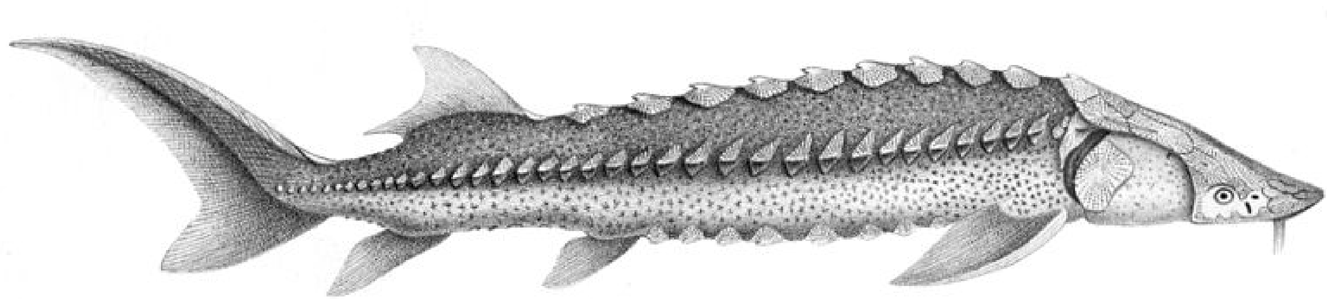
Rocky Reach Reservoir White Sturgeon Indexing and Monitoring Annual Report 2012



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Draft Report

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This report is a summary of the Public Utility District No. 1 of Chelan County *Rocky Reach Reservoir White Sturgeon Indexing and Monitoring* annual research study that was conducted in 2012. This research project is currently being led by Blue Leaf Environmental, Inc. in collaboration with LGL Limited and Columbia Research Specialists. Presiding project research scientists and contact information are listed below.

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Abstract

Chelan County Public Utility District has initiated a white sturgeon (*Acipenser transmontanus*) hatchery supplementation program for the Rocky Reach Reservoir (Reservoir) on the Columbia River. The program has the overall goal of promoting white sturgeon population growth in the Reservoir to a level that is commensurate with available habitat by 2036. In April 2011 the first annual release of juvenile sturgeon (n=6,376) took place and in the spring of 2012 monitoring activities began. The monitoring program consists of a three year indexing study that uses passive integrated transponder (PIT) tags for mark and recapture; and a three year acoustic telemetry investigation of sturgeon movement within the Reservoir. Acoustic receivers (Vemco VR2W, n=15) were deployed throughout the Reservoir beginning in April 2012 and in the spring and fall a total of 35 sturgeon were tagged with acoustic transmitters. To date, movement information has shown 25 of the 35 (71%) sturgeon have not traveled more than 10 km, remaining fairly close to release locations. There has been high use of the upper Reservoir and little downstream movement. Due to low hatchery numbers and a small 2012 release no indexing surveys occurred in 2012. Nevertheless, recapture data from a Northern Pikeminnow Removal Program allowed preliminary estimates of survival and growth to be calculated. Survival of the hatchery fish released in 2011 during their first 2.8-5.4 months in the Reservoir was estimated to be 14.3% (SE = 5.9%), though fish reared at Chelan Hatchery from wild-origin broodstock had a 25.3% survival rate (SE = 10.2%). Extrapolated growth rates of juvenile white sturgeon in the Reservoir averaged 175 mm/year for recaptures in 2011, and 61 mm/year for recaptures in 2012.

Introduction

White sturgeon (*Acipenser transmontanus*) is the largest species of freshwater fish in North America and provides the Columbia River basin with an important cultural, recreational and ecological resource. The population of white sturgeon in the unimpounded reach of the Columbia River below Bonneville Dam is likely the largest and most productive in the world (DeVore et al. 1995). However, populations in upstream impounded reservoirs of the Columbia River, though varied, are generally smaller and less productive (Beamesderfer et al. 1995). Reductions from historical abundance are a result of several anthropogenic factors, including commercial harvest rates in the late 1800s that peaked at over 2,500 tons, and the construction and operation of hydropower dams that restricted sturgeon movements and modified local habitat features (North et al. 1993, Parsley and Beckman 1994, Beamesderfer et al. 1995, Wydoski and Whitney 2003).

In 2001 and 2002, Chelan County Public Utility District (Chelan PUD) commissioned a mark and recapture study to better understand the resident population of white sturgeon in the Rocky Reach Reservoir (Reservoir) prior to the Federal Energy Regulatory Commission (FERC) relicensing of Rocky Reach Hydroelectric Project (Project). The purpose of these studies was to estimate the population status including size, characteristics, and structure. These studies resulted in an estimated sturgeon population of approximately 50 to 115 fish that included the presence of younger age classes, which indicated either some natural recruitment had happened in certain years, likely high water years with favorable spawning conditions, or emigration from upstream populations had occurred (Golder Associates 2003). From this information, the White Sturgeon Technical Group was formed in 2004 and is comprised of stakeholders from Washington State, federal and tribal agencies along with Chelan PUD biologists. The role of the White Sturgeon Technical Group was to advise and coordinate the effort to develop the Rocky Reach Comprehensive White Sturgeon Management Plan (WSMP).

In 2005, the WSMP was completed and has been adaptively implemented over the term of the new FERC license beginning in 2009, with the overall goal of promoting white sturgeon population growth in the Rocky Reach Reservoir to a level that is commensurate with available habitat by 2039. This goal is to be met with the following objectives: 1) increase the white sturgeon population in the Reservoir through supplementation to a level commensurate with available habitat and allowing for appropriate and reasonable harvest; 2) determining the effectiveness of the supplementation program; 3) determining the carrying capacity of available habitat in the Reservoir; and 4) determining natural reproduction potential in the Reservoir, with adjustments to the WSMP supplementation program accordingly. In 2010, Chelan PUD began working towards fulfilling the first objective with the initiation of the supplementation program through the capture of wild fish for broodstock. To this end, the first group of 6,376 hatchery-reared juvenile sturgeon were PIT-tagged in March 2011 and released into the Reservoir in April of 2011.

