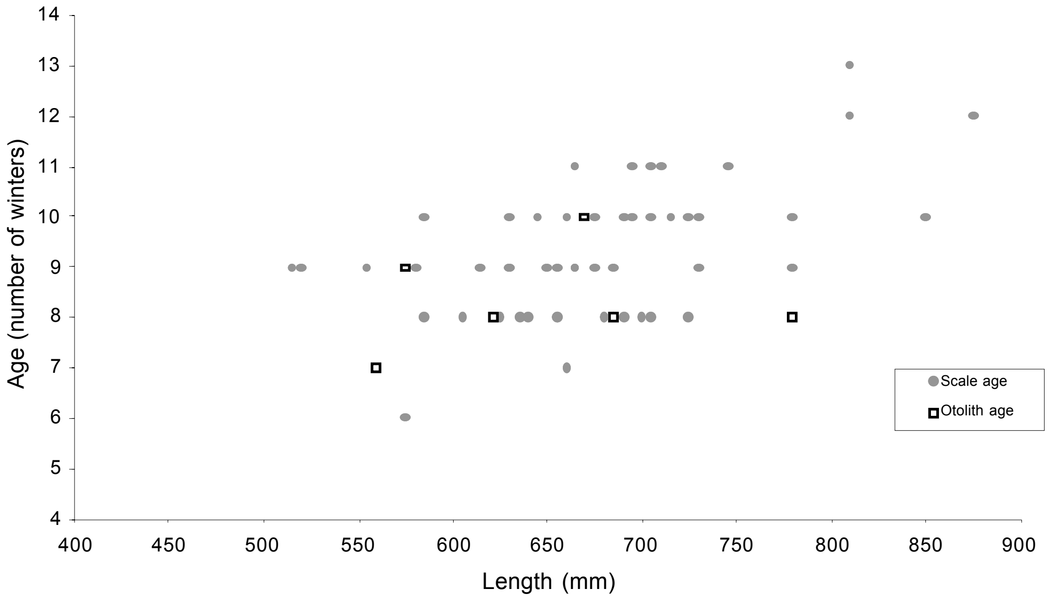

Figure 30 Age at length of bull trout sampled at Duncan Dam determined from scale and otolith samples.

We captured a large proportion of bull trout in the flip bucket more than once a year; for example, one was caught in six of eight drains in 1996. We captured 22.9%, 28.3%, and 27.6% of bull trout more than once in 1995, 1996, and 1997 respectively. I assessed variability in our method of length measurement by comparing multiple measurements within a single year. There was no bias between first and second measurement (two tailed, paired sample t-test, $P = 0.85$, $n = 95$) and the mean difference between measures was 3.52%.

Anglers reported capturing a total of 56 tagged bull trout (Table 14; Fig. 31) up to and including 30 May 1998. Twenty-eight of the recaptures were from fish tagged in 1995 (6.0%), 22 from fish tagged in 1996 (6.4%), and 6 from 1997 tagging (2.7%). Of these recaptures, 9 were also radio-tagged: eight from those radio-tagged in 1995 (18.2%), and 1 from 1996 radio-tagged bull trout (2.1%). Four recaptures (8.7%) were from the 46 bull trout captured at the Houston Creek fish fence.

We also recaptured bull trout across years in the flip bucket. I calculated both repeat year movements to the flip bucket (correcting for angler captures) and growth rates (Table 15).

Table 14 Reported angler recaptures of tagged bull trout.

Floy	Clr.	Tagging			Capture			Days	Distance from	Radio	Released
		Date	Length	Location	Date	Length	Location	at Large	tagging (km)	Tag	
502	W	31-May-95	60.5	Dam	?		Kootenay Lake at Coffee Creek		~ 55		no
508	W	31-May-95	71.0	Dam	6-Oct-95		67 mile on Duncan FSR	128	55		no
568	W	8-Jun-95	69.0	Dam	8-Oct-95		Kootenay Lake at Argenta	122	11		no
583	W	8-Jun-95	74.0	Dam	28-Dec-97	82.0	Kootenay Lake in Crawford Bay	934	65		no
587	W	8-Jun-95	54.5	Dam	16-Jun-95		Kootenay Lake at Davis Creek.	8	15		no
612	W	8-Jun-95	68.5	Dam	10-Mar-96	71.1	?	276			no
617	W	8-Jun-95	65.0	Dam	?		Mouth of upper Duncan River		42.5		no
634	W	14-Jun-95	78.0	Dam	21-Oct-95		Kootenay Lake off Balfour	129	65	9	yes
684	W	22-Jun-95	59.0	Dam	?		Mouth of Glacier Creek		3		no
691	W	22-Jun-95	72.0	Dam	26-Nov-95		Mouth of Glacier Creek	157	3	42	no
786	W	6-Jul-95		Dam	?		Kootenay Lake off Queens Bay		~ 60		no
789	W	6-Jul-95	53.0	Dam	18-May-96		Kootenay Lake at Wilson Creek	317	75		no
791	W	6-Jul-95	83.5	Dam	6-Aug-96	74.9	Kootenay Lake south of Schroeder Creek	397	27		no
794	W	6-Jul-95	63.9	Dam	8-Sep-95		Kootenay Lake in West Arm	64	> 65		no
801	W	29-Jun-95	81.0	Dam	13-Nov-95		Mouth of Glacier Creek	137	3	23	no
810	W	5-Jul-95	78.0	Dam	20-Oct-95	71.4	Mouth of Glacier Creek	107	3	29	no
813	W	29-Jun-95	58.5	Dam	18-Feb-96	66.0	Kootenay Lake near Kaslo	234	20		no
829	W	5-Jul-95	65.5	Dam	1-May-97	68.6	Kootenay Lake off Balfour	666	65	30	no
840	W	6-Jul-95	57.0	Dam	14-Dec-97		Kootenay Lake @ Argenta	892	11		no
851	W	6-Jul-95	92.0	Dam	28-Jan-97	106.7	Kootenay Lake in West Arm	572	> 65		no
861	W	6-Jul-95	61.0	Dam	?	56.0	Kootenay Lake in the North Arm				no
866	W	6-Jul-95	75.0	Dam	?		Kootenay Lake at Coffee Creek		~ 55		no
873	W	6-Jul-95	61.0	Dam	25-Jan-96		Kootenay Lake at Argenta	203	11		no
889	W	6-Jul-95	60.0	Dam	1997?		?	> 500			no
550	Y	26-Jul-95	58.5	Dam	22-Jun-96	60.3	Kootenay Lake off Fry Creek	332	22		no
552	Y	19-Jul-95	52.0	Dam	2-Oct-95		Kootenay Lake at Argenta	75	11		no
557	Y	19-Jul-95	66.5	Dam	?	91.4	?			41	no
575	Y	20-Jul-95	71.5	Dam	20-May-96		Kootenay Lake at Riondel	305	~ 60	43	no
628	Y	6-Jun-96	68.0	Dam	?		?				no
642	W	14-Jun-96	66.5	Dam	15-Jul-96	60.3	Kootenay Lake off Balfour	31	65	12	no
764	W	6-Jul-96		Dam	30-Mar-97		Kootenay Lake off the power lines	267	~ 55		no
527	Y	19-Jul-96	66.0	Dam	20-May-97		Kootenay Lake off Balfour	305	65		no
726	Y	27-Sep-96	57.2	Houston	22-Feb-98	64.0	Duncan Reservoir	513	~ 120		no
816	Y	10-Jul-96	77.0	Dam	31-Mar-97		Kootenay Lake off Fry Creek	264	22.0	73	no
933	Y	11-Jul-96	75.5	Dam	30-Mar-97		Kootenay Lake off Mirror Lake	262	25.0		no
953	Y	5-Sep-96	56.0	L. Duncan	6-Feb-98	63.0	Kootenay Lake	519	> 10		no
8003	Y	10-Jul-96	69.0	Dam	16-Nov-97		Kootenay Lake off Kaslo	494	20		no
8004	Y	10-Jul-96	71.0	Dam	2-Feb-97	73.7	South end of Kootenay Lake	207	> 80		no
8012	Y	14-Aug-96	66.5	Dam	5-Jan-97		Kootenay Lake off Balfour	144	65		no
8031	Y	10-Jul-96	59.0	Dam	24-Feb-97	63.5	Kootenay Lake at Schroeder Creek	229	17.0		no
8044	Y	14-Aug-96	58.5	Dam	25-Dec-96	66.0	Kootenay Lake off Lost Ledge	133	15.0		no
8066	Y	14-Aug-96	60.0	Dam	?	66.0	Kootenay Lake off Wilson Creek		75.0		no
8104	Y	14-Aug-96	67.5	Dam	30-Mar-97	76.2	Kootenay Lake North of Woodbury Creek	228	50.0		no
8117	Y	27-Aug-96	60.5	L. Duncan	5-May-97	61.0	Kootenay Lake off Balfour	251	65		no
8118	Y	27-Aug-96	46.0	Dam	7-Mar-98	58.0	Kootenay Lake in Queens Bay	557	60		no
8130	Y	5-Sep-96	62.0	L. Duncan	10-Nov-96	63.5	Kootenay Lake off Pilot Point	66			no
8142	Y	5-Sep-96	36.0	Dam	23-Dec-97	58.0	Kootenay River	474	>90		yes
8279	Y	3-Oct-96	59.7	Houston	2-Nov-97	63.0	Duncan Reservoir	395	~ 120		yes
8285	Y	2-Oct-96	55.5	Houston	1-Nov-97	68.0	Duncan Reservoir	395	~ 120		yes
8298	Y	27-Sep-96	57.0	Houston	17-Oct-97		Duncan Reservoir	385	~ 120		no
8274	Y	?	?	?	28-Mar-98	60.0	Duncan Reservoir				no
8406	Y	9-Jul-97	67.0	Dam	12-Dec-97		Kootenay Lake off Inkspots	156	25		no
8452	Y	4-Jul-97	73.5	Dam	30-Nov-97		Kootenay Lake off Mirror Lake	149	30		no
8470	Y	23-Jul-97	74.5	Dam	25-Jan-98	77.0	Kootenay Lake @ Argenta	186	11		no
8489	Y	13-Aug-97	60.0	Dam	30-May-98	61.0	Trout Lake	290	> 60		no
8493	Y	25-Aug-97	64.0	Dam	22-May-98	78.0	Kootenay Lake in West Arm	270	>75		yes

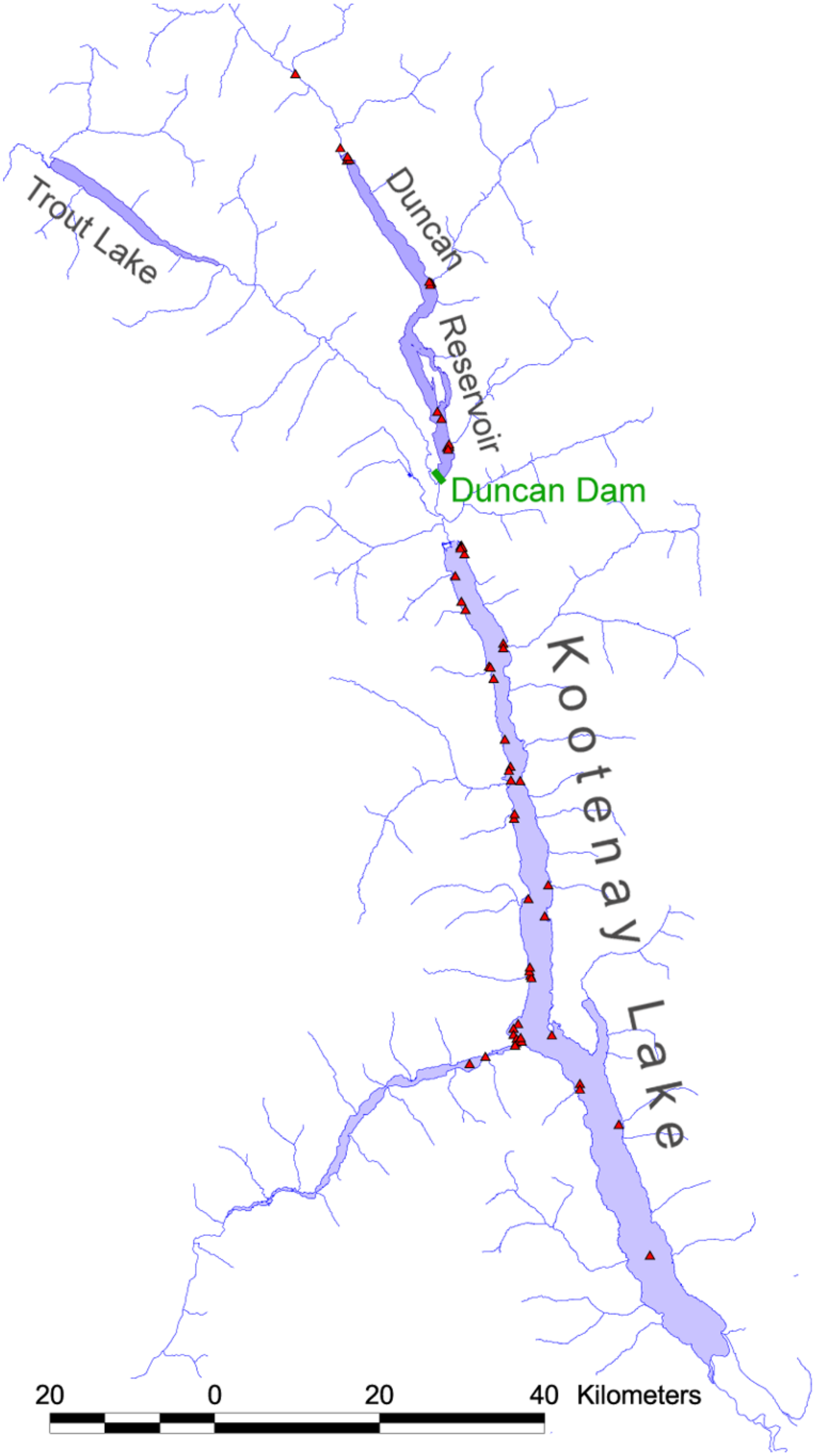

Figure 31 Known location of angler recapture of tagged bull trout from 6 October 1995 to 30 May 1998.

Table 15 Repeat migration and growth estimates calculated from flip bucket recaptures of Floy-tagged bull trout.

Year of tagging	Return Year 1996 #	 %*	 Growth**	 1997 #	 %*	 Growth**	 1996 + 1997 #	 %	 Growth**
1995	35	9.9%	5.4 ± 1.3	17	4.9%	11.0 ± 3.3	4	1.2%	
1996				31	12.1%	6.7±1.9			

* percentage of those tags available after correction for reported angler recaptures
** growth in mm/yr., ± 95% C.I.

3.2.1.1. Population Size Estimates

I calculated the number of bull trout present at the dam at each flip bucket drain (Peterson estimate, Fig. 32). I found no difference between the mean estimates across the three years of data (one-tailed, two sample t-test comparing largest and smallest estimate years, $P = 0.31$), and pooled the data. The mean number of bull trout present at the base of the dam over flip bucket drain dates was 510 ± 170 bull trout *via* the Peterson estimate.

I also calculated the number of bull trout present at the time of flip bucket drains (Fig. 33) and the number immigrating (Fig. 34) and emigrating (Fig. 35) from the base of Duncan Dam between drains (Jolly-Seber estimate). I found significant differences between the mean estimates across years (one-tailed, two sample t-test $P = 0.049$).

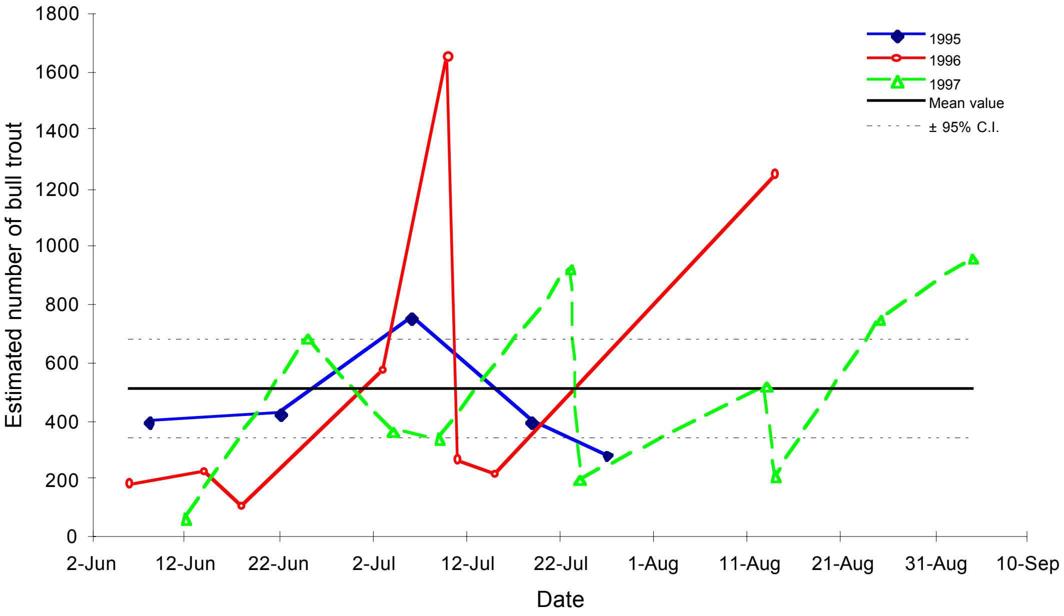

Figure 32 Peterson estimates of the number of bull trout present at the base of Duncan Dam on flip bucket drain dates by year.

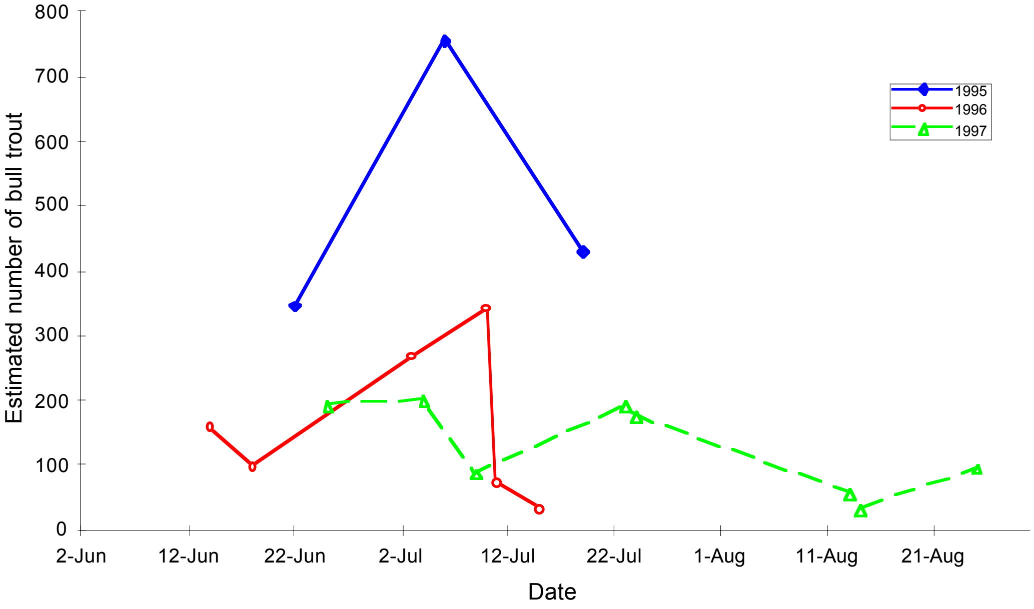

Figure 33 Jolly-Seber estimates of the number of bull trout present at the base of Duncan Dam on flip bucket drain dates by year.

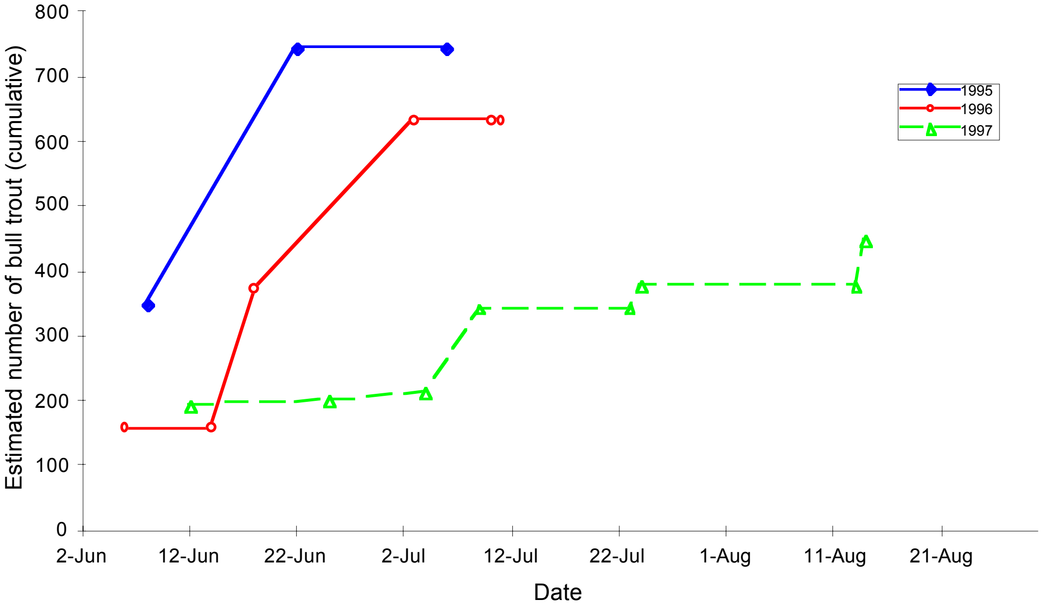

Figure 34 Jolly-Seber estimates of the cumulative number of bull trout immigrating to the base of Duncan Dam between flip bucket drain dates by year.

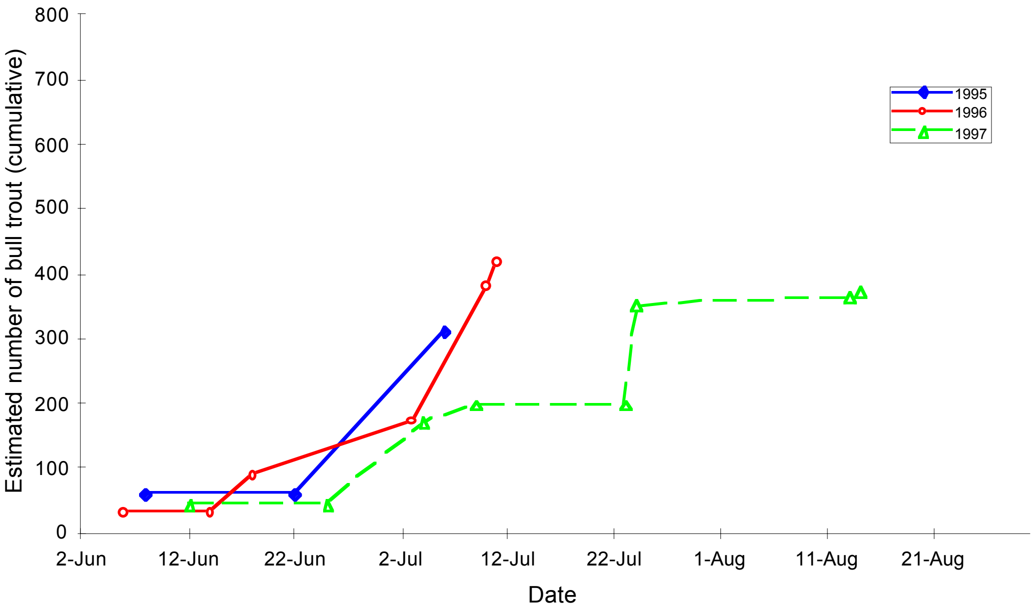

Figure 35 Jolly-Seber estimates of the cumulative number of bull trout emigrating from the base of Duncan Dam between flip bucket drain dates by year.

3.2.1.2. Transfer Success

Estimates of transfer success based on radio-tagged bull trout have been presented previously (Table 11). We also evaluated the fish transfer procedure directly on three occasions by tagging all bull trout prior to and then re-draining the flip bucket immediately after the transfer. The evaluated transfers occurred on 10 July 1996, 23 July 1997, and 13 August 1997. Prior to the transfer there were 76, 34, and 32 bull trout in the flip bucket, respectively. After the transfer, 39 (52.7%), 18 (47.0%), and 16 (50.0%) of the bull trout handled prior to the transfer remained in the flip bucket, respectively. On two occasions at re-drain, we also captured bull trout that were not present before the transfer (13 on 10 July 1996, one on 23 July 1997). Of the 69 bull trout not present in the flip bucket after a monitored transfer, we recaptured one (1.4%) in a subsequent flip bucket drain that year.

3.2.2. SPAWNING

We located and measured spawning sites (Table 16) in Westfall River (Fig 12), and Houston (Fig. 10) and Poplar creeks. Redds in Poplar Creek were at the base of the waterfall, 6 km upstream of the Lardeau River confluence. We failed to locate redd sites during foot surveys of areas in the upper Duncan River system utilized by radio-tagged bull trout, other than Houston Creek and Westfall River.

Table 16 Summary of mean bull trout redd measurements.

Redd Measurement	Mean ± 95 C.I. (n)
Depth	0.28 ± 0.06 m (15)
Length	2.64 ± 1.22 m (15)
Width	0.92 ± 0.22 m (15)
Surface Velocity	0.32 ± 0.04 m/s (10)
Column Velocity (60 %)	0.42 ± 0.10 m/s (15)
Substrate (D90) - Egg Deposition Site	62 ± 6 mm (15)
Substrate (D90) - Final Excavation	91 ± 10 mm (10)

We captured 47 bull trout emigrating from Houston Creek at the Houston Fence. Of these emigrants, one was Floy-tagged (2.1 %) and three were radio-tagged (6.4 %) at the Duncan Dam in 1996. The mean fork length of trapped kelts was 564 ± 27 mm (n = 45, Figure 23). The mean fork length of fish captured at the fence was significantly smaller than that of fish captured at the Duncan Dam (1 tailed t-test, *P* << 0.001). Twenty-one were female, 23 were male, a single bull trout (FL 411 mm) was of indeterminate sex, and two escaped before examination.

The mark recapture estimate of the total number of bull trout in Houston Creek (from radio-tags only, Petersen estimate) was 168. By assuming that the ratio of fish without radio-tags to those carrying them was the same in all destinations (in 1996), I estimate that 500 adult bull trout were present in the upper Duncan system during the 1996 spawning period.

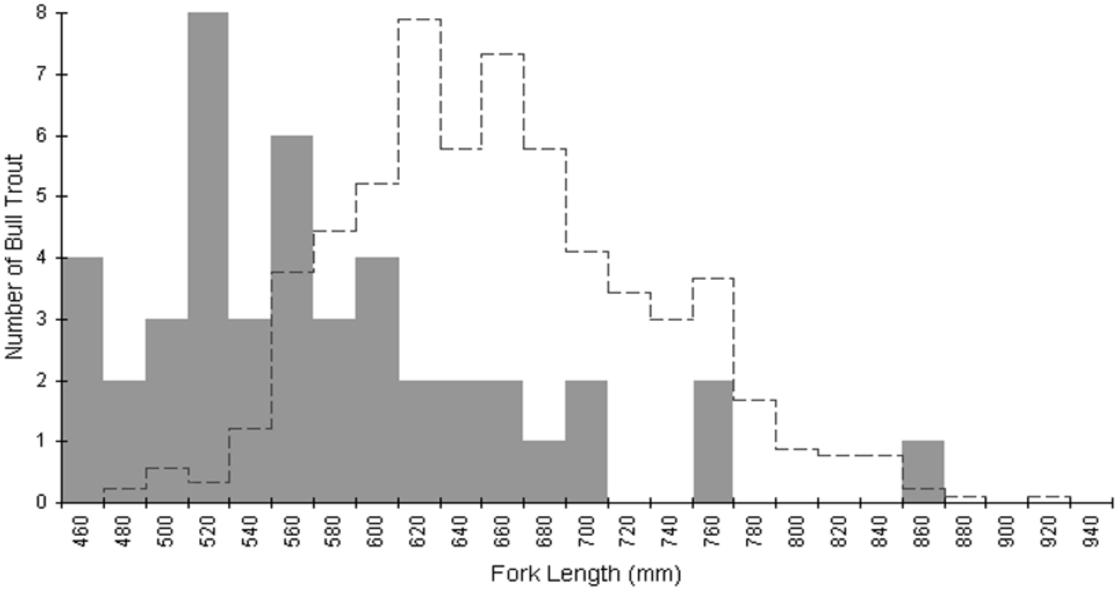

Figure 36 Fork length frequency histogram of bull trout kelts trapped at the Houston Creek fish fence in 1996. Outline of 1995/96 bull trout length frequency histogram (Duncan Dam captures) included for comparison (dashed line).

