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**WHITE STURGEON INVESTIGATIONS  
IN ARROW RESERVOIR, B.C.**

**1998 STUDY RESULTS**

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**- DATA REPORT -**

Prepared for

**B.C. MINISTRY OF ENVIRONMENT, LANDS AND PARKS**  
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by

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**Cover photo:** Early reproductive male white sturgeon (180.5 cm FL, 59.0 kg, 34 years old) captured in the Beaton Flats area, 23 October 1998. Note the right and left pectoral fin scars. The right fin scar is likely an old fin clip from a previous capture by Kootenay Wildlife Services Ltd. in 1995. The left fin scar is a new fin clip taken by R.L. & L. during the October 1998 sampling.

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# 1.0 INTRODUCTION

## 1.1 BACKGROUND

Historically, white sturgeon (*Acipenser transmontanus*) were likely distributed throughout the Columbia River Basin, within the mainstem Columbia and Kootenay rivers in Canada and larger tributaries and lakes within these drainages. These populations would have had access to the Pacific Ocean, although there is a possibility that resident sub-populations may have existed in some parts of the drainage. During the last glaciation, approximately 10 000 years ago, a natural barrier was formed at Bonnington Falls on the lower Kootenay River between the outlet of Kootenay Lake and the Columbia River (Northcote 1973). This barrier isolated white sturgeon in Kootenay Lake and the Kootenay River (termed the Kootenay population) from populations in the Columbia River (termed the Columbia population).

The construction of dams on the Columbia and Kootenay rivers has resulted in additional fragmentation and isolation of white sturgeon populations (Figure 1.1). The earliest dam constructed on the Kootenay River was built over Lower Bonnington Falls in 1897. Subsequently, three other dams, Upper Bonnington, South Slocan, and Corra Linn, were completed in 1907, 1928, and 1932, respectively. In 1944, fish movement between the Columbia and Kootenay rivers was further restricted with the completion of Brilliant Dam, located 2.8 km upstream from the Kootenay-Columbia confluence.

On the Columbia River mainstem, three dams have been constructed since the ratification of the Columbia River Treaty with the United States in 1968. Two dams, Hugh L. Keenleyside and Mica, ensure that adequate storage is available to provide the hydro generation potential and flood control required by the Treaty. Revelstoke Dam, a non-treaty dam, was constructed by BC Hydro for hydro power generation. Hugh L. Keenleyside Dam, a flow regulation facility commissioned in 1968, is the furthest downstream of the dams and is located at the south end of Arrow Reservoir. The river from Hugh L. Keenleyside Dam downstream to Lake Roosevelt is one of the few remaining flowing sections of the Columbia River and supports a small population of white sturgeon. This population also experiences frequent recruitment failures that are likely related to the effects of river regulation and industrial developments (R.L. & L. 1994).

Anecdotal reports of white sturgeon sightings suggest that there may be several remnant populations of white sturgeon trapped behind and/or between dams on both the mainstem Columbia and Kootenay rivers and in larger lakes and tributaries to these systems. Reconnaissance level surveys conducted by Kootenay Wildlife Services Ltd. in 1995 (R.L. & L. 1996) and by R.L. & L. Environmental Services Ltd. in 1997 (R.L. & L. 1998a) recorded the presence of what is likely a remnant population of white sturgeon in Arrow Reservoir between Hugh L. Keenleyside Dam and Revelstoke Dam. Sampling in 1997 also resulted in the capture of a pre-spawning female, with the potential to spawn in 1998.

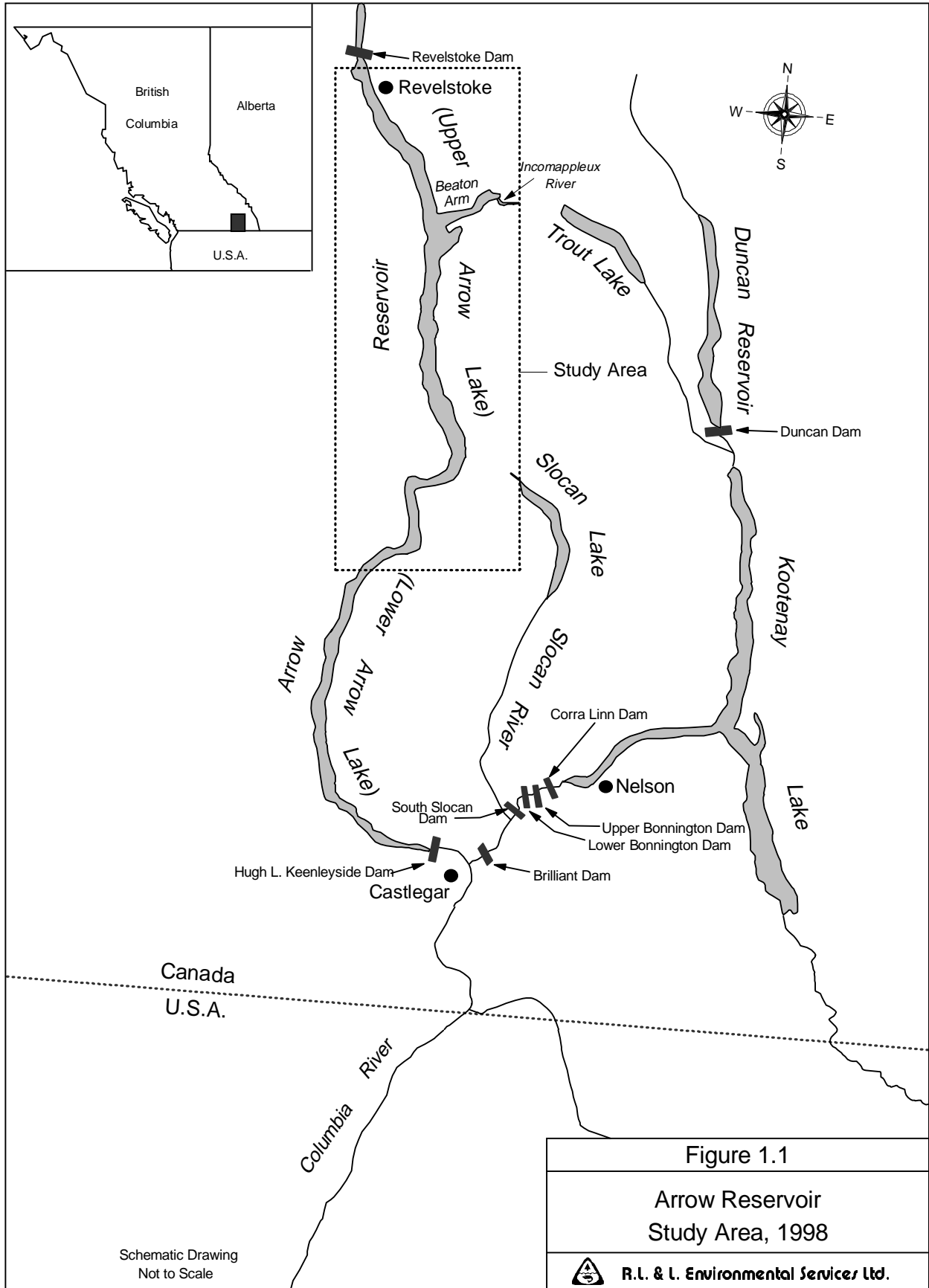


Figure 1.1

Arrow Reservoir  
Study Area, 1998



R.L. & L. Environmental Services Ltd.

Schematic Drawing  
Not to Scale

To obtain additional information on this population, and to determine if spawning may occur in Arrow Reservoir, R.L. & L. Environmental Services Ltd. was contracted by B.C. Ministry of Environment, Lands, and Parks (Kootenay Region) to conduct a white sturgeon sampling and sonic telemetry program on Arrow Reservoir in 1998. Additionally, behaviour exhibited by the reproductively mature female during the June to July spawning season suggested the potential for spawning activity; this behaviour led to the inclusion of an egg sampling program.

## 1.2 OBJECTIVES

The 1998 Arrow Reservoir white sturgeon study program proposed by R.L. & L. Environmental Services Ltd. outlined the following objectives:

- to determine the distribution and abundance of white sturgeon in Arrow Reservoir, with a proportion of the sampling allocated to areas (such as Burton Flats) with habitat characteristics similar to those in areas known to be used by white sturgeon (e.g., Beaton Flats, as identified in the 1997 study).
- to collect life history information from captured white sturgeon, in order to determine growth rates, size-class and age-class composition;
- to determine seasonal movement patterns of white sturgeon in these systems via the use of sonic telemetry;
- to determine the effectiveness of archival tags for collecting continuous habitat preference data from tagged white sturgeon in Arrow Reservoir;
- during the 1998 spawning season, monitor movement patterns of the reproductively mature female white sturgeon tagged in 1997, to determine if this fish would exhibit spawning behaviour; and
- to conduct egg sampling in areas with potential spawning activity, based on the behaviour of the reproductively mature female, and the presence of suitable spawning habitat.

## 1.3 STUDY AREA

Arrow Reservoir is located between the Monashee and Selkirk Mountain ranges. The construction of the Hugh L. Keenleyside Dam in 1968 impounded two pre-existing lakes (Upper Arrow and Lower Arrow) that were originally separated by a section of free-flowing Columbia River. As a result of the dam, these two lakes and large sections of the free-flowing Columbia River were flooded to create one long waterbody. Although the official name of this waterbody is Arrow Reservoir, the upper and lower lakes are still referred to locally as Upper Arrow and Lower Arrow lakes, respectively (Figure 1.1). Revelstoke Dam forms the upper boundary of Arrow Reservoir. At full pool, the reservoir extends to within 10 km downstream of Revelstoke Dam.

## 1.4 STUDY PERIOD

Set line sampling was conducted in August and October 1998, and in March 1999, in the upper portion of Arrow Reservoir (Table 1.1). Boat-based tracking of sonic-tagged fish was conducted on a weekly basis during the late May to late July 1998 period, and on a monthly basis from August 1998 to March 1999. Sampling for white sturgeon eggs was conducted from 3 June to 21 July 1998.

Table 1.1 Sampling periods for the Arrow Reservoir white sturgeon study, 1998-1999.

Activity	Session	Date
Adult Sampling	Summer	10 to 13 August 1998
	Fall	19 to 30 October 1998
	Winter	1 to 4 March 1999
Sonic Tracking	Weekly (Spawning Season)	May to July 1998
	Monthly (Seasonal Survey)	August 1998 to March 1999
Egg Sampling	Weekly (Spawning Season)	3 June to 21 July 1998