In 2012, Chelan PUD commenced addressing the second objective of the WSMP, how effective is the supplementation program, by the implementation of the monitoring program outlined by the WSMP. The monitoring program includes two distinct focuses, the initiation of long term indexing program with a preliminary three year indexing study that uses passive integrated transponder (PIT) tags for mark and recapture and a three year acoustic telemetry investigation of sturgeon movement within the Reservoir. The indexing study will consist of a focused fishing effort in Reservoir to recapture juvenile sturgeon released during each year’s supplemental hatchery release. All released fish will have been tagged with PIT tags and their recapture information will allow Chelan PUD to assess survival and growth rates as well as identify their distribution and habitat selection. The primary goal of the acoustic telemetry investigation is to assess the emigration rates of each supplementation release over three years while additionally providing some insight on the seasonal behavior and habitat use of sturgeon in the Reservoir. Throughout the duration of the monitoring program, information from both PIT and acoustic telemetry studies will be used to define factors that may be contributing to: (1) population growth; (2) the availability and carrying capacity of suitable rearing habitats; and (3) the carrying capacity of the Reservoir.

This report summarizes activities carried out in the initial year of research, 2012.

Methods

Study Site

The Rocky Reach Reservoir on the Columbia River is formed by Rocky Reach Dam (river kilometer, RKM 762) and extends 67 km upstream, northeast to Wells Dam (RKM 829) (Figure 1). There are two tributaries

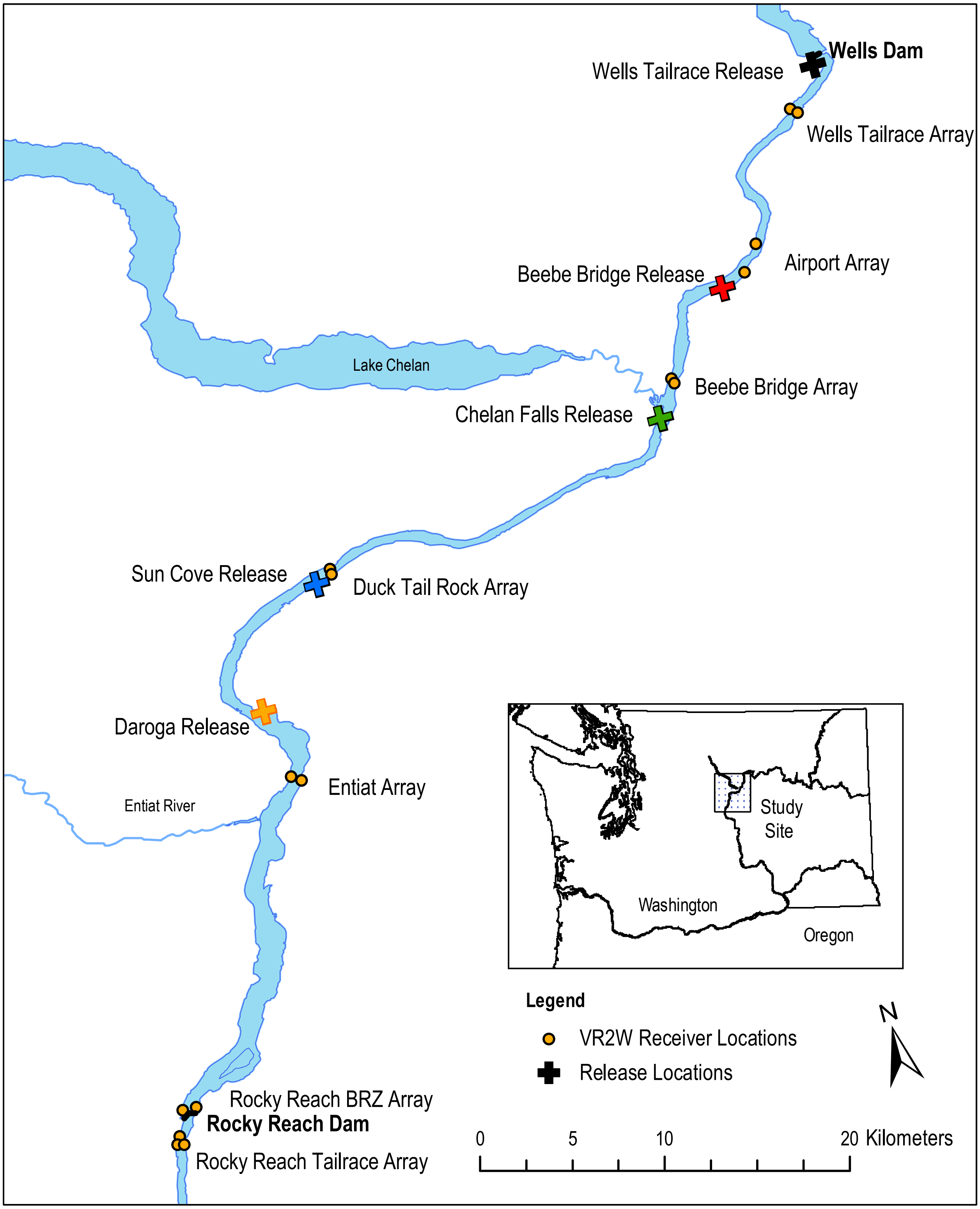

Figure 1. Overview of Rocky Reach Reservoir study area with locations of Vemco VR2W receiver deployment locations and fish release locations in 2012.

that enter the Reservoir from the west, the Entiat River (RKM 778) and the Chelan River (RKM 810). Mean discharge through the Reservoir ranges seasonally from 1,700 m^3/s (60 kcfs) to 5,100 m^3/s (180 kcfs) and mean temperatures range seasonally from 4°C to 19°C.

Timeline Shift

In the original study design, PIT-tagged hatchery sturgeon were to be released in the spring of 2011, 2012, and 2013, with active tracking and indexing studies occurring between 2012 and 2014. However, very few hatchery sturgeon were available for release in 2012 due to detection of white sturgeon iridiovirus in juveniles. The goal was to release 6,500 PIT-tagged as well as 65 acoustic-tagged juvenile sturgeon in 2012, but only 137 PIT-tagged and 10 acoustically tagged fish were released. Due to these circumstances, the timeline was extended to maximize the ability to collect informative results, as follows:

- ≤ 6,500 PIT-tagged sturgeon to be released in 2011, 2013, and 2014, with subsequent stocking levels to be determined by the Rocky Reach Fish Forum (RRFF);
- Indexing surveys scheduled to occur each year from 2013 to 2015; and
- Active acoustic tagging and tracking schedule remain the same, occurring from 2012-2015.

