DOWNTON LAKE RESERVOIR FISH ENTRAINMENT STUDY

1999 INVESTIGATIONS

- DRAFT REPORT -

Prepared for

BC HYDRO
1155 McGill Road
Kamloops, B.C.
V2E 1Z4

O.T.C.
BC Hydro

by

R.L. & L. ENVIRONMENTAL SERVICES LTD.
201 Columbia Avenue
Castlegar, B.C.
V1N 1A2
Phone: (250) 365-0344
Fax: (250) 365-0988

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Cover photo: Upstream view of the tailrace of La Joie Dam showing the position of the tailrace traps.

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EXECUTIVE SUMMARY

The 1999 investigations of fish entrainment at La Joie Dam and powerplant provided insight into the magnitude of the problem and the influence of Downton Lake reservoir water elevations on relative entrainment rates. The study relied upon fish captures from two fyke nets and two inclined plane traps set immediately downstream of the powerplant outfall. A heart trap, set in the forebay of La Joie Dam, provided a source of fish for conducting intentional entrainment experiments to assist in measurement of downstream trap efficiency. Fish captured during the study were primarily rainbow trout. One bridgelip sucker was caught in the each of the forebay and tailrace areas. Coastrange sculpins were also commonly caught in the tailrace. Only rainbow trout were used in entrainment experiments and were the only species for which sufficient data was obtained to allow the projection of total entrainment estimates.

Access to the penstock for reliable entrainment experiments was difficult due to safety concerns that prevented boat operations near the base of the intake tower. As a consequence, only a limited number of fish could be released into the penstock and downstream recoveries were minimal. In one experiment, 28 live fish and two radio tagged fish (one live and one dead) were released through a service shaft into the penstock; two of the live fish and one of the radio-tagged fish were recorded downstream. Additional experiments involved the release of both fish and radishes immediately upstream of the intake, and in the tailrace area immediately below the dam and upstream of the traps.

Since the availability of fish limited the number of fish that could be released, the most definitive measurements of trap efficiency resulted from releases of radishes. Radishes also were released in the service shaft and in front of the trash racks at the base of the intake tower. Releases into the service shaft did not result in downstream recoveries while both the intake release and the tailrace release provided comparable downstream recovery rates. Since inclined plane traps had different catch-rates (11 rainbow trout recovered) than the fyke nets (58 rainbow trout recovered), the fyke nets were used exclusively to estimate total entrainment. Trap efficiency (for radishes) of the combined fyke nets was 4.8% based on 48 recoveries from 1000 releases. Based on this efficiency rate, the total expanded estimate of entrained fish during the study period was 1185 fish with a 95% CI of 789 to 1581.

Entrainment estimates during the time period beyond that covered by the sampling program was completed by developing a regression model that related forebay catch-rate, temperature, turbidity, and Downton Lake water level elevation to downstream fyke net catch-per-unit-effort. Only Downton Lake reservoir water level elevations provided any predictive power and consequently was the only variable used in the model. The entrainment of fish was measured at levels significantly above zero when the reservoir water levels were below 718 m and increased exponentially as the water level dropped to a minimum elevation of 708 m. Estimation of total entrainment from 1 April to 1 August 1999, a period believed to encompass most entrainment based on reservoir water levels, resulted in an estimate of 2993 rainbow trout with a 95% CI of 1691 to 6005.

These estimates are primarily dependent upon the reliability of the downstream trap efficiency estimates. Potential biases include non-entrained fish being captured in downstream traps, dead and live entrained fish being captured at rates differing from those observed using inanimate objects (radishes), and changes to seasonal abundance of forebay fish during the time periods that were not included in the period sampled. These factors could result in either positive or negative biases to the estimates provided. Consequently, the data presented are most useful in defining relative affects of water level elevations on entrainment rates and the relative magnitude of the problem, rather than absolute measurements of number of fish entrained. Of the fish entrained, approximately 60% were captured without injuries. Most of the injured fish recorded were either dead upon capture or likely to die from the injuries sustained.

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Castlegar

Larry Hildebrand	Senior Biologist, Editor
Dana Schmidt	Senior Biologist, Project Manager and Principal Analyst
Rena Vandenbos	Assistant Project Biologist
Rosie Hildebrand	Word Processor

Edmonton

Gary Ash	Principal and Senior Biologist

Prince George

Duncan Hendricks	Project Biologist and Principal Author
Nancy Elliott	Fisheries Biologist

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1.0 INTRODUCTION

Downstream passage of fish at hydroelectric facilities is an important issue due to the loss of fish from upstream populations and the potential for turbine induced mortality (Sorenson et al. 1998). Considerable research has been conducted in this field, although much of the work has been directed towards the downstream passage of anadromous salmonids and clupeids. Consequently, there is limited information available regarding the rates of entrainment for non-migratory, resident species and the mortality caused during turbine passage (Stone and Webster 1992; Sorenson et al. 1998).

Downton Lake reservoir, located in southwestern British Columbia, is formed by La Joie Dam. The reservoir is subject to large drawdowns that usually occur in the spring when the elevation of the impoundment is lowered to accommodate anticipated runoff from snowmelt. During normal operations, drawdowns are typically 30 to 40 m, with the reservoir reaching a minimum elevation of between 710 and 725 m (Hirst 1991). In some years (e.g., 1971, 1972, 1996), the reservoir has been drawn down (drafted) below this elevation. In 1996, the reservoir was drafted to an elevation of less than 700 m for maintenance purposes, a drawdown of approximately 50 m from full pool. When the reservoir is at low levels, the availability of lacustrine habitat is limited to the forebay area of La Joie Dam. During extremely low drawdowns, when the reservoir elevation is less than 700 m, the reservoir habitat becomes completely riverine. The potential concentration of fish near the downstream end of the reservoir during these periods of drawdown may increase their susceptibility to entrainment.

The effects of these drafting operations on the resident fish population of Downton Lake reservoir are unknown. Entrainment at hydroelectric facilities is site-specific and highly dependent on the fish resources (species and age) present. For the non-migratory resident fish populations found in Downton Lake reservoir, the potential susceptibility to entrainment would be greatest for fish that come into close proximity to the intake structure (Taft et al. 1992). In general, large fish are less susceptible to entrainment than smaller fish of the same species. Consequently, smaller fish often constitute the large proportion of fish entrained at hydroelectric facilities (Taft et al. 1992). For non-migratory resident fish, entrainment is often accidental, with fish approaching too close to the intake structure and then unable to escape the approach velocities.

Recently, several studies have focussed on the fisheries resources of Downton Lake reservoir and its tributaries (Griffith 1998; Tisdale 1998; Stefanov 1998). In addition, numerous fisheries studies have been conducted on the Bridge River system. Despite this research, none of the previous studies has addressed the degree of entrainment of resident fish species from Downton Lake reservoir through La Joie Dam.

1.1 STUDY OBJECTIVES

In May 1999, R.L. & L. Environmental Services Ltd. was contracted by BC Hydro to conduct the fisheries component of a hydroacoustic and fisheries entrainment study at La Joie Dam. The study was scheduled to coincide with a scheduled drawdown of Downton Lake reservoir to accommodate high runoff volumes from anticipated snowmelt.

The hydroacoustic component of the study was originally scheduled to be completed by BioSonics, Inc. in two phases. The initial phase was designed to determine the feasibility of hydroacoustic data collection at the La Joie Dam site. If this was successful, a second phase that involved the collection of hydroacoustic data to determine fish entrainment rates would be implemented. The second phase would also involve the simultaneous collection of fisheries information to complement the hydroacoustic program. Due to logistical difficulties and time constraints, only the feasibility phase of the hydroacoustic program was conducted in 1999 (Stables and McFadden 1999); the fisheries collection program was conducted concurrent with the hydroacoustic feasibility study.

The specific objectives of the fisheries study component conducted by R.L. & L. Environmental Services Ltd. were:

- to estimate species composition and relative abundance of fish in the forebay of La Joie Dam;
- to describe and quantify the degree of entrained fish in the tailrace of the La Joie Dam; and
- to review and summarize existing fisheries reports.

2.0 STUDY AREA

2.1 BRIDGE RIVER SYSTEM

Downton Lake reservoir is located on the Bridge River system approximately 80 km upstream from the Fraser River. The reservoir, created by the construction of La Joie Dam in 1951, is used for power generation and also acts as water storage for flood control in the Fraser River system and for downstream power generation at BC Hydro facilities on the Bridge and Seton River systems (Stables and McFadden 1999).

The Bridge River is a sixth order tributary of the Fraser River (1:50 000 scale, based on Strahler 1956) and is approximately 140 km long with a watershed of approximately 4700 km^2 (Figure 2.1). La Joie Dam and Terzaghi Dam divide the Bridge River into three sections referred to as the Lower, Middle, and Upper Bridge River. The Lower Bridge River below Terzaghi Dam, is 40 km long. Carpenter Lake, which is formed by Terzaghi Dam, is 52 km long and has a surface area of 4900 ha at full pool. The Middle Bridge River extends from the head of Carpenter Lake to La Joie Dam and is less than 5 km long when Carpenter Lake is at full pool.

The drainage area of the Upper Bridge River watershed, including Downton Lake reservoir, is 980 km^2. At full pool, the reservoir is 27 km long, exhibits a mean depth of 30 m and a maximum-recorded depth of 80 m, and has a surface area of approximately 2400 ha (Hirst 1991).

2.2 LA JOIE DAM AND GENERATING FACILITY

La Joie Dam is 104 m high and approximately 1000 m long (Hirst 1991). When originally constructed in 1951, La Joie Dam was 87 m high. However, the dam elevation was raised by 17 m (elevation 736.1 m to elevation 753.5 m) in 1955. An intake tower is situated 88 m upstream of the dam crest in the forebay of Downton Lake reservoir. Four penstocks, each with a diameter of 4.27 m, are located within the intake tower. Two penstocks located on the southern end of the tower provide water for the hydroelectric generating station located downstream of the dam. Water from these penstocks is directed into a single steel conduit, 2.74 m in diameter. This tunnel extends to the generation station, which houses a Francis turbine and has a maximum generating capacity of approximately 22 MW (Stables and McFadden 1999; Hirst 1991). At maximum generating capacity and reservoir elevation, flow through the tunnel to the generation unit is approximately 48 m^3/s (Stables and McFadden 1999).

The two penstocks located towards the north side of the tower provide water for a low-level bypass. As with the turbine penstocks, water from the bypass penstocks is directed into a single steel conduit (2.74 m diameter). Bypass flows are discharged via a bifurcated low-level outlet. Flow from the low-level outlet is controlled by two hollow cone valves (Stables and McFadden 1999). When the reservoir is at full pool, an uncontrolled ogee spillway located at the north end of the dam bypasses excess water.

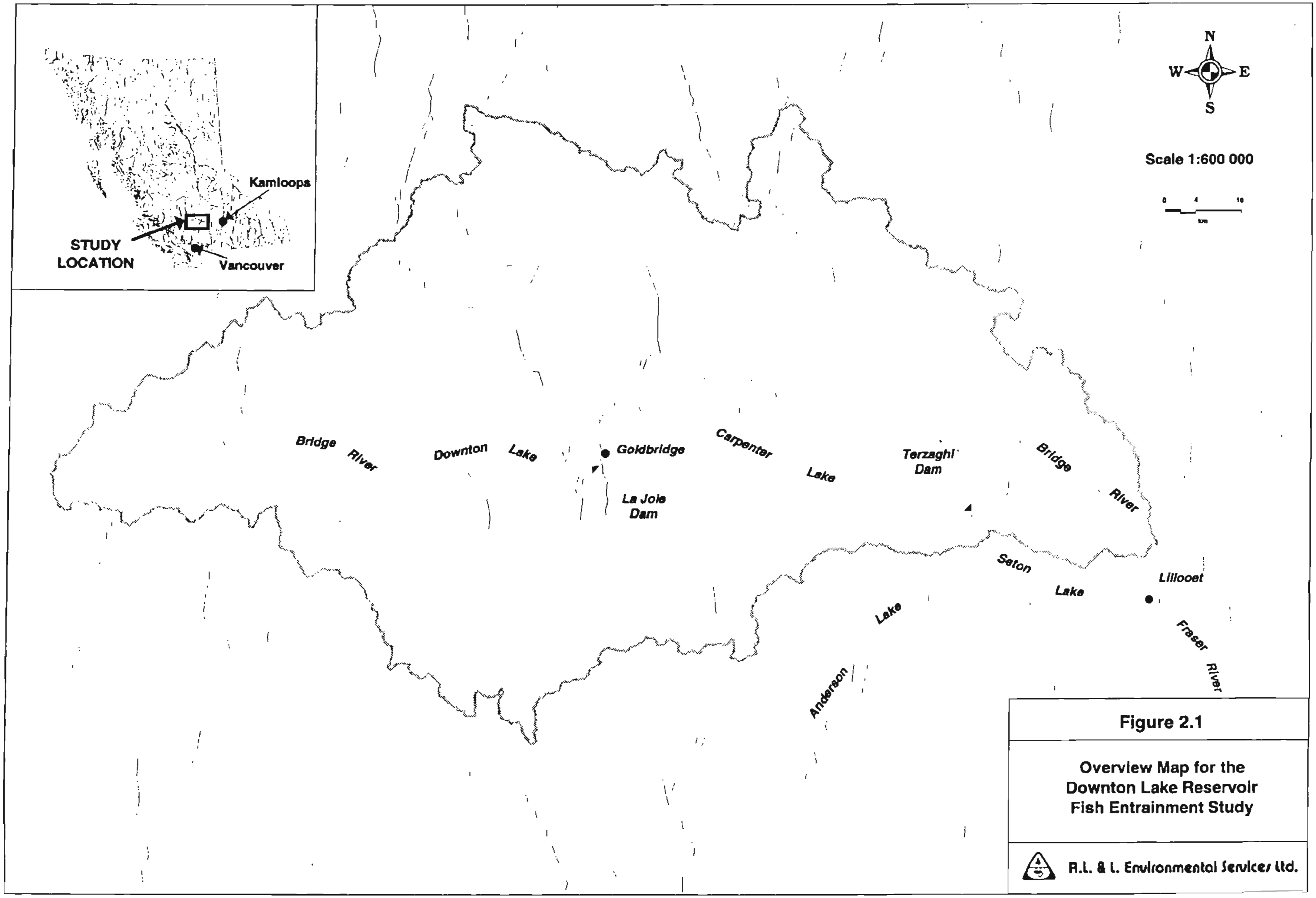

Figure 2.1

Overview Map for the Downton Lake Reservoir Fish Entrainment Study

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2.3 FISHERIES RESOURCES

The Bridge River system supports both anadromous and resident fish species. However, anadromous species are restricted to the Lower Bridge River, and cannot ascend upstream past Terzaghi Dam. In Carpenter Lake, the reservoir formed by Terzaghi Dam, the resident species include rainbow trout (*Oncorhynchus mykiss*), bull trout (*Salvelinus confluentus*), and mountain whitefish (*Prosopium williamsoni*; Hirst 1991). In addition, kokanee (*O. nerka*) have been introduced to the reservoir (Hirst 1991).

Information on fish use of the Middle Bridge River, upstream of Carpenter Lake and below La Joie Dam, is limited. Kokanee from Carpenter Lake likely use the Middle Bridge River for spawning in the fall (i.e., based on information obtained from the Fisheries Information Summary System for B.C.). Coastrange sculpin (*Cottus aleuticus*) and longnose sucker (*Catostomus catostomus*) were recorded in the Middle Bridge River. In addition, slimy sculpin (*C. cognatus*) have been recorded in the Hurley River, a large tributary of the Middle Bridge River.

In Downton Lake reservoir, previous studies have indicated that rainbow trout and bull trout are the only fish species present (Griffith 1998 (unpubl. ms.); Stefanov 1998 (unpubl. ms.); Tisdale 1998 (unpubl. ms.)). Stefanov (1998) (unpubl. ms.) conducted ~~extensive~~ gill netting in the reservoir, including sampling near the dam forebay. Rainbow trout were captured at various depths in several locations within the reservoir. Bull trout were not captured in the forebay area. Based on previous study results, rainbow trout ~~are the only species present in the forebay area and~~ represent the dominant species in the reservoir, including the forebay area.

3.0 METHODS

3.1 PHYSICAL DATA COLLECTION

The study team on a daily basis from 22 May to 17 June 1999 recorded reservoir water surface elevation and power generation data. Elevation data were recorded from a pressure transducer system (digital display unit) installed by BC Hydro on the intake structure. Power generation at the La Joie facility was recorded from a display located on the control panel within the powerhouse. In addition, water temperature and turbidity data for the reservoir were recorded from 31 May to 17 June 1999. All data were obtained from a site located on the west shore of Downton Lake reservoir, in the forebay area (Figure 3.1). Using an optic turbidity meter, three separate turbidity measurements were recorded at the site; the three values were averaged to obtain a mean turbidity value. Water temperatures were obtained using a handheld digital display thermistor accurate to ±1°C.

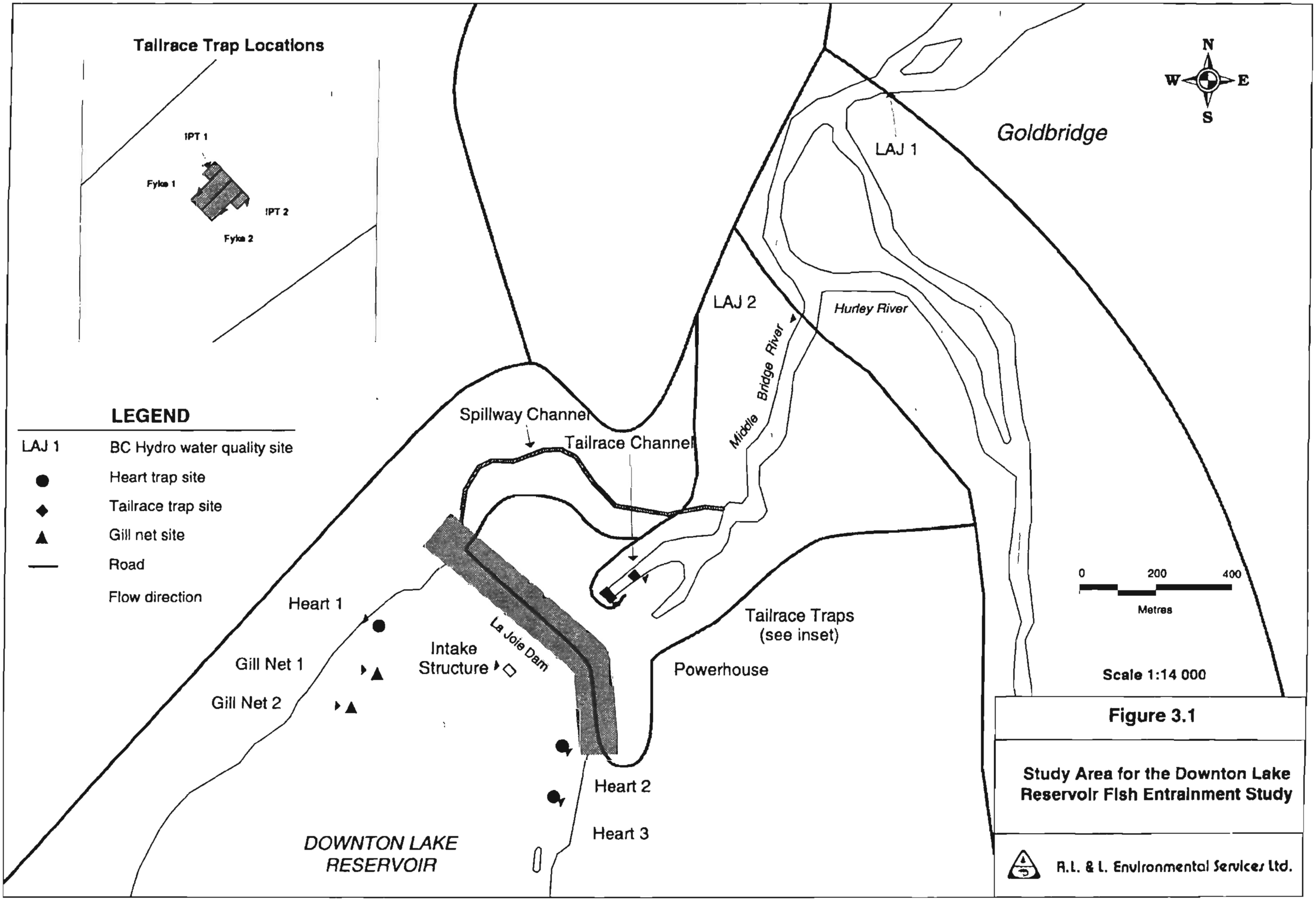
In addition, water temperature, turbidity, and river levels were recorded daily at two monitoring sites (LAJ 1 and LAJ 2) on the Middle Bridge River (Figure 3.1). Turbidity and temperature measurements were recorded at each site using the same techniques employed for the reservoir. River levels were recorded to the nearest centimetre from staff gauges installed in the river at the two monitoring sites. Site LAJ 1 was located at the road crossing near the town site of Goldbridge and downstream from the confluence with the Hurley River (Figure 3.1). Site LAJ 2 was located on the road crossing for the Hurley Forest Service Road, upstream of the Hurley River confluence and approximately 1 km downstream from La Joie Dam.

At Goldbridge, the minimum and maximum air temperatures were obtained on a daily basis at hourly intervals from a continuous recording thermistor. In addition, the amount of precipitation, percent cloud cover, wind direction, and wind velocity were visually estimated at approximately 1400 h each day.

3.2 TAILRACE SAMPLING

To capture fish in the tailrace area, two floating fyke net traps (Fyke 1 and Fyke 2) and two inclined plane traps (IPT 1 and IPT 2) were positioned in the tailrace of La Joie Dam. The traps were situated approximately 100 m downstream from the powerhouse (Figure 3.1). The traps were accessed from the south side of the river using a Zodiac inflatable boat, which was attached to a tether line that extended from the shore to the traps (Plate 1).

The tailrace traps were operated from 21 May to 15 June 1999. Fyke 1 and IPT 1 became operational on 21 May with IPT 2 and Fyke 2 operational on 23 May. All four traps were temporarily removed from service for repair on 12 June. All of the traps were checked twice daily at approximately 12 h intervals. At each servicing, all fish were removed from the live boxes using dip nets and placed in 20 L buckets (Plate 2). Fish from each of the four traps were kept separate and transported to the southeast shore of the Bridge River where they were processed (see Section 3.4).



Tailrace Trap Locations
IPT 1
Fyke 1
IPT 2
Fyke 2
LEGEND
LAJ 1 BC Hydro water quality site
Heart trap site
Tailrace trap site
Gill net site
Road
Flow direction
N
W
E
S
Goldbridge
LAJ 1
LAJ 2
Hurley River
Middle Bridge River
Spillway Channel
Tailrace Channel
Heart 1
Gill Net 1
Gill Net 2
Intake Structure
La Joie Dam
Tailrace Traps (see inset)
Powerhouse
Heart 2
Heart 3
DOWNTON LAKE RESERVOIR
0 200 400
Metres
Scale 1:14 000
Figure 3.1
Study Area for the Downton Lake Reservoir Fish Entrainment Study
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3.2.1 FLOATING FYKE NETS

Each fyke net trap was supported on a 6 m long by 2 m wide floating platform (Plate 3). The mouth of each fyke net was 0.83 m deep by 0.71 m wide and was attached to a rectangular metal frame that was secured to the platform. The cod end of the net was attached to a live box, which was supported by the floating platform. On Fyke 1, the net depth was fixed, and the net sampled from 0.14 to 0.97 m below the surface. On Fyke 2, it was possible to set the net at one of three pre-set depths. Net depth was set to sample from 0.37 to 1.2 m for the entire sample period.

To maintain the traps in position, a cable was pulled across the Bridge River and anchored on each shore. The cable was attached to a large tree on the south shore. On the north shore, where the bank was much steeper, the cable was attached to several concrete blocks positioned on the top of the bank, near the access road to the powerhouse. The anchor point for the north shore was considerably higher than the anchor point for the south shore. A 3 m long "choker" cable was attached to the main cable and anchored into a large boulder along the lower bank of the river to ensure that the main cable was kept approximately level for the section that spanned the river.