3.2.3. JUVENILES

Bull trout juveniles were sampled from sites in Houston Creek (Fig. 37) and the Westfall River (Fig. 38). Age discrimination was based on fork length frequency histograms, and in both systems we found three age classes present (Fig. 39 and 40). We sampled juveniles in 1997 primarily for collection of tissue for molecular work; however, as methodology was consistent, it is possible to compare estimated density at these sites. Plots of relative density of fry (0+) and total number of captures from 1997 sampling in both Houston Creek and Westfall River are presented in Figures 40 and 41, respectively. In 1995, we sampled 52 juveniles from a single site in the Westfall River (UTM Zone 11 5628950N 474700E, Fig. 38). The approximate size of this site was 200 m^2, yielding capture of 0.26 bull trout•m^{-2}. We sampled two sites in Houston Creek in 1996 to assess numbers of juvenile bull trout (site 96-1 UTM 5644900N 478350E, site 96-2 UTM 5647925N 482150E, Fig. 37). The first, a 237 m^2 side channel, resulted in capture of 83 juveniles (0.35 bull trout•m^{-2}). The second Houston Creek site was a shallow braided channel area (sampled area = 485 m^2) which yielded 5 juvenile bull trout (0.01 bull trout•m^{-2}).

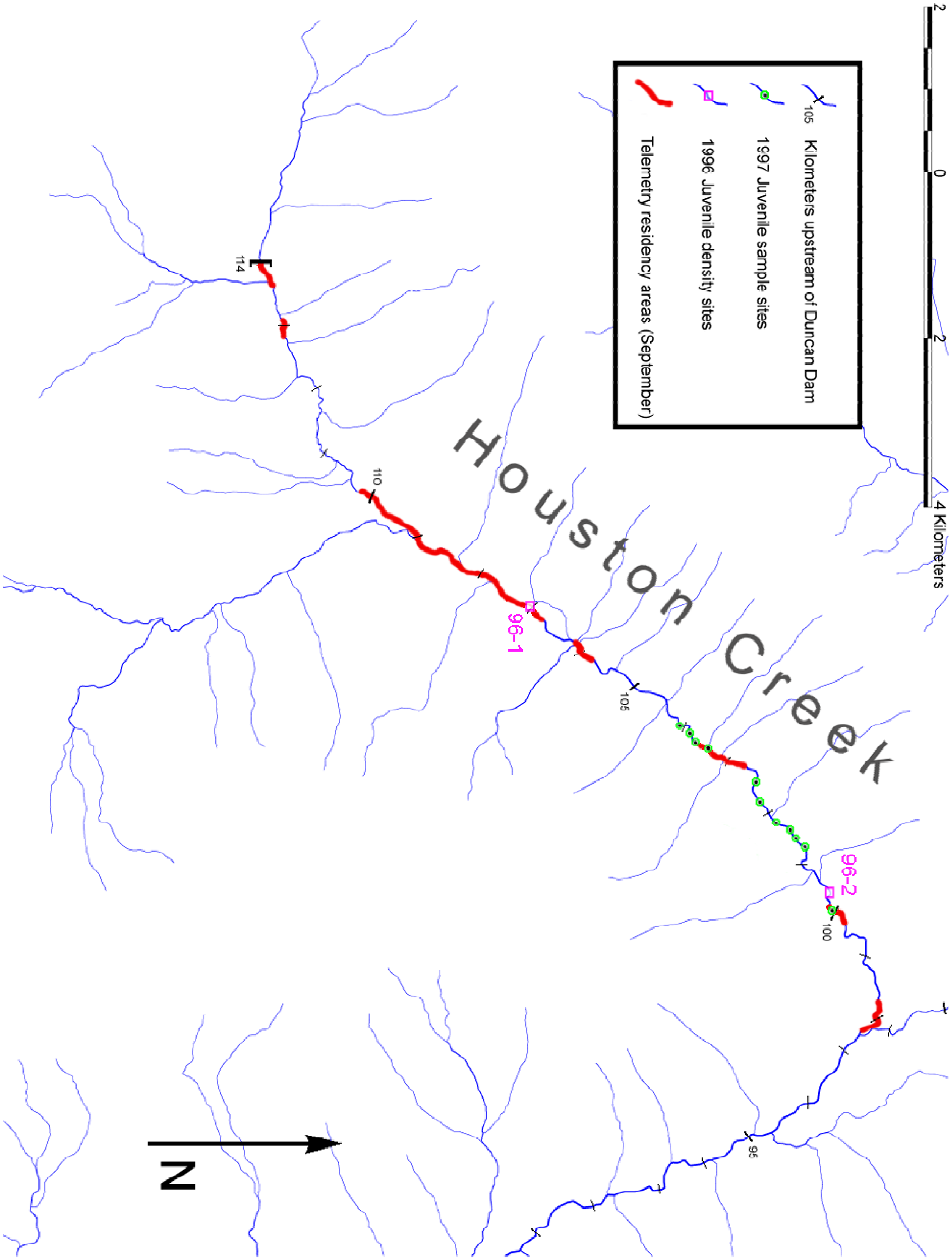

Figure 37 Juvenile sample sites in Houston Creek in relation to telemetry residence areas (September).

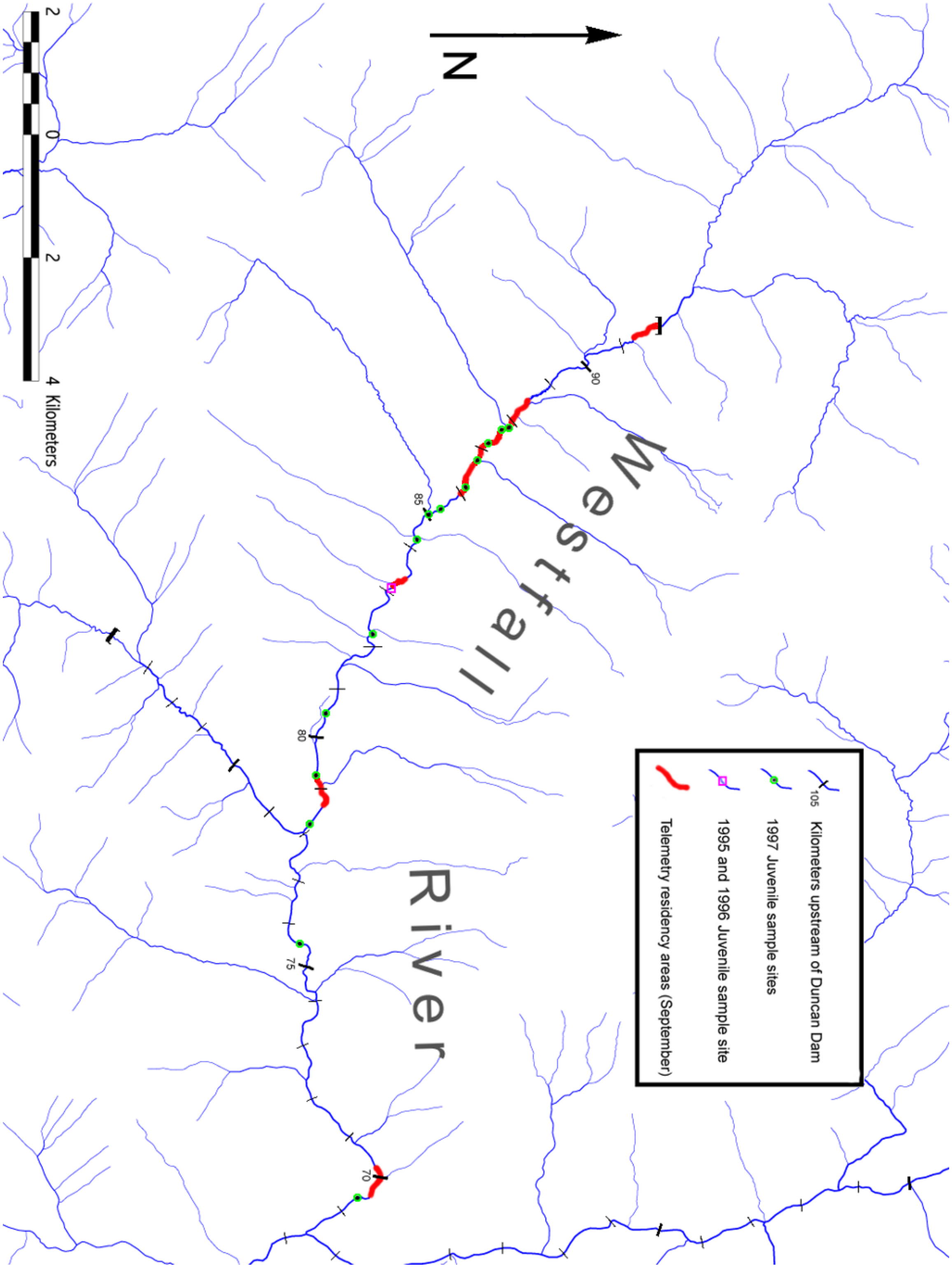

Figure 38 Juvenile sample sites in the Westfall River in relation to telemetry residence areas (September).

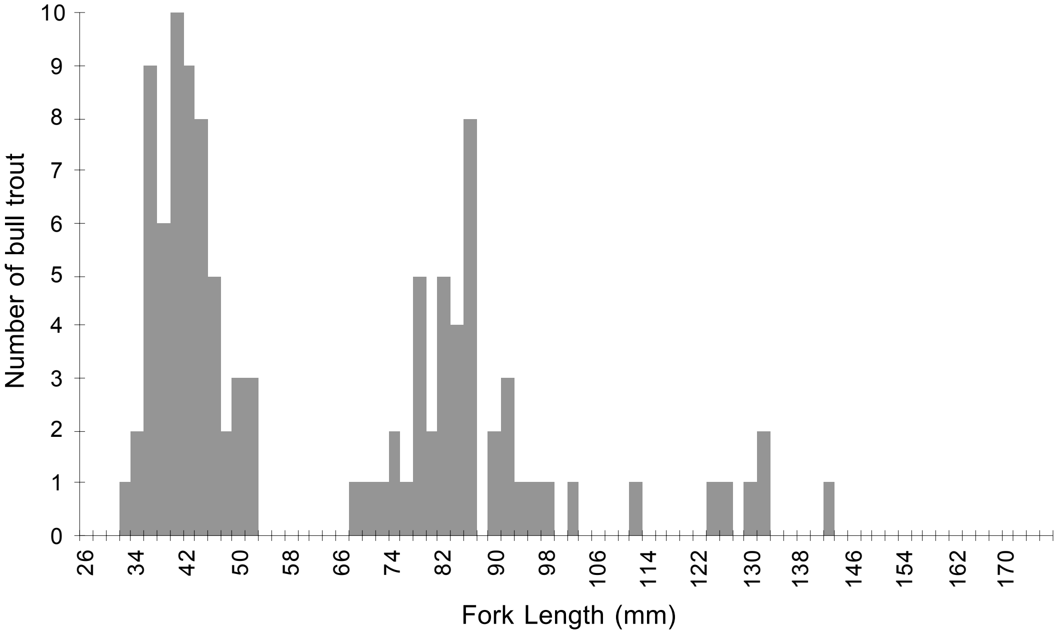

Figure 39 Fork length frequency of juvenile bull trout captured in Houston Creek, 20 - 22 August 1997 (n=104).

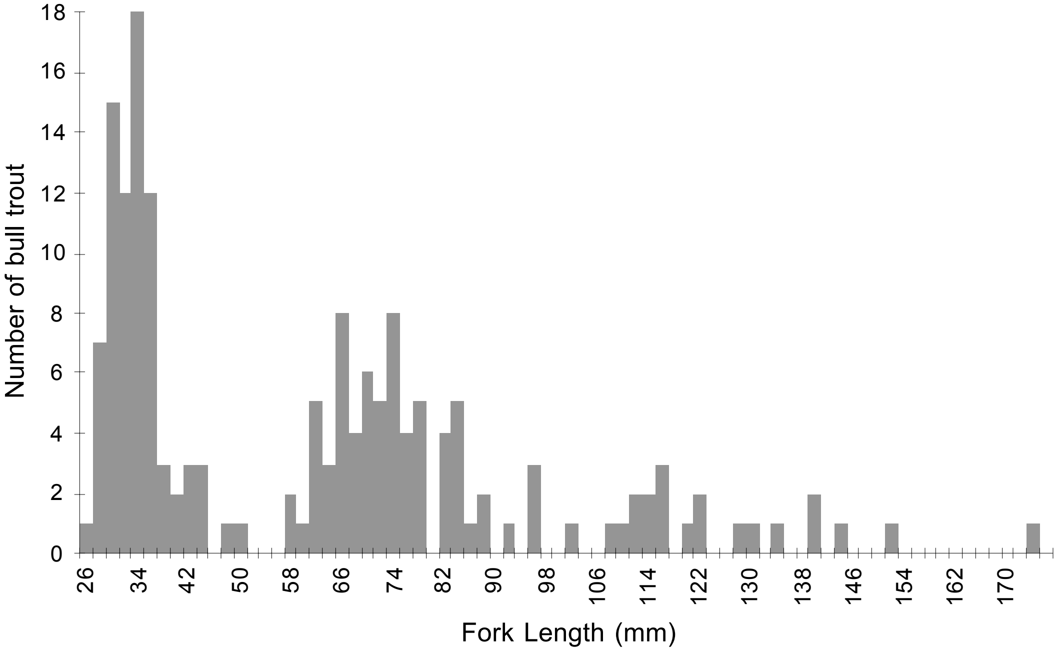

Figure 40 Fork length frequency of juvenile bull trout captured in the Westfall River, 15 July - 12 August 1997 (n = 167).

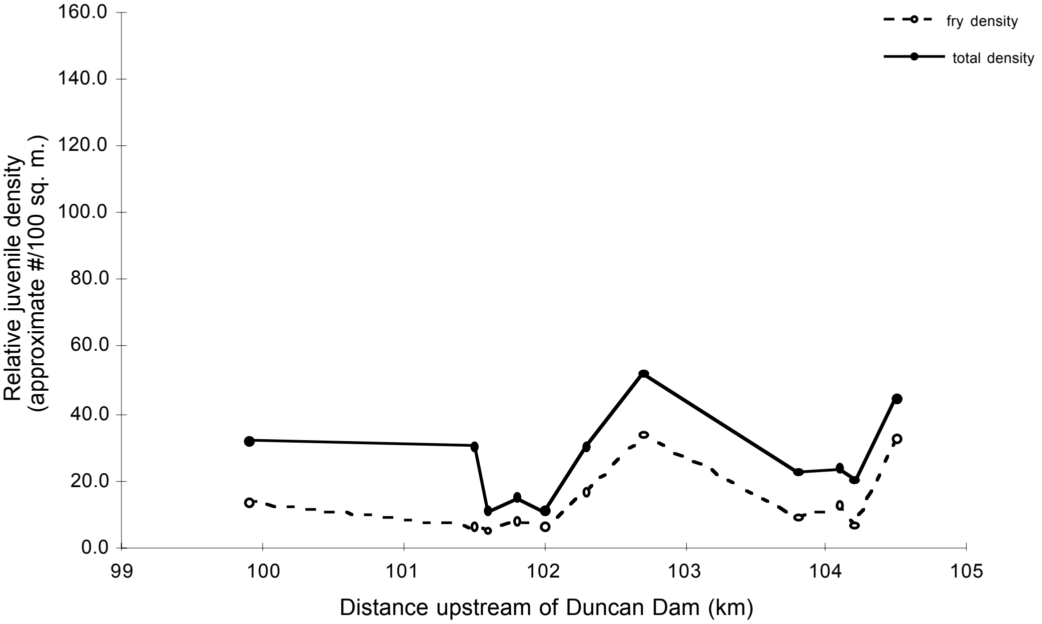

Figure 41 Relative density of fry (0+) and total juvenile bull trout captured in Houston Creek, 20 - 22 August 1997.

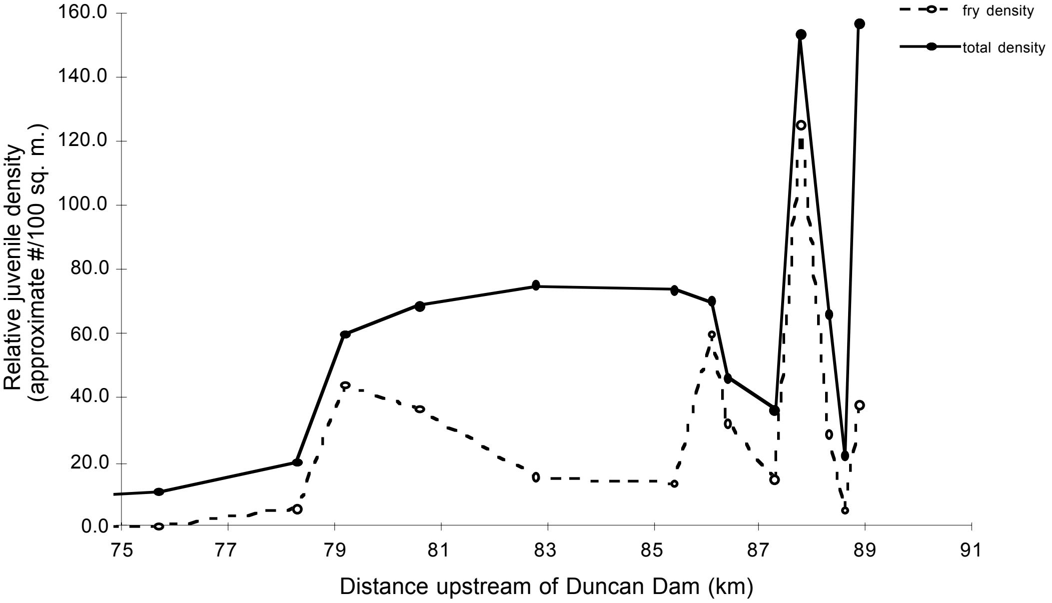

Figure 42 Relative density of fry (0+) and total juvenile bull trout captured in the Westfall River, 15 July - 12 August 1997.

3.2.4. RESIDENT POPULATIONS

The location of all above barrier resident electroshocking sites are illustrated in Figure 43. The life-stages we sampled at these locations, by date, are summarized in Table 17.

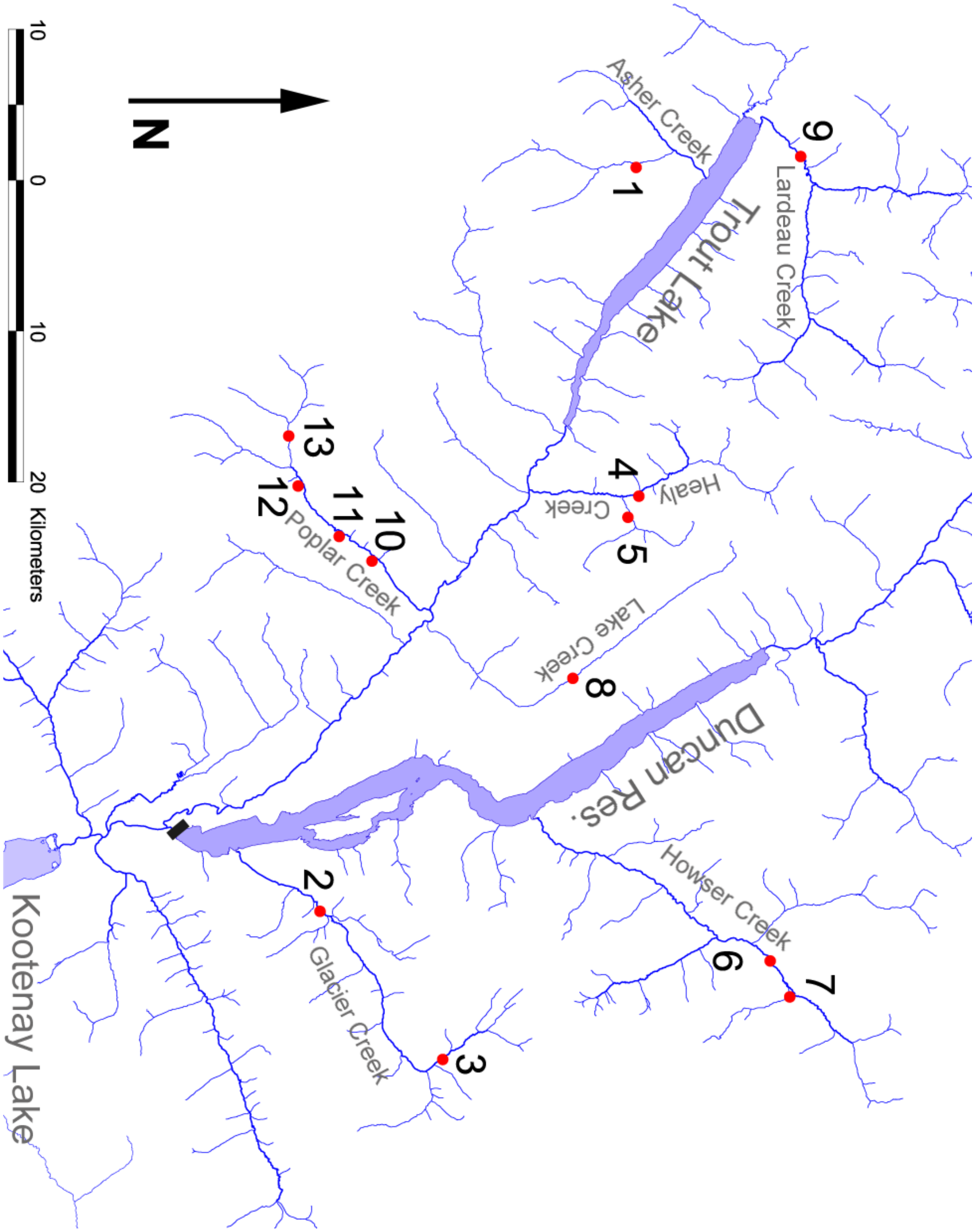

Figure 43 Electrofishing sites above migration barriers in the Duncan River System.

Table 17 Bull trout life-stages present at electrofishing sites above migration barriers in the Duncan River system.

Location	Date	Site * #	Life-stages sampled ** Fry	Juvenile	Immature	Mature
Asher Creek tributary	Sept. 1997	1	X	X	X	
Glacier Creek	Aug. 1996	2	X	X	X	X
	Sept. 1997	3	X	X	X	X
Healy Creek	Sept. 1995	4		X		
	Sept. 1997	4		X	X	
Skinner Creek (trib)	Sept. 1997	5	X	X	X	
Howser Creek	Jun. 1995	6			X	
	Jul. 1995	6	X	X	X	
Tenise Creek (trib)	Jul. 1995	7		X	X	X
	Sept. 1997	7	X	X	X	X
Lake Creek	Aug. 1996	8	X	X		X
Lardeau Creek	Sept. 1997	9	X	X		
Poplar Creek	Sept. 1995	10			X	
	Sept. 1995	10				X
	Sept. 1996	10	X	X	X	
	Sept. 1995	11	X	X	X	
	Sept. 1996	11		X	X	X
	Sept. 1996	12				X
	Sept. 1996	13				X

* site numbers correspond to site numbers in Figure 43
** Fry < 55 mm; Juvenile < 150 mm; Immature > 150 mm; Mature > 150 mm + spawning colouration and/or mature gametes

3.3. MOLECULAR

3.3.1. MITOCHONDRIAL

I resolved three unique haplotype patterns (A,B,C) in the mitochondrial ND 5/6 and Cyt. B/d-Loop regions of sampled bull trout with two of the 11 restriction enzymes used (*Hae* III and *Hin*f I; Table 18). Nine of the 11 restriction enzymes either did not cut the amplified mtDNA fragments or did not reveal RFLPs (Table 19). I found haplotype patterns dependent (Chi square $P < 0.001$, with 1000 randomizations $P < 0.001$) on sample location using the 'Monte' subroutine of the REAP software package (Roff and Bentzen 1989). All but two of the tissue samples collected from bull trout below migration barriers were haplotype A (70 of 72 samples, 96.8 %; Fig. 44). The two B haplotype bull trout from below barrier locations were located immediately below the waterfall on Poplar Creek. I found all haplotypes in bull trout sampled above migration barriers. The proportion of haplotypes A, B, and C were 55.4%, 40.5% and 4.1% respectively in above barrier samples (of 74 bull trout; Table. 19)

I estimated the evolutionary distance (Nei and Tajima 1981) among the three haplotypes found in the Duncan River system using the 'D' subroutine of the REAP software package (McElroy *et al.* 1992). Haplotype A and C showed the greatest difference (d = 0.006660, SE = 0.004743), while haplotypes A and B were more closely related (d = 0.003385, SE = 0.007829). Haplotype B and C show a evolutionary distance (d = 0.003372, SE = 0.005962) very close to that seen between Haplotype A and B.

Table 18 Number of samples digested with the eleven restriction enzymes by individually amplified mtDNA fragment.

Enzyme	Number of samples		Result	
	ND 5/6	Cyt. B/d-Loop	ND 5/6	Cyt. B/d-Loop
Ava II	23	35	--	--
Bam HI	26	13	no cut	no cut
Dpn II	22	34	--	--
Hae III	38	133	--	RFLP
Hind III	26	13	no cut	no cut
Hinf I	41	106	--	RFLP
Nci I	38	41	no cut	--
Pvu II	31	13	--	no cut
Rsa I	27	35	--	--
Sty I	20	24	--	--
Taq I	27	35	--	--

-- - similar fragment pattern in all samples
RFLP - a detected polymorphism
no cut - no restriction sites

Table 19 Mitochondrial haplotype pattern by location used in Chi square (with randomization) analysis.