Northern Pikeminnow Removal Program

Occurring concurrently with the present sturgeon study is a *Northern Pikeminnow Removal Program*, sponsored by Chelan and Douglas County PUDs. Fishing for northern pikeminnow (*Ptychocheilus oregonensis*) occurred throughout the Reservoir, but especially in the tailrace of Wells Dam. Details of the rationale, methods and results can be found elsewhere (e.g., Jerald 2012). However, sufficient numbers of juvenile white sturgeon were captured as by-catch that a description of certain aspects of the program is warranted in this report.

In 2011, northern pikeminnow fishing occurred throughout the Reservoir, but especially in the tailrace of Wells Dam (the 3.2 km area immediately downstream of the dam), for 88 days between 7 April and 11 November. In 2012, the fishing effort was conducted in 64 days between 21 June and 13 October. Typically, 12 to 14 setlines were deployed on each day of fishing. Each setline was comprised of a main line attached to buoy and another line that was weighted at each end with ~100 baited hooks attached. The bait consisted of pet-store crickets (*Gryllus assimilis*) and night crawlers (*Lumbricus terrestris)*. Hook leaders were comprised of 6-pound monofilament line, allowing for the break-away of larger fish such as walleye or adult salmonids. Hooks of varying sizes (sizes 2-6) were deployed at approximately 2 foot intervals along each setline. Setlines were checked once a day, allowing crews to release all non-target fish back into the river unharmed.

All sturgeon that were incidentally captured on northern pikeminnow setlines were measured (fork length, and girth in 2012), weighed (in 2012 only), examined for scute marks, and scanned for PIT tags. Those captured with PIT tags were presumed to be of known identity (with known age, length, and weight at the time of release). Those without PIT tags were aged using fin-ray analysis (Rien and Beamesderfer 1994), and a PIT tag was inserted. All fish were released in a live and healthy state.

Acoustic Tags and Releases

In order to monitor the movements, habitat use, and emigration rates of stocked juvenile white sturgeon, a subset of individuals were tagged with acoustic transmitters. Telemetry gear was in place prior to knowledge of the small 2012 release size, therefore, acoustic monitoring commenced as planned with additional fishing effort to recapture and tag a portion of the 2011 hatchery reared and released sturgeon from the Reservoir. The WSMP outlines acoustic tagging of 1% of each year's supplementation release; however, in order to increase sample size, ten individuals (7% of release) from the 2012 hatchery release were tagged with acoustic transmitters. These sturgeon were tagged with Vemco V7-2 (1.6 g in air, mean delay 600 sec, estimated battery life 185 days) acoustic tags in the hatchery on 18 April 2012. All tagged fish were held for one month to observe tag retention and fish health before being released with the 2012 hatchery release on 16 May 2012, 6 km upstream of Beebe Bridge (Figure 1).

Additionally, 25 sturgeon were recaptured using setlines and tagged with Vemco acoustic transmitters over two periods, 9-13 September (14 fish) and 24-27 October (11 fish) (Table 1). All but one of the 25 recaptured and acoustically tagged fish were from the 2011 supplementation release and had been at large in the reservoir for over a year. Setline methods used to capture juvenile sturgeon were the same as those used under the *Northern Pikeminnow Removal Program* (methods described above). Twenty of the recaptured fish were tagged with V9-2 tags (4.7g in air, mean delay 210 sec, estimated battery life 838

Table 1. Tagged and released white sturgeon including number, location, and type of tags during 2011 and 2012. All fish were PIT tagged at initial release. With the exception of hatchery release BB03 all acoustically-tagged fish were recaptured in the field on the same day as their release.

Release Code	Location	Release Date and Time	PIT Tags Released	Acoustic Tags Released
BB01	Above Beebe Bridge	4/20/2011 15:00	3541	
BB02	Above Beebe Bridge	4/21/2011 15:00	2835	
BB03	Above Beebe Bridge	5/16/2012 14:20	137	10
WT01	Wells Dam Tailrace	9/10/2012 17:45		4
WT02	Wells Dam Tailrace	10/24/2012 12:45		2
WT03	Wells Dam Tailrace	10/25/2012 13:24		1
WT04	Wells Dam Tailrace	10/26/2012 11:00		2
WT05	Wells Dam Tailrace	10/27/2012 13:23		2
CF01	Chelan Falls Boat Launch	9/11/2012 18:00		4
CF02	Chelan Falls Boat Launch	10/25/2012 15:37		1
SC01	Sun Cove Boat Launch	9/12/2012 16:27		3
SC02	Sun Cove Boat Launch	10/27/2012 15:43		2
DR01	Daroga Boat Launch	9/13/2012 17:34		3
DR02	Daroga Boat Launch	10/26/2012 14:10		1

days) and five were tagged with V9P-2 tags (6.4 g in air, mean delay 210 sec, estimated battery life 581 days) which have pressure sensors and transmit the depth of the tag with the acoustic detection. These sturgeon were distributed among four release locations throughout the Reservoir to observe behavior and habitat use: Wells Tailrace, Chelan Falls, Sun Cove and Daroga State Park (Figure 1, Table 1). For analysis sturgeon with detections showing active movement in and out of detection range are assumed to be live while the fate of undetected fish is unknown.

