UPPER COLUMBIA RIVER
JUVENILE WHITE STURGEON MONITORING:
PHASE 4 INVESTIGATIONS,
2005 – 2006

Engineering Earth's Development, Preserving Earth's Integrity

Golder Associates

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2005 – 2006

- FINAL REPORT -

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Cover photo: Juvenile white sturgeon captured at Waneta Eddy.

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EXECUTIVE SUMMARY

In total, 48 606 hatchery raised juvenile white sturgeon were introduced into the Transboundary Recovery Area of the Columbia River, between Hugh L. Keenleyside Dam (HLK) in Canada and Grand Coulee Dam in the U.S., from 2002 to 2005. The majority (42 969) were released into the Keenleyside Reach (HLK to the Canada - U.S. border) from 2002 to 2005, and 5637 were released into the Roosevelt Reach (Canada - U.S. border to Grand Coulee Dam) in 2004 and 2005.

The primary objectives of the present study (2005 - 2006; Phase 4) were to conduct a field sampling program to assess the distribution, abundance, survival, growth, and condition of juvenile white sturgeon within the study area; further identify and describe the location and characteristics of juvenile white sturgeon habitats; and, identify the degree and types of physical deformities in these fish. Sample methods used during the present study were gill nets (each net with mesh sizes of 5.1, 10.2 and 15.2 cm stretch measure), angling, underwater video, and the deployment of an underwater PIT tag reader system. Angling and set line sampling were also evaluated using the results of the 2005 Broodstock Collection Program.

Phase 4 monitoring was conducted in November 2005 and in March and April 2006. Angling, gill net sampling, and underwater video surveys (using the Little Benthic Vehicle; LBV) were conducted in November 2005. LBV surveys and the underwater PIT tag reader system pilot program were conducted in March and April 2006. In total, 124 juvenile white sturgeon were captured during the present study and approximately 883 were observed during LBV surveys. The overall catch-rate of juvenile white sturgeon was 10.2 fish/net-unit (one net-unit = 100 m^2 of net sampled for 24 hours; total effort = 10 net-units); the overall observation-rate was 200 fish/hour (total effort = 4.4 hours). The Washington Department of Fish and Wildlife (WDFW) also conducted gill net sampling in October 2005 for juvenile white sturgeon in the Roosevelt Reach; 462 net-units of sample effort were expended and 212 juvenile white sturgeon were captured (0.5 fish/net-unit). Data for 52 juvenile white sturgeon captured during various other sampling programs were also obtained. In total, life history data was obtained for 388 juvenile white sturgeon (including 19 recaptures) in 2005. During the four days it was operational, the underwater PIT tag reader detected 29 individual PIT tags, of which six were detected twice.

The majority (80%) of juvenile white sturgeon captured and all juveniles observed using the LBV during the present study were at depths of 15 m or more. Of the juvenile white sturgeon recorded by the LBV, 525 (59.5%) were observed over substrate composed of fines with some gravels, 159 (18.0%) were observed over fines, 130 (14.7%) were observed over fines with some gravels and cobbles, 56 (6.3%) were observed over cobbles with some gravels and fines, 10 (1.1%) were observed near boulders with some fines or cobbles and gravels, and 3 (0.3%) were observed over gravels and cobbles.

Juvenile white sturgeon use of the deep (50 m), central portion of Fort Shepherd Eddy was confirmed during an LBV survey conducted on 28 November 2005 (19 juveniles were observed). A juvenile white sturgeon was captured at Genelle Eddy on 9 November 2005; the first capture in this area to date.

Similar to surveys in January and March 2004, and in February 2005, hundreds of juvenile white sturgeon tightly grouped and interspersed with adults were observed during LBV surveys in Waneta Eddy in March 2006. These fish were on the river bottom, aligned facing into the current, exhibited relatively little movement, and were in very close proximity to each other (touching in many instances) within a relatively small area. Many of these juveniles were situated in the “valleys” between low-relief dunes (composed of fines and black slag from the Teck Cominco smelter in Trail, B.C.). This was believed to represent overwintering behaviour because the large group of juveniles was not observed during surveys conducted in August and November 2004, and November 2005.

The movements of 90 hatchery juveniles implanted with sonic tags were monitored during the present study. These fish were released in May 2004 (52 Juveniles; 26 released at HLK Eddy and 26 released at Beaver Creek) and May 2005 (38 juveniles; 15 released at HLK Eddy, 15 released at Beaver Creek and 8 released in the Roosevelt Reach). Sonic tagged fish released in the Keenleyside Reach exhibited two general movement patterns based on where they were released. Fish released in HLK Eddy tended to remain between there and Sturgeon Island (an area of preferred habitat conditions with depths in excess of 15 m, near-bottom current velocities less than 0.5 m/s, and substrates consisting mainly of fines). Fish released at Beaver Creek tended to exhibit a downstream dispersal to preferred habitats in areas such as Fort Shepherd Eddy, Waneta Eddy, or Little Dalles (Roosevelt Reach).

Data obtained from 2002 to 2005 were used to determine the mean fork length (FL) and mean weight (ranges in brackets) of age-1 to 4 hatchery juveniles:

- Age-1 (n = 225): 34.5 cm FL (21.8 to 48.0 cm); 288.5 g (64 to 710 g);
- Age-2 (n = 212): 46.7 cm FL (34.2 to 61.1 cm); 679.2 g (232 to 1592 g);
- Age-3 (n = 169): 52.9 cm FL (42.2 to 68.4 cm); 1010.4 g (414 to 2320 g); and,
- Age-4 (n = 120): 59.6 cm FL (45.9 to 78.8 cm); 1659.1 g (610 to 4750 g).

Hatchery juveniles continued to exhibit relatively high growth rates during the present study. The mean growth rate of age-1 fish captured in 2005 (n = 73; 0.07 cm/day FL and 1.10 g/day) was slightly higher those captured in 2004 (n = 77; 0.06 cm/day FL and 0.85 g/day), but substantially lower than for age-1 fish captured in 2002 (n = 36; 0.11 cm/day FL and 2.01 g/day) and 2003 (n = 37; 0.10 cm/day FL and 1.80 g/day). The mean growth rate of age-2 juveniles captured in 2005 (n = 78; 0.04 cm/day FL and 1.14 g/day) was similar to those captured in 2004 (n = 70; 0.05 cm/day FL and 1.13 g/day), and slightly lower than those captured in 2003 (n = 58; 0.06 cm/day FL and 1.36 g/day). The mean growth rate of age-3 juveniles captured in 2005 (n = 80; 0.04 cm/day FL and 0.90 g/day) was lower than those captured in 2004

(n = 78; 0.04 cm/day FL and 1.31 g/day). Comparisons of mean growth rates of juveniles at different capture locations and with and without pectoral fin deformities were also conducted.

Between release and capture, 94% of juvenile white sturgeon captured from 2002 to 2005 exhibited a decrease in relative weight. This was not considered unusual because the fish were fed in the hatchery before release and then were required to adapt to life in the river. The mean relative weight of all age-1 to 4 fish at release and capture were:

- Age-1 (n = 221) at release: 100.5% (73.1 to 131.0%); at capture: 82.7% (63.1 to 116.5%);
- Age-2 (n = 208) at release: 103.4% (71.6 to 173.9%); at capture: 77.8% (55.5 to 139.6);
- Age-3 (n = 159) at release: 106.0% (70.9 to 155.1%); at capture: 76.0% (56.9 to 129.6%); and,
- Age-4 (n = 115) at release: 110.2% (78.1 to 169.6%); at capture: 82.5% (63.1 to 121.8%).

Of the 350 hatchery juvenile white sturgeon for which the required data was obtained in 2005, 100 (28.6%) exhibited pectoral fin deformities. The incidence of pectoral fin deformities of hatchery juveniles captured in 2002 (n = 36) was 52.8%, of fish captured in 2003 (n = 95) was 50.5%, and of fish captured in 2004 (n = 245) was 42.9%. The incidence of pectoral fin deformities in fish from the 2001 brood year captured from 2002 to 2005 (n = 297) was 47.5%, of 2002 brood year fish (n = 189) was 43.9%, of 2003 brood year fish (n = 164) was 20.1%, and of 2004 brood year fish (n = 73) was 17.8%. This indicated that the incidence of pectoral fin deformities in hatchery juvenile white sturgeon decreased both with each successive year of sampling and brood year.

An estimate of hatchery juvenile survival was conducted using the Cormack-Jolly-Seber (CJS) live recapture data type using Program MARK. Several plausible forms of the CJS model were examined and the conditional Akaike Information Criteria (AIC_c) produced by Program MARK was used to determine the most likely model within each candidate set for making the parameter estimates. The selected model, using the lowest AIC_c scores, resulted in a mean survival estimate of the 2002 (releases) cohort of 0.42 ± 0.097 (S.D.) between the time of release and capture in the fall. The 2003, 2004, and 2005 cohorts were pooled and the mean survival estimate between release and capture in the fall for these combined age-1+ cohorts was 0.21 ± 0.046 (S.D.). The mean survival rate for all subsequent time after the first six months in the river was estimated for all cohorts combined at 0.97 ± 0.019 (S.D.). As the exact number of fish released and incorporated into the analysis was known, the CJS survival parameters and their confidence intervals were used to gain a crude estimate of abundance (along with 95% confidence interval) for the population of juvenile white sturgeon now in the system of 11 378 (7125 to 16 498).

The effects of capture method and gill net mesh size on selectivity for size and age classes were explored by use of the General Linear Model (GLM) for examination of fork length variability as a function of both gear type and mesh size (in the case of gill nets). Gear types with sufficient recoveries for analysis included angling, gill nets and underwater PIT tag reader data (age-class information only). The size selectivity of gill net mesh size was quite apparent (ANOVA

$p < 0.001$; this analysis was limited to Keenleyside Reach releases where all mesh sizes were deployed). The age-class selectivity of gear types and the geographical distribution of fish captured by gill net were also examined.

The nature of the released juvenile white sturgeon population in the Transboundary Recovery Area creates difficulties in developing a long term indexing protocol. The age structure of the population will continue to change over time (i.e., in 2006 age-1+ to 5+ fish will be present, in 2007 age-1+ to 6+, etc.). Eventually gill nets will no longer be effective in capturing the older fish, and other methods will have to be incorporated. Gill net sampling, underwater video surveys, angling, and the underwater PIT tag reader should continue to be the main methods utilized during 2006 monitoring. Regardless of the methods used for long term indexing of the hatchery juvenile population, methods should be standardized in subsequent years. These methods should ensure standard release times and locations of juveniles, maintain constant sampling sites each year, and that gear type and effort are constant. Gill nets should continue to be standardized with three panels, one of each mesh size (5.1, 10.2 and 15.2 cm stretch measure).

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1.0 INTRODUCTION

1.1 BACKGROUND

White sturgeon in the Keenleyside Reach of the Columbia River between Hugh L. Keenleyside Dam (HLK) and the Canada-U.S. border (hereafter termed the study area) have been studied intensively since 1990 (R.L. & L. 1994, 1998, 2001; Hildebrand et al. 1999; Golder 2002, Golder 2003a). These studies have indicated that for approximately the last 30 years, recruitment of white sturgeon in the study area has not occurred at a rate sufficient to maintain the population. The reasons for this remain unclear, but are likely related to industrial developments and the presence and operational characteristics of dams on the mainstem Columbia River (i.e., Hugh L. Keenleyside, Revelstoke, and Mica dams) and on major tributaries (i.e., Brilliant Dam on the Kootenay River and Waneta Dam on the Pend d'Oreille River, as well as upstream dams in Canada and the United States on both rivers; Hildebrand et al. 1999, R.L. & L. 1994, UCWSRI 2002).

In 1993, the confluence of the Pend d'Oreille River and the Columbia River was identified as a white sturgeon spawning area, and in 1999 another spawning area was identified in the Columbia River below Revelstoke Dam (R.L. & L. 2001). To date, these two locations are the only known spawning areas for white sturgeon in the Canadian portion of the Columbia River downstream of Revelstoke Dam. In 2005, white sturgeon spawning was confirmed in the American portion of the Columbia River upstream of Grand Coulee Dam, near Northport (Howell and McLellan 2007). While spawning has been confirmed at these locations, annual recruitment from these spawning events has been extremely limited. As a result of these recruitment problems, the Upper Columbia White Sturgeon Recovery Initiative (UCWSRI) was formed in 2000. The UCWSRI is an international organization with members from state, provincial, and federal fisheries agencies and biologists from First Nations in British Columbia and Washington State. The geographic scope of the Recovery Initiative encompasses all white sturgeon residing in the Columbia River upstream of Grand Coulee Dam. The UCWSRI has developed a Recovery Plan (UCWSRI 2002), of which a key component is the supplementation of the existing white sturgeon population in the Columbia River between HLK and Grand Coulee Dam (i.e., the Transboundary Recovery Area) through broodstock collections, hatchery rearing, and subsequent stocking of juvenile white sturgeon.

Chronic recruitment failure of white sturgeon in the Transboundary Recovery Area of the Columbia River has been demonstrated in many studies from the early 1980s to the present (Hildebrand and Birch 1996; R.L. & L. 1998; DeVore et al. 2000; UCWSRI 2002). The Lake Roosevelt Fisheries Evaluation Program was conducted by the Spokane Tribe of Indians in the northern portion of Lake Roosevelt from 1998 to 2003, and began sampling specifically for juvenile white sturgeon in 2001. During that study, two juvenile white sturgeon (less than 1 m total length) were captured in 1998, one in 1999, two in 2000, one in 2001, and two in 2002; juvenile white sturgeon were not captured in 2003 (C. Lee, Spokane Tribe of Indians, Wellpinit, WA, pers. comm., 2004). One of the juveniles captured in 2002 was a hatchery fish released between Beaver Creek and Waneta Eddy earlier the same year; the remaining fish were wild juveniles. During a separate sampling program conducted in 2001, the Spokane Tribe of Indians deployed 44 gill nets (6 foot by 100 foot panels of 2 inch stretch measure) in the northern portion of Lake Roosevelt between Northport and Kettle Falls, Washington, for a total of 856.8 hours of sample effort; juvenile white sturgeon were not captured (Lee and Underwood 2002). In fall 2002, 924.6 hours of gill net effort expended by the Spokane Tribe of Indians in upper Lake Roosevelt captured six juvenile white sturgeon [62 cm fork length (FL) and under; C. Lee, pers. comm., 2003]; these included two hatchery juveniles that were released in Canada in 2002. Gill net sampling throughout Lake Roosevelt by the Spokane Tribe in Washington State from 1994 to 2002 resulted in an average annual catch of approximately two juvenile white sturgeon (under 1 m in fork length; C. Lee, pers. comm., 2003). The Washington Department of Fish and Wildlife (WDFW) sampled for juvenile white sturgeon in the American portion of the Columbia River upstream of Grand Coulee Dam from 2002 to the present. Catches have increased with each successive year of sampling and are discussed later in this report.

In total, 48 606 hatchery reared juvenile white sturgeon have been released into the Transboundary Recovery Area from 2002 to 2005; 16 503 in 2005, 11 629 in 2004, 11 803 in 2003, and 8671 in 2002 (Appendix A, Table A1). Of these fish, 42 969 (88%) were released in the Keenleyside Reach and 5637 (12%) in the Roosevelt Reach. In total, 90 hatchery reared juvenile white sturgeon have been implanted with sonic tags prior to their release; 52 in 2004 and 38 in 2005. Detailed information regarding release dates and locations, numbers, length, weight, and tags for juveniles released from 2002 to 2005 are provided in Appendix A, Tables A1 to A8.

The Phase 1 juvenile white sturgeon monitoring program was initiated in the fall of 2002 (Golder 2003b). The primary objective of Phase 1 was to conduct a field sampling program to determine appropriate non-destructive methods to assess the distribution, abundance, survival, growth, and condition of juvenile white sturgeon within the study area. The Phase 2 monitoring program (Golder 2005a) was developed based on the results of Phase 1 monitoring, and conducted from October 2003 to March 2004. The Phase 3 monitoring program (Golder 2005b) was developed based on Phases 1 and 2, and conducted from August 2004 to February 2005. The results of the present study are provided in this report and compared with results from 2002 to 2004 studies where appropriate.

1.2 OBJECTIVES

The first priority of the present study approach was to increase the relative rate of encounter (sample size) of tagged individuals from the various cohorts present in the juvenile population in order to improve the accuracy and precision of the survival estimates provided in the 2004 (Phase 3) report (Golder 2005b). Sampling was conducted in a manner designed to enable more robust statistical analyses (i.e., to optimize comparability and decrease variability and uncertainty in the results) than had been available from past study results.

The primary objectives of the Phase 4 (fall 2005 to spring 2006) juvenile white sturgeon monitoring program were to:

1) Conduct a field index monitoring program based on the results of 2002 to 2004 sampling to refine the use of appropriate non-destructive methods for assessing the distribution, abundance, survival, growth, and condition of juvenile white sturgeon with a specific focus on:

   a) maintaining consistency in gear type, sample locations, timing, biological sampling parameters, and habitat measurements established from 2002 to 2004;

   b) maintaining consistency of data acquisition and management by following protocols from the first 3 years of study and continuing to use and update the Upper Columbia Basin White Sturgeon Database;

   c) the continued experimental development of alternative, non-destructive strategies and gear types to sample juvenile white sturgeon within a range of potentially suitable habitats; and,

   d) the continued collaboration with U.S. agencies (i.e., the Washington Department of Fish and Wildlife) to ensure methods are consistent and data are compatible.

2) Prepare a concise technical report outlining the findings and recommendations of Phase 4 studies, including:

   a) assessments of the distribution, abundance, growth, condition, and survival of hatchery-reared juvenile white sturgeon encountered during field sampling;

   b) descriptions of habitat measurements and biological sampling results;

   c) development of a standardized, long-term field monitoring protocol based on the results of sampling; and,

   d) recommendations for the 2006 - 2007 indexing program.

1.3 STUDY AREA

The Columbia River between HLK and Grand Coulee Dam (i.e., the Transboundary Recovery Area) was divided into two reaches for the purpose of the present study. These reaches are:

1) the Keenleyside Reach (HLK to the Canada - U.S. border, including the Kootenay River below Brilliant Dam; and,

2) the Roosevelt Reach (the Canada - U.S. border to Grand Coulee Dam).

The Keenleyside Reach was subdivided into three sections:

1) Upper Section (HLK to the Columbia - Kootenay rivers confluence, including the Kootenay River below Brilliant Dam;

2) Middle Section (immediately downstream of the Columbia - Kootenay rivers confluence to immediately upstream of Beaver Creek; and,

3) Lower Section (Beaver Creek to the Canada - U.S. border).

Phase 4 juvenile white sturgeon monitoring (the present study) was conducted in the Keenleyside Reach. Specific locations within the Keenleyside Reach where sampling was focussed were: HLK Eddy, Balfour Bay, Sturgeon Island, Kootenay Eddy, Sandbar Eddy, Genelle Eddy, Beaver Creek Launch Eddy, Trimac Eddy, Fort Shepherd Eddy, Waneta Eddy, and Rock Eddy (Figure 1.1). Sampling by the Washington Department of Fish and Wildlife (WDFW) was conducted in the Roosevelt Reach, between Gifford and Deadman's Eddy (Figure 1.2).

1.4 STUDY PERIOD

Field sampling activities for juvenile white sturgeon during the present study are summarized in Table 1.1. Gill net sampling was conducted from 7 to 18 November 2005. This period was selected for the following reasons:

- to correspond with the main study periods of the 2002 to 2004 studies;
- to allow hatchery juveniles released in 2005 time to distribute throughout the study area and select suitable rearing habitats;
- higher water clarity during this period that allowed more effective sampling by the LBV300™; and,
- juvenile white sturgeon are concentrated in large, overwintering aggregations at known locations (eg., HLK Eddy and Waneta Eddy) during this period, which facilitated indexing efforts.

Angling was conducted in association with personnel from the Ministry of Water, Land and Air Protection (WLAP) and BC Hydro to test the effectiveness of this method and supplement encounter rates of juveniles. The mobile tracking survey was conducted to determine the degree of use of areas outside of VR2 coverage. Surveys using the Seabotix Little Benthic Vehicle 300™ (LBV) were conducted to observe behaviour, habitat use, and provide additional data on the degree of use of Waneta and Fort Shepherd Eddies. A remote PIT tag reader system was deployed in Waneta Eddy on 26 March 2006. Sampling for juvenile white sturgeon by the WDFW in the Roosevelt Reach was conducted in October 2005.

Table 1.1 Sampling schedule for the upper Columbia River juvenile white sturgeon monitoring, Phase 4 investigations, November 2005 to April 2006.

Angling	Mobile Tracking	Gill Net Sampling	LBV Surveys	Remote PIT Tag Reader
2 November 2005	4 November 2005	7 November 2005 8 November 2005 9 November 2005 10 November 2005 16 November 2005 17 November 2005 18 November 2005	16 November 2005 28 November 2005 24 March 2006 26 March 2006	26 March - 13 April 2006

Figure 1.2 Overview of the Roosevelt Reach study area.

2.0 METHODS

2.1 PHYSICAL PARAMETERS

2.1.1 Discharge

Discharge data for the Columbia River at HLK (including the Arrow Lakes Generating Station) and Birchbank were obtained from BC Hydro Power Records. Discharge data for Brilliant Dam and Waneta Dam were obtained from FortisBC. Mean daily discharges were calculated from the hourly data obtained.

2.1.2 Water Temperature

Water temperature data was obtained from temperature loggers (Vemco 12, accurate to ±0.1°C and Onset Stowaway Tidbit®, accurate to ±0.2°C; programmed to record at hourly intervals) set in the Columbia River below HLK and at the Birchbank Water Station. Kootenay River water temperatures were obtained from thermisters set below Brilliant Dam. Pend d'Oreille River water temperatures were obtained from thermisters set in the Waneta Dam forebay.

2.2 SAMPLE METHODS

2.2.1 Gill Nets

Gill nets were the main sample method used to capture juvenile white sturgeon during the present study. Sample sites were selected based on 2002 to 2004 findings (and a wide range of other studies) that indicated little or no use of shallow, higher velocity habitats, to maintain consistency with previous sampling, and to facilitate statistical comparisons between years. Gill net sample sites from previous years were repeated for comparison purposes; additional effort was expended in Waneta Eddy so effort would be more proportional to abundance and to increase the overall number of juveniles captured.

The nets used were multi-filament, horizontal gill nets of two sizes: 1.8 m deep by 15.2 m long (27.9 m^2) and 1.8 m deep by 45.7 m long (83.6 m^2); each comprised of three equal size panels of differing mesh size (5.1 cm, 10.2 cm and 15.2 cm stretch measure). Panel area was 9.3 m^2 for the small nets and 27.9 m^2 for the large nets. Gill nets were deployed at the bottom of the water column, with a float and float line and two concrete anchors attached to each end of the net. The nets were set in areas with low velocities and uniform substrates to prevent the nets from drifting or snagging on the bottom. The mesh size that each fish was captured in was recorded, along with set depth and orientation to flow.