	Location	Haplotype Pattern		
		A	B	C
Above migration barrier	Asher Creek	0	6	0
	Glacier Creek	0	7	3
	Healy/Skinner creeks	7	0	0
	Howser/Tenise creeks	0	11	0
	Lake Creek	12	0	0
	Lardeau Creek	5	0	0
	Poplar Creek	17	6	0
Below migration barrier	Char Creek	8	0	0
	Duncan Dam	24	0	0
	Duncan Reservoir	2	0	0
	lower Duncan River	1	0	0
	upper Duncan River	10	0	0
	Meadow Creek	1	0	0
	Poplar Creek	5	2	0
	Houston Creek	12	0	0
	Westfall River	7	0	0
	TOTALS	111	32	3

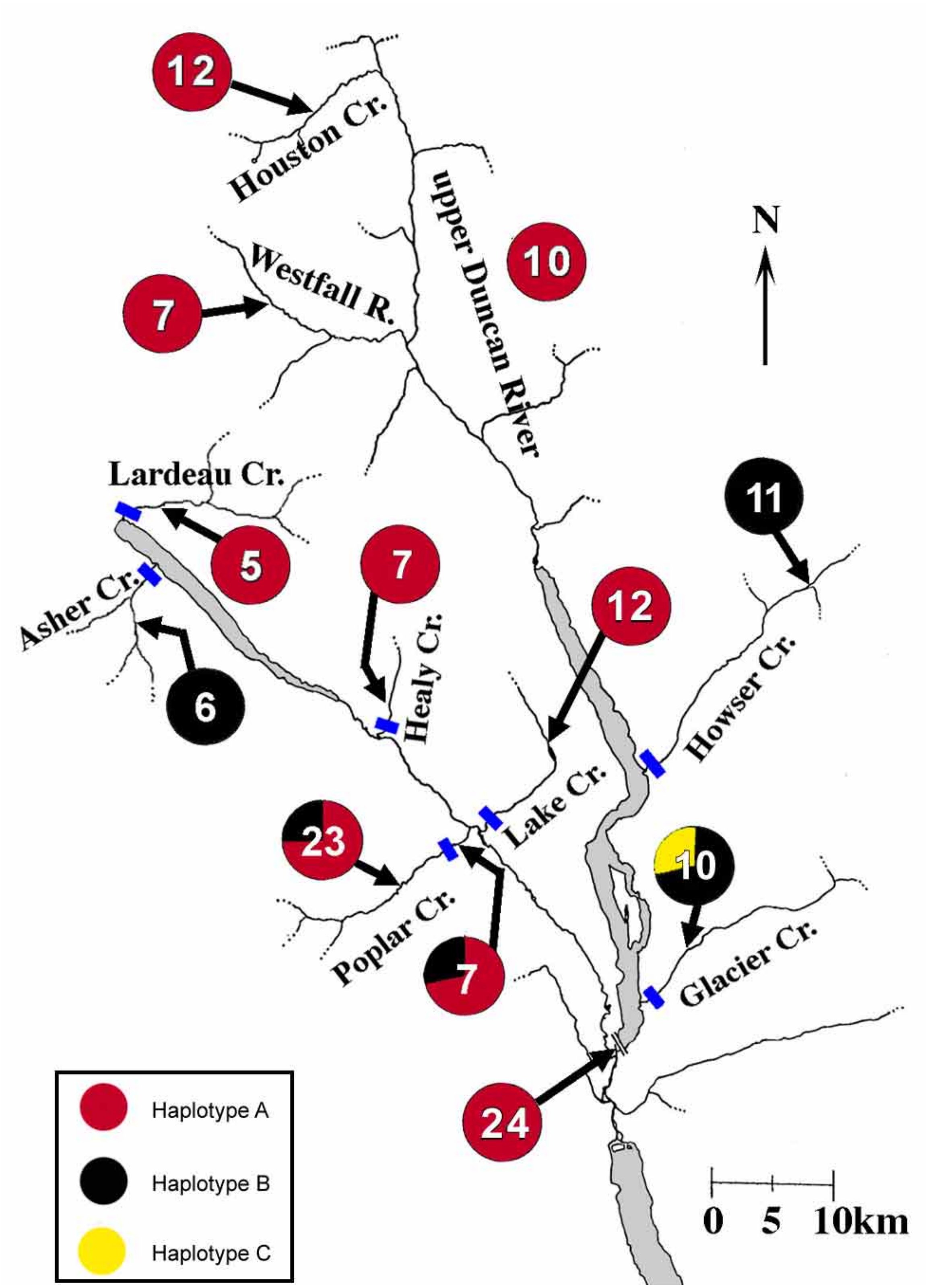

Figure 44 Location and frequency of mtDNA haplotype patterns found in the Duncan River System. Numbers indicate sample size.

3.3.2. MICROSATELLITE

I attempted to score microsatellite alleles from a total of 20 individuals from each age class from Houston Creek and Westfall River; however, some individuals were unscorable at some loci and tissue samples were only collected from seven individuals in the 2+ age class from Houston Creek. I present the number of individuals and alleles scored by loci, stream and age class in Table 20. An example of the allele frequencies by age class and stream, using the *Sco* 19 locus, is presented in Figure 45. Genetic variance over all scored loci was partitioned (the AMOVA routine of the ARLEQUIN) within each age class, among age classes within each stream, and finally between streams and is presented in Figure 46. Only the within age class variance partition was significant (*P* = 0.002 with 1023 permutations). None of the age classes within each stream was significantly different (MARKOV CHAIN DIFFERENTIATION routine of ARLEQUIN) from any other (*P* always > 0.25 with 10000 Markov chain steps). Overall estimate of Fst, grouping age classes for a complete between stream comparison (AMOVA routine of the ARLEQUIN), was 0.03352. Estimates of number of migrants between all age class groupings ranged from a low of 2.9 individuals per generation (between Houston 0+ and Houston 1+ groups) to a high of an infinite number (between Houston 2+ and Westfall 0+, Westfall 0+ and 1+, and Westfall 1+ and Westfall 2+ - Table 21)

Table 20 Microsatellite locus, sample size (N), and number of alleles (Na) scored per stream and age class.

		"Population"					
		Westfall River			Houston Creek		
Locus	Statistic	0+	1+	2+	0+	1+	2+
Omy 77	N	20	19	19	20	20	7
	Na	*3*	*3*	*2*	*3*	*3*	*3*
Sfo 18	N	20	20	20	20	20	7
	Na	*1*	*1*	*1*	*1*	*1*	*1*
Sco 1	N	20	19	20	19	20	7
	Na	*6*	*5*	*7*	*5*	*5*	*5*
Sco 2	N	19	20	18	20	18	7
	Na	*7*	*8*	*8*	*6*	*8*	*5*
Sco 19	N	20	20	18	20	20	5
	Na	*6*	*5*	*4*	*5*	*5*	*3*

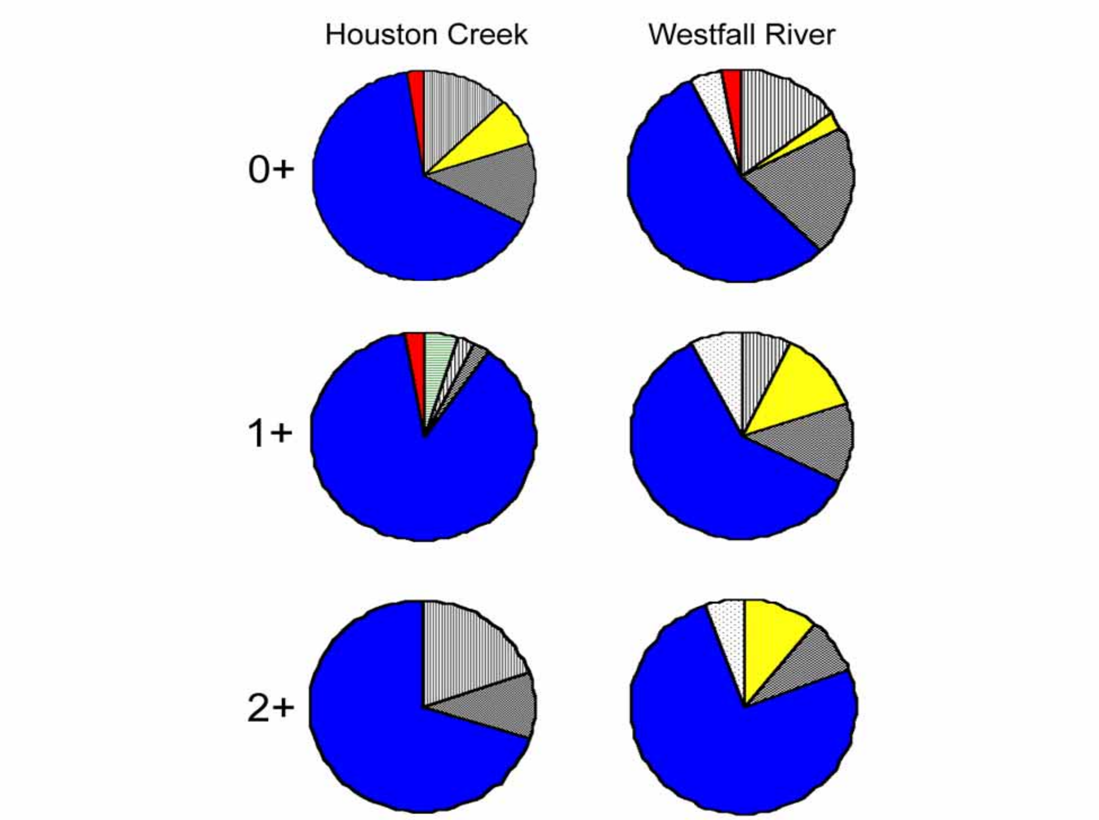

Figure 45 *Sco*19 microsatellite allele frequencies by age class and spawning stream.

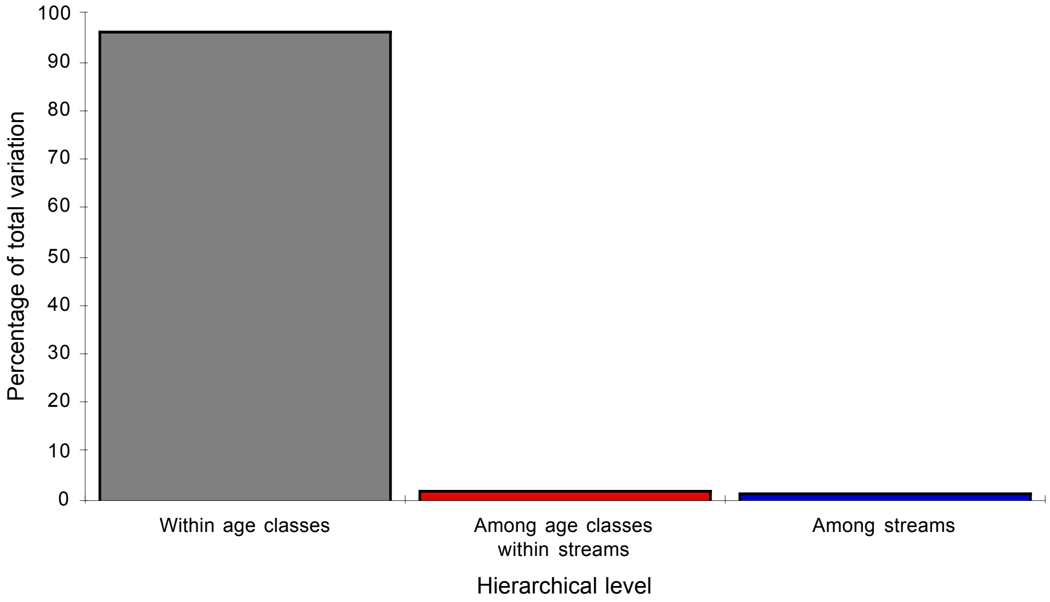

Figure 46 Hierarchical partitioning of genetic variance of five microsatellite loci from juvenile bull trout present in Houston Creek and the Westfall River.

Table 21 Estimated number of reproductive migrants per generation (Nm from Fst = 1/(4Nm + 1)) between all age class pairings in microsatellite assays (inf = an infinite number).

	Houston 0+	Houston 1+	Houston 2+	Westfall 0+	Westfall 1+
Houston 1+	2.93				
Houston 2+	800.34	8.53			
Westfall 0+	5.25	6.60	inf		
Westfall 1+	3.08	14.32	34.80	inf	
Westfall 2+	5.13	22.56	17.61	174.49	inf

3.4. TEMPERATURE AND DISCHARGE

I plotted flow data from the upper Duncan River (Fig. 47) and discharges from Duncan Dam (Fig. 48) over the duration of the project. To evaluate these data relative to long term trends, I plotted April 1 snowpack from 1968 to 1997 (Fig. 49). I also present water temperature data (Figs. 50 - 54) from five locations in the study system over the two years of intensive telemetry. To highlight differences between years of collected data, all figures present the years overlapped. To compare the environmental cues that bull trout encounter during their migration, I plotted temperature, flows, and hours of daylight in the upper Duncan River over the migration period in Figure 55. To allow direct comparisons between the relative magnitude and consistency of these cues, I have plotted each as a proportion of the maximum value during the period and included data from both years of intensive telemetry (Fig. 55).

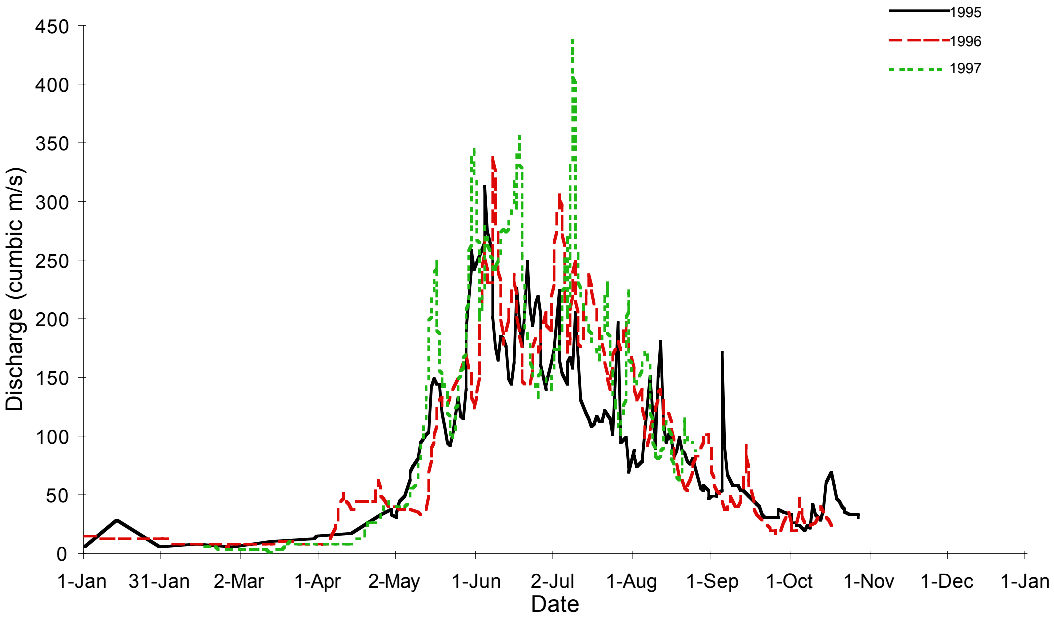

Figure 47 Upper Duncan River discharge (1995 - 1997) as collected by the BCHydro data collection platform (DCP) downstream of the East Creek confluence.

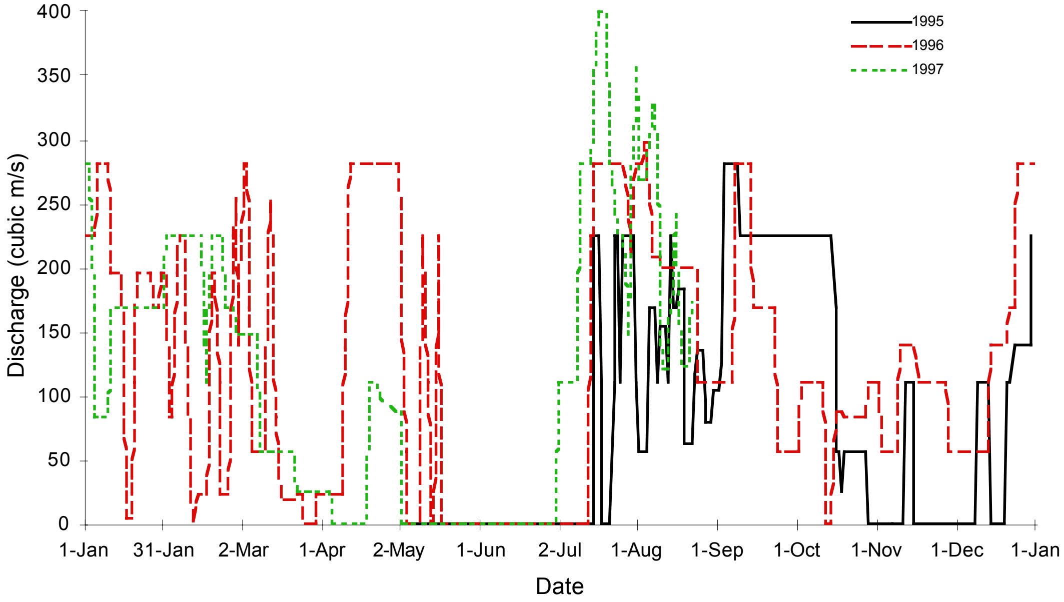

Figure 48 Duncan Dam discharge (1995 - 1997).

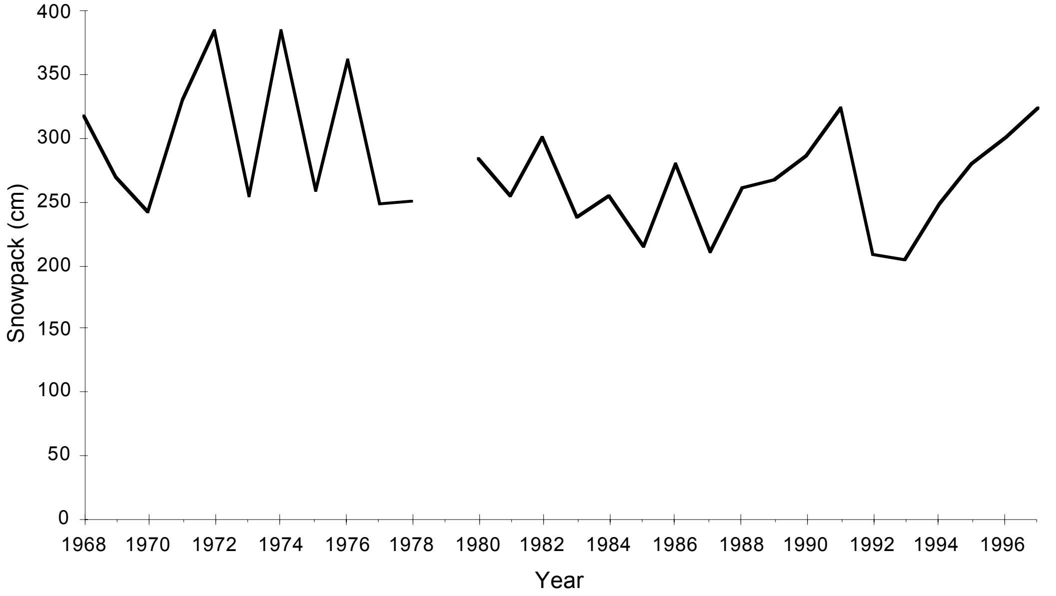

Figure 49 Snowpack trends from the upper Duncan River Valley (1968 - 1997) as measured by B.C. Ministry of Environment data collection platform 2DO9, Mt. Templeman (1880 m).

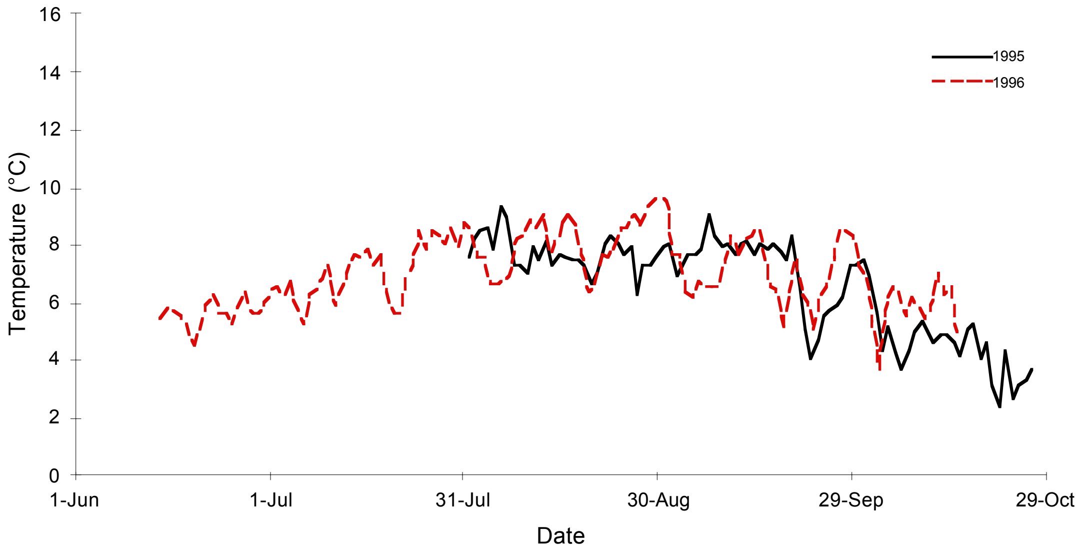

Figure 50 Upper Duncan River water temperature during bull trout migrations (1995 and 1996).

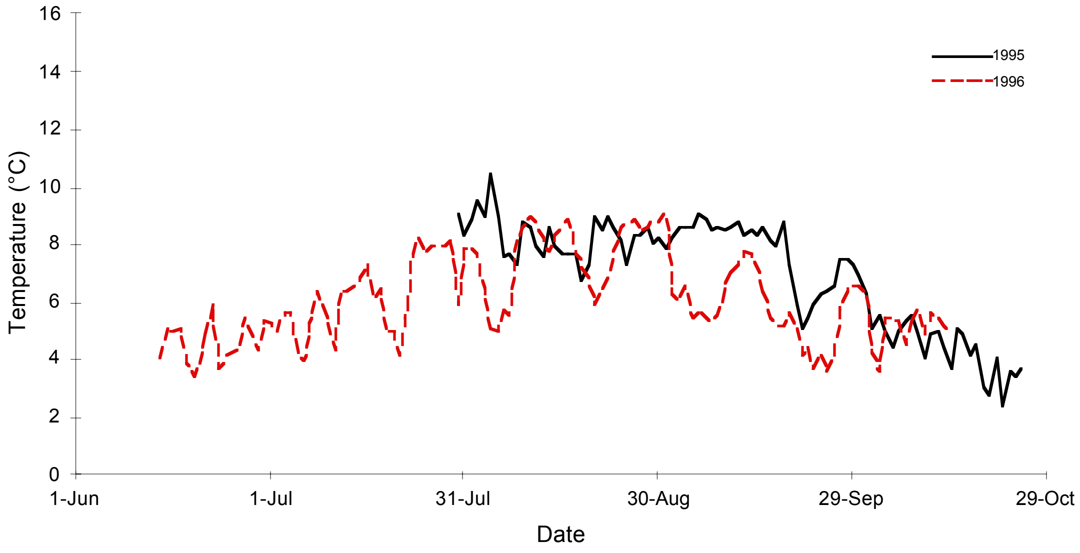

Figure 51 Westfall River water temperature during bull trout migrations (1995 and 1996).

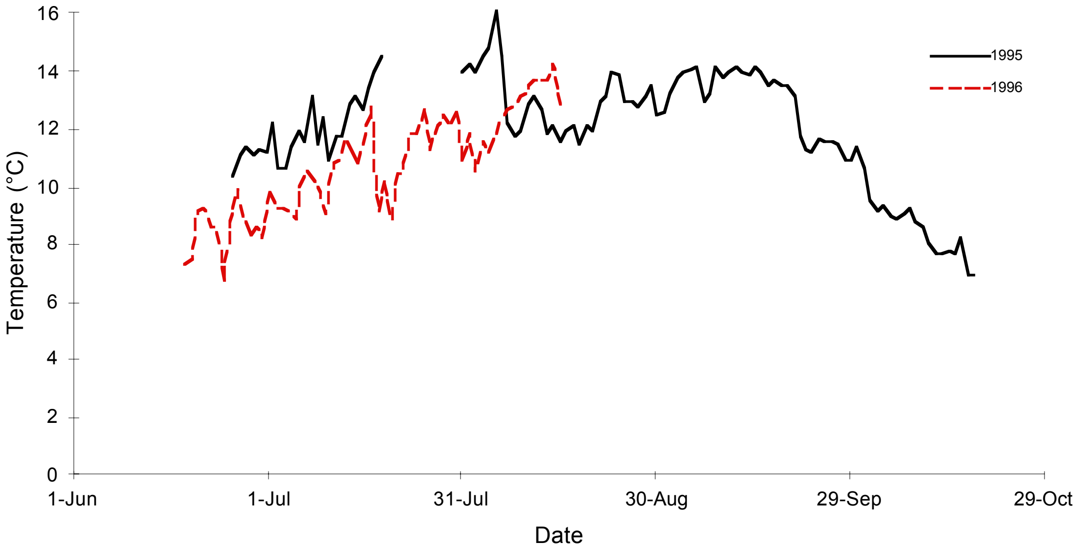

Figure 52 Lardeau River water temperature during bull trout migrations (1995 and 1996).

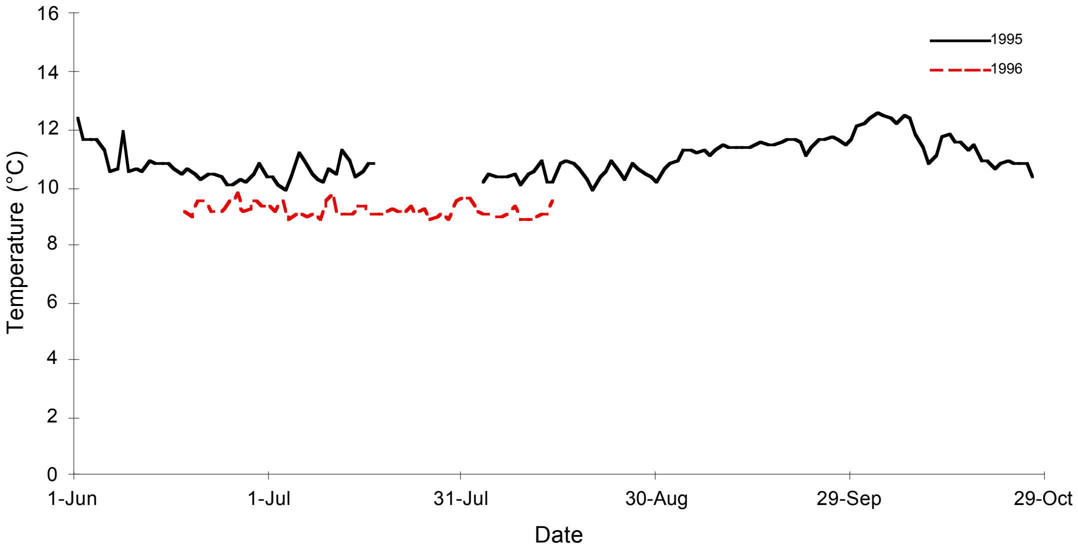

Figure 53 Duncan Dam discharge temperature during bull trout migrations (1995 and 1996).

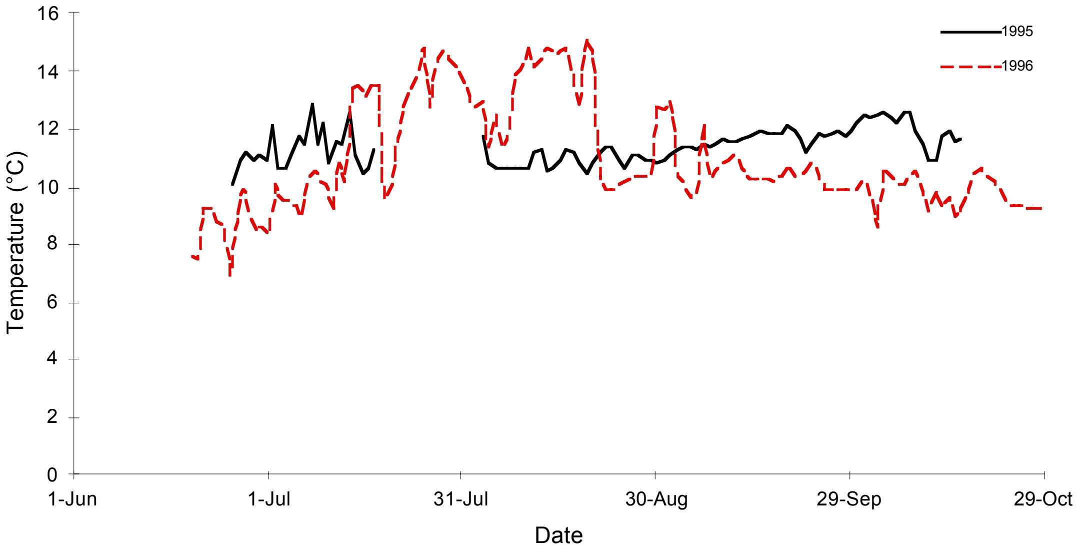

Figure 54 Lower Duncan River water temperature during bull trout migrations (1995 and 1996).