Surgical Implantation

The surgical implantation of acoustic transmitters took place at the Chelan Hatchery (11-13 September 2012) or the Wells Dam tailrace boat launch (9 September and 24-27 October 2012) with a truck-based mobile tagging station. Chelan PUD hatchery staff performed all surgeries in the hatchery and both Chelan PUD and Blue Leaf staff performed mobile surgeries. Sturgeon selected for tagging at the hatchery or recaptured were place in an anesthesia bath (MS-222; 60-80 mg/L) until a loss of equilibrium was attained, at which time they were examined for markings/abnormalities and had biometrics recorded. The fish were then transferred to a surgical table and administered a maintenance dose of anesthesia (MS-222; 19 mg/L). Acoustic transmitters were implanted through an incision centered approximately between both the pectoral and pelvic fins and the lateral and ventral scute lines. The incision was then closed with two to three sutures and the fish was transferred to a recovery bucket with fresh water and aeration. Surgical procedures followed the most up-to-date basin-wide standards (see Liedtke et al. 2012). Sturgeon were held for at least 30 minutes to ensure adequate recovery prior to release.

Receiver Deployment and Data Management

In order to monitor the movements of acoustically-tagged juvenile sturgeon, 15 Vemco VR2W receivers were deployed throughout the Rocky Reach Reservoir and in the Rocky Reach tailrace. Prior to deployment, range testing was performed in a variety of acoustic environmental in the Reservoir and Rocky Reach tailrace to determine a reasonable expectation of detection coverage for the VR2W receivers. There were two methods of deployment: (a) mounted to a steel or concrete anchor built for the purpose of positioning telemetry equipment on the riverbed; or (b) deployed directly on a line using an anchor with floats to keep the line upright in the water column. For both methods, the gear was secured to the shoreline with steel cable or polypro line. Receivers were deployed in pairs at detection locations spread throughout the Reservoir to create zones between which movements could be detected (Figure 1). Two receivers were used at each location to ensure adequate detection coverage over varied bathometry and provide a failsafe if a receiver was damaged or lost. A total of three receivers were deployed below Rocky Reach Dam to ensure detection of emigration in a noisy and fast moving environment.

Receivers were pulled to the surface, inspected, and downloaded approximately bi-monthly. Data were downloaded to a field laptop running Vemco VUE software and then subsequently transferred to a SQL database for processing and analysis. Detections of acoustic tags were filtered for invalid data including non-study tags, detections before release, and detections recorded less than 3 times in a 30 minute period.

Population Indexing

Recaptured sturgeon were recorded in both 2011 and 2012 as part of the *Northern Pikeminnow Removal Program* or during efforts to capture sturgeon for acoustic tag application (full indexing efforts will begin in 2013 as previously described). It was possible to perform preliminary analyses of growth rates (DeVries and Frie 1996), condition factor (Anderson and Neumann 1996, Bolger and Connolly 1989) and survival (see below). For fish caught more than once in a given year, data from the first recapture was used in analyses of growth and condition factor.

Survival Estimation

Survival of the hatchery-released juvenile sturgeon was assessed using mark recapture data and a Cormack-Jolly-Seber (CJS) model (Lebreton et al. 1992). Analyses were performed using the program 'MARK' (White and Burnham 1999). The model was used to estimate the probability of detection (p) during the 2011 northern pikeminnow sampling effort, and apparent survival (ϕ) for the period between release and the 2011 northern pikeminnow sampling. The CJS model requires two surveys 'post release' to be able to distinguish the effects of survival from detection probability. With the data available (pikeminnow bycatch from 2011 and 2012), it was possible to estimate the survival of fish released in 2011, for the period from release (April 2011) until the northern pikeminnow sampling period in 2011 (i.e., for the first 2.8-5.4 months in the Reservoir).

In future years, several CJS models will be tested (e.g., allowing p and ϕ to vary among survey periods; forcing p to be the same for each survey year; forcing ϕ to be the same for all years; forcing both p and ϕ to be the same for each survey year), and AIC will be used to select the most parsimonious among them. This year, because only a single survival estimate was being calculated, it did not make sense to run multiple models. However, in future years, sturgeon survival rates will be compared between rearing locations (i.e., Marion Drain vs. Chelan) and parental origins (i.e., wild-origin broodstock vs. captive broodstock) by including the factors as model terms. This year, too few recapture data were available to resolve differences among these groups.

The survival models don't explicitly allow for emigration, but in future years, we expect to be able to calculate 'true' survival rates from apparent survival rates using emigration rates that will be determined from the active tracking results. For now, we have used simulation modeling to speculate about the effect of various emigration rate values on survival estimates. The number of fish in the 'available' population at 0% emigration was assumed to be that at release. Emigration rates were varied from 0% to 80% (in 10% increments), which reduced the numbers of available fish in the simulated populations. Using the simulated population numbers, it was possible to re-calculate survival estimates, and hence determine the potential effects of emigration on perceived survival.

Database Development

To establish and maintain a sound data set for the Chelan PUD long term white sturgeon supplementation and monitoring program, our team has worked closely with Chelan PUD biologists and IT staff to build the foundation of a 20-year project database. The database was created in SQL Server, and a user interface was created in Microsoft Access for viewing information, importing and updating data, querying, and generating reports. Additionally, WebFOCUS software has been used for processing and writing reports. The database includes each fish's study information that has been released into the Reservoir, such as the hatchery and broodstock; biometric characteristics; acoustic and PIT tagging information; and release, recapture, and detection by acoustic tag and/or PIT tag. The database and project files are backed up and synced to Chelan PUD servers on a regular basis.

Currently, our team is working on further design and development changes as project needs and tasks progress. With the basic structure in place, upkeep has been maintained with ongoing data management, quality control, and information processing for the database and related systems used during the project.

Results

Environmental Conditions

The river flows during 2012 were considerably higher than the ten year mean throughout the spring and summer months. The average difference in spring and summer over the ten year mean was 62 kcfs with peak flows above 300 kcfs (Figure 2). Both 2011 and 2012 were considered high water event years for the Columbia River basin. Early in 2012, temperatures were fairly close to the 10 year mean, whereas those from mid-June through September ranged from 1-2°C below the 10 year mean (Figure 2).