Gill nets were originally set during the day in the upper section of the Keenleyside Reach for approximately 3 hour periods to assess the degree of by-catch and the condition of white sturgeon captured. Fish were not captured during the daytime sets, so gill nets were set overnight. Daytime sets were not used in the middle (between the Kootenay River and

Beaver Creek) and lower sections (Beaver Creek to the Canada - U.S. border) due to the time required to process fish and travel between sections, and because of limited daylight hours.

2.2.2 Underwater Video Surveys

During the present study, the SeaBotix Little Benthic Vehicle 300™ (LBV) remotely operated underwater vehicle was used to observe juvenile white sturgeon behaviour and habitat use. The use of this system provided a visual record of habitat parameters and the availability and use of bottom cover in areas where juvenile white sturgeon were observed. LBV surveys were conducted in Waneta Eddy to attempt to locate the large aggregation of overwintering juveniles, as in previous years, and Fort Shepherd Eddy to provide a visual record of habitats in the deep portion of the eddy and data on the use of the area by juvenile white sturgeon. Footage obtained was reviewed in the office at slow speeds and the number of juvenile white sturgeon recorded was counted. If the LBV was manoeuvred away from a group of juveniles and the same group was observed later (based on location and bottom features), these fish were not counted twice.

The SeaBotix Little Benthic Vehicle 300™ consisted of the LBV with protective bumper frame, control console, surface power supply, and 300 m umbilical. The features of the LBV included: a four thruster configuration (2 forward, 1 lateral, and 1 vertical), 270° field of vision, 180° camera tilt, 2 video cameras (0.3 lux colour and 0.03 lux low-light black and white), halogen lights that track the cameras, dual scaling lasers (to aid in determining the size of objects/fish observed), and sensors for depth, heading, and temperature. Images captured by the cameras were transferred to the surface monitor via a fiber-optic cable enclosed in an 8.4 mm diameter umbilical cord.

Before the LBV was placed in the water, the thrusters and cameras were tested, the unit was vacuum tested to ensure that it was watertight, and the heading sensor was calibrated. The unit was then placed in the water to verify it was neutrally buoyant and the depth sensor was calibrated. The thruster controls were checked again in the water and then the unit was sent down to the river bottom. The LBV was then manoeuvred in the desired direction(s) to obtain footage of habitat and fish. This unit can be operated at depths up to 300 m and in current speeds of up to 150 cm/s (3 knots), although its mobility decreases as current speed increases (mainly due to increased drag on the umbilical).

2.2.3 Sonic Telemetry

In total, 90 juvenile white sturgeon have been implanted with sonic tags; 52 from the 2002 brood year that were held over and released in May 2004 (Appendix A, Tables A5 and A6), and 38 from the 2004 brood year that were released in May 2005 (Appendix A, Table A3). Aside from the mobile tracking survey conducted on 4 November 2005 as part of the present study, movements of these fish were monitored as part of the Upper Columbia white sturgeon stock monitoring and data management program, funded by BC MOE, as well as by the WDFW, funded by the Spokane Tribe of Indians and the Bonneville Power Administration. A detailed description of the methods used is available in the 2004 - 2005 annual report for the stock monitoring and data management program (Golder 2005c). As a component of the Brilliant Expansion Project white sturgeon monitoring program (funded by Columbia Power Corporation; Golder 2004c), two VR1 receivers were deployed in the Kootenay River on 7 February 2003 (Table 2.1). These units were replaced on 12 February 2004 with VR2 receivers capable of detecting the sonic tags implanted in juvenile white sturgeon (V8SC-2H-R04K and V8SC-2L-R04K coded transmitters; 69.0 kHz). In June 2003, VR2 receivers were deployed in HLK, Fort Shepherd, and Waneta eddies (Figure 1.1). These stations have been maintained and in continuous operation since that time. In order to improve coverage of the study area, additional VR2s were deployed as summarized in Table 2.1.

Table 2.1 Summary of VR2 receiver locations within the Transboundary Recovery Area, March 2006.

Receiver Location[a]	River Kilometre[b]	Date of Initial Deployment	UTM Coordinates (Zone 11U)		Date of Last Download
			Easting	Northing	
Keenleyside Reach					
HLK Eddy	0.1	16 June 2003	444068	5465568	22 March 2006
Balfour Bay	2.6	19 May 2004	446344	5465677	22 March 2006
Sturgeon Island	6.5	19 May 2004	450071	5464576	22 March 2006
Waldie's Island	9.1	16 June 2005	452602	5464200	22 March 2006
Sandbar Eddy	20.8	16 June 2005	451442	5453375	22 March 2006
Genelle	25.5	20 May 2004	448577	5450181	22 March 2006
Sullivan Creek	27.5	20 June 2005	448180	5448314	22 March 2006
Rivervale	35.5	13 February 2004	446375	5441042	22 March 2006
Rock Island	43.2	20 May 2004	452598	5438292	22 March 2006
Trimac	51.7	20 June 2005	455594	5431297	22 March 2006
Fort Shepherd Eddy	52.0	16 June 2003	455477	5431057	22 March 2006
Waneta Eddy	55.4	16 June 2003	454483	5428171	22 March 2006
Rock Eddy	56.0	20 June 2005	453912	5428078	22 March 2006
Kootenay River					
Kootenay Eddy	0.1K	7 February 2003	452765	5462748	22 March 2006
Brilliant Bridge	2.0K	7 February 2003	454261	5462927	22 March 2006
Roosevelt Reach					
Deadman's Eddy	68	20 June 2004	553298	5420500	11 January 2006[c]
Northport	71	28 June 2005	440950	5417217	16 March 2006
Little Dalles	82	20 June 2004	564508	5412808	16 March 2006
China Bend	90	2 April 2005	432097	5407746	16 March 2006
North Gorge	96	3 June 2004	574250	5403125	16 March 2006
Marcus Island	114	21 June 2004	575752	5391965	16 March 2006
Kettle Falls Bridge	123	28 June 2005	417730	5386783	16 March 2006
Rickey Point	130	3 June 2004	584137	5377202	16 March 2006
Barnaby Island	141	21 June 2004	589850	5366721	2 April 2005
Gifford	160	1 August 2005	414227	5348853	17 March 2006
Hunters	180	1 August 2005	410217	5332359	17 March 2006

[a] See Figures 1.1 and 1.2 for VR2 locations.
[b] River kilometres measured downstream from HLK in the Columbia River and upstream from the mouth in the Kootenay River.
[c] This VR2 was lost sometime between 11 January and 16 March 2006.

2.2.4 Angling

BC Hydro, BC MOE, and Golder personnel participated in angling as part of juvenile white sturgeon monitoring on 2 November 2005 at Waneta Eddy. Worms, kokanee, roe, maggots, and eulachon were used as bait. Sampling consisted of two boats with four anglers and another boat with two work-up personnel. Juvenile white sturgeon captured by anglers were transferred to the work-up boat and processed as described in Section 2.2.8.

Angling was also conducted as part of the 2005 Broodstock Collection Program in June 2005. Although pre-spawning adult white sturgeon were targeted during this program, juveniles were frequently captured. A detailed description of angling methods used in that study can be found in the 2004 broodstock report (Golder 2005e).

2.2.5 Set Lines

Sampling by set line was not conducted during the present study; however, this method resulted in the capture of juvenile white sturgeon during the 2005 Broodstock Collection Program. A detailed description of this method can be found in the 2004 broodstock report (Golder 2005e).

2.2.6 Underwater PIT Tag Reader System

The pilot underwater PIT tag reader system was deployed on 26 March 2006. The main components of this system were:

- a floating wooden platform (Plate 1): 122 cm long by 122 cm wide by 22 cm deep; filled with styrofoam floatation;
- a weather resistant metal box (Plate 1): 92 cm long by 61 cm wide by 30 cm deep; bolted to the floating platform;
- an underwater housing (manufactured by Prevco Subsea LLC; Plate 2): 45 cm long, 30 cm in diameter, anodized aluminum cylinder; that housed the PIT tag reader; and,
- a 66 cm long by 31 cm wide waterproof, flat-plate antenna (manufactured by Biomark Inc.; Plate 2).

Golder's Destron-Fearing Model 2001F-ISO PIT tag reader was sent to Biomark Inc. and was modified to be powered by 12 V batteries and for use with the underwater housing and flat-plate antenna. The PIT tag reader was placed inside the underwater housing (Plate 3) and the cables (power, communication and antenna) attached to the connections inside the underwater housing. The underwater housing was attached to an anchor frame using hose clamps and bungee cords, and a garden hose was cut open and placed over the antenna cable to provide protection (Plate 4). The antenna flanges were cable tied together at either end, with the cable inside the protective hose also attached to protect the cable insertion (Plate 5). A rope that was shorter than the antenna cable was attached to the anchor frame and antenna plate to relieve stress on the antenna cable.

The power and communication cables were fed through a hole in the bottom of the floating platform and into the weather resistant box. Anchors (two 65 pound concrete anchors with 2 m of chain) were deployed approximately 5 m upstream and 5 m downstream of where the system was to be set. The anchor lines were measured to reach the river bottom, but remain as tight as possible, and 5 m lines were then attached from the marked floats to the floating platform. The floating platform was deployed off the boat and the underwater housing and antenna were lowered from the boat together to prevent stress on the antenna cable. Marked polyform LD-2 floats were attached to each corner of the platform to provide extra floatation and improve visibility (Plate 6). Signage with Golder contact information was affixed to each side of the weather resistant box. The boat was attached to the anchor lines during the deployment procedure. As a result of surging flows within the eddy, the anchors drifted from the targeted area of 19 m depth to an area of 16 m depth.

Once the system was deployed, two 80 amp-hour, deep cycle, sealed, valve regulated, non-spillable batteries were set up in series in the weather resistant box (Plate 7). The reader was then powered up and communication with the unit was established using a laptop computer. The unique delay was set to 60 seconds (i.e., a PIT tag would only be recorded once for each minute it was above the antenna); to save memory space, which was limited to 4000 tag detections with associated time and date stamps. As a test of the system, a PIT tag was affixed to the LBV which was then driven directly over the antenna. The PIT tag was detected and recorded by the system, which provided confirmation that the system was working. A marker float (and associated lines and anchors) was deployed on each side of the platform, a sufficient distance away to prevent the ropes becoming tangled. To attract fish to the antenna, frozen kokanee were cut up and placed into a bait canister (Plate 8), which was deployed approximately 10 m upstream of the antenna location. The batteries in the weather resistant box were swapped out for fully charged batteries after each download, and the bait in the canister was replaced.

2.2.7 Boat Electroshocking

The effectiveness of boat electroshocking as a juvenile white sturgeon capture method was assessed during the Lower Columbia River Fish Indexing Program (LCRFIP), a separate program conducted by Golder Associates Ltd. for BC Hydro from 19 September to 1 November 2005. This program involved 6 weeks of intensive sampling to document the composition and abundance of fish species that used nearshore habitats in the Columbia River throughout the Keenleyside Reach. In the event juvenile white sturgeon were captured during the electroshocking surveys, the crew was equipped with a PIT tag reader and the equipment to conduct the necessary life history work-up. A detailed description of this sample method is provided in the 2004 LCRFIP report (Golder 2005d).

2.2.8 Life History Data Collection

Captured juvenile white sturgeon were placed in a 75 L cooler of water to which fresh river water was frequently added. The fish were scanned for PIT tags using a Destron Fearing Model 2001F-ISO portable transceiver system and checked for external marks (i.e., lateral scute removals and previous pectoral fin clips) and abnormalities. If a PIT tag was not found, one was implanted subdermally behind the head on the left side of the fish. The following measurements (to the nearest mm) were taken along the left side of each juvenile white sturgeon: snout (tip of snout to the beginning of the eye), head (tip of snout to the end of the opercular opening), fork length (FL: tip of snout to the “fork” where the upper and lower caudal lobes meet), total length (TL: tip of snout to the point where the upper and lower caudal lobes meet, then to the tip of the upper caudal fin lobe), and girth (circumference of fish just behind the pectoral fin insertions). Fish were weighed (to the nearest g) using an Ohaus 5000 g digital scale (±2 g). Due to time constraints (i.e., the onset of darkness), only fork length, total length, and weight were measured for many fish. After processing, fish were released when they had recovered sufficiently to swim away of their own volition.

External exams were conducted for all juvenile white sturgeon captured during the present study according to protocols provided by BC MOE (a modified United States Geological Survey form). External exams included: condition of eyes, head, barbels, body surface, opercles, gills, and fins. Any abnormalities were recorded and notable abnormalities were photographed.

Fin ray sections (for ageing purposes) were obtained from three wild juveniles captured in the Roosevelt Reach by the WDFW. DNA fin samples were also taken from these three fish. Stomach samples were not obtained during the present study since a decision was made by the UCWSRI Technical Working Group (TWG) not to sacrifice fish for stomach content analysis and there were no mortalities during sampling. However, six stomach samples were collected by the WDFW in the Roosevelt Reach from juveniles that succumbed to the sample procedure (five hatchery fish and one wild fish).

2.2.9 Relative Weight

The relative weight index (W_r) is a commonly used method for comparing the condition of fish populations. The index is expressed as a percent and is calculated as:

$$W_r = \frac{W}{W_s} * 100$$

where W is the weight of the sampled fish in kilograms, and W_s is the length-specific standard-weight value for a particular species. For the purposes of this report, the W_s used for calculating W_r was from Beamesderfer (1993):

$$W_s = \alpha * L^{\beta}$$

where α = 1.952 E^{-6} and ß = 3.232 and L is the total length of the individual fish in cm. These parameters were derived by the regression-line-75th percentile technique (RLP) recommended by Murphy et al. (1991). The RLP technique takes the 75th percentile weights for each 1 cm total length interval and then regresses these values onto length to develop the W_s (Murphy et al. 1991). This RLP was based on populations of white sturgeon from five rivers in the Pacific North-West (Beamesderfer 1993).

During 2003 (Golder 2005a), where total lengths (TL) were not available from release or field data, they were calculated from the fork lengths (FL) using a factor of 1.110 (Beamesderfer 1993). Total length data was available in the 2001 brood hatchery release data, but not for the 2002 to 2004 brood years. Relative weights originally calculated (using a factor of 1.110) for 2002 and 2003 brood fish at the point of release appeared high (approximately 30% higher than 2001 brood fish at the point of release). Therefore, the 2001 brood release data was used to calculate a new FL to TL conversion factor. The mean TL/FL ratio calculated using these 8671 fish was 1.200. The TL at release of 2002 to 2004 brood fish was therefore calculated using a factor of 1.200 and relative weights were determined using the resulting total lengths (see Section 3.3.4.3).

Low numbers of juveniles captured from 2002 to 2005 exhibited malformed or shortened upper caudal fins. Discrepancies were also noted in total length data obtained from various sources. The mean TL/FL ratio of all juveniles captured from 2002 to 2005 by Golder (n = 342) was calculated as 1.198 (very similar to the conversion factor above). This value was used to calculate the TL of juveniles for which this data was missing, or obviously incorrect.

2.2.10 Survival Estimates

Survival estimates used the Cormack-Jolly-Seber (CJS) live recapture data type using Program MARK. The following assumptions were used for the survival estimates:

1. equal probability of capture was assumed for all cohorts sampled during the fall sampling period;
2. the probability of capturing a marked individual of a particular cohort at a given time was equal to the proportion of marked members in the population at that time;
3. fish did not lose their marks during the study period; and,
4. all marks were reported on recovery.

For Program MARK survival estimates, a candidate model set was constructed. Detailed descriptions of the alternative formulations of CJS survival estimates are available in the Program MARK help file. The analysis examined several plausible forms of the CJS model and used the conditional Akaike Information Criteria (AIC_c) produced by Program MARK for determining the most likely model within each candidate set for making the parameter estimates. Models that were used in the analysis were selected from a limited set of all possible models that were believed to have some reasonable likelihood of reflecting the current understanding of the biology of juvenile white sturgeon.

All fish from different release areas were grouped for the overall survival estimates. Apparent survival was estimated for the 2002 cohort during their first 6 months, the 2003 cohort for their first 6 months and all cohorts once they had been in the river for greater than 6 months. Probability of capture was estimated for 3 time periods, (2002-2003; 2003-2004, 2004-present). PIT tag losses were assumed to be negligible with all non-PIT tagged fish without scute removals assumed to be wild fish. Wild fish numbers were negligible and were not used in estimating survival.

A goodness-of-fit (GOF) test was completed on the models using the MARK median C-hat GOF procedure. The resultant Quasi-Akaike Conditional Informational Criteria ($QAIC_c$) were then used to evaluate if over or under dispersion would impact model selection. C-hat values ranging from 0.5 to 4 were assessed.

2.2.11 Analysis of Factors Affecting Size at Capture

The effect of capture method and gill net mesh size on selectivity for size and age classes were explored by use of the General Linear Model (GLM) for examination of fork length variability as a function of both gear type and mesh size in the case of gill nets. Gear types with sufficient recoveries for analysis included angling, gill nets and underwater PIT tag reader data. In the case of data collected by the underwater PIT tag reader, only age-class information was obtained by identification of the individual fish. Contingency table analysis was used for hypothesis testing of differences in gear type selectivity for age class categorical data. Both Pearson Chi-square and Likelihood Ratio Chi-Square test results are reported. Geographical trends in FL of captured juvenile white sturgeon for each age class were evaluated graphically for 2003, 2004, and 2005 juvenile white sturgeon captures. Analysis was limited to Keenleyside Reach released hatchery fish only, where gill nets were standardized for having all mesh sizes of 5.1, 10.2, and 15.2 cm. All analyses of capture selectivity were completed using SYSTAT version 11 statistical software.

3.0 RESULTS

3.1 PHYSICAL PARAMETERS

3.1.1 Discharge

Mean daily discharges of the Columbia River between 1 September 2005 and 18 March 2006 were obtained from Arrow Lakes Reservoir below HLK (via HLK and Arrow Lakes Generating Station combined) and the Birchbank Water Station, for the Kootenay River from Brilliant Dam, and for the Pend d'Oreille River from Waneta Dam (Figure 3.1). During this period, the Columbia River at Birchbank followed a typical, post-impoundment discharge pattern of declining and lower discharges in the fall, increasing to a peak in December (as a result of fall precipitation events and downstream power generation requirements during the winter), with decreasing discharges through late December and January down to baseflow conditions in February. Peak discharge at Birchbank during this period was 3012 m^3/s on 14 December and minimum discharge was 1049 m^3/s on 14 February.

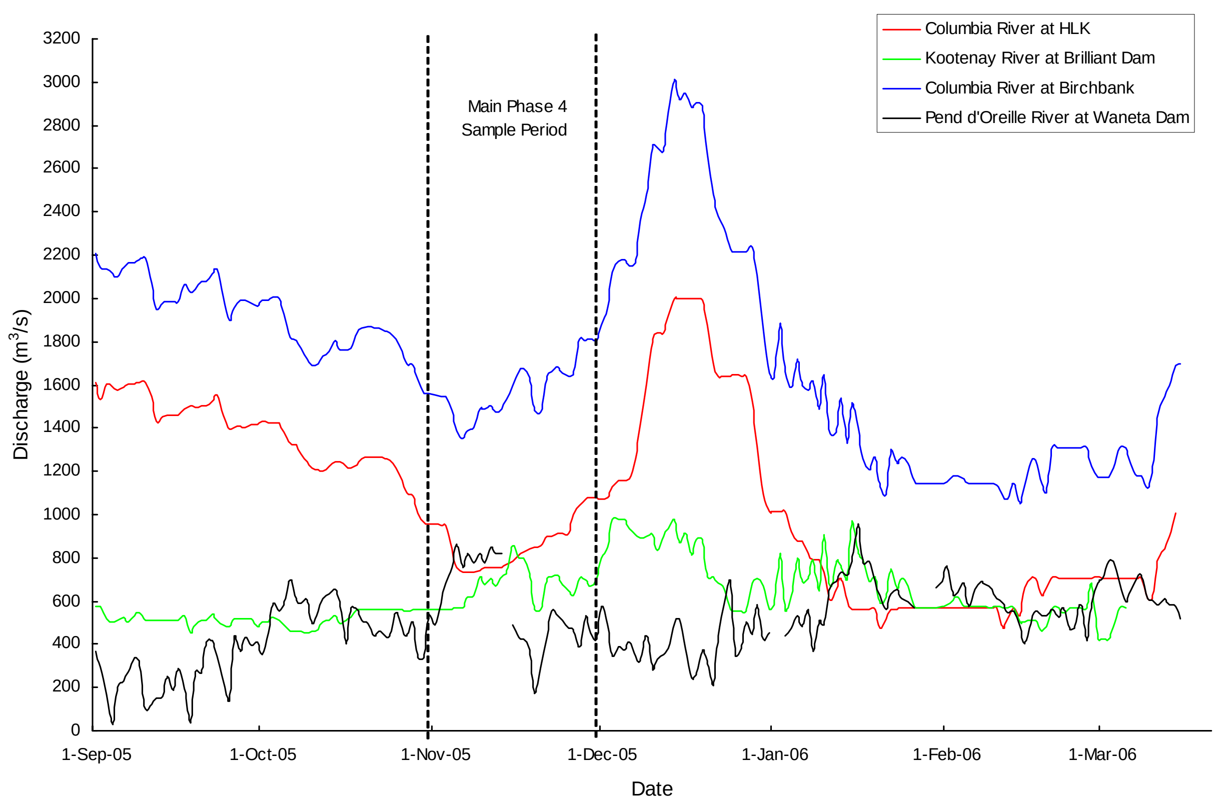

Figure 3.1 Mean daily discharge of the Columbia River at Hugh L. Keenleyside Dam and Birchbank, the Kootenay River at Brilliant Dam, and the Pend d'Oreille River at Waneta Dam, 1 September 2005 to 18 March 2006.

Over the 1 September 2005 to 5 March 2006 period, discharge from Brilliant Dam remained quite stable during September and October, generally increased from November to mid-December, exhibited relatively minor fluctuations until late January, and was stable for the remainder of the period. Maximum and minimum discharge occurred on 3 December (980 m^3/s) and 1 March (426 m^3/s), respectively. Mean daily discharge from Waneta Dam generally fluctuated between 955 m^3/s (16 January) and 101 m^3/s (10 September), with the exception of the 18 and 4 September, when discharge dropped to 37 m^3/s and 31 m^3/s, respectively.

Discharge in the Columbia and Kootenay rivers generally increased over most of the main study period, but exhibited some fluctuation. Discharge in the Pend d'Oreille River fluctuated between a high of 867 m^3/s on 5 November and a low of 171 m^3/s on 19 November.

3.1.2 Water Temperature

Water temperatures from 1 September 2005 to 22 March 2006 were recorded in the Columbia River upstream (HLK tailrace) and downstream (Birchbank Water Station) of the influence of the Kootenay River, as well as in the Kootenay River (Brilliant Dam tailrace) and Pend d'Oreille River (Waneta Dam forebay; Figure 3.2). Water temperatures in all three rivers followed a typical seasonal pattern, and declined until late February. Mean daily water temperatures in the HLK tailrace decreased from 17.1°C in early September to 3.2°C in mid-February, and at Birchbank from 17.4 to 3.1°C in late February. Water temperatures in the Kootenay and Pend d'Oreille rivers followed similar patterns.