## 2.0 METHODOLOGY

### 2.1 CAPTURE TECHNIQUES

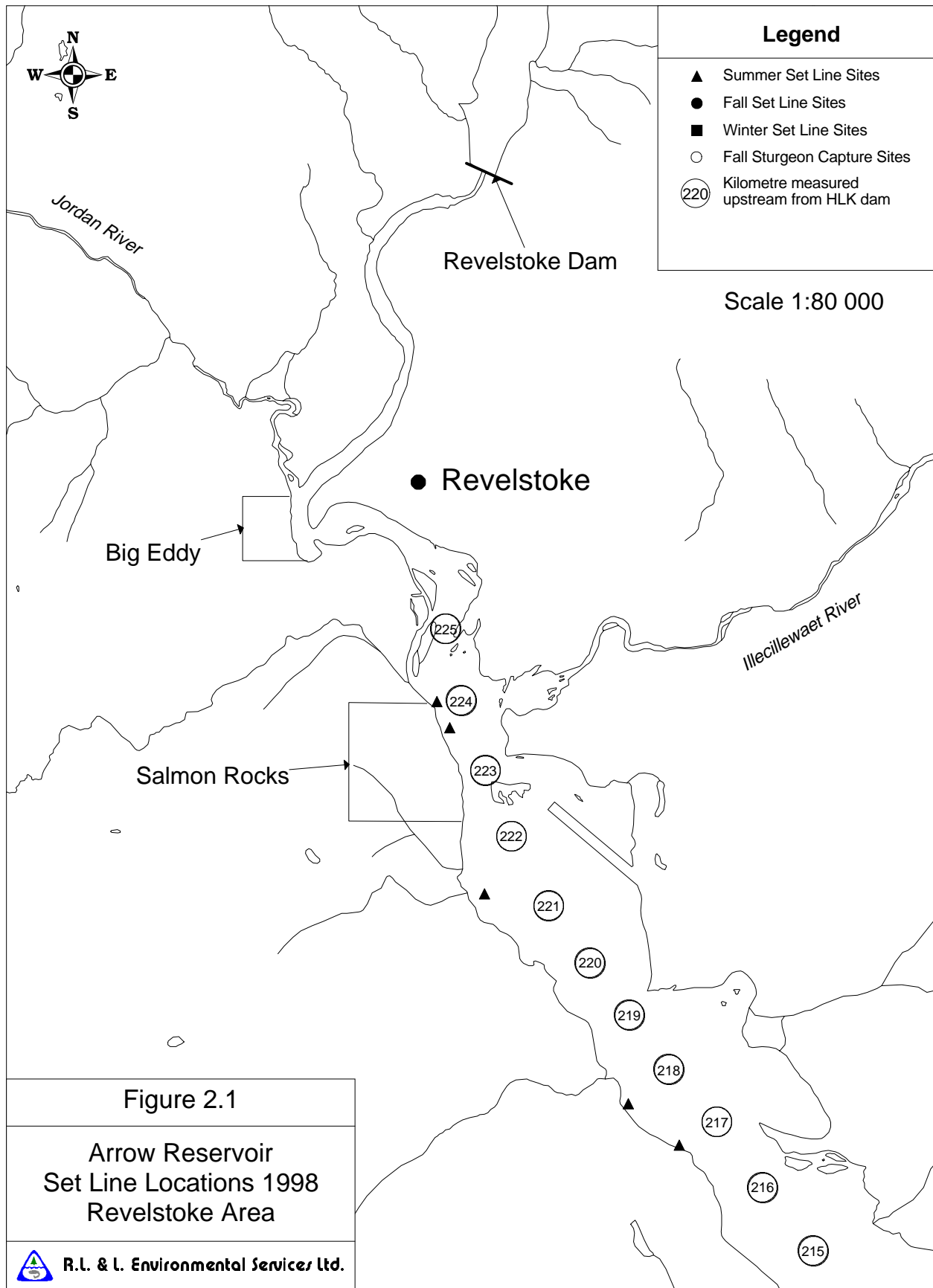
#### 2.1.1 Set Lines

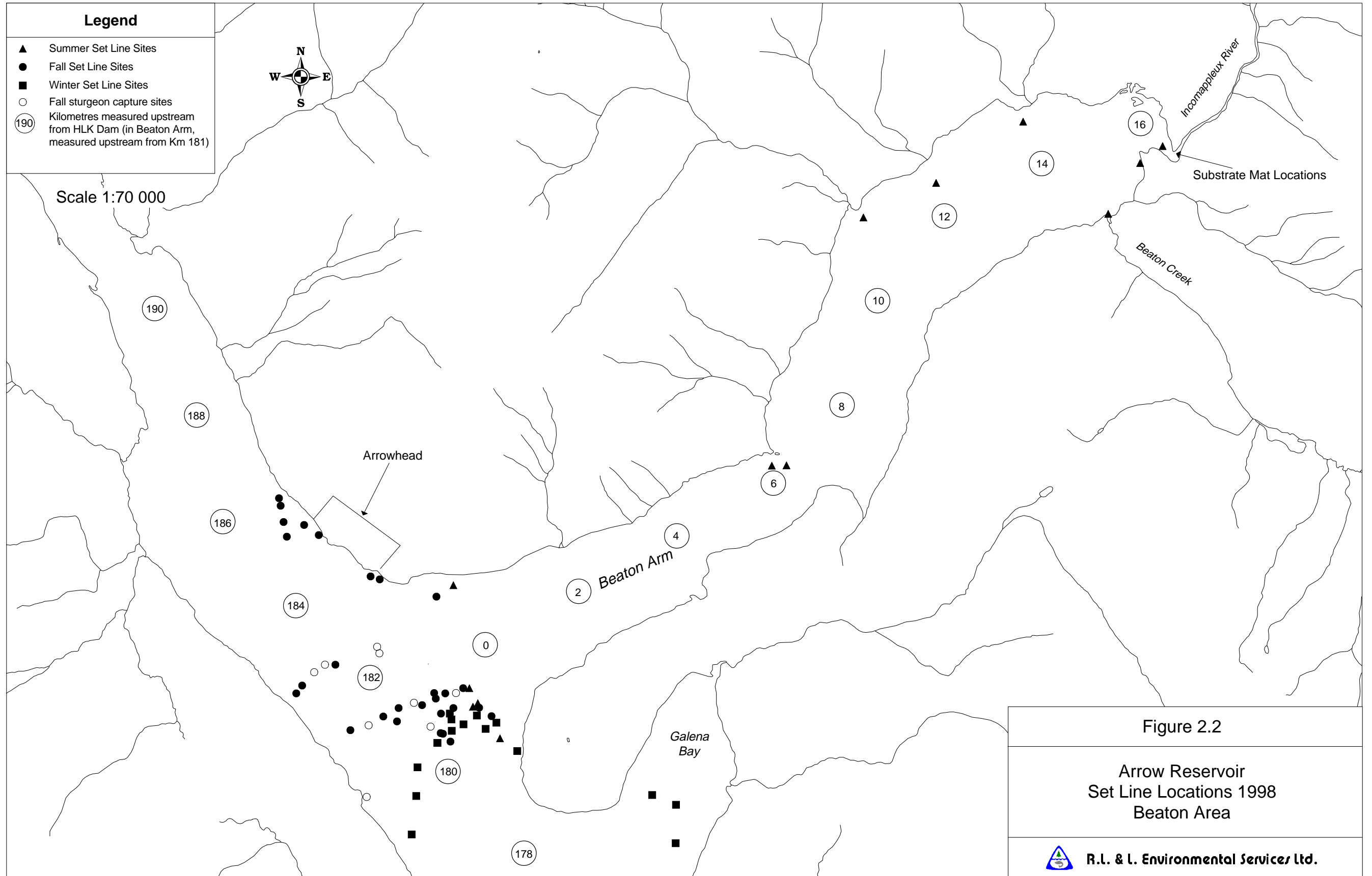
Set lines were the primary method used to capture white sturgeon in Arrow Reservoir. This method provides the greatest catch-rate of white sturgeon and is less selective than other sample gear (Elliot and Beamesderfer 1990). Two set line configurations were used: medium lines (40 m mainline with eight hooks), and long lines (180 m mainline with 30 hooks). The type of set line deployed was determined by habitat conditions at each sampling location. Each set line generally consisted of a 1.3 cm diameter mainline rope with circle halibut hooks attached at approximately 5.0 m intervals. The hook lines consisted of a 0.64 cm swivel snap and a 0.5 m long dropper line tied between the swivel and the hook. In the summer sampling session, hook sizes used were 12/0, 14/0, and 16/0. The use of these hook sizes resulted in a large burbot (*Lota lota*) by-catch, primarily on the two smaller hook sizes. To reduce this by-catch, only large hooks (16/0) were used in the fall and winter sampling sessions.

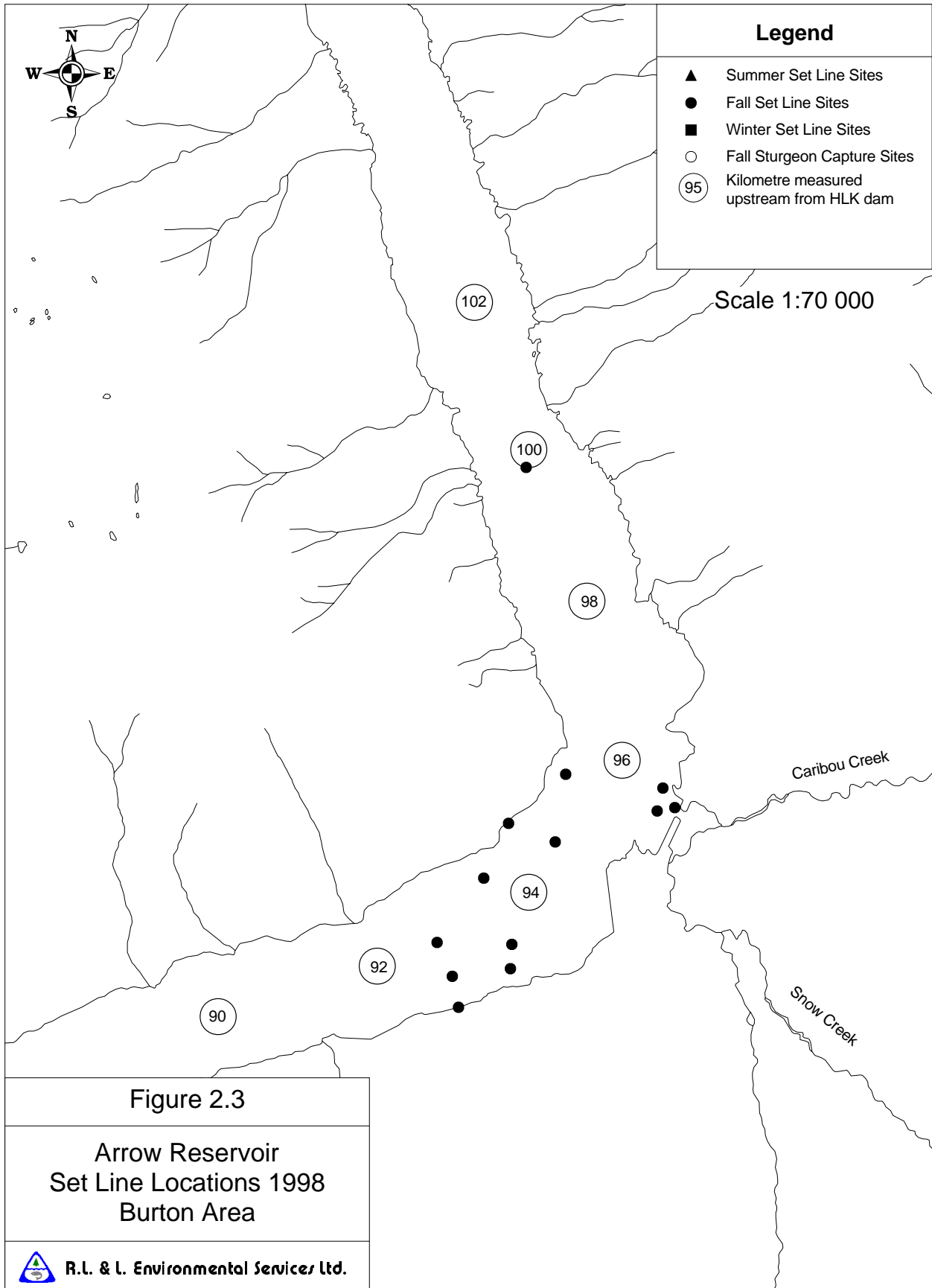
Sharpened hooks were baited with kokanee obtained from Meadow Creek and Hill Creek kokanee spawning channels, or with pickled squid obtained from J. Devore (Washington Department of Fish and Game). To ensure the set line remained in position and the hooks rested on the bottom, 4.5 kg anchors were attached to each end of the set line during deployment. Buoys were attached to the anchors to facilitate retrieval.

Set lines were deployed from a boat and generally set overnight in nearshore areas of varying depths (i.e., near Revelstoke and within Beaton Arm; Figures 2.1 and 2.2, respectively) or in mid-lake areas over flat bottoms (i.e., Beaton Flats and Burton Flats; Figures 2.2 and 2.3, respectively). These areas were selected based on visual assessments of surface conditions and bottom configuration as determined with a depth sounder. The number of set lines deployed varied according to the number of suitable locations within an area and the number of lines a crew could effectively set and retrieve. The UTM coordinates at sample sites were measured using a Garmin 45 handheld GPS unit. Coordinates at sample locations represent uncorrected, non-average values. Summaries of set line sampling times and frequencies are provided in Appendix A, Table A1.

Data recorded at each set line included date, location, set duration, water temperature, minimum and maximum depth, number of hooks, and catch. Catch-per-unit-effort (CPUE=no. fish/100 hook-hours) was calculated for each set.







Captured fish were brought to the boat and noosed behind the pectoral fins and around the caudal peduncle. The fish were then held securely by the crew, while the boat was driven slowly to shore. Once on shore, fish were placed into a 2.5 m by 1.0 m stretcher constructed of a waterproof plastic laminate material; the head of the fish was placed in a hood located at one end of the stretcher. This had a calming effect on the fish. Fish were left in the water during processing (except during the weight measurement) so the fish could respire normally during processing. After processing, fish were removed from the stretcher and released once normal respiration, orientation, and swimming behaviour were observed by the study team.

Incidental captures of other fish species were removed from the set lines, identified, and then measured for length. Any incidental captures in good condition after processing were marked with a Floy tag and released.

### **2.1.2 Substrate Mats**

The behaviour of the reproductively mature female during the 1998 spawning season was suggestive of pre-spawning activity; the fish moved from Beaton Flats to near the confluence of Beaton Arm and the Incomappleux River (15.5 km from the mouth of Beaton Arm). Based on preliminary observations in the mouth of the Incomappleux River (Plate 1; Figure 2.2), habitat conditions were deemed to have potential suitability for use by white sturgeon spawning (i.e., high velocities, depths greater than 3 m, cobble/boulder substrates). Therefore, a white sturgeon egg capture program was initiated in the area.

Artificial substrate mats were employed to capture eggs of white sturgeon. This technique has been used successfully to identify white sturgeon spawning areas and monitor spawning intensity and success in the Columbia and Kootenay rivers (R.L. & L. 1994, Marcuson et al. 1995). Substrate mats were constructed of filter material (latex-coated animal hair) cut into 76 cm by 91 cm sections and secured within an angle iron frame with strips of flat bar. The strips were held in place with nuts and bolts to allow removal of the filter material for cleaning. Two sections of filter material were placed back to back within each frame; this ensured that the filter material always faced up, regardless of how the frame rested on the river bottom. The substrate mat was attached to a shore-line anchor rope that held the substrate mat in place. A buoy line was also attached to the substrate mat to mark its location in the river. A summary of substrate mat sampling times and sampling frequencies are provided in Appendix A, Table A2. Locations of sample sites are plotted in Figure 2.4.

## **2.2 SEASONAL MOVEMENT AND POPULATION ESTIMATES**

### **2.2.1 Fish Marking**

In 1998, all of the white sturgeon captured for the first time (i.e., not previously marked by the study team) were marked with a numbered Floy™ T-anchor tag, a Passive Integrated Transponder (PIT) tag from Biosonics Inc., and by the removal of a section of the left pectoral fin (i.e., used for ageing purposes). The Floy tag and fin clip marking techniques used during the 1998 sampling program have been in use on the Columbia River system since 1990. PIT tags were introduced as a marking system in 1992, and have since been a standard component of the fish marking program.

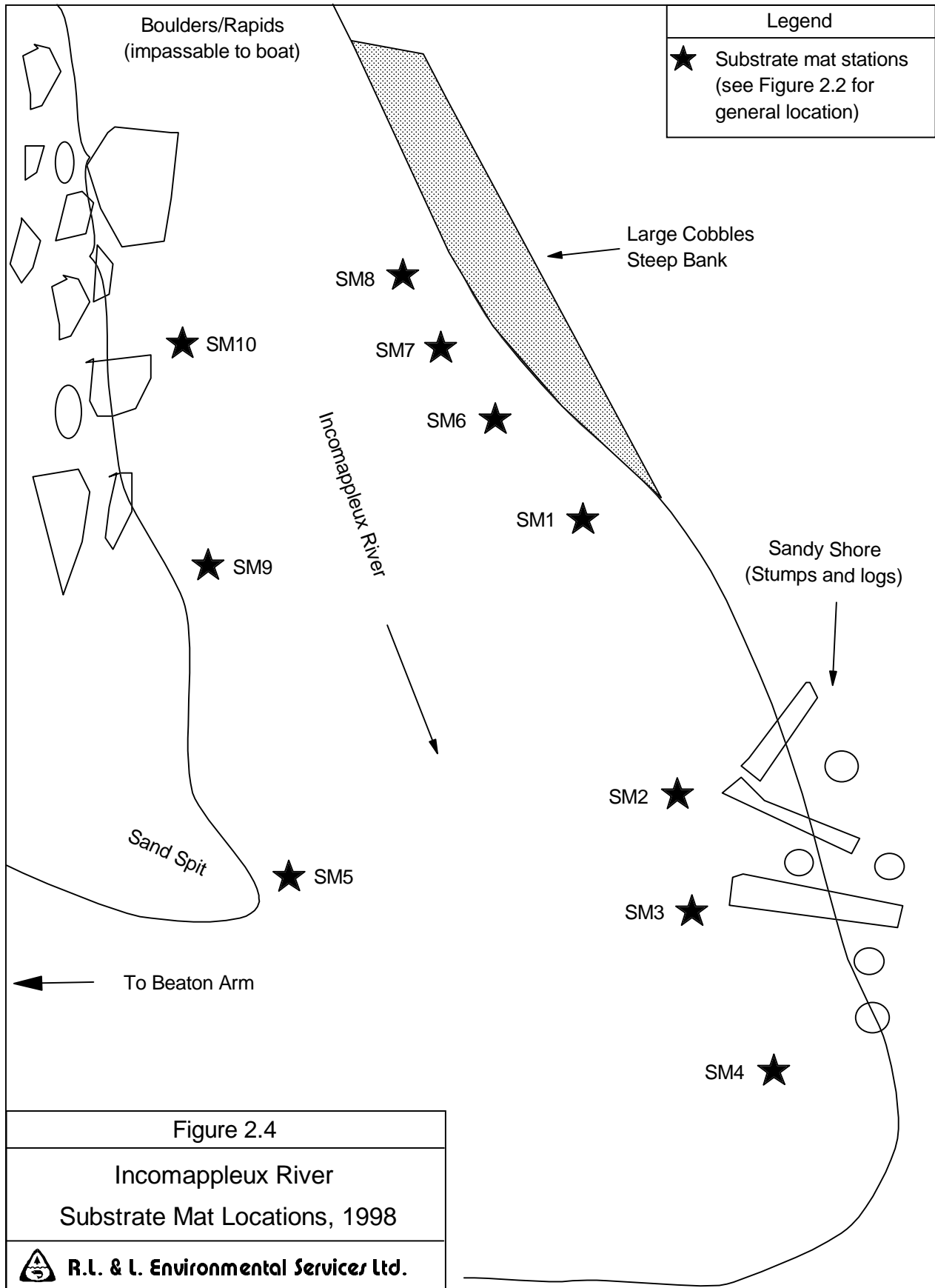


Figure 2.4

Incomappleux River  
Substrate Mat Locations, 1998



R.L. & L. Environmental Services Ltd.