Acoustic Telemetry

From the first release of acoustically tagged sturgeon on 16 May 2012 to the final download of 2012 (6-7 December 2012), 120,530 unique detections were recorded on Vemco VR2W receivers deployed throughout Reservoir and in the tailrace of Rocky Reach Dam (Table 2). Of the 35 sturgeon released with implanted acoustic tags, 29 (83%) have been detected on at least one receiver with three or more detections within a 30 minute period. A substantial majority, 94% of all detections, were recorded on three receivers, the Wells Tailrace 1 and 2 receivers and the Airport 2 receiver (Table 2, Figure 3). These three receivers were located near areas in which tagged sturgeon resided for extended periods throughout the study period. Interestingly, the Airport 1 receiver, which was located among the three top-detecting receivers (and only 1.2 km upstream of Airport 2 receiver), had far fewer acoustic detections (0.4% of total). The Airport 1 receiver nevertheless recorded a similar number of individuals, suggesting that it was not located near the areas in which sturgeon resided, but detected them passing by (Figure 3).

The largest number of individual tags and the longest residence times at receivers were recorded at or upstream of Beebe Bridge, in the top 18 km of the 70 km study area (Table 2, Figure 4). The majority of the movements by released fish were in an upstream direction over a mean distance of 8 km; four of the nine fish released in the bottom half of the Reservoir (Sun Cove and Daroga) returned at least as far upstream as Beebe Bridge (Figure 3). With the exception of Wells Dam tailrace releases, which were at the very upstream portion of the Reservoir, there were 38 upstream movements between the release point and detection arrays, compared with six downstream movements for a net upstream movement of 87.4 km for all fish (Table 3). The mean distance of downstream movements was 5 km and all of the recorded

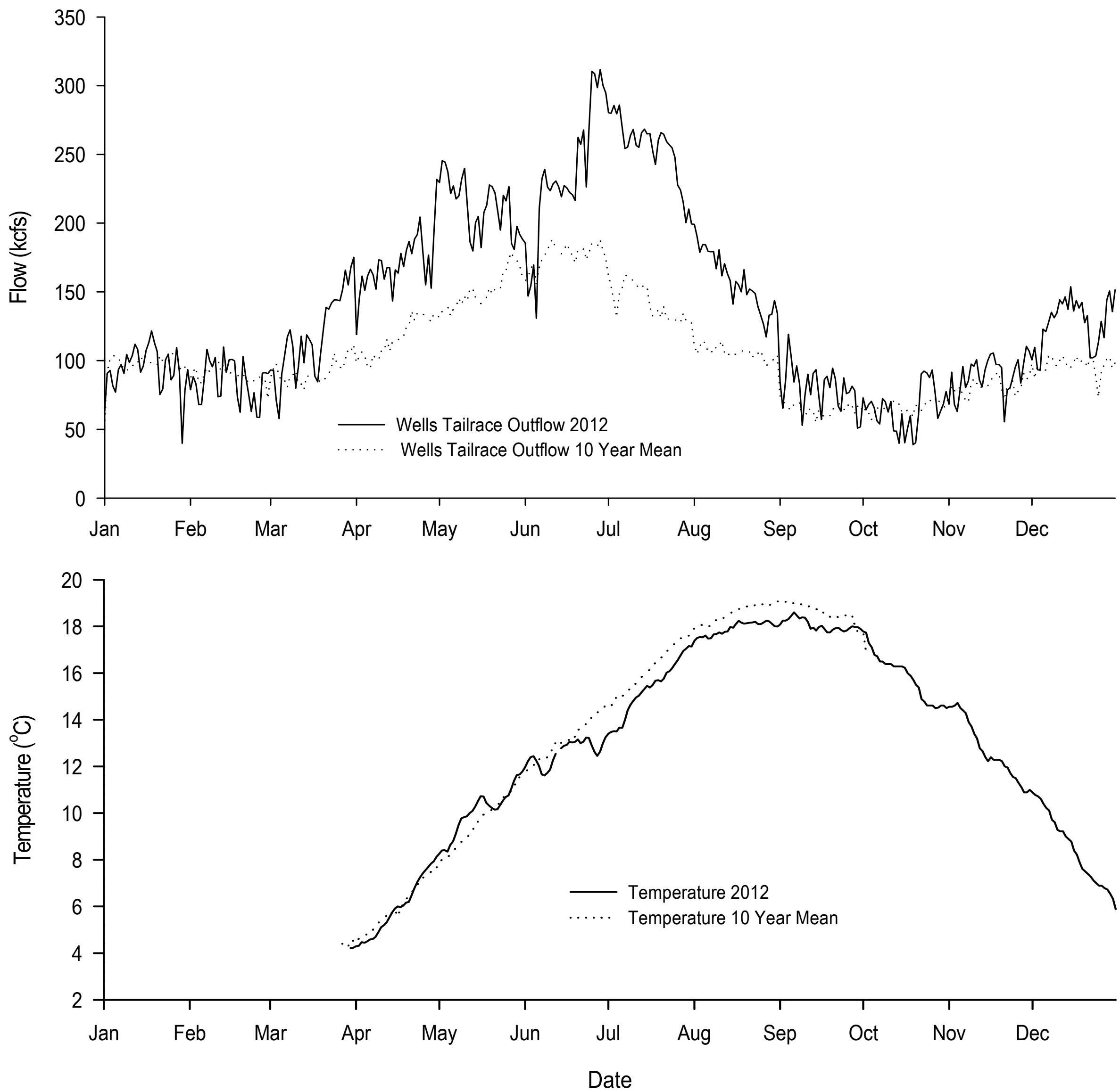

Figure 2. **River flow (top) and temperature (bottom) including the ten year mean measured in the Wells Dam tailrace water quality site (data source: http://www.cbr.washington.edu/dart/river.html).**

Table 2. Number of individual white sturgeon detected at each receiver along with the total number of detections for each receiver. Note that Beebe Bridge 2 was not installed from 20 November to 7 December due to a snagged cable.

Detection Location	RKM	Number of Individual Tags Detected	Total Detections
Wells Tailrace 1	826.8	13	18,683
Wells Tailrace 2	826.7	15	57,297
Airport 1	819.0	12	447
Airport 2	817.8	17	37,468
Beebe Bridge 1	811.2	13	1,307
Beebe Bridge 2	811.1	9	1,855
Duck Tail Rock 1	794.0	9	2,753
Duck Tail Rock 2	793.8	9	628
Entiat 1	780.7	3	53
Entiat 2	780.7	2	32
Rocky Reach BRZ 1	762.9	0	0
Rocky Reach BRZ 2	762.9	0	0
Rocky Reach Tailrace 1	761.8	1	2
Rocky Reach Tailrace 3	761.2	1	2
Rocky Reach Tailrace 2	761.2	1	3
Total		29	120,530

Table 3. Number of tags released by release site with number detected at least one receiver including movements up and downstream between release and detections arrays and total distance covered.