Each floating fyke net platform was attached to the main cable with a 30 m long wire rope bridle. The bridle was attached to a pulley and could slide along the main cable crossing. Ropes attached to the pulley allowed the trap to be pulled across the river from either shore and positioned in the main flow of the river channel.

3.2.2 INCLINED PLANE TRAPS

Each IPT trap consisted of an inclined aluminum punch-plate screen and live box secured between two aluminum pontoons. The trap was approximately 2.5 m long and 1.5 m wide; the plane was approximately 0.7 m wide. The angle of the inclined plane was fixed, although an aluminum plate attached to the top of the plane could be pivoted up or down to adjust the crest of water in the live box. The depth of the trap could not be adjusted. Both IPTs sampled the water column from the surface down to a depth of 0.5 m.

The IPTs were secured to the outside of the floating fyke nets with ropes. One IPT was positioned near the stern of each fyke net, allowing the IPT to be serviced from the crew platform on the fyke net (Plate 3). IPT 1 was operated from 21 May to 16 June 1999; IPT 2 was operational from 23 May to 16 June 1999.

3.3 FOREBAY SAMPLING

Heart traps and gill nets were employed to capture fish in Downton Lake reservoir. Although the heart traps were the primary method for fish collection, two small-mesh gill nets (6.4 cm stretched measure) were set to determine if additional uninjured fish for the entrainment experiment could be captured.

One heart trap, supplied by BC Hydro, was set in the shallow areas on the west shore of the forebay near the road access (Heart 1; Plate 4). This trap was operated at this location from 30 May to 4 June 1999 and then moved to the east shore of the reservoir (Heart 2) on 5 June to reduce debris fouling (Plate 5). The trap was operated in this location from 5 to 12 June 1999. A second trap was supplied by B.C. Ministry of Environment, Lands and Parks and was employed from 8 to 12 June 1999. This trap was also set on the east shore (Heart 3), in a small bay (Figure 3.1). All of the traps were serviced using a Zodiac inflatable boat with a 15 Hp outboard motor. In general, the traps were checked daily. Live fish were removed from the trap into two 40 L holding tubs and transported to a net pen (see Section 3.4). The fluctuating reservoir levels required that the heart traps were serviced daily to ensure they were operating properly. Following retrieval of the fish, the nets were repositioned to optimize their performance.

Wind conditions and debris loading, especially at Heart 1, likely affected trap efficiency. Heart 1 was located along the northwest shore of the reservoir and was subject to greater debris loading due to exposure to prevailing winds. Winds were very strong on 4 June 1999, which resulted in debris, including large logs, small woody debris, and small pieces of pumice, becoming entangled in the net. The large logs caused the lead portion of the heart trap to submerge in several places.

3.4 FISH DATA COLLECTION

Fish collected in the tailrace area were identified to species, measured for fork length (FL to the nearest millimetre), and weighed (to the nearest gram). In addition, ageing structures (primarily scales) were collected from all sportfish species. Both live and dead fish were examined for external damage. External injuries were classified into the following six categories:

- missing eye;
- lacerations;
- severed body part;
- impact injury;
- internal hemorrhaging; and
- external bruising.

The level of scale loss was also estimated to the nearest 10%, but differentiation between trap-induced versus entrainment-induced scale loss or injury was not attempted. Dead fish were retained and frozen intact for subsequent use in experimental releases. However, in an attempt to gain a better understanding of the nature of turbine-induced injuries, some of the fish were examined for internal injuries. Rainbow trout captured in the tailrace area were marked by clipping the adipose fin. All fish captured in the tailrace traps were released downstream from the traps.

Fish collected in the forebay area also were identified to species and measured for fork length (FL to the nearest millimetre) and weighed (to the nearest gram). Ageing structures (scales) were collected from sportfish species. Fish were retained until sufficient numbers were collected to conduct the entrainment experiments. Fish captured were initially transferred to a holding pen located in the forebay. The holding pen was relocated to the tailrace area on 7 June 1999 to reduce the likelihood of net pen damage from wave action in the reservoir. Fish captured in the forebay were marked with a series of fin clips or punches to uniquely identify the experimental group. The marking included clipping of the caudal fin as well as punches through the caudal and dorsal fins.

3.5 TRAP EFFICIENCY EXPERIMENTS

To determine the capture efficiencies of the downstream traps, several trap efficiency experiments were conducted. These experiments included:

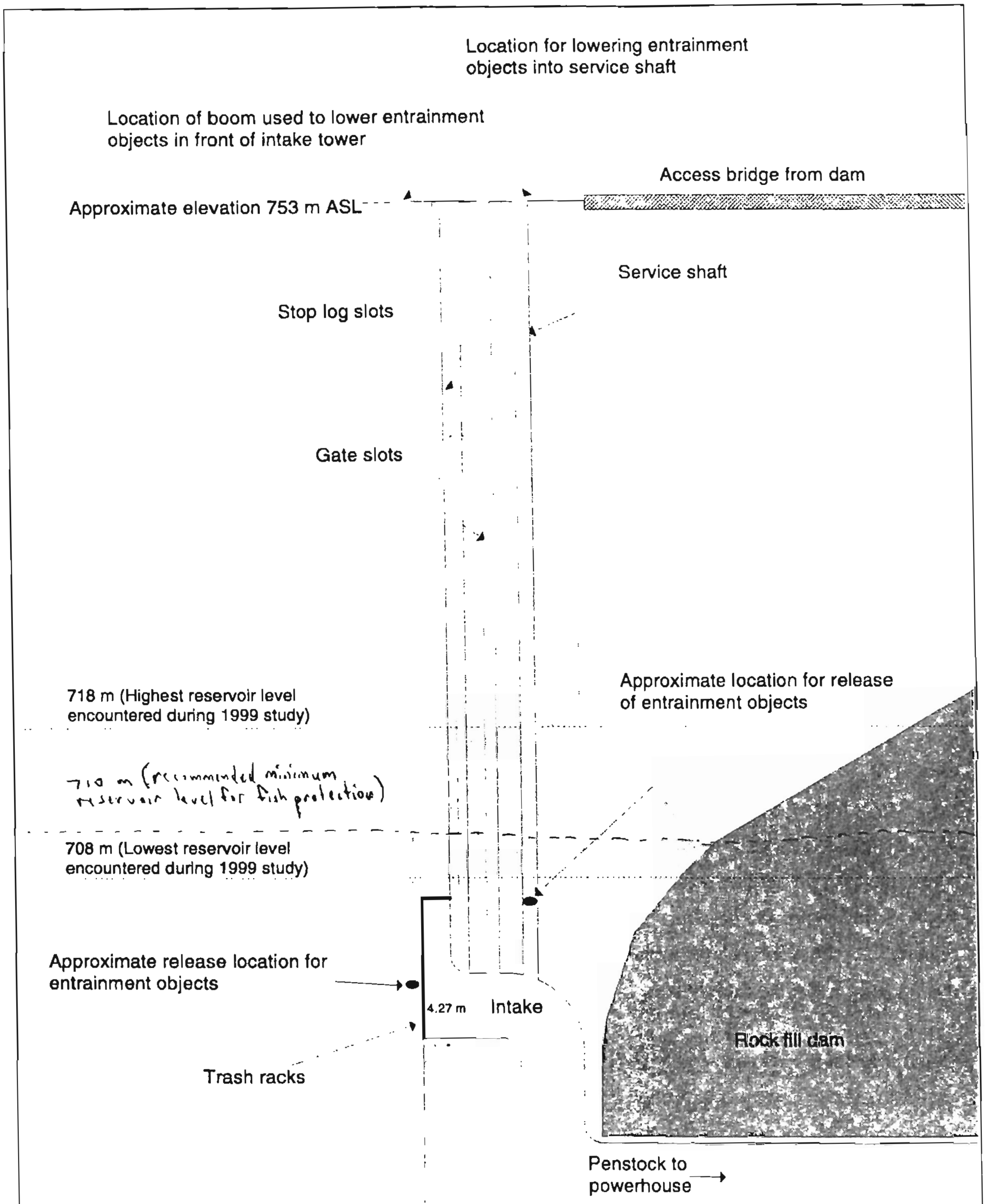
- the release of live fish into the penstock;
- the release of inanimate objects (e.g., radishes) into the penstock;
- the release of radio-tagged fish into the penstock;
- the release of dead fish into the tailrace, upstream from the tailrace traps;
- the release of inanimate objects into the tailrace, upstream from the tailrace traps; and
- the release of live fish into the tailrace, upstream from the tailrace traps.

Live fish collected in the forebay were retained for the trap efficiency experiments. In addition, dead fish collected in the tailrace traps also were retained for trap efficiency experiments; however, live fish collected from the tailrace area were not used for entrainment experiments.

3.5.1 PENSTOCK RELEASES

To determine the efficiency of the downstream traps, the study team released live fish as well as inanimate objects into the turbine intakes. Since local BC Hydro safety requirements ~~safety regulations~~ prohibited the use of boats in the forebay near the intake structure, all work was conducted from the platform of the intake tower.

Fish and inanimate objects were introduced into an access shaft that lead to the penstocks (Figure 3.2). Test objects were lowered into the shaft in a bucket and released using a remote mechanism that emptied the contents of the bucket when the bucket reached the desired depth. Test objects could not be lowered directly into the penstock area because of a jog in the service shaft (Figure 3.2). In total, 190 radishes were released into the shaft on one single occasion on 3 June 1999. In addition, 30 marked rainbow trout (29 live, one dead) were released into the penstock via the access shaft on the same day. The rainbow trout were uniquely marked with a fin clip, which allowed them to be identified from other fish marked during the study.



Note: Figure is for illustrative purposes only. Dimensions and locations are approximate.

Figure 3.2

Cross-sectional Diagram of the Intake Structure at La Joie Dam

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To help determine movements of fish out of the intake structure, two radio-tagged rainbow trout (one live and one dead) were introduced into the access shaft. American Telemetry Systems (ATS) low frequency radio tags (41.460 and 41.640 MHz) were employed for the study. Each tag weighed approximately 9 g. To reduce the effects of the implantation, the live fish selected for radio tagging exceeded 300 g in weight. Prior to implantation, this fish was anaesthetised by immersion in a bath of water mixed with clove oil (70 mg/L) following the methods outlined in Anderson et al. (1995). The radio tag was implanted into the stomach of the fish by manually inserting the tag into the esophagus. The antenna was allowed to protrude from the mouth of the fish following implantation. The fish recovered in a tank of water and was held for 1 h prior to release. The field crew monitored the movements of both the live and dead radio-tagged fish to determine if they were entrained through the power facility and into the Middle Bridge River. The area downstream of the dam was monitored continuously using an ATS radio receiver equipped with a whip antenna for several hours following the release of the radio-tagged rainbow trout.

The study team also attempted to entrain inanimate objects and other fish by releasing them directly in front of the intakes in the forebay. Due to the design of the intake structure, the fish could not be lowered directly from the top of the intake structure (Figure 3.2; Plates 6 and 7). Therefore, a 5 m long boom was attached to the intake structure directly overhead of the southeast intake to ensure that objects lowered to the water would not strike the trash rack structure when lowered below an elevation of 697 m. A pulley was secured at the end of the boom to aid in raising and lowering the release device.

The test objects were placed inside a plastic 20 L bucket filled with water. A short section of pipe was attached to the bottom of the pail to ensure that the bucket and its contents would sink when lowered into the water (Plate 8). The bucket was lowered to the desired depth (i.e., in front of the intake) using a rope threaded through the pulley. To retain the contents of the bucket when in the water, a mesh cover was positioned over the top of the bucket and secured in place with a rubber cord. A second rope was attached to the rubber cord, and when pulled, removed the cover from the bucket and released the contents. This technique was repeated several times using small quantities of radishes and oranges until the proper release technique was developed. Oranges were only used to develop this technique and were not deployed in the entrainment tests.

Once the technique was established, an experimental release of 300 radishes was conducted on 4 June 1999. Following the release, the downstream traps were checked for recaptures. On 11 June 1999, 11 rainbow trout (10 live, 1 dead) also were released in this manner. For both releases, the bucket was lowered to a position directly in front of the intake, where water velocity and therefore entrainment, was presumed to be the highest.

3.5.2 TAILRACE RELEASES

In addition to the penstock releases, fish and inanimate objects were released directly into the tailrace from immediately below the powerhouse to test the efficiency of the traps. An initial trial release of 200 peanuts (in the shell) was conducted on 22 May 1999. However, the use of peanuts was discontinued because of unsatisfactory results. Radishes were employed for subsequent releases. In total, 1200 radishes were released in three separate experiments conducted on 23 May (*n*=200), 1 June (*n*=500), and 8 June 1999 (*n*=500). On all occasions, the release objects were placed in 22 L buckets and were released simultaneously into the tailrace from the ledge at the downstream end of the powerhouse. Following the releases, the traps were checked to determine recaptures.

Live and dead rainbow trout also were released directly into the tailrace to determine trap efficiency. On 1 June 1999, 62 live rainbow trout were released. The fish were uniquely marked with a hole punch in the caudal fin to distinguish them from other fish marked during the study. The fish were transported from a holding pen in the forebay area to the powerhouse in a large, truck-mounted tank. The tank was supplied with oxygen to ensure the fish were maintained in good condition during transportation. The fish were transported from the truck into the powerhouse in 25 L buckets and placed in one of two holding tanks positioned on the ledge near the tailrace. Once all of the fish were in the tanks, the fish from both tanks were simultaneously released into the tailrace.

On 4 June 1999, dead rainbow trout were released into the tailrace. To increase the number of released objects, a mixture of whole fish and fish parts were released. Smaller fish were retained whole for the experiment. Larger fish were cut into several pieces, each approximately 100 mm long. All of the dead fish were placed in one bucket and released into the tailrace from the ledge on the powerhouse, similar to other tailrace releases. The traps were checked for recaptures following the releases.

3.5.3 TRAP EFFIENCY AND ENTRAINMENT ESTIMATION

The initial study plan involved determining the trap efficiency estimates from the one-site mark-recapture experiment by minor modification of the methods described by Carlson et al. (1998). Radish recovery experiments were the only test that provided adequate information to estimate trap efficiencies. Recaptures of marked fish releases were of insufficient number to provide useful information.

The terms used in the formula to calculate trap efficiency are defined as follows:

- h = stratum index (capture period or specific type of test and a corresponding trap efficiency trial);
- i = daily capture period corresponding to an assumed fixed reservoir water elevation level;
- L = number of strata or periods ($h = 1, 2, \ldots, L$);
- M_h = number of marked objects released in stratum h;
- M = total number of marked objects released ($= \Sigma M_h$);
- m_h = number of marked objects recaptured in h;

u_h = number of fish caught in trap during strata h;

u_i = number of fish caught in trap during the *ith* day;

N_h = total fish population size in *h*,;

N = total fish population size (= ΣN_h); and

e_h = object capture probability (trap efficiency) in *h* (= m_h/M_h)

The parameters *L*, M_h, and *M* are known and the random variables are u_h and m_h All captures occur at one location so that *M* and M_h refer to the upstream releases.

The objective is to estimate the entrained fish population by applying an estimate of trap efficiency to the number of trapped fish. The variety of mark release methods used requires that each experiment is considered as a separate stratum unless the data indicate recovery rates are not distinguishable. For each stratum *h*, the fundamental estimator is a Peterson estimate of the unmarked population:

$$\tilde{N}_h = \frac{u_h M_h}{m_h}, \qquad (1)$$

An approximately unbiased estimate of N_h is:

$$\hat{N}_h = \frac{u_h (M_h + 1)}{m_h + 1} \qquad (2)$$

An approximately unbiased variance estimate of $\hat{N}_h$ is:

$$v(\hat{N}_h) = \frac{(M_h + 1)(u_h + m_h + 1)(M_h - m_h)u_h}{(m_h + 1)^2 (m_h + 2)} \qquad (3)$$

The approximately unbiased stratum estimators are $\hat{N}_h$ and $v(\hat{N}_h)$ The total fish entrainment estimate for the period that was sampled is:

$$\hat{N} = \sum_{h=1}^{L} \hat{N}_h \qquad (4)$$

and the variance estimate is:

$$v(\hat{N}) = \sum_{h=1}^{L} v(\hat{N}_h) \qquad (5)$$

An approximate 95% confidence interval for $\hat{N}$ is:

$$\hat{N} \pm 1.96\sqrt{v(\hat{N})} \qquad (6)$$

Strata were aggregated by testing for consistency. The null hypothesis (H_0) of constant capture probability over all sampling periods was tested using a Chi-square test of homogeneity. If the test was non-significant, the strata were pooled (equivalent to accepting H_0) and the estimator was applied to estimate $\hat{N}$ (Equation 2). The advice of Carlson et al. (1998) was followed to set a conservative significance level for accepting H_0 of α=0.15). The method consists of a test of homogeneity for the rows of an *L*-by-2 contingency table of M–R counts. Tag loss in all experiments was assumed to be zero. As sufficient samples were not obtained to distinguish among temporal strata, the variance and mean were estimated from aggregated samples over mark-recapture tests that were homogeneous.

These methods allow estimation of entrainment while the trap studies were ongoing. Projections of the number of fish entrained throughout the study period were based on a relationship of CPUE (catch-per-unit-effort) of the downstream traps to reservoir water elevations. Assuming this relationship did not change over time, the proportion of the total number of fish entrained during the time period of this study could then be estimated by applying the catch-rate over the range of reservoir elevations during the time periods when entrainment was likely. The estimate is bound by the projection confidence limits of the regression relationship. For these confidence limits to be unbiased, an assumption is required that the observed relationship must hold over time; the accuracy of this assumption has not been determined.

Catch for each day (u_i) was regressed against reservoir water level elevations after transformation following Sokal and Rolf (1981) by:

$$Log(u_i + 1) = \alpha + \beta \bullet Elev_i + e \qquad (7)$$

The prediction standard error at each lake elevation on the *ith* day equals:

$$\hat{S}_{Log(u_i+1)} = \sqrt{s^2\left[1 + \frac{1}{n} + \frac{(Elev)_i - \overline{(Elev)}^2}{\sum d(Elev)^2}\right]} \qquad (8)$$

where s^2=the variance of e from Equation 7 and *d(Elev)*=the mean deviation of *Elev*. The confidence interval for catch at each *i* is:

$$CI_{.05} = Log(u_i + 1) \pm t_{.05(n-2)} \bullet \hat{S}_{Log(u_i+1)} \qquad (9)$$

The estimate of the total number of fish entrained during the expanded period was estimated by:

$$\hat{N} = \sum_{i} \left[\frac{EXP\,(Log\,(u_i+1))-1}{e_h} \right] \qquad (10)$$

The 95% confidence bounds were estimated by substituting the maximum and minimum values resulting from Equation 9 for $Log(u_i+1)$ into Equation 10. The variance component from Equation 5 was not included in the estimate. The biases associated with applying catch-rates based on inanimate object recoveries and the presence of fish other than those entrained in the tailrace most likely overwhelm sampling errors; consequently total population estimates should be considered as indices of relative abundance rather than estimates of actual entrainment levels. Confidence in the estimate of total entrainment should be based on the confidence in the assumption that trap catch-rates and inanimate object trap efficiencies reflect capture of entrained fish and trap efficiency of entrained fish.

4.0 RESULTS

4.1 PHYSICAL DATA

At the commencement of the study, reservoir elevation was 708.13 masl (all reservoir elevations are given as metres above sea level unless specified otherwise). Reservoir levels during the study decreased to 708.0 m on 23 May 1999, then steadily increased until the termination of the study on 17 June 1999 (Appendix A, Figure A1). At the completion of the study, reservoir elevation was recorded at 718.18 m. All physical data recorded during the study are included in Appendix A, Table A1.

In general, generation at the La Joie Dam powerplant increased with rising reservoir levels. The lowest generation of 6.5 MW was recorded on 24 May 1999, when reservoir elevation was 708.09 m. Generation had increased to 13.3 MW by 17 June 1999 when the project was completed. Major alterations in the operation of the La Joie dam powerplant were not made from the beginning of the study until 16 June 1999. The increase in generation of the plant over the course of the study was the result of increased head as reservoir levels rose. On 16 June 1999, flow was diverted from the turbine through the low-level release structure. This resulted in a substantial alteration of the flow regime in the tailrace area. The tailrace traps were damaged during this event and the sample program was subsequently discontinued.

Discharge in the tailrace area of La Joie Dam increased approximately 0.14 m throughout the study period as reservoir levels increased (Appendix A, Figure A1). In the Bridge River downstream of the Hurley River confluence (Site LAJ 1), water levels ranged from 1.16 to 1.87 m (Appendix A, Figure A1).

Surface water temperatures in the forebay area of Downton Lake reservoir ranged from 11.5°C on 31 May 1999 to 20.0°C on 15 June 1999 (Appendix A, Table A1). In the Bridge River at LAJ 2 (upstream of Hurley River), water temperatures over this same period ranged from 8.0 to 11.8°C. Downstream of the Hurley River at LAJ 1, water temperatures in the Bridge River ranged from 2.9 to 8.7°C and were generally lower than temperatures recorded at LAJ 2. Temperatures at LAJ 1 were affected by the influence of the Hurley River. During periods of snowmelt, as indicated by high turbidity levels, water temperatures decreased substantially. During these same periods, water temperatures and turbidity in the tailrace area remained relatively stable.

Debris loads in both the reservoir and the tailrace were highly variable and appeared dependent on wind conditions on the reservoir. Debris loads in the traps were considered low during approximately 85% of the trap checks, medium on 8%, and high on 7% of the occasions the traps were checked. Trap location affected the debris load.

4.2 FOREBAY FISH SAMPLING

Rainbow trout was the dominant fish species captured in the forebay of La Joie Dam during sampling in 1999. In total, 161 rainbow trout were captured during sampling in the forebay; 159 were captured using heart traps and two were captured during trial sampling with gill nets. In addition to rainbow trout, one bridgelip sucker was captured in a heart trap (Appendix B, Table B1).

Rainbow trout captured in the forebay ranged in fork length from 104 to 338 mm (Figure 4.1). The weight of captured rainbow ranged from 14 to 360 g. All of the rainbow trout captured in the forebay were retained for trap efficiency tests. The bridgelip sucker was 440 mm long and weighed 1336 g; this fish was released unmarked into the reservoir. Several size-classes of rainbow trout were captured during sampling in the forebay (Figure 4.1). The heart traps were selective in capturing larger rainbow trout, with the majority (71%) of fish being greater than 200 mm.

The CPUE for the heart traps varied considerably during the course of the study (Appendix B, Table B2). In general, CPUE values for the heart traps decreased over the course of the field program, with the highest catch-rate (0.50 fish/h) obtained on 31 May 1999. As the reservoir level increased, heart trap catch-rates may have slightly declined (Figure 4.2).

4.3 TAILRACE FISH SAMPLING

In total, 89 fish were captured in the traps located in the tailrace. Of the fish captured, 72 were rainbow trout, with the remainder composed of coastrange sculpin (n=16) and bridgelip sucker (n=1). Four partial rainbow trout carcasses were recovered in the tailrace traps. In addition, internal body parts were recovered on several occasions in the traps, including eyes and pyloric caeca. One rainbow trout released alive into the tailrace area after capture in the tailrace traps was subsequently recaptured in Fyke 1. This fish was the only recapture of a fish released into the tailrace.

Fork lengths of rainbow trout captured in the tailrace traps ranged from 79 to 337 mm; weights ranged from 4 to 404 g (Appendix B, Table B1). Total lengths of the coastrange sculpin captured in the tailrace traps ranged from 53 to 73 mm. The bridgelip sucker captured in the tailrace had a fork length of 374 mm and weighed 514 g. The size-classes of rainbow trout captured in the tailrace were similar to those captured during sampling in the forebay (Figure 4.1). Smaller fish constituted a larger portion of the catch in the tailrace than in the forebay; 34% of the fish captured in the tailrace were less than 200 mm FL.