### **2.2.2 Population Estimate**

A white sturgeon population estimate was derived from mark-recapture data using the Modified Schnabel Estimation Technique described in Krebs (1989). Confidence Intervals (CI) were calculated at the 95% levels (using a Poisson distribution). Assumptions and systematic errors associated with this technique are outlined in Krebs (1989). Sample sizes (both number of mark-recapture sessions and number of fish captured) were the minimum size allowable for the calculation of a population estimate which resulted in low confidence in the estimate. This population estimate should be regarded as preliminary.

### **2.2.3 Sonic Telemetry**

To assist in assessing the extent and purpose (e.g., home territory, dispersal, spawning behaviour, habitat utilization) of white sturgeon movements, internally implanted sonic transmitters were used. All white sturgeon captured without an existing sonic tag were equipped with one during the 1998 program.

The sonic transmitters used were manufactured by Sonotronics. The transmitters were 65 mm in length and 18 mm in diameter, weighed 8 g in air, and had either a 48 month rated life span (Model CT-82-3-M) or an 18 month life span (high output tags, Model CHP-87-L/M). The high output tags ( $n=2$ ) were used in an attempt to increase signal reception during the thermally stratified late summer period. All sonic transmitters had unique codes and operated within a frequency range of 730 kHz (48-month tags) or 760 kHz (18-month tags). The surgical procedures used to internally implant sonic transmitters in white sturgeon followed those described in Hildebrand and English (1991).

Tracking of sonic-tagged white sturgeon was conducted from a boat, using either a omni- or a uni-directional hydrophone. A 50-foot extension cable was attached to the omni-directional hydrophone during late-summer and early fall, to lower the hydrophone below the metalimnion. Theoretically, the range of the tags should be increased if the hydrophone is below the thermal stratification layer, since this layer can act as a barrier to the sonic signal (M. Gregor, Sonotronics, Tucson, Arizona, pers. comm., 1998). The majority of tracking occurred in the area upstream of Km 170. However, the entire system (Hugh L. Keenleyside Dam to Revelstoke) was tracked in August, and the area between Km 90 (Burton) and Km 170 was tracked monthly between May and August.

### **2.2.4 Archival Tags**

Two of the white sturgeon caught in Arrow Reservoir in 1997 were equipped with archival tags (R.L. & L. 1998a). These tags were programmed to continuously measure and record water pressure (depth) and temperature data at one hour intervals. Since the archival tags must be recovered to retrieve the data, fish equipped with these tags also were equipped with a sonic tag to increase their chance of recapture. Attempts were made to recapture these individuals during each of the sampling sessions in the 1998 study.

The archival tags were prototype models manufactured by Advanced Telemetry Systems. The tags were 50 mm in length and 14 mm in diameter, powered by a 3.6 Volt battery. The maximum data storage capacity of the tags was 32 746 bytes. The tags were designed to measure water temperature and pressure to within an accuracy of  $\pm 0.5^{\circ}\text{C}$  and  $\pm 2$  PSI, respectively.

## **2.3 LIFE HISTORY DATA**

### **2.3.1 Length and Weight**

White sturgeon were measured for fork length (FL), snout to post-opercular edge length (SL), and total length (TL) to the nearest 0.5 cm. Girth was measured behind the pectoral fins to the nearest 0.5 cm. Weight was determined using a 135 kg capacity spring scale accurate to  $\pm 2.3$  kg.

### **2.3.2 Growth Characteristics**

Brennan and Cailliet (1989) reported that calcified structures (pectoral fin rays, opercles, clavicles, cleithra, medial nuchals, and dorsal scutes) used to age white sturgeon did not result in significantly different estimates of age. Pectoral fin rays appeared to provide the highest accuracy and did not require sacrificing the fish.

A section from the leading left pectoral fin ray was removed from all captured white sturgeon for ageing purposes. Fin ray sections were obtained by making two cuts with a sterilized hacksaw blade or sidecutter pliers; the first cut was made approximately 5 mm distal from the point of articulation (knuckle) of the pectoral fin and the second was made approximately 10 mm distal from the first. Sections were then separated from the fin with a sterilized surgical knife and pliers and placed in an envelope marked with the appropriate information. Care was taken not to sever the artery close to the articulation of the fin ray. If there was any bleeding from the area of the removed fin section, the area was swabbed with an antiseptic and pressure was applied to seal the wound.

Four to six transverse sections (0.3 to 0.6 mm thickness) were obtained from each fin ray using a jewellers saw. The sections were permanently mounted on glass microscope slides using a synthetic-mounting medium. Fin ray sections were examined with a dissecting microscope using transmitted light. The age of the fish was determined by counting translucent zones (i.e., annuli) in the basal cross sections using the methods described by Cuerrier (1951), Beamesderfer et al. (1989), Brennan and Cailliet (1991), and Rien and Beamesderfer (1994).

Older fish were difficult to age due to crowded annuli caused by slow growth in later life. Each fin ray sample was examined twice by an experienced reader and an age assigned at each reading. In cases where the two ages disagreed by more than three years, the sample was examined a third time and a final age was established.

### **2.3.3 Sex and Maturity**

Sex and maturity of white sturgeon were determined by surgical examination. Surgical procedures were similar to those developed for white sturgeon in the United States and described by Beamesderfer et al. (1989). The descriptions of maturity stages generally followed the qualitative histological classifications described by Conte et al. (1988) and are outlined in Appendix B, Table B1. Subjective assessments were used when the maturity stage was intermediate relative to the classification system. The surgical procedures used followed those described in Hildebrand and English (1991) and R.L. & L. (1998a).

### **2.3.4 Genetic Analysis**

A sample of soft tissue was collected for molecular genetic DNA analysis from all white sturgeon sampled in Arrow Reservoir in 1997. A small section of the distal end of the pelvic fin was removed, cut into thin sections using surgical scissors, and preserved in labelled vials containing 99% ethanol. The DNA samples were forwarded to S. Pollard (B.C. Ministry of Fisheries, Victoria) for genetic analyses.

## 3.0 RESULTS

### 3.1 DISTRIBUTION AND CATCH

#### 3.1.1 Set Lines

In total, 14 white sturgeon were captured prior to the current study; all of these fish were captured in the portion of the reservoir known locally as Upper Arrow Lake, with the majority captured on Beaton Flats (Km 181.0; Figure 2.2). Based on these results, a recommendation of the 1997 study was that sampling be conducted in other areas with characteristics similar to Beaton Flats, as a possible means to increase white sturgeon captures.

In the present study, sampling during the summer (11 to 14 August 1998) occurred in a number of the same areas (Figures 2.1 and 2.2) where white sturgeon were sampled in 1997 (R.L. & L. 1998a). Sampling in the fall (19 to 30 October 1998) was more focussed, with intensive sampling in Beaton Flats (Figure 2.2), a known overwintering area, and in Burton Flats (Figure 2.3), an area with similar bottom, depth, and flow characteristics to Beaton Flats. Sampling in the winter (1 to 4 March 1999) was focussed exclusively on the Beaton Flats area (Figure 2.2).

In total, 10 white sturgeon were captured in Arrow Reservoir in 21 596 hook-hours of set line effort (Appendix A, Table A1). All 10 were captured in the Beaton Flats/Galena Bay area (Figure 2.2) during the fall sample session (11 745 hook-hours). Two of these fish were recaptures from the 1997 sampling program. Another was a potential recapture from the 1995 sampling program, based on the presence of a right pectoral fin ray scar. This fish, however, showed no evidence of a previous Floy tag or PIT tag.

Surface water temperatures at summer set line sites ranged between 19.4 and 21.4°C in the Beaton Arm and Beaton Flats area, and between 11.2 and 11.9°C in the Revelstoke area (water temperatures in this area are influenced by the release of hypolimnetic water through Revelstoke Dam). Surface water temperatures in the fall sampling sessions ranged between 9.6 and 10.5°C, with similar temperatures in the Burton and Beaton Flats areas. During the winter sampling session, surface water temperatures ranged between 3.1 and 3.7°C. Sampled depths ranged between 1.8 and 42.2 m, with all white sturgeon captured at depths greater than 11 m (mean capture depth=15.0 m).

The set line sampling also yielded an incidental catch of 11 burbot; nine of these were captured in the summer session. Hook sizes were subsequently changed from three hook sizes (12/0, 14/0, 16/0) to the largest hook size of (16/0) in an attempt to minimize burbot by-catch. Available information (R.L. & L. unpublished data; J. Devore, Washington Department of Fish & Game, Vancouver, pers. comm., 1998) suggest that the three hook sizes capture sturgeon equally, while data from the summer sampling session suggested that burbot were more frequently captured on size 12/0 and 14/0 hooks (R.L. & L. unpublished data). Only one burbot was captured in the fall sampling session (15 596 hook-hours) when only the large hooks were used compared to the 36 burbot captured in the 1997 fall sampling session (15 872 hook-hours) when the three hook sizes were used.

### 3.1.2 Substrate Mats

The lower section of the Incomappleux River was considered a potential spawning area, based on the proximity of the pre-spawning female just prior to and during the spawning season, and the presence of potentially suitable spawning habitat (see Section 2.1.1). Artificial substrate mats were deployed at the mouth of the Incomappleux River between 3 June and 21 July in an attempt to capture white sturgeon eggs (Figure 2.1; Plates 1 and 2). In total, 4131 mat-hours of sampling occurred, with the majority of sets between 100 and 215 mat-hours in duration (Appendix A, Table A2). Four substrate mats became snagged on bottom debris and were not recovered. As the water levels in the Arrow Reservoir increased (due to reservoir filling), the white water section of the Incomappleux River became less extensive; the substrate mat sample sites were moved further upstream every two to three weeks to reflect this shift in local conditions (Plates 1 and 2). White sturgeon eggs were not captured by substrate mat sampling in 1998; one egg (not a white sturgeon egg) was captured on 10 June. Water temperatures in the Incomappleux River during the sampling period ranged from 7.3 to 11.2°C. These temperatures were lower than those measured during the white sturgeon spawning season on the Columbia River (R.L. & L. 1998a), but were similar to those measured during the spawning season on the Kootenay River (Paragamian et al. 1997).

### 3.2 POPULATION ESTIMATE

A preliminary population estimate was made for the upper section of Arrow Reservoir. Mark-recapture data from three years of sampling were used for the population estimate (Table 3.1). Using the modified Schnabel Method (Krebs 1989) and the data presented in Table 3.1, the white sturgeon population (adults) was estimated at 78 fish (95% CI=23 to 440). Using a recapture of three fish (i.e., adding the one fish captured in 1998 that may have been originally captured in 1995), the estimate changed to 52 fish (95% CI=19 to 191).

Table 3.1 Mark-recapture data used to estimate white sturgeon population size in the upper section of Arrow Reservoir, 1995-1998.

Sample Year	Number Caught	Number Recaptured	Number of New Marks	Number of Marks at Large
1995	5	- <sup>a</sup>	5	-
1997	9	0	9	5
1998	10	2 <sup>b</sup>	8	14
<b>Total</b>	<b>24</b>	<b>2<sup>b</sup></b>	<b>-</b>	<b>22</b>

<sup>a</sup> Not applicable

<sup>b</sup> Does not include one fish that was captured in 1998 with evidence of a possible previous capture (pectoral fin ray scar).

This estimate is considered preliminary as the sample size (three mark periods, two recapture periods) is the minimum required to derive a population estimate. The confidence in this estimate is further reduced by the small number of fish ( $n=22$ ) sampled in the three years of study.

### 3.3 LIFE HISTORY DATA

The 10 white sturgeon captured in Arrow Reservoir in 1998 ranged in length from 131.5 to 216.5 cm FL (mean=195.0 cm FL; Appendix C, Table C1). This was almost identical to the size-range reported for the nine white sturgeon captured in 1997 (R.L. & L. 1998a). Ages of these fish ranged from 34 to 52 years (i.e., 1946 to 1964 year-classes).

All captured white sturgeon were surgically examined to determine sex and maturity. Half of the captured fish were males and half were females. Two females were in mid- to late vitellogenesis (see Appendix B, Table B1 for a description of the developmental stages); one of these (Floy O32506) is expected to be in spawning condition in 1999. The other late development female (Floy O32505) exhibited an egg size that was borderline between two different sexual development stage categories and therefore may be in spawning condition during either 1999 or 2000.

The burbot captured in 1998 ranged in size between 56.5 and 72.5 cm TL and in weight between 850 and 1800 g (Appendix C, Table C2). Only three of these burbot were released in good condition; the rest had either swallowed a hook or exhibited swim bladder expansion due to being caught at depth. All burbot caught at depth had their swim bladders deflated using the technique of Bruesewitz et al. (1993); some of these burbot, however, had extreme levels of expansion and everted stomachs (stomach visible in the mouth). These fish did not appear to be in good condition when released, as their swimming ability and orientation were poor.

### 3.4 SONIC TELEMETRY

In 1997, nine white sturgeon were equipped with sonic transmitters. Boat-based tracking for these fish has occurred on either a monthly (late summer-winter-spring) or weekly (early summer) basis since their capture (Appendix D, Table D1). Another eight fish were equipped with sonic transmitters in late October 1998. Tracking for these fish has occurred on a monthly basis since their initial capture. As noted in the 1997 study (R.L. & L. 1998a), efficiency of the tracking was greatest during the winter months (October to March), with some transmitted signals received at distances greater than 4 km. This was likely due to the absence of a strong thermocline in the winter; sonic signals have been shown to be affected strongly by temperature gradients (M. Gregor, pers. comm., 1998). Tracking efficiency was poor in the summer months, with only one of nine sonic-tagged fish located during late summer tracking sessions.