During the November study period, water temperatures in the Columbia River below HLK decreased from 9.1 to 7.0°C, and downstream of the Columbia-Kootenay rivers confluence from 9.4 to 7.3°C. Water temperatures in the Kootenay River decreased from 10.4 to 7.4°C and in the Pend d'Oreille River from 11.1 to 7.1°

3.2 FISH CAPTURE/OBSERVATION METHODS

3.2.1 Gill Nets

The majority of juvenile white sturgeon ($n = 102$; 82% of juveniles captured during the present study; 2005) were captured by gill net. In total, the 36 gill nets set resulted in 590.3 net-hours or 10.0 net-units (one net-unit = 100 m^2 of net sampled for 24 hours). The effort expended and catch in each area sampled is provided in Appendix B, Table B1 and summarized in Table 3.1. The overall catch-rate of juvenile sturgeon was 10.2 fish/net-unit, compared to 3.8 fish/net-unit in 2002 (Phase 1; Golder 2003b), 7.6 fish/net-unit in 2003 (Phase 2; Golder 2005a), and 7.5 fish/net-unit in 2004 (Phase 3; Golder 2005b). The catch-rate was lower in HLK Eddy and higher in Balfour Bay during the present study than in 2002 to 2004 studies (Table 3.1). The catch-rate in Kootenay and Sandbar eddies was lower during the present study than in 2004. Juvenile white sturgeon were not captured in Fort Shepherd or Rock eddies during the present study. The catch-rate in Waneta Eddy was similar to that recorded in 2004, lower than in 2003, and higher than 2002. A juvenile white sturgeon was captured in Genelle Eddy during the present study; this represented the first capture in this area.

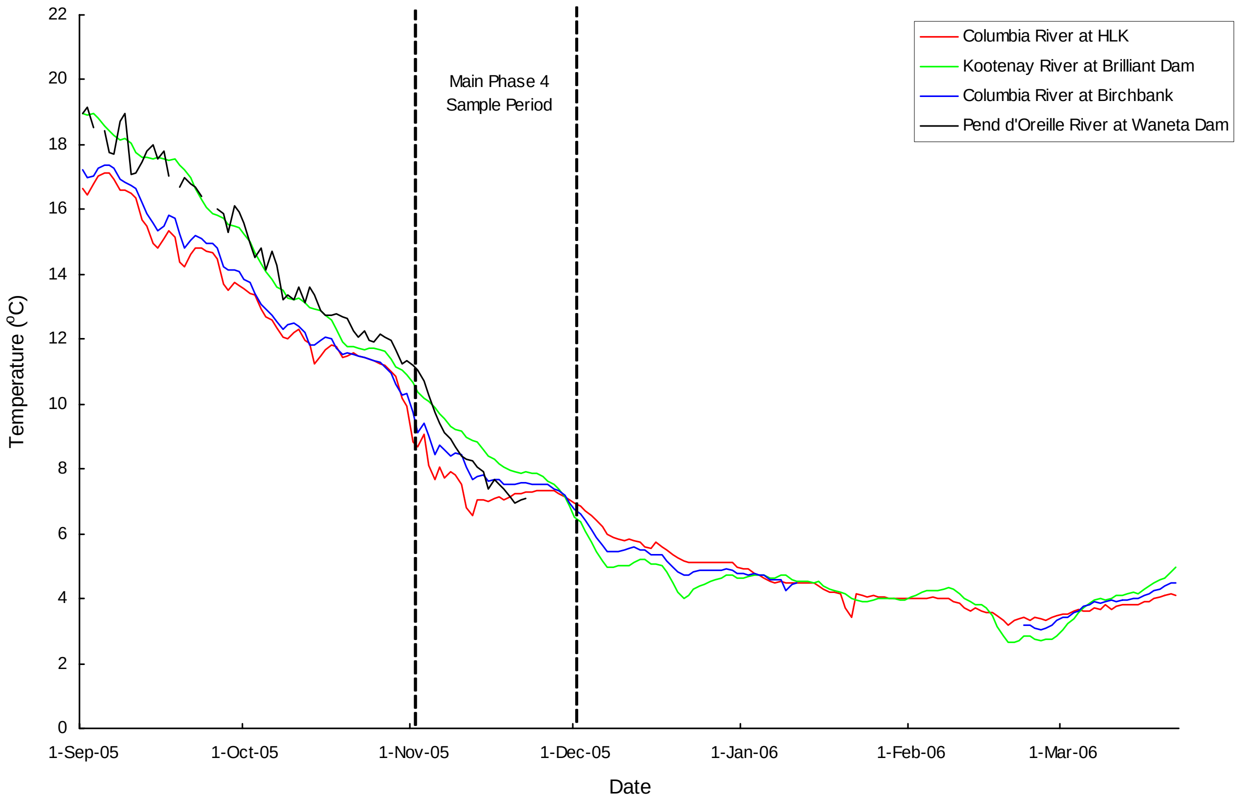

Figure 3.2 Mean daily water temperatures in the Columbia River at Hugh L. Keenleyside Dam and the Birchbank Water Station, in the Kootenay River at Brilliant Dam, and the Pend d'Oreille River at Waneta Dam, 1 September 2005 to 22 March 2006.

Table 3.1 Summary of gill net sample effort, catch and catch-rate of juvenile white sturgeon; 2002 to 2005.

Location[a]	Phase 1 (2002)			Phase 2 (2003)			Phase 3 (2004)			Phase 4 (2005)		
	Effort[b]	No. Cap.	Catch-rate[c]	Effort[b]	No. Cap.	Catch-rate[c]	Effort[b]	No. Cap.	Catch-rate[c]	Effort[b]	No. Cap.	Catch-rate[c]
HLK	3.76	17	4.5	0.49	28	57.0	4.83	39	8.1	2.47	6	2.4
BB	0.80	0	0.0	0.82	1	1.2	1.22	2	1.6	0.57	2	3.5
KE	1.30	0	0.0	1.12	0	0.0	1.23	10	8.2	0.59	2	3.4
SE	0.58	0	0.0	0.87	0	0.0	0.92	7	7.6	0.45	1	2.2
GE	NS[d]	NS[d]	NS[d]	1.96	0	0.0	0.95	0	0.0	0.45	1	2.2
FSE	NS[d]	NS[d]	NS[d]	1.67	0	0.0	3.32	7	2.1	1.56	0	0.0
WE	1.18	19	16.2	0.60	48	80.1	1.95	58	29.7	2.85	90	31.6
RE	NS[d]	NS[d]	NS[d]	0.36	0	0.0	0.55	2	3.7	0.24	0	0.0
Subtotal	**7.62**	**36**	**4.7**	**7.89**	**77**	**9.8**	**14.97**	**125**	**8.4**	**9.18**	**102**	**11.1**
Rest[e]	**1.93**	**0**	**0.0**	**2.27**	**0**	**0.0**	**1.77**	**0**	**0.0**	**0.84**	**0**	**0.0**
Total	**9.55**	**36**	**3.8**	**10.16**	**77**	**7.6**	**16.74**	**125**	**7.5**	**10.02**	**102**	**10.2**

[a] See Figure 1.1 for sample locations. HLK = HLK Eddy; BB = Balfour Bay; KE = Kootenay Eddy; SE = Sandbar Eddy; GE = Genelle Eddy; FSE = Fort Shepherd Eddy; WE = Waneta Eddy; RE = Rock Eddy.
[b] Effort is in net-units; one net-unit = 100 m^2 of net sampled for 24 hours.
[c] Catch-rate = number of juvenile white sturgeon captured per net-unit.
[d] NS = not sampled (these locations were not sampled during Phase 1 monitoring).
[e] Rest = rest of study area.

During the present study, daytime gill net sets were only conducted in the upper section (HLK Eddy to Kootenay Eddy). Juvenile white sturgeon (or incidental species) were not captured by daytime sets. The total effort expended for daytime sets was 0.50 net-units; overnight effort was 9.52 net-units.

During the present study, each gill net used was composed of equal areas of 5.1, 10.2, and 15.2 cm stretch measure mesh. Each mesh size was fished for one third of the total effort, or 3.34 net-units. Catch-rates for each mesh size were 9.6 fish/net-unit (5.1 cm; *n* = 32 fish), 14.4 fish/net-unit (10.2 cm; *n* = 48 fish), and 6.6 fish/net-unit (15.2 cm; *n* = 22 fish; Appendix B, Table B1). A difference in the size of juveniles captured by the three different mesh sizes was apparent from the results of the present study (Table 3.2; ANOVA $p < 0.001$; see Sections 3.3.4.7 and 4.2.4).

Table 3.2 Comparison of juvenile white sturgeon fork length by gill net mesh size during Phase 4 monitoring, November 2005.

Fork Length (cm)	**Mesh Size (cm stretch measure)**		
	5.1	**10.2**	**15.2**
Mean	44.3	49.9	54.5
Minimum	31.8	38.0	32.5
Maximum	56.8	66.2	71.6
Standard Error	1.3	0.7	2.4
n	31	48	20
ANOVA	**p < 0.001**		

Washington Department of Fish and Wildlife (WDFW) personnel expended 462 net-units of effort in the Roosevelt Reach from 3 to 27 October 2005; 212 juvenile white sturgeon were captured (M. Howell, WDFW, Colville, Washington, U.S.A., pers. comm., 2006). The overall catch-rate of juvenile sturgeon was 0.5 fish/net-unit (Appendix B, Table B2). Gill nets used by the WDFW measured 91.44 m long by 3.66 m deep. If the nets were treated as 1.83 m deep for comparison purposes (i.e., since juveniles were rarely captured in the upper portion of the nets), the catch-rate would increase to 0.9 fish/net-unit (based on 231 net-units of effort).

3.2.1.1 Incidental Catch

During the present study, 22 fish were captured incidentally during gill net sampling. The majority (*n* = 18; 81.8%) were non-sportfish species (Appendix B, Table B3) and consisted of longnose sucker (*n* = 11), largescale sucker (*n* = 6), and peamouth (*n* = 1). The only sportfish species captured incidentally was lake whitefish (*n* = 4). In total, 68% of the incidental captures were released alive.

3.2.2 Underwater Video

In total, 4.4 hours of underwater footage was obtained using the LBV during the present study; 2.7 hours at Waneta Eddy and 1.6 hours at Fort Shepherd Eddy. An estimated 880 juvenile, 6 sub-adult, and 8 adult white sturgeon, as well as 17 fish of other species were observed (Appendix B, Table B4). In total, approximately 860 juvenile white sturgeon were observed at Waneta Eddy and 19 were observed at Fort Shepherd Eddy. A summary of juvenile white sturgeon observations and the habitat characteristics associated with these observations is provided in Appendix B, Table B5, and further described in Section 3.3.2.

During the survey in Waneta Eddy on 16 November 2005, a total of 356 juvenile white sturgeon were observed. These fish were either alone or in groups that ranged from 2 to 67 fish (Appendix B, Table B5). The large aggregations of juvenile white sturgeon previously observed at this location in January 2004, March 2004, and February 2005 were not observed on this date (Golder 2005a and 2005b). However, the juveniles that were observed exhibited similar behaviour to those observed in the large aggregation recorded on 24 March 2006 (see below), but with lower numbers and densities. During this and the following surveys described below, it was noted that the scaling lasers on the LBV appeared to spook juvenile white sturgeon when attempts were made to get size estimates of fish observed.

An LBV survey was conducted in Fort Shepherd Eddy on 28 November 2005. This represented the first time observations were made in the approximately 50 m deep central portion of this eddy. In total, 19 juvenile and one adult white sturgeon were observed during this survey. The dominant substrates of the deep portion of Fort Shepherd Eddy were boulders and cobbles, but areas of gravels and fines were also observed. Large woody debris was also observed in several areas.

An LBV survey was conducted in Waneta Eddy on 24 March 2006, to determine if the large aggregations of juveniles previously observed in the eddy were present and to identify the best location for deployment of the underwater PIT tag reader system. In total, approximately 500 juvenile white sturgeon (812 fish/hour) were observed, including one large aggregation estimated to consist of over 350 fish (Appendix B, Table B5). The location of this group was marked using an anchor, rope and float, which was used to determine the location to deploy the underwater PIT tag reader system on 26 March 2006. The majority of these fish were observed tightly grouped and interspersed with adults in one large aggregation, similar to that observed on 19 January and 29 March 2004 (Phase 2; Golder 2005a), and on 24 February 2005 (Phase 3; Golder 2005b). These fish were on the river bottom, aligned facing into the current, exhibited relatively little movement, and were in very close proximity to each other (touching in many instances) within a relatively small area. The majority of juveniles observed over substrates comprised mainly of fines and black slag (from the Teck Cominco smelter in Trail) were situated in the lee of the “valleys” between the low-relief dunes (still facing into the current).

The LBV was deployed on 26 March 2006 at Waneta Eddy to check whether the large aggregation of juveniles observed on 24 March was still present at the same location and to observe the underwater PIT tag system after it was deployed to determine if there were any problems with the deployment. Although a small number of juveniles were observed (12 fish), the large aggregation was no longer at the marked location. This was similar to observations made during 2003 to 2004 monitoring (Golder 2005a), when a large aggregation marked on one day moved to a new location on the next day. The deployment of the underwater PIT tag reader system was successful and problems with the deployment configuration were not observed during the LBV survey.

3.2.3 Sonic Telemetry

The majority of sonic tags implanted in the 52 juvenile white sturgeon released in May 2004 and the 38 released in May 2005 were detected by the VR2 stations deployed in the Keenleyside and Roosevelt reaches. The VR2 stations were in constant operation prior to, during, and after the present study. Information on the movement of juvenile implanted with sonic tags is provided in Section 3.3.3.

3.2.4 Angling

In total, 34 hook-hours of angling effort were expended on 2 November 2005 at Waneta Eddy as part of the present study; 22 juvenile white sturgeon were captured (catch-rate of 0.6 fish/hook-hour; Appendix B, Table B6). Angling was also conducted during the 2005 Broodstock Collection Program (June 2005) where 125 hook-hours of angling effort captured 25 juvenile white sturgeon (0.2 fish/hook-hour; Golder, unpublished data). Of these 25 fish, 3 were captured at Fort Shepherd Eddy (48 hook-hours; 0.1 fish/hook-hour) and 22 were captured at Waneta Eddy (71 hook-hours; 0.3 fish/hook-hour). The total number of juvenile white sturgeon captured by angling during 2005 was 47 and the overall catch-rate was 0.3 fish/hook-hour. Angling appeared to be more effective at capturing larger, older fish than smaller, younger fish (Table 3.3).

Table 3.3 Summary of age and size of juvenile white sturgeon captured by angling during the present study and the 2005 Broodstock Collection Program.

Age	*n*	Fork Length (cm)			Weight (g)		
		Mean	Minimum	Maximum	Mean	Minimum	Maximum
1+	2	33.0	32.3	33.6	218.5	208	229
2+	2	43.6	41.8	45.3	501.0	491	511
3+	13	49.9	43.0	62.5	883.8	630	1613
4+	30	56.4	47.0	70.5	1379.3	610	2860

3.2.5 Set Lines

Set line sampling was not conducted as a component of the present study. This was the main sample method used during the 2005 Broodstock Collection Program, when 14 650 hook-hours of sample effort were expended (Golder, unpublished data). In total, two hatchery juvenile white sturgeon were captured using this method, resulting in an overall catch-rate of 0.03 fish/100 hook-hours (Appendix B, Table B7). These fish were both from the 2001 brood year (i.e., age-4+); one was released on 14 May 2002 in the Kootenay River (52.0 cm FL and 1134 g at capture) and one was released on 17 May 2002 between Beaver Creek and Waneta Eddy (61.0 cm FL and 1814 g at capture).

3.2.6 Underwater PIT Tag Reader System

The underwater PIT tag reader was successfully downloaded on 27 March 2006, the day after it was deployed. A total of 12 detections had been recorded: 10 individual tags of which two were detected twice. The system was downloaded again on 30 March 2006: a total of 23 detections were recorded (19 individual tags of which four were detected twice). Over the first 4 days after deployment of the system, a total of 29 individual PIT tags were detected and six tags were detected twice. The time between the first and second detections for these six tags were approximately 2 minutes, 14 minutes, 2.5 hours, 3 hours, 21 hours, and 22.5 hours.

The system was downloaded again on 5 April 2006. The laptop could not communicate with the reader. The batteries were swapped out, after which communication was successful. However, the system had reverted to default settings, the date and time reverted to 1 June 1996, and there were no tag detections in the memory. Discussions with Biomark indicated the problem was most likely related to the failure of the lithium battery inside the reader. The two 100 amp-hour 12 V batteries were replaced with three 80 amp-hour 12 V batteries. Based on the draw of the system (1.2 amps/hour), these batteries were calculated to provide over 8 days of life. Replacing the lithium battery would have required pulling up the system, opening the underwater housing and the reader, closing them back up, performing a vacuum test of the underwater housing, and redeploying the system. The decision was made to leave the system in place and to download it 5 days later (i.e., well before the new 12 V batteries expired).

When next checked on 10 April 2006, the system had shifted and the floats attached to the anchor lines were now beside each other. When downloaded, the reader had not detected any tags. The 12 V batteries were replaced and the reader was successfully communicated with afterwards. The date and time remained correct, however. This indicated that the problem was not the lithium battery as previously thought. The decision was then made to remove the system on 13 April 2006. During the removal of the system, it was noted that the cables and ropes were quite tangled, and that, coupled with the drifting of the system, may have resulted in stress to the antenna cable insertion despite the precautions taken to prevent this. The system will be sent to Biomark for repair and modification as required.

3.2.7 Boat Electroshocking

During the 2005 LCRFIP, approximately 240 km (about 40 km during each of six sample sessions conducted from 19 September to 1 November) of nearshore habitat were sampled by boat electroshocking within the present study area. Juvenile white sturgeon were not captured during the 2005 LCRFIP (Golder 2006).

3.3 JUVENILE WHITE STURGEON

Unless otherwise specified, data in the following sections are based on a total of 381 juvenile white sturgeon (388 including seven fish captured twice in 2005) for which life history data were obtained in 2005. In total, 379 hatchery juveniles and two wild juveniles were captured in 2005. Life history data of juvenile white sturgeon were obtained from the following sources:

- 124 from the present study (including 5 fish captured twice in 2005);
    - 102 during gill net sampling (2 were also captured by angling, 2 were also captured during the 2005 Broodstock Collection Program, and 1 was captured twice during gill net sampling);
    - 22 during angling;

- 212 from Roosevelt Reach juvenile white sturgeon sampling conducted by WDFW (gill netting; WDFW unpublished data); one was captured twice by the WDFW and one was also captured during sampling conducted by the Colville Confederated Tribes for the Environmental Protection Agency (EPA);
- 27 from the 2005 Broodstock Collection Program;
  - 25 by angling;
  - 2 by set line;
- 12 from Spokane Tribe of Indians Fish Assemblage Sampling for the EPA (gill netting; WDFW unpublished data);
- 11 from sampling conducted by the Colville Confederated Tribes for the EPA (gill netting; WDFW unpublished data); and,
- 2 from a WDFW Limnetic Survey (gill netting; WDFW unpublished data).

3.3.1 Distribution

A summary of the distribution (capture locations) of the 388 juvenile white sturgeon included in this analysis (data obtained as described above) is provided in Table 3.4. The majority (*n* = 336; 86.6%) of these fish were captured during the present study (*n* = 124; 32.0%) and during juvenile white sturgeon sampling conducted by the WDFW (*n* = 212; 54.6%). The main areas where juvenile white sturgeon were captured were Waneta Eddy (*n* = 136; 35.1%), Little Dalles (*n* = 55; 14.2%) and downstream of Little Dalles to China Bend (*n* = 55; 14.2%). Approximately 80% (*n* = 190) of the 237 juveniles captured in the Roosevelt Reach in 2005 were captured in a 41 km section between Little Dalles (RKm 82) and the downstream end of Marcus Flats (Kettle Falls Bridge; RKm 123); an area where 45% of the sample effort was expended (209 of 462 net-units).

In total, approximately 900 juvenile white sturgeon were observed using the LBV. With the exception of 19 observed at Fort Shepherd Eddy, all of these fish were observed at Waneta Eddy.

Since 2002, a total of 755 juvenile white sturgeon have been captured in the Transboundary Recovery Area (24 of these fish have been captured twice). A summary of where these fish were captured is provided in Appendix B, Table B8. The majority of these fish were captured during 2002 to 2005 monitoring (*n* = 366; 48.5%) and during juvenile white sturgeon sampling conducted by the WDFW (*n* = 336; 44.5%). Despite the low catch during the present study (*n* = 6; 1.5%), HLK Eddy was one of the main areas where juvenile white sturgeon were captured from 2002 to 2005 (*n* = 91; 11.7%), along with Waneta Eddy (*n* = 278; 35.7%), Little Dalles (*n* = 82; 10.5%) and downstream of Little Dalles to China Bend (*n* = 79; 10.1%). Similar to 2005 results, approximately 80% (*n* = 286) of the 361 juveniles captured in the Roosevelt Reach from 2002 to 2005 were captured in a 41 km section between Little Dalles (RKm 82) and the downstream end of Marcus Flats (Kettle Falls Bridge; RKm 123).

Table 3.4 Summary of capture methods and locations of juvenile white sturgeon for which data was obtained from June to November 2005 (the number of recaptured fish are in brackets).

Location[a]	River Km[b]	Capture Method						All Methods	
		Gill Net		Angling		Set Line			
		No.	%	No.	%	No.	%	No.	%
HLK Eddy	0.1	6	1.8					**6**	**1.5**
Balfour Bay	2.5	2	0.6					**2**	**0.5**
Kootenay Eddy	0.1K	2	0.6					**2**	**0.5**
Sandbar Eddy	21.0	1	0.3					**1**	**0.3**
Genelle Eddy	25.4	1	0.3					**1**	**0.3**
Fort Shepherd Eddy	52.0			3	6.4			**3**	**0.8**
Waneta Eddy	55.4	80 (10)	26.5	40 (4)	93.6	2	100.0	**122 (14)**	**35.1**
Keenleyside Reach Subtotal	**0.1-55.4**	**92 (10)**	**30.1**	**43 (4)**	**100.0**	**2**	**100.0**	**137 (14)**	**38.9**
Deadman's Eddy to Northport	67.5-71.7	11	3.2					**11**	**2.8**
Five-mile Creek area	75.1-75.2	18	5.3					**18**	**4.6**
Northport Hole to Onion Creek	76.7-79.4	10	2.9					**10**	**2.6**
Little Dalles	82.6-83.1	54 (1)	16.2					**54 (1)**	**14.2**
Marble to China Bend	84.1-93.7	53 (2)	16.2					**53 (2)**	**14.2**
North Gorge area	95.0-99.0	21 (1)	6.5					**21 (1)**	**5.7**
Bossburg to Marcus Island	100.5-112.9	25 (1)	7.7					**25 (1)**	**6.7**
Marcus Flats	115.3-121.2	32	9.4					**32**	**8.2**
Kettle Falls to Martin Creek	123.5-135.6	8	2.4					**8**	**2.1**
Roosevelt Reach Subtotal	**67.5-135.6**	**232 (5)**	**69.9**	**0**	**0.0**	**0**	**0.0**	**232 (5)**	**61.1**
Total	**0.1-135.6**	**324 (15)**	**100.0**	**43 (4)**	**100.0**	**2**	**100.0**	**369 (19)**	**100.0**

[a] See Figures 1.1 and 1.2 for sample locations.
[b] River kilometres measured downstream from HLK. A "K" designation indicates distance in the Kootenay River upstream from the mouth.