Captures in the tailrace traps generally declined throughout the study at a much faster rate than was observed in the heart traps (Appendix B, Table B3). For rainbow trout captured in the fyke nets, daily CPUE values for the tailrace fyke net catches combined ranged from 0.07 to 0.20 fish/h per trap (Figure 4.3). Mean catch-rates were substantially different between the IPTs (Appendix B, Table B3). The CPUE for Fyke 1 was highest, with a mean CPUE of 0.09 fish/h. Fyke 2 had the next highest capture rate at 0.034 fish/h, followed by IPT 1 (0.019 fish/h) and IPT 2 (0.006 fish/h).

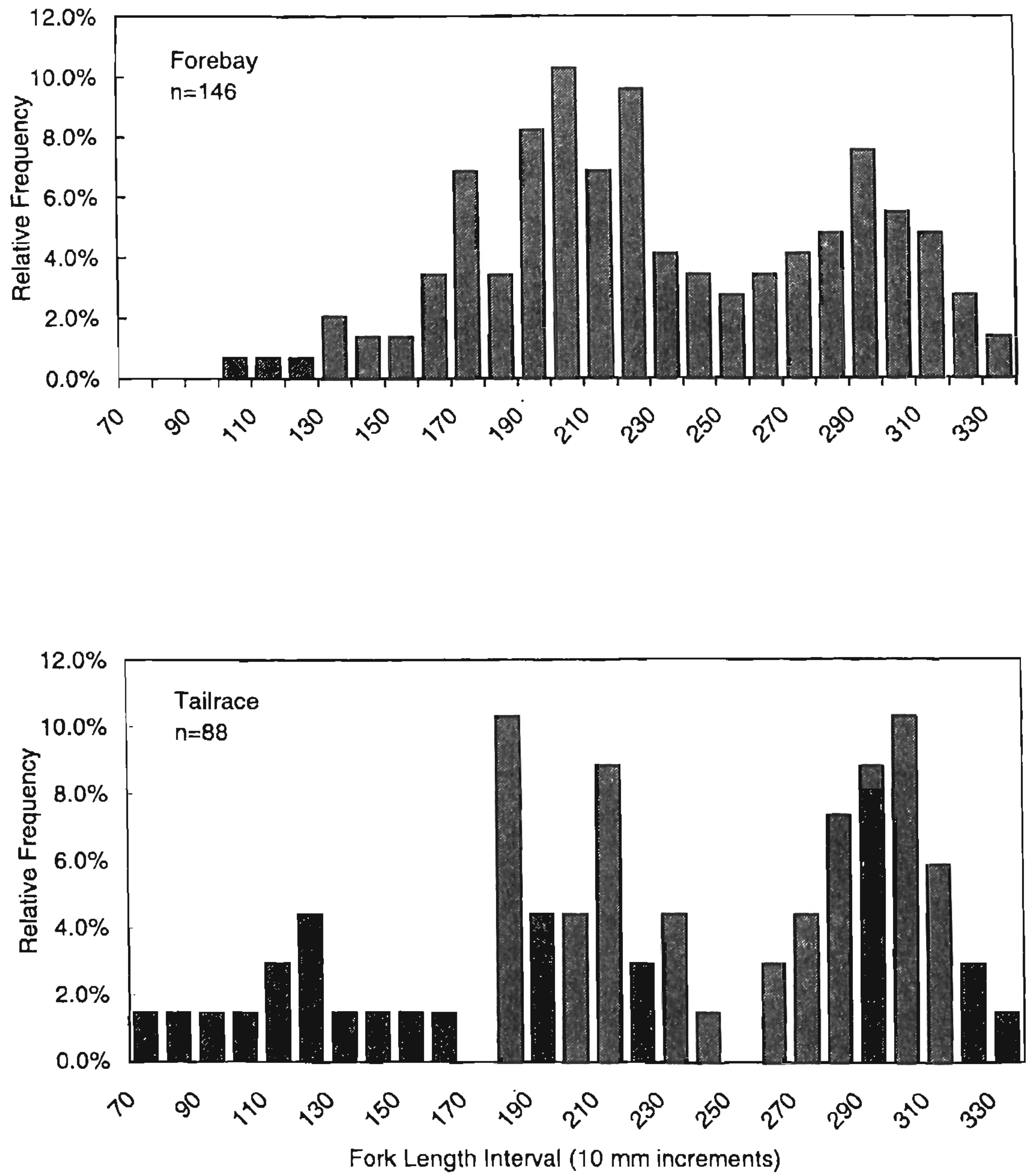


Figure 4.1 Length-frequency distribution for rainbow trout captured in the forebay of Downton Lake reservoir and in the tailrace of La Joie Dam, May and June 1999.

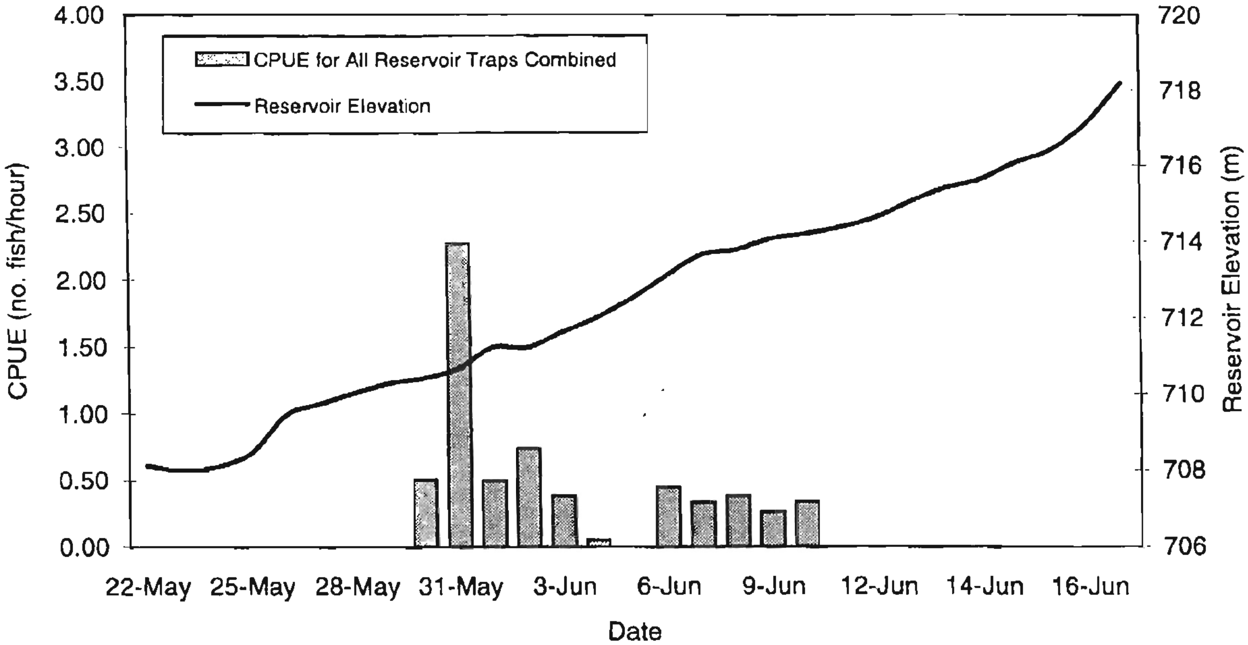


Figure 4.2 Catch-per-unit-effort (CPUE) for rainbow trout captured in heart traps set in the forebay of Downton Lake reservoir (30 May to 12 June 1999) and corresponding reservoir surface elevations (22 May to 17 June 1999).

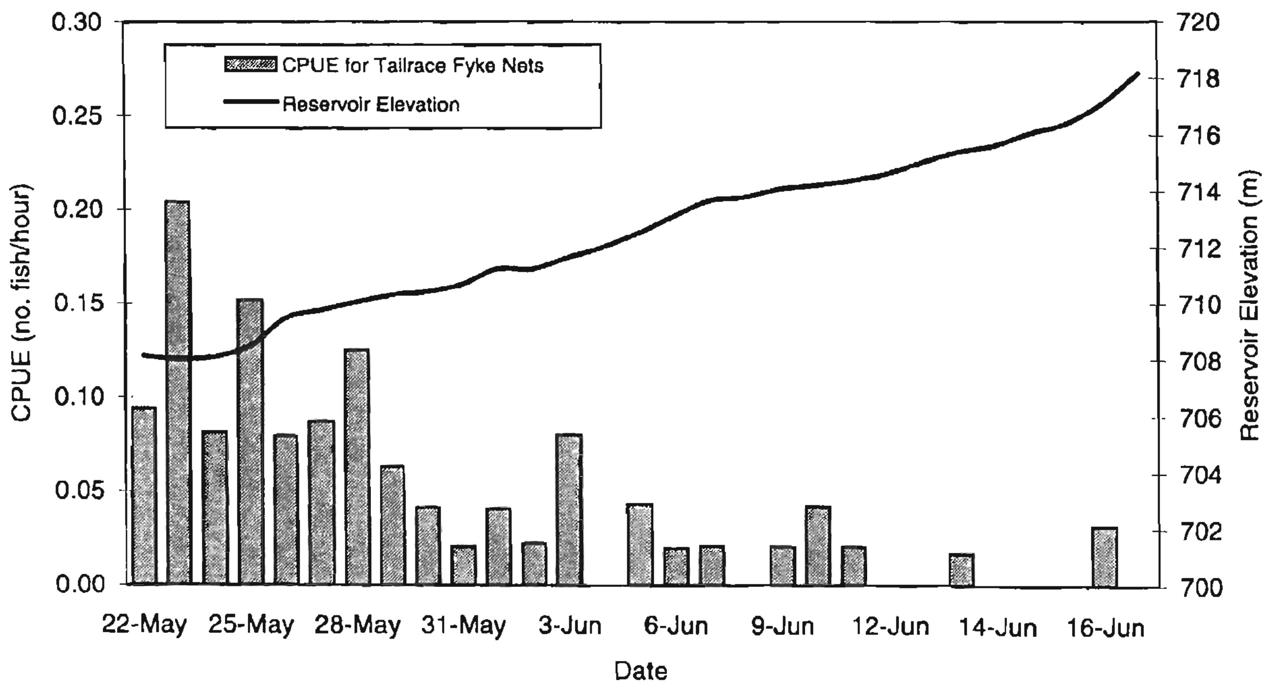


Figure 4.3 Catch-per-unit-effort (CPUE) for rainbow trout captured in the tailrace fyke nets and corresponding surface elevations of Downton Lake reservoir, 22 May to 17 June 1999.

4.4 FISH INJURY

Rainbow trout were the only fish species captured in the tailrace traps that showed any indication of injury; dead sculpins or suckers were not recovered. In total, 31 dead rainbow trout (including four partial carcasses) were recovered in the tailrace traps. This represented 43% of the total rainbow trout catch from these traps.

Scale loss was the most common injury recorded for rainbow trout captured in the tailrace traps, with 53% of fish (excluding partial carcasses) exhibiting some degree of scale loss (Figure 4.4). A higher degree of scale loss was noted among the dead rainbow trout. Of the 31 dead rainbow trout recovered (excluding partial carcasses), 51% (*n*=16) had greater than 5% scale loss and 35% (*n*=11) had greater than 40% scale loss. Among live rainbow trout, the degree of scale loss was lower. Only one live fish had scale loss that exceeded 5% and none were captured with scale loss that exceeded 10% (Appendix B, Table B4).

In addition to scale loss, 36.8% (*n*=25) of the rainbow trout were injured in some manner that could be observed by the field crews. Other than scale loss, lacerations were the most common injury observed, with 12 (28%) of the 43 fish possessing at least one laceration (Figure 4.5). External bruising (*n*=8; 19%) and internal haemorrhaging (*n*=7; 16%) were the next most common forms of injury. Severed body parts, impact injuries, and missing eyes also were noted (Appendix B, Table B5; Plate 9). Injuries of any type were not observed on the sculpins or on the bridgelip sucker captured in the tailrace traps.

Turbine induced injuries were less frequently recorded for smaller rainbow trout, especially those less than 150 mm FL (Figure 4.6). Injuries were not observed on rainbow trout less than 110 mm FL and only one fish less than 150 mm FL suffered some form of injury other than scale loss.

4.5 TRAP EFFICIENCY EXPERIMENTS

4.5.1 TAILRACE RELEASES

The release of radishes and peanuts were the two methods used to determined capture efficiencies of the tailrace traps. Peanuts, which were employed in an initial trial, proved to be unsuitable for use in entrainment experiments because they floated and were easily affected by the turbulence in the tailrace area. Many of the peanuts released into the tailrace area were washed onto the river banks immediately downstream of the powerhouse. In addition, since the peanuts floated, they were not suitable for determining the efficiency of the fyke nets, which did not sample the surface of the water column. Of the 200 peanuts released into the tailrace, only 6 were recovered (Table 4.1). All of the peanuts were recovered in IPT 1. Based on these results, the use of peanuts was discontinued as a method to determine trap efficiencies.

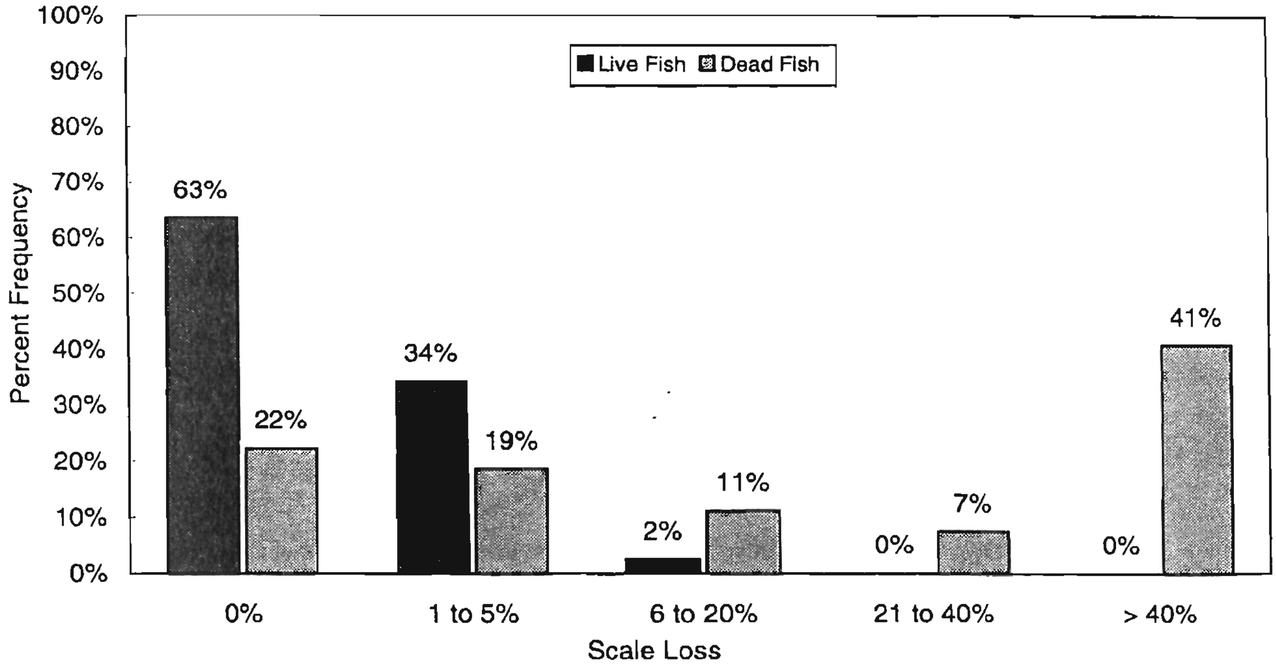


Figure 4.4 Scale loss (reported as percent of total body surface area) recorded among dead and live rainbow trout captured in tailrace traps below La Joie Dam, May to June 1999.

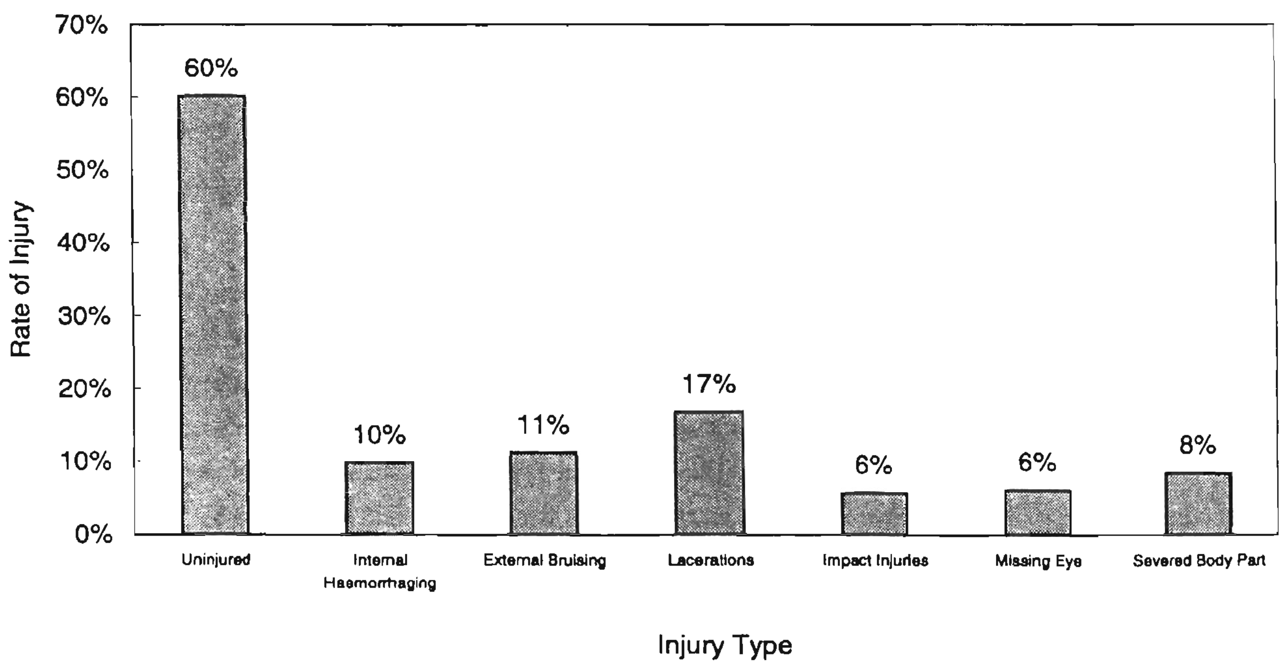


Figure 4.5 Types and rates of injuries observed in rainbow trout captured in tailrace traps below La Joie Dam, May to June 1999.

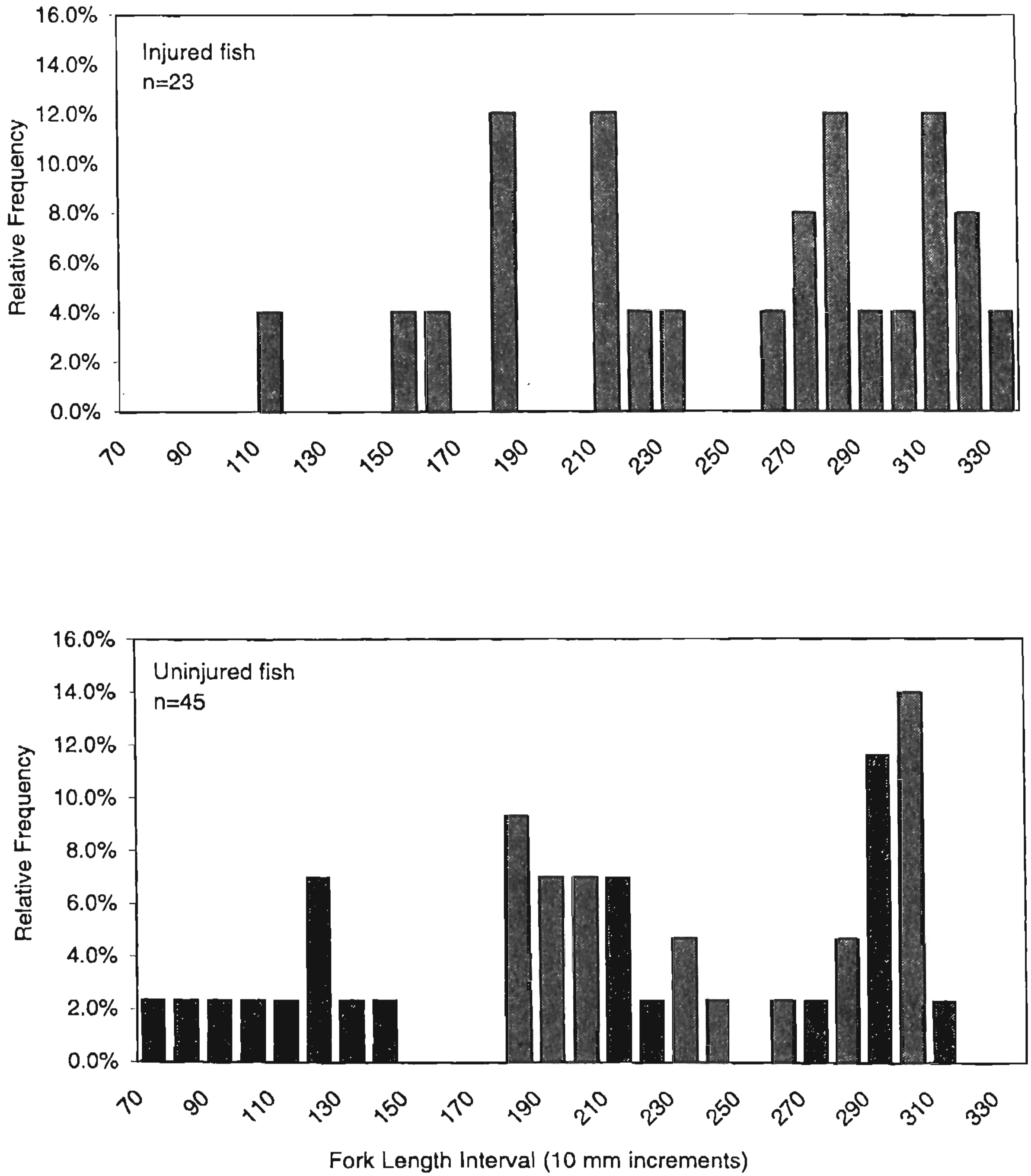


Figure 4.6 Length-frequency distribution for injured and non-injured rainbow trout captured in the tailrace of La Joie Dam, May and June 1999.

Table 4.1 Summary of experimental releases conducted to test tailrace trap efficiency, 25 May to 12 June 1999.

Release Location	Object	Date	No. Released	No. Recaptured
Tailrace	Peanuts	22 May	200	6
	Radishes	23 May	200	18
	Radishes	1 June	500	39
	Live rainbow trout	1 June	62	0
	Dead rainbow trout	4 June	46	1
	Radishes	8 June	500	24
Penstock (via service shaft)	Radishes	3 June	190	0
	Rainbow trout	3 June	30*	2
(via intake)	Radishes	4 June	300	23
	Live rainbow trout	11 June	10	0
	Dead rainbow trout	11 June	1	0

* Includes 29 live fish (one with an implanted radio tag and 28 marked with a fin punch) and one dead fish with an implanted radio tag.

Radishes proved to be the more effective of the two methods employed, but as was observed for the peanuts, the dispersal of radishes also was influenced by turbulence in the tailrace. After release, many radishes were carried into the nearshore eddies, especially near the low-level outlet. Following releases on 1 June and 8 June 1999, radishes were recovered in the downstream traps for several days. In total, 1200 radishes were released into the tailrace on three separate occasions. Of these, 81 were recovered in the traps (Table 4.1). However, unknown to the field crew, Fyke 1 became non-operational during part of the release period on 8 June 1999 because of a mechanical failure, which reduced the recapture rate. Consequently, data from this trial were excluded from the analysis.

Live fish (*n*=62) also were released into the tailrace area but none were recaptured in the tailrace traps. Of the 46 fish parts released into the tailrace on 4 June 1999, only one was recovered.

4.5.2 PENSTOCK RELEASES

None of the 190 radishes released into the service shaft were recovered in the tailrace traps (Table 4.1). After their release, radishes were observed floating on the water surface in the service shaft. Of the 28 marked rainbow trout released into the service shaft on 3 June, two were recovered in a downstream tailrace fyke net. Of the 300 radishes released in front of the intake on 4 June, 23 were recovered in the tailrace.