Release Site	Total Tags Released	Tags Detected	Upstream Movements	Total km Upstream	Downstream Movements	Total km Downstream	Net Upstream Movement
Wells Tailrace	11	8			16	101.4	-101.4
Beebe Bridge	10	9	11	28.8	3	21.4	7.4
Chelan Falls Boat Launch	5	4	10	55.4			55.4
Sun Cove Boat Launch	5	4	7	34.8			34.8
Daroga Boat Launch	4	4	10	115.1	3	23.9	91.2
Totals	35	29	38	234.1	22	146.7	87.4
Totals without Wells Tailrace			38	234.1	6	45.3	188.8

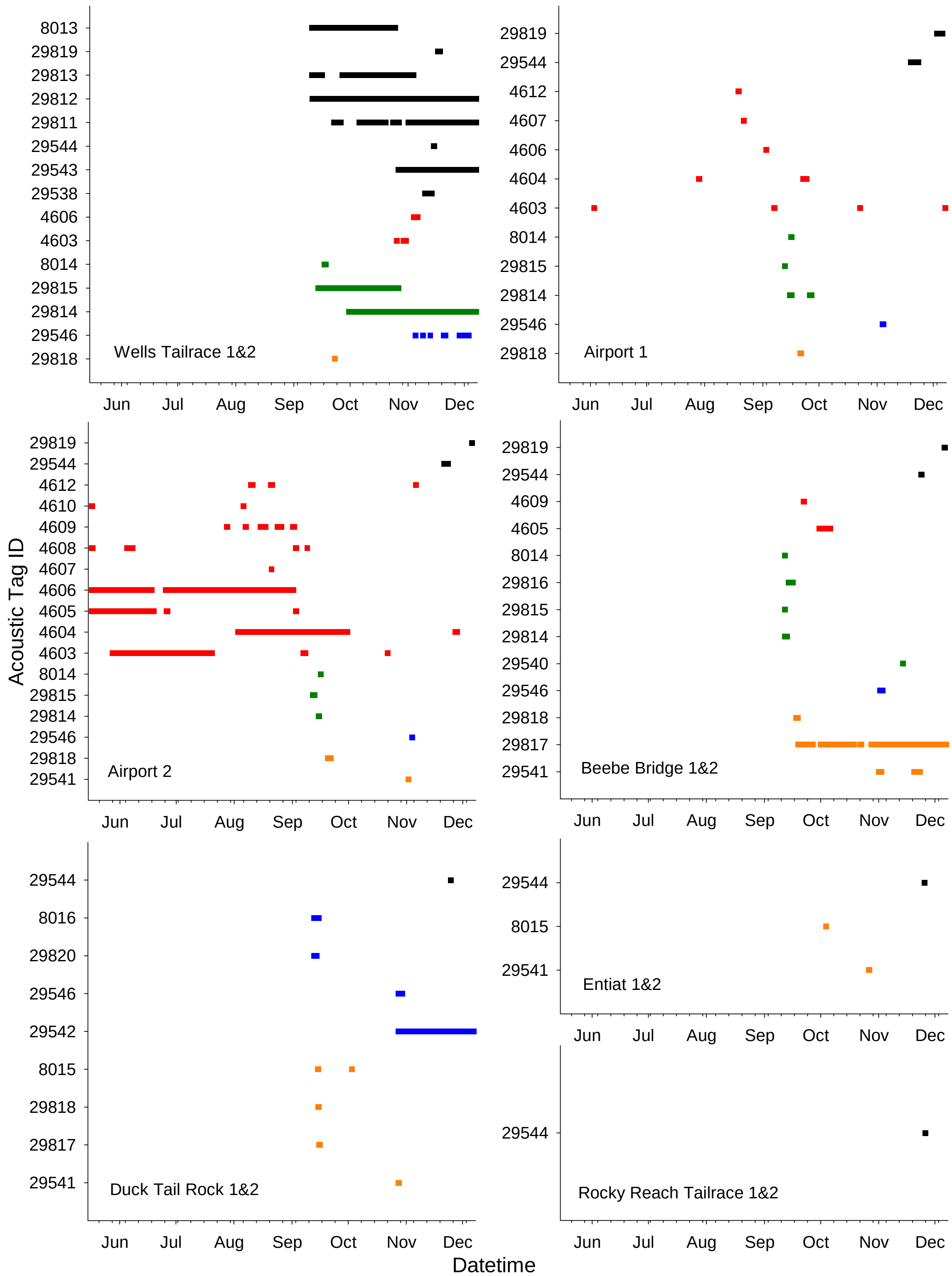

Figure 3. **Detections of all acoustically-tagged study fish, by detection location, from the first release (16 May 2012) to the last download (6-7 December 2012). Detections are colored by release location as follows: Wells Tailrace (black), Beebe Bridge (red), Chelan Falls (green), Sun Cove (blue), and Daroga (orange).**