3.3.2 Characteristics of Selected Habitats

During the present study, gill nets were set in different depth strata to assess juvenile white sturgeon use of different depths (Table 3.5). Gill net depths were derived by calculating the mean of the minimum and maximum depth of each net set. The minimum depth at which juvenile white sturgeon were captured was 6.5 m (Appendix C, Table C1). A summary of juvenile white sturgeon captured and the catch-rate of these fish in the depth strata sampled by the WDFW is provided in Table 3.6. The minimum capture depth recorded during 2005 sampling by the WDFW was 5.8 m.

Specific depth data for juvenile white sturgeon captured during the 2005 Broodstock Collection Program was unavailable. The 22 juveniles captured by angling at Waneta Eddy on 2 November 2005 were caught between 15 and 20 m depth. The 12 juvenile captured during sampling in the Roosevelt Reach by the Spokane Tribe of Indians were at 10 m depth; of the juveniles captured by the Colville Confederated Tribes for which depth data was available, 7 were captured at 18 m depth and 1 at 20 m depth; the 2 juveniles captured during the WDFW limnetic survey were captured at 40 m depth (WDFW unpublished data).

Table 3.5 Summary of juvenile white sturgeon captured and catch-rate by gill net in different depth strata during 2002 to 2005 monitoring.

Depth (m)	Number of Nets				Effort (net-units)[a]				Number Captured				CPUE (No./net-unit)[b]			
	2002	2003	2004	2005	2002	2003	2004	2005	2002	2003	2004	2005	2002	2003	2004	2005
< 10	23	35	19	7	3.01	5.93	6.85	2.75	0	0	35	2	0.0	0.0	5.1	0.7
10 - 14.9	18	24	18	11	1.57	3.48	4.87	2.59	3	28	27	23	1.9	8.0	5.5	8.9
15 - 19.9	23	14	16	13	4.84	0.71	4.39	3.18	32	49	60	52	6.6	69.4	13.7	16.4
⩾ 20	2	2	1	5	0.13	0.04	0.63	1.50	1	0	3	25	7.7	0.0	4.8	16.7
Total	**66**	**75**	**54**	**36**	**9.55**	**10.16**	**16.74**	**10.02**	**36**	**77**	**125**	**102**	**3.8**	**7.6**	**7.5**	**10.2**
< 15	**41**	**59**	**37**	**18**	**4.58**	**9.41**	**11.72**	**5.34**	**3**	**28**	**62**	**25**	**0.7**	**3.0**	**5.3**	**4.7**
⩾ 15	**25**	**16**	**17**	**18**	**4.97**	**0.75**	**5.02**	**4.68**	**33**	**49**	**63**	**77**	**6.6**	**65.3**	**12.5**	**16.5**

[a] One net-unit = 100 m^2 of net sampled for 24 hours.
[b] CPUE = catch-per-unit-effort.

Table 3.6 Summary of juvenile white sturgeon captured and catch-rate by gill net in different depth strata sampled by the WDFW, October 2004 and 2005 (data provided by WDFW).

Depth (m)	Number of Nets		Effort (net-units)[a]		Number Captured		CPUE (No./net-unit)[b]	
	2004	2005	2004	2005	2004	2005	2004	2005
5 - 9.9	7	5	21.45	16.04	5	2	0.2	0.1
10 - 14.9	18	11	55.99	35.82	6	16	0.1	0.4
15 - 19.9	34	29	110.55	88.93	26	61	0.2	0.7
20 - 24.9	22	28	72.41	91.44	33	43	0.5	0.5
25 - 29.9	26	30	83.87	95.75	34	74	0.4	0.8
30 - 34.9	3	8	9.68	25.89	0	10	0.0	0.4
35 - 39.9	6	11	19.14	32.97	1	1	0.1	< 0.1
40 - 44.9	2	7	6.59	21.49	0	5	0.0	0.2
45 - 49.9		8		25.18		0		0.0
50 - 54.9		7		22.02		0		0.0
55 - 59.9								
60 - 64.9		1		3.16		0		0.0
Total	**118**	**145**	**379.66**	**458.69**	**105**	**212**	**0.3**	**0.5**
< 15	**25**	**16**	**77.44**	**51.85**	**11**	**18**	**0.1**	**0.3**
⩾ 15	**93**	**129**	**302.23**	**406.83**	**94**	**194**	**0.3**	**0.5**

[a] One net-unit = 100 m^2 of net sampled for 24 hours.
[b] CPUE = catch-per-unit-effort.

For analysis purposes, the number of juvenile white sturgeon observed using the LBV was set at 883 fish (Appendix B, Table B4). All of the 356 juveniles observed at Waneta Eddy on 16 November 2005 were between 15 and 21 m in depth. Of the 496 juvenile observed at Waneta Eddy on 24 March 2006, 483 were between 19 and 21 m depth and 13 were between 15 and 19 m depth. The 12 juveniles observed at Waneta Eddy on 26 March 2006 were also all between 15 and 20 m depth. Of the 19 Juveniles observed at Fort Shepherd Eddy on 28 November 2005, four were between 37 and 44 m depth and 15 were between 45 and 50 m depth.

Almost all (878 of 883; 99.4%) of the juveniles observed using the LBV during the present study were associated with substrate composed at least partially of fines, 715 (81.0%) were associated with gravels, 191 (21.6%) were associated with cobbles, and 10 (1.1%) were associated with boulders (Table 3.7). Substrate and habitat conditions in Waneta Eddy and Fort Shepherd Eddy are discussed in Section 4.1.1. Prior to the LBV survey conducted at Fort Shepherd Eddy on 28 November 2005, substrate conditions there were unknown.

Table 3.7 Summary of substrates over which juvenile white sturgeon were observed during LBV surveys at Waneta and Fort Shepherd eddies, November 2005 and March 2006.

Substrate[a]	Juvenile White Sturgeon Observed	
	n	%
Waneta Eddy		
Fines	155	17.9
Fines and Gravel	523	60.5
Fines, Gravel & Cobble	127	14.7
Cobble, Gravel & Fines	55	6.4
Gravel & Fines	2	0.2
Gravel & Cobble	2	0.2
Waneta Eddy Total	**864**	**100**
Fort Shepherd Eddy		
Fines	4	21.1
Fines, Cobble & Gravel	3	15.8
Cobble, Fines & Gravel	1	5.3
Boulder & Fines	8	42.1
Cobble, Gravel & Boulder	2	10.5
Cobble	1	5.3
Fort Shepherd Eddy Total	**19**	**100**

[a] Substrates are listed from most to least dominant. Fines include black slag from the Teck Cominco smelter in Trail, B.C.

3.3.3 Movement

3.3.3.1 Keenleyside Reach

In May 2004, the 52 hatchery juvenile white sturgeon held over from the 2002 brood year for high output sonic tag implantation were released in the Keenleyside Reach. Half of these fish were released at Beaver Creek on 12 May (Appendix A, Table A5) and half at HLK Eddy on 13 May (Appendix A, Table A6). A summary of when these fish were last detected is provided in Table 3.8.

In May 2005, 30 hatchery juvenile white sturgeon implanted with sonic tags (2004 brood year) were released in the Keenleyside Reach. These fish were released on 4 May, split evenly between HLK Eddy and Beaver Creek; half were implanted with high output V8 pingers and half with low output V8 pingers (Appendix A, Table A3). A summary of when these fish were last detected is provided in Table 3.9.

In the Keenleyside Reach, little difference was observed between the detection effectiveness of the low and high output V8 pingers that were implanted in juveniles released in May 2005. This may reflect the narrower channel width of the Columbia River in the Keenleyside Reach as compared to the Roosevelt Reach, as well as the tendency of the juveniles to concentrate in the discrete larger eddy and lower velocity habitats within the Keenleyside Reach (i.e., HLK Eddy to Sturgeon Island, Fort Shepherd Eddy, and Waneta Eddy).

Table 3.8 Summary of last detections of high output sonic tags implanted in hatchery reared juvenile white sturgeon released in the Keenleyside Reach in May 2004.

Last Detected	Released at HLK		Released at Beaver Creek		Total *n*
	n	Tag IDs	*n*	Tag IDs	
never reliably detected	1	1864	5	1856, 1865, 1883, 1894, 1900	6
May 2004	3	1858, 1892, 1901	4	1853, 1879, 1885, 1888	7
June 2004	6	1870, 1876, 1882, 1889, 1891, 1897	5	1855, 1859, 1893, 1904, 1905	11
July 2004	1	1867	1	1873	2
Aug. 2004	1	1902	2	1857, 1863	3
Sep. 2004	1	1903	1	1886	2
Nov. 2004	2	1862, 1868			2
Mar. 2005	1	1896			1
Apr. 2005			1	1880	1
May 2005	1	1881	1	1875	2
June 2005	2	1854, 1899			2
Aug. 2005	1	1895			1
Sep. 2005			3	1869, 1871, 1872	3
Mar. 2006 (present)	6	1860, 1866, 1874, 1887, 1890, 1898	3	1861, 1877, 1884	9

Table 3.9 Summary of last detections of high and low output sonic tags implanted in hatchery reared juvenile white sturgeon released in the Keenleyside Reach in May 2005.

Last Detected	Released at HLK			Released at Beaver Creek			Total *n*
	n	Tag IDs		*n*	Tag IDs		
		Low Output	High Output		Low Output	High Output	
never reliably detected				5	1805	1821, 1827, 1831, 1833	5
May 2005	1	1812		1	1810		2
June 2005	2	1802	1824	2	1803	1819	4
July 2005	2		1820, 1822	1	1801		3
Aug. 2005	1	1807		1	1809		2
Oct. 2005	1		1826	1	1813		2
Dec. 2005	3	1804, 1806	1836				3
Mar. 2006 (present)	5	1800, 1808, 1814	1830, 1834	4	1811	1829, 1835, 1837	9

3.3.3.2 Keenleyside Reach Dispersal

The movement patterns of individual juvenile white sturgeon implanted with sonic tags and released in May 2004 are presented in Appendix D, Figure D1; the detection histories of fish not included in Figure D1 (due to lack of detections, unreliable detections, or detections only on the day of release that indicated no movement) are described in Appendix D, Table D1. The dispersal of juveniles released at Beaver Creek on 12 May 2004 that were detected in areas other than Fort Shepherd Eddy and/or Waneta Eddy is depicted in Appendix D, Figure D2.

The movement patterns of the 26 juveniles released at HLK Eddy on 13 May 2004 are summarized as follows:

- 1 fish was not reliably detected after release (#1864);
- 24 fish were only detected between HLK Eddy and Sturgeon Island;
    - 7 were only detected between HLK Eddy and Sturgeon Island;
        - 2 of these fish were last detected in June 2004 (#1876 and 1889);
        - 1 was last detected in May 2005 (#1881);
        - 1 was last detected in August 2005 (#1895);

        - 3 were last detected in March 2006 (the last download; #1866, 1874, and 1898);

    - 6 were only detected at HLK Eddy;
        - 2 only on the day of release (#1892 and 1901);
        - 1 was last detected in June 2004 (#1870);
        - 1 was last detected in July 2004 (#1867);
        - 2 were last detected in March 2006 (#1887 and 1890);

    - 11 were only detected at HLK Eddy and Balfour Bay;
        - 3 were last detected in June 2004 (#1882, 1891, and 1897);
        - 1 was last detected in August 2004 (#1902);
        - 1 was last detected in September 2004 (#1903);
        - 2 were last detected in November 2004 (#1862 and 1868);
        - 1 was last detected in March 2005 (#1896);
        - 2 were last detected in June 2005 (#1854 and 1899);
        - 1 was last detected in March 2006 (#1860); and,

- 1 fish (#1858) moved downstream and was last detected at Rivervale on 25 May 2004.

The movement patterns of the 26 juveniles released at Beaver Creek on 12 May 2004 are summarized as follows:

- 5 fish were not reliably detected after release (#1856, 1865, 1883, 1894, and 1900);

- 14 fish were detected only in the lower section of the Keenleyside Reach (Fort Shepherd and Waneta eddies);

    - 9 were detected only at Fort Shepherd Eddy;
        - 4 were last detected in June 2004 (#1855, 1859, 1893, and 1905);
        - 1 was last detected in July 2004 (#1873);
        - 2 were last detected in August 2004 (#1857 and 1863);
        - 1 was last detected in April 2005 (#1880);
        - 1 was last detected in March 2006 (#1884);

    - 5 moved to Waneta Eddy and were subsequently only detected there;
        - 1 was detected only on the day of release (#1853);
        - 2 were last detected in May 2004 (#1879 and 1888);
        - 1 was last detected in June 2004 (#1904);
        - 1 was last detected in May 2005 (#1875);

- 5 fish moved downstream into the Roosevelt Reach;

    - 2 remained at Little Dalles;
        - 1 was last detected in September 2005 (#1869);
        - 1 was last detected in March 2006 (#1861);

    - 1 was last detected at North Gorge in September 2004 (#1886);

    - 1 was last detected at Kettle Falls Bridge in May 2004 (#1885);

    - 1 moved back into the Keenleyside Reach to the Kootenay River and was last detected in September 2005; (#1871);

- 2 fish moved into the upper section of the Keenleyside Reach;
    - 1 was last detected in September 2005 (#1872); and,
    - 1 was last detected in March 2006 (#1877).

The movements of individual juvenile white sturgeon implanted with sonic tags and released in May 2005 are presented in Appendix D, Figure D3; the detection histories of fish not included in Figure D3 (due to lack of detections, unreliable detections, or detections only on the day of release that indicated no movement) are described in Appendix D, Table D2. The dispersal patterns of juveniles released at Beaver Creek on 4 May 2005 that did not remain at Fort Shepherd Eddy and/or Waneta Eddy are depicted in Appendix D, Figure D4. Of the 15 juveniles released at HLK Eddy, 13 were detected only at this location and Balfour Bay, and 2 were detected only between HLK Eddy and Sturgeon Island. Of the 15 juveniles released at Beaver Creek, 6 were detected only at Fort Shepherd and Waneta eddies (1 at Fort Shepherd Eddy only), 4 moved downstream into the Roosevelt Reach, and 5 were not reliably detected after release.

3.3.3.3 Overwintering Areas of Sonic Tagged Juveniles Released in the Keenleyside Reach

All of the juvenile white sturgeon released at HLK Eddy in May 2004 for which overwintering locations could be determined were located between HLK Eddy and Sturgeon Island (Table 3.10). Of the 26 juveniles released at Beaver Creek in May 2004, one overwintered at Balfour Bay, two at Fort Shepherd Eddy, one at Waneta Eddy, and two at Little Dalles (one of which overwintered there during both winters at-large). The remaining juveniles were detected sporadically during the winter periods, therefore an overwintering location could not be assigned with confidence.

Table 3.10 Summary of overwintering locations of juvenile white sturgeon implanted with sonic tags and released in the Keenleyside Reach, May 2004.

Release Location	**Overwintering Location**	**Sonic Tag IDs Detected During the Winter Period**	
		2004 - 2005	**2005 - 2006**
HLK Eddy	HLK Eddy	1860	1860, 1887, 1890
	HLK Eddy to Balfour Bay		1898
	Balfour Bay	1854	1874
	HLK Eddy to Sturgeon Island	1895	
	Sturgeon Island		1866
Beaver Creek	Balfour Bay		1877
	Fort Shepherd Eddy	1872, 1880	
	Waneta Eddy	1875	
	Little Dalles	1861, 1869	1861

Similar to fish released in May 2004, all of the juveniles released at HLK Eddy in May 2005 for which overwintering locations could be determined were located between HLK Eddy and Sturgeon Island (Table 3.11). Of the 15 juveniles released at Beaver Creek in May 2005, two overwintered at Fort Shepherd Eddy and two at Little Dalles.

Table 3.11 Summary of overwintering locations during the winter of 2005/2006 of juvenile white sturgeon implanted with sonic tags and released in May 2005.

Release Location	**Overwintering Location**	**Sonic Tag IDs Detected**
HLK Eddy	HLK Eddy	1800, 1804, 1808, 1814, 1830, 1836
	HLK Eddy to Balfour Bay	1834
	HLK Eddy to Sturgeon Island	1806
Beaver Creek	Fort Shepherd Eddy	1811, 1835
	Little Dalles	1829, 1837
Nancy Creek/Marcus Flats (Roosevelt Reach)	Fort Shepherd Eddy	1823

3.3.3.4 Roosevelt Reach

On 11 May 2005, eight hatchery juvenile white sturgeon (2004 brood year) implanted with sonic tags were released in the Roosevelt Reach. Half of these fish were implanted with high output V8 pingers and half with low output V8 pingers (Appendix A, Table A3). A summary of when these fish were last detected is provided in Table 3.12.

Table 3.12 Summary of last detections of high and low output sonic tags implanted in hatchery reared juvenile white sturgeon released in the Roosevelt Reach in May 2005.

Last Detected	Low Output Tag IDs	High Output Tag IDs
May 2005	1815	
July 2005	1818	
August 2005		1825, 1828
November 2005	1816	1832
March 2006 (present)	1817	1823

In the Roosevelt Reach, high output V8 pingers appeared to be more effective (i.e., had a higher detection rate) than the low output pingers that were implanted in juveniles released in May 2005. This was likely due to the greater width of the Columbia River in this reach compared to the Keenleyside Reach, as well as the tendency of the juveniles to be less concentrated in specific habitats.

3.3.3.5 Roosevelt Reach Dispersal

The movement patterns of individual juvenile white sturgeon implanted with sonic tags and released in the Roosevelt Reach in May 2005 are shown in Appendix D, Figure D3 and Appendix D, Figure D5. Of the eight juveniles released in the Nancy Creek/Marcus Flats area, seven remained in the Roosevelt Reach and one moved upstream into the Keenleyside Reach to Fort Shepherd Eddy where it has since remained.

3.3.3.6 Overwintering Areas of Sonic Tagged Juveniles Released in the Roosevelt Reach

The one juvenile released in the Roosevelt Reach for which an overwintering location could be determined is included in Table 3.11. In addition to this fish, one juvenile (#1816) was detected at Little Dalles until 26 November 2005 and another juvenile (#1832) was detected at Hunters until 14 November 2005. These were the last dates these fish were detected; therefore it was unknown whether they overwintered in nearby areas or moved to areas without VR2 coverage.

3.3.4 Life History Information

Summaries of release dates and locations of juvenile white sturgeon (by family) from 2002 to 2005 are provided in Appendix A, Tables A2 to A8; Table A1 provides a summary of all hatchery juveniles released to date. Life history data obtained during the present study and those studies mentioned in Section 3.3 are provided in Appendix C, Table C1. Summaries of fork length, total length, and weight for hatchery juveniles captured from 2002 to 2005 are provided in Appendix C, Table C2.

3.3.4.1 Length and Weight

The following provides a summary of the mean fork length (FL) and weight of age-1 to age-4 juveniles (with ranges) captured to date (additional information is provided in Appendix C, Table C2; length-frequency distributions are provided in Figure 3.3):

- Age-1: 34.5 cm FL (21.8 to 48.0 cm), 289 g (64 to 710 g);
- Age-2: 46.7 cm FL (34.2 to 61.1 cm), 679 g (232 to 1592 g);
- Age-3: 52.9 cm FL (42.2 to 68.4 cm), 1010 g (414 to 2320 g); and,
- Age-4: 59.6 cm FL (45.9 to 78.8 cm), 1659 g (610 to 4750 g).

Wild juveniles were not captured during the present study; however, three were captured by WDFW in October 2005. These wild juveniles, along with those captured from 2002 to 2004, are included in Table 3.13. Information for the wild juveniles (and hatchery juveniles) captured in 2005 is provided in Appendix C, Table C1. Additional information for wild juveniles captured from 2002 to 2004 is available in the 2002 to 2004 reports (Golder 2003b, 2005a, and 2005b).

Table 3.13 Life history summary of wild juvenile white sturgeon captured from 2002 to 2005.

Sample Number[a]	Capture Location[b]	RKm[b]	Capture Method[c]	Capture Date	Fork Length (cm)	Weight (g)	PIT Tag Number Applied	Age (Year Class)
2	HLK Eddy	0.4	gill net	29 Oct. 2002	69.0	2700	41104C6808	-[d]
43	Upstream Ft. Shep. Eddy	50.0	ES	23 Sep. 2003	63.2	1780	406E0C6478	4 (1999)[e]
154	Fort Shepherd Eddy	52.0	angling	10 May 2004	86.5	3629	7F7E6A4152	-
156	Waneta Eddy	55.0	angling	23 Jun. 2004	95.0	5443	127452485A	7 (1997)[e]
218	Waneta Eddy	54.9	gill net	16 Sep. 2004	55.7	990	none (mortality)	3 (2001)[e]
293	Marcus - old river channel	117.4	gill net	8 Oct. 2004	45.7	732	985120022625430	3 (2001)[e]
362	China Bend	92.5	gill net	26 Oct. 2004	37.5	328	985120022624437	3 (2001)[e]
522	Marcus Flats	116.9	gill net	7 Oct. 2005	72.9	2650	985120027487439	-
525	Marcus Flats	116.9	gill net	7 Oct. 2005	93.0	7000	none (mortality)	-
597	China Bend	90.7	gill net	21 Oct. 2005	47.5	786	985120028039238	-

[a] Identifier used in Appendix C, Table C1 and previous reports.
[b] See Figures 1.1 and 1.2 for locations; river kilometres measured downstream from HLK.
[c] ES = boat electroshocking.
[d] Data not available.
[e] Fin ray sections were difficult to age due to indistinct annuli (fish had not laid down strong annuli patterns) and/or fin abnormalities. As such, the ages assigned were considered the most likely age. Sample number 156 was at least 7 years old, but possibly older (most likely 7 to 9). The middle of the fin ray was deformed, making it difficult to determine if annuli were present in this portion of the fin ray section.

Figure 3.3 Length-frequency distributions of age-1, 2, 3 and 4 hatchery juvenile white sturgeon released and captured from 2002 to 2005.

Figure 3.3 Concluded.

3.3.4.2 Growth

For comparison purposes, the daily growth rates (fork length and weight) of hatchery juveniles (for which the required data was available) captured from 2002 to 2005 were calculated. Comparisons of the mean daily growth rate of age-1 to age-4 hatchery juveniles captured from 2002 to 2005 are provided in Appendix C, Table C3. The apparent trend of slower growth of age-1 fish with each successive release noted during 2002 to 2004 monitoring was not apparent in the 2005 results [mean growth of age-1 fish captured during 2002 ($n = 36$) was 0.11 cm/day FL and 2.01 g/day; of fish captured in 2003 ($n = 37$) was 0.10 cm/day and 1.80 g/day; in 2004 ($n = 77$) was 0.06 cm/day and 0.85 g/day; and in 2005 ($n = 73$) was 0.07 cm/day and 1.10 g/day]. The mean growth rate of age-2 fish was similar in 2003, 2004, and 2005. The mean growth rate of age-3 fish captured in 2005 ($n = 80$; 0.04 cm/day and 0.90 g/day) was similar for fork length, but lower for weight than that exhibited by age-3 fish captured in 2004 ($n = 78$; 0.04 cm/day and 1.31 g/day). The mean growth of age-4 fish captured in 2005 ($n = 116$) was 0.03 cm/day and 1.28 g/day. The fork length (Figure 3.4) and weight (Figure 3.5) at release and capture of hatchery juvenile white sturgeon captured in the Transboundary Recovery Area from 2002 to 2005 are provided below.