Of the nine fish tracked between fall 1997 and early spring 1999, three exhibited an observed movement range of greater than 44 km since their original capture; four moved more than 13 km (Appendix D, Table D1; Figure 3.1). All movements greater than 5 km occurred in the late spring to mid-fall periods of 1997 and 1998. One fish (Sonic Tag #3-8-3) has not demonstrated any movement since March 1998, despite being located in all but one of the tracking sessions (August). This fish has either shed its internal sonic transmitter or has died.

During the spring and summer, white sturgeon moved either upstream from Beaton Flats (but remained within the main body of the reservoir) or into Beaton Arm (Figure 3.1). Tagged fish were never located further downstream than Galena Bay, an area with similar habitat as the Beaton Flats area. The three fish that moved more than 44 km were all found on at least occasion near Revelstoke (two fish in Big Eddy at Km 230, one fish near Salmon Rocks at Km 222). These fish also appeared to use the section of reservoir between Km 190 and 195. This section of the reservoir was not obviously different than the areas adjacent to it. The four fish that moved between 13 and 20 km all moved into Beaton Arm during the spring and/or summer period. One of these fish (Sonic Tag #3-5-6) was a reproductively mature female that was expected to be in spawning condition in 1998. This fish moved into the top end of Beaton Arm in the late May period and was regularly found in the area through the June and July period. This area of the reservoir was near the confluence with the Incommappleux River; the lower section of this river exhibits conditions potentially suitable for white sturgeon spawning (see Section 3.1).

During the winters of 1997 and 1998, all but one of the nine white sturgeon tagged in 1997 were found to reside in the Beaton Flats/Galena Bay area (Figure 3.1). The one exception was a early reproductive male (Sonic Tag #2-7-5) that overwintered in Beaton Flats in 1997, and moved into Beaton Arm in the summer of 1998; this fish has not been located since 8 July 1998.

In late October 1998, eight more white sturgeon were captured and equipped with sonic transmitters. These fish have been tracked on a monthly basis during the winter of 1998-1999 (Appendix D, Table D1) and have all been located in the Beaton Flats/Galena Bay area. This is similar to results of the 1997 winter surveys that recorded all tagged fish in this same area.

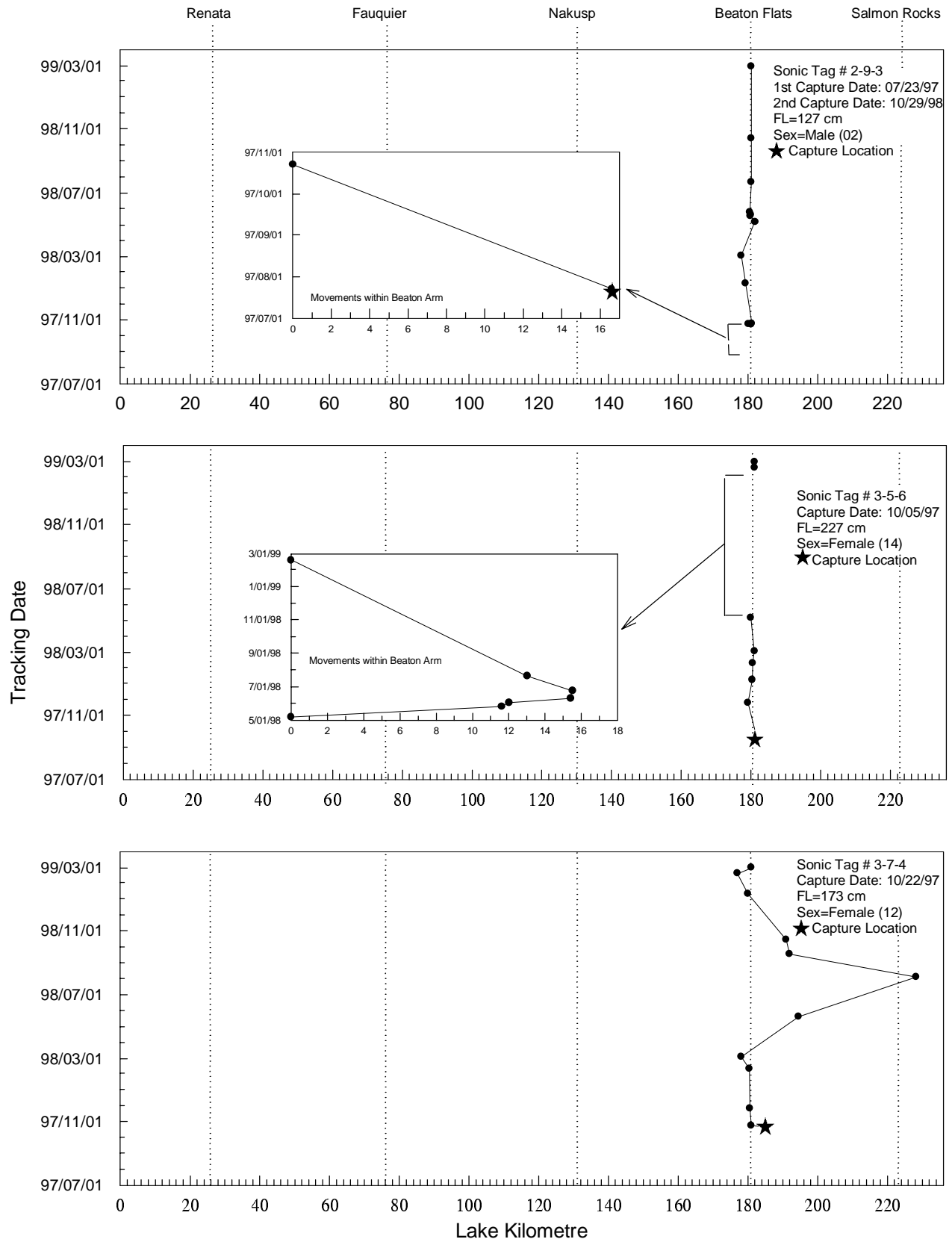


Figure 3.1 Summary of movements of sonic-tagged white sturgeon in Arrow Reservoir, 1997-1999. Lake kilometre is measured upstream from Hugh L. Keenleyside Dam; distance in Beaton Arm is measured upstream from Km 181.0 in the main arm of the lake.

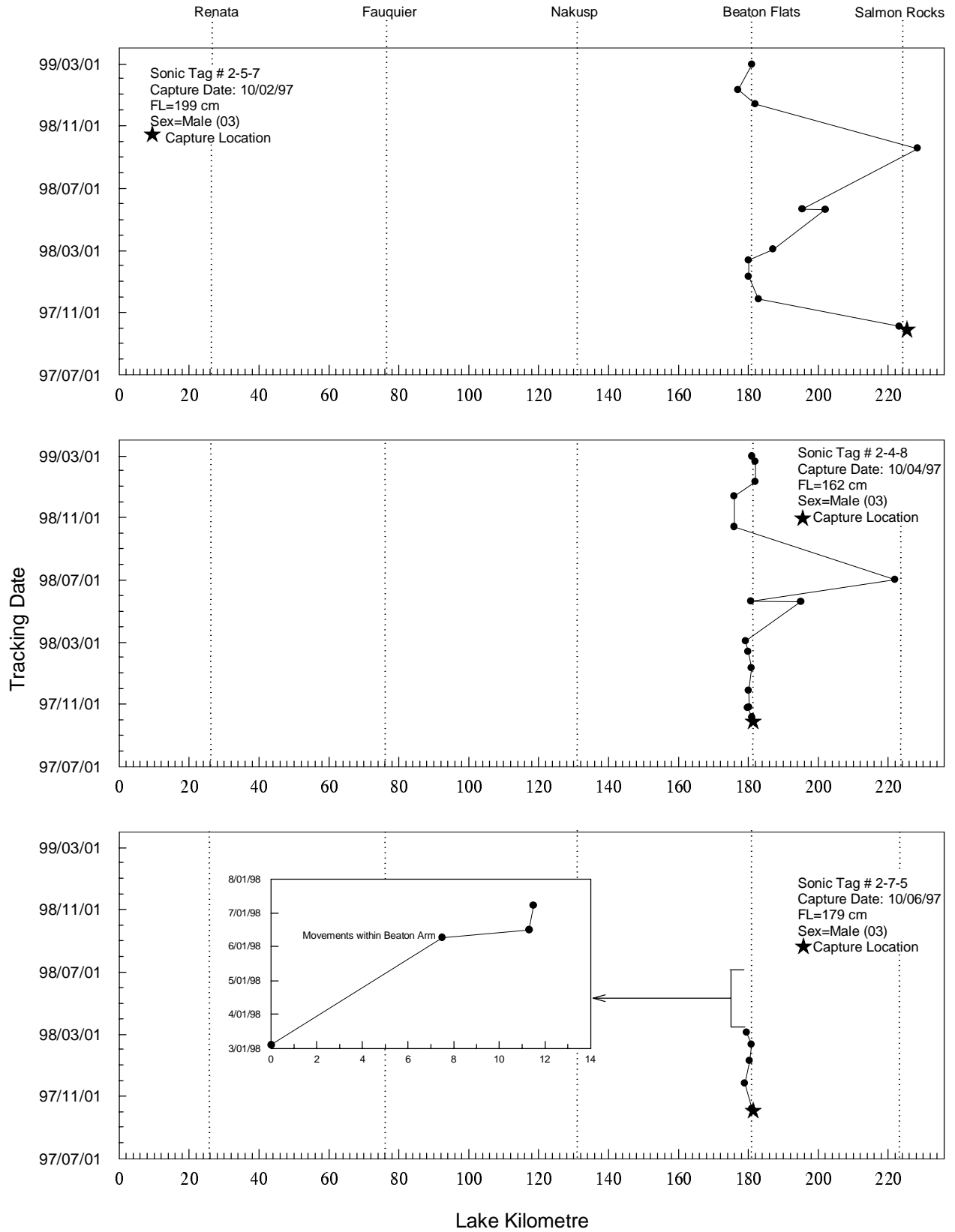


Figure 3.1 Continued.

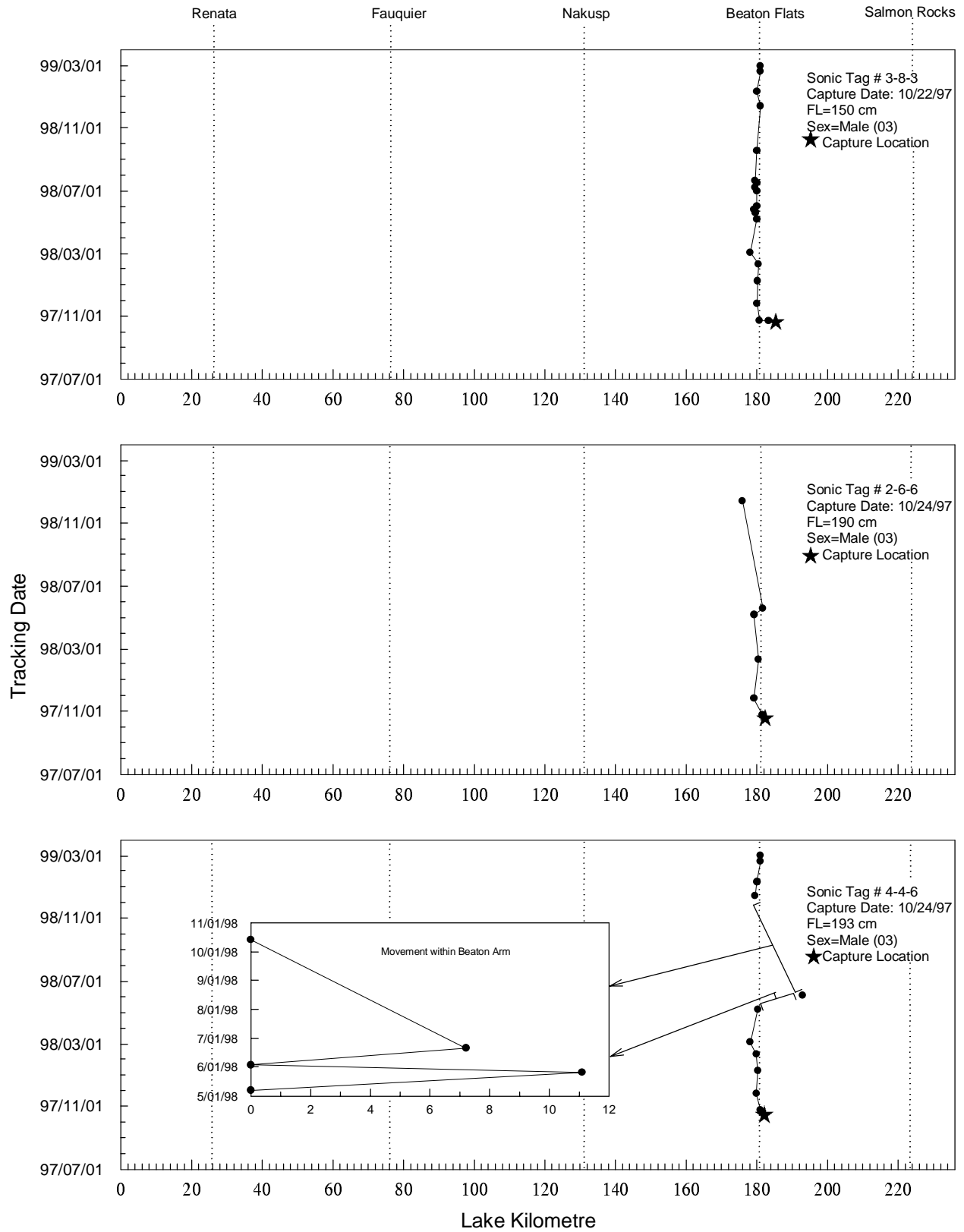


Figure 3.1 Concluded.

## 4.0 DISCUSSION

### 4.1 DISTRIBUTION AND CATCH

Evidence obtained in 1998 supports the previous study findings that suggest white sturgeon primarily use the upper section of Arrow Reservoir. Since 1995, all white sturgeon have been captured upstream of Km 177 (Galena Bay), although tracking occurred downstream to Km 90 on a monthly basis between May and September 1998, and downstream to Km 0 in August 1998. This evidence is somewhat equivocal, since the reservoir downstream of Galena Bay is substantially deeper (i.e., the range of a sonic transmitter may be reduced) and has been sampled less intensively than the upper section.