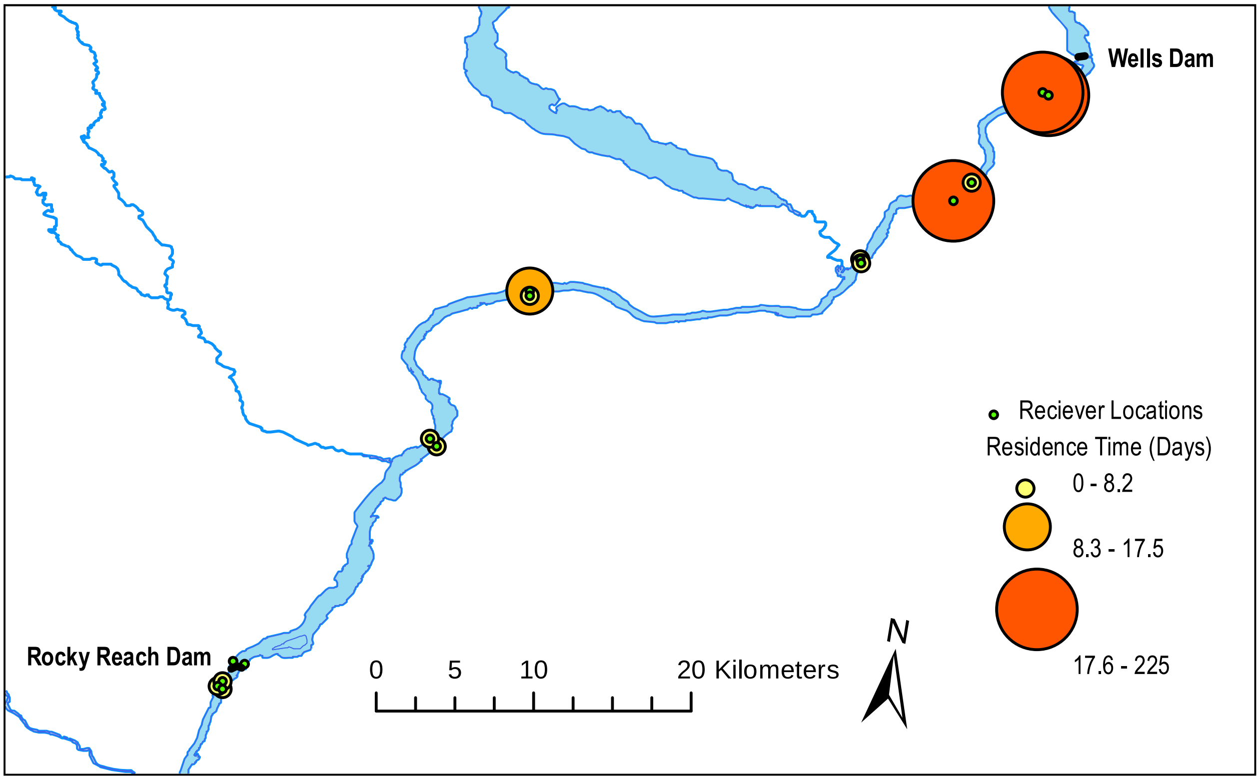

Figure 4. Residence time in days of all tagged sturgeon at each receiver throughout the study area, from the first release (16 May 2012) to the last download (6-7 December 2012).

downstream movements occurred after 21 September, with the majority recorded in October and November (2012). Ten of the 35 tagged fish (29%) moved more than 10 km upstream (6), downstream (3) or both (1). Complete detection histories of each acoustic tagged sturgeon are found in Appendix B.

Sturgeon from the initial hatchery release above Beebe Bridge (BB03) stayed close to their initial release site, with nine of the ten fish being detected at Airport 2 (0.8 km upstream), many for months at a time. In late September through November, two individuals from the BB03 release moved up to the Wells tailrace receivers, and two individuals moved down to the Beebe Bridge receivers (Figure 3). Of the 11 fish released in the Wells tailrace (WT01-05), nine stayed close to their release location at or above the Wells tailrace receivers (which are 2.5 km downstream of the release site). In contrast, three of the five fish released at Chelan Falls (CF01-02) immediately moved back upstream 18 km to the Wells tailrace receivers. Likewise, as previously mentioned, four of the nine fish from the lower reservoir releases (SC01-02 & DR01-02) quickly moved upstream. In fact, one individual (ID 29818, Figure B-7) traveled 42.3 km in seven days (within two days of release) to return to the general proximity of its recapture location.

Five sturgeon were release with depth-sensor tags, four of which have been detected since release. Three of these fish were detected for short periods of time as they passed by receivers; whereas one (ID 8013) resided near the two Wells Tailrace receivers from the time of its release (10 September) to its second recapture on 25 October 2012 (Figure 5). This sturgeon utilized much of the available depths ranging from 5 to 20 m (mean depth 14.5 m) but showed periods of tighter depth use. For example, there was an 8-day period starting 26 September during which this sturgeon kept to a 3 to 4 m depth range, whereas it more typically occupied a 10 to 15 m depth range each day. Diel patterns of shallower at night and deeper during the day were observed during specific periods (Figure 6). However, over the entire detection period of ID 8013 diel movements were variable and showed no statistical difference between daylight and nighttime hours. When looking at the hour of each detection for all fish at all receiver locations there was a 16% increase in the number of detections at nighttime hours over day, likely a result of movements shallower (close to near-shore receiver locations) (Figure 7).

Emigration

A total of 31 PIT tagged sturgeon from the 2011 supplementation release (0.49% of total) have been detected downstream of the Reservoir, 28 at the Rocky Reach Dam Juvenile Bypass System (JBS) PIT antennas, two at the McNary Dam Juvenile Bypass PIT antennas, and one which was recaptured in the Rocky Reach tailrace in June of 2011 (Figure 8). Most of this emigration was immediate as 25 of the 31 fish were detected at the Rocky Reach JBS within 3 days of release. The original source of these fish was as follows: 26 (84%) Marion Drain Hatchery from captive broodstock, 4 (13%) Chelan Hatchery from captive broodstock, and 1 (3%) Marion Drain Hatchery from wild-origin broodstock.

To date, only one acoustic tagged sturgeon from the Chelan PUD supplementation program has been detected emigrating from the Reservoir, moving 58 km from the Airport 2 receiver to the Rocky Reach tailrace receivers in 78 hours (Wells tailrace release, ID 29544, Appendix B, Figure B-3). The movement occurred at the end of November, 583 days after initial release and approximately one month following recapture, acoustic tagging and release.

Growth and Survival

PIT-Tagged Fish Recaptured in 2011

In 2011, a total of 66 white sturgeon capture events were recorded during pikeminnow fishing efforts. Each fish was scanned, and 65 were found to have been PIT tagged (Figure 8), the 66th fish was presumed to be from a group of sturgeon that were PIT tagged and released by Columbia River Inter-Tribal Fish Commission (CRITFC) into Rock Island Reservoir. Of the 65 PIT tagged fish, three were captured twice in 2011, leaving a total of 62 unique individuals that were recaptured in 2011. Based on PIT-tag identities, all 62 sturgeon were PIT-tagged by Chelan PUD in March 2011 (as part of the group of 6,376 PIT-tagged hatchery sturgeon that were released in April 2011). Seven fish that were in the Reservoir for less than 60 days were not included in analyses of growth, condition or survival, leaving 55 unique fish that were recaptured between 15 July and 30 September 2011 (i.e., that were at large for between 2.8 and 5.4 months post-release and available for further analysis).