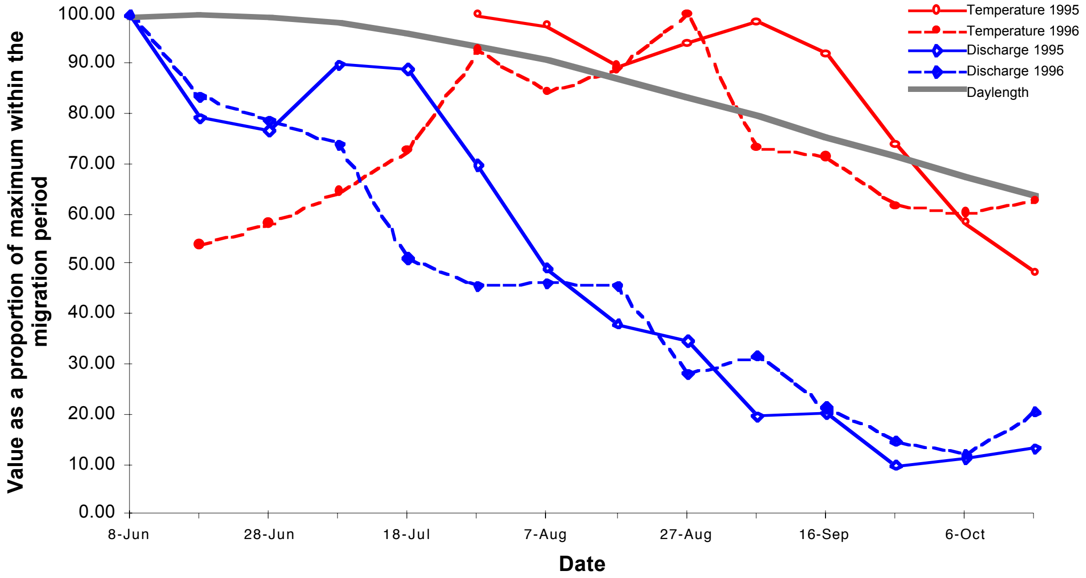

Figure 55 Temperature, discharge, and daylength in the upper Duncan River as a percentage of maximums over the migration period (1995 and 1996).

4. DISCUSSION

4.1. TELEMETRY

Overall, telemetry proved a very useful tool for quantifying movements and locating spawning sites in the Duncan River System. We selected bull trout for size and sex, and as a result, the average size of radio-tagged bull trout (691.6 ± 12.1 mm, n = 94) was larger than the average at Duncan Dam in either 1995/96 or 1997 (652.0 ± 5 mm, n = 533 and 687 ± 10.6 mm, n = 221, respectively). We still had a reasonable size range (Fig. 6) of bull trout radio-tagged for evaluation of the tributary size hypothesis (McPhail and Murray 1979); however, the effect of this size difference in making inferences from these movement data is unknown. The effect of transmitter implantation itself on movement is also unclear, although many studies have suggested that in general such procedures do not alter behavior or social interactions. (see Stasko and Pincock 1977; Martin *et al.* 1995; Swanberg 1996). In this study, we found that bull trout carrying transmitters often migrated to the extent of available habitat. We also located untagged bull trout in proximity to radio-tagged fish in all locations we examined, suggesting that their behavior was similar.

In terms of survival, our application of transmitters to bull trout was very successful. Immediate post surgery mortality was 2%, which when compared to mortality from catch and release fisheries is very low. For example, 3.8% mortality rates were documented in steelhead (*Oncorhynchus mykiss*) broodstock hook and line fisheries with a large sample size (n=5,002; Olmsted and McGregor 1998). Low water temperatures at Duncan Dam (approx. 10ºC throughout the tag application period, Fig. 53) and passive handling techniques prior to anesthesia likely played a significant role in this success. Mortality occurred at Duncan dam early in the project (Table 4), but short term complications from surgery were unlikely as we found all bull trout released at locations other than the dam to have moved subsequent to release. Our lack of consistent detection of radio-tagged individuals in deep water makes estimating longer term survival difficult. The loss of radio signal density, or attenuation, in deep water is well documented (i.e., Weeks *et al.* 1977). In this study, I believe that long term survival (beyond the functional duration of the radio-tags) was very good. For example, of 67 bull trout carrying radio-tags into the upper Duncan River System, only two suggested mortality with lack of movement (less than 3%) However, the lack of movement that suggests mortality may have been the result of tag expulsion (Marty and Summerfelt 1986).

We were able to identify many spawning locations within the Duncan River System. In 1995 and 1996, we located at least one radio-tagged bull trout in every tributary of the upper Duncan River without a barrier to migration within two kilometers of its confluence (Table 5). The two largest tributaries, Westfall River and Houston Creek, account for over half of the tagged migrants, and the overall distribution of bull trout by destination does not appear to vary over time (Table 5). Three tributaries of the lower Duncan River System (Healy, Poplar, and Hamill creeks) were also the destination of tagged bull trout.

We found that the destinations of migrant bull trout were of two basic types: the residence phase was spent either immediately below a migration barrier, or at a location not influenced by a migration barrier. The majority of radio-tagged bull trout resided at locations not influenced by migration barriers. Spawning migrations to the limit of available habitat are common in bull trout with spawning occurring in the first suitable habitat downstream of barriers (McPhail and Murry 1979; Baxter and McPhail 1995; G. Haas, *pers. comm*.; R. Olmsted, *pers. comm*.). Aerial surveys suggest that the quantity of suitable sized spawning substrate was lower at locations immediately below migration barriers than at sites not influenced by migration barriers.

I found the general pattern of bull trout migration in the Duncan River System typified by a directed immigration to a particular destination, residence of approximately one month within a short distance of that destination, and a rapid emigration relative to the time of immigration and residence. In the upper Duncan River, we tracked enough radio-tagged bull trout to look more rigorously at these movements. Comparisons of the 1995 and 1996 migration statistics show the two years to be very similar (Table 6). Time of immigration, residence, and emigration do not differ between destinations in the upper Duncan River or the year of migration (Table 6). The average bull trout immigrating to a destination in the upper Duncan River began moving upstream of the Dam on 8 July. The average bull trout arrived at its residence location on 29 August (after a 51 day immigration moving less than 2 Km/day) and remained there for 32 days until 28 September. Just over nine days later, moving close to 10 km/day, the average emigrant returns to Duncan Reservoir (8 October). Despite this predictable pattern, the comparisons highlighted some variation.

We found bull trout size varied by migratory destination but not by year (Table 6). Closer examination of the data used in calculation of the length ANOVA (Fig. 7) shows that the bull trout migrating to the Westfall River in 1995 were larger than the bull trout migrating to other tributaries that year. In 1996, no such trend was apparent. The Westfall River is the largest tributary of the upper Duncan River. This finding gives some support to the tributary size hypothesis (McPhail and Murry 1979).

As a way to summarize the movement data collected in the upper Duncan River System, I plotted average movement over ten day intervals for all tagged bull trout migrating to Houston Creek, Westfall River, and destinations in the mainstem upper Duncan River (Fig. 8). The first two panels of Figure 8 (8.a. and 8.b.) highlight the relatively scattered nature of radio-tagged bull trout early in the immigration. By the last week in July (Fig. 8.c.) immigrant bull trout have started to ascend the upper Duncan River. Progress upstream is relatively constant over the next several weeks (Fig. 8.d. to 8.g.) but proximity to residence areas appears to tighten spatial distribution of bull trout in each destination (Fig. 8.h.). By the end of September (Fig. 8.i.) early emigrants expand the spatial distribution of tagged bull trout, and by October (Fig. 8.j. and 8.k.) most emigrants have returned to the reservoir.

Bull trout migrating to destinations in the lower Duncan River system showed differences in the timing of the stages of migration when compared to upper Duncan River migrants (Table 7). The low number of radio-tagged bull trout migrating in the lower river system makes comparison qualitative, but in general we found these fish began their immigration about two to three weeks earlier. Immigration time was very similar, roughly 50 days, bringing these bull trout to their residence areas roughly three weeks earlier than the average upper Duncan River migrant. Interestingly, the start and duration of emigration remain the same, regardless of location above or below the dam, resulting in almost a doubling of the residence time for lower Duncan River migrants. Perhaps this emigration timing reflects a common spawning period in all destination streams, with radio-tagged bull trout emigrating immediately afterwards.

The large majority of radio-tagged bull trout migrating to destinations in the upper Duncan River are confirmed to have successfully passed downstream through Duncan Dam (overall 46 of 58 bull trout, ranging from 74 - 100% of migrants by year). Exceptions were fish harvested by anglers in the reservoir

(1995 only), two apparent mortalities in the upper Duncan River, and non-functional transmitters post migration. Timing of downstream emigration from the reservoir appears related to discharge from Duncan Dam. In 1995, with intermittent discharges from late mid-October to mid-December (Fig. 48), we noticed that radio-tagged bull trout became concentrated in the reservoir within 10 km of the dam. In 1996, more consistent discharges in the fall (Fig. 48) appeared to prevent concentration in the reservoir post spawning. When we were able to document emigration through the dam (Table 8), movement generally occurred with discharge higher than 100 m^3/s (Fig. 48). Based on spring time tracking locations and angling recoveries, it seems likely that all migrant bull trout successful in emigrating through the dam returned to Kootenay Lake to overwinter.

A notable telemetry result was six consecutive year repeat migrations to the upper Duncan River System by radio-tagged fish (three males and three females). The high proportion changing their residence location (Table 9) was the impetus for microsatellite assays of genetic variability within spawning tributaries in the upper Duncan System. Small numbers of reproductive individuals moving between spawning sites will tend to quickly homogenize genetic differences existing between the two (Hartl and Clark 1989; Mills and Allendorf 1996). The average size of bull trout changing residence location (685.8 mm) was smaller than the average radio-tagged bull trout (691.6 mm). Although discussed in detail later, we found no mtDNA variation in bull trout sampled from three locations in the upper Duncan River. Also, microsatellite assays of juveniles residing in Houston Creek and the Westfall River suggest that levels of gene flow between the two spawning streams is high enough to prevent strong population differentiation. These findings support the tributary size hypothesis of McPhail and Murray (1979), in that high gene flow combined with evidence of bull trout switching migratory destination indicate that some portion of bull trout change their spawning stream in the upper Duncan River over time. Also, in one of two years, the largest bull trout were located in the largest tributary. However, of the radio-tagged bull trout switching destination from year to year, none changed to a larger tributary (Table 9). In terms of tributary size hypothesis, the data collected here is equivocal; clearly additional work is needed.

Although presented under a different results heading, bull trout not having a distinct migratory movement pattern (non-migratory movements) have many similarities with the upper Duncan River migrants. The average total time tracked in a summer is roughly equivalent (approximately 77 days for non-migrants and approximately 82 days for upper Duncan River migrants). Most ‘non-migrants’ returned to Kootenay Lake, although we tracked one to an overwintering location in Trout Lake and one remained in the lower Duncan River over the winter of 1995/96 (likely a mortality). In particular, the movements specifically at Duncan Dam (Fig. 25) of ‘non-migrants’ (blue) when compared to those of migrants (red) are difficult to distinguish. Movements of ‘non-migrants’ correspond to the timing of migration shifts of upper Duncan River migrants. Bull trout in the ‘non-migrant’ category arrived at the dam on average in early July, similar to the migrants. Also, the ‘non-migrant’ bull trout generally left the base of Duncan Dam near the end of September, as migrants began to leave residence areas. These observations suggest that many of the bull trout present at Duncan Dam over the summer months attempt to ascend through the discharge structure but are unsuccessful; however, it is possible that some portion of these fish were present at the base of the dam for reasons other than ascent, such as foraging. Estimates of transfer success from radio-tagged bull trout each year of the project range from none to one-third successful (Table 11). When compared to the number confirmed to have emigrated, it is clear that decent through the discharge structure is easier for radio-tagged bull trout than ascent.

We tracked 10 bull trout in the lower Duncan River exclusively: four fish entering the river the summer following tag application, and six tagged there. Lack of movement to the dam (three of the four returning bull trout migrated to the upper Duncan drainage the previous summer) suggest these movements were not spawning related. Angling in August 1996 suggested many bull trout are present in the lower Duncan River, likely feeding on migrant kokanee (*Oncorhynchus nerka*). Additional angling effort by BCHydro in 1997 (Olmsted and den Biesen 1998) suggest bull trout densities in the lower Duncan River downstream of the dam are highest from early September to early November, corresponding to high kokanee (*O. nerka*) densities.

I used movement to the dam as a surrogate for repeat spawning attempt (Table 12). In total, 46.8 % of tagged bull trout returned to the Dam the year following their radio-tagging (29 of 62). Nine of 14 (64.3 %) came in three consecutive summers, and two of four (50 %) were present at the dam in four successive summers.

4.2. POPULATION SURVEYS

Accessing the flip bucket to capture bull trout for radio-tagging allowed us to collect biological data from a large number of adult bull trout. Table 13 summarizes the number and location of all bull trout Floy-tagged during this project.

Cumulative catch in the flip bucket at Duncan Dam (Fig. 27) shows 1995 having a very consistent and relatively high recruitment (*via* the slope of the line) of new bull trout through the sample period, with a noticeable slowdown toward the end of July. In contrast, we found a lower level of recruitment that was more evenly distributed through a longer period in 1996 (Fig. 27). There was a suggestion of increased recruitment through late June and early July in 1996 that approached the slope of the cumulative catch line in 1995 (Fig. 27). 1997 shows a step like pattern that suggests higher recruitment to the flip early to mid-June followed by a sharp rise in early July. Outside these two periods, the 1997 recruitment slope is very similar to 1996 (Fig. 27). The 1998 data, collected by BCHydro (den Biesen 1999), captured the largest number of bull trout over the summer period, with a cumulative catch pattern most similar in shape to 1997, with the highest recruitment period in late July (Fig 27). By plotting the BCHydro data in this fashion, their finding of high recruitment in the spring (mid to late May) has been ignored; however, to realistically compare these data to those collected during this project, I only plotted BCHydro data collected over a similar time period. The early spring BCHydro data (not included in Fig. 27) does demonstrate that bull trout arrive at the dam earlier than this study would suggest (den Biesen 1999).

We collected fork length, post-orbit - hypural length (POHL), standard length, and weight from a sub-sample of the bull trout we handled. Fork length averaged 652 ± 5 mm in 1995/96 and 687 ± 11 mm in 1997 (n = 533 and 221 respectively, Fig. 28). BCHydro 1998 data (den Biesen 1999) show a 665 mm average, roughly mid-way between the 1995/96 and 1997 data. Standard length and POHL were collected in order to determine if secondary sexual characteristics became apparent over each sampling season. If relative snout length increased during a summer, this would be evident in an increasing ratio between standard length and POHL. Examination of these data gave no suggestion of this expected trend, suggesting that secondary sexual characteristics, specifically snout lengthening, were not evident across our sample dates at Duncan Dam.

Scale and otolith data (Fig. 30) suggest that length at age is variable. Differences in individual growth rates can be explained by differences in life history. The age at which a particular juvenile leaves the rearing location for more productive downstream habitats, the age at first spawning, and the frequency of subsequent spawning events would certainly have large impacts on growth. The variation of length at age seen here (Fig 30), on the order of 200 to 300 mm within a single age class, is likely a result of life history variation. As well, errors in aging could explain some of this variation. Scale and otolith ages are within the same range of fork lengths, suggesting that scales allow reasonable age estimation.

The application of Floy-tags allowed for the recapture of tagged bull trout. The high rate of recapture in the flip bucket (from 23 - 28%) corroborates the radio-tag data suggesting that bull trout remain below Duncan Dam for extended periods (roughly two months on average, Fig. 25). Multiple measurements also allowed the calculation of measurement variability. By using a measuring technique that emphasized lack of handling, our measurements varied by 3.5% on average, without bias. Recaptures across years at the flip bucket (Table 15) suggests that repeat year spawning attempt (*via* simply movements to Duncan dam) ranged from 9.9 to 12.1% and alternate year attempt was 4.9%. Only 1.2% of bull trout returned to the dam in three successive years. These numbers are relatively small when compared to those for radio-tagged bull trout (Table 12); however, the number of Floy-tag returns includes only those actually recaptured in the flip bucket, whereas the radio-tag total comes from all received below the dam (may not have been recaptured in the flip bucket). Floy-tag loss (see below) may also play a role in this discrepancy. Table 15 also gives estimated growth across years. The one and two year growth estimates from bull trout tagged in 1995 (54 and 110 mm, respectively) correspond well in terms of an approximate 55 mm growth rate per year. These growth estimates also correspond with previous tagging work in the Duncan River system. Fleck (1977) calculated an approximate 50 mm growth rate per year from angler recaptures of bull trout tagged in Meadow Creek. The single year estimate for 1996 - 1997 (67 mm), is noteworthy considering the ongoing fertilization of Kootenay Lake. Unfortunately, without control data, it is impossible to attribute this higher growth to increased productivity as a result of fertilization. It is important to note that measurement error was without bias (equally likely to underestimate as overestimate length) and sample size was reasonable (Table 15) to give confidence in growth estimates.

Anglers recaptured tagged bull trout primarily from Kootenay Lake (71.3%; Table 14). Duncan reservoir recaptures account for 19.6%, Trout Lake 1.8%, and 7.1% of angled bull trout were captured from unreported locations (Table 14 and Fig. 31). Only 7.1% of angler recaptures were released. Notable recaptures were a 360 mm bull trout tagged in the tailrace of Duncan Dam that was recaptured in the Kootenay River south of Kootenay Lake (Table 12). Another was the capture of the largest bull trout tagged at the Dam (920 mm on 6 July 1995), caught in the West Arm of Kootenay Lake on 28 January 1997 at 1067 mm. Largely, these recoveries mirror the results of previous mark-recapture experiments conducted on bull trout trapped at the kokanee enumeration fence in Meadow Creek (Duncan River System) in the 1970s (Fleck 1977). The location and rough distribution of recaptures is almost identical, with Fleck (1977) reporting rare recaptures in both Trout Lake and the Kootenay River south of Kootenay Lake, with the majority occurring in Kootenay Lake. It would appear that bull trout spawning in different locations within the Duncan River System have very similar movement patterns. Angler recaptures of tagged bull trout, when previous data are included (Fleck 1977), gives the same result as radio-tagging in terms of general distribution of Duncan River bull trout throughout the Kootenay System.

Recaptures also allowed for population size estimation at Duncan Dam. The calculated average of 510 ± 170 bull trout per year via the Peterson estimate (Fig. 32) seems reasonable given the capture totals over each season (Table 13). This estimate would suggest that we were Floy-tagging roughly half the bull trout present below the dam each summer. By sampling over a larger time period (May to September), 1998 tagging (den Biesen 1999) likely marked a larger portion of the total number of bull trout present below the dam over that season. When corrected to include only first time captures, 1998 sampling captured 636 bull trout (den Biesen 1999); which is still within the confidence limits of the Peterson estimate. Unfortunately, our radio-tagging data indicate that the assumption of closure vital to the Peterson estimate (Greenwood 1996) is violated. This violation would tend to inflate estimates. To avoid the closure violation of the Peterson estimate, I also calculated estimates of population size using the open-model Jolly-Seber estimator. Numbers of bull trout calculated *via* this estimator varied significantly by year (Fig. 33). Figure 33 presents the estimates of the number of bull trout located at the dam at plotted drain dates. These estimates correspond reasonably with the cumulative captures we saw in drains (Fig. 27) in that 1995 appears to have the highest numbers at the dam during this study (from over 300 to nearly 750 bull trout - Fig. 33) and the 1996 and 1997 estimates are more linear (ranging from less than 50 to over 300 bull trout present at a given drain - Fig. 33). The Jolly-Seber estimate suggests that the largest number of bull trout were present in early July (least obvious in 1997). Jolly-Seber estimates of cumulative immigration to the dam (Fig. 34) correspond well with actual cumulative captures (Fig. 27). The 1995 and 1996 estimates suggest that the immigration to Duncan Dam was largely during the month of June, while the 1997 estimate - albeit less pronounced - shows the peak immigration in early July. Cumulative emigration estimates (Fig. 35) show very similar peaks in 1995 and 1996 (late June / early July). The 1997 estimate of cumulative emigration (Fig 35) has a similar late June rise in emigration rates, followed by a sharp peak in late July. We cannot assume that these estimates represent the number of fish transferred to the reservoir, as emigration from the system also includes bull trout leaving the area below the dam in the downstream direction.

Unfortunately, recent data collected in the Wigwam River (Kootenay System, south east British Columbia) suggests that Floy-tag loss from bull trout over multiple years sampling is common (Baxter and Westover 1999). Baxter and Westover (1999) evaluated a three-year data set and estimated single year Floy-tag loss from bull trout averaged 13.6 %. Two year Floy-tag loss averaged 35.4 %. If over two years, more than one third of bull trout we Floy-tagged had lost their marks, any inferences from these data would be very seriously biased. Population size estimates would be inflated by high mark loss rates. A secondary mark (opercular punch) was applied in 1996 to assess tag loss, but we found that rapid healing (within two to three weeks) made this mark unreliable. More surprising, Baxter and Westover (1999) found that passive integrated transponder (PIT) tags also had high loss rates from bull trout. One year PIT-tag losses averaged 10.6 %, and two year losses averaged 13.8 %. All the population estimates presented here represent within-season estimates, and as such are likely biased less seriously; however, it is important to emphasize that tag loss bias would overestimate population size. Clearly, any inferences about across year survival or repeat spawning attempt (Table 15) should be interpreted with caution.

Our estimate of the number of bull trout successful at ascending the discharge structure (*via* tagging before and recapture in the flip bucket following transfers) is approximately 50 %. Our estimates are confounded by the ability of bull trout to leave the flip bucket either through the dam (transferred upstream) or downstream back to the tailrace. The recapture of one bull trout presumed transferred in subsequent drains during the same season (1.4 %), suggests that the actual transfer rate is somewhat less than 50%.

We changed the transfer methodology over the first year of the project. The method outlined in this report represents a return to the original methodology of 'Dutchy' Wageningen (first senior operator at Duncan Dam). We consider this method the most efficient at allowing bull trout to ascend the discharge structure at Duncan Dam. Critical to the success of this method is the timing of gate changes during the transfer process. In particular, the amount of time allowed for bull trout to exit the discharge tunnel before re-establishment of the fish attracting flow is vital. Failure to allow ample time can lead mortality (observed in 1995) of bull trout remaining in the tunnel. This mortality is due to the small opening of the LLOG (< 80 mm) necessary for fish attracting flow during the summer. In contrast, bull trout emigrating through the discharge structure in the fall do so with an LLOG opening of up to 3 m.

Spawning surveys located redd sites in Houston Creek, the Westfall River, and Poplar Creek. The measured habitat variables at bull trout redds (Table 16) conform well with the range found by other researchers (summarized in Baxter and McPhail 1996). The observation of spawning below the migration barrier in Poplar Creek, where little substrate of suitable size exists, suggests that spawning was possible (if not likely) at the destinations of all radio-tagged bull trout in the upper Duncan River. The lack of evidence of spawning within the mainstem upper Duncan River at telemetry destinations is puzzling. Radio-telemetry in the Clark Fork River, USA (Swanberg 1996) found a proportion of the tagged bull trout, generally smaller individuals, migrated to areas downstream of spawning locations and did not participate in spawning. Studies have found that often a proportion of migrating char do not ripen or take part in spawning (as cited in Swanberg 1996; D McPhail, *pers. comm.*). Hypotheses concerning this migration by non-spawning fish include foraging and avoidance of seasonally unfavorable conditions (Swanberg 1996). In the upper reaches of the Duncan River system, we captured only two large adult mountain whitefish (*Prosopium williamsoni*) in all sampling, so feeding is not likely the explanation for non-spawning in this study. Perhaps the non-spawners migrate to avoid summer temperatures in shallow waters of Kootenay Lake.

The model of bull trout reaching a barrier, or impediment, to migration and spawning in the first available habitat downstream could be used as a hypothesis to describe tracked movements of bull trout below the dam. We found no evidence of spawning immediately downstream of Duncan Dam. Electrofishing (1996 and 1997) in the lower tailrace (roughly 1 km downstream of the dam) failed to locate juvenile bull trout. From radio-tagging, some bull trout moving to Duncan Dam subsequently migrate to tributaries of the lower Duncan and Lardeau rivers for spawning; perhaps this reflects the nearest available spawning habitat.

We recaptured 47 emigrant bull trout at the fish fence on Houston Creek. The emigrant bull trout captured at the fence were, on average, significantly smaller than those tagged at the dam (Fig. 36). The three largest bull trout (Fig. 36) were radio-tagged (transported and released upstream of the dam in 1996). One of the fence captures was Floy-tagged at Duncan Dam, thus confirmed to have ascended the dam in 1996. I presume that a number of the untagged fish captured at the fish fence passed upstream through the dam in 1996, but length data suggest that the majority must have migrated to Houston Creek from somewhere else. The only places these smaller, likely younger, bull trout could come from was either the Duncan Reservoir or from within the upper Duncan River. The estimate of 168 spawning bull trout in Houston Creek was made from radio-tagged fish only, avoiding the tag loss bias seen with Floy-tags. Although crude, the total estimate of 500 bull trout in the upper Duncan River seems reasonable given the year to year similarity in distribution of radio-tagged bull trout, with the assumption that non radio-tagged bull trout had a similar distribution.

Our juvenile sampling in Houston Creek and Westfall River, although primarily for collection of tissue for genetic comparisons, gives informative data on juvenile aggregations in these streams. From length frequency plots (Fig. 39, Fig. 40), three age classes (0+ to 2+) were present in these tributaries of the upper Duncan River. Sample sizes of the first two age classes were large enough to estimate mean size. In the Westfall River, 0+ (fry) bull trout averaged roughly 34 - 35 mm and 1+ fish averaged approximately 74 mm (Fig. 40). In the later Houston Creek samples (Fig. 39), fry averaged roughly 42 mm and 1+ fish 84 mm. Differences in average size likely reflect the timing of sampling, not different growth regimes in the two tributaries. Figures 37 and 38 show the distribution of sample sites in the two systems over sampling in 1996 and 1997. Our access to Houston Creek (Fig. 37) by foot is evident in the reduced spatial sampling area when compared to Westfall River (Fig. 38). The two 1996 electrofishing sites in Houston Creek (Fig. 37) highlight the importance of proximity to spawning locations in juvenile density. Site 96-1, much closer to telemetry determined residence locations, had more than 20 times the density of juvenile bull trout than site 96-2 (Fig. 37). Sampling in 1997 was more directed to locations of high juvenile density, and as such, absolute numbers of bull trout (as high as approximately 1.6 bull trout/m^2 - Figs. 41 and 42) should not be compared with 1996 electrofishing sites. In 1997 we focused effort in small side channels, near large woody debris, and in shallow stream margin areas, and did not sample other habitat.

In terms of relative densities, our 1997 data are noteworthy. In Westfall River sampling (Fig. 38), we sampled through the areas of telemetry residence, demonstrating relatively high fry densities at these and other locations of confirmed spawning. There is apparent spatial separation of fry from older juveniles throughout the Westfall River (Fig. 42). Where we found large numbers of fry we generally found fewer older juveniles. This pattern makes intuitive sense, with juveniles becoming more dispersed from spawning locations as they age; however, there may be more to the apparent habitat shift. Generally, we captured fry in the extreme margins of main channel areas. We more often captured older juveniles in wood-filled side channel areas and in small first order tributaries. A similar pattern was observed (D. McPhail and P. Mylechrist*, pers. comm.*) in the Canadian portion of the Skagit River basin (S.W. British Columbia). In the Skagit River, bull trout fry were confined to the mainstem while the age of juveniles increased with increasing distance from the mainstem within first order tributaries. In the Skagit, it would appear that as juveniles grew, they tended to reside further upstream in small tributaries. A hypothesis for these observations (P. Mylechrist, *pers. comm.*) was that older juveniles tended to vacate the mainstem near spawning areas to avoid predation by spawning adults. Spawning bull trout respond aggressively to lures, and we found a 1+ bull trout in the stomach of an adult at the 1995/96 Westfall River electrofishing site (Fig. 38). Perhaps avoidance of cannibalism is partially responsible for juvenile distribution.

The pattern of juvenile distribution in Westfall River sampling was not as apparent in Houston Creek (Fig. 41). Likely this is an artifact of the limited area covered by Houston Creek sample sites (Fig. 37) and their location downstream of primary telemetry residence areas. Like the Westfall samples, we generally captured fry in very shallow margin areas of the main channel, whereas older juveniles were most often captured in low-flow, wood-filled side channels. Often, these side channels were formed by beaver (*Castor canadiensis*) activity.