The two radio-tagged rainbow trout (i.e., one live and one dead) released into the service shaft were monitored by radio receiver for several minutes following release on 3 June 1999. The radio signal from the live rainbow trout was picked up in the Middle Bridge River, below La Joie Dam, approximately 8 h after release. The fish was tracked down river to near the Hurley River confluence and subsequently remained near this point. The radio signal from the tag implanted in the dead rainbow trout was not received following release.

None of the 10 live and one dead rainbow trout released in the forebay in front of the penstock intake were recaptured (Table 4.1).

4.6 ENTRAINMENT ESTIMATES

Estimates of entrainment could only be completed by making certain assumptions about the recapture experiments and how they applied to fish that were naturally entrained (Appendix C, Tables C1 to C5). The type of traps used in this study would be expected to have different capture rates for live fish than for dead fish. In addition, live fish could originate from downstream locations (i.e., from within the tailrace) and not reflect the entrained population. The optimal method of obtaining accurate trap efficiencies is to intentionally entrain marked fish and observe their downstream recovery rates. In the present study, the difficulty in accessing the penstock inlets required conducting a range of other experiments to provide an assessment of downstream trap performances (Appendix C, Table C1).

Live fish released in the tailrace were not recaptured; releases of dead fish were limited by the number of dead fish available and resulted in only one recovery. Of 28 tagged live fish released into the penstock via the service shaft, two were recovered in the downstream traps (Appendix C, Table C1). These data are insufficient to allow a credible population expansion based on downstream capture rates. However, the several experiments using radishes resulted in sufficient recoveries to provide an estimate with statistical limits on the estimated trap efficiency. The assumption that dead fish recapture rates were similar to the radish recapture rate is most likely not valid. However, applying the radish recovery estimator and its variance to the trap capture rates provided some idea as to the magnitude of entrainment that occurred during the study period.

Trap efficiency estimates by mark and recapture were tested for homogeneity by a Chi-square test, prior to aggregation (Appendix C Table C2). The IPTs captured only 11 rainbow trout compared to the 58 rainbow trout caught in the fyke nets. The radish experiments were treated separately for the other tests. The service shaft releases did not result in entrainment; therefore, these data were excluded from the analysis. One intake release and three tailrace releases of radishes were examined for consistency of recovery rates in the fyke nets. Only the 8 June 1999 release provided a recovery rate (1.2% per trap) significantly different from the other three experiments (2.4% per trap). Since the 8 June release occurred when one of the fyke nets were inoperative during part of the experiment, the projections were made using only the aggregated data from the earlier three experiments (Appendix C, Table C3). Confidence limits (95%) based on the fyke net radish recoveries applied only during the days that traps were deployed, ranged from 789 to 1581 with a mean of 1185 (Appendix C, Table C5). These estimates assumed 100% of all rainbow trout caught in the tailrace traps represented entrained fish. The recovery of one fish that was originally caught in the tailrace traps, tagged and released, and then subsequently recaptured back in the tailrace traps indicates this assumption was violated. However, the single recovery of a tagged fish released in the tailrace area does not allow a reliable estimation of the proportion of captured fish that were not entrained.

Despite the low catch-rates, a highly significant relationship of fyke net CPUEs to reservoir elevation was observed (Figure 4.7; Appendix C, Table C4). Factors such as emigration of the forebay fish population either upstream out of the forebay area or downstream through the dam also could influence entrainment rates. However, when forebay heart trap CPUEs (Appendix B, Table B2), mean daily water temperature, mean daily discharge, and forebay turbidity (Appendix A, Table A1) were tested as covariates, these variables were not found to significantly affect CPUE of the fyke nets. Consequently, a model developed with only reservoir elevation as the predictor variable was used in further projections. Projections of the fyke net CPUEs outside of the study period was completed by relating downstream fyke net CPUE to the Downton Lake reservoir elevations (Figure 4.8; Appendix C, Table C5). This projection assumed a per fyke net catch-rate of 2.4% and resulted in a total entrainment estimate of 2993 rainbow trout (95% prediction limit of the regression=1691 to 6005 fish). This estimate was limited to the low reservoir elevation period of 1 April to 1 August 1999. Since the annual minimum water level occurred during the course of the study and was included in the data collection period used for development of the regression, projections of entrainment losses that occurred prior to the beginning of the study (i.e., by extrapolation from reservoir elevations) was justified. This extrapolation assumed entrainment rates as a function of reservoir elevation did not change over time. For this condition to be maintained, fish populations subject to entrainment (i.e., those present in the forebay) would need to remain somewhat constant. The CPUE variation of the forebay heart traps did not significantly affect tailrace CPUE during the sampling period, suggesting forebay abundance may have been reasonably stable over the period that entrainment was projected.

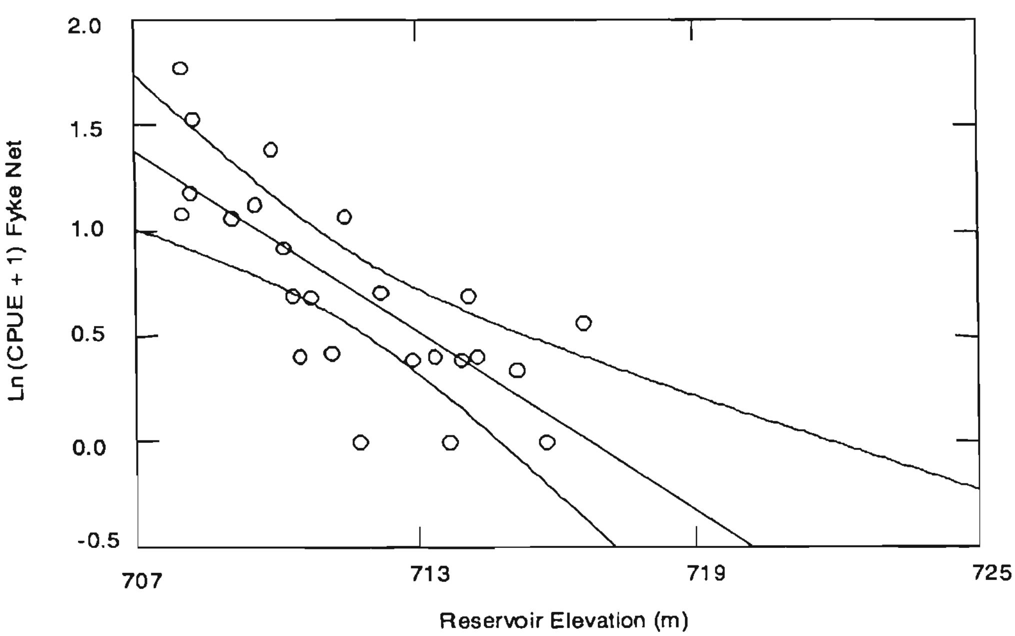
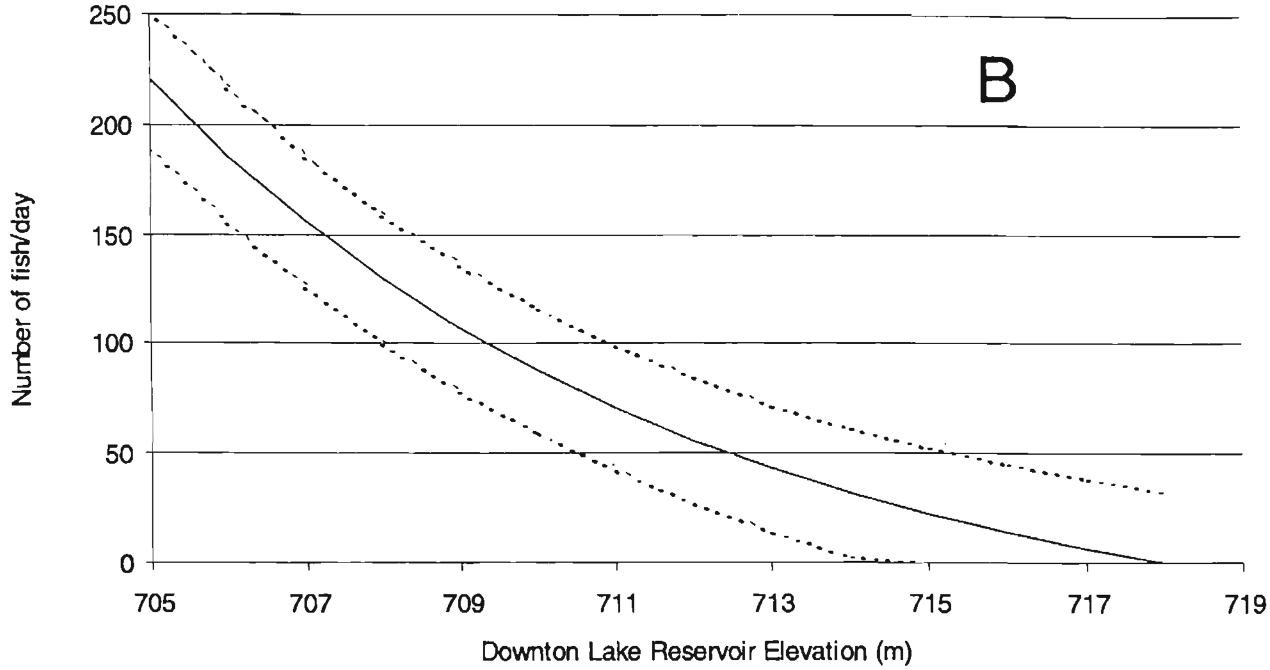


Figure 4.7 Relationship of fyke net catch-per-unit-effort (CPUE=no. fish/day) to the surface elevation of Downton Lake reservoir. The linear fit with 95% CI of the regression line are projected.



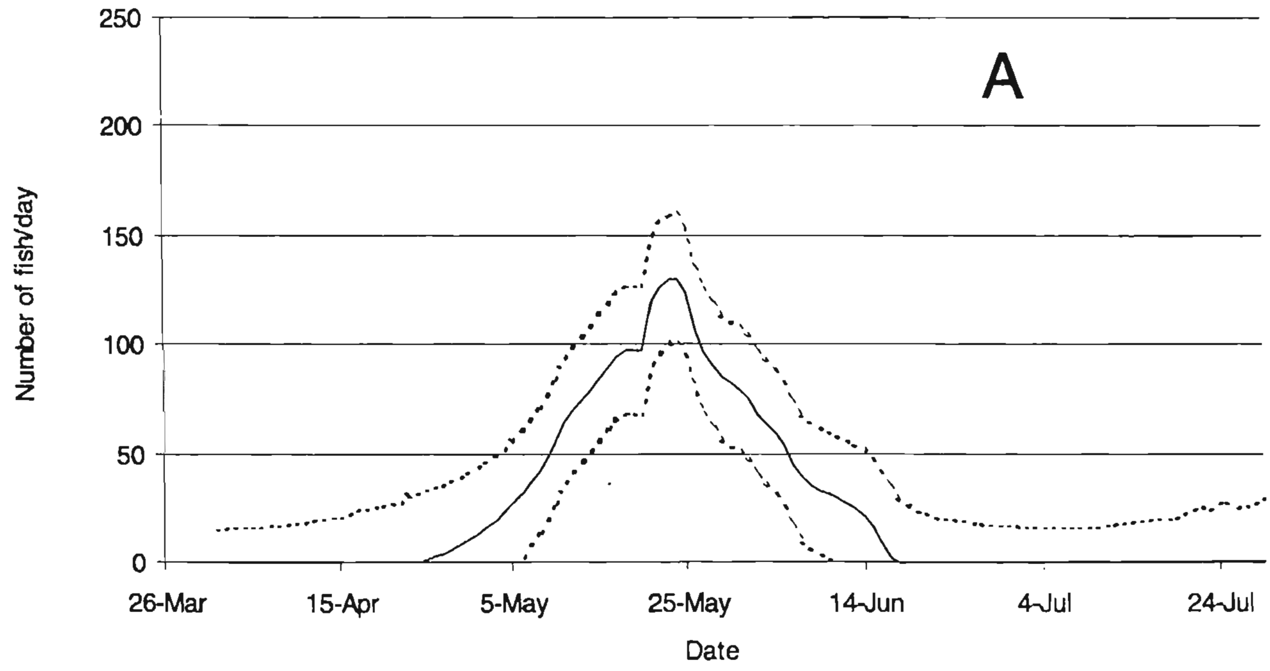


Figure 4.8 Projections of rainbow trout entrainment rates at the La Joie Dam powerplant over time (A) and as a function of the reservoir forebay elevation (B) during 1999. Dotted lines indicate the 95% CI for the projected entrainment rate at any given elevation of Downton Lake reservoir.

5.0 DISCUSSION AND RECOMMENDATIONS

5.1 FISH SPECIES ASSEMBLAGE

As was the case in previous studies on Downton Lake reservoir, in the present study, rainbow trout were the dominant species captured in the forebay. Bridgelip sucker, the only other species recorded in the forebay area, had not been previously reported from Downton Lake reservoir.

Coastrange sculpin were captured in the tailrace traps but were not captured in the forebay during this study. This species has not been reported from Downton Lake reservoir or in tributaries to the reservoir in previous studies. The sampling gear employed during this study (heart traps and gill nets) and in previous studies (gill nets) targeted large fish. As a result, the information currently available is not considered to provide an accurate description of species assemblage in Downton Lake reservoir. Generally, a variety of gear types are required to determine fish species assemblages of reservoirs (Hayes et al. 1996).

5.2 MORTALITY AND INJURIES

Three general types of injury can occur as the result of entrainment at a hydroelectric facility: (1) physical contact with the turbine blades; (2) rapid pressure changes; and (3) shear forces and turbulence (Eicher Associates 1987). Fish may also experience stress from passage, which can affect their survival.

Mechanical injuries are caused by the fish coming in contact with solid surfaces of the turbine. Mechanical injuries include severed or ground bodies, skeletal fractures, scraped or crushed heads, internal haemorrhaging, lacerations or bruises, and missing or popped eyes (Eicher 1988). Lacerations, bruising, and internal haemorrhaging were observed in fish captured in the tailrace traps.

Fish size is one of the most important factors affecting mortality during turbine passage (Stone and Webster 1992). In a summary of entrainment studies, Stone and Webster (1992) observed that estimated mortality rates for naturally entrained fish were approximately 6% for Francis turbines. The review also found that larger fish suffered higher mortality rates, ranging from 10 to 30%. In studies conducted with rainbow trout at a facility with a Francis turbine, mortality rates increased substantially with an increase in fish length. Larger rainbow trout, ranging in size from 228 to 401 mm, suffered up to 39% mortality rates depending on turbine characteristics (Stone and Webster 1992). The results of the present study also indicated that smaller fish were less likely to suffer injury than larger fish.

In addition to mechanical injury, rapid pressure changes can cause internal injury or mortality in fish. The pressure experienced by a fish passing through a turbine depends on flow rate and the location of the fish in the water column when it is entrained. Fish are more sensitive to pressure decreases than to pressure increases, and rapid decrease in pressure can cause the swim bladder to expand (Stone and Webster 1992). Fish subject to rapid pressure changes often suffer from ruptured or perforated swim bladders (Stone and Webster 1992; Stokesbury and Dadswell 1991). Most fish in the present study were not examined for internal injury, and consequently, the degree of pressure related injuries could not be estimated.

Cavitation is an extreme case of variable pressures within the turbine. Cavitation can cause haemorrhaging and localized body pulping in fish. In studies by Cramer and Oligher (1990), induced cavitation substantially increased mortality rates of experimental fish. Since cavitation is undesirable due to deleterious effects on turbines, turbines are designed and operated to minimize this condition. In the present study, internal haemorrhaging, as indicated by bleeding from the anal vent, was observed in 10% of the fish captured in the tailrace traps. The cause of the haemorrhaging could not be definitively attributed to cavitation and may have resulted from mechanical impacts.

Shear and turbulence injuries occur when a fish is subject to two or more high velocity flows that are incidental to each other. This typically occurs at the leading edges of runner blades. Torn gill covers, popped eyes, and decapitation are characteristic injuries; however, these injuries are often difficult to distinguish from injuries caused by other sources, such as mechanical damage (Groves 1972). In the present study, a common injury observed for rainbow trout captured in the tailrace traps was a laceration to the isthmus or opercular area of the fish. At the time of sampling, these injuries were classified as lacerations; however, some of these may have been shear-induced injuries.

Methods were not employed during the study to differentiate between trap-induced injury from turbine induced injury. Many of the injuries observed, such as lacerations and haemorrhaging, were consistent with turbine passage; other types of injury such as scale loss, however, may have resulted from trapping. Scale loss among dead fish was greater than among live fish recovered in the tailrace traps. The high levels of scale loss observed for dead fish may have resulted from turbulence within the trap. The study team observed that turbulence in the live boxes of the IPTs was much greater than in the fyke nets and in general, scale loss was greatest for fish caught in the IPTs. The IPT live boxes lacked any form of baffles that would provide refuge from turbulent flow. The fyke nets, which employed a two-baffle system, provided a much calmer holding environment for captured fish.

High levels of net or trap induced injury are common in many studies and can result in an over estimation of entrainment mortality rates because of the cumulative effects of turbine passage and stress of net collection (Stone and Webster 1992). Many studies employ some form of control to quantify trap induced mortality rates. This was not possible during this study due to the low numbers of fish captured in the forebay. In future studies, control groups should be used to determine trap induced mortality and injury, if possible.

5.3 TRAP EFFICIENCY

A method of directly introducing objects into the intake area of the penstock of La Joie Dam was not devised during the 1999 field program. Safety regulations prohibited the use of watercraft in the vicinity of the intake structure which limited options to introduce fish or other objects into the intake area. As a result, all releases were conducted from the top of the intake structure, situated approximately 50 m above the water surface. Two methods of entraining objects into the penstocks from the top of the intake tower were investigated. One method involved releasing objects into the penstock area via a service shaft accessible from the top of the intake structure. The other method involved lowering objects from the intake structure and releasing them into the area in front of the trash rack over the penstock intake. Objects were also released from the powerhouse directly into the tailrace as part of the trap efficiency tests.

Based on the experience gained during the course of these releases, radishes were the most suitable objects employed in the trap efficiency experiments. Radishes were used because: (1) they could be obtained in the large quantities needed for the experiments; (2) they were approximately neutrally buoyant; (3) they do not have any deleterious effects on water quality; and (4) they would not cause damage to the turbine during passage. For these reasons, radishes are recommended for use in future entrainment and trap efficiency experiments, if sufficient live fish are not available.

Fish released via the service shaft would have had to travel to the bottom of the shaft, then actively swim laterally for several meters in order to be entrained into the penstock. From the diagrams available, there were not any other apparent exits from the service shaft. Based on the design of the shaft, the study team did not believe that inanimate objects could be entrained from this location. The lack of recaptures from the release of 180 radishes into the service shaft supported this assessment. In addition, a radio tag was implanted in a dead rainbow trout and the fish was released in the shaft. The tag was not relocated in the tailrace area during six hours of monitoring following the release. These data suggest that inanimate objects could not be consistently entrained from this location.

The release of live fish in the service shaft was more successful than the releases of inanimate objects. Of the 29 live rainbow trout released into the service shaft, two were recaptured in a downstream trap. In addition, the radio tag implanted in the live rainbow trout released in the shaft was located in the tailrace area following the release. The signal for the radio-tagged fish was located several hours following the release, and the tag (and presumably the fish) was located at the confluence of the Hurley River with the Middle Bridge River.

Regurgitation of radio tags implanted in the stomach is commonly reported in the literature (Olson and Kuehl 1988). In the present study, the poor success rate of entraining inanimate objects from the service shaft indicates that it is unlikely that a regurgitated tag could be entrained from the shaft. This suggests the live rainbow trout did not regurgitate the tag and that this fish moved out of the service shaft, into the penstock, and passed through the facility into the Bridge River. Based on the successful recovery of at least three of the 29 live fish introduced, the service shaft does present a potentially viable location for introducing live fish. There would be a need to determine if live fish introduced into the shaft actually were entrained through the plant, through additional telemetry studies.

Fish and radishes also were released into the forebay area immediately in front of the penstock intakes. This method resulted in the recapture of 23 out of 300 radishes released; however, none of the 10 live rainbow trout released in this manner were recaptured. Stables and McFadden (1999) estimated that water velocities at the intake mouth ranged from 1.4 to 1.8 m/s. These velocities are substantially less than the burst swimming speed of rainbow trout in the size range captured in the forebay (Katapodis 1990). This suggests that rainbow trout released directly in front of the trash racks could avoid entrainment and move into the forebay area. Consequently, the release of fish in this area was not considered a suitable method for entrainment experiments or trap efficiency tests. It is possible [illegible] there is a flow attraction with declining reservoir [illegible] and crowding of fish in the residual water body but this was not tested.

In other entrainment studies, the most common method employed for entraining fish into turbine intakes involves some form of introduction pipe. The pipe allows fish to be introduced into the desired location within the intake structure or dam (Stone and Webster 1992). The use of an introduction pipe system has several advantages in comparison with other methods. Once the pipe is installed, it allows a more consistent introduction of fish into an exact location, either in the turbine intake or tailrace. Introduction pipes are typically 7 to 10 cm in diameter and are constructed out of a combination of rigid and flexible materials that allow the pipe to be positioned within the intake area (Olson and Kuehl 1988; Mathur et al. 1996). This approach allows fish to be introduced into an area where water velocities are sufficient to ensure entrainment. Generally, fish are released head-first down the pipe and are flushed down the pipe with water.

Use of an introduction pipe system was not an option at the La Joie Dam site given the resources available during the 1999 field program. With increased planning, some form of introduction pipe could be constructed at the intake structure in future studies. There are several possibilities for the placement of the pipe. Although an introduction pipe could be installed from the top of the intake structure, the location would require fish to travel a considerable distance through the pipe. This would undoubtedly be stressful for the fish and would add an unwanted variable to the efficiency tests. Another option is to install an introduction pipe from a floating barge near the intake structure. This approach would reduce the length of the pipe and the resultant stress on fish. However, this would require the use of boats in the vicinity of the intake structure, which was not allowed during the 1999 study. Presumably, with low intake velocities and a marked "no entry zone" periodic approach by boat could be explored. If the introduction pipe is installed during a scheduled plant shutdown and is close enough to the intake!

5.4 ENTRAINMENT ESTIMATION

Fish entrainment at La Joie Dam was difficult to quantify. This was because partial-discharge nets, with no means of preventing the intrusion of tailrace resident fish, were employed as the method of fish collection in the tailrace. The use of partial-discharge nets can result in non-representative samples because of: (1) the intrusion of tailrace fish; (2) the avoidance of the trap by entrained fish; and (3) the uneven distribution of fish in the water column (Stone and Webster 1992). Previous studies have indicated that intrusion of tailrace fish is a common problem in entrainment studies (Sorenson et al. 1998; Stone and Webster 1992).

clarify [illegible]

Could place pipe from the side of the dam at low reservoir levels as in Plate #7. With a funnel opening, perhaps a gin pole / pulley could drop fish into the opening, eliminating the need for a boat.

Only one release experiment of live fish into the tailrace was conducted during the study. Of the 62 rainbow trout released, none were recaptured in the traps. The lack of recaptures likely indicated that some degree of trap avoidance occurred. However, fish that are entrained through turbines are often disoriented following passage. Consequently, these fish may tend to remain in the main flow of water in the channel. Fish that are not disoriented by turbine passage may be more likely to seek lower velocity areas such as the eddies along shore, rather than follow the main flow in the channel. The study team observed that some of the radishes released into the turbulent tailrace area were carried into the calmer, nearshore areas. Fish also could utilize these areas to avoid the high velocity areas directly downstream of the draft tube exits. These factors could result in the live fish that were released for efficiency tests being less susceptible to the traps than entrained fish. As a result, it was difficult to determine to what degree trap avoidance was a factor affecting trap efficiency.

Full-discharge netting in the tailrace is usually the preferred method of fish collection used in entrainment studies because it reduces or eliminates many of the problems associated with partial-discharge nets (Stone and Webster 1992). Despite its benefits, however, full-discharge netting is not practical at all facilities. At the La Joie Dam facility, the installation of the full-flow nets in the tailrace would be very difficult and expensive. Velocities in the tailrace are high and may preclude the use of any form of full-discharge sampling directly downstream of the dam.