Figure 3.4 Fork length of hatchery juvenile white sturgeon at release and capture, 2002 to 2005.

Figure 3.5 Weight of hatchery juvenile white sturgeon at release and capture, 2002 to 2005.

Comparisons of the mean daily growth rate and 95% CI of the mean of age-1 to 4 hatchery juveniles captured from 2002 to 2005 in the upper, middle, or lower sections of the Keenleyside Reach and in the Roosevelt Reach are provided in Appendix C, Table C4. The trends identified are based on the presented CI's on this table. The highest mean growth rates were exhibited by fish captured in the upper section of the Keenleyside Reach for all of the ages examined, although only one age-4 fish was captured in the upper section. The low numbers of juveniles captured in the middle section during each year precluded comparisons. The mean growth rate exhibited by age-1 fish captured in the lower section of the Keenleyside Reach (n = 45; 0.09 cm/day and 1.45 g/day) was higher than that same aged fish captured in the Roosevelt Reach (n = 142; 0.06 cm/day and 0.97 g/day). The mean growth rate exhibited by age-2 fish captured in the lower section (n = 79; 0.05 cm/day and 1.02 g/day) and the Roosevelt Reach (n = 83; 0.05 cm/day and 1.15 g/day) were similar. The mean growth rate of age-3 and 4 fish captured in the lower section of the Keenleyside Reach (age-3; n = 82: 0.04 cm/day and 0.85 g/day; age-4; n = 58: 0.03 cm/day and 0.95 g/day) was lower than those captured in the Roosevelt Reach (age-3; n = 43: 0.04 cm/day and 1.31 g/day; age-4; n = 57: 0.04 cm/day and 1.60 g/day).

Comparisons of the mean daily growth rate and 95% CI of the means of age-1 to 4 hatchery juveniles captured from 2002 to 2005 with and without pectoral fin deformities (see Section 3.3.4.4) are provided in Appendix C, Table C5. The following trends identified are based on the differences between the 95% CI's identified in Table C5. The mean growth rates of the groups of fish examined (fish with deformed pectoral fins vs. fish without of each age-class) were generally similar. The greatest differences in mean growth rates between fish with and without pectoral fin deformities were exhibited by age-1 fish. Age-1 fish with deformities exhibited a higher mean growth rate (n = 58; 0.09 cm/day and 1.53 g/day) than age-1 fish without deformities (n = 155; 0.07 cm/day and 1.16 g/day). The highest mean growth rate was exhibited by age-1 fish with pectoral fin deformities that were considered major (see Section 3.3.4.4 for definitions; n = 34; 0.10 cm/day and 1.57 g/day). The mean growth rates of age-2, 3, and 4 juveniles with and without pectoral fin deformities were similar.

In total, 19 hatchery juvenile white sturgeon were recaptured (i.e., have been captured twice from 2002 to 2005) during 2005 monitoring. Of these fish, three were previously captured in 2003, nine were previously captured in 2004, and seven were captured twice in 2005. Excluding the seven fish captured twice in 2005, 17 juvenile white sturgeon have been captured twice from 2002 to 2005. The growth rates of these fish between initial release and their first capture event, subsequent release and second capture event, and initial release and second capture event are provided in Appendix C, Table C6. Growth rates for fork length were substantially higher between initial release and the first capture event than between subsequent release and the second capture event for all of these fish. With the exception of three of these fish, growth rates were also higher for weight between initial release and the first capture event than between subsequent release and the second capture event.

3.3.4.3 Relative Weight

The relative weight (W_r) index for juvenile white sturgeon released and captured from 2002 to 2005 is summarized in Table 3.14. The W_r index for age-1 hatchery juveniles at point of release and capture is depicted in Figure 3.6, for age-2 fish in Figure 3.7, and for age-3 and 4 fish in Figure 3.8. The weight vs. length for fish released and captured (2002 to

2005) was plotted in relation to theoretical weight vs. length curves for relative weights of 100%, 75% and 50% (Figure 3.9). This plot highlights that all juveniles captured from 2002 to 2005 were in better than average condition (i.e., all juveniles showed W_r values higher than 50%).

Table 3.14 Mean, minimum and maximum relative weight of hatchery juvenile white sturgeon (for which relative weight could be determined) released and captured from 2002 to 2005.

Brood Year	Release Year	Capture Year	Age	*n*	Relative Weight (%)					
					At Release			At Capture		
					Mean	Minimum	Maximum	Mean	Minimum	Maximum
2001	2002	2002	1	37	100.1	80.6	118.4	91.7	71.9	116.5
2002	2003	2003	1	37	103.4	79.5	131.0	82.3	69.0	109.8
2003	2004	2004	1	77	104.6	82.4	126.4	82.1	65.5	97.1
2004	2005	2005	1	70	94.8	73.1	123.8	78.9	63.1	108.9
All Age-1+ Fish				**221**	**100.5**	**73.1**	**131.0**	**82.7**	**63.1**	**116.5**
2001	2002	2003	2	58	106.1	74.7	171.2	76.2	58.8	99.2
2002	2003	2004	2	73	103.3	82.8	133.9	73.8	55.5	96.3
2003	2004	2005	2	77	101.3	71.6	173.9	82.8	59.2	139.6
All Age-2+ Fish				**208**	**103.4**	**71.6**	**173.9**	**77.8**	**55.5**	**139.6**
2001	2002	2004	3	79	105.0	70.9	155.1	78.6	58.5	123.8
2002	2003	2005	3	80	107.0	83.3	145.9	73.4	56.9	129.6
All Age-3+ Fish				**159**	**106.0**	**70.9**	**155.1**	**76.0**	**56.9**	**129.6**
2001	**2002**	**2005**	**4**	**115**	**110.2**	**78.1**	**169.6**	**82.5**	**63.1**	**121.8**

Of the fish released and captured in the same year (i.e., age-1+ fish; *n* = 221), 5.0% (*n* = 11) of their relative weights at the point of capture were over 100%, and 84.2% (*n* = 186) were over 75% (Figure 3.6). Of the age-2+ fish for which relative weight was determined (*n* = 208), six (2.9%) exhibited relative weights over 100% and 114 (54.8%) were over 75% (Figure 3.7). Of the age-3+ fish for which relative weight was determined (*n* = 159), 10 (6.3%) exhibited relative weights over 100% and 58 (36.5%) were over 75% (Figure 3.8). Of the age-4+ fish for which relative weight was determined (*n* = 115), 10 (8.7%) exhibited relative weights over 100% and 83 (72.2%) were over 75% (Figure 3.8).

Figure 3.6 Frequency distribution of relative weights of age-1 hatchery juvenile white sturgeon at release and capture, 2002 to 2005. Note: bins for relative weight represent a range of 4 (i.e., 52 = 52 to 56).

Figure 3.6 Concluded.

Figure 3.7 Frequency distribution of relative weights of age-2 hatchery juvenile white sturgeon at release and capture, 2002 to 2005. Note: bins for relative weight represent a range of 4 (i.e., 52 = 52 to 56).

Figure 3.8 Frequency distribution of relative weights of age-3 (top and middle) and age-4 (bottom) hatchery juvenile white sturgeon at release and capture, 2002 to 2005. Note: bins for relative weight represent a range of 4 (i.e., 52 = 52 to 56).

Figure 3.9 Length vs. weight (relative weight) plot for hatchery juvenile white sturgeon released and captured from 2002 to 2005. 2002 releases were captured in 2002 (age-1), 2003 (age-2), 2004 (age-3), and 2005 (age-4). 2003 releases were captured in 2003 (age-1), 2004 (age-2), and 2005 (age-3). 2004 releases were captured in 2004 (age-1) and 2005 (age-2). All 2005 releases were age-1 when captured in 2005.

3.3.4.4 Pectoral Fin Deformities

A summary of the incidence of pectoral fin deformities by family in hatchery juvenile white sturgeon captured from 2002 to 2005 is provided in Appendix C, Table C7. Of the 350 hatchery juvenile white sturgeon captured and examined for deformities in 2005 (not including recaptures), 100 (28.6%) exhibited pectoral fin deformities. The majority (88%) of these deformities were in the form of shrivelled or shrunken pectoral fins: 7 (7%) were shrivelled or shrunken as well as curled, wavy, or rolled; 4 (4%) were normal sized and wavy; and 1 (1%) was normal sized and curled. Of the 100 fish that exhibited pectoral fin deformities, 74 (74%) had one deformed fin and 26 (26%) had both fins deformed. Of the 74 fish that exhibited one deformed pectoral fin, 39 (52.7%) exhibited deformities of the left pectoral fin and 35 (47.3%) of the right pectoral fin.

Pectoral fin deformities were classified as either minor or major. Pectoral fin deformities were considered major if one or both fins were 50% of normal size or less and minor if both fins were greater than 50% of normal size. For example, a fish with one normal sized fin and one fin less than half the normal size was considered to have a major deformity; a fish with one fin 80% and the other 60% of normal size was considered to have a minor deformity. Based on these classifications, 77 (77% of fish with deformities) exhibited pectoral fin deformities that were considered major and 23 (23%) that were considered minor. Severity classifications for all juvenile white sturgeon captured from 2002 to 2005 are provided in Appendix C, Table C8.

The overall incidence of pectoral fin deformities in hatchery juvenile white sturgeon captured from 2002 to 2005 was 37.5% (272 of 726 fish; Appendix C, Table C7). The deformity rate of 2001 brood fish captured from 2002 to 2005 was 47.5%, of 2002 brood fish captured from 2003 to 2005 was 43.9%, of 2003 brood fish captured in 2004 and 2005 was 20.1%, and of 2004 brood fish captured in 2005 was 17.8%. The incidence of pectoral fin deformities in juveniles captured in 2002 was 52.8%, in 2003 was 50.5%, in 2004 was 42.9%, and in 2005 was 28.6%. Only one of the 10 wild juveniles captured from 2002 to 2005 exhibited pectoral fin deformities; both fins of this fish were slightly curled and of normal size (considered a minor deformity). Deformed (i.e., curled) pectoral fins are occasionally observed in wild white sturgeon in the study area, but at a much lower frequency than observed for the hatchery releases. The majority of pectoral fin deformities observed for hatchery juveniles consisted of stunted/shrivelled fins. Pectoral fin deformities are discussed further in Section 4.2.2.

3.3.4.5 Captures by Family

A summary of juvenile white sturgeon released and captured (by family) in the Transboundary Recovery Area from 2002 to 2005 is provided in Table 3.15. Of the 8671 juvenile white sturgeon (2001 brood year) released into the Keenleyside Reach in 2002, 304 (3.5%) have been captured to date (2002 to 2005). Of the 11 855 juvenile white sturgeon (2002 brood year) released into the Keenleyside Reach in 2003, 189 (1.6%) have been captured (2003 to 2005). Of the 11 577 juvenile white sturgeon (2003 brood year) released into the Transboundary Recovery Area in 2004, 171 (1.5%) have been captured (2004 and 2005). Of the 16 503 juvenile white sturgeon (2004 brood year) released into the Transboundary Recovery Area in 2005, 77 (0.5%) have been captured (2005). The greatest recovery rate for a specific family group from 2002 to 2005 was from family 01-wf (4.5%; 22 fish of this family were released in 2002 and 1 has been captured). Families 01-6 and 01-5 had the second highest recovery rates from 2002 to 2005 (3.8% each). The highest recovery rates for 2002 brood fish were from family 02-2 (1.8%), for 2003 brood fish were from family 03-6 (2.6%), and for 2004 brood fish were from family 04-7 (0.7%). The majority of fish from families 03-6 and 04-7 were captured in the Roosevelt Reach, where 1882 and 1956 fish from these families, respectively, were released.

Table 3.15 Summary of hatchery juvenile white sturgeon releases and captures by family, 2002 to 2005 (recaptures are not included in the percent captured column).

Brood Year	Family[a]	Number Released	Number Captured									Percent Captured
			2002	2003		2004		2005		2002-2005		
			Orig.[b]	Orig.[b]	Recap.[b]	Orig.[b]	Recap.[b]	Orig.[b]	Recap.[b]	Orig.[b]	Recap.[b]	
2001	01-1	2090	9	14		11	1	23	1	**57**	**2**	**2.7**
	01-2	990	3	6		10		7	1	**26**	**1**	**2.6**
	01-3	1966	13	18		24	1	15	1	**70**	**2**	**3.6**
	01-5	680	3	5		8		10		**26**	**0**	**3.8**
	01-6	2923	9	13	1	31		59	3	**112**	**4**	**3.8**
	01-wf	22	1	0	1	0		0		**1**	**1**	**4.5**
	unknown	N/A	1	2		4		5		**12**	**0**	**N/A**
2001 Brood Total		**8671**	**39**	**58**	**2**	**88**	**2**	**119**	**6**	**304**	**10**	**3.5**
2002	02-1	4357		10		25		35	4	**70**	**4**	**1.6**
	02-2	2495		7		17		20	1	**44**	**1**	**1.8**
	02-3	2228		6		12		11	1	**29**	**1**	**1.3**
	02-4	2775		14		18	1	8	3	**40**	**4**	**1.4**
	unknown	N/A		0		1		5	1	**6**	**1**	**N/A**
2002 Brood Total		**11 855**		**37**		**73**	**1**	**79**	**10**	**189**	**11**	**1.6**
2003	03-1	948				2		1		**3**	**0**	**0.3**
	03-2	1383				3		2		**5**	**0**	**0.4**
	03-3	377				2		3		**5**	**0**	**1.3**
	03-4	1842				9		8		**17**	**0**	**0.9**
	03-5	2311				6		2		**8**	**0**	**0.3**
	03-6	4716				56		68	2	**124**	**2**	**2.6**
	unknown	N/A				4		5		**9**	**0**	**N/A**
2003 Brood Total		**11 577**				**82**	**0**	**89**	**2**	**171**	**2**	**1.5**
2004	04-1	1750						7		**7**	**0**	**0.4**
	04-2	2440						15		**15**	**0**	**0.6**
	04-3	1805						2		**2**	**0**	**0.1**
	04-4	1815						4		**4**	**0**	**0.2**
	04-5	2730						7		**7**	**0**	**0.3**
	04-6	1799						10		**10**	**0**	**0.6**
	04-7	4164						30	1	**30**	**1**	**0.7**
	unknown	N/A						2		**2**	**0**	**N/A**
2004 Brood Total		**16 503**						**77**	**1**	**77**	**1**	**0.5**
unknown[c]	unknown	N/A	0	0		2		2		**4**	**0**	**N/A**
All Broods		**48 606**	**39**	**95**	**2**	**245**	**3**	**366**	**19**	**745**	**24**	**1.5**
Wild Fish		**N/A**	**1**	**1**		**5**		**3**		**10**	**0**	**N/A**

[a] The first two digits represent brood year (i.e., 01 - 2001); last digit represents family ID from that brood year; wf = wild fry (hatched from captured wild eggs); unknown = could not be found in release data or PIT tag was not detected at capture.
[b] Orig. = original capture; Recap. = recapture.
[c] Brood year could not be determined due to difficulty in reading scute removal patterns.

3.3.4.6 Survival Analysis

The hatchery juvenile white sturgeon population has predominantly been sampled during the fall of 2002, 2003, 2004, and 2005. PIT tag marked fish from the UCRWSI hatchery program were seeded into the Columbia River at one or more intervals during the spring and summer of these years. The relative rate of recovery of the tags among years was used to develop a Cormack-Jolly-Seber (CJS) survival model to assess the overall success of the hatchery program. The model parameters were initially estimated using the logistic link function with the lowest scored model and subsequently rerun using the Monte Carlo Markov Chain (MCMC) procedures in Program MARK. These parameter estimates from the MCMC procedures were used in subsequent analysis and are described in detail in Appendix E.

The selected model, using the lowest Akaike Information Criteria (AIC_c) scores, resulted in a mean survival estimate for the 2002 cohort of 0.42 ± 0.097 (S.D.) between the time of release and capture in the fall of 2002. The 2003, 2004 and 2005 cohorts were pooled and the mean survival estimate between the time of release and the fall capture for these combined age-1 cohorts was 0.21 ± 0.046 (S.D.) The mean survival rate for all subsequent time after the first six months in the river was estimated for all cohorts combined at 0.97 ± 0.019 (S.D.). Wild juvenile fish were rarely encountered and are not included in the analysis. The 2003 to 2005 cohorts were pooled because the winning model pooled these cohorts. Time varying models where these cohorts were not pooled were fitted, but due to the low recapture rate these models were not able to converge.

As the exact number of fish released and incorporated into the analysis is known, the CJS survival parameters and their confidence intervals were used to develop a crude estimate of abundance for the population of juvenile sturgeon now in the system (Table 3.16).

Table 3.16 Survival and abundance estimates (with Confidence Intervals; CI) based on tag recoveries using Program MARK. The abundance estimates are derived from the survival estimates and the number of tagged fish released and included in the analysis (not purposefully removed from the population).

Hatchery Juvenile White Sturgeon Survival Rate							
Study Year	**Tagged Fish Released and Included in Analysis**	**Survival Rate in First 6 Months (Fish 1 - 1.5 years of age)**	**95% CI**	**Subsequent Survival Rate (Fish > 1.5 years of age)**	**95% CI**	**Mean Estimated Abundance as of 2005**	**95% CI on Estimated Abundance**
2002	8666	0.42	0.27-0.63	0.97	0.93-0.99	3321	2135-4982
2003	11 820	0.205	0.13-0.31	0.97	0.93-0.99	2284	1445-3336
2004	11 738	0.205	0.13-0.31	0.97	0.93-0.99	2338	1435-3313
2005	16720	0.205	0.13-0.31	0.97	0.93-0.99	3434	2108-4865
Total						**11378**	**7125-16498**

The survival numbers were also used to project survival and abundance of each cohort over 21 years (2002 to 2022; Appendix F, Tables F1 and F2). The overall abundance of all combined cohorts, assuming 10 000 fish are seeded each year (beyond 2005) from the hatchery program, was projected using the survival estimates obtained from the CJS analysis.

3.3.4.7 Analysis of Factors Affecting Size-at-Capture

The size selectivity of the gill net mesh panels of a particular mesh size was quite apparent (Figure 3.10; ANOVA $p < 0.001$). Length frequencies of the groupings were reasonably approximated with normal distributions based on density plots of the data. This analysis was limited to Keenleyside Reach releases and recaptures where all mesh sizes were deployed. The size of juvenile sturgeon in the Roosevelt and Keenleyside reaches was similar, but statistically different during periods when data from fish collected in the same mesh size (5.1 cm) were compared (ANOVA $p = 0.025$); the average size was slightly smaller in the Roosevelt Reach. The effect of mesh size on fork length (FL) of captured fish was consistent over all years of data collection (Figure 3.11).

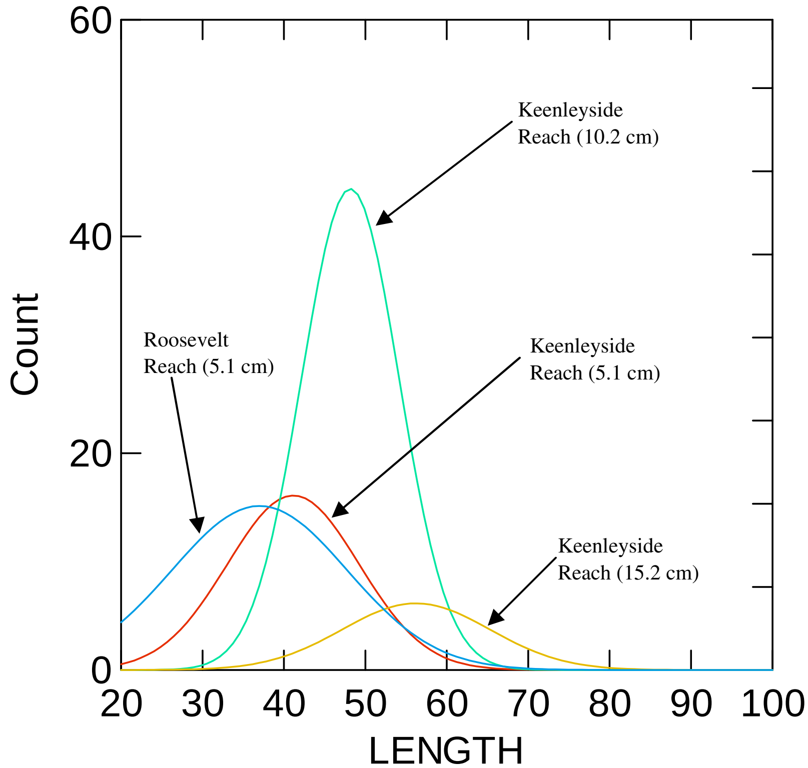

Figure 3.10 A normal curve fit to the length-frequency data collected for juvenile white sturgeon using gill net mesh sizes of 5.1 cm (blue = Roosevelt Reach; red = Keenleyside Reach), 10.2 cm and 15.2 cm (Keenleyside Reach only).

The age-class selectivity of gear types on the FL of captured juvenile white sturgeon was also explored for fish captured in 2005 at Waneta Eddy using gill nets (3 panels of 5.1, 10.2 and 15.2 cm stretch-measure mesh), angling, and the prototype underwater PIT tag reader. Table 3.17 indicates the proportion of each age class that were captured or recorded by each gear type and the results of the statistical tests. There were no statistical differences between age-class frequencies of the PIT tag reader records and the gill net captures (Chi-square $p = 0.19$, 3 df, $n = 89$ gill net; 36 PIT tags). The PIT tag records and gill net captures were grouped for comparison with angling catches. The age-classes of juveniles captured by angling were different from those obtained from the combined gill net catches and PIT tag records (Chi-square $p < 0.01$, 3 df, $n = 125$ gill net and PIT tags; 47 angling captures). The age-class selection of the angling catch was strongly biased for the large age-4 fish and against the 1, 2 and 3 age classes.

The geographical distribution of fish captured by gill nets was also examined. Only data from gill nets comprised of all three mesh sizes and juvenile sturgeon that were released in the Keenleyside Reach were used in the analysis. This eliminated any geographical differences that may have been caused by gear type, differences in the numbers of fish from each age-class, or size-at-release that may have occurred between the Roosevelt Reach and Keenleyside Reach releases. Figure 3.12 illustrates the geographical trend in FL for each age-class for fish captured in 2005, which included fish released in the Keenleyside Reach and captured in the Roosevelt Reach. The trends were consistent over age-classes, which indicated that within the flowing Keenleyside Reach, the size-at-age decreased with distance downstream for all age-classes captured. The opposite trend appeared for fish captured in the Roosevelt Reach, as average size-at-age increased with downstream distance in the reservoir. There was also an apparent trend for the distribution of age-classes to parallel that of FL, with older fish more likely to be encountered further downstream in the Roosevelt Reach. Sample sizes in the Keenleyside Reach upstream of Waneta Eddy were too small to determine if age-class abundance paralleled that of FL. Fish collected in 2005 that met the criteria were limited to the Keenleyside Reach, in this case, the same trend previously noted also occurred (Figure 3.13) and was also the case in 2003 (Figure 3.14).