Based on capture rates and movement information, sampling for white sturgeon should be most efficient during the period of time when fish are actively feeding and congregated in the Beaton Flats area (i.e., between mid-October and mid-May). Past sampling suggests that fish are actively feeding in the late October period (i.e. catch-rates are high) when temperatures are in the 7 to 10°C range. Sampling conducted in early March 1999 (i.e., at surface water temperatures of approximately 3°C), however, failed to capture white sturgeon despite intensive sampling in the same area where up to 15 sonic-tagged fish were present. This may suggest that white sturgeon exhibit reduced feeding activity during late winter.

Changing the hook-size used to sample white sturgeon substantially reduced the by-catch of burbot, while resulting in similar catch-rates of white sturgeon to the 1997 fall capture program (R.L. & L. 1998a). Given that burbot is a species of concern in some systems in British Columbia (i.e., Kootenay system), use of only large size hooks during white sturgeon sampling on Arrow Reservoir should continue.

### 4.2 POPULATION ESTIMATE

In 1998, white sturgeon were recaptured for the first time in the three years of sampling. Two confirmed recaptures from 1997, and one possible recapture from 1995 allowed the first population estimate for white sturgeon in Arrow Reservoir. The population estimate, 52 fish (95% CI=19 to 191) using the conservative approach of assuming the third fish was a recapture, is still very preliminary given the low sample size so far. This population estimate would be improved with further sampling. If the white sturgeon population size is actually at the higher end of the estimate, it may be possible that enough white sturgeon remain in the reservoir to maintain their population, assuming that appropriate spawning habitat is available.

An alternative approach to enumerating the population size in the reservoir, or at least those individuals that congregate in Beaton Flats during the winter period, may be the use of new sonar technology. One technique that may be feasible has been developed by Deepwater Scanning Services; this technique uses continuous underwater sonar scans in clear water systems to obtain images of objects on the bottom and in the water column. Objects that move, such as fish, can be differentiated from stationary images, such as logs. Given the large size of white sturgeon in the system (i.e., that separates them from other fish species), it may be possible to use this technique to enumerate white sturgeon in the area. A preliminary test of this technique was conducted by Deepwater Scanning Services and R.L. & L. on 8 March 1999. Results from this test will be provided in a subsequent document.

### **4.3 LIFE HISTORY DATA**

All white sturgeon captured in the last three years of sampling were adults based on size and age. These white sturgeon were all older than the 1966 year-class, suggesting that these fish have been in the reservoir since construction of Hugh L. Keenleyside Dam in 1968. Evidence of recruitment to this population since the dam was constructed has not been obtained. There are several areas which may contain potential spawning habitat for white sturgeon. These include the lower section of the Incomappleux and Illecillewaet rivers, and the tailrace of Revelstoke Dam. Water temperatures in these areas during the spawning season, however, may be too low for successful spawning.

Three female white sturgeon in pre-spawning condition (i.e., 18% of the catch) have been captured since 1997. This is a substantially higher proportion of this maturity-class than was recorded in the white sturgeon population in the Columbia River downstream of Hugh L. Keenleyside Dam (R.L. & L. 1997) and in the Fraser River (R.L. & L. 1998b, 1998c). The reason for the large proportion of pre-spawners in the Arrow Reservoir system is not obvious at this point. Captured white sturgeon do appear to be in very good condition (Plates 3 and 4) in comparison to fish captured recently in the Columbia River below Hugh L. Keenleyside Dam, but this cannot be determined quantitatively due to the small sample size of fish captured.

### **4.4 MOVEMENTS**

Movements recorded in the present study represent the first year and a half of movement data for white sturgeon in Arrow Reservoir. As such, conclusions about seasonal movement patterns in the population are preliminary, especially since white sturgeon have been tracked during only one spring, summer, and fall. White sturgeon use of Beaton Flats (and, in 1998, the nearby Galena Bay area) indicate this area represents an important overwintering habitat; all but one sonic-tagged white sturgeon has been located in Beaton Flats during every winter period since their original capture. The one exception, a fish that has not been located since July 1998, was found to use the Beaton Flats area during the first winter after its capture (1997-1998). Previous studies in the lower Columbia River and the Kootenay River have identified that white sturgeon undertake seasonal migrations to winter holding areas (Haynes et al. 1978; Apperson and Anders 1991).

In the present study, white sturgeon used a variety of areas during the spring and early summer periods (with most fish not located during late summer). Several areas of higher use were noted: 1) near Revelstoke (Km 222 to 228); 2) the reservoir upstream of Beaton Flats (Km 190 to 195); and 3) Beaton Arm (Km 181-0.0 to 181-16.5). These three areas had very different habitat characteristics. The system near Revelstoke is riverine, with cool water temperatures. The reservoir upstream of Beaton Flats represents an inundated section of the former Columbia River channel and currently exhibits shallow depths and low water velocities. Beaton Arm is an extremely deep (up to 250 m) arm of the original Upper Arrow Lake. Further tracking, and possibly habitat sampling, may reveal why white sturgeon in the system tend to use these areas (and move between them) in the spring and early summer period. Further sampling is also necessary to reveal where the white sturgeon reside in the late summer period. The high output transmitters applied to two fish captured in the fall 1998 sampling program are intended to test the differences in reception characteristics between these and the standard transmitters under thermally stratified conditions experienced during the late summer period.

Tracking efforts in the spring and summer of 1999 and/or 2000 should also be focussed on following the movements of the two pre-spawning female white sturgeon tagged in the present study. White sturgeon have the potential to spawn in the system, although evidence so far suggests that recruitment has not occurred since construction of Hugh L. Keenleyside Dam.

## 5.0 RECOMMENDATIONS

The present study comprised the third year of white sturgeon studies on Arrow Reservoir. Based on results from these studies, the following should be considered for inclusion in future studies:

- Conduct further sampling to improve the population estimate for white sturgeon in Arrow Reservoir as a means to determine whether the population is large enough to be reproductively viable.
- Conduct further sampling to attempt to capture white sturgeon equipped with archival tags in 1997; the information on these tags will provide data on depth and temperature preferences of the individual tagged white sturgeon.
- Increase tracking frequency between May and July, and focus tracking efforts on the pre-spawning females expected to spawn in 1999 to determine the location of potential spawning areas. The recapture of these females after the spawning period should be a priority to determine whether spawning actually occurred.
- Conduct egg sampling in areas with potential spawning activity based on the behaviour of reproductively mature female white sturgeon, and the presence of suitable spawning habitat.
- Continue monthly tracking of sonic-tagged white sturgeon between the May to October period, to determine seasonal movement patterns. Tracking during the winter period is of lower priority, as the winter movement patterns in the upper reservoir are comparatively well understood.

Future studies could also involve the use of new sonar technology to identify and enumerate white sturgeon during the late winter period when the majority of fish are located in the Beaton Flats area and reservoir levels are low. This technology could potentially answer questions related to the number of white sturgeon overwintering in the area, their spatial distribution (i.e., distributed as groups or as individuals), and the depths at which they reside.

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## **PHOTOGRAPHIC PLATES**



**Plate 1** Incomappleux River viewed downstream to the mouth, 2 June 1998. The whitewater area downstream of the cobble beach on the left bank was considered as potential spawning habitat for white sturgeon.



**Plate 2** Upstream of the Incomappleux River mouth, 1 July 1998. The cobble beach on the right bank (near the first visible float on the right-center of the photograph) is the same as in Plate 1. Higher reservoir levels have substantially reduced the amount of white water habitat.



**Plate 3** Early vitellogenic female white sturgeon (210.0 cm FL, 80.5 kg, 41 years old) captured in Beaton Flats, 28 October 1998.



**Plate 4** Early reproductive male white sturgeon (196.5 cm FL, 65.4 kg, 45 years old) captured on Beaton Flats, 24 October 1998.

**APPENDIX A**  
**CAPTURE DATA**

Table A1 Summary of catch and catch-rate for white sturgeon (WST) and other fish species captured by set line in Arrow Reservoir, 1998-1999.

Survey Session	Location (km) <sup>a</sup>	Station	UTM <sup>b</sup>		Set		Pulled		Duration (h)	Water				No. Hooks	Hook-Hours	Catch				Total Catch	Total CPUE
			Easting	Northing	Date	Time	Date	Time		Temp (°C)		Depth (m)				WST		Burbot			
										Set	Pull	Min.	Max.			No.	CPUE <sup>c</sup>	No.	CPUE		
Summer	181.0-15.0	SSL98-01	448513	5620847	11-Aug-98	13:44	12-Aug-98	10:39	20.9	21.6	21.4	10.2	11.5	8	167.3	0	0.00	0	0.00	0	0.00
	181.0-16.0	SSL98-02	449183	5621857	11-Aug-98	14:06	12-Aug-98	10:59	20.9	21.6	21.4	5.0	8.2	8	167.1	0	0.00	1	0.60	1	0.60
	181.0-16.5	SSL98-03	449528	5622121	11-Aug-98	14:30	12-Aug-98	11:32	21.0	21.6	21.4	7.6	7.7	8	168.3	0	0.00	2	1.19	2	1.19
	181.0-14.7	SSL98-04	447072	5622883	11-Aug-98	14:57	12-Aug-98	11:54	21.0	21.6	21.4	1.8	3.3	8	167.6	0	0.00	0	0.00	0	0.00
	181.0-13.0	SSL98-05	445360	5621982	11-Aug-98	15:18	12-Aug-98	12:11	20.9	21.6	21.4	8.1	11.2	8	167.1	0	0.00	1	0.60	1	0.60
	181.0-11.2	SSL98-06	443975	5621526	11-Aug-98	15:40	12-Aug-98	12:31	20.8	21.6	21.4	5.2	9.3	8	166.8	0	0.00	1	0.60	1	0.60
	181.0-7.3	SSL98-07	442017	5617239	11-Aug-98	16:15	12-Aug-98	13:08	20.9	21.6	21.4	11.6	30.2	8	167.1	0	0.00	0	0.00	0	0.00
	181.0-6.8	SSL98-08	441750	5617264	11-Aug-98	16:38	12-Aug-98	13:25	20.8	21.6	21.4	13.1	27.0	8	166.3	0	0.00	0	0.00	0	0.00
	181.0	SSL98-09	435814	5613607	12-Aug-98	14:11	13-Aug-98	10:19	20.1	19.4	20.3	17.1	18.2	8	161.1	0	0.00	0	0.00	0	0.00
	181.0	SSL98-10	435908	5613660	12-Aug-98	14:24	13-Aug-98	10:29	20.1	19.4	21.1	17.4	18.0	8	160.7	0	0.00	1	0.62	1	0.62
	181.0	SSL98-11	436224	5612980	12-Aug-98	15:12	13-Aug-98	10:44	19.5	19.4	20.7	42.2	48.5	8	156.3	0	0.00	1	0.64	1	0.64
	181.0	SSL98-12	435736	5615842	12-Aug-98	15:50	13-Aug-98	11:31	19.7	19.4	20.3	12.0	16.1	8	157.5	0	0.00	1	0.64	1	0.64
	181.0	SSL98-13	435789	5613952	12-Aug-98	16:10	13-Aug-98	11:09	19.0	19.4	20.3	14.2	14.4	8	151.9	0	0.00	1	0.66	1	0.66
	223.9	SSL98-14	414961	5648279	13-Aug-98	14:08	14-Aug-98	9:14	19.1	11.2	11.0	12.2	16.0	8	152.8	0	0.00	0	0.00	0	0.00
	224.0	SSL98-15	414828	5648669	13-Aug-98	14:28	14-Aug-98	9:41	19.2	11.2	11.0	4.2	4.6	8	153.7	0	0.00	0	0.00	0	0.00
	221.3	SSL98-16	415154	5645880	13-Aug-98	14:55	14-Aug-98	9:56	19.0	11.3	11.0	8.2	8.6	8	152.1	0	0.00	0	0.00	0	0.00
	217.4	SSL98-17	416803	5642667	13-Aug-98	15:32	14-Aug-98	10:12	18.7	11.9	11.2	7.3	10.7	8	149.3	0	0.00	0	0.00	0	0.00
	216.9	SSL98-18	417036	5641952	13-Aug-98	15:48	14-Aug-98	10:29	18.7	11.7	11.1	13.8	17.6	8	149.5	0	0.00	0	0.00	0	0.00
<b>Summer Subtotal</b>															<b>2882.3</b>	<b>0</b>	<b>0.00</b>	<b>9</b>	<b>0.31</b>	<b>9</b>	<b>0.31</b>
Fall	96.0	SSL98B1	435999	5536958	19-Oct-98	14:14	20-Oct-98	9:57	19.7	10.5	9.6	1.4	6.6	30	591.5	0	0.00	0	0.00	0	0.00
Burton	96.3	SSL98B3	436127	5537239	19-Oct-98	15:06	20-Oct-98	10:48	19.7	10.4	9.8	4.6	5.1	8	157.6	0	0.00	0	0.00	0	0.00
Flats	96.1	SSL98B2	436220	5536970	19-Oct-98	14:39	20-Oct-98	11:16	20.6	10.4	9.7	2.3	5.0	8	164.9	0	0.00	0	0.00	0	0.00
	95.0	SSL98B4	434707	5536741	19-Oct-98	15:32	20-Oct-98	11:28	19.9	10.5	10.0	8.4	9.1	8	159.5	0	0.00	0	0.00	0	0.00
	93.7	SSL98B6	433774	5536408	20-Oct-98	13:24	21-Oct-98	9:41	20.3	10.1	9.9	20.7	21.0	8	162.3	0	0.00	0	0.00	0	0.00
	93.0	SSL98B7	433233	5535251	20-Oct-98	13:47	21-Oct-98	10:06	20.3	10.1	9.8	14.0	14.6	8	162.5	0	0.00	0	0.00	0	0.00
	93.8	SSL98B8	433957	5535259	20-Oct-98	14:11	21-Oct-98	10:28	20.3	10.1	9.9	13.0	13.1	8	162.3	0	0.00	0	0.00	0	0.00
	95.1	SSL98B5	434936	5537550	20-Oct-98	12:39	21-Oct-98	11:23	22.7	10.1	9.9	15.1	18.0	30	682.0	0	0.00	0	0.00	0	0.00
	94.5	SSL98B9	434015	5535554	20-Oct-98	14:28	21-Oct-98	13:43	23.3	10.4	10.0	12.1	13.2	8	186.0	0	0.00	0	0.00	0	0.00
	96.3	SSL98B3	436088	5537218	20-Oct-98	11:03	21-Oct-98	14:05	27.0	10.1	9.7	5.2	6.7	8	216.3	0	0.00	0	0.00	0	0.00
	100.0	SSL98B13	434933	5541370	21-Oct-98	12:05	22-Oct-98	9:13	21.1	9.9	9.9	15.9	16.5	30	634.0	0	0.00	0	0.00	0	0.00
	95.0	SSL98B10	434104	5537092	21-Oct-98	9:58	22-Oct-98	9:45	23.8	9.9	- <sup>d</sup>	21.8	24.0	8	190.3	0	0.00	0	0.00	0	0.00
	93.1	SSL98B11	433103	5535692	21-Oct-98	10:18	22-Oct-98	10:01	23.7	9.9	9.8	16.9	17.1	8	189.7	0	0.00	0	0.00	0	0.00
	93.0	SSL98B12	433266	5534866	21-Oct-98	11:04	22-Oct-98	11:15	24.2	9.8	9.6	7.1	10.2	8	193.5	0	0.00	0	0.00	0	0.00
<b>Fall Burton Flats Sampling Subtotal</b>															<b>3852.3</b>	<b>0.0</b>	<b>0.00</b>	<b>0.0</b>	<b>0.00</b>	<b>0.0</b>	<b>0.00</b>

Continued...