We sampled bull trout populations above migration barriers in seven drainages in the Duncan River system (Fig. 43). Asher and Lardeau creeks (both draining into Trout Lake) were the only two systems where we did not locate mature bull trout (Table 17). We sampled with electrofishing at these sites (Fig. 43), and captured no other fish species. We were able to capture bull trout with relative ease compared to most sites in Houston Creek or Westfall River, suggesting that densities in these obligatory resident populations are high. This sampling was expressly for the collection of tissue for genetic comparisons.

4.3. MOLECULAR

Mitochondrial DNA has properties that make it very useful for population differentiation studies. Occurring at about 1000 copies per somatic cell, mtDNA evolves faster than most single copy nuclear DNA (Berg and Ferris 1984), and is assumed to be selectively neutral (but see Ballard and Kreitman 1996). This faster evolution is primarily due to its maternal inheritance, which reduces the effective population size, and thus amplifies the effects of random genetic drift (causing the random loss of haplotypes from a population; Ferguson *et al*. 1995). Restriction fragment analysis allows for the indirect visualization of changes in the mtDNA sequence through the loss or gain of restriction sites. Restriction enzymes recognize a short, distinct sequence of DNA and a precise single base substitution can remove or add a recognition site. Differences in number of restriction sites, or size of restriction fragments is resolved by size fractioning the fragments using gel electrophoresis. Differences in restriction fragment gel banding pattern is indicative of sequence divergence. The extent of restriction enzyme coverage in this project was 34.6 restriction sites, which is equivalent to determining the nucleotide base sequence (sequencing) of 150 base pairs. This represents a relatively modest amount of sequence coverage (E. Taylor, *pers. comm.*).

We found the three identified haplotype patterns (A, B, and C) in very specific locations (Fig. 44). Haplotype A, the most common type, was found in all of the below barrier sample locations and in four above barrier resident populations (Table 19). Haplotype B was found in four above barrier locations as well as one below a barrier (Poplar Creek; Table 19). Haplotype C was found restricted to a single above barrier resident population in Glacier Creek (Table 19). The estimated sequence divergence (d) between haplotypes (A to C = 0.66%, A to B = 0.34%, B to C = 0.34%) is as expected for within species diversity in close geographic proximity (E. Taylor, *pers. comm.*). Recent mtDNA studies of rainbow trout (*O. mykiss*) within British Columbia estimated genetic distances, between the most different haplotypes, of 1.3 to 1.5 % (M. McCusker, *pers. comm.*). Recent broad scale bull trout mtDNA studies (Taylor *et al.* 1999) in B.C. place all three of the haplotypes found in this study within the 'interior' grouping in their coastal *vs* interior lineage split. This split likely represents genetic divergences occurring during the late Pleistocene in distinct glacial refugia prior to recolonization of the province (Taylor *et al.* 1999).

The finding of haplotype A exclusively in all locations below barriers (except below the barrier in Poplar Creek; Fig. 44) suggests: (i) that enough genetic exchange is occurring among spawning sites to prevent unique haplotypes from developing for each, or (ii) that genetic drift has yet to cause divergence (population sizes large or a short time since separation). The apparent absence of haplotype A from above barrier populations sampled in Glacier, Howser, and Asher creeks suggests that these three populations have not had recent genetic exchange with their below barrier populations. The occurrence of both A and B haplotypes above and below the migration barrier in Poplar Creek is a noteworthy result, suggesting that there either has been (or currently is) genetic exchange across the migration barrier or that genetic drift has not eliminated haplotype A above the barrier. The proportion of B haplotype individuals above and below the barrier on Poplar Creek is very similar (~ 35 to 40 %; Fig. 44). One of the B haplotype individuals below the barrier at Poplar Creek was clearly a spawning migrant (> 500 mm, mature male). The presence of the B haplotype upstream of the barrier suggests that the migrant B haplotype individual below the barrier could be returning to its natal stream (homing). Like Poplar Creek, those above barrier populations containing the A haplotype exclusively (Healy, Lake and Lardeau creeks), may currently have (or did have) genetic exchange with below barrier populations.

There are several possible explanations for the overall haplotype pattern, and all relate to the immediate post glacial recolonization of the area. The B and C haplotypes may have recolonized the area first when conditions allowed access to some locations currently above migration barriers. This initial colonization would have been followed by bull trout with the A haplotype at a time when their access to some above barrier areas was blocked. Conversely, all haplotypes may have arrived simultaneously, and it is the process of random genetic drift that has produced the pattern. Our finding of different haplotype patterns above various migration barriers (Table 19) may indicate the availability of certain streams to secondary colonization, or simply the random effects of genetic drift.

With the resolution provided by our mtDNA analyses, no evidence of population structure was found in the group of bull trout sampled at the Duncan Dam or their offspring in the upper Duncan River. With a smaller sample size (n=8), but much higher resolution, the results of Taylor *et al*. (1999) support the assertion of no mtDNA population structure in samples from Duncan Dam. The below barrier migrant bull trout as a whole appear to have little mtDNA variability (one haplotype accounting for close to 97 % of samples). Comparisons of populations existing above migration barriers found them to be relatively diverse. As suggested by the broad scale work of Taylor *et al*. (1999), and found here, the majority of bull trout genetic diversity resides within individual populations. Conservation efforts must attempt to protect as many populations in as many different geographic regions as possible (Taylor *et al.* 1999).

Microsatellite DNA analysis allows for a better resolution of fine scale genetic differentiation than mtDNA. By focusing on two tributaries in the upper Duncan River system, I attempted to evaluate the effect of the observed variability in migratory destination of radio-tagged bull trout (Table 9) on genetic structure. Despite the switching hypothesis of McPhail and Murray (1979), salmonids generally, and bull trout it particular, are thought to exhibit strong spawning site fidelity (McPhail and Taylor 1995; Baxter 1997; Swanberg 1996; Spruell *et al*. 1998). Site fidelity would give rise to high levels of genetic population structure at the spawning site level. Movement of even a small number (1 or 2 individuals per generation) of reproductive bull trout between spawning sites/streams would tend to reduce genetic differentiation between them (Hartl and Clark 1989; Mills and Allendorf 1996). If the radio-tagged bull trout observed moving between spawning sites over multiple years spawned at both locations, and this pattern was similar for non-tagged fish, we would expect little evidence of population structure to exist between sites in the upper Duncan River. By comparing Houston Creek and Westfall River, I used systems with confirmed spawning and high juvenile densities.

I was conservative when separating samples into age classes from length frequency. In Westfall River samples, bull trout < 54 mm were considered 0+, 1+ from 54 to 93 mm, and 2+ from 105 to 155 mm (Fig. 40). In Houston Creek samples, I considered fish < 60 mm 0+, from 60 to 100 mm 1+, and those > 110 mm 2+ (Fig. 39). By setting the age breaks at these lengths, I was able to avoid including samples that were difficult to clearly place in a specific age category. The apparent lack of 2+ bull trout in Houston Creek probably reflects the smaller portion of the stream sampled and lower total catch, as the relative frequency of different age classes between Houston Creek and Westfall River appears very similar (Fig. 39, Fig. 40)

All but one (*Sfo*18) of the microsatellite loci I amplified from juvenile bull trout were polymorphic (Table 20), with number of alleles ranging from one to eight (*Sco*2). Figure 45 shows the distribution of *Sco*19 alleles among all age classes by stream and shows in general, the prevalence of a single allele over all samples, from over 50% (Westfall 0+, Fig. 45) to nearly 80% (Houston 1+, Fig. 45). The allele frequency pattern evident in Figure 45 is roughly equivalent to those seen with the other loci. Generally, age class divisions within a stream had variable allele frequencies, and these were different than the comparable age class allele frequencies in the other stream. This pattern of high variance in allele frequency within age classes is evident from the AMOVA partitioning presented in Figure 46. When all loci are combined, variance in allele frequency attributable to that existing within age classes, the only significant variance partition, accounts for 96.7% of available genetic variance. Pairwise comparisons of age classes found them all to be significantly different from one another. This analysis highlights the variability that exists from year to year within each spawning stream; a particular age class in one stream is as likely to be similar to another from the same stream as it is to one from the other stream. Overall, when all age classes from Houston Creek and Westfall River are grouped by stream, the estimate of subdivision from allele frequencies (Fst) was 0.0335. This calculated Fst value roughly represents a very low level of population differentiation (Hartl and Clark 1989). For comparison, Taylor and Costello (1999) calculated Fst from bull trout sampled in the Columbia/Kootenay and the Peace region (across three separate watersheds within each region) and found mean Fst's of 0.143 and 0.189 respectively.

From pairwise Fst calculations across age classes, it is possible to estimate the number of reproductive migrants between them from the relationship: $Fst = 1/(4Nm + 1)$; where Nm equals the number of migrants (Table 21). Estimating gene flow (the number of migrants) from Fst statistics alone is tenuous at best (Bossart and Prowell 1998; Whitlock and McCauley 1999), but when combined with the telemetry evidence, these data (Table 21) suggest that migration drives the low genetic population differentiation found between Houston Creek and Westfall River bull trout.

4.4. TEMPERATURE AND DISCHARGE

Temperature data show slight variability between the two years of intensive telemetry, with water temperatures generally warmer in 1995 than 1996 (Figs. 50 to 54). Peak discharges were higher in both the upper Duncan River (Fig. 47) and Duncan Dam (Fig. 48) in 1996. It is clear from the similarity in the telemetry data over the two years that minor temperature and discharge variability have little effect on migration timing. Figure 49 suggests that 1995 and 1996 were years of high snowpack, but certainly not extreme relative to historic highs, suggesting that our telemetry findings are not overly biased by abnormal environmental conditions over the study period.

The timing of immigration to the upper Duncan River occurs during the gradual decrease in flow volume subsequent to the spring freshet (Fig 47). Spawning site residence and emigration occur as the flow volumes decrease gradually to winter lows (Fig. 47). Temperature during the immigration phase fluctuate between approximately 5.5 and 9.5 ^{o}C, whereas temperatures during the emigration are beginning a rapid drop to temperatures below 3 ^{o}C by the end of October (Fig. 50, Fig. 51).

Temperature and discharge vary between the upper and lower river, yet timing of bull trout migrations are similar in both. Temperature fluctuations below the dam (Fig. 54) are less severe than those recorded in the upper Duncan River (Fig. 50). These temperatures are moderated by the uniformly cool discharge from the dam (Fig. 53) and the warming effects of Trout Lake through the Lardeau River (Fig. 52). Discharge differences between above and below dam locations differ as well. The movement of bull trout from the lower Duncan River to Kootenay Lake occurred while the dam was discharging between 50 and 100 $m^3 \bullet s^{-1}$ in 1996 and with stable high discharge (225 $m^3 \bullet s^{-1}$) in 1995. In the upper Duncan River, emigration occurs as the flow volume stabilizes at a low flow (below 50 $m^3 \bullet s^{-1}$).

Allan (1987) found that the end of active spawning in Line Creek (Kootenay River system) was associated the water temperatures dropping below 5 ^{o}C. The timing of emigration from the upper Duncan River system, the best estimate of the end of active spawning, occurs while temperatures fall over a range that includes the 5 ^{o}C mark; however, temperature fluctuations make the designation of a specific temperature marking the end of spawning difficult.

5. CONCLUSIONS

Objective 1. Quantify migratory timing and identify key migratory and spawning habitats of bull trout captured at the dam

- Average immigration timing of bull trout, from Duncan Dam to the upper Duncan River system, is 51 days, from 8 July to 29 August.
- Once at a destination, migrant bull trout remain in the area for an average of 32 days, from 30 August to 28 September.
- Average emigration timing, from the upper Duncan River to the Duncan Reservoir, is just over 9 days, from 29 September to 8 October.
- Migratory timing remained the same with minor fluctuations in discharge and water temperature.
- Primary spawning tributaries of the upper Duncan River are Houston Creek and the Westfall River, but all tributaries of the upper Duncan River without a barrier to migration within the first two kilometers of the mainstem were the destination of at least one radio-tagged bull trout.
- The best estimate of number of bull trout migrating to the upper Duncan River is roughly 500 individuals, many of which were smaller (younger) than bull trout sampled at Duncan Dam (likely these bull trout originated from the Duncan Reservoir).
- Two-thirds of repeat migrations by radio-tagged bull trout to the upper Duncan River resulted in a change of destination of more than 10 km between years. One-third also changed their destination tributary.
- Radio-tagged bull trout also migrated to Poplar and Healy creeks, tributary to Lardeau River, and Hamill Creek, tributary to the lower Duncan River.

Objective 2. Evaluate interactions of bull trout with Duncan Dam, with the intent to modify, if necessary, dam operations to facilitate bull trout movements.

- The average number of bull trout present at the base of Duncan Dam during sampling periods (via the closed-model Peterson estimate) was 510 ± 170.
- Joly-Seber population estimates (open-model) of number of bull trout present at the base of Duncan Dam over sampling periods range from < 50 to > 750 individuals.
- Bull trout are successful at ascending (approximately 50 % of those present at the base of Duncan Dam in a given summer) and descending (approximately 80 %) the discharge structure at Duncan Dam.
- The fish transfer procedure was modified over the first year of the project to what is believed the most efficient method (detailed in section 2.2.1.1., page 12).
- Average timing of descent through the discharge structure was 23 January ± 30 days, and descent generally corresponded to high discharges (> 100 m^3/s).

Objective 3. Evaluate the contribution of hypothesized sub-populations to the bull trout interacting with Duncan Dam.

- Mitochondrial DNA analyses found genetic diversity largely restricted to resident bull trout populations existing above migration barriers. No mtDNA variation was found in bull trout sampled from below Duncan Dam or in the upper Duncan River.
- Microsatellite DNA comparisons of age structured juvenile bull trout aggregations in Houston Creek and Westfall River suggest a low level of genetic population differentiation. Nearly all of the existing genetic variance exists within individual age classes in the two streams. Reproductive migrants between the streams likely cause the observed low level of differentiation.

- Although not a direct objective of this report, the data presented here are both consistent with (lack of genetic population structure, spawning stream switching, 1995 bull trout size assortment by tributary) and contrary to (1996 lack of bull trout size assortment by tributary, bull trout switching to smaller spawning streams) the McPhail and Murray (1979) stream size hypothesis. Additional work is needed.

6. REFERENCES

Allan, J.H. 1987. Fisheries Investigations in Line Creek - 1987. Report prepared for Line Creek Resources Ltd., Sparwood, British Columbia, 67 p.

Angers, B., L. Bernatchez, A. Angers and L. Desgroseillers. 1995. Specific microsatellites loci for brook charr reveal strong population subdivision on a microgeographic scale. Journal of Fish Biology 47(Supplement A): 177 - 185

Anonymous. 1986. Annual Report to the Governments of The United States and Canada. Columbia River Treaty Permanent Engineering Board, Washington D.C. and Ottawa Ont. 49 p.

Ballard, J.W.O. and M. Kreitman. 1995. Is mitochondrial DNA a strictly neutral marker? Trends Ecol. Evol. 10: 485-488.

Baxter, J.S. 1997. Aspects of the Reproductive Ecology of Bull Trout (Salvelinus confluentus) in the Chowdae River, British Columbia. MSc. Thesis. University of British Columbia, Vancouver, B.C. 97 p.

Baxter, J.S. and J.D. McPhail. 1996. Bull trout spawning and rearing habitat requirements: summary of the literature. B.C. Ministry of Environment, Lands and Parks. Fisheries Technical Circular No. 98, 27 p.

Baxter, J.S. and B. Westover. 1999. Wigwam R. Bull Trout - HCTF Progress Report (1998). , B.C. Ministry of Environment, Lands and Parks. Fisheries Progress Report K054, VIII + 21 p. + 8 App.

Berg, W. J. and S.D. Ferris. 1984. Restriction endonuclease analysis of salmon mitochondrial DNA. Can. J. Fish. Aquat. Sci. 41: 1041-1047.

Bidgood, B.F. 1980. Field surgical procedure for implantation of radio tags in fish. Fisheries Research Report Number 20. Alberta Fish and Wildlife Division - Department of Energy and Natural Resources. Edmonton, Alberta.

Bossart, J.L. and D.P. Prowell. 1998. Genetic estimates of population structure and gene flow: limitations, lessons and new directions. TREE 13: 202-206.

Chapman, P. 1981. Where the Lardeau River Flows. Sound Heritage Series, Number 32. Provincial Archives of British Columbia - Sound and Moving Images Division.

den Biesen, D. 1999. Bull trout (*Salvelinus confluentus*) tagging program at Duncan Dam, 1998. Report prepared by: BCHydro, Kootenay Generation Area, Castlegar, B.C. Prepared for: Ministry of Environment, Lands and Parks, Nelson, B.C. 18 p.

Fleck, J.L. 1977. Summary of Dolly Varden Tagging Program Meadow Creek 1970-1976. Unnumbered technical report of the Fish and Wildlife Branch, Kootenay Region. Nelson, B.C.

Ferguson A., J.B. Taggart, P.A Prodohl, O. McMeel, C. Thompson, C. Stone, P. McGinnity, and R. A. Hiynes. 1995. The application of molecular markers to the study and conservation of fish populations, with special reference to *Salmo*. J. Fish Biol. 47A: 103-126.

Goetz, F. 1989. Biology of the Bull Trout: a Literature Review. Willamette National Forest, Oregon. 53 p.

Greenwood, J.J.D. 1996. Ecological Census Techniques. Cambridge University Press, New York. 336 p.

Hansen, M.M., E.E. Nielsen, and K-L.D. Mensberk. 1997. The problem of sampling families rather than populations: relatedness among individuals in samples of brown trout (*Salmo trutta* L.). Mol. Ecol. 6: 469-474.

Harrison, S. and A. Hastings. 1996. Genetic and evolutionary consequences of metapopulation structure. TREE 11: 180-183.

Hartl, D.L. and A.G. Clark. 1989. Principles of Population Genetics, Second Edition. Sinauer Associates, Inc. Sunderland. 682 p.

Jarne, P. and P.J.L. Lagoda. 1996. Microsatellites, from molecules to populations and back again. TREE 11: 424-429

Jones, A. 1994. Meadow Creek Cedar Ltd. Five Year Development Plan For License A30171 1994-1998.

Kristoffersen, K. and Klemetsen, A. 1991. Age determination of arctic charr (*Salvelinus alpinus*) from surface and cross section of otoliths related to otolith growth. Nordic J. Freshw. Res. 66: 98-107.

Martin, S.W., J.A. Long and T.N. Pearsons. 1995. Comparison of survival, gonad development, and growth between rainbow trout with and without surgically implanted dummy radio transmitters. N. Am. J. Fish. Man. 15: 494-498.

Marty, G.D. and R.C. Summerfelt. 1986. Pathways and mechanisms for expulsion of surgically implanted dummy transmitters from channel catfish. Trans. Am. Fish. Soc. 115: 577-589.

McLeod, C. and T. Clayton. 1993. Fish Radio Telemetry Demonstration Project - Upper Athabasca River - May to August, 1992. R.L. & L. Environmental Services Ltd. Northern River Basins Study. Edmonton, Alberta.

McElroy, D., P. Morgan, E. Bermingham, and I. Kornfield. 1992. REAP: an integrated environment for the manipulation and phylogenetic analysis of restriction data. Journal of Heredity 83: 157-158

McKinley, R.S., G. Power and H.E. Kowalyk. 1992. Transmitter attachment/implant - laboratory manual. Ontario Hydro Research - Environmental Research Department, Toronto, Ontario and University of Waterloo - Biology Department, Waterloo, Ontario. 15 p.

McPhail, J.D. and J.S. Baxter. 1995. A review of bull trout (*Salvelinus confluentus*) life-history and habitat use in relation to compensation and improvement opportunities. B.C. Ministry of Environment, Lands and Parks. Fisheries Technical Circular No. 104, 48 p.

McPhail, J.D. and C.B. Murray. 1979. The early life history and ecology of Dolly Varden (*Salvelinus malma*) in the upper Arrow Lakes. Report to BCHydro and Ministry of Environment, Fisheries Branch, 113 p.

McPhail, J.D. and E.B. Taylor. 1995. The Skagit char project. Final report to the Skagit Environmental Endowment Commission. Seattle Wa.

Morris, D.B., K. Richard and J.M. Wright. 1996. Microsatellites from rainbow trout (*Oncorhynchus mykiss*) and their use for genetic study of salmonids. Can. J. Fish. Aquat. Sci. 53: 120-126

Mills, L.S. and F.W. Allendorf. 1996. The one-migrant-per-generation rule in conservation and management. Conservation Biology 10: 1509-1518.

Nei, M. and F. Tajima. 1983. Maximum likelihood estimation of the number of nucleotide substitutions from restriction sites data. Genetics 105: 207-217.

Olmsted, W.R. and D. den Biesen. 1998. Bull Trout (*Salvelinus confluentus*) tagging program, lower Duncan River, 1997. Report prepared by: BCHydro, Kootenay Generation Area, Castlegar, B.C. Prepared for: Ministry of Environment, Lands and Parks, Nelson, B.C. 19 p. + App.

Olmsted, W.R. and I.A. McGregor. 1997. Review of Fraser River steelhead trout (*Oncorhynchus mykiss*). Draft report prepared for Fraser River Action Plan, B.C. Ministry of Environment, Lands and Parks, Department of Fisheries and Oceans.

Peterson, G.R. and I.L. Withler. 1965. Effect on fish and game species of the development of Duncan Dam for hydro-electric purposes. Management Publication 8, British Columbia Fish and Wildlife Branch. 70 p.

Roff, D.A. and P. Bentzen. 1989. The statistical analysis of mitochondrial DNA polymorphisms: χ^2 and the problem of small samples. Mol. Biol. Evol. 6: 539-545.

Schneider, S.J., M. Kueffer, D. Roessli, and L. Excoffier. 1997. ARLEQUIN version 1: an exploratory population genetics software environment. Genetics and Biometry Laboratory, University of Geneva, Switzerland.

Shafthuizen, J. 1993. Kootenay Lake Forest District Small Business Forest Enterprise Program 1993-1997. Five Year Development Plan.

Spruell, P., B. Reiman, K. Knudsen, F. Utter, and F. Allendorf. 1998. Genetic population structure within streams: microsatellite analysis of bull trout populations. Ecology of Freshw. Fish. *In Press.*

Stasko, A.B. and D.G. Pincock. 1977. Review of underwater biotelemetry, with emphasis on ultrasonic techniques. J. Fish. Res. Board Can. 34: 1261 - 1285.

Swanberg, T. 1996. The Movement and Habitat Use of Fluvial Bull Trout in the Upper Clark Fork River Drainage. MSc. Thesis, University of Montana, 61p.

Taylor, E.B., C.J. Foote and C.C. Wood. 1996. Molecular genetic evidence for parallel life-history evolution within a pacific salmon (sockeye salmon and kokanee, *Oncorhynchus nerka*). Evolution 50: 401- 416.

Taylor, E.B. and A. Costello. 1999. Microsatellite DNA polymorphism in bull trout (*Salvelinus confluentus)* from two watersheds in British Columbia: Progress Report. Prepared for the Ministry of Environment, Lands and Parks, Victoria, B.C., 27p.

Taylor, E.B., S. Pollard and D. Louie. 1999. Mitochondrial DNA variation in bull trout (*Salvelinus confluentus*) from northwestern North America: implications for zoogeography and conservation. Mol. Ecol. 8: *In Press*

Taggart, J.B., R.A. Hynes, P.A. Prodohl, and A. Ferguson. 1992. A simplified protocol for routine total DNA isolation from salmonid fishes. J. Fish Biol. 40: 963-965.

Whitlock, M.C. and D.E. McCauley. 1999. Indirect measures of gene flow and migration: Fst ≠ 1/(4Nm+1). J. Heredity 82:117-125.

Winter, J.D. 1983. Underwater Biotelemetry. in "Fisheries Techniques" eds. L.A. Nielsen and D.L. Johnson. Am. Fish. Soc. Bathesda, Maryland.

Weeks, R.W. et al. 1977. Fish tracking from the air. in "Proceedings: First International Conference on Wildlife Biotelemetry" ed. F. M. Long. International Conference on Wildlife Biotelemetry, University of Wyoming. Laramie, Wyoming. pp. 63 - 67.

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7. APPENDICES

7.1. PHOTOGRAPHIC PLATES

Plate 1. Bull trout attempting to jump the impassable waterfall on Poplar Creek.

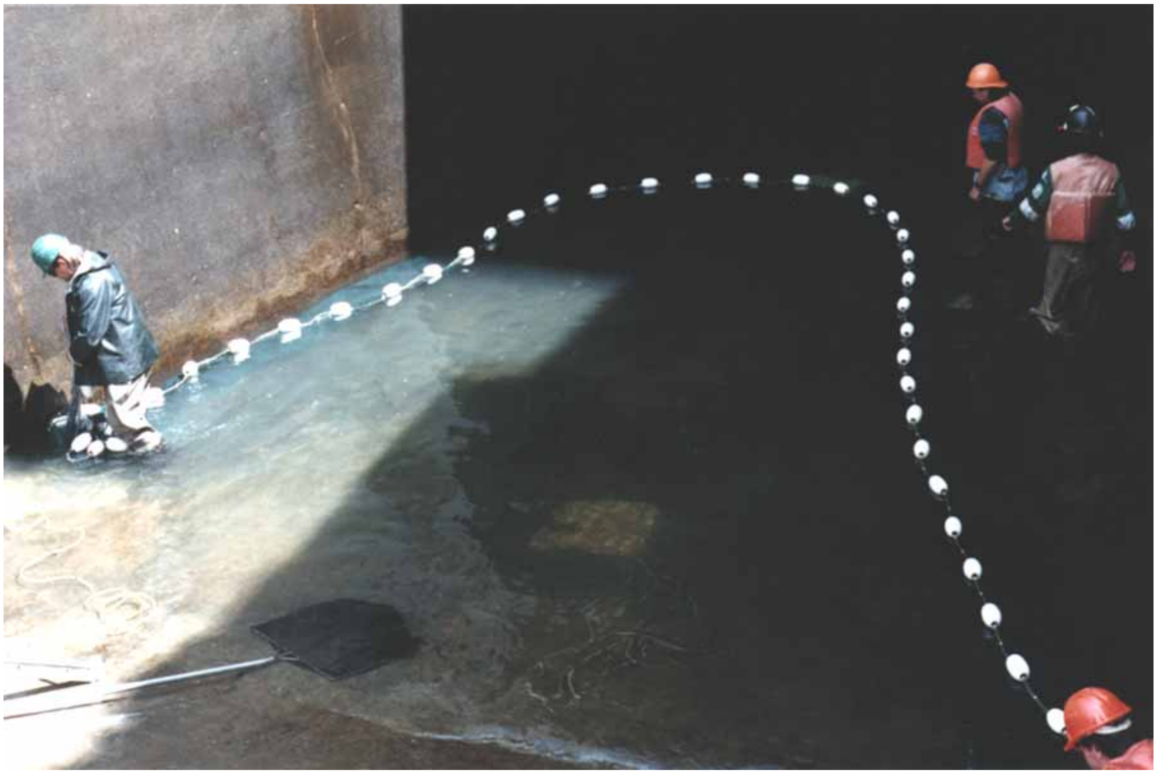

Plate 2. Crowding bull trout in the flip bucket with a seine net during a flip bucket drain

Plate 3. A large bull trout tagged in the flip bucket

Plate 4. The Floy-tagging method. Bull trout is lightly held between the legs of the kneeling tagger. The fish remains relatively calm during tagging and measuring.