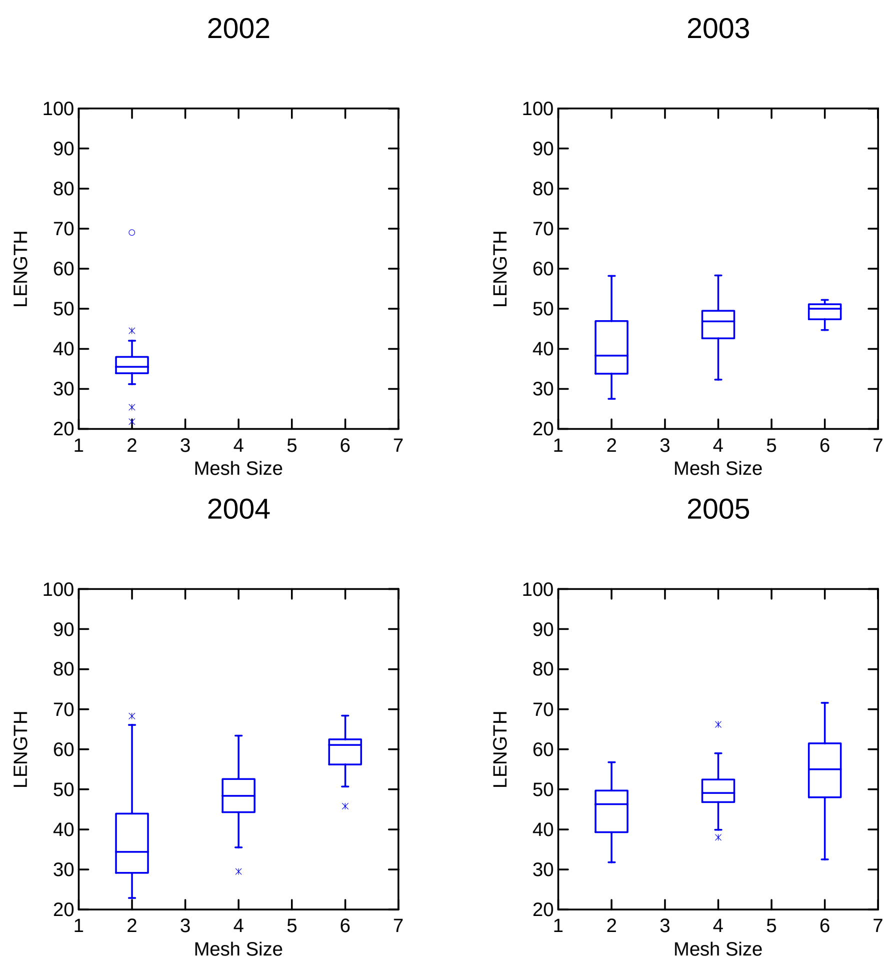

Figure 3.11 Box plot of length-frequencies of juvenile white sturgeon captured during each Phase (year) as a function of gill net mesh size (in inches; 2 = 5.1 cm; 4 = 10.2 cm; 6 = 15.2 cm).

Table 3.17 Summary of comparisons of the age-class frequencies of juvenile white sturgeon captured by gill net and angling, and detected by the underwater PIT tag reader at Waneta Eddy in 2005.

Age-class	**Method**			**Total**	***n***
	Gill Net	**Angling**	**PIT Tag Reader**		
1+	7.9%	4.2%	5.6%	6.4%	11
2+	11.2%	4.2%	25.0%	12.2%	21
3+	46.1%	27.7%	30.6%	37.8%	65
4+	34.8%	63.8%	38.9%	43.6%	75
Total	**100%**	**100%**	**100%**	**100%**	**172**
n	**89**	**47**	**36**	**172**	

Comparison of gill nets with PIT tag reader standard deviates [(observed - expected)/square root (expected)].

Age-class	**Gill Net**	**PIT Tag Reader**
1+	0.234	-0.368
2+	-0.959	1.508
3+	0.653	-1.027
4+	-0.184	0.289

Test Statistic	**Value**	**df**	**Probability**
Pearson Chi-square	4.984	3	0.173
Likelihood Ratio Chi-square	4.805	3	0.187

Comparison of gill net and PIT tag reader combined with angling.

Age-class	**Method**		**Total**	***n***
	Gill Net & PIT Tag Reader	**Angling**		
1+	7.2%	4.3%	6.4%	11
2+	15.2%	4.3%	12.2%	21
3+	41.6%	27.7%	37.8%	65
4+	36.0%	63.8%	43.6%	75
Total	**100%**	**100%**	**100%**	**172**
n	**125**	**47**	**172**	

Comparison of gill nets and PIT tag reader combined with angling standard deviates [(observed - expected)/square root (expected)].

Age-class	**Gill Net & PIT Tag Reader**	**Angling**
1+	0.356	-0.580
2+	0.957	-1.561
3+	0.693	-1.130
4+	-1.288	2.100

Test Statistic	**Value**	**df**	**Probability**
Pearson Chi-square	11.638	3	0.009
Likelihood Ratio Chi-square	12.102	3	0.007

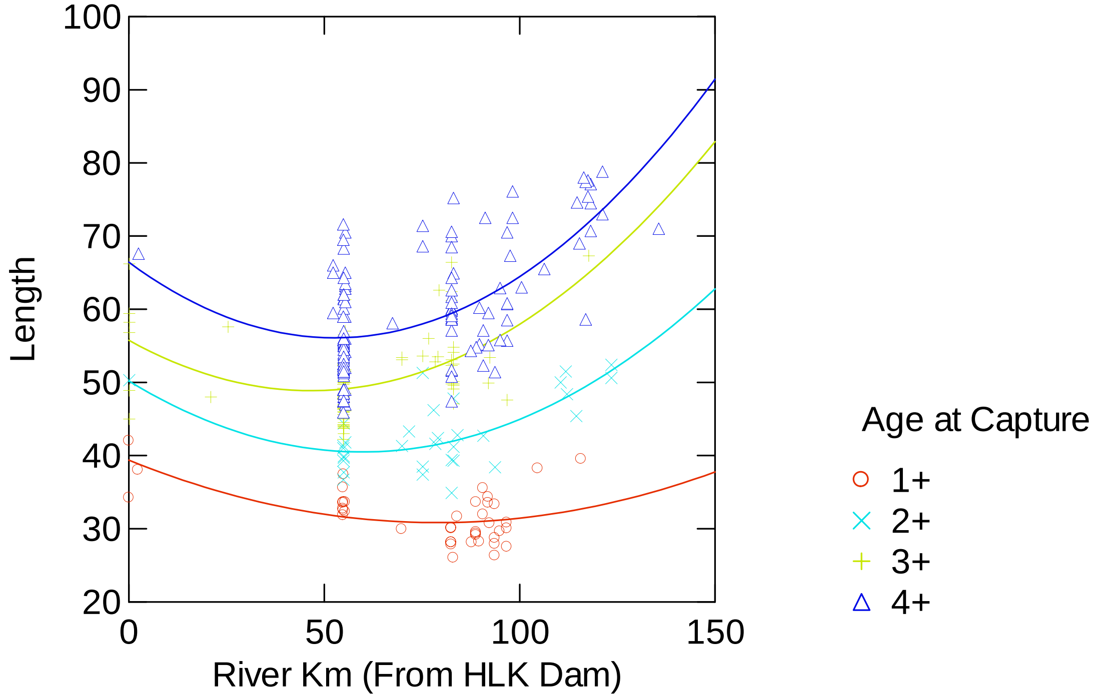

Figure 3.12 Fork length of age-1 to 4 juvenile white sturgeon captured in 2005 (Keenleyside Reach releases only) as a function of age-class and river kilometre. Trend line is a quadratic smoother.

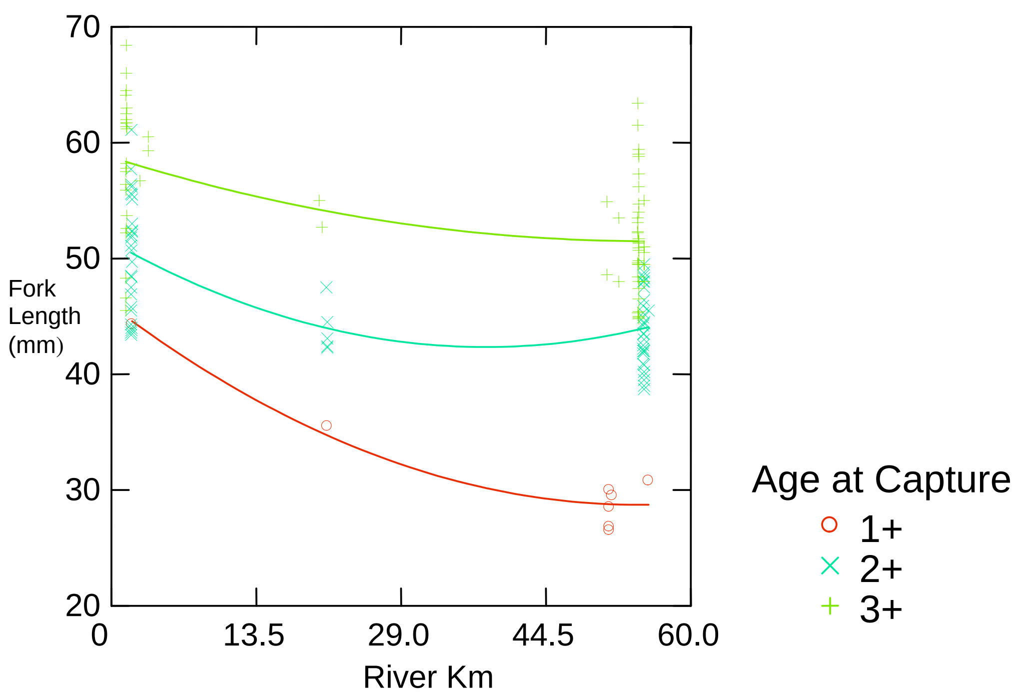

Figure 3.13 Fork length of age-1 to 3 juvenile white sturgeon captured in 2004 (Keenleyside Reach releases only) as a function of age-class and river kilometre. Trend line is a quadratic smoother.

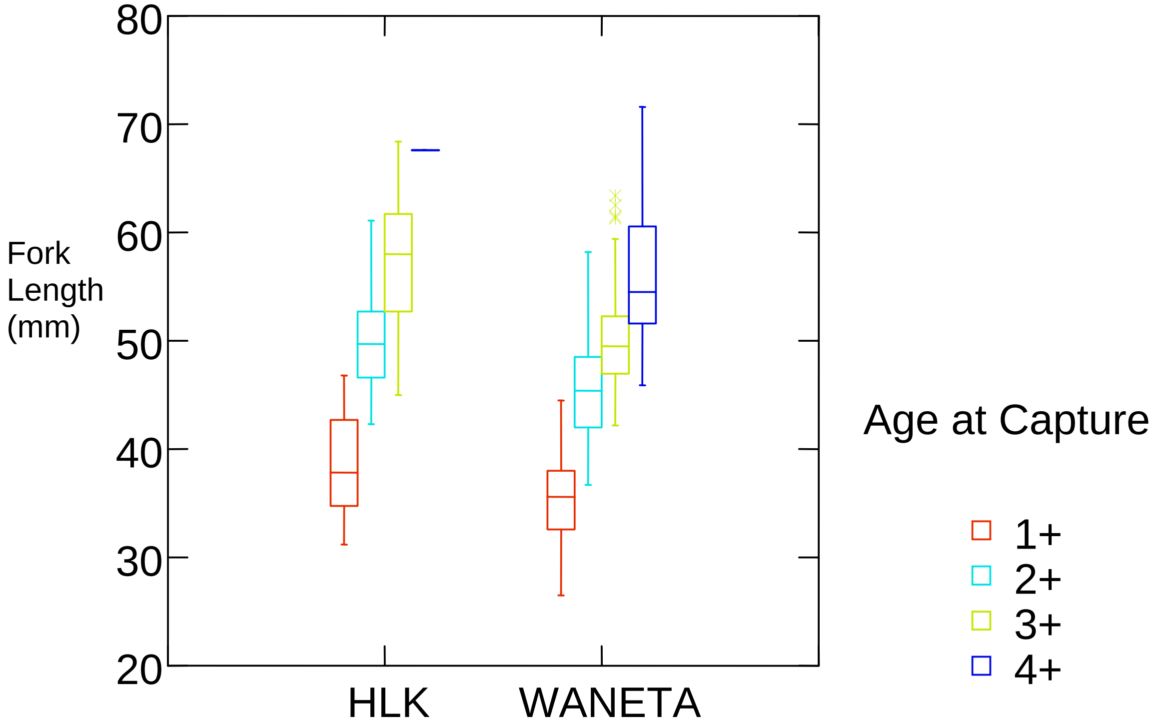

Figure 3.14 Comparison of Fork length distribution of Age-1,2, 3 and 4 juvenile white sturgeon captured in 2003 (Keenleyside Reach releases only) near the HLK Dam area and the Waneta Area. Only a single age-4 sturgeon was captured in the HLK Dam Area. Box plots indicate Median, Quartiles, and range of the data within 1.5 x the Intra-Quartile distance. Outlier data points beyond this distance are indicated with an asterisk.

4.0 DISCUSSION

4.1 DISTRIBUTION AND ABUNDANCE

In 2005, 385 hatchery juvenile white sturgeon were captured (including 12 that were also captured in previous years and seven that were captured twice in 2005) and approximately 883 were observed using the LBV. The three main capture areas were Waneta Eddy (35.1% of total fish captured by all sample programs in 2005), Little Dalles (14.2%) and the section of the Roosevelt Reach between RKm 84.1 (Marble) and 93.7 (China Bend; 14.2%; Table 3.4). All of the juveniles observed during LBV surveys, with the exception of 19 observed at Fort Shepherd Eddy, were at Waneta Eddy (Appendix B, Table B4). Hatchery juveniles were also captured at HLK Eddy (*n* = 6), Balfour Bay (*n* = 2), Kootenay Eddy (*n* = 2), Sandbar Eddy (*n* = 1), Genelle Eddy (*n* = 1), Fort Shepherd Eddy (*n* = 3), and between Deadman's Eddy and Martin Creek (RKm 67.5 to 135.6) in the Roosevelt Reach (*n* = 237).

Similar to 2002 to 2004 results, juvenile white sturgeon continued to exhibit a clumped distribution within the Keenleyside Reach during 2005. Juvenile white sturgeon were recorded in the same areas within the Keenleyside Reach where high use by adult white sturgeon has been documented (HLK to Norns Creek, Kootenay Eddy, Fort Shepherd Eddy, and Waneta Eddy; R.L. & L. 1994, 1998, 2001). The largest numbers of juveniles were recorded in Waneta Eddy, where catch-rates were similar to 2004 (Table 3.1). The low number of juveniles captured at HLK Eddy (6 juveniles; 2.4 fish/net-unit; the lowest since sampling began in 2002) was considered unusual as gill nets were set in the same locations as previous years. The reduced catch-rate at HLK Eddy was attributed to the behaviour of juvenile white sturgeon; specifically, the tendency of these fish to aggregate in large groups in the main eddy habitats within the Keenleyside Reach and the movement of these aggregations. During 2003 to 2005 monitoring, large aggregations of juveniles were observed at Waneta Eddy, the location of the group marked, and same area checked again soon after. In each instance the aggregation of juveniles was no longer in the same location. This indicates that the aggregations regularly move within the eddy habitats. If these aggregations were not located in the same portion of the eddy when gill net sampling was conducted, fish would have a lower likelihood of being captured. The high level of aggregation may effect capture probabilities from year to year. This will generally not bias results of survival estimates from mark/recapture analysis but may lower precision of the estimates. Spatial effects may be a problem however, if capture probabilities are different among sampling areas and age class distributions are not equivalent among areas. A sensitivity analysis of the survival estimates to these assumptions could be completed in the future.

During 2004 higher catch-rates in areas other than HLK Eddy and Waneta Eddy were recorded (Golder 2005b). Juveniles were captured at Kootenay Eddy, Sandbar Eddy, Fort Shepherd Eddy, and Rock Eddy, areas where they had not previously been captured. 2005 results indicated lower catch-rates in these areas compared to 2004 (Table 3.1). Gill net sampling during 2002, 2003, and 2005 was conducted in November of each respective year, whereas two gill net sessions were conducted during 2004 (September and November). The juvenile white sturgeon catch in these areas was higher during September 2004 than in November 2004 and 2005 (Table 4.1). This suggested that juvenile white sturgeon exhibit seasonal behaviour similar to adults; i.e., they disperse to feeding and holding areas during the spring and summer and tend to move to overwintering areas in the fall (R.L. & L 1994, 1998, 2001). This also suggested that these fish may be more active during non-winter months, and thus more susceptible to passive sample gear (i.e., gill nets).

Table 4.1 Comparison of gill net effort and juvenile white sturgeon catch-rates at Kootenay Eddy, Sandbar Eddy, Fort Shepherd Eddy, and Rock Eddy during Phase 3 (September and November 2004) and Phase 4 (November 2005) monitoring.

Location	Sep. 2004 (Phase 3)			Nov. 2004 (Phase 3)			Nov. 2005 (Phase 4)		
	Effort[a]	No.	CPUE[b]	Effort[a]	No.	CPUE[b]	Effort[a]	No.	CPUE[b]
Kootenay Eddy	0.61	6	9.8	0.61	4	6.6	0.59	2	3.4
Sandbar Eddy	0.48	5	10.4	0.44	2	4.5	0.45	1	2.2
Fort Shepherd Eddy	1.72	7	4.1	1.60	0	0.0	1.56	0	0.0
Rock Eddy	0.29	2	6.9	0.26	0	0.0	0.24	0	0.0
Total	**3.10**	**20**	**6.5**	**2.91**	**6**	**2.1**	**2.84**	**3**	**1.1**

[a] Effort is in net-units; one net-unit = 100 m^2 of net sampled for 24 hours.
[b] CPUE (catch-per-unit-effort) = number of juvenile white sturgeon captured per net-unit.

Juvenile white sturgeon were not captured at Fort Shepherd Eddy during the present study; however, 19 were observed there using the LBV and three juveniles were captured at this location by angling on 13 June 2005 during the Broodstock Collection Program. Of the 21 juveniles implanted with sonic tags and released in May 2004 at Beaver Creek, nine (43%) were detected only in Fort Shepherd Eddy. Of the 10 sonic tagged juveniles released at Beaver Creek in May 2005, five were detected only at Fort Shepherd and Waneta eddies and one was detected only at Fort Shepherd Eddy. This supports last years results that indicated Fort Shepherd Eddy also appears to be an important habitat for juvenile white sturgeon in the study area (but is difficult to effectively sample with gill nets due to currents and depth).

During the present study, daytime gill net sets were only conducted in the upper section (HLK Eddy to Kootenay Eddy). Juvenile white sturgeon (or incidental species) were not captured by daytime sets. The total effort expended for daytime sets was 0.50 net-units; overnight effort was 9.52 net-units. During 2002 monitoring, the catch-rate of daytime gill net sets was higher than overnight sets in HLK and Waneta eddies, the only areas where juvenile white sturgeon were captured (8.3 vs. 3.8 fish/net-unit in HLK Eddy and 19.2 vs. 15.3 fish/net-unit in Waneta Eddy; Golder 2003b). Detailed diel comparisons were not conducted during 2003 monitoring, because although 7.1 net-units of overnight sample effort was expended, overnight sets were not conducted in HLK or Waneta eddies to avoid potential mortalities (Golder 2005a). During 2004 monitoring, the catch-rate was higher for daytime gill net sets in Balfour Bay (6.3 fish/net-unit vs. 0.9 for overnight sets), but lower in HLK Eddy (3.0 fish/net-unit vs. 8.9) and the upper section (2.8 fish/net-unit vs. 7.1) of the Keenleyside Reach as a whole. The small sample size of juveniles captured during daytime sets and the inconsistent catch-rates due to the clumped distribution of these fish precluded in-depth diel comparisons.

4.1.1 Habitat Characteristics

The results of the present study support the findings of 2002 to 2004 monitoring, which indicated that juvenile white sturgeon exhibit a higher use of deepwater eddy habitats within the Keenleyside Reach, of which HLK Eddy and Waneta Eddy were the two main areas of use. Both areas provided depths in excess of 15 m throughout the year and are characterized by higher counter-current velocities along the eddy margins with calmer velocities in the centre of the eddies. Higher proportions of boulder, cobble, and gravel were present in the substrate along the eddy margins and depositional substrates (silt, sand, fine gravels) were more prevalent in the central portions of the eddies.

The LBV survey conducted in Fort Shepherd Eddy on 28 November 2005 provided the first visual record of substrate conditions in the eddy. In the deep (approximately 50 m), central portion of the eddy, substrates were dominated by boulders and cobble. Areas of gravel and fines were also present, often in the spaces between large boulders. Current velocity was estimated at less than 0.5 m/s (conditions preferred by juvenile white sturgeon; see Section 4.1.1.3) in the central portion of the eddy. Large woody debris was also noted in several of the areas observed.

Habitat conditions in the smaller eddy habitats (Kootenay Eddy, Sandbar Eddy and Rock Eddy) were similar to those in HLK Eddy and Waneta Eddy. Kootenay and Sandbar eddies provided the current velocities (less than 0.5 m/s; Section 4.1.1.3) and substrates (Section 4.1.1.2) that seem to be preferred by juvenile white sturgeon. The maximum depth in Kootenay Eddy was approximately 13 m and in Sandbar Eddy approximately 11 m, slightly less than the preferred depths of 15 m or more. Rock Eddy appears to provide the least suitable conditions of these three eddies, with maximum depths of about 8 or 9 m and higher velocities than the other eddies. The substrate conditions in Rock Eddy are also currently unknown, but believed to be comprised largely of bedrock and larger cobbles and boulders.

4.1.1.1 Depth

2002 to 2005 results suggested that the use of habitats of less than 10 m depth was higher during non-winter months when juveniles were more dispersed and lower during the winter when juveniles tended to concentrate more in the deeper main eddy habitats (i.e., HLK and Waneta eddies). Juvenile white sturgeon were not captured in depths less than 10 m in 2002 or 2003. During November 2004 and 2005, two juveniles were captured in this depth stratum, whereas 33 were captured during September 2004. Only three juveniles were captured between 10 and 15 m depth in 2002, compared to 28, 27, and 23 during 2003, 2004, and 2005, respectively. During all years sampled the highest catch was in the 15 to 20 m depth strata.