<sup>a</sup> Distances are measured upstream from Hugh L. Keenleyside Dam to Revelstoke Dam through the main channel (refer to Figure 3.1). For hyphenated locations, first value indicates distance to Galena Bay (Km 177.0), Beaton Flats (Km 181.0), or Salmon Rocks (Km 223.5); second value indicates distance into Galena Bay, Beaton Arm, or Illecillewaet River, respectively.

<sup>b</sup> Coordinates represent non-averaged, uncorrected GPS readings.

<sup>c</sup> CPUE=no. fish/100 hook-hours.

<sup>d</sup> Data not available.

Table A1 Continued.

Survey Session	Location (km) <sup>a</sup>	Station	UTM <sup>b</sup>		Set		Pulled		Duration (h)	Water				No. Hooks	Hook-Hours	Catch				Total Catch	Total CPUE
			Easting	Northing	Date	Time	Date	Time		Temp (°C)		Depth (m)				WST		Burbot			
										Set	Pull	Min.	Max.			No.	CPUE <sup>c</sup>	No.	CPUE		
Fall	181.0	SSL98B14	435661	5613893	22-Oct-98	12:57	23-Oct-98	11:19	22.4	10.6	10.5	15.5	17.2	30	671.0	0	0.00	0	0.00	0	0.00
Beaton	181.0	SSL98B15	435777	5613848	22-Oct-98	14:13	23-Oct-98	11:47	21.6	10.6	10.5	16.1	17.2	8	172.5	0	0.00	0	0.00	0	0.00
Flats	180.5	SSL98B19	436120	5613373	22-Oct-98	14:33	23-Oct-98	12:01	21.5	10.5	- <sup>d</sup>	28.7	30.2	8	171.7	0	0.00	0	0.00	0	0.00
	183.0	SSL98B16	433425	5617086	22-Oct-98	13:39	23-Oct-98	14:04	24.4	10.4	10.5	16.2	19.9	8	195.3	1	0.51	0	0.00	1	0.51
	182.0	SSL98B17	434222	5614904	22-Oct-98	13:50	23-Oct-98	15:58	26.1	10.4	10.5	16.7	17.4	8	209.1	0	0.00	1	0.48	1	0.48
	180.5	SSL98B18	433701	5612261	22-Oct-98	14:07	23-Oct-98	16:19	26.2	10.3	10.5	14.5	16.4	8	209.6	0	0.00	0	0.00	0	0.00
	181.0	SSL98B14	433701	5612261	23-Oct-98	11:45	24-Oct-98	10:23	22.6	10.5	10.3	16.9	17.4	30	679.0	0	0.00	0	0.00	0	0.00
	181.0	SSL98B15	433701	5612261	23-Oct-98	11:57	24-Oct-98	10:54	23.0	10.5	10.3	16.9	16.9	8	183.6	0	0.00	0	0.00	0	0.00
	180.5	SSL98B19	433701	5612261	23-Oct-98	12:15	24-Oct-98	11:08	22.9	10.5	10.3	21.5	27.0	8	183.1	0	0.00	0	0.00	0	0.00
	180.5	SSL98B18	433701	5612261	23-Oct-98	16:25	24-Oct-98	11:27	19.0	10.5	9.7	14.4	14.5	8	152.3	1	0.66	0	0.00	1	0.66
	181.0	SSL98B21	434220	5614802	23-Oct-98	16:12	24-Oct-98	13:43	21.5	10.5	10.2	17.0	17.1	8	172.1	0	0.00	0	0.00	0	0.00
	183.0	SSL98B16	433425	5617086	23-Oct-98	15:50	24-Oct-98	14:02	22.2	10.5	10.2	15.8	17.1	8	177.6	0	0.00	0	0.00	0	0.00
	183.0	SSL98B20	435406	5615748	23-Oct-98	13:53	24-Oct-98	14:20	24.4	10.5	-	12.6	12.8	8	195.6	0	0.00	0	0.00	0	0.00
	180.1	SSL98B18	433661	5612148	24-Oct-98	13:35	25-Oct-98	9:58	20.4	9.8	9.8	13.4	14.9	8	163.1	0	0.00	0	0.00	0	0.00
	180.5	SSL98B19	436152	5613458	24-Oct-98	11:23	25-Oct-98	10:17	22.9	10.3	10.1	19.0	19.6	8	183.2	0	0.00	0	0.00	0	0.00
	181.0	SSL98B15	436152	5613458	24-Oct-98	11:02	25-Oct-98	10:30	23.5	10.3	10.1	17.2	18.0	8	187.7	0	0.00	0	0.00	0	0.00
	181.0	SSL98B14	436152	5613458	24-Oct-98	10:48	25-Oct-98	10:43	23.9	10.3	10.0	16.4	17.0	30	717.5	0	0.00	0	0.00	0	0.00
	181.0	SSL98B21	434270	5614766	24-Oct-98	13:55	25-Oct-98	11:11	21.3	10.2	10.1	16.7	17.1	8	170.1	0	0.00	0	0.00	0	0.00
	183.0	SSL98B16	433435	5616991	24-Oct-98	14:10	25-Oct-98	11:28	21.3	10.2	10.1	19.7	20.0	8	170.4	0	0.00	0	0.00	0	0.00
	183.0	SSL98B20	435409	5615594	24-Oct-98	14:27	25-Oct-98	11:43	21.3	10.4	10.2	12.1	12.5	8	170.1	0	0.00	0	0.00	0	0.00
	183.0	SSL98B22	434424	5616117	25-Oct-98	12:47	26-Oct-98	10:39	21.9	10.2	10.2	8.4	16.7	30	656.0	0	0.00	0	0.00	0	0.00
	183.0	SSL98B23	434263	5616189	25-Oct-98	12:58	26-Oct-98	10:55	21.9	10.2	10.2	16.7	17.1	8	175.6	0	0.00	0	0.00	0	0.00
	184.0	SSL98B25	432791	5617804	25-Oct-98	13:26	26-Oct-98	11:38	22.2	10.1	10.2	-	-	8	177.6	0	0.00	0	0.00	0	0.00
	184.0	SSL98B24	432807	5617665	25-Oct-98	13:17	26-Oct-98	11:46	22.5	10.1	10.2	15.8	17.8	8	179.9	0	0.00	0	0.00	0	0.00
	182.0	SSL98B26	432820	5617366	25-Oct-98	14:02	26-Oct-98	11:56	21.9	10.0	10.2	9.5	9.8	8	175.2	0	0.00	0	0.00	0	0.00
	182.0	SSL98B27	432847	5617096	25-Oct-98	14:23	26-Oct-98	12:09	21.8	10.1	10.2	10.2	11.2	8	174.1	0	0.00	0	0.00	0	0.00
	181.0	SSL98B28	433187	5617270	25-Oct-98	14:37	26-Oct-98	12:55	22.3	10.1	10.2	16.2	16.7	8	178.4	0	0.00	0	0.00	0	0.00
	181.3	SSL98B32	432779	5614379	26-Oct-98	14:16	27-Oct-98	10:00	19.7	10.2	9.6	14.1	14.8	8	157.9	0	0.00	0	0.00	0	0.00
	181.0	SSL98B33	432656	5614255	26-Oct-98	14:25	27-Oct-98	10:08	19.7	10.2	9.6	10.3	10.5	8	157.7	0	0.00	0	0.00	0	0.00
	181.2	SSL98B31	433031	5614590	26-Oct-98	14:12	27-Oct-98	10:20	20.1	10.2	9.7	-	-	8	161.1	1	0.62	0	0.00	1	0.62
	181.0	SSL98B30	433238	5614704	26-Oct-98	14:05	27-Oct-98	11:42	21.6	10.2	9.6	12.4	13.0	8	172.9	1	0.58	0	0.00	1	0.58
	181.3	SSL98B29	433430	5614682	26-Oct-98	13:50	27-Oct-98	13:00	23.2	10.2	9.6	12.3	12.8	30	695.0	0	0.00	0	0.00	0	0.00
	181.0-0.3	SSL98B35	435923	5613573	26-Oct-98	15:00	27-Oct-98	13:24	22.4	10.2	9.6	21.4	27.2	8	179.2	0	0.00	0	0.00	0	0.00
	181.0-0.5	SSL98B34	436123	5613393	26-Oct-98	14:55	27-Oct-98	13:32	22.6	10.2	9.6	18.8	20.2	8	180.9	0	0.00	0	0.00	0	0.00
	181.0	SSL98B36	435538	5613890	27-Oct-98	14:06	28-Oct-98	9:55	19.8	9.6	10.0	14.8	15.0	30	594.5	2	0.34	0	0.00	2	0.34
	181.0-0.5	SSL98B37	435142	5613946	27-Oct-98	14:16	28-Oct-98	12:38	22.4	9.6	10.0	14.1	15.4	8	178.9	0	0.00	0	0.00	0	0.00
	181.0	SSL98B38	434756	5613814	27-Oct-98	14:26	28-Oct-98	13:12	22.8	9.6	10.0	13.9	14.0	8	182.1	1	0.55	0	0.00	1	0.55

Continued...

<sup>a</sup> Distances are measured upstream from Hugh L. Keenleyside Dam to Revelstoke Dam through the main channel (refer to Figure 3.1). For hyphenated locations, first value indicates distance to Galena Bay (Km 177.0), Beaton Flats (Km 181.0), or Salmon Rocks (Km 223.5); second value indicates distance into Galena Bay, Beaton Arm, or Illecillewaet River, respectively.

<sup>b</sup> Coordinates represent non-averaged, uncorrected GPS readings.

<sup>c</sup> CPUE=no. fish/100 hook-hours.

<sup>d</sup> Data not available.

Table A1 Concluded.

Survey Session	Location (km) <sup>a</sup>	Station	UTM <sup>b</sup>		Set		Pulled		Duration (h)	Water				No. Hooks	Hook-Hours	Catch				Total Catch	Total CPUE
			Easting	Northing	Date	Time	Date	Time		Temp (°C)		Depth (m)				WST		Burbot			
										Set	Pull	Min.	Max.			No.	CPUE <sup>c</sup>	No.	CPUE		
Fall	181.0	SSL98B39	434470	5613752	27-Oct-98	14:24	28-Oct-98	15:00	24.6	9.6	10.0	13.3	13.6	8	196.8	0	0.00	0	0.00	0	0.00
Beaton	181.0	SSL98B40	434173	5613638	27-Oct-98	14:40	28-Oct-98	15:33	24.9	9.6	10.0	14.4	14.4	8	199.1	0	0.00	0	0.00	0	0.00
Flats	181.0	SSL98B42	433549	5613468	27-Oct-98	14:54	28-Oct-98	15:39	24.8	9.6	10.0	16.0	16.2	8	198.0	0	0.00	0	0.00	0	0.00
Cont'd	181.0	SSL98B41	433888	5613513	27-Oct-98	14:48	28-Oct-98	15:45	24.9	9.6	10.0	14.2	16.4	8	199.6	1	0.50	0	0.00	1	0.50
	181.2	SSL98B43	435456	5613630	28-Oct-98	12:46	29-Oct-98	12:40	23.9	10.0	9.8	24.5	25.7	8	191.2	0	0.00	0	0.00	0	0.00
	181.0	SSL98B44	435221	5613556	28-Oct-98	13:08	29-Oct-98	12:56	23.8	10.0	9.8	17.3	18.0	8	190.4	0	0.00	0	0.00	0	0.00
	181.0	SSL98B45	435000	5613347	28-Oct-98	15:30	29-Oct-98	13:13	21.7	10.0	9.8	18.8	18.8	8	173.7	2	1.15	0	0.00	2	1.15
	181.0	SSL98B46	435680	5613964	29-Oct-98	11:28	30-Oct-98	9:56	22.5	9.8	9.8	15.5	15.6	8	179.7	0	0.00	0	0.00	0	0.00
	181.0	SSL98B47	435340	5613912	29-Oct-98	11:55	30-Oct-98	10:09	22.2	9.8	9.8	15.5	16.1	8	177.9	0	0.00	0	0.00	0	0.00
	181.0	SSL98B48	435158	5613842	29-Oct-98	12:03	30-Oct-98	10:19	22.3	9.8	9.8	14.3	14.4	8	178.1	0	0.00	0	0.00	0	0.00
	181.0	SSL98B49	434898	5613752	29-Oct-98	12:50	30-Oct-98	10:37	21.8	9.8	9.8	14.8	15.0	8	174.3	0	0.00	0	0.00	0	0.00
	180.9	SSL98B50	434408	5613516	29-Oct-98	13:08	30-Oct-98	10:53	21.8	9.8	9.8	14.3	14.4	8	174.0	0	0.00	0	0.00	0	0.00
<b>Fall Beaton Flats Sampling Subtotal</b>															<b>11744.6</b>	<b>10.0</b>	<b>0.09</b>	<b>1.0</b>	<b>0.01</b>	<b>11.0</b>	<b>0.09</b>
Late	181.0	SSL99-01	434671	5612641	1-Mar-99	12:00	2-Mar-99	10:05	22.1	3.5	3.5	8.5	9.1	8	176.7	0	0.00	0	0.00	0	0.00
Winter	181.0	SSL99-02	435375	5613223	1-Mar-99	12:30	2-Mar-99	10:39	22.1	3.6	3.6	5.8	13.0	8	177.2	0	0.00	0	0.00	0	0.00
	180.8	SSL99-03	435603	5613311	1-Mar-99	12:53	2-Mar-99	11:13	22.3	3.7	3.7	8.5	9.7	8	178.7	0	0.00	0	0.00	0	0.00
	177.0-1.0	SSL99-04	438839	5611607	1-Mar-99	13:53	2-Mar-99	13:00	23.1	3.3	3.4	18.0	21.1	8	184.9	0	0.00	0	0.00	0	0.00
	177.0-1.0	SSL99-05	439245	5611375	1-Mar-99	14:10	2-Mar-99	13:27	23.3	3.2	3.3	23.7	24.0	8	186.3	0	0.00	0	0.00	0	0.00
	181.0	SSL99-06	435091	5613037	2-Mar-99	10:33	3-Mar-99	10:00	23.4	3.5	3.9	6.9	13.9	8	187.6	0	0.00	0	0.00	0	0.00
	181.0	SSL99-07	435393	5613431	2-Mar-99	10:57	3-Mar-99	10:23	23.4	3.7	3.1	2.5	2.7	8	187.5	0	0.00	0	0.00	0	0.00
	180.5	SSL99-08	435989	5613182	2-Mar-99	11:33	3-Mar-99	11:00	23.5	3.6	3.3	30.0	31.0	8	187.6	0	0.00	0	0.00	0	0.00
	180.2	SSL99-09	436199	5613265	2-Mar-99	11:55	3-Mar-99	11:24	23.5	3.4	3.3	4.8	6.2	8	187.9	0	0.00	0	0.00	0	0.00
	177.0-0.8	SSL99-10	439151	5610684	2-Mar-99	14:08	3-Mar-99	12:24	22.3	3.5	3.3	26.2	27.5	8	178.1	0	0.00	0	0.00	0	0.00
	181.0	SSL99-11	434416	5611451	2-Mar-99	15:08	3-Mar-99	12:45	21.6	3.5	3.4	11.7	14.2	8	172.9	0	0.00	0	0.00	0	0.00
	181.0	SSL99-06b	435091	5613037	3-Mar-99	10:15	4-Mar-99	10:16	24.0	3.7	3.2	4.6	5.3	8	192.1	0	0.00	0	0.00	0	0.00
	181.0	SSL99-07b	435377	5613539	3-Mar-99	10:48	4-Mar-99	10:28	23.7	3.1	3.2	2.5	2.7	8	189.3	0	0.00	0	0.00	0	0.00
	180.9	SSL99-12	435863	5613443	3-Mar-99	11:18	4-Mar-99	10:38	23.3	3.3	3.3	5.0	6.5	8	186.7	0	0.00	1	0.54	1	0.54
	180.2	SSL99-09	436199	5613265	3-Mar-99	11:40	4-Mar-99	11:00	23.3	3.4	3.3	4.8	5.2	8	186.7	0	0.00	0	0.00	0	0.00
	181.0	SSL99-13	434585	5612130	3-Mar-99	12:58	4-Mar-99	11:14	22.3	3.4	3.4	29.0	29.5	8	178.1	0	0.00	0	0.00	0	0.00
	179.9	SSL99-14	436509	5612711	3-Mar-99	13:14	4-Mar-99	11:35	22.4	3.4	3.3	8.2	9.5	8	178.8	0	0.00	0	0.00	0	0.00
<b>Late Winter subtotal</b>															<b>3117.1</b>	<b>0.0</b>	<b>0.00</b>	<b>1.0</b>	<b>0.03</b>	<b>1.0</b>	<b>0.03</b>
<b>Grand Total</b>															<b>21596.2</b>	<b>10.0</b>	<b>0.05</b>	<b>11.0</b>	<b>0.05</b>	<b>21.0</b>	<b>0.10</b>