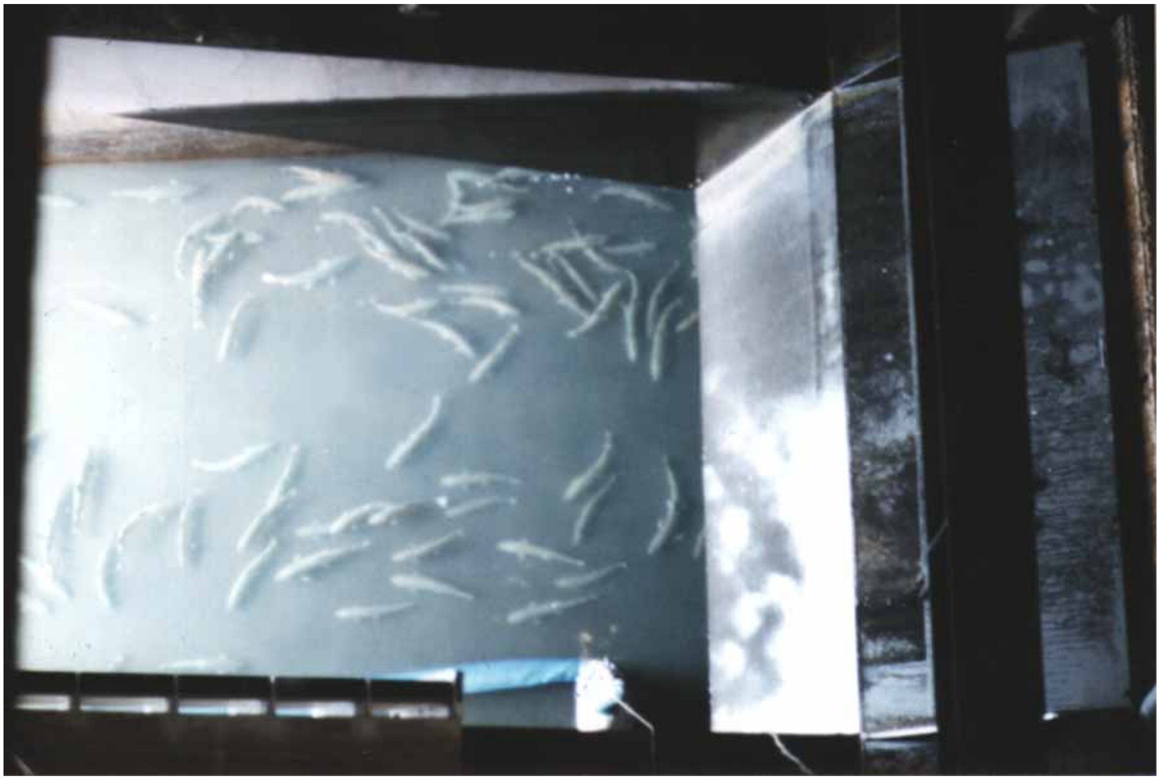

Plate 5. View from above into the drained flip bucket. Pump visible with blue hose. (courtesy D. Atagi)

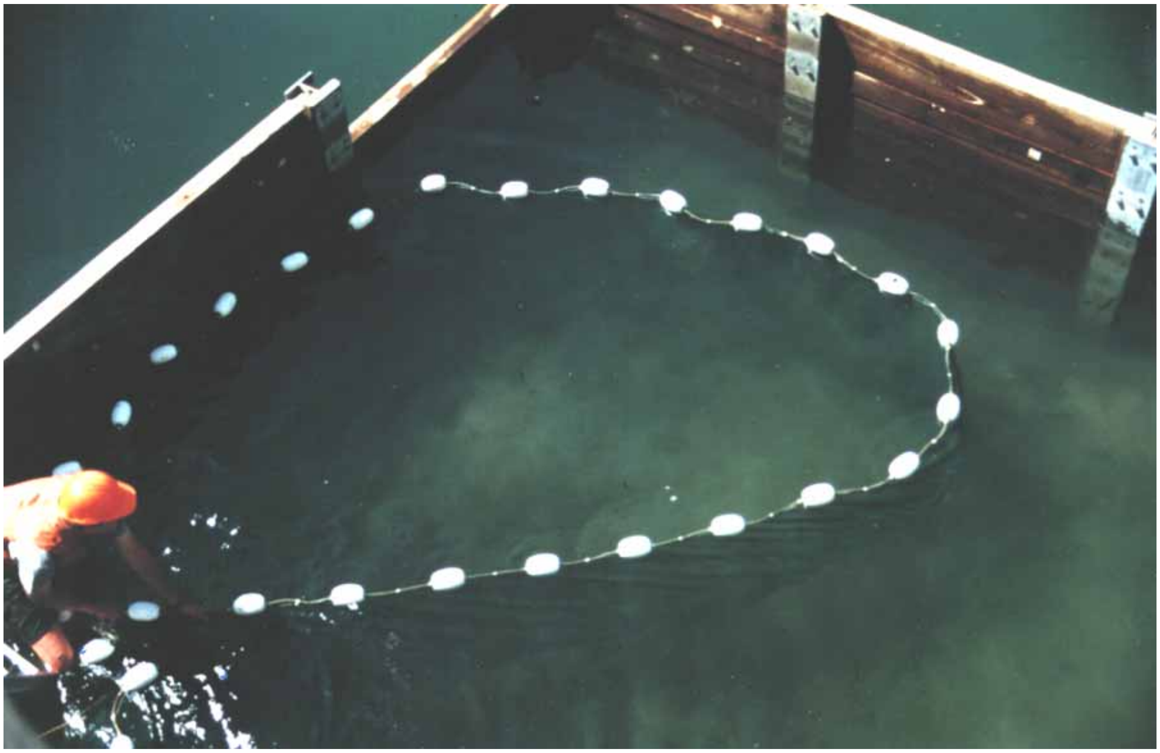

Plate 6. Crowding bull trout in the weir

Plate 7. Foot tracking in Healy Creek.

Plate 8. Cessna 172 with antenna attached.

Plate 9. Fish attracting flow from the flip bucket showing function of the fish weir.

Plate 10. The Low Level Operating Gate (LLMG) being lowered to begin a fish transfer.

Plate 11. Houston Creek juvenile sample site 96-1.

Plate 12. Houston Creek juvenile sample site 96-2.

Plate 13. Fish fence setup on Houston Creek.

Plate 14. Remains of the Houston Creek fence after a high water event.

Plate 15. A well healed surgery scar 110 days after implant.

7.2. RADIO-TAGGING DATA

Data collected from all radio-tagged bull trout is summarized.

Note: Fish # = RT in text
Ch = channel
FL units are cm
Weight (mass) units are kg

Fish #	Ch	Tag Code	Frequency	Date Tagged	Tagging - release location	Floy	FL	Weight	Sex
1	5	100	149.400	7-Jun-95	Dam - Flip	526W	59.5	1.93	F
2	5	101	149.400	7-Jun-95	Dam - Flip	528W	63.5	2.61	F
3	5	103	149.400	13-Jun-95	Dam - Flip	631W	63.0	2.75	M
4	5	104	149.400	13-Jun-95	Dam - Flip	577W	64.0	2.80	M
5	5	105	149.400	13-Jun-95	Dam - Flip	632W	63.0	2.45	M
6	5	107	149.400	13-Jun-95	Dam - Flip	547W	65.5	2.50	F
7	5	108	149.400	13-Jun-95	Dam - Flip	609W	71.0	3.60	M
8	5	109	149.400	13-Jun-95	Dam - Flip	633W	69.5	3.25	F
9	5	110	149.400	14-Jun-95	Dam - Flip	634W	78.0	5.50	M
10	5	111	149.400	14-Jun-95	Dam - Flip	637W	73.0	4.10	M
11	5	112	149.400	14-Jun-95	Dam - Flip	640W	66.0	2.95	F
12	5	113	149.400	14-Jun-95	Dam - Flip	642W	66.5	2.65	M
13	5	115	149.400	21-Jun-95	Dam - Flip	644W	73.0	4.30	F
14	5	116	149.400	21-Jun-95	Dam - Flip	645W	67.5	2.80	M
15	5	117	149.400	21-Jun-95	Dam - Flip	646W	68.0	3.10	F
16	5	118	149.400	21-Jun-95	Dam - Flip	648W	69.5	2.65	F
17	22	119	149.740	21-Jun-95	Dam - Flip	650W	71.0	3.65	M
18	22	120	149.740	22-Jun-95	Dam - Flip	750W	70.5	3.25	M
19	22	122	149.740	27-Jun-95	Dam - Flip	540W	68.0	2.25	M
20	22	123	149.740	27-Jun-95	Dam - Flip	748W	63.0	2.75	M
21	22	124	149.740	27-Jun-95	Dam - Flip	749W	71.0	3.30	M
22	22	125	149.740	28-Jun-95	Dam - Reservoir	763W	67.5	2.80	F
23	22	126	149.740	28-Jun-95	Dam - Reservoir	801W	81.0	5.45	F
24	22	127	149.740	28-Jun-95	Dam - Reservoir	802W	65.5	2.70	M
25	22	128	149.740	29-Jun-95	Dam - Reservoir	803W	74.5	4.35	F
26	22	129	149.740	29-Jun-95	Dam - Reservoir	761W	70.5	3.35	M
27	22	131	149.740	29-Jun-95	Dam - Reservoir	804W	67.0	3.20	F
28	22	133	149.740	29-Jun-95	Dam - Reservoir	812W	67.0	3.05	M
29	5	100	149.400	5-Jul-95	Dam - Reservoir	810W	78.0	4.80	M
30	22	134	149.740	5-Jul-95	Dam - Reservoir	829W	65.5	2.90	F
31	22	135	149.740	5-Jul-95	Dam - Reservoir	833W	64.0	2.90	M
32	22	136	149.740	5-Jul-95	Dam - Reservoir	520W	64.5	2.80	M
33	22	137	149.740	5-Jul-95	Dam - Reservoir	775W	68.5	3.40	M
34	31	138	150.120	13-Jul-95	Dam - Reservoir	518Y	85.0	5.90	M
35	31	141	150.120	18-Jul-95	Dam - Reservoir	520Y	72.5	3.50	M
36	31	142	150.120	18-Jul-95	Dam - Reservoir	524Y	87.5	7.60	M
37	31	143	150.120	18-Jul-95	Dam - Reservoir	525Y	65.0	2.80	F
38	31	140	150.120	19-Jul-95	Dam - Reservoir	533W	66.5	3.10	M
39	31	144	150.120	19-Jul-95	Dam - Reservoir	890W	65.5	2.90	M
40	31	145	150.120	19-Jul-95	Dam - Reservoir	554Y	69.0	3.20	F
41	31	147	150.120	19-Jul-95	Dam - Reservoir	557Y	66.5	2.80	F
42	31	148	150.120	19-Jul-95	Dam - Reservoir	691W	72.5	4.00	M
43	31	146	150.120	20-Jul-95	Dam - Reservoir	575Y	71.5	3.80	M
44	31	149	150.120	20-Jul-95	Dam - Reservoir	689W	70.0	3.40	F
45	31	150	150.120	20-Jul-95	Dam - Reservoir	675W	68.5	3.10	F
46	31	151	150.120	20-Jul-95	Dam - Reservoir	619W	68.0	2.80	F
47	5	108	149.400	27-Jul-95	Dam - Flip	703W	71.0	3.80	M
48	15	1	148.100	23-Aug-95	Upper Duncan River - same	711W	54.5	2.70	M
49	15	2	148.100	3-Sep-95	Upper Duncan River - same	712W	81.0	5.00	F
9	31	156	150.120	6-Jun-96	Dam - Flip	634W	80.5	6.20	M
50	31	152	150.120	6-Jun-96	Dam - Flip	518W	66.5	3.00	M
51	31	153	150.120	6-Jun-96	Dam - Flip	848Y	78.0	4.40	M
52	31	155	150.120	6-Jun-96	Dam - Flip	849Y	71.0	3.20	M

Fish #	Ch	Tag Code	Frequency	Date Tagged	Tagging - release location	Floy	FL	Weight	Sex
10	20	101	149.700	14-Jun-96	Dam - Reservoir	636Y	77.0	4.80	M
53	5	121	149.400	14-Jun-96	Dam - Reservoir	642Y	65.0	2.80	M
54	5	122	149.400	14-Jun-96	Dam - Reservoir	643Y	68.5	3.10	M
55	5	123	149.400	14-Jun-96	Dam - Reservoir	638Y	69.5	3.80	M
56	5	124	149.400	14-Jun-96	Dam - Reservoir	641Y	72.0	4.00	M
57	31	154	150.120	14-Jun-96	Dam - Flip	637Y	66.5	3.00	M
58	5	125	149.400	18-Jun-96	Dam - Reservoir	846Y	68.5	3.60	M
59	5	126	149.400	18-Jun-96	Dam - Reservoir	664W	69.5	3.50	F
60	5	127	149.400	18-Jun-96	Dam - Reservoir	557W	68.5	3.00	M
4	20	102	149.700	3-Jul-96	Dam - Reservoir	577W	71.5	3.30	M
61	5	128	149.400	3-Jul-96	Dam - Reservoir	815Y	67.0	2.70	M
62	5	129	149.400	3-Jul-96	Dam - Reservoir	879W	61.0	1.80	F
63	5	130	149.400	3-Jul-96	Dam - Reservoir	811Y	64.0	2.70	M
64	20	103	149.700	3-Jul-96	Dam - Reservoir	812Y	68.5	3.50	M
65	20	104	149.700	3-Jul-96	Dam - Reservoir	814Y	76.5	5.10	M
66	20	105	149.700	3-Jul-96	Dam - Reservoir	915Y	68.5	3.20	M
67	15	3	148.100	10-Jul-96	Dam - Reservoir	817Y	69.0	3.00	M
68	15	4	148.100	10-Jul-96	Dam - Reservoir	907Y	59.5	2.10	M
69	15	5	148.100	10-Jul-96	Dam - Reservoir	604W	66.0	2.40	M
70	20	106	149.700	10-Jul-96	Dam - Reservoir	921Y	73.0	3.90	M
71	20	107	149.700	10-Jul-96	Dam - Reservoir	821Y	75.5	3.50	M
72	20	108	149.700	10-Jul-96	Dam - Reservoir	819Y	80.0	4.60	M
73	20	109	149.700	10-Jul-96	Dam - Reservoir	816Y	77.0	4.40	M
74	20	110	149.700	10-Jul-96	Dam - Reservoir	818Y	75.5	3.40	M
75	15	6	148.100	15-Jul-96	Dam - Reservoir	8019Y	74.5	4.40	M
76	15	7	148.100	15-Jul-96	Dam - Reservoir	922Y	62.5	2.80	M
77	15	9	148.100	15-Jul-96	Dam - Reservoir	8017Y	69.5	3.50	F
78	15	10	148.100	15-Jul-96	Dam - Reservoir	828W	70.0	3.30	M
79	15	11	148.100	15-Jul-96	Dam - Reservoir	8036Y	67.5	2.90	M
80	15	12	148.100	15-Jul-96	Dam - Reservoir	8007Y	60.0	2.50	M
81	20	114	149.700	15-Jul-96	Dam - Reservoir	923Y	76.0	4.90	M
82	20	115	149.700	15-Jul-96	Dam - Reservoir	611Y	78.0	5.40	M
83	5	131	149.400	7-Aug-96	Tailrace - Tailrace	672W	68.0	3.50	M
84	5	132	149.400	7-Aug-96	Tailrace - Tailrace	950Y	73.5	4.30	M
85	5	133	149.400	7-Aug-96	Tailrace - Tailrace	944Y	72.5	4.20	M
20	20	111	149.700	14-Aug-96	Dam - Reservoir	748W	72.0	4.20	M
35	5	134	149.400	14-Aug-96	Dam - Reservoir	520Y	75.5	4.00	M
39	20	112	149.700	14-Aug-96	Dam - Reservoir	822Y	69.5	3.40	M
86	20	113	149.700	14-Aug-96	Dam - Flip	8053Y	73.0	4.20	M
87	5	135	149.400	27-Aug-96	Hamill Creek - Same	8099Y	63.5	3.60	M
88	15	13	148.100	27-Aug-96	Hamill Creek - Same	8100Y	59.5	3.00	M
89	15	17	148.100	27-Aug-96	Hamill Creek - Same	8084Y	59.5	2.70	M
90	15	19	148.100	27-Aug-96	Hamill Creek - Same	824Y	65.0	3.90	M
91	15	20	148.100	5-Sep-96	Hamill Creek - Same	952Y	54.5	2.30	M
92	15	21	148.100	5-Sep-96	Hamill Creek - Same	953Y	56.0	2.10	M

7.3. MIGRATION DATA

The migration statistics of all bull trout migrating to the upper Duncan River (used in 2 way ANOVA analysis) is summarized.

Note: Imm = immigration
Res = residence
Em = emigration
Rate units are km•day^{-1}
Time units are days

Tag #	Start im	Imm time	Imm rate	Im/res	Res time	Res/em	Em rate	Em time	End em	Res mark	Em end mark	Em dist.	Em time	Dest
26	17-Jun	61.00	1.64	17-Aug	51.00	7-Oct	8.08	12.00	19-Oct	100	3	97	12.00	1
27	29-Jun	67.00	1.49	4-Sep	8.00	12-Sep	6.94	9.00	21-Sep	100	37.5	62.5	9.00	1
28	29-Jun	52.00	1.92	20-Aug	34.00	23-Sep	5.00	20.00	13-Oct	100	0	100	20.00	1
29	5-Jul	51.00	1.96	25-Aug	37.00	1-Oct	5.11	19.00	20-Oct	100	3	97	19.00	1
31	4-Jul	55.00	1.82	28-Aug	34.00	1-Oct	6.47	15.00	16-Oct	100	3	97	15.00	1
34	13-Jul	55.00	1.82	6-Sep	28.00	4-Oct	24.00	2.00	6-Oct	100	52	48	2.00	1
38	18-Jul	42.00	2.38	29-Aug	36.00	4-Oct	26.25	2.00	6-Oct	100	47.5	52.5	2.00	1
43	20-Jul	36.00	2.78	25-Aug	37.00	1-Oct	11.50	5.00	6-Oct	100	42.5	57.5	5.00	1
21	14-Jun	61	1.639	14-Aug	44	27-Sep	5.350	10	7-Oct	100	46.5	53.5	10	1
55	14-Jun	61	1.639	14-Aug	47	30-Sep	7.643	7	7-Oct	100	46.5	53.5	7	1
56	15-Jul	30	3.333	14-Aug	57	10-Oct	53.500	1	11-Oct	100	46.5	53.5	1	1
59	15-Jul	38	2.632	22-Aug	36	27-Sep	4.864	11	8-Oct	100	46.5	53.5	11	1
62	15-Jul	38	2.500	22-Aug	43	4-Oct	12.125	4	8-Oct	95	46.5	48.5	4	1
64	10-Jul	45	2.222	24-Aug	32	25-Sep	3.821	14	9-Oct	100	46.5	53.5	14	1
67	10-Jul	47	2.128	26-Aug	32	27-Sep	4.458	12	9-Oct	100	46.5	53.5	12	1
68	10-Jul	47	2.128	26-Aug						100				1
71	10-Jul	55	1.818	3-Sep	23	26-Sep	4.458	12	8-Oct	100	46.5	53.5	12	1
73	3-Jul	62	1.613	3-Sep	28	1-Oct	13.375	4	5-Oct	100	46.5	53.5	4	1
75	15-Jul	50	2.000	3-Sep						100				1
76	3-Jul	71	1.408	12-Sep	13	25-Sep	5.944	9	4-Oct	100	46.5	53.5	9	1
80	18-Jun	87	1.149	13-Sep						100				1
81	7-Jun	102	0.980	17-Sep						100				1
22	28-Jun	67.00	1.12	3-Sep	24.00	27-Sep	19.00	2.00	29-Sep	75	37	38	2.00	2
23	28-Jun	71.00	1.06	7-Sep	23.00	30-Sep	12.50	4.00	4-Oct	75	25	50	4.00	2
25	29-Jun	47.00	1.60	15-Aug	53.00	7-Oct	11.17	6.00	13-Oct	75	8	67	6.00	2
33	5-Jul	30.00	2.50	4-Aug	54.00	27-Sep	6.82	11.00	8-Oct	75	0	75	11.00	2
36	18-Jul	57.00	1.21	13-Sep	30.00	13-Oct	8.83	3.00	16-Oct	69	42.5	26.5	3.00	2
49	3-Sep	27.00	0.46	30-Sep	8.00	8-Oct	14.40	5.00	13-Oct	75	3	72	5.00	2
10	14-Jun	70	1.071	23-Aug	36	28-Sep	3.167	9	7-Oct	75	46.5	28.5	9	2
20	14-Aug	32	2.344	15-Sep	31	16-Oct	28.500	1	17-Oct	75	46.5	28.5	1	2
57	14-Jun	74	1.014	27-Aug						75				2
61	3-Jul	44	1.705	16-Aug	42	27-Sep	3.167	9	6-Oct	75	46.5	28.5	9	2
65	3-Jul	63	1.190	4-Sep	25	29-Sep	3.167	9	8-Oct	75	46.5	28.5	9	2
72	10-Jul	46	1.630	25-Aug	30	24-Sep	2.375	12	6-Oct	75	46.5	28.5	12	2

Tag #	Start im	Imm time	Imm rate	Im/res	Res time	Res/em	Em rate	Em time	End em	Res mark	Em end mark	Em dist.	Em time	Dest
74	10-Jul	62	1.113	10-Sep	29	9-Oct	11.250	2	11-Oct	69	46.5	22.5	2	2
77	15-Jul	31	2.419	15-Aug						75				2
78	15-Jul	59	1.271	12-Sep						75				2
79	15-Jul	36	2.083	20-Aug	36	25-Sep	7.125	4	29-Sep	75	46.5	28.5	4	2
24	27-Jun	68.00	1.25	3-Sep	32.00	5-Oct	0.74	51.00	25-Nov	85	47.5	37.5	51.00	3b
30	2-Jul	56.00	1.52	27-Aug	31.00	27-Sep	4.21	19.00	16-Oct	85	5	80	19.00	3b
37	18-Jul	44.00	1.70	31-Aug						75		75		3d
39	19-Jul	47.00	2.02	4-Sep	26.00	30-Sep	18.25	4.00	4-Oct	95	22	73	4.00	3a
40	19-Jul	52.00	1.63	9-Sep	21.00	30-Sep	1.53	19.00	19-Oct	85	56	29	19.00	3b
41	19-Jul	31.00	2.42	19-Aug	46.00	4-Oct	32.50	1.00	5-Oct	75	42.5	32.5	1.00	3d
42	19-Jul	32.00	2.66	20-Aug	45.00	4-Oct	3.64	22.00	26-Oct	85	5	80	22.00	3b
44	20-Jul	33.00	2.88	22-Aug	32.00	23-Sep	4.77	11.00	4-Oct	95	42.5	52.5	11.00	3a
46	20-Jul	31.00	2.58	20-Aug	20.00	9-Sep	6.25	6.00	15-Sep	80	42.5	37.5	6.00	3c
30	7-Aug	37	2.622	13-Sep						95				3a
39	14-Aug	30	2.833	13-Sep	13	26-Sep	3.500	11	7-Oct	85	46.5	38.5	11	3b
40	14-Aug	27	3.148	10-Sep	16	26-Sep	1.925	20	16-Oct	85	46.5	38.5	20	3b
58	18-Jun	58	1.672	15-Aug	42	26-Sep	4.208	12	8-Oct	95	46.5	50.5	12	3a
60	18-Jun	60	1.000	17-Aug	39	25-Sep	1.929	7	2-Oct	60	46.5	13.5	7	3e
66	3-Jul	52	1.635	24-Aug						85				3c
69	10-Jul	44	2.205	23-Aug	15	7-Sep	2.196	23	30-Sep	95	46.5	50.5	23	3a
32	5-Jul	60.00	1.00	3-Sep	31.00	4-Oct	17.50	1.00	5-Oct	60	42.5	17.5	1.00	4
35	18-Jul	62.00	1.13	18-Sep	11.00	29-Sep	5.50	5.00	4-Oct	70	42.5	27.5	5.00	4
45	20-Jul	47.00	1.28	5-Sep	25.00	30-Sep	9.50	4.00	4-Oct	60	22	38	4.00	4
4	3-Jul	34	1.765	6-Aug	53	28-Sep	1.688	8	6-Oct	60	46.5	13.5	8	4
22	12-Jul	35	1.857	16-Aug	40	25-Sep	2.056	9	4-Oct	65	46.5	18.5	9	4
35	14-Aug	20	3.900	3-Sep	23	26-Sep	2.625	12	8-Oct	78	46.5	31.5	12	4
51	6-Jun	90	0.667	4-Sep	20	24-Sep	0.900	15	9-Oct	60	46.5	13.5	15	4
53	14-Jun	86	0.698	8-Sep	13	21-Sep				60				4
54	14-Jun	70	0.857	23-Aug	47	9-Oct	1.929	7	16-Oct	60	46.5	13.5	7	4

7.4. FLOY-TAGGING DATA

In 1995, Floy-tags were labeled ‘BC ENVIRONMENT NELSON C000###’ and were either white or yellow. The numbering of the white Floy-tags ranged from ‘C000500’ to ‘C000900’; yellow tags from ‘C000500 to C000605’. The length of the coloured portion of both tag colours used in 1995 was 30 mm. In 1996 and 1997, we used yellow tags identical to those in 1995 (C000606 - C000695) as well as different yellow tags (coloured portion 40 mm, ‘333 VICTORIA ST. NELSON, BC   MIN. OF ENV ####’) with numbering ranging from 8001 to 8300.

All Floy-tags applied over the three years of the project are summarized.