In both 2003 and 2004, five juvenile white sturgeon were captured and/or observed at depths of 1 to 3 m during boat electroshocking surveys conducted in shallow, nearshore habitats of the Keenleyside Reach during the LCRFIP (Golder 2004 and 2005d). Similar effort was also expended during the 2002 and 2005 LCRFIP surveys, but juvenile white sturgeon were not captured (Golder 2003c and 2006). These results indicate a low, sporadic use of shallow, nearshore habitats by juvenile white sturgeon during the fall period. The proportion of juveniles released into the

Keenleyside Reach that utilized shallow, nearshore habitats was lower in 2004 and 2005 than 2003, which suggested the use of these habitats has not increased in relation to the total number of juveniles released into the Keenleyside Reach.

The low use of shallow water habitats by juvenile white sturgeon is supported by the results of an ultrasonic telemetry study conducted in the Kootenay River (spelled Kootenai in the United States) in Idaho and British Columbia during the summer and early fall of 1999 and 2000 (hereafter termed the 1999-2000 Kootenay River telemetry study). In that study, the minimum depth where juvenile white sturgeon were recorded was 3.1 m (see below and Table 4.2; Young 2002). A 1987 to 1991 study of white sturgeon in the Columbia River downstream from McNary Dam (hereafter termed the 1987-1991 lower Columbia study) reported 6 m (impounded areas) and 2 m (unimpounded section below Bonneville Dam) as the minimum depths where juvenile white sturgeon were recorded (Parsley et al. 1993).

During the 1987-1991 lower Columbia study, juvenile white sturgeon were most often captured within the channel thalweg (Parsley et al. 1993). During the 1999-2000 Kootenay River telemetry study, approximately 60% of juvenile white sturgeon detections were made in glides, 52% in the thalweg, 50% in the outside bend of the river channel, and 40% in pools. The high percentage of detections associated with these areas indicated that juvenile white sturgeon actively sought and used deeper areas of the Kootenay River (Young 2002). In 2001, sampling conducted in the Canadian portion of the Kootenay River from Kootenay Lake upstream (hereafter termed the 2001 Kootenay River study) indicated juvenile white sturgeon were generally captured in deep areas associated with river bends; few were captured in the shallow, flat bottom glides between bends (Neufeld and Spence 2002). In 2002, sampling conducted in the same portion of the Kootenay River (hereafter termed the 2002 Kootenay River study) using gill nets also indicated juvenile catches were greatest in deeper water habitats (Neufeld and Spence 2004).

During the 2001 Kootenay River study, 58% (223.7 hours) of gill net effort was expended in depths less than 15 m and 42% (164.2 hours) of gill net effort was expended in depths over 15 m, but 84% of juvenile white sturgeon were captured by the deeper sets (Neufeld and Spence 2002; Table 4.2). The mean minimum set depth where juvenile white sturgeon were captured during the 2002 Kootenay River study was 14.1 m and the mean maximum was 20.1 m, within a range of 5 to 30 m (Neufeld and Spence 2004). During the 1999-2000 Kootenay River telemetry study, the mean depth for all white sturgeon contacts was 11.5 m (95% C.I. = 10.9 to 12.1 m); the minimum contact depth was 3.1 m and the maximum was 23.0 m (Young 2002). During the 1987-1991 lower Columbia study, the median depth where juvenile white sturgeon (150 to 1030 mm FL) were captured in impounded areas was 19 m (range between 6 and 58 m) and in the unimpounded lower river (downstream of Bonneville Dam) was 16 m (range between 2 and 40 m); over 80% were captured in depths over 10 m and over 65% were captured in depths over 15 m (Parsley et al. 1993). The ranges given above may be somewhat misleading because very few fish were captured in depths of less than 5 m and the substantial majority were captured in depths over 10 m.

In the present study, the minimum depth where juvenile white sturgeon were captured was 6.5 m (by gill net; average depth of the set); juveniles were not observed under depths of 15 m by the LBV. During the 2001 Kootenay River study, the minimum depth of gill net sets that captured juvenile white sturgeon ranged between 5.2 and 25.5 m, with a mean of 15.7 m; the maximum depth of gill net sets that captured juvenile white sturgeon ranged between 10.1 and 29.2 m, with a mean of 19.6 m. Significant differences were noted between the depths of gill net sets that captured juvenile white sturgeon and the depths of all gill net sets ($p < 0.001$). Of the 97 juvenile white sturgeon captured by gill net sampling during the 2001 study, 84% (81) were captured at depths over 15 m (Neufeld and Spence 2002).

During the 2002 Kootenay River study, significant differences were not observed ($p > 0.05$) between the depths of gill net sets that captured juvenile white sturgeon and all gill net sets. A comparison of mean set depths, however, indicated that proportionally more juvenile white sturgeon were captured between the 14 and 19 m depth range; approximately 30% of captures occurred in this depth range where 15% of the total effort was expended (Neufeld and Spence 2004).

Table 4.2 Comparison of depth distribution information for juvenile white sturgeon in the Columbia and Kootenay rivers.

Study	Sample Method	Depth Parameters	Data Source
1999 - 2000 Kootenay River	Telemetry	Mean = 11.5 m (95% C.I. = 10.9 to 12.1 m) Range = 3.1 to 23.0 m	Young 2002
2001 Kootenay River	Gill Net	Mean minimum = 15.7 m (range = 5.2 to 25.5 m) Mean maximum = 19.6 m (range = 10.1 to 29.2 m)	Neufeld and Spence 2002
2002 Kootenay River	Gill Net	Mean minimum = 14.1 m; mean maximum = 20.1 m Range = 5 to 30 m	Neufeld and Spence 2004
1987 - 1991 Lower Columbia River	Various	Impounded areas: median = 19 m (range = 6 to 58 m) Unimpounded: median = 16 m (range = 2 to 40 m) Over 80% captured at depths > 10 m; over 65% at > 15 m	Parsley et al. 1993
Phase 1 Juvenile Sturgeon	Gill Net ROV	Mean = 16.5 m (range = 11.0 to 20.1 m) Mean = 12.5 m (range = 8.5 to 19.5 m)	Golder 2003b
Phase 2 Juvenile Sturgeon	Gill Net ROV Diver Survey	Mean = 15.2 m (range = 10.4 to 19.8 m) Mean = 19.5 m (range = 10.0 to 25.4 m) Mean = 15 m	Golder 2005a
2003 LCRFIP	Boat Electroshocking	Range = 1 to 3 m (5 fish)	Golder 2004b
Phase 3 Juvenile Sturgeon	Gill Net ROV	Mean = 13.7 m (range = 7.1 to 20.2 m) Mean = 17.1 m (range = 10.0 to 22.4)	Golder 2005b
Oct. 2004 WDFW Juvenile Sturgeon Study	Gill Net	Mean = 21.2 m (range = 8.4 to 38.3 m)	Howell and McLellan 2006
2004 Broodstock Collection Program	Angling Set Line	Waneta Eddy: Mean = 17.0 m (range = 15.0 to 22.2 m) Fort Shepherd Eddy: Mean = 45.9 m (43.0 to 48.0 m) Waneta Eddy: Range = 14.3 to 17.8 m (2 fish)	Golder 2005e
2004 LCRFIP	Boat Electroshocking	Range = 1 to 3 m (1 fish captured, 3 observed)	Golder 2005d
2004 TCW-aAERA[a]	Boat Electroshocking	3 m (1 fish)	Golder, unpublished data
Present Study	Gill Net Angling ROV (LBV)	Mean = 16.7 m (range = 6.5 to 21.5 m) Range = 15 to 20 m Waneta Eddy: Range = 15 to 21 m Fort Shepherd Eddy: Range = 37 to 50 m	Present Study
Oct. 2005 WDFW Juvenile Sturgeon Study	Gill Net	Mean = 22.4 m (range = 5.8 to 42.1 m) Note: only 2 were captured in depths < 10m and 18 < 15 m	WDFW, unpublished data
2005 Broodstock Collection Program	Angling Set Line	Data not available Range = 15 to 22 m (2 fish)	Golder, unpublished data

[a] TCW-aAERA = Teck Cominco Wide-area Aquatic Ecological Risk Assessment.

4.1.1.2 Substrate

During the present study, fines were the dominant substrate recorded in areas where juvenile white sturgeon were captured and observed. This was similar to findings from 2002 to 2004 (Golder 2003b, 2005a and 2005b), and to results of other studies in the Columbia, Kootenay, and Snake rivers, where sand was reported as the dominant substrate selected by juvenile white sturgeon (Young 2002). During the 1999-2000 Kootenay River telemetry study, the majority of juvenile white sturgeon contacts were in areas with sand substrate (61%), followed by clay/silt/mud (26%; i.e., fines = 87%), small cobble (8%), large cobble (3%), gravel (1%), and boulder (1%; Young 2002). During the 1987-1991 lower Columbia study, approximately one-third of juvenile white sturgeon recorded in the impounded sections were over sand substrate and 99% of observations in the unimpounded section (downstream of Bonneville Dam) were over sand, although this was the predominant substrate in the lower reach (Parsley et al. 1993).

4.1.1.3 Current Velocity

The velocity characteristics of Waneta Eddy in relation to overwintering use by juvenile white sturgeon were examined in late March 2004 by the Waneta Expansion Power Corporation (Golder 2005f). An Aqua-Vu underwater camera and a Price AA current meter were attached to a 100 pound lead "fish" to determine the presence of juvenile white sturgeon in the area and obtain velocity measurements. Surveys were restricted to 15 m or deeper based on the results of 2002 and 2003 juvenile monitoring. Velocity measurements were taken at 30 locations where juvenile white sturgeon were recorded and another 30 locations where juveniles were not recorded. The mean velocity at locations where juveniles were observed was 0.27 m/s, with a range of 0.08 to 0.55 m/s (S.D. = 0.12); the mean depth at these locations was 18.2 m, with a range of 15.0 to 20.4 m (S.D. = 1.4). The mean velocity at locations where juveniles were not observed was 0.30 m/s, with a range of 0.07 to 0.49 m/s (S.D. = 0.11); the mean depth was 18.1 m, with a range of 15.4 to 21.3 m (S.D. = 2.1).

The depth, velocity, substrate, discharge and water temperature data examined during the velocity study did not indicate substantial differences in habitat characteristics between areas where juvenile white sturgeon were or were not present. ASL Environmental Sciences Inc. conducted a COCIRM (Coastal Ocean Circulation Model) numerical model run using these data, to provide further insight into differences between areas where juveniles were present and absent. Locations where juveniles were present were in the central portion of Waneta Eddy (the low speed core), with one group situated near the shear zone between the Pend d'Oreille River and the eddy. The juveniles were located in an area of weak upward velocities (< 0.05 m/s), and were absent from areas that exhibited weak downward or near-zero vertical velocities.

The similarities in velocity measurements and substrate composition among areas where juveniles were and were not present did not indicate that their location within the 15 m plus depth contour at the time of sampling was strongly related to differences in either of these variables (Golder 2005f). The only consistent finding of this study was that aggregations of juveniles were always recorded at depths of 15 m or greater, at velocities less than 0.5 m/s (one juvenile was recorded at 0.55 m/s), and over substrates with a high proportion of fines. These findings are consistent with the results of 2002 to 2005 juvenile white sturgeon monitoring.

The specific locations of juveniles within the low speed core of the eddy did not appear to be strongly related to current velocity, substrate conditions, or water temperature, as these conditions were similar throughout the area. The location of the aggregation at any given time within this area of similar habitat conditions was considered more likely a reflection of food entrainment patterns into the eddy, perhaps influenced by vertical velocity vectors and proximity to the shear zone. This assumption is based on one study, which should be repeated to verify that the observations represent a consistent winter use pattern within Waneta Eddy (Golder 2005f).

4.1.1.4 Cover

Use of instream cover by juvenile white sturgeon was not specifically assessed during the present study; therefore, the following is based solely on cover present in the immediate area where juveniles were observed. None of the approximately 864 juvenile white sturgeon observed using the LBV at Waneta Eddy were associated with cover. Of the 19 juveniles observed at Fort Shepherd Eddy, 10 (52.6%) were associated with boulders and two (10.5%) were associated with woody debris. These results are consistent with the findings of 2002 to 2004 studies that also showed a low association of juvenile white sturgeon and cover (Golder 2003b, 2005a, and 2005b).

These results were also similar to findings of the 1999-2000 Kootenay River telemetry study, where juvenile white sturgeon were most often located in habitats without cover (42%), followed by velocity breaks (30%), submerged logs and root wads (9.0%), rock (8%), wood and brush (6%), and submerged non-woody vegetation (6%; Young 2002). Diving observations made during the 1999-2000 Kootenay River telemetry study suggested that in many cases, juveniles observed in areas without cover had access to nearby submerged structures that would have provided velocity refugia. The author suggested Kootenay River juvenile white sturgeon may have been using habitats with velocity refugia for energy conservation as well as for feeding. These results suggested that juvenile white sturgeon do not generally actively seek cover, but may use nearby cover if available.

4.1.2 Movement

Based on VR2 detection histories, the majority (62 of 80; 77.5%) of sonic tagged juvenile white sturgeon released in 2004 and 2005 remained within 10 km of their release locations. Of the 40 juveniles released at HLK Eddy in 2004 and 2005, only one (2.5%) was detected further downstream than Sturgeon Island. Of 32 juveniles released at Beaver Creek, 11 (34.4%) exhibited movements greater than 10 km (i.e., moved to locations other than Fort Shepherd and Waneta eddies). Of the eight juveniles released in the Roosevelt Reach in 2005, six (75%) exhibited movements greater than 10 km.

The tendency of hatchery reared juvenile white sturgeon to remain near their release location appeared to be related to the habitat characteristics in the immediate vicinity. Juveniles released at HLK Eddy are placed directly into habitats where high use has been recorded (the majority of the 7 km of the Columbia River immediately downstream of HLK provides low velocity, deep water habitat). This area is also believed to provide an abundance of food in the form of *Mysis relicta*, a freshwater shrimp entrained from Arrow Lakes Reservoir. During juvenile white sturgeon monitoring from 2002 to 2004 (Phase 1 to 3), 57 stomach samples were obtained from age-1 to 3 fish and examined; over 93% of total prey items were *Mysis relicta*, with a 100% frequency of occurrence in non-empty stomachs (Golder 2003b, 2005a, and 2005b).

Sonic tagged juveniles released at Beaver Creek tended to move downstream until the habitat conditions described above were encountered. The data suggested that these fish moved downstream with the current; some remained in Fort Shepherd Eddy, the first large area with current velocities less than 0.5 m/s and depths in excess of 15 m. Others continued downstream and some remained in Waneta Eddy, the next such area. Fewer of these fish travelled downstream past Waneta Eddy and remained at Little Dalles, while fewer still travelled downstream of Little Dalles. Of the sonic tagged juveniles released at Beaver Creek in 2004 and 2005, three released in 2004 and none of the fish released in 2005 were detected in the upper section of the Keenleyside Reach. These three fish still moved downstream before moving upstream: two to Fort Shepherd Eddy and one to Little Dalles.

The sonic tagged juveniles released at Nancy Creek/Marcus Flats in May 2005 exhibited the greatest average movement range of the release groups examined (36.2 km; Table 4.3). Low velocity, deep water habitats, and fine substrates are abundant in the Roosevelt Reach. However, based on 15 stomach samples of juveniles captured in the Roosevelt Reach in 2004 examined by the WDFW, *Mysis relicta* comprised a smaller proportion of their diet in this area (51.2% of total prey items; 66.7% frequency of occurrence). The generally greater movement ranges of juveniles in the Roosevelt Reach may be a result of an increased need to actively search for food. Lower current velocities in the reservoir portion of the Roosevelt Reach also may result in a lower likelihood of remaining in areas that provide velocity refugia.

4.1.2.1 Net Movement

Tagged hatchery juveniles released in both 2004 and 2005 in the Keenleyside Reach exhibited similar net movements (Table 4.3). Mean net movements of juveniles released at HLK Eddy in 2004 (4.3 km) and 2005 (3.0 km), and those released at Beaver Creek in 2004 (21.4 km) and 2005 (21.5 km) were very similar between release years. Juveniles released in the Roosevelt Reach (Nancy Creek/Marcus Flats area) in 2005 exhibited the greatest mean net movement (36.2 km).

Table 4.3 Summary of net movements of sonic tagged juvenile white sturgeon monitored during the present study, for which reliable detections were obtained, 2004 to 2006.

Details	*n*	Movement Range (km)		
		Mean	Minimum	Maximum
2004 Releases				
Released at HLK	25	4.3	0.0	35.4
Released at Beaver Creek	21	21.4	4.7	75.7
Released in the Keenleyside Reach)	**46**	**12.1**	**0.0**	**75.7**
2005 Releases				
Released at HLK	15	3.0	2.5	6.4
Released at Beaver Creek	11	21.5	4.4	82.7
Released in the Keenleyside Reach	**26**	**10.8**	**2.5**	**82.7**
Released in the Roosevelt Reach	**8**	**36.2**	**3.0**	**68.3**
All Juveniles released in 2005	**34**	**16.8**	**2.5**	**82.7**

The majority of movements detected were in a downstream direction (Table 4.4). The movement patterns exhibited by sonic tagged juveniles differed based on the location they were released. This was likely a result of the different habitat conditions in the vicinity of the release locations (Section 4.1.2). A summary of upstream and downstream detected movements of juveniles released at the three different release locations and as one group are provided in Table 4.4.

Table 4.4 Summary of the detected upstream and downstream movements of sonic tagged juvenile white sturgeon released in the Transboundary Recovery Area in May 2004 and 2005.

n	%	Movement Details
Released in May 2004 or 2005 at HLK		
1	2.4	not detected
6	14.6	no detected movement (detected only at HLK Eddy)
28	68.3	upstream and downstream movement (between HLK Eddy and Sturgeon Island)
5	12.2	only downstream movement detected (but detected for relatively short period of time and not downstream of Sturgeon Island)
1	2.4	only downstream movement detected (last detected at Rivervale on 25 May 2004)
41	**100**	**Total**
Released in May 2004 or 2005 at Beaver Creek		
9	22.0	not detected
27	65.9	only downstream movement detected (4 of these fish moved downstream past Waneta Eddy)
2	4.9	upstream and downstream movement (but moved greater distance downstream)
3	7.3	upstream and downstream movement (but moved greater distance upstream)
41	**100**	**Total**
Released in May 2005 in the Roosevelt Reach		
2	25.0	upstream and downstream movement (but moved greater distance upstream)
2	25.0	only downstream movement detected
4	50.0	only upstream movement detected
8	**100**	**Total**
All sonic tagged juveniles released in May 2004 and 2005		
10	11.1	not detected
6	14.6	no detected movement (detected only at HLK Eddy)
28	68.3	upstream and downstream movement (between HLK Eddy and Sturgeon Island)
5	12.2	only downstream movement detected (but detected for relatively short period of time and not downstream of Sturgeon Island)
30	33.3	only downstream, movements detected
2	2.2	upstream and downstream movement (but moved greater distance downstream)
4	4.4	only upstream movements detected
5	5.6	upstream and downstream movement (but moved greater distance upstream)
90	**100**	**Total**

4.1.2.2 Movement Within Waneta Eddy

The location of the aggregation of juvenile white sturgeon recorded in Waneta Eddy during the LBV survey conducted on 24 March 2006 was marked for deployment of the underwater PIT tag reader system. The aggregation was no longer in the same location on 26 March 2006. This was similar to previous surveys, where the aggregation of juvenile white sturgeon recorded in Waneta Eddy during LBV surveys conducted in January and March 2004 was located in different portions of the eddy during each of these surveys. The aggregation was found on 29 March 2004 and its location marked with an anchor and float line. On 30 March 2004, examination using the LBV indicated that the aggregation was no longer present in the same area. The movement of the aggregation(s) to different portions of Waneta Eddy between these surveys indicated that the fish moved as a group, suggestive of schooling behaviour. The differences in the locations of the aggregation may either reflect random movements for feeding and/or holding within Waneta Eddy, or may be in response to habitat conditions not examined during the velocity study (Section 4.1.1.3; Golder 2005f).

4.2 JUVENILE WHITE STURGEON CONDITION

All of the juvenile white sturgeon captured during the present study were in good condition and none succumbed to the sample procedure. Even those fish that had deformed pectoral fins appeared healthy and exhibited growth rates similar to fish without deformities. The pectoral fin deformities appear to have minimal effect on the growth of age-1 to 4 fish. It is still unknown whether these deformities will have a greater effect on these fish as they continue to mature and reach later stages of their life cycle.

4.2.1 Relative Weight and Growth

Although the relative weight index has been used extensively in fisheries management, more extensive investigations into its properties and limitations are only beginning to emerge (e.g., Brenden and Murphy 2003). This index is based on the assumption that there is a universal theoretically optimal population for a species to which all individuals may be compared (Murphy et al. 1991).

The mean relative weight for all hatchery juvenile white sturgeon captured from 2002 to 2005, for which relative weight at capture and release could be determined ($n = 703$), was 104.2% at release and 79.7% at capture. The relative weight at capture was similar to the mean relative weight for juveniles captured during the 2001 (82%) and 2002 (84%) Kootenay River studies (Neufeld and Spence 2002, 2004). Between release and capture, 94.3% ($n = 663$) of fish captured from 2002 to 2005 exhibited a decrease in relative weight (5.7%; $n = 40$ exhibited an increase). This was similar to the 2002 Kootenay River study, where 27 of 32 (84%) juveniles captured from the fall 2000 release and 50 of 52 (96%) juveniles captured from the spring 2001 release exhibited a decrease in relative weight (Neufeld and Spence 2002).

Relative weight is based on the length vs. weight of a particular fish compared to the population "normal". Growth rates or the age of fish are not taken into account. The usefulness of relative weight for inter-population comparisons appeared to be limited and it is better used for comparisons of the same population over time. As an example, an age-3 fish captured in the Kootenay River (31.9 cm TL and 135 g) and an age-1 fish captured in the Columbia (50.8 cm TL and 484 g) both had relative weights of 95%. The relative weights of these fish indicates that they are both in good condition based on their weight at length, but does not provide information on size-at-age or growth rates.

All of the juvenile white sturgeon captured during the present study increased in FL, TL, and weight after their initial release. The mean growth rate of age-1 juveniles decreased slightly between 2002 and 2003 monitoring, decreased substantially during 2004 monitoring, and increased slightly during 2005 monitoring (see Section 3.3.4.2 and Appendix C, Tables C3 to C5). The mean growth rate of age-2 fish was slightly lower during 2004 monitoring than during 2003; the mean growth rates were similar during 2004 and 2005 monitoring. The mean growth rate of age-3 fish was lower in 2005 than in 2004.

The mean relative weight (at capture) of age-1 fish captured in 2002 (91.7%) was higher than that of age-1 fish captured in subsequent years (range from 78.9% in 2005 to 82.3% in 2003; Table 3.14). The mean relative weight of age-2 fish captured in 2002 (76.2%) and 2003 (73.8%) was similar, but increased to 82.8% for fish captured in 2005. The mean relative weight of age-3 fish captured in 2005 (73.4%) was approximately 5% lower than age-3 fish captured in 2004 (78.6%). The mean relative weight of age-4 fish captured in 2005 was 82.5%. These data suggest that although the growth of juveniles has generally slowed with subsequent releases, fish are still in relatively good condition based on their weight at a particular length.