Regardless of whether full or partial-discharge sampling is employed, it is usually desirable to attach sampling nets directly to the dam structure, thus excluding tailrace fish from the nets (Sorenson et al. 1998; Stone and Webster 1992). Sorenson et al. (1998) describe a method for the installation of a net system in the stop-log slots of the draft tubes. Although this method was successful in many respects, the flows at the La Joie Dam facility probably preclude the use of a similar system. In addition, the tailrace area immediately downstream of the dam is very turbulent and is not suited for a floating livebox. Servicing the net would also be very difficult because of the turbulence, and consequently, any sampling in the area immediately downstream of the powerhouse would require the use of a crane for safety reasons.

In several studies, fyke nets have been employed in the turbine intake area. The nets are lowered into the intake using the trash rack slots. Although this approach eliminates problems of tailrace fish intrusion, its application at the intake structure of La Joie Dam would be impractical. Furthermore, this technique has several disadvantages, that include high mortality rates in captured fish and potential for net loss into the turbines with subsequent damage to the facility (Stone and Webster 1992).

The entrainment patterns over time and relationship of water elevation to entrainment rate provide a reasonable description of temporal variation and the impact of forebay water level declines on relative entrainment rates at La Joie Dam. Estimates of total entrainment however, are more likely to be biased. The total entrainment estimate relied on use of the trap efficiency estimates derived from three radish release experiments. Radishes were used because of a lack of tagged fish recoveries and the limited numbers of fish available for experimental releases. The results of two other radish release experiments were not included in the estimate. In one case, the radishes were released through the service shaft and were not entrained but floated on the surface. In the other case, a tailrace radish release experiment on

8 June 1999, the small number of recoveries (n=6) was statistically different from the other three release experiments and was affected by one trap being inoperable during part of the recovery period. The recovery rate of radishes in the tailrace IPTs and fyke nets would likely be influenced by the type of capture method, with IPTs more effective at capturing floating objects and fyke nets more effective at capturing objects beneath the surface. Since a low number of rainbow trout were captured in the IPTs (n=11), these data were not used in the overall estimation of entrainment even though the IPT radish recovery rates were similar to the fyke nets.

The tailrace traps employed in the present study sampled near the surface of the water column. Although placement of a fyke net near the bottom of the tailrace water column was considered, this was not feasible given the nature of the flows in the tailrace area. Consequently, the vertical distribution of entrained fish (both live and dead) in the water column in the tailrace area could not be ascertained. The downstream dispersion pattern of fish killed during passage is not known. Carcasses or portions thereof, may tend to settle out of the water column following entrainment. However, the capture of several partial fish carcasses in the tailrace traps indicated that some dead fish did remain within the upper portion of the water column. Injuries and disorientation resulting from entrainment also may make the fish more vulnerable to recapture.

An additional bias in the estimates of trap efficiency was the presence of non-entrained fish in the tailrace. These fish may either have been present from earlier entrainment periods or may be fish that resided in the Middle Bridge River. Evidence from meristic data, such as weight or length, did not suggest the presence of multiple stocks. A single marked fish released from the tailrace traps was subsequently recovered, which suggested that at least some of the fish captured were not entrained. However, 40% of fish caught in fyke nets exhibited some form of injury, which suggest a sizeable component of the catch was entrained. Although an estimate of injury rates for fish that passed through the dam was not obtained, the injury rate observed for all fish was compared with results reported from other studies on the impacts of powerplant entrainment on resident fish. In addition, the response of trap catch-rates to changes in water level elevations suggested most of the rainbow trout were likely entrained.

Coastrange sculpins, the other common fish caught in the traps, did not sustain injuries and were not caught in the forebay heart traps, although heart traps were not optimal gear for targeting these species in the forebay. The lack of injuries and the lack of a temporal trend in catch-rates relating to reservoir water level elevation, suggested the entrainment rate for this species was low. [illegible]

This combination of factors create uncertainty as to the actual capture efficiency of the fyke nets, which was used as the basis for the estimation of entrainment numbers. The uncertainties may create either under or overestimates of trap efficiency, which may result in the population numbers presented being either lower or higher than the actual numbers entrained. Based on these uncertainties, the estimates should be used as an order of magnitude indicator of the extent of the entrainment problem, rather than absolute indicator of the number of entrained fish. The temporal trends in entrainment rate and the response of the entrainment rate to water level elevations are considered reasonable estimates since essentially the full range of the reservoir water level elevations that coincided with high entrainment rates, was included in the sampling period. The extension of the entrainment estimates outside of the sampling period through regression analysis suggested about 60% of the fish were entrained during the periods when sampling was not conducted. Projections prior to the sampling program could be biased if the numbers of fish present in the forebay area of the reservoir changed during the earlier projected period. The relatively small change in abundance observed in the forebay trap catches did not have a discernible effect on downstream entrainment rates. However, the forebay heart trap data were collected over a limited amount of time and the movement of the trap during the study may have biased the time trend of relative abundance of rainbow trout reported. Since the only significant environmental variable, reservoir water level elevation, essentially trended one direction over time, there is a reasonable possibility that other factors may also have influenced entrainment rates. That said, however, since temperature, turbidity, and forebay fish abundance were not significant correlates, the variation in entrainment observed was likely primarily related to reservoir elevation. Future studies should focus on techniques that improve abundance estimation by either intensifying sampling efforts or by the use of alternative technology, such as radio telemetry.

5.5 RECOMMENDATIONS

Based on the results of the 1999 field program, R.L. & L. Environmental Services Ltd. has developed the following recommendations for future studies.

1. If affordable, the release of 100 (minimum) to 200 (preferable) radio-tagged fish into the reservoir, coupled with automated monitoring in the tailrace, should provide an estimate of the rate of entrainment of forebay fish. Tracking of fish downstream and subsequent determination of movements could be used to estimate survival rates. Mark-recapture of tagged forebay fish by deployment of multiple traps could provide an estimate of the population at risk by use of a Schnabel estimator. A power analysis should be completed prior to initiating the study to provide a more precise estimate of the minimum number of radio tags needed to measure an assumed rate of entrainment with a given level of precision. To minimize variance of the entrainment estimator, the probable abundance of fish predicted from the reservoir elevation model should be used to ensure the number of tagged fish released is a constant proportion of the expected number of fish entrained. These techniques would provide a method preferable to either netting or hydroacoustics, unless an intensively engineered total discharge netting system could be deployed. Since the debris entrainment rate in the area (i.e., as suggested by debris observed in the downstream traps) appears to be high when compared with fish entrainment, hydroacoustics could potentially grossly overestimate entrainment rates. Methods to behaviourally separate fish targets from entrained debris are still in the developmental stage and cannot be reliably deployed at this time.

2. If an approach similar to that used in the present study is selected for use in future studies, the following recommendations should be considered to improve study results:

- Increased sampling in the tailrace. An increase in the proportion of the total flow sampled in the tailrace area would be desirable. This would increase the efficiency of the traps and lead to greater statistical confidence in estimating entrainment rates. Increased sampling could be achieved by employing more floating fyke nets or inclined plane traps, as well as tangle nets. Agree, however tangle nets would capture more tailrace fish.

- The development of an introduction pipe system. A consistent method of fish introductions into the dam outlet is required. The most common technique is the use of an introduction pipe system. The pipe should introduce fish into the penstock area downstream of the trash racks to minimize the potential for fish to escape entrainment. Entrainment should be confirmed through the use of radio telemetry on several occasions until field crews are satisfied that the placement of the introduction pipe is correct. BC Hydro engineers involved with dam safety issues as well as potential structural hazards associated with deployment of the pipe system should be part of a team developing specifications and field installation procedures.

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PHOTOGRAPHIC PLATES

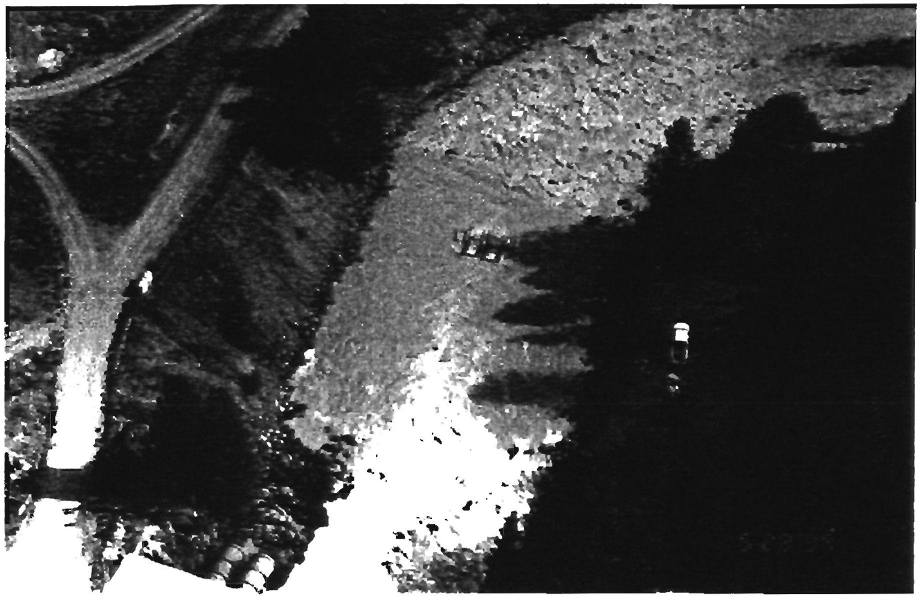

Plate 1 Aerial view of the tailrace traps positioned downstream of La Joie Dam.

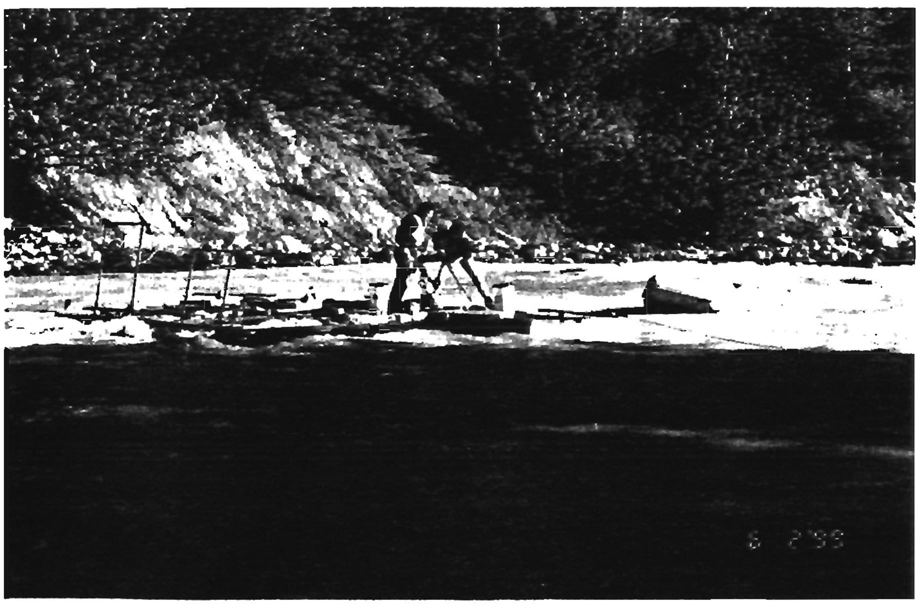

Plate 2 Servicing the tailrace traps. Dip nets were used to remove fish from live boxes on the traps into 20 L transport containers.

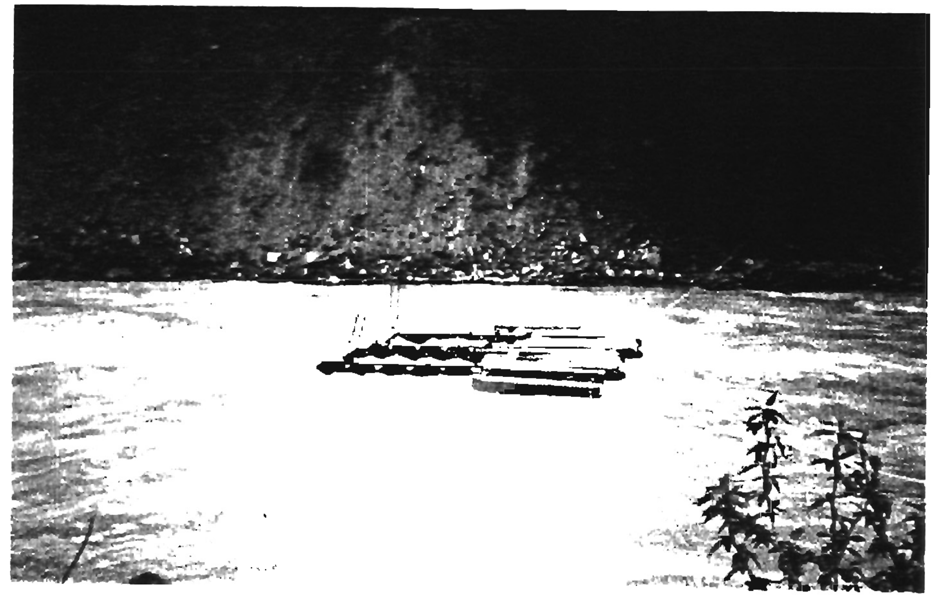

Plate 3 Side view of the tailrace traps showing IPT 2 in the foreground. The IPT is attached to Fyke 2 with ropes at the bow and stern of the IPT.

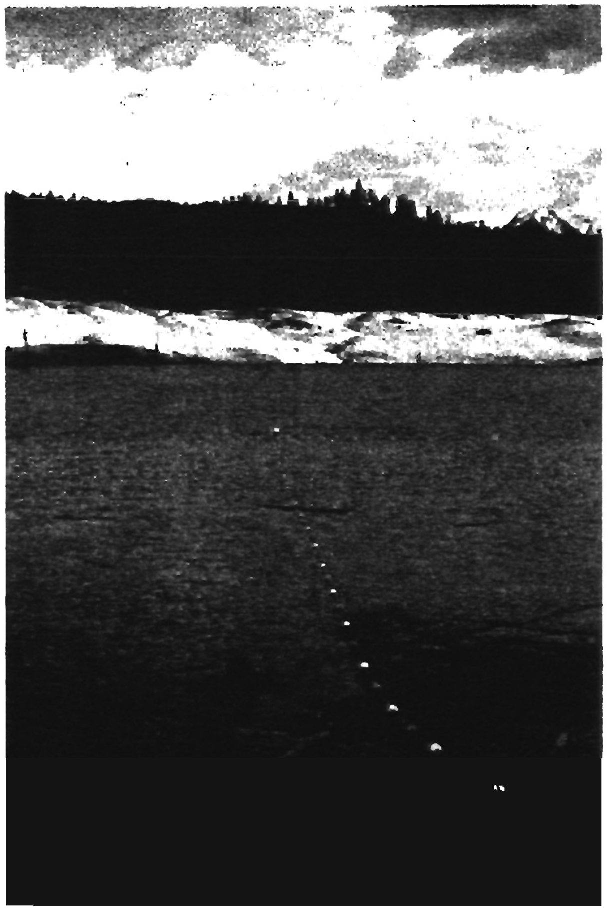

Plate 4 Heart 1 trap location in the forebay of Downton Lake reservoir. The float line of the lead net extends out perpendicular to the shore.

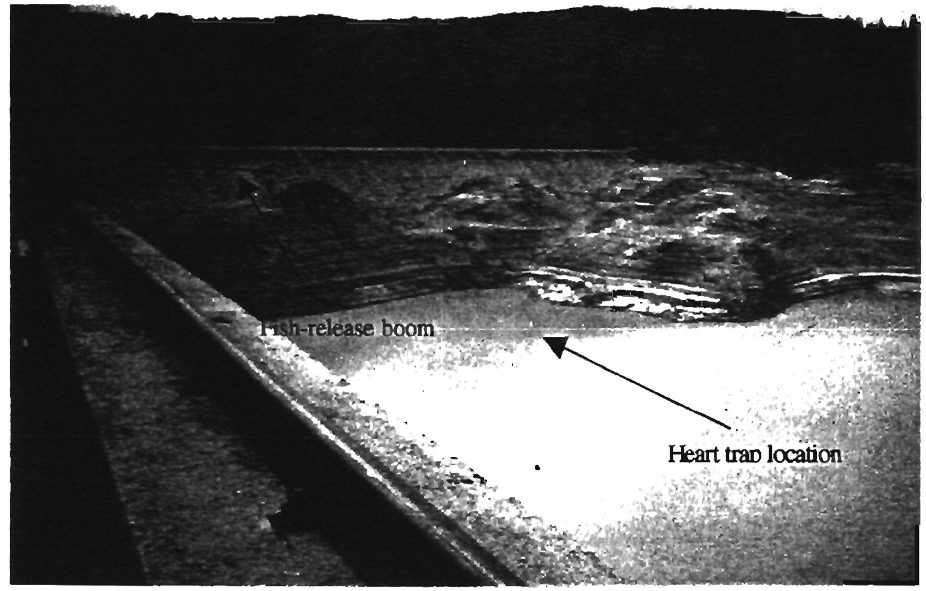

Plate 5 Heart 2 trap location. The boom for lowering the fish-release bucket is visible in the upper left of photo.

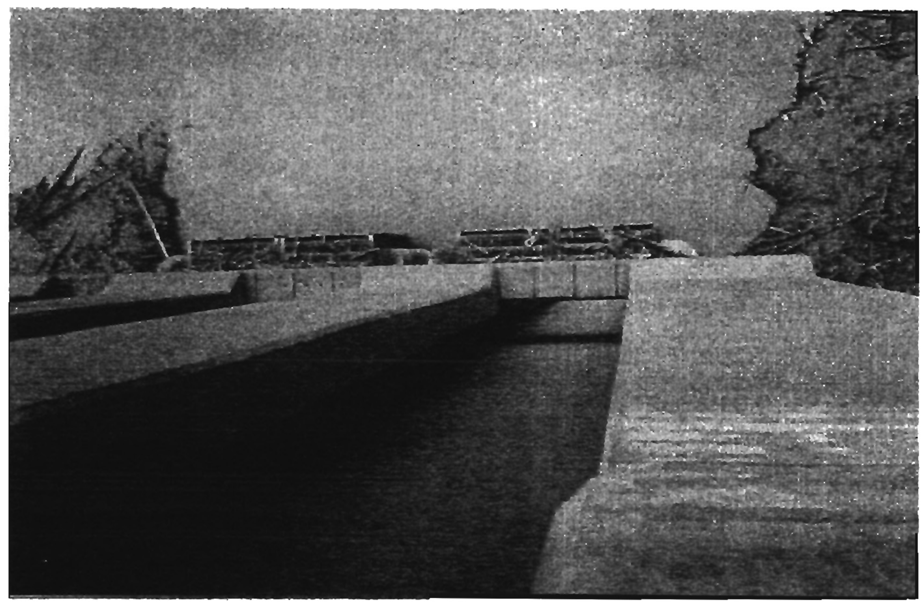

Plate 6 View down the stop log slots illustrating why the trash racks prevented any object from being lowered into the intake from the top of the intake structure. Photo taken April 1996 at a reservoir elevation of 698 masl (BC Hydro photo).

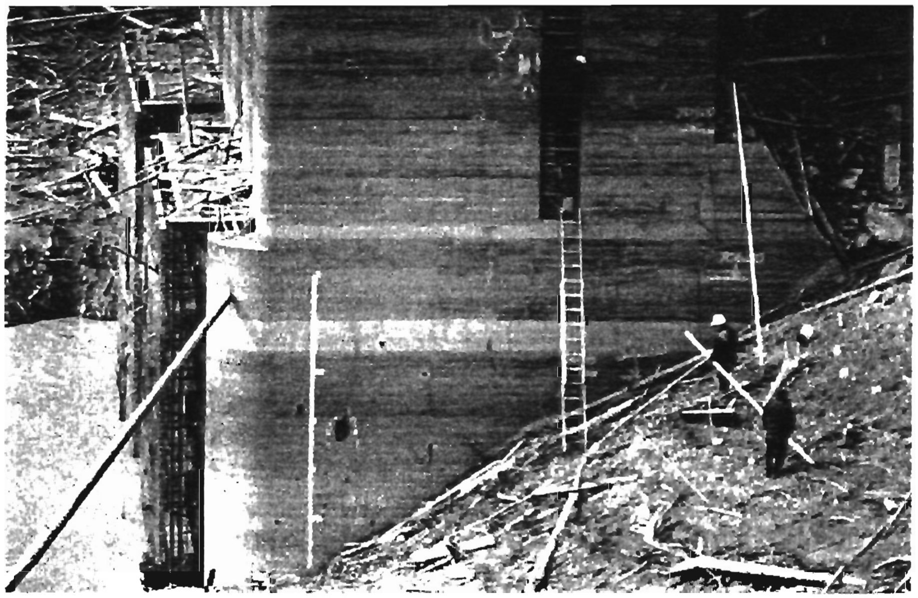

Plate 7 A view of the intake structure base showing the trash racks in front of the intakes. Photo taken April 1996 at a reservoir elevation of 698 masl (BC Hydro photo)

Plate 8 The fish-release bucket being lowered from the intake structure. The weight below the bucket ensures that the bucket sinks while the lid prevents objects from leaving the bucket until it reaches the proper depth.

Plate 9 Partial carcass of a rainbow trout captured in the tailrace traps.

APPENDIX A

PHYSICAL DATA

Table A1 Physical data recorded at La Joie Dam, Downton Lake reservoir, and Middle Bridge River, 21 May to 17 June 1999.