Note: all length units (FL, SL, POHL) are cm
Weight (mass) units are kg

Tag #	Colour	Date Tagged	Location Tagged	FL	SL	POHL	Weight	Sex	Radio tag #
501	W	31-May-95	Weir	57.5				F	
502	W	31-May-95	Weir	60.5				M	
503	W	31-May-95	Weir					F	
504	W	31-May-95	Weir	72.5				F	
505	W	31-May-95	Weir	66.0				F	
506	W	31-May-95	Weir	52.0				M	
507	W	31-May-95	Weir	49.5				M	
508	W	31-May-95	Weir	71.0				F	
509	W	31-May-95	Weir	64.5				M	
510	W	31-May-95	Weir	72.5				M	
511	W	31-May-95	Weir	64.0				F	
512	W	31-May-95	Weir	70.0				F	
513	W	31-May-95	Weir	72.5				F	
514	W	31-May-95	Weir	71.0				F	
515	W	31-May-95	Weir	74.0				F	
516	W	31-May-95	Weir	62.0				M	
517	W	1-Jun-95	Weir	62.0					
518	W	6-Jun-96	Flip	66.5	60.0	53.5	3.00	M	50
519	W	1-Jun-95	Weir	72.0				F	
520	W	1-Jun-95	Weir	65.0					
521	W	7-Jun-95	Weir	63.5			2.4	F	
522	W	7-Jun-95	Weir	64.5			2.6	F	
523	W	7-Jun-95	Weir	63.5			2.7	F	
524	W	7-Jun-95	Weir	66.0			3.1	F	
527	W	7-Jun-95	Weir	74.5			4.2	F	
528	W	7-Jun-95	Weir	63.5			2.4	F	2
529	W	8-Jun-95	Flip						
530	W	8-Jun-95	Flip						
531	W	8-Jun-95	Flip						
532	W	8-Jun-95	Flip						
533	W	8-Jun-95	Flip						
534	W	8-Jun-95	Flip						
535	W	8-Jun-95	Flip						
536	W	8-Jun-95	Flip						
537	W	8-Jun-95	Flip					M	
538	W	8-Jun-95	Flip						
539	W	8-Jun-95	Flip						
540	W	8-Jun-95	Flip	68	60.5	55.5	2.1	M	19
542	W	8-Jun-95	Flip	53.5					
543	W	8-Jun-95	Flip	56.5					
544	W	8-Jun-95	Flip	74.0					
545	W	8-Jun-95	Flip	73.0					
546	W	8-Jun-95	Flip	67.3					
547	W	8-Jun-95	Flip	64.5			2.3	F	6
548	W	8-Jun-95	Flip	68.0					
549	W	8-Jun-95	Flip	65.5					
550	W	8-Jun-95	Flip	77.0					
551	W	8-Jun-95	Flip	65.0					
552	W	8-Jun-95	Flip	65.5					
553	W	8-Jun-95	Flip	72.5					
554	W	8-Jun-95	Flip	67.0					
555	W	8-Jun-95	Flip	81.0			4.5	F	
556	W	8-Jun-95	Flip	63.0	57.0	52.0	1.9	F	
557	W	18-Jun-96	Flip	68.5	63.0	56.0	3.00	M	60
558	W	8-Jun-95	Flip	53.0					
559	W	8-Jun-95	Flip	50.0					
560	W	8-Jun-95	Flip	64.5					
561	W	8-Jun-95	Flip	58.0					
562	W	8-Jun-95	Flip	72.0					
563	W	8-Jun-95	Flip	80.0					
564	W	8-Jun-95	Flip	82.5					
565	W	8-Jun-95	Flip	58.5					
566	W	8-Jun-95	Flip	66.0					
567	W	8-Jun-95	Flip	67.0					
568	W	8-Jun-95	Flip	69.0					
569	W	8-Jun-95	Flip	73.0					
570	W	8-Jun-95	Flip	58.0					
571	W	8-Jun-95	Flip	59.0					

Tag #	Colour	Date Tagged	Location Tagged	FL	SL	POHL	Weight	Sex	Radio tag #
572	W	8-Jun-95	Flip	72.5					
573	W	8-Jun-95	Flip	66.0					
574	W	8-Jun-95	Flip	75.0				M	
575	W	8-Jun-95	Flip	58.0				F	
576	W	8-Jun-95	Flip	77.0				M	
577	W	8-Jun-95	Flip	67.0			2.6	F	4
578	W	8-Jun-95	Flip	69.0					
580	W	8-Jun-95	Flip	62.0				M	
582	W	8-Jun-95	Flip	77.0				F	
583	W	8-Jun-95	Flip	74.0				M	
584	W	8-Jun-95	Flip	74.5					
585	W	8-Jun-95	Flip	64.0					
586	W	8-Jun-95	Flip	65.0					
587	W	8-Jun-95	Flip	55.5			1.6		
588	W	8-Jun-95	Flip	66.0					
589	W	8-Jun-95	Flip	68.0					
590	W	8-Jun-95	Flip	76.0					
591	W	8-Jun-95	Flip	59.0					
592	W	8-Jun-95	Flip	59.5					
593	W	8-Jun-95	Flip	65.5					
594	W	8-Jun-95	Flip	69.0					
595	W	8-Jun-95	Flip	70.5					
596	W	8-Jun-95	Flip	60.0					
597	W	8-Jun-95	Flip	65.0					
598	W	8-Jun-95	Flip	73.5					
599	W	8-Jun-95	Flip	72.0					
600	W	8-Jun-95	Flip	62.0					
601	W	8-Jun-95	Flip	77.0			4.8	?	
602	W	8-Jun-95	Flip	63.5					
603	W	8-Jun-95	Flip	61.5			2.2	F	
604	W	10-Jul-96	Flip	66.0	60.0	53.5	2.40	F	69
606	W	8-Jun-95	Flip	55.0					
607	W	8-Jun-95	Flip	70.0					
608	W	8-Jun-95	Flip	65.5					
610	W	8-Jun-95	Flip	60.0					
611	W	8-Jun-95	Flip	67.0				M	
612	W	8-Jun-95	Flip	66.5			3.1	F	
613	W	8-Jun-95	Flip	61.0					
614	W	8-Jun-95	Flip	57.5					
615	W	8-Jun-95	Flip	67.5					
616	W	8-Jun-95	Flip	61.0					
617	W	8-Jun-95	Flip	65.0					
618	W	8-Jun-95	Flip	69.0					
619	W	8-Jun-95	Flip	64.0					
620	W	8-Jun-95	Flip	72.0					
621	W	8-Jun-95	Flip	62.0					
622	W	8-Jun-95	Flip	75.0					
623	W	8-Jun-95	Flip	74.0					
624	W	8-Jun-95	Flip	67.0					
625	W	8-Jun-95	Flip	59.0			2.0	F	
626	W	8-Jun-95	Flip	64.0					
627	W	8-Jun-95	Flip	65.0					
628	W	8-Jun-95	Flip	62.0					
629	W	8-Jun-95	Flip	62.0					
630	W	8-Jun-95	Flip	62.5					
631	W	13-Jun-95	Wier	63.0			2.5	M	3
632	W	13-Jun-95	Wier	63.0			2.2		5
633	W	13-Jun-95	Wier	69.5			3.0	F	8
634	W	6-Jun-96	Flip	80.5	73.5	66.5	6.20	M	9
635	W	14-Jun-95	Wier	62.5			2.1	F	
636	W	14-Jun-95	Wier	69.0			2.7	F	
637	W	14-Jun-95	Wier	73.0		57.0	3.8	M	10
638	W	14-Jun-95	Wier	65.5			2.5	F	24
639	W	14-Jun-95	Wier	62.0			2.3	F	
640	W	14-Jun-95	Wier	66.0		53.5	2.7	M	11
641	W	14-Jun-95	Wier	60.5			2.0	F	
642	W	14-Jun-95	Wier	66.5		54.5	2.4	M	12

Tag #	Colour	Date Tagged	Location Tagged	FL	SL	POHL	Weight	Sex	Radio tag #
643	W	14-Jun-95	Wier					M	
644	W	21-Jun-95	Wier	73.0	65.5	59.5	3.9	F	13
645	W	21-Jun-95	Wier	67.5	60.5	55.5	2.6	M	14
646	W	21-Jun-95	Wier	68.0	60.5	55.0	2.8	F	15
647	W	21-Jun-95	Wier	66.5	60.5	55.0	2.4	M	
648	W	21-Jun-95	Wier	69.5	63.5	58.5	2.4	F	16
649	W	21-Jun-95	Wier	71.0	64.0	58.0	3.3	M	17
651	W	22-Jun-95	Flip	59.5					
653	W	22-Jun-95	Flip	85.5				M	
654	W	22-Jun-95	Flip	86.5					
655	W	22-Jun-95	Flip	72.0					
656	W	22-Jun-95	Flip	73.0					
657	W	22-Jun-95	Flip	61.0					
658	W	22-Jun-95	Flip	61.5					
659	W	22-Jun-95	Flip	56.0					
660	W	22-Jun-95	Flip	74.5					
661	W	22-Jun-95	Flip	79.0					
662	W	22-Jun-95	Flip	62.0					
663	W	22-Jun-95	Flip	58.0					
664	W	18-Jun-96	Flip	69.5	65.0	56.0	3.50	M	59
665	W	22-Jun-95	Flip	75.0					
666	W	22-Jun-95	Flip						
667	W	22-Jun-95	Flip	59.0					
668	W	22-Jun-95	Flip	62.0					
669	W	22-Jun-95	Flip	71.0					
670	W	22-Jun-95	Flip	66.0					
671	W	22-Jun-95	Flip	76.0					
672	W	7-Aug-96	Pond	68.0	61.5	55.0	3.50	M	83
673	W	22-Jun-95	Flip	68.0					
674	W	22-Jun-95	Flip	61.0					
675	W	22-Jun-95	Flip	71.0					
676	W	22-Jun-95	Flip	56.0					
677	W	22-Jun-95	Flip	73.0					
678	W	22-Jun-95	Flip	65.5					
679	W	22-Jun-95	Flip	65.0					
680	W	22-Jun-95	Flip	64.5					
681	W	22-Jun-95	Flip	64.0					
682	W	22-Jun-95	Flip	64.0					
683	W	22-Jun-95	Flip	58.5					
684	W	22-Jun-95	Flip	59.0					
685	W	22-Jun-95	Flip	57.0					
686	W	22-Jun-95	Flip	73.5					
687	W	22-Jun-95	Flip	57.0					
688	W	22-Jun-95	Flip	73.5					
689	W	22-Jun-95	Flip	69.0					
690	W	22-Jun-95	Flip	64.5					
691	W	22-Jun-95	Flip	72.0					
692	W	22-Jun-95	Flip	72.5					
693	W	22-Jun-95	Flip	78.5					
694	W	22-Jun-95	Flip	63.0					
695	W	22-Jun-95	Flip	75.0					
696	W	22-Jun-95	Flip	72.0					
697	W	22-Jun-95	Flip	61.0					
698	W	22-Jun-95	Flip						
699	W	22-Jun-95	Flip	74.5					
700	W	22-Jun-95	Flip	77.5	69.5	62.0	4.3		
701	W	27-Jul-95	Flip	61.0					
702	W	27-Jul-95	Flip	55.0					
703	W	27-Jul-95	Flip	71.0	64.5	58.0	3.8	M	7
704	W	27-Jul-95	Flip	64.0					
705	W	27-Jul-95	Flip	69.0					
706	W	27-Jul-95	Flip	71.0					
708	W	22-Aug-95	Mouth of upper Duncan (MUD)	50.5					
709	W	22-Aug-95	MUD	45.5					
710	W	23-Aug-95	MUD	45.0					
711	W	23-Aug-95	MUD	54.5	50.5	45.0	2.7	F	48
712	W	3-Sep-95	64.5K on the Duncan FS Road	81.0	73.5	64.5	5.0	F	49

Tag #	Colour	Date Tagged	Location Tagged	FL	SL	POHL	Weight	Sex	Radio tag #
713	W	20-Sep-95	Tail - Bottom end	54.5				M	
714	W	20-Sep-95	Tail - Bottom end	57.5					
715	W	20-Sep-95	Above Hamil Creek (I. Duncan)	57.0					
717	W	24-Sep-95	Meadow Cr. above enumeration fence	~50					
718	W	24-Sep-95	Meadow Cr. above enumeration fence	~60					
719	W	24-Sep-95	Meadow Cr. above enumeration fence	~65					
720	W	24-Sep-95	Meadow Cr. GILLED on enumeration fence	~45					
721	W	24-Sep-95	Meadow Cr. GILLED on enumeration fence	~55					
722	W	25-Sep-95	Meadow Cr. below enumeration fence	~45					
723	W	27-Sep-95	Poplar Cr. - below barrier	59.0				M	
724	W	27-Sep-95	Poplar Cr. - below barrier	68.5				M	
725	W	27-Sep-95	Meadow Cr. below enumeration fence	70.5				M	
726	W	22-Jun-95	Flip	63.5					
727	W	22-Jun-95	Flip	64.5					
728	W	22-Jun-95	Flip	75.0					
729	W	22-Jun-95	Flip	55.0					
730	W	22-Jun-95	Flip	68.5					
731	W	22-Jun-95	Flip	66.0					
732	W	22-Jun-95	Flip	69.0					
733	W	22-Jun-95	Flip	59.0					
734	W	22-Jun-95	Flip	64.0					
735	W	22-Jun-95	Flip	54.5					
736	W	22-Jun-95	Flip	78.0					
737	W	22-Jun-95	Flip	63.5					
738	W	22-Jun-95	Flip	58.0					
739	W	22-Jun-95	Flip	59.0					
740	W	22-Jun-95	Flip	57.0					
741	W	22-Jun-95	Flip	62.0					
742	W	22-Jun-95	Flip	57.0					
743	W	22-Jun-95	Flip	61.5					
744	W	22-Jun-95	Flip	60.5					
745	W	22-Jun-95	Flip	61.5					
746	W	22-Jun-95	Flip	66.5					
747	W	22-Jun-95	Flip	63.5					
748	W	27-Jun-95	Wier	63.0	58.5	50.5	2.5	M	20
749	W	27-Jun-95	Wier	71.0	63.0	57.0	3.0	M	21
750	W	22-Jun-95	Flip	70.5	61.5	58.0	3.0	M	18
751	W	22-Jun-95	Flip	74.0					
752	W	22-Jun-95	Flip	60.0					
753	W	22-Jun-95	Flip	66.0					
754	W	22-Jun-95	Flip	76.0					
755	W	22-Jun-95	Flip	65.0					
756	W	22-Jun-95	Flip	66.0					
757	W	22-Jun-95	Flip	52.0					
758	W	22-Jun-95	Flip	66.0					
759	W	22-Jun-95	Flip	63.0					
760	W	22-Jun-95	Flip	67.0					
761	W	22-Jun-95	Flip	70.5	63.5	56.5	3.1	M	26
762	W	22-Jun-95	Flip	62.0					
763	W	22-Jun-95	Flip	67.5	61.0	55.5	2.6	M	22
764	W	22-Jun-95	Flip	64.0					
765	W	22-Jun-95	Flip	69.0					
766	W	22-Jun-95	Flip	61.5					
767	W	22-Jun-95	Flip	77.0				M	
768	W	22-Jun-95	Flip	75.5					
769	W	22-Jun-95	Flip	66.0					
770	W	22-Jun-95	Flip	72.5					
771	W	22-Jun-95	Flip	69.5					
772	W	22-Jun-95	Flip	63.5					
774	W	22-Jun-95	Flip	71.5					
775	W	22-Jun-95	Flip	68.5					
776	W	6-Jul-95	Flip	86.0					
777	W	6-Jul-95	Flip	65.5					
778	W	6-Jul-95	Flip	54.5					
779	W	6-Jul-95	Flip	74.5					
780	W	6-Jul-95	Flip	74.0					
781	W	6-Jul-95	Flip	83.0					

Tag #	Colour	Date Tagged	Location Tagged	FL	SL	POHL	Weight	Sex	Radio tag #
782	W	6-Jul-95	Flip	72.5					
783	W	6-Jul-95	Flip	73.0					
784	W	6-Jul-95	Flip	76.0					
785	W	6-Jul-95	Flip	75.5					
786	W	6-Jul-95	Flip	-					
787	W	6-Jul-95	Flip	56.5					
788	W	6-Jul-95	Flip	62.0					
789	W	6-Jul-95	Flip	53.0					
790	W	6-Jul-95	Flip	66.0					
791	W	6-Jul-95	Flip	83.5					
792	W	6-Jul-95	Flip	58.0					
793	W	6-Jul-95	Flip	56.0					
794	W	6-Jul-95	Flip	63.9					
795	W	6-Jul-95	Flip	70.5					
796	W	6-Jul-95	Flip	55.5					
797	W	6-Jul-95	Flip	63.5					
798	W	6-Jul-95	Flip	54.5					
799	W	6-Jul-95	Flip	62.5					
800	W	6-Jul-95	Flip	68.9					
801	W	28-Jun-95	Weir	81.0	73.0	67.0	5.0	M	23
802	W	28-Jun-95	Weir	65.5			2.5	F	24
803	W	29-Jun-95	Weir	74.5	67.5	61.5	4.0	M	25
804	W	29-Jun-95	Weir	70.5	61.5	56.0	2.9	M	27
805	W	29-Jun-95	Pond	58.0	52.0	48.0	1.5	F	
806	W	29-Jun-95	Pond						
807	W	29-Jun-95	Pond						
808	W	29-Jun-95	Pond						
809	W	29-Jun-95	Pond						
810	W	5-Jul-95	Weir	78.0	71.0	64.0	4.8	M	29
811	W	29-Jun-95	Pond						
812	W	29-Jun-95	Pond	67.0	60.0	54.0	2.7	M	28
813	W	29-Jun-95	Pond	58.5	52.0	47.0	1.7	M	
814	W	2-Jul-95	Pond	44.0					
815	W	2-Jul-95	Pond	30.0	approx only				
816	W	2-Jul-95	Pond	79.0					
817	W	2-Jul-95	Pond	55.0					
818	W	2-Jul-95	Pond	48.0					
819	W	2-Jul-95	Pond	49.5					
820	W	2-Jul-95	Pond	50.0	approx only				
821	W	2-Jul-95	Pond	36.5					
822	W	2-Jul-95	Pond	59.0					
823	W	3-Jul-95	Pond	60.0					
824	W	3-Jul-95	Pond	62.0					
825	W	3-Jul-95	Pond	36.0					
826	W	3-Jul-95	Pond	61.0					
827	W	3-Jul-95	Pond	76.0					
828	W	5-Jul-95	Weir	51.5	47.0	41.5	1.2	-	
829	W	5-Jul-95	Weir	65.5	59.5	54.0	2.9	F	30
830	W	5-Jul-95	Weir	61.5	56.0	50.5	2.2	F	
831	W	5-Jul-95	Weir	57.5	52.5	48.0	1.8	F	
832	W	5-Jul-95	Weir	61.5	55.5	50.5	2.4	M	
833	W	5-Jul-95	Weir	64.0	58.0	57.5	2.9	M	31
834	W	5-Jul-95	Weir	55.5	49.5	45.0	1.6	F	
835	W	6-Jul-95	Weir	64.5					
836	W	6-Jul-95	Weir	61.5					
837	W	6-Jul-95	Weir	64.0					
838	W	6-Jul-95	Weir	62.5					
839	W	6-Jul-95	Weir	66.0					
840	W	6-Jul-95	Weir	57.0					
841	W	6-Jul-95	Weir	63.5					
842	W	6-Jul-95	Weir	65.5					
843	W	6-Jul-95	Weir	60.5					
844	W	6-Jul-95	Flip	54.0					
845	W	6-Jul-95	Flip	67.0					
846	W	6-Jul-95	Flip	66.0					
847	W	6-Jul-95	Flip	69.0					
848	W	6-Jul-95	Flip	74.5					

Tag #	Colour	Date Tagged	Location Tagged	FL	SL	POHL	Weight	Sex	Radio tag #
849	W	6-Jul-95	Flip	57.5					
850	W	6-Jul-95	Flip	64.5					
851	W	6-Jul-95	Flip	92.0			9.7		
852	W	6-Jul-95	Flip	81.5					
853	W	6-Jul-95	Flip	62.0					
854	W	6-Jul-95	Flip	76.0					
855	W	6-Jul-95	Flip	69.0					
856	W	6-Jul-95	Flip	82.5					
857	W	6-Jul-95	Flip	62.0					
858	W	6-Jul-95	Flip	61.0					
859	W	6-Jul-95	Flip	65.5					
860	W	6-Jul-95	Flip	64.0					
861	W	6-Jul-95	Flip	61.0					
862	W	6-Jul-95	Flip	63.0					
863	W	6-Jul-95	Flip	52.0					
864	W	6-Jul-95	Flip	63.5					
865	W	6-Jul-95	Flip	54.5					
866	W	6-Jul-95	Flip	75.0					
867	W	6-Jul-95	Flip	80.0					
868	W	6-Jul-95	Flip	61.5					
869	W	6-Jul-95	Flip	68.0					
870	W	6-Jul-95	Flip	60.0					
871	W	6-Jul-95	Flip	68.5					
872	W	6-Jul-95	Flip	-					
873	W	6-Jul-95	Flip	61.0					
874	W	6-Jul-95	Flip	60.0					
875	W	6-Jul-95	Flip	61.0					
877	W	6-Jul-95	Flip	78.0					
878	W	6-Jul-95	Flip	84.0					
879	W	3-Jul-96	Flip	61.0	56.0	51.0	1.80	F	62
880	W	6-Jul-95	Flip	69.5					
881	W	6-Jul-95	Flip	72.0					
882	W	6-Jul-95	Flip	53.5					
883	W	6-Jul-95	Flip	61.0					
884	W	6-Jul-95	Flip	66.0					
885	W	6-Jul-95	Flip	60.0					
886	W	6-Jul-95	Flip	67.0					
887	W	6-Jul-95	Flip	65.5					
888	W	6-Jul-95	Flip	57.5					
889	W	6-Jul-95	Flip	60.0					
890	W	6-Jul-95	Flip	67.0					
891	W	6-Jul-95	Flip	59.0					
892	W	6-Jul-95	Flip	54.5					
893	W	6-Jul-95	Flip	66.5					
894	W	6-Jul-95	Flip	58.5					
895	W	6-Jul-95	Flip	67.0					
896	W	6-Jul-95	Flip	59.5					
897	W	6-Jul-95	Flip	56.5					
898	W	6-Jul-95	Flip						
899	W	6-Jul-95	Flip	53.0					
900	W	6-Jul-95	Flip	55.0					
501	Y	6-Jul-95	Flip	61.5					
502	Y	6-Jul-95	Flip	70.0					
503	Y	6-Jul-95	Flip	67.5					
504	Y	6-Jul-95	Flip	64.5					
505	Y	6-Jul-95	Flip	55.0					
506	Y	6-Jul-95	Flip	58.0					
507	Y	6-Jul-95	Flip	56.5					
508	Y	6-Jul-95	Flip	56.0					
509	Y	6-Jul-95	Flip	54.5					
510	Y	6-Jul-95	Flip	52.5					
511	Y	6-Jul-95	Flip	73.0					
512	Y	6-Jul-95	Flip	54.0					
513	Y	6-Jul-95	Flip	57.0					
514	Y	6-Jul-95	Flip	54.5					
515	Y	12-Jul-95	pond	34.0					
516	Y	13-Jul-95	weir	62.5	57.0	51.5	2.2	F	

Tag #	Colour	Date Tagged	Location Tagged	FL	SL	POHL	Weight	Sex	Radio tag #
517	Y	13-Jul-95	weir	57.5	52.0	48.5	1.7	F	
518	Y	13-Jul-95	weir	85.0	77.0	69.0	5.9	M	34
519	Y	18-Jul-95	wier	58.0	53.0	49.0	1.6	M	
520	Y	18-Jul-95	Weir	72.5	66.0	59.0	3.5	M	35
522	Y	5-Jun-96	Pond	67.3					
523	Y	5-Jun-96	Pond	58.0					
524	Y	18-Jul-95	Weir	87.5	78.0	68.0	7.6	M	36
525	Y	18-Jul-95	Weir	65.0	59.0	54.0	2.8	F	37
527	Y	19-Jul-95	flip	66.0					
528	Y	19-Jul-95	flip	67.0					
529	Y	19-Jul-95	flip	66.0					
530	Y	19-Jul-95	flip	63.0					
531	Y	19-Jul-95	flip	83.0					
532	Y	19-Jul-95	flip	56.0					
533	Y	19-Jul-95	flip	73.0					
534	Y	19-Jul-95	flip	61.0					
535	Y	19-Jul-95	flip	64.5					
536	Y	19-Jul-95	flip	63.0					
537	Y	19-Jul-95	flip	57.0					
538	Y	19-Jul-95	flip	47.0					
539	Y	19-Jul-95	flip	63.5					
540	Y	19-Jul-95	flip	65.5					
541	Y	19-Jul-95	flip	64.0					
542	Y	19-Jul-95	flip	66.0					
543	Y	19-Jul-95	flip	61.0					
544	Y	19-Jul-95	flip	60.5					
545	Y	19-Jul-95	flip	61.5					
546	Y	20-Jul-95	wier	58.5	53.0	47.0	1.7		
547	Y	20-Jul-95	wier	62.5	56.5	51.5		F	
548	Y	20-Jul-95	wier	57.5					
549	Y	20-Jul-95	wier	60.0					
550	Y	26-Jul-95	wier	58.5					
551	Y	19-Jul-95	wier	51.5	46.5	41.5	1.1	?	
552	Y	19-Jul-95	wier	52.0	46.5	42.0	1.4	M	
553	Y	19-Jul-95	wier	58.5	53.5	48.5	1.8	M	
554	Y	19-Jul-95	Weir	69.0	63.0	57.5	3.2	?	40
555	Y	19-Jul-95	wier	62.5	56.5	52.5	2.2	M	
556	Y	20-Jul-95	wier	68.5	62.0	56.5	3.2	M	
557	Y	19-Jul-95	Weir	66.5	60.5	56.0	2.8	F	41
558	Y	19-Jul-95	flip	69.5					
559	Y	19-Jul-95	flip	59.0					
560	Y	19-Jul-95	flip	60.0					
561	Y	19-Jul-95	flip	75.5					
562	Y	19-Jul-95	flip	70.5					
563	Y	19-Jul-95	flip	55.0					
564	Y	19-Jul-95	flip	72.5					
565	Y	19-Jul-95	flip	75.5					
566	Y	19-Jul-95	flip	67.5					
567	Y	19-Jul-95	flip	54.0					
568	Y	19-Jul-95	flip	57.0					
569	Y	19-Jul-95	flip	61.0					
570	Y	19-Jul-95	flip	50.0					
571	Y	19-Jul-95	flip	60.5					
572	Y	19-Jul-95	flip	55.0					
573	Y	19-Jul-95	flip	44.5					
574	Y	20-Jul-95	wier	51.5	46.5	42.5	1.1		
575	Y	20-Jul-95	Weir	71.5	65.0	57.5	3.8	M	43
578	Y	18-Jun-96	Flip						
601	Y	27-Sep-95	Meadow Cr. - just below the settling basin	63.5				M	
602	Y	27-Sep-95	Meadow Cr. below enumeration fence	43.5				M	
603	Y	27-Sep-95	Meadow Cr. above enumeration fence	51.0				F	
605	Y	28-Sep-95	Meadow Cr. above enumeration fence	45.5				M	
607	Y	23-Jul-97	flip	32.3					
608	Y	6-Jun-96	Flip	81.5					
609	Y	6-Jun-96	Flip	67.0					
610	Y	26-Jun-96	Flip	56.0					
611	Y	15-Jul-96	Flip	78.0	71.0	65.5	5.40	M	82

Tag #	Colour	Date Tagged	Location Tagged	FL	SL	POHL	Weight	Sex	Radio tag #
612	Y	6-Jun-96	Flip	61.0					
613	Y	6-Jun-96	Flip	61.5					
614	Y	6-Jun-96	Flip	76.0					
615	Y	6-Jun-96	Flip	57.5					
617	Y	6-Jun-96	Flip	66.0					
618	Y	6-Jun-96	Flip	66.5					
619	Y	6-Jun-96	Flip	55.0					
620	Y	6-Jun-96	Flip	58.5					
621	Y	6-Jun-96	Flip	81.3				M	
622	Y	6-Jun-96	Flip	46.5					
623	Y	6-Jun-96	Flip	63.5					
624	Y	6-Jun-96	Flip	60.0					
625	Y	6-Jun-96	Flip	59.0					
626	Y	6-Jun-96	Flip	76.0					
627	Y	6-Jun-96	Flip	61.5					
628	Y	6-Jun-96	Flip	68.0					
629	Y	7-Aug-96	Pond	47.5	42.5	39.0	1.4	F	
630	Y	6-Jun-96	Flip	60.0					
631	Y	6-Jun-96	Flip	64.0					
632	Y	6-Jun-96	Flip	65.5					
633	Y	6-Jun-96	Flip	55.0					
634	Y	6-Jun-96	Flip	63.5					
635	Y	6-Jun-96	Flip	71.0					
636	Y	14-Jun-96	Flip	77.0	69.0	62.5	4.80	M	10
637	Y	14-Jun-96	Flip	66.5	59.5	55.0	3.00	M	57
638	Y	14-Jun-96	Flip	69.5	66.0	58.5	3.80	M	55
641	Y	14-Jun-96	Flip	72.0	66.0	59.0	4.00	M	56
642	Y	14-Jun-96	Flip	65.0	59.5	54.5	2.80	M	53
643	Y	14-Jun-96	Flip	68.5	62.0	55.5	3.10	M	54
644	Y	25-Jun-96	Pond	49.0					
645	Y	26-Jun-96	Pond	59.5					
646	Y	26-Jun-96	Pond	52.0					
726	Y	27-Sep-96	Houston Fence	57.2				F	
727	Y	9-Oct-96	Houston Fence	44.2			0.6	M	
728	Y	9-Oct-96	Houston Fence	55.8			1.3	F	
729	Y	9-Oct-96	Houston Fence	49.0			0.8	F	
730	Y	9-Oct-96	Houston Fence	54.9			1.3	F	
776	Y	6-Jun-96	Flip	65.0					
777	Y	6-Jun-96	Flip	59.0					
778	Y	14-Jun-96	Flip	63.0					
779	Y	14-Jun-96	Flip	79.0					
779	Y	3-Oct-96	Houston Fence	75.9				M	
780	Y	14-Jun-96	Flip	76.5					
781	Y	14-Jun-96	Flip	68.0					
782	Y	14-Jun-96	Flip	64.0					
784	Y	14-Jun-96	Flip	68.0					
787	Y	14-Jun-96	Flip	68.0					
789	Y	14-Jun-96	Flip	72.0					
791	Y	18-Jun-96	Flip						
792	Y	14-Jun-96	Flip	67.5					
794	Y	14-Jun-96	Flip	60.5					
797	Y	14-Jun-96	Flip	71.0					
800	Y	14-Jun-96	Flip	60.5					
801	Y	14-Jun-96	Flip	67.0					
802	Y	14-Jun-96	Flip	64.0					
803	Y	14-Jun-96	Flip	62.0					
804	Y	14-Jun-96	Flip	67.0					
805	Y	14-Jun-96	Flip	68.0					
806	Y	14-Jun-96	Flip	67.0					
807	Y	14-Jun-96	Flip	62.0					
810	Y	14-Jun-96	Flip	66.0					
811	Y	3-Jul-96	Flip	64.0	58.5	52.0	2.70	F	63
812	Y	3-Jul-96	Flip	68.5	62.0	55.5	3.50	M	64
814	Y	3-Jul-96	Flip	76.5	70.5	63.5	5.10	M	65
815	Y	3-Jul-96	Flip	67.0	61.0	54.5	2.70	M	61
816	Y	10-Jul-96	Flip	77.0	70.5	63.0	4.40	M	73
817	Y	10-Jul-96	Flip	69.0	62.5	54.5	3.00	M	67