<sup>a</sup> Distances are measured upstream from Hugh L. Keenleyside Dam to Revelstoke Dam through the main channel (refer to Figure 3.1). For hyphenated locations, first value indicates distance to Galena Bay (Km 177.0), Beaton Flats (Km 181.0), or Salmon Rocks (Km 223.5); second value indicates distance into Galena Bay, Beaton Arm, or Illecillewaet River, respectively.

<sup>b</sup> Coordinates represent non-averaged, uncorrected GPS readings.

<sup>c</sup> CPUE=no. fish/100 hook-hours.

<sup>d</sup> Data not available.

Table A2 Summary of substrate mat sampling effort in the Incommappleux River, 3 June to 21 July 1998.

Station <sup>a</sup>	Set		Pull		Duration (h)	Water			Catch (eggs)			Comments	
	Date	Time	Date	Time		Temp (°C)		Depth (m)	WST <sup>b</sup>	Other	Total		
						Set	Pull						
SM1	3-Jun-98	11:37	16-Jun-98	11:24	311.8	7.3	7.4	3.0	0	0	0	snagged, unable to pull for two weeks	
SM2	3-Jun-98	11:43	9-Jun-98	15:29	147.8	7.5	9.1	3.5	0	0	0		
SM3	3-Jun-98	11:47	10-Jun-98	10:38	166.9	7.5	9.8	3.5	0	0	0	snagged, unable to pull for two weeks	
SM4	3-Jun-98	11:50	10-Jun-98	11:00	167.2	7.5	9.8	3.5	0	0	0		
SM5	3-Jun-98	12:36	15-Jun-98	14:07	289.5	8.1	8.0	3.5	0	0	0	snagged, could not be retrieved	
SM2	9-Jun-98	15:49	- <sup>c</sup>	-	-	9.1	-	-	0	0	0		
SM3	10-Jun-98	10:51	16-Jun-98	10:58	144.1	9.8	7.1	3.0	0	0	0	unidentified egg	
SM4	10-Jun-98	11:14	15-Jun-98	14:23	123.2	9.8	7.5	3.0	0	1	1		
SM1	16-Jun-98	11:17	24-Jun-98	14:46	195.5	7.1	8.6	-	0	0	0		
SM4	15-Jun-98	14:38	24-Jun-98	14:12	215.6	8.0	8.5	-	0	0	0		
SM5	16-Jun-98	11:32	24-Jun-98	15:00	195.5	7.9	8.6	-	0	0	0		
SM6	15-Jun-98	14:31	24-Jun-98	14:24	215.9	8.0	8.6	-	0	0	0		
SM1	24-Jun-98	14:55	1-Jul-98	13:19	166.4	8.6	10.0	6.0	0	0	0		
SM5	24-Jun-98	15:12	1-Jul-98	15:51	168.7	8.5	9.8	2.5	0	0	0		
SM7	24-Jun-98	14:17	1-Jul-98	12:28	166.2	8.5	9.8	3.0	0	0	0		
SM8	24-Jun-98	14:30	1-Jul-98	13:53	167.4	8.3	10.3	5.0	0	0	0		
SM9	24-Jun-98	15:29	-	-	-	8.6	-	5.0	0	0	0		snagged, could not be retrieved
SM1	1-Jul-98	13:34	8-Jul-98	12:05	166.5	10.0	11.0	-	0	0	0		
SM7	1-Jul-98	12:44	8-Jul-98	11:17	166.5	11.1	10.3	3.0	0	0	0	snagged, could not be retrieved	
SM8	1-Jul-98	14:02	8-Jul-98	11:39	165.6	10.3	10.3	-	0	0	0		
SM10	1-Jul-98	13:09	8-Jul-98	12:25	167.3	10.9	11.2	5.0	0	0	0	snagged, could not be retrieved	
SM1	8-Jul-98	12:18	16-Jul-98	14:45	194.5	11.0	10.9	5.3	0	0	0		
SM7	8-Jul-98	11:33	16-Jul-98	15:35	196.0	10.3	10.9	4.5	0	0	0	snagged, could not be retrieved	
SM8	8-Jul-98	11:54	-	-	-	10.3	-	-	0	0	0		
SM10	8-Jul-98	12:40	-	-	-	11.2	-	4.5	0	0	0	snagged, could not be retrieved	
SM1	16-Jul-98	15:00	21-Jul-98	12:00	117.0	10.9	9.3	5.2	0	0	0		
SM7	16-Jul-98	15:58	21-Jul-98	12:30	116.5	10.9	9.3	3.0	0	0	0		
<b>Total</b>					<b>4131.3</b>				<b>0</b>	<b>1</b>	<b>1</b>		

<sup>a</sup> For location of substrate mat stations, refer to Figure 2.4.

<sup>b</sup> WST=white sturgeon.

<sup>c</sup> Data not available.

**APPENDIX B**  
**SEX AND MATURITY DATA**

Table B1 Sexual development state descriptions used to determine sex and maturity of white sturgeon in Arrow Reservoir in 1998-1999.

Sex	Code	Development State Description <sup>a</sup>
Male	01	Non-reproductive, testes appear as thin strips with no pigmentation
	02	Maturing; small testes; some folding may be apparent; translucent, smoky pigmentation
	03	Early reproductive; large testes, folds beginning to form lobes; some pigmentation still present; testes more white than cream coloured
	04	Late reproductive; testes large, often filling posterior of body cavity; white with little or no pigmentation
	05	Ripe; milt flowing; large white lobular testes; no pigmentation
	06	Spent; testes pinkish-white, flaccid, and strongly lobed
	10	General unknown maturity
Female	11	Non-reproductive; ovaries small, folded with no visible oocytes; tissue colour white to yellowish
	12	Pre-vitellogenic, moderate size ovary with small eggs present (0.2 to 0.5 mm diameter); may have "salt and pepper" appearance
	13	Early vitellogenic; large ovary varying in colour from white to yellowish-cream to light grey; eggs 0.6 to 2.1 mm in diameter
	14	Late vitellogenic; ovaries large with pigmented oocytes still attached to ovarian tissue; eggs 2.2 to 2.9 mm in diameter; sometimes with salt and pepper appearance
	15	Ripe; eggs fully pigmented and easily detached from ovarian tissue; eggs 3.0 to 3.4 mm in diameter
	16	Spent; ovaries are flaccid with some residual fully developed eggs
	17	Pre-vitellogenic with attritic oocytes; small eggs (<0.5 mm diameter) present; dark pigmented tissue present that may be reabsorbed eggs
	20	General unknown maturity
Unknown	97	Adult based on size, no surgical examination
	98	Juvenile/Sub-adult based on size, no surgical examination
	99	Gonad undifferentiated or not visible during surgical examination

<sup>a</sup> Descriptions of maturity state classification adapted from Conte et al. (1988).

**APPENDIX C**  
**LIFE HISTORY DATA**

Table C1 Life history information for white sturgeon captured in Arrow Reservoir during 1998.

Date	Location (km) <sup>a</sup>	UTM <sup>b</sup>		Length			Girth (cm)	Weight (kg) <sup>c</sup>	Sex <sup>d</sup>	Depth (m)	Age	Floy Tag		PIT Tag No.	Capture Code <sup>f</sup>	Sonic tag	Tag Life (months)	Bait Type	Comments
				Fork (cm)	Total (cm)	Snout (cm)						C <sup>e</sup>	No.						
		Easting	Northing	(cm)	(cm)	(cm)													
23-Oct-98	183.0	433425	5617086	180.5	203.0	40.5	72.5	59.0	03	20.8	34	O	32501	757B0C2A6B	0 <sup>g</sup>	6-10 <sup>h</sup>	18	Kokanee	Black spots, testes large, folded, white, some lobes.
24-Oct-98	181.5	433661	5612148	210.0	236.5	50.5	93.0	80.4	13	14.9	41	O	32502	7F7D520552	0	8-8 <sup>h</sup>	18	Squid	Egg diameter~1.1mm. Black spots. Egg sample.
27-Oct-98	181.2	433031	5614590	196.5	216.5	47.0	79.5	65.4	03	11.7	45	O	32504	7F7D7D3342	0	3-3-3-5	18	-	Testes, very little lobing, filling 1/3 body cavity.
27-Oct-98	181.0	433238	5614704	208.0	232.5	49.0	88.5	-	14	11.5	52	O	32505	7F7B036047	0	2-4-4-4	18	-	Egg diameter~2.2mm, fills body cavity, egg sample.
28-Oct-98	181.0	435538	5613890	192.5	217.0	46.0	76.0	-	-	14.6	-	O	30789	4158683235	2	4-4-6	48	Squid	Surgery and DNA scars healing, fin clip is healing.
28-Oct-98	181.0	435538	5613890	216.5	244.0	49.5	92.0	-	14	14.6	45	O	32506	7F7D7D783F	0	3-4-6	48	Squid	Egg diameter~2.8mm, egg sample.
28-Oct-98	181.0	434756	5613814	184.0	207.5	40.5	75.0	-	03	13.3	39	O	32507	41586D6404	0	4-6-8	48	Squid	Black spots, blunt nose. Gonads with lots of lobes.
28-Oct-98	181.0	433888	5613513	216.0	239.0	51.5	96.5	-	13	14.9	47	O	32508	4159673663	0	4-5-9	48	Squid	Egg diameter~1.8 mm. Egg sample.
29-Oct-98	181.0	435000	5613347	131.5	150.5	30.5	50.5	-	-	19.0	-	P	29864	41586D5257	2	2-9-3	48	-	Floy scar infected, new Pit tag, likely has two Pits.
29-Oct-98	181.0	435000	5613347	214.5	240.5	49.0	86.5	-	12	19.0	42	O	32509	41586A7E77	0	5-6-9	48	Squid	Small white eggs dorsally, ovaries large, white.

<sup>a</sup> Distances are measured upstream from Hugh L. Keenleyside Dam to Revelstoke Dam through the main channel.

<sup>b</sup> Coordinates represent non-averaged, uncorrected GPS readings.

<sup>c</sup> Some fish were not weighed as stretcher was lost during sampling on 27 October 1998.

<sup>d</sup> For a description of the sexual maturity codes, see Appendix B, Table B1.

<sup>e</sup> Colour: O=orange, P=pink.

<sup>f</sup> Capture code: 0=first capture; 2=recapture.

<sup>g</sup> This fish appeared to have a right pectoral fin ray scar from a previous fin clip, although there was no evidence of a previous Floy or PIT tag.

<sup>h</sup> Indicates high output sonic tag.

Table C2 Summary of the incidental burbot ( $n=11$ ) catch from Arrow reservoir, 1998-1999.

Species	Location (km) <sup>a</sup>	Date	Weight (g)	Length (mm)	Floy Tag		Capture Code <sup>c</sup>	Hook Size
					Colour <sup>b</sup>	Number		
Burbot	181.0-16.0	12/08/98	1000	615			1	- <sup>d</sup>
Burbot	181.0-16.5	12/08/98	1100	635			1	12/0
Burbot	181.0-16.5	12/08/98	1800	725			1	12/0
Burbot	181.0-13.0	12/08/98	1500	670			1	12/0
Burbot	181.0-11.0	12/08/98	1250	625			0	14/0
Burbot	181.0	13/08/98	1200	650	O	6551	0	12/0
Burbot	181.0	13/08/98	1100	640	O	6552	0	14/0
Burbot	181.0	13/08/98	850	605			1	12/0
Burbot	181.0	13/08/98	900	570			1	12/0
Burbot	182.0	23/10/98	1310	695			1	16/0
Burbot	181.0	3/4/99	-	565			0	16/0

<sup>a</sup> Distances are measured upstream from Hugh L. Keenleyside Dam to Revelstoke Dam. For hyphenated locations, first value indicates distance to mouth of Beaton Arm (Km 181.0), second value indicates distance into Beaton Arm.

<sup>b</sup> O=orange.

<sup>c</sup> Capture code: 0=first time capture, released alive; 1=first time capture, dead.