Date	Powerhouse		Downton Lake Reservoir						Middle Bridge River at Goldbridge Bridge						Middle Bridge River at Hurley Road Bridge						Weather[a]	Air Temp. Min.[a] (°C)	Air Temp. Max.[a] (°C)	Wind Strength[a,b]	Wind Direction[a]
	Time	Generation (MW)	Time	Temp. (°C)	Turb. 1 (NTU)	Turb. 2 (NTU)	Turb. 3 (NTU)	Elevation (masl)	Time	Temp. (°C)	Turb. 1 (NTU)	Turb. 2 (NTU)	Turb. 3 (NTU)	Elevation (m)	Time	Temp. (°C)	Turb. 1 (NTU)	Turb. 2 (NTU)	Turb. 3 (NTU)	Elevation (m)					
21-May									16:38	7.8	22	22	22	1.16	16:55	11	74	74	75	0.83		2	20	L	SW
22-May	8:37	6.7	8:52					708.13	13:14	6.1	19	19	19	1.18	13:25	11	78	78	77	0.83	no rain	4	25	L	SW
23-May	10:38	6.7	10:50					708.00	17:40	8.7	30	29	29	1.23	17:30	11	88	88	83	0.83	no rain	4	25	L	SW
24-May	8:35	6.5	8:47					708.09	18:46	8.3	74	75	75	1.33	18:54	12	108	108	108	0.83	no rain	8	26	L	SW
25-May	7:31	6.9	7:45					708.46	20:58	5.6	62	62	62	1.43	20:55	12	128	129	128	0.85	no rain	12	25	VS	NE
26-May	8:10	7.2	16:04					709.45	9:22	2.9	43	44	44	1.39	9:36	11	155	156	158	0.84	no rain	2	20	L	SW
27-May	9:25	7.5	11:00					709.75	16:05	3.8				1.34	16:00	12				0.85	no rain	4	22	S	SW
28-May	8:50	7.7	14:56	19.0				710.04	14:50	6.5	34	34	34	1.30	14:56	11	170	171	170	0.85	no rain	6	26	L	SW
29-May	7:50	8.0	13:52	15.0				710.29	14:35	5.4	39	38	38	1.30	14:30	10	262	263	261	0.85	light rain	4	17	S	SW
30-May	7:56	8.0	10:01	13.0				710.42	18:00	6.3	38	38	38	1.28	18:11	10	234	235	235	0.85	light rain	3	17	L	SW
31-May	8:08	8.0	15:00	11.5	340	340	340	710.68	21:18	7.8	40	40	40	1.36	21:00	10	210	212	212	0.85	partly sunny; no rain	8	24	VS	SW
1-Jun	8:08	8.1	18:55	12.5	191	191	192	711.23	18:34	4.8	35	35	34	1.36	18:44	10	169	169	170	0.85	cloudy, rain in a.m.	6	16	L	SW
2-Jun	8:18	8.5	13:37	17.0	193	194	194	711.23	14:11	6.5	30	29	29	1.30	14:01	10	158	159	158	0.85	no rain	7	21	L	SW
3-Jun	8:05	8.7	14:00	17.0	203	205	204	711.63	17:30	4.5	16	16	16	1.40	17:23	10	140	138	137	0.88	no rain	7	25	L	SW
4-Jun	8:19	8.9	15:10	14.0	275	276	275	712.01	19:40	4.0	59	58	58	1.44	19:46	11	125	123	123	0.88	light rain	12	17	VS	SW
5-Jun	9:11	9.2	9:30	12.6	285	283	287	712.50	18:40	4.8	130	131	132	1.47	18:52	11	118	122	123	0.90	windy, cloudy; light rain	11	17	VS	SW
6-Jun	8:18	9.6	12:04	12.6	280	275	270	713.10	21:05	5.8	27	29	29	1.39	20:58	10	112	111	114	0.90	no rain	6	15	VS	SW
7-Jun	8:00	10.0	18:54	13.7	259	255	258	713.65	18:49	6.8	22	21	21	1.35	19:29	10	106	107	109	0.89		4	15	S	SW
8-Jun	8:08	10.1	10:00	14.0	235	234	236	713.78	18:42	5.6	21	21	21	1.32	18:50	10	101	103	103	0.90		4	24	L	SW
9-Jun	8:30	10.0	16:42	12.5	205	204	206	714.07	17:00	7.5	20	19	19	1.28	15:30	10	93	94	95	0.89	light rain			VS	SW
10-Jun	9:45	10.2	11:00	12.5	84	84	85	714.20	11:50	6.0	19	19	20	1.30	12:11	10	99	98	98	0.89				L	SW
11-Jun	8:00	10.5	11:00	12.5	81	81	81	714.37	19:00	8.0	21	21	21	1.32	17:30	10	108	112	111	0.89					
12-Jun	12:40		12:15	16.0	127	126	126	714.62	11:50	5.5	19	19	20	1.35	12:00	9	111	110	110	0.88					
13-Jun	8:45	11.0	18:00					715.04	17:10	6.5	23	23	24	1.44	17:30	9	96	96	95	0.89					
14-Jun	8:25	11.0	9:25	16.0	63	63	63	715.40	11:00	4.0	28	27	26	1.55	10.50	9	94	93	93	0.90					
14-Jun			19:50	17.0	83	82	82	715.62	19:25	7.5	31	30	28	1.58	19:35	8	90	91	91	0.90					
15-Jun	8:00	11.5	9.00	17.0	65	65	65	716.07	9:25	4.0	110	110	108	1.68	9:15	8	85	89	89	0.90					
15-Jun			19:15	20.0	81	81	82	716.41	18.50	7.0	94	92	90	1.69	19:00	8	82	84	87	0.92					
16-Jun	11:30	12.3	11:15	18.0	125	119	122	717.12	10:55	4.0	283	284	285	1.87	11:00	8	84	83	83	0.97					
17-Jun	8:40	13.3	8:20	17.0	65	65	64	718.18	8:00	4.0	160	158	157	1.82	8:05	8	74	74	74	0.97					

[a] Recorded at Goldbridge townsite.

[b] Wind Strength: L=low; S=strong; VS=very strong.

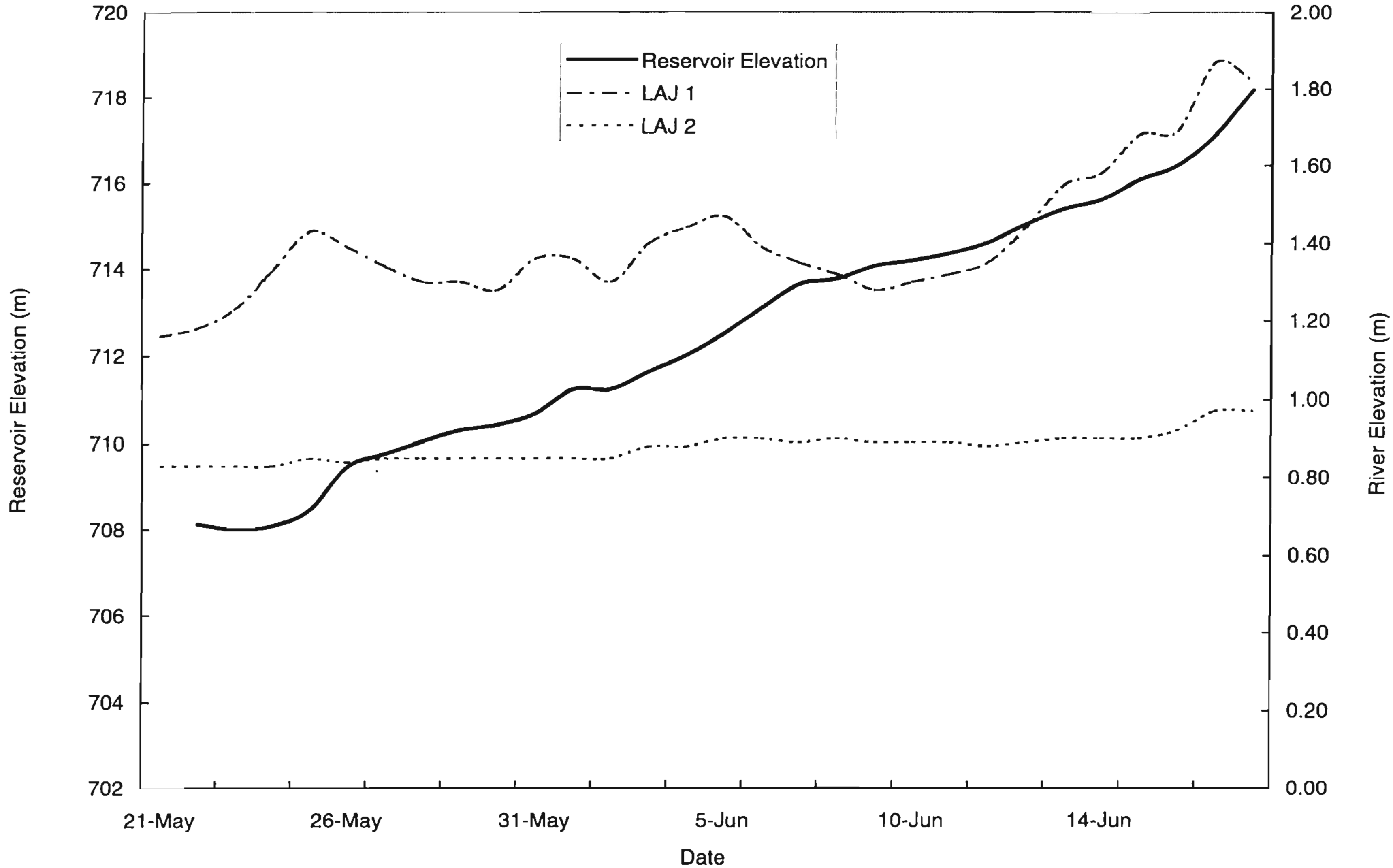

Figure A1 Elevation in Downton Lake reservoir and river levels in the Middle Bridge River at monitoring sites LAJ 1 and LAJ 2, 21 May to 17 June 1999.

APPENDIX B

FISH CAPTURE DATA

Table B1 Continued.

Sample Number	Species[a]	Fork Length (mm)	Weight (g)	Sex-Maturity[b]	Aging Method[c]	Pull Date	Pull Time	Site[d]	Capture Code[e]	Mark[f]	Released-Retained	Scale Loss (%)	Damage Code 1[g]	Damage Code 2[g]	Comments
45	RB	210	80	8	SC	28-May	20:30	FYKE2	0	AC	Released	2			No visible damage.
46	RB	266	170		SC	28-May	20:30	FYKE1	0	AC	Released	5			Some lacerations, markings, similar to gill net marks; did not appear recent.
47	RB	278	160	8	SC	28-May	20:30	FYKE1	0	AC	Released	2	LA		Some lacerations; markings, similar to gill net marks, did not appear recent
48	RB	321	236		SC	29-May	8:10	FYKE1	1	None	Retained	5	SE		Head wrenched backwards, torn isthmus, otoliths collected.
49	RB	121	18		SC	29-May	8:10	FYKE1	0	AC	Released	0			No visible damage
50	RB	294	200	19	SC	29 May	8:10	FYKE1	0	AC	Released	0			No visible damage
51	RB	301	404	17	SC	30-May	8:30	FYKE1	1	None	Retained	10	LA	IH	Laceration between pelvic fins. Bleeding from vent
52	RB	151	40		SC	30-May	8.30	FYKE2	1	None	Retained	100	IH		Bleeding from vent, no external signs of damage scale loss possible due to trap.
53	RB	278	216		SC	31-May	10:00	HEART1	0	FCTC	Retained	0			No visible damage
54	RB	304	286		SC	31-May	10:00	HEART1	0	FCTC	Retained	0			No visible damage
55	RB	210	92		SC	31-May	10:00	HEART1	0	FCTC	Retained	0			No visible damage
56	RB	303	268		SC	31-May	10:00	HEART1	0	FCTC	Retained	0			No visible damage.
57	RB	313	284		SC	31-May	11:10	GN1	0	FCTC	Retained	5			No visible damage.
58	RB	259	174		SC	31-May	10:00	HEART1	0	FCTC	Retained	0			No visible damage.
59	RB	207	94	8	SC	31-May	10:00	HEART1	0	FCTC	Retained	0			No visible damage
60	RB	298	262		SC	31 May	10:00	HEART1	0	FCTC	Retained	0			No visible damage.
61	RB	263	200		SC	31-May	10:00	HEART1	0	FCTC	Retained	0			No visible damage.
62	RB	201	82		SC	31-May	10:00	HEART1	0	FCTC	Retained	0			No visible damage
63	RB	311	246		SC	31-May	11:10	GN1	0	FCTC	Retained	5			No visible damage.
64	RB	223	110	8	SC	31-May	10.00	HEART1	0	FCTC	Retained	0			No visible damage
65	RB	205	80		SC	31-May	10:00	HEART1	0	FCTC	Retained	0			No visible damage
66	RB	205	88		SC	31 May	20:30	FYKE1	0	AC	Released	2			No visible damage.
67	RB	85	6		SC	1 Jun	9:00	FYKE1	0	AC	Released	0			No visible damage
68	RB	306	270		SC	1-Jun	11:00	HEART1	0	HPTC	Retained	0			No visible damage
69	RB	171	48		SC	1 Jun	11:00	HEART1	0	HPTC	Retained	0			No visible damage
70	RB	281	220		SC	1-Jun	11:00	HEART1	0	HPTC	Retained	0			No visible damage
71	RB	178	54		SC	1-Jun	11.00	HEART1	0	HPTC	Retained	0			No visible damage
72	RB	311	252	8		1-Jun	11.00	HEART1	0	HPTC	Retained	0			No visible damage
73	RB	275	202	8		1-Jun	11:00	HEART1	0	HPTC	Retained	0			No visible damage
74	RB	306	194		SC	1-Jun	11.00	HEART1	0	HPTC	Retained	0			No visible damage
75	RB	226	110	8	SC	1 Jun	11.00	HEART1	0	HPTC	Retained	0			No visible damage
76	RB	271	206		SC	1-Jun	11:00	HEART1	0	HPTC	Retained	0			No visible damage
77	RB	288	238		SC	1-Jun	11 00	HEART1	0	HPTC	Retained	0			No visible damage
78	RB	290	254			1-Jun	11:00	HEART1	0	HPTC	Retained	0			No visible damage
79	RB	264	170			1-Jun	11:00	HEART1	0	HPTC	Retained	0			No visible damage
80	RB	302	256			1 Jun	11.00	HEART1	0	HPTC	Retained	0			No visible damage
81	RB	225	110			1-Jun	11:00	HEART1	0	HPTC	Retained	0			No visible damage.
82	RB	240	130			1-Jun	11 00	HEART1	0	HPTC	Retained	0			No visible damage
83	RB	286	200			1-Jun	11:00	HEART1	0	HPTC	Retained	0			No visible damage
84	RB	163	50			1-Jun	11:00	HEART1	0	HPTC	Retained	0			No visible damage
85	RB	149	28			1-Jun	11 00	HEART1	0	HPTC	Retained	0			No visible damage
86	RB	193	64			1-Jun	11:00	HEART1	0	HPTC	Retained	0			No visible damage
87	RB	277	200			1-Jun	11 00	HEART1	0	HPTC	Retained	0			No visible damage
88	RB	213	100	8		1-Jun	11 00	HEART1	0	HPTC	Retained	0			No visible damage

Continued..

[a] RB=rainbow trout, CAL=coastrange sculpin; BSU=bridgelip sucker

[b] Sex and maturity codes: 7 and 17=male and female, respectively in early spawning condition. 8 and 18=male and female respectively, advanced spawning condition, 19=spent female.

[c] SC=scales

[d] For trap site locations see Figure 3.1

[e] Capture Codes: 0=first capture, released; 1=first capture, sacrificed/dead; 2=recapture, released, 3=recapture, sacrificed/dead.

[f] AC=adipose clip; FCTC=fin clip, top of caudal, HPTC=hole punch, top of caudal; HPBC=hole punch, bottom of caudal

[g] Damage Codes: EB=external bruising ; SE=severed body parts ; LA=lacerations; IM=impact injury, ME=missing eye(s); HI=internal hemorrhaging.

Table B1 Data collected from fish captured in the La Joie Dam tailrace and Downton Lake reservoir forebay, 21 May to 16 June 1999.

Sample Number	Species [a]	Fork Length (mm)	Weight (g)	Sex-Maturity [b]	Aging Method [c]	Pull Date	Pull Time	Site [d]	Capture Code [e]	Mark [f]	Released-Retained	Scale Loss (%)	Damage Code 1 [g]	Damage Code 2 [g]	Comments
1	RB	210	98		SC	22-May	7:30	IPT1	1	None	Retained	0	EB		No visible damage to exterior of fish; fish discolored, possibly from below dam.
2	RB	312	300		SC	22-May	7:30	FYKE1	1	None	Retained	0	SE		Head cleaved in two up to the operculum; most of right side of head missing.
3	RB	192	86		SC	22-May	20:00	FYKE1	0	AC	Released	0			No visible damage.
4	RB	180	62		SC	22-May	20:00	FYKE1	0	AC	Released	0	LA		Piece of operculum missing; recent injury; fish active and in good health.
5	RB	101	4		SC	23-May	6:50	FYKE1	0	AC	Released	0			No visible damage.
6	RB	312	192		SC	23-May	6:50	FYKE1	0	AC	Released	5	EB		Minor scale loss. Fish discoloured
7	RB	300	260		SC	23-May	20:15	FYKE1	0	AC	Released	0			No visible damage.
8	RB	215	86		SC	23-May	20:15	FYKE1	0	AC	Released	2			Scale loss approx. 2%.
9	RB	192	68		SC	23-May	20:15	IPT2	0	AC	Released	5			Scale loss approx. 2 to 5%.
10	RB	287	198		SC	23-May	20:40	FYKE1	0	None	Retained	5	LA	BR	moribund; laceration near caudal peduncle; internal bleeding & 10% scale loss.
11	RB	272	212		SC	23-May	20:15	FYKE2	1	None	Retained	5	LA	EB	Laceration near operculum. Scale loss approx. 10%. Extensive discoloration.
12	RB				SC	23-May	20:40	FYKE2	1	None	Released	0	SE	ME	only head was recovered; one eye missing; fish length est. at 300 mm
13	RB	130	22		SC	24-May	7:00	FYKE2	0	AC	Released	0			No visible damage.
14	BSU	374	514			24-May	20:58	FYKE1	0	None	Released	0			No visible damage.
15	RB	280	222		SC	26-May	20:58	FYKE1	0	AC	Released	2			No visible damage.
16	RB	200	70		SC	24-May	20:58	FYKE1	0	AC	Released	5			No visible damage.
17	RB	300	232		SC	24-May	20:58	FYKE1	0	AC	Released	10			No visible damage.
18	RB	298	274		SC	24-May	20:58	IPT1	1	None	Retained	50			Major scale loss, possibly from IPT.
19	RB	285	216		SC	24-May	20:58	IPT1	1	None	Retained	50	IM		Major scale loss. May have been struck near dorsal .
20	RB	297	214	18	SC	24-May	20:58	IPT1	1	None	Retained	10			No visible damage; gravid female; eggs released in trap.
21	RB	270	100		SC	25-May	6:50	FYKE2	0	AC	Released	2			No visible damage.
22	RB	300	270		SC	25-May	6:50	FYKE2	1	None	Retained	20			No visible damage.
23	RB	296	248		SC	25-May	6:50	FYKE2	1	None	Retained	2	ME		Missing eyeball.
24	RB	117	18		SC	25-May	6:50	FYKE1	1	None	Retained	0	LA		Major laceration behind operculum.
25	CAL	63	2			25-May	6:50	FYKE1	0	None	Released	0			No visible damage.
26	RB	285	222		SC	25-May	20:10	FYKE1	0	AC	Released	5			No visible damage.
27	RB	301	266		SC	25-May	20:10	FYKE1	1	None	Retained	40			No visible damage.
28	RB	186	64		SC	25-May	20:10	IPT1	1	None	Retained	0			No visible damage Trap mortality?
29	RB	265	184		SC	25-May	20:10	FYKE2	1	None	Retained	70	LA		Major laceration to body. Stomach extended out from laceration.
30	RB	120	18		SC	26-May	7:00	IPT2	1	None	Retained	0			No visible damage. Trap mortality?
31	RB	215	96		SC	26-May	7:00	FYKE1	0	AC	Released	0			No visible damage.
32	RB		16		SC	26-May	7:00	FYKE2	1	None	Released	0	SE		Only tail section of the fish, up to the adipose , was recovered.
33	RB	235	136		SC	26-May	7:00	FYKE2	1	None	Retained	50	LA	IM	Small laceration near operculum. Possible impact injury near head.
34	RB	235	128		SC	26-May	21:30	IPT1	0	AC	Released	0			No visible damage.
35	RB	297	238		SC	26-May	21:30	FYKE2	0	AC	Released	0			No visible damage.
36	RB	79	8		SC	27-May	8:30	FYKE2	0	AC	Released	0			No visible damage.
37	RB	280	216		SC	27-May	8:30	FYKE1	0	AC	Released	0	IM	LA	Injury on ventral surface between pects; sub-cutaneous bleeding; good condition
38	RB		72		SC	27-May	8:30	FYKE2	1	None	Released	5	SE		Only rear portion recovered; length estimated at 280 mm..
39	RB	337	378	8	SC	27-May	20:30	FYKE2	1	None	Retained	0	IM	IH	Impact near middle portion of body. Internal bleeding through vent.
40	RB	163	44		SC	28-May	9:00	FYKE1	1	None	Retained	95	IH		Bleeding from vent; testes severely damaged; broken bones in body cavity.
41	RB	307	274		SC	28-May	9:00	FYKE2	0	AC	Released	0			No visible damage.
42	RB	181	60	8		28-May	9:00	IPT1	0	AC	Released	2			No visible damage; scales embedded; spawner.
43	RB	94	8		SC	28-May	9:00	IPT1	0	AC	Released	0			No visible damage.
44	RB	220	94	7		28-May	13:00	FYKE2	0	AC	Released	0	LA		Laceration on side and ventral portion of fish; scales embedded; spawner.

Continued. .

[a] RB=rainbow trout; CAL=coastrange sculpin; BSU=bridgelip sucker.

[b] Sex and maturity codes: 7 and 17=male and female, respectively in early spawning condition; 8 and 18=male and female respectively, advanced spawning condition; 19=spent female.

[c] SC=scales.

[d] For trap site locations see Figure 3.1.

[e] Capture Codes: 0=first capture, released; 1=first capture, sacrificed/dead; 2=recapture, released; 3=recapture, sacrificed/dead.

[f] AC=adipose clip; FCTC=fin clip, top of caudal; HPTC=hole punch, top of caudal; HPBC=hole punch, bottom of caudal.

[g] Damage Codes: EB=external bruising ; SE=severed body parts ; LA=lacerations; IM=impact injury; ME=missing eye(s); HI=internal hemorrhaging.

Table B1 Continued.

Sample Number	Species[a]	Fork Length (mm)	Weight (g)	Sex-Maturity[b]	Aging Method[c]	Pull Date	Pull Time	Site[d]	Capture Code[e]	Mark[f]	Released-Retained	Scale Loss (%)	Damage Code 1[g]	Damage Code 2[g]	Comments
133	RB	156	14		SC	2-Jun	9:30	HEART1	0	HPBC	Retained	0			No visible damage.
134	RB	181	68	8	SC	2-Jun	19:30	FYKE1	0	AC	Released	0	EB		Some minor bruising.
135	RB	326	222		SC	3-Jun	8:30	FYKE2	1	None	Retained	30	LA	EB	Laceration to head and operculum
136	RB	249	152		SC	3-Jun	8:30	FYKE1	0	AC	Released	0			No visible damage.
137	CAL	64	2			3-Jun	8:30	FYKE1	0	None	Released	0			No visible damage.
138	RB	305	260		SC	3-Jun	10:00	HEART1	0	HPBC	Retained	0			No visible damage.
139	RB	319	322		SC	3-Jun	10:00	HEART1	0	HPBC	Retained	0			No visible damage.
140	RB	216	118		SC	3-Jun	10:00	HEART1	0	HPBC	Retained	0			No visible damage.
141	RB	191	74	8	SC	3-Jun	10:00	HEART1	0	HPBC	Retained	0			No visible damage.
142	RB	209	94		SC	3-Jun	10:00	HEART1	0	HPBC	Retained	0			No visible damage.
143	RB	226	116		SC	3-Jun	10:00	HEART1	0	HPBC	Retained	0			No visible damage.
144	RB	251	152		SC	3-Jun	10:00	HEART1	0	HPBC	Retained	0			No visible damage.
145	RB	173	56		SC	3-Jun	10:00	HEART1	0	HPBC	Retained	0			No visible damage.
146	RB	233	122		SC	3-Jun	10:00	HEART1	0	HPBC	Retained	0			No visible damage.
147	RB	306	252		SC	3-Jun	10:00	HEART1	0	HPBC	Retained	0			No visible damage.
148	RB	220	114		SC	3-Jun	10:00	HEART1	0	HPBC	Retained	0			No visible damage.
149	RB	253	166		SC	3-Jun	10:00	HEART1	0	HPBC	Retained	0			No visible damage.
150	RB	174	54		SC	3-Jun	10:00	HEART1	0	HPBC	Retained	0			No visible damage.
151	RB	164	48		SC	3-Jun	10:00	HEART1	0	HPBC	Retained	0			No visible damage.
152	RB	267	168		SC	3-Jun	10:00	HEART1	0	HPBC	Retained	0			No visible damage.
153	RB	315	284		SC	3-Jun	10:00	HEART1	0	HPBC	Retained	0			No visible damage.
154	RB	215	92		SC	3-Jun	10:00	HEART1	0	HPBC	Retained	0			No visible damage.
155	RB	178	68		SC	3-Jun	10:00	HEART1	0	HPBC	Retained	0			No visible damage.
156	RB	308	244		SC	3-Jun	20:30	FYKE1	0	AC	Released	0			No visible damage.
157	RB	185	58			3-Jun	20:30	FYKE1	2	HPBC	Released	0			No visible damage; recaptured fish from release of fish in air shaft at 12:10.
158	RB	187	74		SC	4-Jun	9:30	IPT1	0	AC	Released	0			No visible damage.
159	RB	315	238			4-Jun	15:00	HEART1	0	HPBC	Retained	0			No visible damage; escaped net pen; unable to obtain accurate weight.
160	RB	338	348			4-Jun	15:00	HEART1	0	HPBC	Retained	0			No visible damage; escaped net pen; unable to obtain accurate weight.
161	RB	217				4-Jun	15:00	HEART1	0	HPBC	Retained	0			No visible damage; escaped net pen; unable to obtain accurate weight.
162	RB	168				4-Jun	15:00	HEART1	0	HPBC	Retained	0			No visible damage; escaped net pen; unable to obtain accurate weight
163	RB	179		8		4-Jun	15:00	HEART1	0	HPBC	Retained	0			No visible damage; escaped net pen; unable to obtain accurate weight.
164	RB	137				4-Jun	15:00	HEART1	0	HPBC	Retained	0			No visible damage; escaped net pen; unable to obtain accurate weight.
165	RB	104				4-Jun	15:00	HEART1	0	None	Released	0			No visible damage; too small to mark; unable to obtain accurate weight.
166	RB	205				4-Jun	15:00	HEART1	0	HPBC	Retained	0			No visible damage; escaped net pen; unable to obtain accurate weight.
167	RB	204				4-Jun	15:00	HEART1	0	HPBC	Retained	0			No visible damage; escaped net pen; unable to obtain accurate weight.
168	RB	204		8		4-Jun	15:00	HEART1	0	HPBC	Retained	0			No visible damage; escaped net pen; unable to obtain accurate weight.
169	RB	228				4-Jun	15:00	HEART1	0	HPBC	Retained	0			No visible damage; escaped net pen; unable to obtain accurate weight.
170	RB	315	282		SC	5-Jun	19:30	FYKE1	2	HPBC	Released	0			No visible damage; fish entrained through air shaft.
171	RB	227	110		SC	5-Jun	19:30	FYKE1	0	AC	Released	5			No visible damage.
172	RB	174				5-Jun	10:30	HEART1	0	HPBC	Retained	0			No visible damage; unable to obtain accurate weight
173	RB	120	18		SC	6-Jun	8:40	IPT1	0	AC	Released	0			No visible damage.
174	RB	232	122		SC	6-Jun	8:40	IPT1	3	AC	Released	70			No visible damage; may have died in trap; recap after release below dam.
175	RB	293	262		SC	6-Jun	8:40	FYKE1	1	None	Retained	50			No visible damage. Discolored, may have been dead for some time.
176	CAL	67	2			6-Jun	8:40	FYKE2	0	None	Released	0			No visible damage.