Tag #	Colour	Date Tagged	Location Tagged	FL	SL	POHL	Weight	Sex	Radio tag #
818	Y	10-Jul-96	Flip	75.5	69.0	61.5	3.40	M	74
819	Y	10-Jul-96	Flip	80.0	73.0	65.5	4.60	M	72
821	Y	10-Jul-96	Flip	75.5	68.5	61.0	3.50	M	71
822	Y	14-Aug-96	Flip	69.5	63.0	56.5	3.40	M	39
823	Y	27-Aug-96	Lower Duncan	57.0	51.0	47.5	2.4		
824	Y	27-Aug-96	Lower Duncan	65.0	58.0	52.0	3.90	M	90
826	Y	6-Jun-96	Flip	71.0	65.0	58.5	4.6		
827	Y	14-Jun-96	Flip	65.0					
828	Y	14-Jun-96	Flip	56.0					
829	Y	14-Jun-96	Flip	62.0					
830	Y	14-Jun-96	Flip	74.0					
831	Y	14-Jun-96	Flip	57.5					
832	Y	14-Jun-96	Flip	68.0					
834	Y	14-Jun-96	Flip	60.5					
835	Y	14-Jun-96	Flip	67.5					
837	Y	14-Jun-96	Flip	61.0					
838	Y	14-Jun-96	Flip	68.5					
841	Y	14-Jun-96	Flip	58.0					
842	Y	14-Jun-96	Flip	62.0					
844	Y	14-Jun-96	Flip	62.5					
845	Y	14-Jun-96	Flip	66.0					
846	Y	18-Jun-96	Flip	68.5	63.5	56.5	3.60	M	58
847	Y	14-Jun-96	Flip	72.5					
848	Y	6-Jun-96	Flip	78.0	71.5	64.5	4.40	M	51
849	Y	6-Jun-96	Flip	71.0	64.5	59.0	3.20	M	52
850	Y	6-Jun-96	Flip	70.0	64.5	58.5	3.8		
901	Y	3-Jul-96	Flip	78.5					
902	Y	3-Jul-96	Flip	65.0					
903	Y	3-Jul-96	Flip	67.5					
904	Y	3-Jul-96	Flip	55.0					
905	Y	3-Jul-96	Flip	57.5					
906	Y	3-Jul-96	Flip	60.5					
907	Y	10-Jul-96	Flip	59.5	53.5	48.5	2.10	M	68
908	Y	3-Jul-96	Flip	60.0					
909	Y	3-Jul-96	Flip	72.0					
910	Y	3-Jul-96	Flip	65.5					
911	Y	3-Jul-96	Flip	64.5					
912	Y	3-Jul-96	Flip	55.5					
913	Y	3-Jul-96	Flip	58.5					
914	Y	3-Jul-96	Flip	62.0					
915	Y	3-Jul-96	Flip	68.5	63.0	56.0	3.20	M	66
915	Y	3-Jul-96	Flip	67.0					
916	Y	3-Jul-96	Flip	62.5					
917	Y	3-Jul-96	Flip	60.5					
918	Y	3-Jul-96	Flip	62.0					
920	Y	10-Jul-96	Flip	61.5					
921	Y	10-Jul-96	Flip	73.0	67.0	59.5	3.90	M	70
922	Y	15-Jul-96	Flip	62.5	57.0	51.0	2.80	M	76
923	Y	15-Jul-96	Flip	76.0	70.0	60.0	4.90	M	81
924	Y	10-Jul-96	Flip	64.0					
925	Y	10-Jul-96	Flip	62.0					
927	Y	11-Jul-96	Flip	60.5					
929	Y	11-Jul-96	Flip	57.5					
930	Y	11-Jul-96	Flip	63.5					
931	Y	11-Jul-96	Flip	62.0					
932	Y	11-Jul-96	Flip	66.0					
933	Y	11-Jul-96	Flip	75.5					
934	Y	7-Aug-96	Pond	49.0	45.0	40.0			
935	Y	11-Jul-96	Flip	56.5					
937	Y	11-Jul-96	Flip	62.0					
938	Y	11-Jul-96	Flip	56.0					
939	Y	11-Jul-96	Flip	72.0					
940	Y	11-Jul-96	Flip	61.5					
941	Y	7-Aug-96	Pond	63.5					
942	Y	7-Aug-96	Pond	51.0					
943	Y	7-Aug-96	Pond	66.0	60.0	53.0	3.0		
944	Y	7-Aug-96	Pond	72.5	66.0	60.0	4.20	M	85

Tag #	Colour	Date Tagged	Location Tagged	FL	SL	POHL	Weight	Sex	Radio tag #
945	Y	7-Aug-96	Pond	54.5	49.5	44.0	2.1		
946	Y	7-Aug-96	Pond	57.5					
947	Y	7-Aug-96	Pond	61.0					
948	Y	7-Aug-96	Pond	51.0					
949	Y	7-Aug-96	Pond	43.5					
950	Y	7-Aug-96	Pond	73.5	67.5	61.5	4.30	M	84
951	Y	5-Sep-96	Lower Duncan	54.5	49.0	45.0	2.0	F	
952	Y	5-Sep-96	Lower Duncan	54.5	49.5	45.0	2.30	M	91
953	Y	5-Sep-96	Lower Duncan	56.0	50.0	46.5	2.10	M	92
954	Y	5-Sep-96	Lower Duncan	54.0	49.5	44.5	2.0	M	
8001	Y	10-Jul-96	Flip	55.0					
8002	Y	10-Jul-96	Flip	55.0					
8003	Y	10-Jul-96	Flip	69.0					
8004	Y	10-Jul-96	Flip	71.0					
8005	Y	10-Jul-96	Flip	57.0					
8006	Y	10-Jul-96	Flip	75.0					
8007	Y	15-Jul-96	Flip	60.0	54.5	49.5	2.50	M	80
8008	Y	10-Jul-96	Flip	56.5					
8009	Y	10-Jul-96	Flip	60.0					
8010	Y	10-Jul-96	Flip	61.0					
8011	Y	10-Jul-96	Flip	56.5					
8012	Y	10-Jul-96	Flip	59.0					
8013	Y	10-Jul-96	Flip	60.0					
8014	Y	10-Jul-96	Flip	64.0					
8015	Y	10-Jul-96	Flip	66.0					
8016	Y	10-Jul-96	Flip	57.0					
8017	Y	15-Jul-96	Flip	69.5	62.5	57.5	3.50	F	77
8018	Y	10-Jul-96	Flip	64.0					
8019	Y	10-Jul-96	Flip	73.5					
8019	Y	15-Jul-96	Flip	74.5	67.0	60.0	4.40	M	75
8020	Y	10-Jul-96	Flip	55.0					
8021	Y	10-Jul-96	Flip	60.0					
8022	Y	10-Jul-96	Flip	71.0					
8023	Y	10-Jul-96	Flip	58.5					
8024	Y	10-Jul-96	Flip	60.5					
8025	Y	10-Jul-96	Flip	60.0					
8026	Y	10-Jul-96	Flip	66.5					
8027	Y	10-Jul-96	Flip	68.0					
8028	Y	10-Jul-96	Flip	64.5					
8029	Y	10-Jul-96	Flip	75.5					
8030	Y	10-Jul-96	Flip	66.0					
8031	Y	10-Jul-96	Flip	59.0					
8032	Y	10-Jul-96	Flip	67.0					
8033	Y	10-Jul-96	Flip	59.0					
8034	Y	10-Jul-96	Flip	57.0					
8035	Y	10-Jul-96	Flip	60.0					
8036	Y	15-Jul-96	Flip	67.5	61.5	54.5	2.90	F	79
8037	Y	10-Jul-96	Flip	74.0					
8038	Y	10-Jul-96	Flip	62.0					
8039	Y	10-Jul-96	Flip	61.0					
8040	Y	10-Jul-96	Flip	57.5					
8041	Y	10-Jul-96	Flip	65.5					
8042	Y	10-Jul-96	Flip	65.5					
8044	Y	10-Jul-96	Flip	60.0					
8045	Y	10-Jul-96	Flip	68.0					
8046	Y	10-Jul-96	Flip	64.5					
8047	Y	10-Jul-96	Flip	60.0					
8048	Y	10-Jul-96	Flip	62.5					
8049	Y	10-Jul-96	Flip	67.5					
8050	Y	10-Jul-96	Flip	66.0					
8051	Y	10-Jul-96	Flip	65.0					
8052	Y	14-Aug-96	Flip	82.0					
8053	Y	14-Aug-96	Flip	73.0	67.0	60.5	4.20	M	86
8054	Y	14-Aug-96	Flip	61.0					
8056	Y	14-Aug-96	Flip	52.0					
8057	Y	14-Aug-96	Flip	70.0					
8058	Y	14-Aug-96	Flip	83.0					

Tag #	Colour	Date Tagged	Location Tagged	FL	SL	POHL	Weight	Sex	Radio tag #
8059	Y	14-Aug-96	Flip	64.0					
8060	Y	14-Aug-96	Flip	63.0					
8061	Y	14-Aug-96	Flip	55.5					
8062	Y	14-Aug-96	Flip	58.0					
8063	Y	14-Aug-96	Flip	67.0					
8064	Y	14-Aug-96	Flip	65.5					
8065	Y	4-Jul-97	Flip	68.0					
8066	Y	14-Aug-96	Flip	60.0					
8067	Y	14-Aug-96	Flip	64.5					
8068	Y	14-Aug-96	Flip	57.5					
8069	Y	14-Aug-96	Flip	65.0					
8070	Y	14-Aug-96	Flip	62.0					
8071	Y	14-Aug-96	Flip	54.0					
8072	Y	14-Aug-96	Flip	57.5					
8073	Y	14-Aug-96	Flip	61.0					
8074	Y	14-Aug-96	Flip	64.5					
8075	Y	14-Aug-96	Flip	62.0					
8076	Y	14-Aug-96	Flip	60.0					
8077	Y	14-Aug-96	Flip	66.0					
8078	Y	14-Aug-96	Flip	63.5					
8079	Y	14-Aug-96	Flip	53.0					
8080	Y	14-Aug-96	Flip	62.0					
8081	Y	14-Aug-96	Flip	64.0					
8082	Y	14-Aug-96	Flip	59.5					
8083	Y	14-Aug-96	Flip	60.5					
8084	Y	27-Aug-96	Lower Duncan	59.5	53.5	47.5	2.70	M	89
8085	Y	14-Aug-96	Flip	54.5					
8086	Y	14-Aug-96	Flip	50.0					
8087	Y	14-Aug-96	Flip	48.5					
8088	Y	14-Aug-96	Flip	62.0					
8089	Y	14-Aug-96	Flip	68.5					
8090	Y	27-Aug-96	Lower Duncan	59.5				M?	
8091	Y	27-Aug-96	Lower Duncan	60.5				F	
8092	Y	27-Aug-96	Lower Duncan	51.5					
8093	Y	27-Aug-96	Lower Duncan	45.0					
8094	Y	27-Aug-96	Lower Duncan	54.0					
8095	Y	27-Aug-96	Lower Duncan	50.0					
8096	Y	27-Aug-96	Lower Duncan	63.5				M	
8097	Y	27-Aug-96	Lower Duncan	58.5				M	
8098	Y	27-Aug-96	Lower Duncan	59.0	53.5	47.5	2.5	F	
8099	Y	27-Aug-96	Lower Duncan	63.5	58.0	52.0	3.60	M	87
8100	Y	27-Aug-96	Lower Duncan	59.5	53.0	47.5	3.00	M	88
8101	Y	14-Aug-96	Flip	69.0					
8102	Y	14-Aug-96	Flip	79.0					
8103	Y	14-Aug-96	Flip	75.0					
8104	Y	14-Aug-96	Flip	67.5	61.5	56.0	3.5		
8105	Y	14-Aug-96	Flip	55.0					
8106	Y	14-Aug-96	Flip	70.5					
8107	Y	14-Aug-96	Flip	77.0					
8108	Y	14-Aug-96	Flip	67.0					
8109	Y	14-Aug-96	Flip	63.0					
8110	Y	14-Aug-96	Flip	58.0					
8111	Y	14-Aug-96	Flip	64.5					
8112	Y	14-Aug-96	Flip	49.5					
8113	Y	27-Aug-96	End of tail	53.5					
8114	Y	27-Aug-96	End of tail	43.0					
8115	Y	27-Aug-96	End of tail	44.5					
8116	Y	27-Aug-96	End of tail	59.0					
8117	Y	27-Aug-96	End of tail	60.5					
8118	Y	27-Aug-96	End of tail	46.0					
8119	Y	5-Sep-96	Lower Duncan	54.0				M	
8121	Y	5-Sep-96	Lower Duncan	48.0				M	
8122	Y	5-Sep-96	Lower Duncan	42.0				M	
8123	Y	5-Sep-96	Lower Duncan	52.0				F	
8124	Y	5-Sep-96	Lower Duncan	61.0				M	
8125	Y	5-Sep-96	Lower Duncan	52.0				M	
8126	Y	5-Sep-96	Lower Duncan	49.5				M	

Tag #	Colour	Date Tagged	Location Tagged	FL	SL	POHL	Weight	Sex	Radio tag #
8127	Y	5-Sep-96	Lower Duncan	31.0				J	
8128	Y	5-Sep-96	Lower Duncan	51.0				M	
8129	Y	5-Sep-96	Lower Duncan	45.5				M	
8130	Y	5-Sep-96	Lower Duncan	62.0				F	
8131	Y	5-Sep-96	Lower Duncan	66.5				M	
8132	Y	5-Sep-96	Lower Duncan						
8133	Y	5-Sep-96	Lower Duncan	55.0				F	
8134	Y	5-Sep-96	Lower Duncan	66.0				F	
8135	Y	5-Sep-96	Lower Duncan	56.0				F	
8136	Y	5-Sep-96	Lower Duncan	45.0					
8137	Y	5-Sep-96	Lower Duncan	50.0					
8138	Y	5-Sep-96	Lower Duncan	47.5					
8139	Y	5-Sep-96	Lower Duncan	39.0					
8140	Y	5-Sep-96	Lower Duncan	38.0					
8141	Y	5-Sep-96	Lower Duncan	50.0					
8142	Y	5-Sep-96	Lower Duncan	36.0					
8143	Y	5-Sep-96	Lower Duncan	36.5					
8144	Y	5-Sep-96	Lower Duncan	46.0			1.2		
8148	Y	27-Sep-96	Meadow Creek Spawning Channel	49.5				M	
8149	Y	27-Sep-96	Meadow Creek Spawning Channel	53.0				M	
8150	Y	27-Sep-96	Meadow Creek Spawning Channel	~40				M?	
8201	Y	27-Sep-96	Meadow Creek Spawning Channel	55.0				M	
8202	Y	27-Sep-96	Meadow Creek Spawning Channel	51.0				M	
8203	Y	27-Sep-96	Meadow Creek Spawning Channel	49.0				M	
8204	Y	27-Sep-96	Meadow Creek Spawning Channel	49.5				F	
8205	Y	1-Oct-96	Meadow Creek Spawning Channel	51.0				F	
8206	Y	2-Oct-96	Meadow Creek Spawning Channel	48.0				M	
8207	Y	2-Oct-96	Meadow Creek Spawning Channel	51.0				M	
8208	Y	2-Oct-96	Meadow Creek Spawning Channel	54.0				F	
8210	Y	12-Jun-97	Flip	81.0					
8211	Y	12-Jun-97	Flip	70.0					
8212	Y	12-Jun-97	Flip	62.5					
8213	Y	12-Jun-97	Flip	68.5					
8214	Y	12-Jun-97	Flip	72.0					
8215	Y	12-Jun-97	Flip	73.5					
8217	Y	12-Jun-97	Flip	56.5					
8218	Y	12-Jun-97	Flip	64.0					
8219	Y	12-Jun-97	Flip	67.0					
8220	Y	12-Jun-97	Flip	58.0					
8221	Y	12-Jun-97	Flip	57.5					
8222	Y	12-Jun-97	Flip	68.5					
8223	Y	12-Jun-97	Flip	72.0					
8224	Y	12-Jun-97	Flip	74.5					
8225	Y	12-Jun-97	Flip	71.0					
8226	Y	12-Jun-97	Flip	75.5					
8227	Y	12-Jun-97	Flip	68.5					
8228	Y	12-Jun-97	Flip	63.5					
8229	Y	12-Jun-97	Flip	71.0					
8230	Y	12-Jun-97	Flip	63.5					
8231	Y	12-Jun-97	Flip	71.0					
8232	Y	12-Jun-97	Flip	66.5					
8233	Y	12-Jun-97	Flip	68.5					
8234	Y	12-Jun-97	Flip	70.0					
8235	Y	12-Jun-97	Flip	71.0					
8236	Y	12-Jun-97	Flip	73.0					
8238	Y	12-Jun-97	Flip	67.0					
8239	Y	12-Jun-97	Flip	70.0					
8240	Y	12-Jun-97	Flip	67.0					
8241	Y	12-Jun-97	Flip	63.0					
8242	Y	12-Jun-97	Flip	66.0					
8243	Y	12-Jun-97	Flip	54.0					
8245	Y	3-Oct-96	Meadow Creek Spawning Channel	58.5				F	
8246	Y	1-Oct-96	Meadow Creek Spawning Channel	49.0				M	
8247	Y	1-Oct-96	Meadow Creek Spawning Channel	57.0				M	
8248	Y	27-Sep-96	Meadow Creek Spawning Channel	39.0				M	
8249	Y	27-Sep-96	Meadow Creek Spawning Channel	45.0				M	
8251	Y	12-Jun-97	Flip	54.0					

Tag #	Colour	Date Tagged	Location Tagged	FL	SL	POHL	Weight	Sex	Radio tag #
8252	Y	12-Jun-97	Flip	69.5					
8253	Y	12-Jun-97	Flip	63.5					
8254	Y	12-Jun-97	Flip	71.5					
8255	Y	12-Jun-97	Flip	59.0					
8256	Y	12-Jun-97	Flip	70.0					
8257	Y	12-Jun-97	Flip	67.5					
8258	Y	12-Jun-97	Flip	77.5					
8259	Y	12-Jun-97	Flip	65.5					
8260	Y	12-Jun-97	Flip	70.5					
8261	Y	12-Jun-97	Flip	83.5					
8263	Y	9-Oct-96	Houston Fence	52.0			1.0	M	
8264	Y	9-Oct-96	Houston Fence	41.1			0.6	?	
8265	Y	9-Oct-96	Houston Fence	59.5			1.7	F	
8266	Y	9-Oct-96	Houston Fence	85.1			5.6	M	
8267	Y	9-Oct-96	Houston Fence	50.6				F	
8268	Y	9-Oct-96	Houston Fence	55.9				M	
8269	Y	3-Oct-96	Houston Fence	45.2				M	
8270	Y	3-Oct-96	Houston Fence	51.5				F	
8271	Y	3-Oct-96	Houston Fence	52.0				M	
8272	Y	3-Oct-96	Houston Fence	58.1				F	
8273	Y	3-Oct-96	Houston Fence	62.2			1.9	F	
8275	Y	3-Oct-96	Houston Fence	68.3				F	
8276	Y	3-Oct-96	Houston Fence	54.5				M	
8277	Y	3-Oct-96	Houston Fence	53.8				M	
8278	Y	3-Oct-96	Houston Fence	65.6				M	
8279	Y	3-Oct-96	Houston Fence	62.6				M	
8280	Y	3-Oct-96	Houston Fence	57.5				F	
8281	Y	3-Oct-96	Houston Fence	50.0				M	
8282	Y	3-Oct-96	Houston Fence	51.1				M	
8283	Y	3-Oct-96	Houston Fence	46.5				F	
8284	Y	3-Oct-96	Houston Fence	66.6				M	
8285	Y	2-Oct-96	Houston Fence	55.5				M	
8286	Y	2-Oct-96	Houston Fence	51.1				F	
8287	Y	2-Oct-96	Houston Fence	59.3				F	
8288	Y	2-Oct-96	Houston Fence	50.5				F	
8289	Y	2-Oct-96	Houston Fence	60.6				M	
8290	Y	2-Oct-96	Houston Fence	60.8				F	
8291	Y	2-Oct-96	Houston Fence	50.4				F	
8292	Y	2-Oct-96	Houston Fence	49.2				M	
8293	Y	2-Oct-96	Houston Fence	64.5				F	
8294	Y	2-Oct-96	Houston Fence	55.7				M	
8295	Y	2-Oct-96	Houston Fence - new floy tag	68.0			3	M	55
8296	Y	27-Sep-96	Houston Fence	46.3				M	
8298	Y	27-Sep-96	Houston Fence	57.0				F	
8299	Y	27-Sep-96	Houston Fence	40.1				M	
8300	Y	27-Sep-96	Houston Fence	53.5				M	
8301	Y	12-Jun-97	Flip	64.0					
8302	Y	12-Jun-97	Flip	64.0					
8303	Y	25-Jun-97	Flip	79.0					
8304	Y	25-Jun-97	Flip	84.5					
8305	Y	25-Jun-97	Flip	69.0					
8308	Y	25-Jun-97	Flip	64.0					
8310	Y	25-Jun-97	Flip	53.0					
8311	Y	25-Jun-97	Flip	59.5					
8312	Y	25-Jun-97	Flip	75.0					
8313	Y	23-Jul-97	flip	49.8					
8314	Y	25-Jun-97	Flip	69.5					
8315	Y	25-Jun-97	Flip	64.5					
8316	Y	25-Jun-97	Flip	54.5					
8317	Y	25-Jun-97	Flip	60.0					
8351	Y	25-Jun-97	Flip	77.0					
8352	Y	25-Jun-97	Flip	85.0					
8353	Y	25-Jun-97	Flip	64.5					
8354	Y	25-Jun-97	Flip	62.5					
8355	Y	25-Jun-97	Flip	71.5					
8356	Y	25-Jun-97	Flip	62.0					
8357	Y	25-Jun-97	Flip	64.0					

Tag #	Colour	Date Tagged	Location Tagged	FL	SL	POHL	Weight	Sex	Radio tag #
8358	Y	25-Jun-97	Flip	65.5					
8359	Y	25-Jun-97	Flip	71.5					
8360	Y	25-Jun-97	Flip	80.5					
8361	Y	25-Jun-97	Flip	69.5					
8362	Y	25-Jun-97	Flip	70.5					
8363	Y	25-Jun-97	Flip	58.0					
8364	Y	25-Jun-97	Flip	66.0					
8365	Y	25-Jun-97	Weir	83.0					
8366	Y	25-Jun-97	Weir	73.5					
8367	Y	25-Jun-97	Weir	66.0					
8368	Y	25-Jun-97	Weir	70.0					
8369	Y	25-Jun-97	Weir	72.0					
8371	Y	4-Jul-97	Flip	91.0					
8373	Y	4-Jul-97	Flip	64.5					
8374	Y	4-Jul-97	Flip	62.0					
8375	Y	4-Jul-97	Flip	60.5					
8377	Y	4-Jul-97	Flip	67.0					
8378	Y	4-Jul-97	Flip	60.0					
8379	Y	4-Jul-97	Flip	67.5					
8380	Y	4-Jul-97	Flip	65.0					
8381	Y	4-Jul-97	Flip	58.0					
8382	Y	4-Jul-97	Flip	62.0					
8383	Y	4-Jul-97	Flip	65.0					
8384	Y	4-Jul-97	Flip	65.0					
8387	Y	4-Jul-97	Flip	64.0					
8389	Y	4-Jul-97	Weir	67.0					
8390	Y	4-Jul-97	Weir	59.5					
8391	Y	4-Jul-97	Weir	68.5					
8401	Y	9-Jul-97	Flip	69.5					
8402	Y	9-Jul-97	Flip	68.0					
8403	Y	9-Jul-97	Flip	63.0					
8404	Y	9-Jul-97	Flip	70.0					
8405	Y	9-Jul-97	Flip	83.5					
8406	Y	9-Jul-97	Flip	67.0					
8407	Y	23-Jul-97	flip	71.5					
8409	Y	23-Jul-97	flip	77.0					
8410	Y	23-Jul-97	flip	76.5					
8411	Y	23-Jul-97	flip	68.5					
8412	Y	23-Jul-97	flip	63.5					
8413	Y	23-Jul-97	flip	66.5					
8414	Y	23-Jul-97	flip	73.0					
8415	Y	23-Jul-97	flip	64.0					
8416	Y	23-Jul-97	flip	63.0					
8417	Y	23-Jul-97	flip	67.0					
8418	Y	23-Jul-97	flip	58.5					
8424	Y	13-Aug-97	flip	65.0					
8425	Y	13-Aug-97	flip	68.0					
8426	Y	13-Aug-97	flip	68.5					
8427	Y	13-Aug-97	flip	58.0					
8428	Y	13-Aug-97	flip	60.5					
8429	Y	13-Aug-97	flip	66.0					
8430	Y	13-Aug-97	flip	61.5					
8431	Y	13-Aug-97	flip	66.5					
8432	Y	13-Aug-97	flip	59.5					
8433	Y	25-Aug-97	flip	62.5					
8434	Y	25-Aug-97	flip	63.5					
8451	Y	4-Jul-97	Flip	69.0					
8452	Y	4-Jul-97	Flip	73.5					
8453	Y	4-Jul-97	Flip	67.0					
8454	Y	4-Jul-97	Flip	68.5					
8455	Y	4-Jul-97	Flip	75.0					
8456	Y	4-Jul-97	Flip	71.0					
8457	Y	4-Jul-97	Flip	74.5					
8458	Y	4-Jul-97	Flip	62.0					
8460	Y	4-Jul-97	Flip	58.5					
8461	Y	4-Jul-97	Flip	55.0					
8462	Y	4-Jul-97	Flip	66.5					

Tag #	Colour	Date Tagged	Location Tagged	FL	SL	POHL	Weight	Sex	Radio tag #
8463	Y	4-Jul-97	Flip	59.5					
8464	Y	4-Jul-97	Flip	60.0					
8465	Y	4-Jul-97	Flip	55.0					
8466	Y	4-Jul-97	Flip	63.0					
8468	Y	23-Jul-97	flip	91.0				M	
8469	Y	23-Jul-97	flip	78.5					
8470	Y	23-Jul-97	flip	74.5					
8471	Y	23-Jul-97	flip	78.0					
8472	Y	23-Jul-97	flip	75.0					
8473	Y	23-Jul-97	flip	82.5					
8474	Y	23-Jul-97	flip	69.0					
8475	Y	23-Jul-97	flip	75.5					
8476	Y	23-Jul-97	flip	62.5					
8477	Y	23-Jul-97	flip	65.0					
8478	Y	23-Jul-97	flip	62.5					
8479	Y	23-Jul-97	flip	66.0					
8480	Y	23-Jul-97	flip	60.5					
8482	Y	24-Jul-97	flip	75.0					
8484	Y	13-Aug-97	flip	72.0					
8485	Y	13-Aug-97	flip	67.5					
8486	Y	13-Aug-97	flip	71.0					
8487	Y	13-Aug-97	flip	73.7					
8489	Y	13-Aug-97	flip	60.0					
8490	Y	13-Aug-97	flip	61.0					
8491	Y	25-Aug-97	flip	64.0					
8492	Y	25-Aug-97	flip	77.5					
8493	Y	25-Aug-97	flip	64.0					
8494	Y	25-Aug-97	flip	67.0					
8495	Y	25-Aug-97	flip	71.5					
8496	Y	25-Aug-97	flip	67.5					
8497	Y	25-Aug-97	flip	70.5					
8498	Y	25-Aug-97	flip	49.5					
8499	Y	25-Aug-97	flip	64.5					
8500	Y	25-Aug-97	flip	71.5					