<sup>d</sup> Data not available.

**APPENDIX D**  
**SONIC TELEMETRY RESULTS**

Table D1 Descriptive movement summary for white sturgeon equipped with sonic transmitters in Arrow Reservoir, 1997-1999.

Sonic Tag #	Released		Sex <sup>b</sup>	Tracking Date	Location (km) <sup>a</sup>	Movement (km) <sup>c</sup>	Movement Summary
	Date	Location (km) <sup>a</sup>					
2-9-3	23-Jul-97	181.0-16.6	02	23-Oct-97	181.0	-16.6	This early reproductive male was initially captured at the north end of Beaton Arm in July 1997. It was located again in October 1997 at Beaton Flats, where it has been observed on seven different occasions since the 1997-1998 winter. This male was recaptured in October 1998, on Beaton Flats. In 1.5 years of tracking, this fish had a movement range of at least 18.3 km.
				8-Jan-98	179.3	-1.7	
				4-Mar-98	178.1	-1.2	
				7-May-98	182.0	3.9	
				19-May-98	180.7	-1.3	
				21-May-98	180.8	0.1	
				26-May-98	180.5	-0.3	
				22-Jul-98	181.0	0.5	
				14-Oct-98	181.0	0.0	
				1-Mar-99	181.0	0.0	
<b>Maximum Movement Range</b>						<b>0.0/-18.3</b>	
2-5-7	2-Oct-97	223.2	03	25-Nov-97	179.2	-44.0	This early reproductive male (equipped with an archival tag) was captured in Beaton Flats in the fall of 1997, where it was located during the two subsequent winters. In mid-May 1998, the fish was located 21 km upstream, near the confluence of the Akolkolex River, then was found downstream 6.6 km the next day. Although the fish was not located again during the summer, it was located upstream of Revelstoke in Big Eddy in mid-September 1998, and then was found in Beaton Flats again December 1998. In 1.5 years, the fish moved within a range of at least 51.4 km in the Upper Arrow Reservoir area.
				8-Jan-98	180.4	1.2	
				9-Feb-98	180.5	0.1	
				4-Mar-98	178.1	-2.4	
				20-May-98	202.0	23.9	
				21-May-98	195.4	-6.6	
				17-Sep-98	228.4	33.0	
				13-Dec-98	182.0	-46.4	
				10-Jan-99	177.0-1.0	5.0	
				1-Mar-99	181.0	4.0	
<b>Maximum Movement Range</b>						<b>5.2/-46.2</b>	
2-4-8	4-Oct-97	181.0	03	23-Oct-97	180.2	-0.8	This early reproductive male (equipped with an archival tag) was captured in Beaton Flats in the fall of 1997, where it was located during the two subsequent winters. In mid-May 1998, this fish was located 14 km upstream of Beaton Flats, and then was found the next day back at the flats. In early July, the fish was located 41 km upstream, just below the confluence with the Illecillewaet River. In October and December 1998, the fish was located near the Galena Bay Ferry Landing, and then was found 5 km upstream in Beaton Flats between January and March 1999. This fish moved within a range of at least 46 km during the last 1.5 years.
				25-Nov-97	180.1	-0.1	
				8-Jan-98	180.9	0.8	
				9-Feb-98	179.9	-1.0	
				4-Mar-98	179.2	-0.7	
				20-May-98	195.0	15.8	
				21-May-98	180.8	-14.2	
				2-Jul-99	222.0	41.2	
				14-Oct-98	176.0	-4.8	
				13-Dec-98	176.0	0.0	
				10-Jan-99	182.0	6.0	
				18-Feb-99	182.0	0.0	
				1-Mar-99	181.0	-1.0	
<b>Maximum Movement Range</b>						<b>41.0/-5.0</b>	
3-5-6	5-Oct-97	181.0	14	25-Nov-97	179.2	-1.8	This late vitellogenic female (expected to spawn in 1998) was captured on Beaton Flats in the fall of 1997. She overwintered in the area, and then moved into Beaton Arm in the spring of 1998. Throughout the 1998 spawning season (June-July), she was found just downstream of the confluence of the Incomappleux River, at the north end of Beaton Arm. She was not located again until February 1999, when she was found in Beaton Flats. This female moved over a range of 17.3 km during the past year.
				8-Jan-98	180.4	1.2	
				9-Feb-98	180.5	0.1	
				4-Mar-98	181.0	0.5	
				7-May-98	180.0	-1.0	
				26-May-98	181-11.6	12.6	
				2-Jun-98	181.0-12.0	0.4	
				10-Jun-98	181.0-15.4	3.4	
				24-Jun-98	181.0-15.5	0.1	
				21-Jul-98	181-13.0	-2.5	
				18-Feb-99	181.0	13.0	
				1-Mar-99	181.0	0.0	
				<b>Maximum Movement Range</b>			

Continued...

<sup>a</sup> Distances are measured upstream from Hugh L. Keenleyside Dam to Revelstoke Dam. For hyphenated locations, first value indicates distance in the lake; second value indicates distance into sidechannel.

<sup>b</sup> For description of sex codes refer to Appendix B, Table B1.

<sup>c</sup> A negative movement designates a downstream movement; a positive movement designates an upstream movement.

Table D1 Continued.

Sonic Tag #	Released		Sex <sup>b</sup>	Tracking Date	Location (Km) <sup>a</sup>	Movement (Km) <sup>c</sup>	Movement Summary
	Date	Location (km) <sup>a</sup>					
2-7-5	6-Oct-97	181.0-0.0	03	25-Nov-97	179.0	-2.0	This early reproductive male was captured on Beaton Flats in October 1997. It overwintered in the area, then was located in Beaton Arm on three occasions in June and July 1998. This fish has not been located since July 1998.
				8-Jan-98	180.3	+1.3	
				9-Feb-98	180.9	+0.6	
				4-Mar-98	179.5	-1.4	
				9-Jun-98	181.0-7.5	9.0	
				16-Jun-98	181.0-11.3	3.8	
				8-Jul-98	181.0-11.5	0.2	
<b>Maximum Movement Range</b>						<b>11.5/-2.0</b>	
3-8-3	22-Oct-97	183.3	03	23-Oct-97	180.8	-2.5	This early reproductive male was captured on Beaton Flats in October 1997. It overwintered in the Beaton Flats area, and has been located on the flats in the majority of the following tracking sessions. It is possible that fish either shed its tag, or died based on the lack of demonstrated movement since March 1998.
				25-Nov-97	180.1	-0.7	
				8-Jan-98	180.2	0.1	
				9-Feb-98	180.5	0.3	
				4-Mar-98	178.1	-2.4	
				7-May-98	180.0	1.9	
				19-May-98	179.6	-0.4	
				21-May-98	179.6	0.0	
				26-May-98	179.2	-0.4	
				2-Jun-98	180.0	0.8	
				1-Jul-98	180.0	0.0	
				8-Jul-98	179.5	-0.5	
				17-Jul-99	180.0	0.5	
				21-Jul-98	179.5	0.0	
				17-Sep-98	180.0	0.5	
				13-Dec-98	181.0	1.0	
				10-Jan-99	180.0	-1.0	
18-Feb-99	181.0	1.0					
1-Mar-99	181.0	0.0					
<b>Maximum Movement Range</b>						<b>0.0/-5.2</b>	
3-7-4	22-Oct-97	183.1	12	23-Oct-97	181.0-0.9	-3.0	This pre-vitellogenic female was captured on Beaton Flats in October 1997. It overwintered in the area, and then was located upstream on four occasions between May 1998 and January 1999. On three of four occasions it was found near the confluence with Tank Creek, and on one occasion it was found in Big Eddy, upstream of Revelstoke. This fish returned to Beaton Flats for the winter of 1998-1999.
				25-Nov-97	180.5	-1.4	
				9-Feb-98	180.4	-0.1	
				4-Mar-98	178.1	-2.3	
				20-May-98	194.5	+16.4	
				4-Aug-98	228.2	33.7	
				17-Sep-98	192.0	-36.2	
				14-Oct-98	191.0	-1.0	
				10-Jan-99	180.0	-11.0	
				18-Feb-99	177.0	-3.0	
1-Mar-99	181.0	4.0					
<b>Maximum Movement Range</b>						<b>44.9/-6.1</b>	
2-6-6	24-Oct-97	181.6	03	25-Nov-97	179.2	-2.4	This early reproductive male was captured on Beaton Flats in October 1997. It overwintered in the area in 1997-1998 and 1998-1999. This fish was not located during the summer or fall period of 1998.
				9-Feb-98	180.5	+1.3	
				7-May-98	179.2	-1.3	
				19-May-98	181.7	2.5	
13-Dec-98	176.0	5.7					
<b>Maximum Movement Range</b>						<b>0.1/-5.6</b>	

Continued...

<sup>a</sup> Distances are measured upstream from Hugh L. Keenleyside Dam to Revelstoke Dam. For hyphenated locations, first value indicates distance in the lake; second value indicates distance into sidechannel.

<sup>b</sup> For description of sex codes refer to Appendix B, Table B1.

<sup>c</sup> A negative movement designates a downstream movement; a positive movement designates an upstream movement.

Table D1 Continued.

Sonic Tag #	Released		Sex <sup>b</sup>	Tracking Date	Location (Km) <sup>a</sup>	Movement (Km) <sup>c</sup>	Movement Summary
	Date	Location (km) <sup>a</sup>					
4-4-6	24-Oct-97	181.0	03	25-Nov-97	179.9	-1.1	This early reproductive male was captured on Beaton Flats during October 1997, and overwintered in the area in 1997-1998 and 1998-1999. During the summer period, this fish was located in Beaton Arm, then upstream near the confluence with Tank Creek, and then back in Beaton Arm.
				8-Jan-98	180.3	+0.4	
				9-Feb-98	179.9	-0.4	
				4-Mar-98	178.1	-1.8	
				7-May-98	180.3	+2.2	
				26-May-98	181-11.1	11.8	
				3-Jun-98	193.0	23.8	
				21-Jul-98	181-7.2	-19.2	
				14-Oct-98	182.0	8.2	
				13-Dec-98	179.5	2.5	
				10-Jan-99	180.0	0.5	
				18-Feb-99	181.0	1.0	
				1-Mar-99	181.0	0.0	
<b>Maximum Movement Range</b>						<b>12/-1.5</b>	
3-4-6	28-Oct-98	181.0	14	13-Dec-98	181.0	0.0	This late vitellogenic female (expected to spawn in 1999) captured on Beaton Flats in the fall of 1998, was located in the area in every winter tracking session.
				10-Jan-99	178.5	-2.5	
				18-Feb-99	181.0	2.5	
				1-Mar-99	181.0	0.0	
<b>Maximum Movement Range</b>						<b>0.0/-2.5</b>	
2-4-4-4	27-Oct-98	181.0	14	13-Dec-98	181.0	0.0	This mid-to-late vitellogenic female (expected to spawn either 1999 or 2000), was captured on Beaton Flats in the fall of 1998, and was located in the area during all winter tracking sessions.
				10-Jan-99	178.5	-2.5	
				18-Feb-99	180.0	1.5	
				1-Mar-99	180.0	0.0	
<b>Maximum Movement Range</b>						<b>0.0/-2.5</b>	
4-5-9	28-Oct-98	181.0	13	13-Dec-98	178.0	-3.0	This early vitellogenic female was captured at the bottom end of Beaton Flats in the fall of 1998. Since then, the fish has moved between Beaton Flats and Galena Bay (4.0 km range of movement).
				10-Jan-99	180.0	2.0	
				18-Feb-99	177.0	-3.0	
				1-Mar-99	180.0	3.0	
<b>Maximum Movement Range</b>						<b>0.0/-4.0</b>	
8-8	24-Oct-98	178.5	13	13-Dec-98	178.0	-0.5	This early vitellogenic female was captured at the bottom end of Beaton Flats in the fall of 1998. Since then, the fish has moved between Beaton Flats and Galena Bay (3.0 km range of movement).
				10-Jan-99	177.0	1.0	
				18-Feb-99	177.0	0.0	
				1-Mar-99	180.0	3.0	
<b>Maximum Movement Range</b>						<b>1.5/-1.5</b>	
3-3-3-5	27-Oct-98	181.0	3	13-Dec-98	178.0	3.0	This early reproductive male has moved between Galena Bay and Beaton Flats, since it was captured in the fall of 1998.
				10-Jan-99	177.0	-1.0	
				18-Feb-99	180.0	3.0	
				1-Mar-99	180.0	0.0	
<b>Maximum Movement Range</b>						<b>0.0/-4.0</b>	
5-6-9	29-Oct-98	181.0	12	13-Dec-98	179.5	0.5	This pre-vitellogenic female was captured on Beaton Flats in October 1998. It has since been located in Galena Bay and on Beaton Flats.
				10-Jan-99	177.0	-2.5	
				18-Feb-99	180.0	3.0	
				1-Mar-99	181.0	1.0	
<b>Maximum Movement Range</b>						<b>0.0/-4.0</b>	

Continued...

<sup>a</sup> Distances are measured upstream from Hugh L. Keenleyside Dam to Revelstoke Dam. For hyphenated locations, first value indicates distance in the lake; second value indicates distance into sidechannel.

<sup>b</sup> For description of sex codes refer to Appendix B, Table B1.

<sup>c</sup> A negative movement designates a downstream movement; a positive movement designates an upstream movement.

Table D1 Concluded.

Sonic Tag #	Released		Sex <sup>b</sup>	Tracking Date	Location (Km) <sup>a</sup>	Movement (Km) <sup>c</sup>	Movement Summary
	Date	Location (km) <sup>a</sup>					
6-10	23-Oct-98	183.0	3	13-Dec-98	176.0	7.0	This early reproductive male was captured at the top of Beaton Flats in the fall of 1998. It has since been located in Galena Bay (between December 1998 and March 1999).
				10-Jan-99	177.0	1.0	
				18-Feb-99	177.0	0.0	
				1-Mar-99	177.0	0.0	
<b>Maximum Movement Range</b>						<b>0.0/-7.0</b>	
4-6-8	23-Oct-98	181.0	3	13-Dec-98	176.0	5.0	This early reproductive male was captured on Beaton Flats, located in Galena Bay in December 1998, and then was found in Beaton Flats between January and March 1999.
				10-Jan-99	178.5	2.5	
				18-Feb-99	181.0	2.5	
				1-Mar-99	181.0	0.0	
<b>Maximum Movement Range</b>						<b>0.0/-5.0</b>	

<sup>a</sup> Distances are measured upstream from Hugh L. Keenleyside Dam to Revelstoke Dam. For hyphenated locations, first value indicates distance in the lake; second value indicates distance into sidechannel.

<sup>b</sup> For description of sex codes refer to Appendix B, Table B1.

<sup>c</sup> A negative movement designates a downstream movement; a positive movement designates an upstream movement.