Continued...

[a] RB=rainbow trout; CAL=coastrange sculpin; BSU=bridgelip sucker.

[b] Sex and maturity codes: 7 and 17=male and female, respectively in early spawning condition; 8 and 18=male and female respectively, advanced spawning condition; 19=spent female.

[c] SC=scales.

[d] For trap site locations see Figure 3.1.

[e] Capture Codes: 0=first capture, released; 1=first capture, sacrificed/dead; 2=recapture, released; 3=recapture, sacrificed/dead.

[f] AC=adipose clip; FCTC=fin clip, top of caudal; HPTC=hole punch, top of caudal; HPBC=hole punch, bottom of caudal.

[g] Damage Codes: EB=external bruising ; SE=severed body parts ; LA=lacerations; IM=impact injury; ME=missing eye(s); HI=internal hemorrhaging.

Table B1 Continued.

Sample Number	Species[a]	Fork Length (mm)	Weight (g)	Sex-Maturity[b]	Aging Method[c]	Pull Date	Pull Time	Site[d]	Capture Code[e]	Mark[f]	Released-Retained	Scale Loss (%)	Damage Code 1[g]	Damage Code 2[g]	Comments
89	RB	248	140	7		1-Jun	11:00	HEART1	0	HPTC	Retained	0			No visible damage.
90	RB	287	246			1-Jun	11:00	HEART1	0	HPTC	Retained	0			No visible damage.
91	RB	221	102			1-Jun	11:00	HEART1	0	HPTC	Retained	0			No visible damage.
92	RB	147	34			1-Jun	11:00	HEART1	0	HPTC	Retained	0			No visible damage.
93	RB	157	50			1-Jun	11:00	HEART1	0	HPTC	Retained	0			No visible damage.
94	RB	193	76			1-Jun	11:00	HEART1	0	HPTC	Retained	0			No visible damage.
95	RB	130	26			1-Jun	11:00	HEART1	0	HPTC	Retained	0			No visible damage.
96	RB	292	240			1-Jun	11:00	HEART1	0	HPTC	Retained	0			No visible damage.
97	RB	180	60	8		1-Jun	11:00	HEART1	0	HPTC	Retained	0			No visible damage.
98	RB	202	84	8		1-Jun	11:00	HEART1	0	HPTC	Retained	0			No visible damage.
99	RB	277	186			1-Jun	11:00	HEART1	0	HPTC	Retained	0			No visible damage.
100	RB	261	168			1-Jun	11:00	HEART1	0	HPTC	Retained	0			No visible damage.
101	RB	324	326			1-Jun	11:00	HEART1	0	HPTC	Retained	0			No visible damage.
102	RB	213	98			1-Jun	11:00	HEART1	0	HPTC	Retained	0			No visible damage.
103	RB	297	242			1-Jun	11:00	HEART1	0	HPTC	Retained	0			No visible damage.
104	RB	289	168			1-Jun	11:00	HEART1	0	HPTC	Retained	0			No visible damage.
105	RB	287	216			1-Jun	11:00	HEART1	0	HPTC	Retained	0			No visible damage.
106	RB	291	222			1-Jun	11:00	HEART1	0	HPTC	Retained	0			No visible damage.
107	RB	199	86	8		1-Jun	11:00	HEART1	0	HPTC	Retained	0			No visible damage.
108	RB	167	48	8		1-Jun	11:00	HEART1	0	HPTC	Retained	0			No visible damage.
109	RB	236	114			1-Jun	11:00	HEART1	0	HPTC	Retained	0			No visible damage.
110	RB	203	86			1-Jun	11:00	HEART1	0	HPTC	Retained	0			No visible damage
111	RB	184	72	8		1-Jun	11:00	HEART1	0	HPTC	Retained	0			No visible damage.
112	RB	207	94			1-Jun	11:00	HEART1	0	HPTC	Retained	0			No visible damage.
113	RB	214	96			1-Jun	11:00	HEART1	0	HPTC	Retained	0			No visible damage.
114	RB	123	20			1-Jun	11:00	HEART1	0	HPTC	Retained	0			No visible damage.
115	RB	198	86	8		1-Jun	11:00	HEART1	0	HPTC	Retained	0			No visible damage.
116	RB	194	74			1-Jun	11:00	HEART1	0	HPTC	Retained	0			No visible damage.
117	RB	139	28			1-Jun	11:00	HEART1	0	HPTC	Retained	0			No visible damage.
118	RB	210	84		SC	1-Jun	15:00	FYKE1	1	None	Retained	90	LA	IH	Laceration near dorsal; bleeding from vent; otoliths collected..
119	RB	210	92	8	SC	2-Jun	8:30	IPT2	1	None	Retained	50	IH	EB	Bruising; no obvious lacerations or impacts; internal bleeding; otoliths taken
120	CAL	64				2-Jun	8:30	IPT2	0	None	Released	0			No visible damage.
121	CAL	71				2-Jun	8:30	FYKE1	0	None	Released	0			No visible damage.
122	CAL	69				2-Jun	8:30	FYKE2	0	None	Released	0			No visible damage.
123	RB	267	154		SC	2-Jun	9:30	HEART1	0	HPBC	Retained	0			No visible damage.
124	RB	284	208	8	SC	2-Jun	9:30	HEART1	0	HPBC	Retained	0			No visible damage.
125	RB	242	114		SC	2-Jun	9:30	HEART1	0	HPBC	Retained	0			No visible damage.
126	RB	244	108		SC	2-Jun	9:30	HEART1	0	HPBC	Retained	0			No visible damage.
127	RB	239	106		SC	2-Jun	9:30	HEART1	0	HPBC	Retained	0			No visible damage.
128	RB	258	150		SC	2-Jun	9:30	HEART1	0	HPBC	Retained	0			No visible damage.
129	RB	291	208		SC	2-Jun	9:30	HEART1	0	HPBC	Retained	0			No visible damage.
130	RB	195	54		SC	2-Jun	9:30	HEART1	0	HPBC	Retained	0			No visible damage.
131	RB	183	42		SC	2-Jun	9:30	HEART1	0	HPBC	Retained	0			No visible damage.
132	RB	167	18		SC	2-Jun	9:30	HEART1	0	HPBC	Retained	0			No visible damage.

Continued…

[a] RB=rainbow trout; CAL=coastrange sculpin; BSU=bridgelip sucker.

[b] Sex and maturity codes: 7 and 17=male and female, respectively in early spawning condition; 8 and 18=male and female respectively, advanced spawning condition; 19=spent female.

[c] SC=scales.

[d] For trap site locations see Figure 3.1.

[e] Capture Codes: 0=first capture, released; 1=first capture, sacrificed/dead; 2=recapture, released; 3=recapture, sacrificed/dead.

[f] AC=adipose clip; FCTC=fin clip, top of caudal; HPTC=hole punch, top of caudal; HPBC=hole punch, bottom of caudal.

[g] Damage Codes: EB=external bruising ; SE=severed body parts ; LA=lacerations; IM=impact injury; ME=missing eye(s); HI=internal hemorrhaging.

Table B1 Concluded.

Sample Number	Species[a]	Fork Length (mm)	Weight (g)	Sex-Maturity[b]	Aging Method[c]	Pull Date	Pull Time	Site[d]	Capture Code[e]	Mark[f]	Released-Retained	Scale Loss (%)	Damage Code 1[g]	Damage Code 2[g]	Comments
221	CAL	60	2			11-Jun	8:40	FYKE2	0	None	Released	0			No visible damage.
222	CAL	67	2			11-Jun	8:40	FYKE2	0	None	Released	0			No visible damage.
223	RB	206	72		SC	11-Jun	8:30	FYKE1	1	None	Released	2			Dead
224	RB	325	300		SC	11-Jun	9:30	HEART2	0	HPTC	Retained	0			No visible damage.
225	RB	300	254		SC	11-Jun	9:30	HEART2	0	HPTC	Retained	0			No visible damage.
226	RB	215	104		SC	11-Jun	9:30	HEART2	0	HPTC	Retained	0			No visible damage.
227	RB	112	92		SC	11-Jun	9:30	HEART2	0	HPTC	Retained	0			No visible damage.
228	RB	196	80		SC	11-Jun	9:30	HEART2	0	HPTC	Retained	0			No visible damage
229	RB	172	58		SC	11-Jun	9:30	HEART2	0	HPTC	Retained	0			No visible damage
230	RB	204	96		SC	11-Jun	9:30	HEART2	0	HPTC	Retained	0			No visible damage
231	RB	213	110		SC	11-Jun	9:30	HEART2	0	HPTC	Retained	0			No visible damage.
232	CAL	60				14-Jun	8:30	FYKE1	0	None	Released	0			No visible damage.
233	RB	195				14-Jun	20:45	FYKE1	1	None	Retained	65			Dead
234	CAL	53				15-Jun	8:15	FYKE2	0	None	Released	0			No visible damage.
235	CAL	65				15-Jun	8:15	FYKE2	0	None	Released	0			No visible damage
236	RB	318				16-Jun	12:00	FYKE1	1	None	Retained	5	IH	EB	Dead, bruised, internal bleeding

[a] RB=rainbow trout; CAL=coastrange sculpin; BSU=bridgelip sucker

[b] Sex and maturity codes: 7 and 17=male and female, respectively in early spawning condition; 8 and 18=male and female respectively, advanced spawning condition; 19=spent female.

[c] SC=scales.

[d] For trap site locations see Figure 3.1.

[e] Capture Codes: 0=first capture, released, 1=first capture, sacrificed/dead; 2=recapture, released; 3=recapture, sacrificed/dead.

[f] AC=adipose clip; FCTC=fin clip, top of caudal, HPTC=hole punch, top of caudal; HPBC=hole punch, bottom of caudal.

[g] Damage Codes: EB=external bruising ; SE=severed body parts ; LA=lacerations; IM=impact injury; ME=missing eye(s); HI=internal hemorrhaging.

Table B1 Continued.

Sample Number	Species[a]	Fork Length (mm)	Weight (g)	Sex-Maturity[b]	Aging Method[c]	Pull Date	Pull Time	Site[d]	Capture Code[e]	Mark[f]	Released-Retained	Scale Loss (%)	Damage Code 1[g]	Damage Code 2[g]	Comments
177	RB	165	62		SC	7-Jun	8:40	FYKE1	1	None	Retained	0	SE		No head, missing from pectoral s backwards.
178	CAL	56				7-Jun	8:40	FYKE1	0	None	Released	0			No visible damage.
179	CAL	73				7-Jun	8:40	FYKE2	0	None	Released	0			No visible damage.
180	CAL	64				7-Jun	8:40	FYKE2	0	None	Released	0			No visible damage.
181	CAL	60				7-Jun	8:40	FYKE2	0	None	Released	0			No visible damage.
182	CAL	70				7-Jun	8:40	FYKE1	0	None	Released	0			No visible damage.
183	RB	333	360		SC	7-Jun	10:00	HEART2	0	HPTC	Retained	0			No visible damage.
184	RB	298	284		SC	7-Jun	10:00	HEART2	0	HPTC	Retained	0			No visible damage.
185	RB	314	276		SC	7-Jun	10:00	HEART2	0	HPTC	Retained	0			No visible damage.
186	RB	291	266		SC	7-Jun	10:00	HEART2	0	HPTC	Retained	0			No visible damage.
187	RB	291	280		SC	7-Jun	10:00	HEART2	0	HPTC	Retained	0			No visible damage.
188	RB	221	104	8	SC	7-Jun	10:00	HEART2	0	HPTC	Retained	0			No visible damage.
189	RB	229	134	8	SC	7-Jun	10:00	HEART2	0	HPTC	Retained	0			No visible damage.
190	RB	206	98		SC	7-Jun	10:00	HEART2	0	HPTC	Retained	0			No visible damage.
191	RB	197	84		SC	7-Jun	10:00	HEART2	0	HPTC	Retained	0			No visible damage.
192	RB	207	86		SC	7-Jun	10:00	HEART2	0	HPTC	Retained	0			No visible damage.
193	RB	324	324		SC	8-Jun	10:00	HEART2	0	HPTC	Retained	0			No visible damage.
194	RB	290	250		SC	8-Jun	10:00	HEART2	0	HPTC	Retained	0			No visible damage.
195	RB	196	78	8	SC	8-Jun	10:00	HEART2	0	HPTC	Retained	0			No visible damage.
196	RB	293	276		SC	8-Jun	10:00	HEART2	0	HPTC	Retained	0			No visible damage.
197	RB	242	142		SC	8-Jun	10:00	HEART2	0	HPTC	Retained	0			No visible damage.
198	RB	233	126		SC	8-Jun	10:00	HEART2	0	HPTC	Retained	0			No visible damage.
199	RB	224	124	8	SC	8-Jun	10:00	HEART2	0	HPTC	Retained	0			No visible damage.
200	RB	222	110	8	SC	8-Jun	10:00	HEART2	0	HPTC	Retained	0			No visible damage.
201	RB	276	204		SC	9-Jun	10:15	HEART2	0	HPTC	Retained	0			No visible damage.
202	RB	225	136		SC	9-Jun	10:15	HEART2	0	HPTC	Retained	0			No visible damage.
203	BSU	440	1336		SC	9-Jun	10:15	HEART2	0	HPTC	Released	0			No visible damage.
204	RB	206	88		SC	9-Jun	10:15	HEART2	0	HPTC	Retained	0			No visible damage.
205	RB	322	348		SC	9-Jun	10:15	HEART2	0	HPTC	Retained	0			No visible damage.
206	RB	196	62		SC	9 Jun	10:15	HEART2	0	HPTC	Retained	0			No visible damage.
207	RB	218	144		SC	9-Jun	10:15	HEART2	0	HPTC	Retained	0			No visible damage.
208	RB	221	156		SC	9-Jun	10:15	HEART2	0	HPTC	Retained	0			No visible damage.
209	RB	230	168		SC	9-Jun	10:15	HEART2	0	HPTC	Retained	0			No visible damage.
210	RB	201	132		SC	9-Jun	10:15	HEART2	0	HPTC	Retained	0			No visible damage.
211	RB	175	54		SC	9-Jun	10:30	HEART3	0	HPTC	Retained	0			No visible damage.
212	RB	186	50		SC	9-Jun	20:30	FYKE1	0	HPTC	Released	0	EB		Bruising on tail; thin
213	RB	147	28		SC	10-Jun	8:30	FYKE1	0	None	Released	0			No visible damage.
214	RB	187	76		SC	10-Jun	9:30	HEART2	0	HPTC	Retained	0			No visible damage.
215	RB	234	128		SC	10-Jun	9:30	HEART2	0	HPTC	Retained	0			No visible damage.
216	RB	199	82		SC	10-Jun	9:30	HEART2	0	HPTC	Retained	0			No visible damage.
217	RB	227	116		SC	10-Jun	9:30	HEART2	0	HPTC	Retained	0			No visible damage.
218	RB	188	68		SC	10-Jun	9:30	HEART2	0	HPTC	Retained	0			No visible damage.
219	RB	176	56			10-Jun	9:30	HEART2	0	HPTC	Retained	0			No visible damage.
220	RB	116	16		SC	10-Jun	20:15	FYKE1	0	None	Released	0			No visible damage.

Continued...

[a] RB=rainbow trout; CAL=coastrange sculpin; BSU=bridgelip sucker.

[b] Sex and maturity codes: 7 and 17=male and female, respectively in early spawning condition; 8 and 18=male and female respectively, advanced spawning condition; 19=spent female.

[c] SC=scales.

[d] For trap site locations see Figure 3.1.

[e] Capture Codes: 0=first capture, released; 1=first capture, sacrificed/dead; 2=recapture, released; 3=recapture, sacrificed/dead.

[f] AC=adipose clip; FCTC=fin clip, top of caudal; HPTC=hole punch, top of caudal; HPBC=hole punch, bottom of caudal.

[g] Damage Codes: EB=external bruising ; SE=severed body parts ; LA=lacerations; IM=impact injury; ME=missing eye(s); HI=internal hemorrhaging.

Table B3 Summary of fish species captured and catch-per-unit-effort (CPUE) in fyke net traps and inclined plane traps positioned downstream of La Joie Dam, May and June 1999.

FYKE NET TRAP RESULTS

Date	Fyke 1					Fyke 2					Total for Fyke Nets				
	Set Duration (h)	RB[a]		CAL[a]		Set Duration (h)	RB		CAL		Set Duration (h)	RB		CAL	
		No.	CPUE (fish/h)	No.	CPUE (fish/h)		No.	CPUE (fish/h)	No.	CPUE (fish/h)		No.	CPUE (fish/h)	No.	CPUE (fish/h)
22-May	32.00	3	0.094	0	0.000	NA	NA	NA	NA	NA	32.00	3	0.094	0	0.000
23-May	24.25	5	0.206	0	0.000	10.08	2	0.198	0	0.000	34.33	7	0.204	0	0.000
24-May[b]	24.72	3	0.121	0	0.000	24.50	1	0.041	0	0.000	49.22	4	0.081	0	0.000
25-May	23.20	3	0.129	1	0.043	23.08	4	0.173	0	0.000	46.28	7	0.151	1	0.022
26-May	25.33	1	0.039	0	0.000	25.33	3	0.118	0	0.000	50.67	4	0.079	0	0.000
27-May	23.00	1	0.043	0	0.000	23.00	3	0.130	0	0.000	46.00	4	0.087	0	0.000
28-May	24.00	3	0.125	0	0.000	24.00	3	0.125	0	0.000	48.00	6	0.125	0	0.000
29-May	23.75	3	0.126	0	0.000	23.75	0	0.000	0	0.000	47.50	3	0.063	0	0.000
30-May	24.00	1	0.042	0	0.000	24.00	1	0.042	0	0.000	48.00	2	0.042	0	0.000
31-May	24.25	1	0.041	0	0.000	24.25	0	0.000	0	0.000	48.50	1	0.021	0	0.000
1-Jun	24.50	2	0.082	0	0.000	24.50	0	0.000	0	0.000	49.00	2	0.041	0	0.000
2-Jun	22.50	1	0.044	1	0.044	22.50	0	0.000	1	0.044	45.00	1	0.022	2	0.044
3-Jun	25.00	3	0.120	1	0.040	25.00	1	0.040	0	0.000	50.00	4	0.080	1	0.020
4-Jun	24.00	0	0.000	0	0.000	24.00	0	0.000	0	0.000	48.00	0	0.000	0	0.000
5-Jun	23.00	2	0.087	0	0.000	23.00	0	0.000	0	0.000	46.00	2	0.043	0	0.000
6-Jun	25.17	1	0.040	0	0.000	25.17	0	0.000	1	0.040	50.33	1	0.020	1	0.020
7-Jun	23.83	1	0.042	2	0.084	23.83	0	0.000	3	0.126	47.67	1	0.021	5	0.105
8-Jun	23.50	0	0.000	0	0.000	23.50	0	0.000	0	0.000	47.00	0	0.000	0	0.000
9-Jun	24.50	1	0.041	0	0.000	24.58	0	0.000	0	0.000	49.08	1	0.020	0	0.000
10-Jun	23.67	2	0.085	0	0.000	23.67	0	0.000	0	0.000	47.33	2	0.042	0	0.000
11-Jun	24.25	1	0.041	0	0.000	24.25	0	0.000	2	0.082	48.50	1	0.021	2	0.041
14-Jun	29.25	1	0.034	1	0.034	29.25	0	0.000	0	0.000	58.50	1	0.017	1	0.017
15-Jun	22.50	0	0.000	0	0.000	22.50	0	0.000	2	0.089	45.00	0	0.000	2	0.044
16-Jun	15.75	1	0.063	0	0.000	15.75	0	0.000	0	0.000	31.50	1	0.032	0	0.000
Total	**579.92**	**40**	**0.069**	**6**	**0.010**	**533.50**	**18**	**0.034**	**9**	**0.017**	**1113.42**	**58**	**0.052**	**15**	**0.013**

[a] RB=rainbow trout; CAL=coastrange sculpin.

[b] One bridgelip sucker captured on 24 May 1999 in Fyke 1 is excluded from the totals

INCLINED PLANE TRAP RESULTS

Date	IPT 1					IPT 2					Total for IPTs				
	Set Duration (h)	RB[a]		CAL[a]		Set Duration (h)	RB		CAL		Set Duration (h)	RB		CAL	
		No.	CPUE (fish/h)	No.	CPUE (fish/h)		No.	CPUE (fish/h)	No.	CPUE (fish/h)		No.	CPUE (fish/h)	No.	CPUE (fish/h)
22-May	32.00	1	0.031	0	0.000	NA	NA	NA	NA	NA	32.00	1	0.031	0	0.000
23-May	24.33	0	0.000	0	0.000	10.00	1	0.100	0	0.000	34.33	1	0.029	0	0.000
24-May[b]	24.63	3	0.122	0	0.000	24.58	0	0.000	0	0.000	49.22	3	0.061	0	0.000
25-May	23.20	1	0.043	0	0.000	23.08	0	0.000	0	0.000	46.28	1	0.022	0	0.000
26-May	25.33	1	0.039	0	0.000	25.33	1	0.039	0	0.000	50.67	2	0.039	0	0.000
27-May	23.00	0	0.000	0	0.000	23.00	0	0.000	0	0.000	46.00	0	0.000	0	0.000
28-May	24.00	2	0.083	0	0.000	24.00	0	0.000	0	0.000	48.00	2	0.042	0	0.000
29-May	23.75	0	0.000	0	0.000	23.75	0	0.000	0	0.000	47.50	0	0.000	0	0.000
30-May	24.00	0	0.000	0	0.000	24.00	0	0.000	0	0.000	48.00	0	0.000	0	0.000
31-May	24.25	0	0.000	0	0.000	24.25	0	0.000	0	0.000	48.50	0	0.000	0	0.000
1-Jun	24.50	0	0.000	0	0.000	24.50	0	0.000	0	0.000	49.00	0	0.000	0	0.000
2-Jun	22.50	0	0.000	0	0.000	22.50	1	0.044	1	0.044	45.00	1	0.022	1	0.022
3-Jun	25.00	0	0.000	0	0.000	25.00	0	0.000	0	0.000	50.00	0	0.000	0	0.000
4-Jun	24.00	1	0.042	0	0.000	24.00	0	0.000	0	0.000	48.00	1	0.021	0	0.000
5-Jun	23.00	0	0.000	0	0.000	23.00	0	0.000	0	0.000	46.00	0	0.000	0	0.000
6-Jun	25.17	2	0.079	0	0.000	25.17	0	0.000	0	0.000	50.33	2	0.040	0	0.000
7-Jun	23.83	0	0.000	0	0.000	23.83	0	0.000	0	0.000	47.67	0	0.000	0	0.000
8-Jun	23.50	0	0.000	0	0.000	23.50	0	0.000	0	0.000	47.00	0	0.000	0	0.000
9-Jun	24.50	0	0.000	0	0.000	24.58	0	0.000	0	0.000	49.08	0	0.000	0	0.000
10-Jun	23.75	0	0.000	0	0.000	23.67	0	0.000	0	0.000	47.42	0	0.000	0	0.000
11-Jun	24.25	0	0.000	0	0.000	24.25	0	0.000	0	0.000	48.50	0	0.000	0	0.000
14-Jun	29.25	0	0.000	0	0.000	17.50	0	0.000	0	0.000	46.75	0	0.000	0	0.000
15-Jun	22.50	0	0.000	0	0.000	22.50	0	0.000	0	0.000	45.00	0	0.000	0	0.000
16-Jun	15.75	0	0.000	0	0.000	15.75	0	0.000	0	0.000	31.50	0	0.000	0	0.000
Total	**580.00**	**11**	**0.019**	**0**	**0.000**	**521.75**	**3**	**0.006**	**1**	**0.002**	**1101.75**	**14**	**0.013**	**1**	**0.001**

[a] RB=rainbow trout; CAL=coastrange sculpin

[b] One bridgelip sucker captured on 24 May 1999 in Fyke 1 is excluded from the totals

Table B2 Summary of rainbow trout captured using heart traps in the forebay of Downtown Lake reservoir, 30 May to 12 June 1999.