A comparison of the mean growth rates of age-1 to 4 hatchery juveniles captured in the upper, middle, and lower sections of the Keenleyside Reach, and in the Roosevelt Reach indicated growth rates of all age-classes were highest for fish captured in the upper section of the Keenleyside Reach, although only one age-4 fish was captured there during the present study. Age-1 to 3 fish captured in the middle section of the Keenleyside Reach (age-4 fish were not captured in the middle section) were not included in this comparison due to low sample sizes. The mean growth rate of age-1 fish was higher in the lower section of the Keenleyside Reach than in the Roosevelt Reach. The mean growth rates of age-2 to 4 fish were higher in the Roosevelt Reach than in the lower section of the Keenleyside Reach.

The reason for the lower growth rates of age-1 fish in the Roosevelt Reach and higher growth rates of age-2 to 4 fish was unknown, but may be due to the time required to adapt to life in the river after release. After the initial year-at-large in the Roosevelt Reach, the increased growth rates in following years may reflect either greater foraging efficiency with age or increased knowledge of better feeding locations. In the Keenleyside Reach, the higher growth rates exhibited by fish captured in the upper section were likely a result of greater food availability (i.e., entrained mysids), as well as less competition for food as a result of lower juvenile densities in the Broadwater area (HLK to Norns Creek Fan) than in the Waneta area.

2004 monitoring results indicated that the proportion of *Mysis relicta* in the diet of age-1 to 3 juveniles decreased with increased distance downstream of HLK (Golder 2005b). In age-1 fish, 99.3% of the stomach contents of fish captured in the Keenleyside Reach ($n = 4$) were mysids, compared to 69.0% for fish captured in the Roosevelt Reach ($n = 13$). A similar pattern of decreased mysid abundance in the diet with downstream distance from HLK was also observed for age-2 and age-3 juveniles. The availability of *Mysis relicta* is believed to be a main factor affecting the growth rates of juvenile white sturgeon released in the Transboundary Recovery Area.

Results of the present study did not support the apparent trend of declining growth rates for juvenile white sturgeon with each successive release in the Transboundary Recovery Area as reported in the 2004 report (Phase 3; Golder 2005b). The mean growth rate of age-1 fish captured in 2005 was higher than age-1 fish captured in 2004. The mean growth rate of age-2 fish captured in 2005 was similar to age-2 fish captured in 2004. However, the mean growth rate of age-3 fish captured in 2004 was higher than in 2005.

The growth rates of juvenile white sturgeon released in the Transboundary Recovery Area of the Columbia River continue to be substantially higher than hatchery juveniles released in the Kootenay River. The mean growth rate (calculated from yearly growth rates) for juvenile white sturgeon in the 2001 Kootenay River study was 0.03 cm/day FL and 0.17 g/day; nine fish had lost weight (Neufeld and Spence 2002). The mean growth rate for juveniles captured during the 2002 Kootenay River study was 0.01 cm/day FL and 0.17 g/day (Neufeld and Spence 2004). Data on the growth of hatchery reared juvenile white sturgeon in the Kootenay River since 1990, indicated average growth increments of fish captured after up to 8 years at-large were 0.02 cm/day and 0.56 g/day (calculated based on average yearly growth; Ireland et al. 2002). The condition factor of 77% of hatchery white sturgeon decreased between release and recapture. The lower growth rates of juvenile white sturgeon captured during the 2002 Kootenay River study may have resulted from higher proportions of older fish in the sample (Neufeld and Spence 2004).

The decreases in weight of many juvenile white sturgeon captured in the 2001 and 2002 Kootenay River studies were thought to be a result of adaptation time (i.e., the time it takes hatchery sturgeon to adapt to the natural environment). Ireland et al. (2002) stated that growth rates and condition factors within the first 1 to 3 years after release were often poor as many hatchery fish had difficulty adapting to natural conditions. Results of 2002 to 2005 monitoring indicate that in the Columbia River study area juvenile white sturgeon adapt quickly to natural conditions. Decreases in weight between release and recapture were not exhibited by any juvenile white sturgeon captured from 2002 to 2005. On average, age-1 fish captured in 2002 and 2003 in the Columbia River exhibited growth rates approximately four times as great in length and approximately 10 times as great in weight compared to fish captured during the 2001 and 2002 Kootenay River studies. On average, age-1 fish captured in 2004 and 2005 in the Columbia River exhibited growth rates approximately double in length and four times as great in weight as Kootenay River fish. These differences in growth rates may also be influenced by food availability.

From 2002 to 2005, growth rates of individual juvenile white sturgeon ranged from 0.02 to 0.16 cm/day FL and from 0.10 to 3.77 g/day. The highest (0.11 cm/day FL and 3.77 g/day), third highest (0.10 cm/day FL and 3.64 g/day) and tenth highest (0.10 cm/day FL and 3.19 g/day) growth rates in weight were exhibited by three fish from the group that was held over in the hatchery and raised to a larger size to allow for sonic tag implantation. The larger size-at-release of these fish may have provided a competitive feeding advantage over the fish released at a smaller size.

4.2.2 Pectoral Fin Deformities

The observed incidence of pectoral fin deformities in hatchery juvenile white sturgeon has decreased with each successive brood year. With the exception of 2001 and 2002 brood fish captured in 2004, the incidence of pectoral fin deformities has also decreased with each successive year of sampling (Table 4.5).

Table 4.5 Summary of the incidence of pectoral fin deformities by brood year, for juvenile white sturgeon (for which deformity data was available) captured in the Transboundary Recovery Area from 2002 to 2005.

Brood Year	Capture Year[a]														
	2002			2003			2004			2005			2002 - 2005		
	No.	Def.	%	No.	Def.	%	No.	Def.	%	No.	Def.	%	No.	Def.	%
2001	36	19	52.8	58	30	51.7	88	50	56.8	115	42	36.5	**297**	**141**	**47.5**
2002				37	18	48.6	73	37	50.7	79	28	35.4	**189**	**83**	**43.9**
2003							82	17	20.7	82	16	19.5	**164**	**33**	**20.1**
2004										73	13	17.8	**73**	**13**	**17.8**
unknown[b]							2	1	50.0	1	1	100.0	**3**	**2**	**66.7**
All	**36**	**19**	**52.8**	**95**	**48**	**50.5**	**245**	**105**	**42.9**	**350**	**100**	**28.6**	**726**	**272**	**37.5**

[a] No. = number of juvenile white sturgeon captured; Def. = number with deformities; % = percentage of fish captured with deformities.
[b] Unknown = brood year could not be determined by scute removal pattern and PIT tag was not detected of found in release data.

The mean daily growth rates of juvenile white sturgeon with pectoral fin deformities were generally similar to fish without deformities (Appendix C, Table C5). This suggested that at least during the initial four years-at-large the deformities did not appear to have a substantial negative effect on successful feeding in the natural environment. The mean growth rate of age-1 juveniles with pectoral fin deformities captured from 2002 to 2005 was actually higher than those without deformities. The mean growth rates of age-2, 3, and 4 juveniles with and without pectoral fin deformities were similar. The severity of pectoral fin deformities (i.e., major or minor) did not have a noticeable effect on the growth of juveniles. The long term (e.g., when these fish switch to a more piscivorous diet and during spawning) effects of these deformities remain unknown and should be monitored over time. The cause(s) of these pectoral fin deformities also remain unknown. Earlier broodstock captures in recent years has hastened and improved the success of spawning in the hatchery. This reduced time spent in the hatchery by adult fish used for broodstock may in turn have resulted in the reduced incidence of pectoral fin deformities noted above.

4.2.3 Survival

The CJS estimates of survival remain tentative. Despite narrower confidence intervals than the 2004 (Phase 3) estimate for the survival rates, uncertainty still exists concerning the assumptions used in the modelling effort. Immigration and emigration are not incorporated into the model as inter-regional tag recovery data is too sparse to effectively model movements. With subsequent years of sampling, the degree of closure of these sturgeon populations to migration should be identified through recapture and telemetry data. The high degree of spatial aggregation of juvenile sturgeon that is apparent from video studies of the winter aggregations suggests that the assumption of equal probability of sampling tagged fish of different cohorts may be easily violated. If different cohorts aggregate in a non-random manner, other aggregations may be undetected and may not be vulnerable to the sampling methods. The models used for determining survival assume equal vulnerability of size/age groups to the sampling gear, and that similar proportions of cohorts among years will occur in the sampling areas proportionate to their abundance. As indicated in the analysis of size selectivity of gill nets, the gear used is inherently selective for size and age-classes. However, the limited comparison of the underwater remote PIT tag reader data with the gill net data suggests that the gill net recovery rates by age-class may reasonably reflect the relative abundance of age classes 1+ through 4+ that are present at the sampling site.

The geographic data analysis also indicated significant trends in distribution by size within age-classes, and trends are likely present among age-classes. If sufficient recovery data are available in subsequent years as a result of successful deployment of the remote underwater PIT tag reader or other methods, more complex models can be developed to address these issues. However, the data suggests that the hatchery program is highly successful in meeting its objectives. Regardless of biases, based on tag recovery data, juvenile sturgeon from the four age cohorts are very abundant relative to the existing wild stock. It was also noted that once juvenile sturgeon pass through their first 6 months at-large, their survival rates are indistinguishable from those of adult sturgeon, based on the current analysis and associated assumptions.

Projections of the fish population into subsequent years are highly speculative. Density dependency will likely impact survival rates as abundances continue to increase. However, based on the limited comparison of gear types and the consistent record of larger (and apparently older) animals downstream from the major concentrations of juvenile sturgeon within the Keenleyside Reach (Figure 3.12), biases associated with the survival of the older age classes should be negative (estimated survival should be lower because of the relative movement of older age class fish out of the sampling areas). With the high (93-99%) estimate of survival this bias would likely be insignificant.

In the future, if factors such as time of release, family group, and release location are to be evaluated for their influence on survival, increasing the number of tagged juvenile sturgeon captured is desirable. The pilot underwater remote PIT tag reader system showed promise of providing this increased resolution through the detection of large numbers of tags that will aid in the effective evaluation of capture efficiencies and spatial variation.

4.2.4 Analysis of Fork Length and Age-Class Selectivity

The analysis demonstrates strong effects of gill net mesh size on the size and age-classes of juvenile sturgeon captured by this method. The standardization of multiple panel gill nets of designated mesh size is essential for cross border comparison of results. Recording of the mesh size from where each sturgeon is captured will provide improved precision for subsequent analyses.

Preliminary comparison of age-class structure of fish recorded by the underwater PIT tag reader as compared to the three panel gill net catches is promising. Although sample sizes were small, the results indicated similar proportions of age-classes were collected. Angling indicated a strong bias for larger, older age-classes of fish. This suggested that angling methods deployed in this study were clearly not randomly sampling age-classes with equal probability. The use of gear directed towards the capture of larger fish (broodstock) increased this bias. Any use of these data in evaluation of survival or growth would require sufficient recaptures to correct for age and size based biases in capture probabilities.

Geographic patterns of FL for each age-class sampled indicated a common trend among age-classes and over sample years. Within the flowing Keenleyside Reach of the Columbia River, there was a tendency for larger fish to be captured upstream in the areas sampled near HLK Eddy and smaller fish of the same age-class to be found downstream at the areas sampled near and within Waneta Eddy. Within the Roosevelt Reach, the trend was reversed, with larger fish tending to be found downstream and an apparent distribution of older fish also following this same trend.

In the analysis of survival of the juvenile sturgeon for each age class by mark-recapture, recapture probabilities of each age-class were assumed to be similar over the multiple sites sampled, as sufficient recaptures were not available to examine recapture probabilities by age class and location. The evaluation of geographic trends suggested that age-class capture probabilities were likely different at any given location because of the distribution of juvenile sturgeon by size as well as age-class. Although this may result in biases in the mark-recapture analysis, these are likely not large compared the variability in survival measurements as a result of limited numbers of samples.

The underwater PIT tag reader data suggested that age-class composition of gill net catches and that recorded by the PIT tag readers was similar, at least within the limited confines of the prototype deployment of this new technology. If further use of this technology is successful in increasing sample sizes by one order of magnitude, sufficient recaptures will be obtained to evaluate spatial and gear type biases that may occur. The strong bias of angling toward larger fish limited the utility of this method to evaluate either growth or survival of juvenile sturgeon during the first three years following release. The strong selectivity of gill nets also suggested that as the cohorts age, the sampling method of gill nets will likely be limited in its effectiveness to collect older juvenile fish. The underwater PIT tag reader may be very useful in monitoring survival by tag recaptures, particularly for these older age-classes. Growth rates will still require either gill net or set line catches to supplement the survival estimates in order to assess future trends in the white sturgeon population. Given the abundance of young sturgeon, this evaluation is important to determine density dependency and ultimately successful recruitment to mature adults of fish from the hatchery program.

5.0 PROPOSED LONG TERM INDEXING PROTOCOL

The nature of the released juvenile white sturgeon population in the Transboundary Reach creates difficulties in terms of developing a static long term indexing protocol. Gill nets were the most effective method used to sample juveniles during 2002 to 2004 monitoring. Gill nets continued to be effective during the present study (2005), but the results of the 2004 and 2005 Broodstock Collection Programs and angling conducted during 2005 indicated that hook and line methods will likely become more effective as fish age. If the use of gill nets were continued to the exclusion of hook and line methods, captures would be biased towards smaller, younger fish. The reverse would also be true if the use of hook and line methods were used to the exclusion of gill nets. As younger fish continue to be added to the population and the fish already present continue to grow, it will be necessary to use a greater variety of capture methods and expend more sample effort in order to obtain samples from all cohorts.

The distribution of juvenile white sturgeon in the study area has also changed during the first four years of these studies. During 2002 and 2003 monitoring, juveniles were encountered almost exclusively in HLK Eddy and Waneta Eddy. During 2004 and 2005 monitoring, juveniles were also recorded in several locations they were not during 2002 and 2003 monitoring (Kootenay Eddy, Sandbar Eddy, Fort Shepherd Eddy, and Rock Eddy). This raises the question as to whether areas where juveniles have not previously been captured should continue to be sampled, or whether effort should be concentrated in the areas of highest density in order to capture the highest number of fish possible. Based on the one sample session not conducted in November (Phase 3 sampling in September 2004), juveniles also appear to be more widely distributed during non-winter months. The catch-rate during 2004 monitoring was higher in September than November and consideration should be given to additional seasonal sampling to determine the most ideal sample times.

The clumped distribution of juveniles in the study area also creates difficulties in developing a long term indexing protocol. Sampling can be “hit and miss”; a gill net set in the same location may catch 20 fish one day and zero the next. The large aggregations of juveniles in some areas have been shown to move from day to day. If a net is set near a large aggregation of fish and the fish move towards the net, large numbers will likely be captured. Conversely, if the fish move in the other direction or remain stationary, fewer fish will be captured. An example of this was provided by the differences in gill net catch rates in HLK Eddy from 2002 to 2005, specifically the low catch-rate recorded in 2005. The majority of effort was expended during overnight sets in 2002, 2004 and 2005, which resulted in catch-rates of 4.5, 8.1 and 2.4 fish/net-unit, respectively. Gill net sampling in HLK Eddy during 2003 consisted of daytime sets only and resulted in a catch-rate of 57 fish/net-unit. These variations in catch-rate likely reflect the behaviour of the aggregations of juvenile white sturgeon in the Keenleyside Reach rather than changes in the density of these fish in HLK Eddy.

5.1 SAMPLE METHODS

The analysis of the data suggests that the studies have developed to the point where standardized methods should continue to be employed in subsequent years. These methods should ensure standard release times and locations of the juvenile fish, maintain constant sampling sites each year, and ensure the gear type (e.g., gill net mesh size) deployed and the length of time the gear is deployed are constant. If specific hypotheses are forwarded that are to be subsequently tested by field sampling data, the power to detect an effect of a given magnitude with an assumed sample size should first be determined, prior to field deployment. The current program continues to have too many variables, such as time of release, location of release, location of capture, and capture methodology, to be able to effectively determine the influence of these variables on key life history parameters. Specifics for each of the current and proposed methodologies are discussed.

A primary goal of long term indexing will be unbiased collections of large numbers of fish, in order to improve the accuracy of subsequent survival estimates. Survival is one of the key variables in determining the numbers of fish needed to be released to achieve the desired population target of 2500 adults in the Keenleyside Reach as outlined in the UCWSRI Recovery Plan (UCWSRI 2002). Additional objectives will include the use of data obtained for wild juveniles to determine the conditions leading to recruitment, the assessment of growth and condition to guide stocking strategies, and to continue to improve our understanding of juvenile white sturgeon behaviour and habitat use.

5.1.1 Gill Nets

Gill nets were the main sample method, as well as the most effective, used to capture juvenile white sturgeon in several studies conducted on the Columbia and Kootenay rivers in Canada and the United States (Elliot and Beamesderfer 1993; Lee and Underwood 2002; Neufeld and Spence 2002 and 2004; Young 2002; Ireland et al. 2002). During a study that compared the efficiency and selectivity of gill nets, set lines, and angling at capturing white sturgeon in The Dalles Reservoir (308 to 347 km upstream from the mouth of the Columbia River), gill nets captured the highest percentage (approximately 60% of the total gill net catch) of juvenile white sturgeon between 30 and 70 cm FL (Elliot and Beamesderfer 1993). Gill nets were used as the basis for juvenile white sturgeon abundance indexing in the lower Columbia River in the United States (B. James, Washington Department of Fish and Wildlife, Vancouver, WA, pers. comm., 2002), on a limited basis from 1998 to 2002 in Lake Roosevelt by the Spokane Tribe of Indians (C. Lee, pers. comm., 2004), and for juvenile indexing in the Roosevelt Reach in 2003 and 2004 by the WDFW (Howell and McLellan 2006, 2007). Gill nets have also been the main capture method used during juvenile white sturgeon sampling in the Kootenay River and in Lake Roosevelt in recent years (Lee and Underwood 2002; Neufeld and Spence 2002 and 2004; C. Lee, pers. comm., 2002).

Based on data presented above and the results of 2002 to 2004 monitoring, gill nets were selected as the main method to capture juvenile white sturgeon in 2005. Gill nets should continue to be used for 2006 monitoring and will likely form the basis of future indexing programs, at least while there are still high numbers of young fish present in the study area. Gill net sampling is a relatively low cost capture method that can provide substantial numbers of juvenile white sturgeon from which life history data can be obtained. The continued use of gill nets in the study area will allow comparisons of indexing results with previous study years. Gill nets would likely be fished overnight during 2006 studies.

Gill net sampling should continue to be standardized with three panels (one of each mesh size; 5.1, 10.2 and 15.2 cm stretch measure) in each net being deployed at all sites. Sampling programs in the U.S. and Canada should have the same exact standards to ensure identical methods are followed in the field. Quality control and assurance measures should be developed and uniformly followed by all contributors to the study program. To minimize spatial effects on key life history parameter estimates, sampling effort should be proportionate to abundance. This stratification of effort should be part of the pre-season study design, based on previous years catches, and should not be modified by in-season gill net catch rates. If additional areas of aggregation of juvenile sturgeon are located by alternative methods, these sites can be added to the sampling program as supplements and should be sampled in all subsequent years of sampling. If subsequent analysis suggests minimal size/age segregation by sampling area, these sampling standards could be relaxed.

5.1.2 Underwater Surveys

The LBV proved to be an effective, low disturbance method of observing juvenile white sturgeon, their behaviour, and habitat use in the study area. This was due to the high water clarity of the Columbia River and the concentration of juvenile white sturgeon in localized habitats with deepwater areas and lower velocities relative to mainstem flows. During 2006 monitoring, LBV surveys should again be conducted at Waneta Eddy and Fort Shepherd Eddy for comparison with previous surveys. An extensive LBV survey should also be conducted at HLK Eddy and downstream areas of the river thalweg, if time and budgetary constraints permit.

5.1.3 Hook and Line Methods

Angling and set lines will become more effective as juvenile white sturgeon age and increase in size. The catch of juvenile white sturgeon has increased with each successive year of the Broodstock Collection Program since 2003. Set line captures have remained low, but this was likely due to the nature of the set lines used during broodstock collections (larger hooks targeting adults). Captures of age-4 juveniles on set lines used in the 2005 Broodstock Collection Program indicate older juveniles are starting to recruit to the broodstock collection gear. The catch of juvenile white sturgeon using hook and line methods will likely continue to increase as juvenile white sturgeon age and increase in size. Angling and set line sampling will again be assessed using the results of the 2006 Broodstock Collection Program. Angling and sampling using modified set lines (to target juveniles) should also be conducted during 2006 monitoring. This sampling would likely be limited and used mainly as a test of the effectiveness of hook and line methods at capturing older juveniles.

5.1.4 Underwater Remote PIT Tag Reader

The underwater PIT tag reader pilot program was successful in terms of proving that the system will work. During the first four days of successful operation (before problems occurred), the system detected 29 individual PIT tags, of which six were detected twice. This system has the potential to detect hundreds of tags over a one to two month period. This would substantially increase the number of encounters of tagged juveniles and improve the 2006 survival estimate without the increased stress and potential mortality that would be associated with increased gill net (or other) sampling. The system would be deployed during 2006 monitoring with better anchoring and a targeted depth of 18 to 20 m (i.e., in the deepest portion of Waneta Eddy). The system would be downloaded and checked more frequently to aid in preventing problems and the potential loss of data.

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APPENDIX A

RELEASE DATA

APPENDIX B

FISH CAPTURE AND OBSERVATION DATA

APPENDIX C

LIFE HISTORY INFORMATION

APPENDIX D

MOVEMENT DATA

APPENDIX E

PROGRAM MARK SURVIVAL ANALYSIS

Juvenile hatchery white sturgeon survival from time of release to time of capture.

Parameter estimation by Monte Carlo Markov Chain sampling in Program MARK for selected model.

Phi (1) is survival from initial release to fall capture for fish released in 2002; Phi (2) is survival from initial release to fall capture of fish released in 2003, 2004 and 2005; Phi (3) is annual survival rate for all subsequent age groups and cohorts after the first 6 months in the river.

Real Function Parameters of {phi (1,2=hatch, 3=all else) p (t with t=4=t=3)}MCMC}

Parameter	Mean	St. Dev.	Median	Mode	Percentile							
					2.5th	5th	10th	20th	80th	90th	95th	97.5th
1:Phi	0.4268	0.0968	0.4170	0.3550	0.2661	0.2850	0.3088	0.3404	0.5143	0.5631	0.5987	0.6256
2:Phi	0.2054	0.0465	0.1995	0.1700	0.1312	0.1377	0.1496	0.1630	0.2481	0.2695	0.2889	0.3050
3:Phi	0.9732	0.0186	0.9777	0.9893	0.9271	0.9362	0.9466	0.9586	0.9892	0.9927	0.9949	0.9964
4:p	0.0113	0.0032	0.0108	0.0102	0.0064	0.0069	0.0075	0.0085	0.0139	0.0156	0.0171	0.0184
5:p	0.0170	0.0042	0.0163	0.0140	0.0106	0.1118	0.0120	0.0132	0.0205	0.0227	0.0245	0.0263
6:p	0.0305	0.0068	0.0298	0.0240	0.0197	0.0208	0.0222	0.0240	0.0364	0.0399	0.0427	0.0455

APPENDIX F

PROJECTIONS OF JUVENILE WHITE STURGEON SURVIVAL AND ABUNDANCE

PLATES