Site	Set Date	Set Time	Pull Date	Pull Time	Set Duration (h)	No. of Rainbow Trout	CPUE (fish per h)
Heart 1	30-May	12:00	31-May	10:00	22.00	11	*0.50*
	31-May	13:00	1-Jun	11:00	22.00	50	*2.27*
	1-Jun	11:00	2-Jun	9:30	22.50	11	*0.49*
	2-Jun	9:30	3-Jun	10:00	24.50	18	*0.73*
	3-Jun	10:00	4-Jun	15:00	29.00	11	*0.38*
	4-Jun	15:00	5-Jun	10:30	19.50	1	*0.05*
Total for Heart Trap Site 1					**139.50**	**102**	***0.73***
Heart 2	6-Jun	11:30	7-Jun	10:00	22.50	10	*0.44*
	7-Jun	10:00	8-Jun	10:00	24.00	8	*0.33*
	8-Jun[a]	10:00	9-Jun	10:15	24.25	9	*0.37*
	9-Jun	10:15	10-Jun	9:30	23.25	6	*0.26*
	10-Jun	9:30	11-Jun	9:30	24.00	8	*0.33*
	11-Jun[b]	9:30	12-Jun	9:15	23.75	0	*0.00*
Total for Heart Trap Site 2					**141.75**	**41**	***0.29***
Heart 3	8-Jun	17:00	9-Jun	10:30	17.50	1	*0.06*
	9-Jun	10:30	10-Jun	9:15	22.75	0	*0.00*
	10-Jun	9:15	11-Jun	9:15	24.00	0	*0.00*
	11-Jun[b]	9:15	12-Jun	8:30	23.25	0	*0.00*
Total for Heart Trap Site 3					**87.50**	**1**	***0.01***
Total for All Heart Trap Sites					**368.75**	**144**	***0.39***

[a] A single bridgelip sucker was captured and released.

[b] Fish released, data not recorded.

Table B5 Injuries observed on rainbow trout (dead and live) captured in the tailrace area of La Joie Dam, 21 May to 16 June 1999.

Trap	Live-Dead	Form of Injury												No. Injured Rainbow Trout[a]		No. Uninjured Rainbow Trout		Total No. of Rainbow Trout Captured In Trap
		Internal Haemorrhaging		External Bruising		Laceration		Impact Injuries		Missing Eye		Severed Body Part						
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	
Fyke 1	Live	0	0%	4	14%	4	14%	1	4%	0	0%	0	0%	7	25%	21	75%	**28**
	Dead	4	33%	1	8%	3	25%	0	0%	0	0%	3	25%	8	67%	4	33%	**12**
Total Fyke 1		**4**	**10%**	**5**	**13%**	**7**	**18%**	**1**	**3%**	**0**	**0%**	**3**	**8%**	**15**	**38%**	**25**	**63%**	**40**
Fyke 2	Live	0	0%	0	0%	1	14%	0	0%	0	0%	0	0%	1	14%	6	86%	**7**
	Dead	2	18%	2	18%	4	36%	2	18%	2	18%	3	27%	10	91%	1	9%	**11**
Total Fyke 2		**2**	**11%**	**2**	**11%**	**5**	**28%**	**2**	**11%**	**2**	**11%**	**3**	**17%**	**11**	**61%**	**7**	**39%**	**18**
IPT 1	Live	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	5	100%	**5**
	Dead	0	0%	1	17%	0	0%	1	17%	0	0%	0	0%	2	33%	4	67%	**6**
Total IPT 1		**0**	**0%**	**1**	**9%**	**0**	**0%**	**1**	**9%**	**2**	**33%**	**0**	**0%**	**2**	**18%**	**9**	**82%**	**11**
IPT 2	Live	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	1	100%	**1**
	Dead	1	50%	1	50%	0	0%	0	0%	0	0%	0	0%	1	50%	1	50%	**2**
Total IPT 2		**1**	**33%**	**1**	**33%**	**0**	**0%**	**0**	**0%**	**0**	**0%**	**0**	**0%**	**1**	**33%**	**2**	**67%**	**3**
Grand Total		**7**	**10%**	**9**	**13%**	**12**	**17%**	**4**	**6%**	**4**	**6%**	**6**	**8%**	**29**	**40%**	**43**	**60%**	**72**

[a] Some fish suffered more than one injury. Sum of all fish injuries does not equal total number of fish injured.

Table B4 Estimated scale loss for rainbow trout (dead and live) captured in the tailrace area of La Joie Dam, 21 May to 16 June 1999.

Trap	Live-Dead	Scale Loss Category										Total No.[a]
		0%		1 to 5%		6 to 20%		21 to 40%		> 40%		
		No.	%	No.	%	No.	%	No.	%	No.	%	
Fyke 1	Live	17	61%	10	36%	1	4%	0	0%	0	0%	28
	Dead	2	18%	3	27%	1	9%	1	9%	4	36%	11
Total Fyke 1		**19**	**49%**	**13**	**33%**	**2**	**5%**	**1**	**3%**	**4**	**10%**	**39**
Fyke 2	Live	5	71%	2	29%	0	0%	0	0%	0	0%	7
	Dead	1	13%	2	25%	1	13%	1	13%	3	38%	8
Total Fyke 2		**6**	**40%**	**4**	**27%**	**1**	**7%**	**1**	**7%**	**3**	**20%**	**15**
IPT 1	Live	4	80%	1	20%	0	0%	0	0%	0	0%	5
	Dead	2	33%	0	0%	1	17%	0	0%	3	50%	6
Total Fyke 3		**6**	**55%**	**1**	**9%**	**1**	**9%**	**0**	**0%**	**3**	**27%**	**11**
IPT 2	Live	0	0%	1	100%	0	0%	0	0%	0	0%	1
	Dead	1	50%	0	0%	0	0%	0	0%	1	50%	2
Total Fyke 4		**1**	**33%**	**1**	**33%**	**0**	**0%**	**0**	**0%**	**1**	**33%**	**3**
Grand Total		**32**	**47%**	**19**	**28%**	**4**	**6%**	**2**	**3%**	**11**	**16%**	**68**

[a] Does not include four partial rainbow trout carcasses captured in traps.

APPENDIX C

ENTRAINMENT DATA AND ANALYSIS

Table C2 Chi-squared test for homogeneity of mark experiments using combined fyke net recoveries of marked rainbow trout.

1) All experiments

Penstock Location	Entrainment Object	Date	No. Recaptured	No. Not Recap.	Total	numerator	denominator	T
via Service Shaft	Radishes	3-Jun	0	190	190	27.28	5.08	5.37
	Live rainbow trout	3-Jun	2	26	28	1.51	0.75	2.02
via Intake	Radishes with leaves	4-Jun	16	284	300	60.10	8.02	7.49
	Live rainbow trout	11-Jun	0	11	11	0.09	0.29	0.31
Tailrace	Peanuts in the shell	22-May	0	200	200	30.23	5.35	5.65
	Radishes	23-May	8	192	200	6.26	5.35	1.17
	Radishes	1-Jun	24	476	500	105.15	13.37	7.87
	Live rainbow trout	1-Jun	0	62	62	2.91	1.66	1.75
	Dead fish (parts and whole)	4-Jun	0	46	46	1.60	1.23	1.30
	Radishes	8-Jun	6	494	500	60.00	13.37	4.49
			56	1981	2037		T=	37.43
							df=	9.00
							Chi (.15)=	13.29

Therefore, no homogeneity, no pooling

2) Radish releases only excluding service shaft release

Penstock Location	Entrainment Object	Date	No. Recaptured	No. Not Recap.	Total	numerator	denominator	T
Intake	Radishes with leaves	4-Jun	16	284	300	27.04	10.41	2.60
Tailrace	Radishes	23-May	8	192	200	0.64	6.94	0.09
	Radishes	1-Jun	24	476	500	36.00	17.35	2.07
	Radishes	8-Jun	6	494	500	144.00	17.35	8.30
			54	1446	1500		T=	13.06
							df=	3.00
							Chi (.15)=	5.32

Therefore, no homogeneity, no pooling

3) Radish releases (excludes the 8 June test)

Penstock Location	Entrainment Object	Date	No. Recaptured	No. Not Recap.	Total	numerator	denominator	T
	Radishes with leaves	4-Jun	16	284	300	2.56	13.71	0.19
	Radishes	23-May	8	192	200	2.56	9.14	0.28
	Radishes	1-Jun	24	476	500	0.00	22.85	0.00
			48	952	1000		T=	0.47
							df=	2.00
							Chi (.15)=	3.79

Therefore, homogeneity, can pool!

4) Compare Fyke 1 and Fyke 2

Penstock Location	Entrainment Object	Date	No. Recaptured	No. Not Recap.	Total	numerator	denominator	T
Fyke 1	Radishes	All in 3	27	973	1000	9.00	23.42	0.38
Fyke 2		above	21	979	1000	9.00	23.42	0.38
			48	1952	2000		T=	0.77
							df=	1.00
							Chi (.15)=	2.07

Therefore, homogeneity, can pool!

Table C1 Recapture rates for trap efficiency tests conducted 22 May to 11 June 1999. The 95% CI limits for the trap efficiency estimates are based on a Poisson frequency distribution related to the number of entrainment objects captured during the test.

Location	Entrainment Object	Date	Time	No. Released	IPT 1		IPT 2		Total for IPTs		Fyke 1		Fyke 2		Total for Fyke Nets	
					No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Penstock																
via service shaft	Radishes	3-Jun	12:00	190	0	0.0%	0	0.0%	**0**	**0.0%**	0	0.0%	0	0.0%	**0**	**0.0%**
	Live rainbow trout	3-Jun	12:10	28	0	0.0%	0	0.0%	**0**	**0.0%**	2	7.1%	0	0.0%	**2**	**7.1%**
via intake	Radishes with leaves	4-Jun	14:00	300	4	1.3%	3	1.0%	**7**	**2.3%**	7	2.3%	9	3.0%	**16**	**5.3%**
	Live rainbow trout	11-Jun	11:00	10	0	0.0%	0	0.0%	**0**	**0.0%**	0	0.0%	0	0.0%	**0**	**0.0%**
	Dead rainbow trout	11-Jun	11:00	1	0	0.0%	0	0.0%	**0**	**0.0%**	0	0.0%	0	0.0%	**0**	**0.0%**
Tailrace																
	Peanuts in the shell	22-May	8:40	200	6	3.0%	0	0.0%	**6**	**3.0%**	0	0.0%	0	0.0%	**0**	**0.0%**
	Radishes	23-May	10:38	200	4	2.0%	6	3.0%	**10**	**5.0%**	5	2.5%	3	1.5%	**8**	**4.0%**
	Radishes	1-Jun	20:40	500	8	1.6%	7	1.4%	**15**	**3.0%**	15	3.0%	9	1.8%	**24**	**4.8%**
	Live rainbow trout	1-Jun	12:30	62	0	0.0%	0	0.0%	**0**	**0.0%**	0	0.0%	0	0.0%	**0**	**0.0%**
	Dead fish (parts and whole)	4-Jun	16:00	46	0	0.0%	1	2.2%	**1**	**2.2%**	0	0.0%	0	0.0%	**0**	**0.0%**
	Radishes	8-Jun	13:00	500	11	2.2%	7	1.4%	**18**	**3.6%**	1	0.2%	5	1.0%	**6**	**1.2%**
Total of Radish Tests (23 May, 1 June and 4 June only)				**1000**	**16**	**1.6%**	**16**	**1.6%**	**32**	**3.2%**	**27**	**2.7%**	**21**	**2.1%**	**48**	**4.8%**

Table C4 Regression statistics for fyke net rainbow trout CPUE as a function of Downton Lake reservoir water surface elevation.

Ln (no. of rainbow trout + 1 caught/fyke net day)=a+b x Downton Lake reservoir elevation (m)
N = 24 Multiple R: 0.752 Squared multiple R: 0.566
Standard error of estimate: 0.324

		<95%>					
Effect	**Coefficient**	**Lower**	**Upper**	**Std Error**	**Std Coef**	**t**	**P (2 Tail)**
Constant (a)	101.244	62.308	140.18	18.775	0	5.393	>.001
Reservoir Elevation (b)	-0.141	-0.196	-0.087	0.026	-0.752	-5.354	>.001

Table C3 Entrainment estimate of rainbow trout projected from fyke net capture efficiency estimates conducted on 23 May, 1 June, and 4 June 1999 (see Table B3). Estimates are provided only for the days that sampling was conducted from 22 May to 16 June 1999.

Date	Hours	Catch	Catch/net day	Projections	Variance	95% CI	95% CI
All days	1113	58	1	1185	40769	789	1581
22/May	32	3	2	61			
23/May	34	7	5	143			
24/May	49	4	2	82			
25/May	46	7	4	143			
26/May	51	4	2	82			
27/May	46	4	2	82			
28/May	48	6	3	123			
29/May	48	3	2	61			
30/May	48	2	1	41			
31/May	48	1	0	20			
1/Jun	49	2	1	41			
2/Jun	45	1	1	20			
3/Jun	50	4	2	82			
4/Jun	48	0	0	0			
5/Jun	46	2	1	41			
6/Jun	50	1	0	20			
7/Jun	48	1	1	20			
8/Jun	47	0	0	0			
9/Jun	49	1	0	20			
10/Jun	47	2	1	41			
11/Jun	48	1	0	20			
12/Jun							
13/Jun							
14/Jun	59	1	0	20			
15/Jun	45	0	0	0			
16/Jun	32	1	1	20			

Table C5 Continued.

Date	Rainbow Trout Entrained	95% Lower	95% Upper	Actual	Downton Lake elevation	Predicted SE Ln(CPUE+1)
6-May	31.16	2.22	60.09		714.08	0.34
7-May	36.07	7.29	64.85		713.62	0.33
8-May	41.71	13.05	70.37		713.12	0.33
9-May	48.08	19.49	76.67		712.60	0.33
10-May	55.73	27.15	84.31		712.02	0.33
11-May	64.63	36.03	93.23		711.40	0.33
12-May	69.55	40.91	98.18		711.08	0.33
13-May	74.33	45.64	103.03		710.78	0.33
14-May	79.36	50.60	108.12		710.48	0.33
15-May	84.32	55.47	113.16		710.20	0.33
16-May	89.68	60.75	118.60		709.90	0.33
17-May	94.34	65.35	123.33		709.65	0.33
18-May	97.69	68.70	126.67		709.48	0.34
19-May	97.49	68.51	126.48		709.49	0.34
20-May	97.49	67.99	127.00		709.49	0.34
21-May	120.64	91.02	150.27		708.40	0.34
22-May	125.55	95.82	155.29	3	708.19	0.34
23-May	129.78	100.04	159.53	7	708.01	0.34
24-May	130.03	100.44	159.61	4	708.00	0.34
25-May	123.85	94.69	153.01	7	708.26	0.34
26-May	105.84	76.88	134.81	4	709.08	0.34
27-May	96.36	67.52	125.20	4	709.55	0.34
28-May	89.68	60.90	118.45	6	709.90	0.33
29-May	85.22	56.50	113.95	3	710.14	0.33
30-May	81.78	53.09	110.47	2	710.34	0.33
31-May	79.19	50.55	107.84	1	710.49	0.33
1-Jun	75.00	46.41	103.59	2	710.74	0.33
2-Jun	68.10	39.52	96.68	1	711.17	0.33
3-Jun	63.74	35.17	92.32	4	711.46	0.33
4-Jun	59.61	31.00	88.21	0	711.74	0.33
5-Jun	53.28	24.56	81.99	2	712.20	0.33
6-Jun	44.74	15.89	73.59	1	712.87	0.33
7-Jun	38.97	10.02	67.92	1	713.36	0.33
8-Jun	35.52	6.47	64.57	0	713.67	0.34
9-Jun	32.85	3.72	61.97	1	713.92	0.34
10-Jun	31.03	1.82	60.24	2	714.10	0.34
11-Jun	29.16	0.00	58.47	1	714.28	0.34
12-Jun	27.09	0.00	56.54		714.49	0.34
13-Jun	24.76	0.00	54.45		714.73	0.34
14-Jun	20.98	0.00	51.07	1	715.15	0.34
15-Jun	15.82	0.00	46.55	0	715.76	0.35
16-Jun	9.54	0.00	41.33	1	716.58	0.36
17-Jun	1.88	0.00	34.75		717.73	0.37
18-Jun	0.00	0.00	29.85		718.75	0.38
19-Jun	0.00	0.00	26.75		719.55	0.39
20-Jun	0.00	0.00	24.19		720.28	0.40
21-Jun	0.00	0.00	22.53		720.83	0.41

Continued...

Table C5 Model Projections of total entrainment using the natural logarithm of combined fyke net rainbow trout catch data (Log of rainbow trout per trap day +1). The projections encompassed the period from 1 April through 1 August. The regression parameters and trap efficiency estimate used in projections are listed.

Ln(CPUE+1) = (a) -(b) x Downton Lake reservoir water elevation	Constant (a)	Downton Lake Reservoir Elevation (b)	Fyke Net Trap Efficiency	Standard Error	N	T(.05, df=n-2)
Mean	101.244	-0.141	0.024	0.32	24	2.07

Date	Rainbow Trout Entrained	95% Lower	95% Upper	Actual	Downton Lake elevation	Predicted SE Ln(CPUE+1)
Totals	2993	1691	6005	58		
1-Apr	0.00	0.00	15.28		724.87	0.48
2-Apr	0.00	0.00	15.42		724.55	0.47
3-Apr	0.00	0.00	16.02		724.17	0.47
4-Apr	0.00	0.00	15.95		723.98	0.46
5-Apr	0.00	0.00	16.50		723.64	0.46
6-Apr	0.00	0.00	16.58		723.42	0.45
7-Apr	0.00	0.00	17.20		723.09	0.45
8-Apr	0.00	0.00	17.45		722.89	0.44
9-Apr	0.00	0.00	17.64		722.67	0.44
10-Apr	0.00	0.00	18.26		722.34	0.44
11-Apr	0.00	0.00	18.59		722.07	0.43
12-Apr	0.00	0.00	19.50		721.68	0.42
13-Apr	0.00	0.00	20.26		721.38	0.42
14-Apr	0.00	0.00	20.63		721.16	0.42
15-Apr	0.00	0.00	21.45		720.84	0.41
16-Apr	0.00	0.00	22.34		720.51	0.41
17-Apr	0.00	0.00	23.42		720.17	0.40
18-Apr	0.00	0.00	24.35		719.88	0.40
19-Apr	0.00	0.00	25.39		719.60	0.39
20-Apr	0.00	0.00	26.00		719.39	0.39
21-Apr	0.00	0.00	27.70		719.05	0.38
22-Apr	0.00	0.00	26.94		719.05	0.38
23-Apr	0.00	0.00	30.26		718.37	0.38
24-Apr	0.00	0.00	31.54		718.10	0.37
25-Apr	1.31	0.00	32.97		717.82	0.37
26-Apr	2.65	0.00	34.11		717.61	0.37
27-Apr	3.99	0.00	35.17		717.39	0.36
28-Apr	5.92	0.00	36.80		717.10	0.36
29-Apr	8.31	0.00	38.88		716.75	0.36
30-Apr	10.93	0.00	41.23		716.39	0.35
1-May	13.51	0.00	43.56		716.05	0.35
2-May	16.29	0.00	46.10		715.70	0.35
3-May	19.22	0.00	48.80		715.35	0.35
4-May	22.48	0.00	51.83		714.98	0.34
5-May	26.49	0.00	55.61		714.55	0.34

Continued...

Table C5 Concluded.

Date	Rainbow Trout Entrained	95% Lower	95% Upper	Actual	Downton Lake elevation	Predicted SE Ln(CPUE+1)
22-Jun	0.00	0.00	21.36		721.30	0.42
23-Jun	0.00	0.00	20.36		721.72	0.42
24-Jun	0.00	0.00	19.66		722.08	0.43
25-Jun	0.00	0.00	19.07		722.45	0.44
26-Jun	0.00	0.00	18.46		722.85	0.44
27-Jun	0.00	0.00	17.83		723.25	0.45
28-Jun	0.00	0.00	17.39		723.59	0.46
29-Jun	0.00	0.00	16.99		723.90	0.46
30-Jun	0.00	0.00	16.75		724.16	0.47
1-Jul	0.00	0.00	16.71		724.41	0.47
2-Jul	0.00	0.00	16.47		724.77	0.48
3-Jul	0.00	0.00	16.22		725.13	0.49
4-Jul	0.00	0.00	16.18		725.45	0.49
5-Jul	0.00	0.00	16.14		725.83	0.50
6-Jul	0.00	0.00	16.12		726.25	0.51
7-Jul	0.00	0.00	16.18		726.70	0.52
8-Jul	0.00	0.00	16.26		727.19	0.53
9-Jul	0.00	0.00	16.33		727.69	0.54
10-Jul	0.00	0.00	16.57		728.16	0.55
11-Jul	0.00	0.00	16.99		728.67	0.56
12-Jul	0.00	0.00	17.39		729.27	0.57
13-Jul	0.00	0.00	17.73		729.89	0.58
14-Jul	0.00	0.00	18.41		730.45	0.60
15-Jul	0.00	0.00	19.15		731.12	0.61
16-Jul	0.00	0.00	19.41		731.84	0.63
17-Jul	0.00	0.00	19.81		732.30	0.64
18-Jul	0.00	0.00	20.17		732.70	0.65
19-Jul	0.00	0.00	19.93		733.04	0.65
20-Jul	0.00	0.00	22.17		733.04	0.65
21-Jul	0.00	0.00	24.25		734.17	0.68
22-Jul	0.00	0.00	26.20		735.58	0.71
23-Jul	0.00	0.00	23.46		736.92	0.74
24-Jul	0.00	0.00	26.33		735.87	0.72
25-Jul	0.00	0.00	28.03		737.05	0.75
26-Jul	0.00	0.00	24.45		738.13	0.77
27-Jul	0.00	0.00	25.94		736.58	0.74
28-Jul	0.00	0.00	26.99		737.02	0.75
29-Jul	0.00	0.00	28.31		737.62	0.76
30-Jul	0.00	0.00	29.26		738.37	0.78
31-Jul	0.00	0.00	29.96		738.96	0.79
1-Aug	0.00	0.00	0.00		739.39	0.80