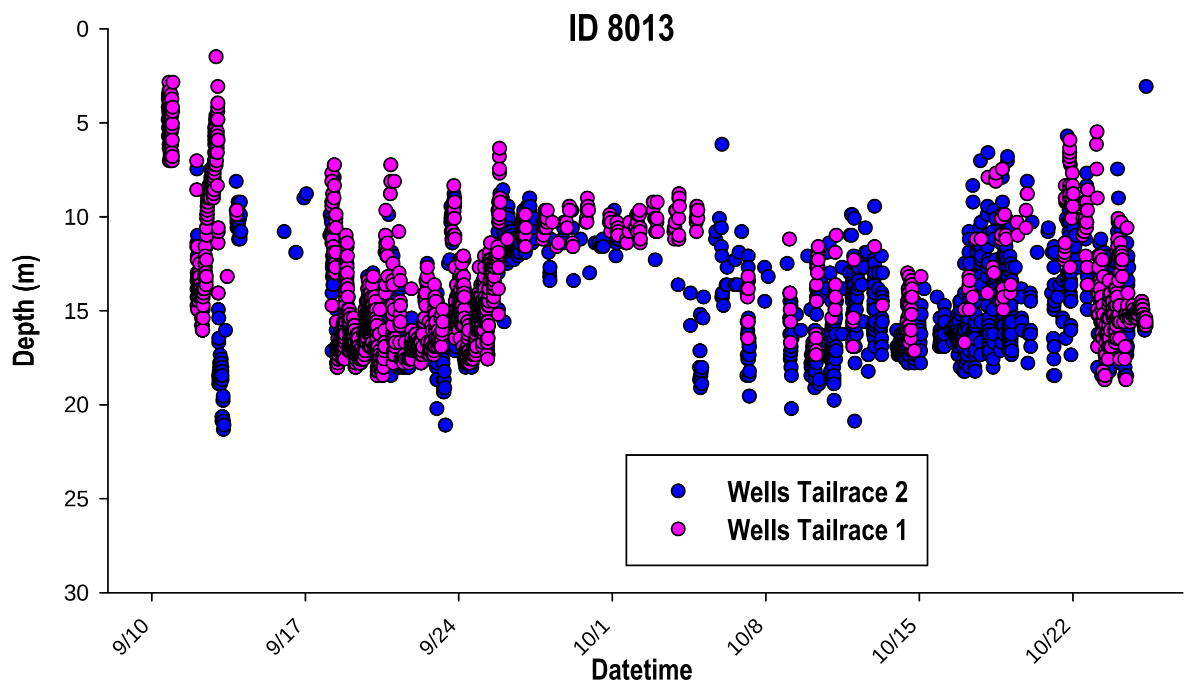

Figure 5. **Depth of the tag (m) transmitted with detections from ID 8013 from the two Wells Dam tailrace receivers.**

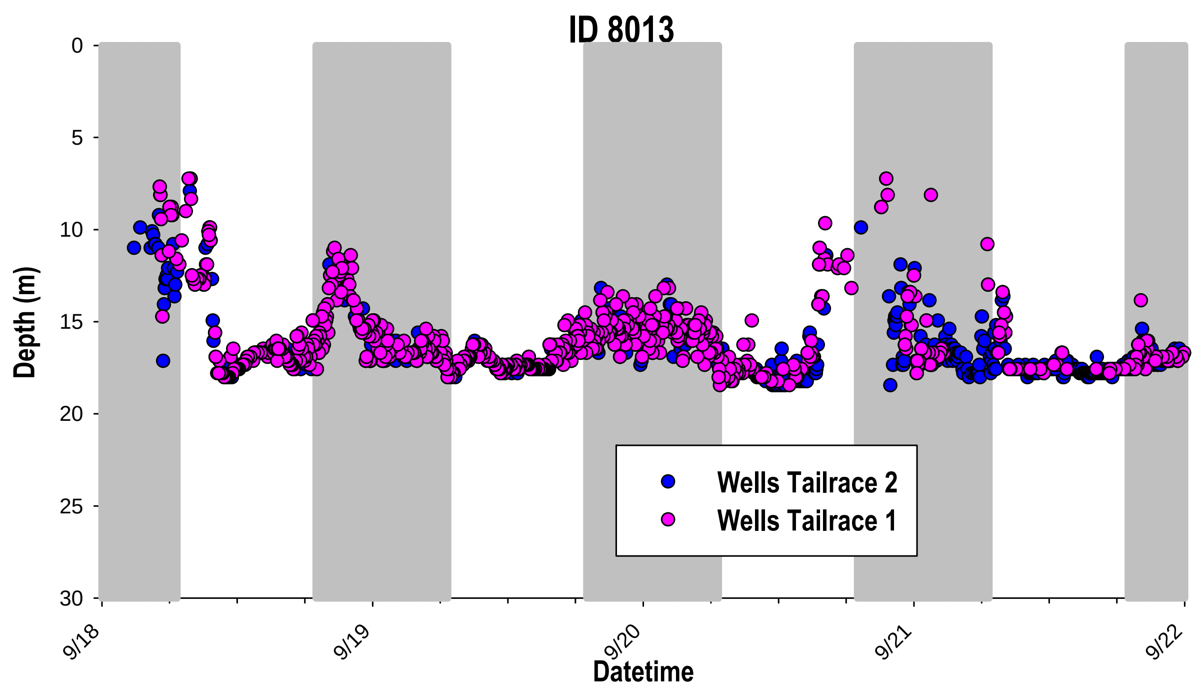

Figure 6. **Depth of the tag (m) transmitted with detections from ID 8013 from the two Wells Dam tailrace receivers, for the period 18-22 September 2012. Gray shading indicates night time periods.**

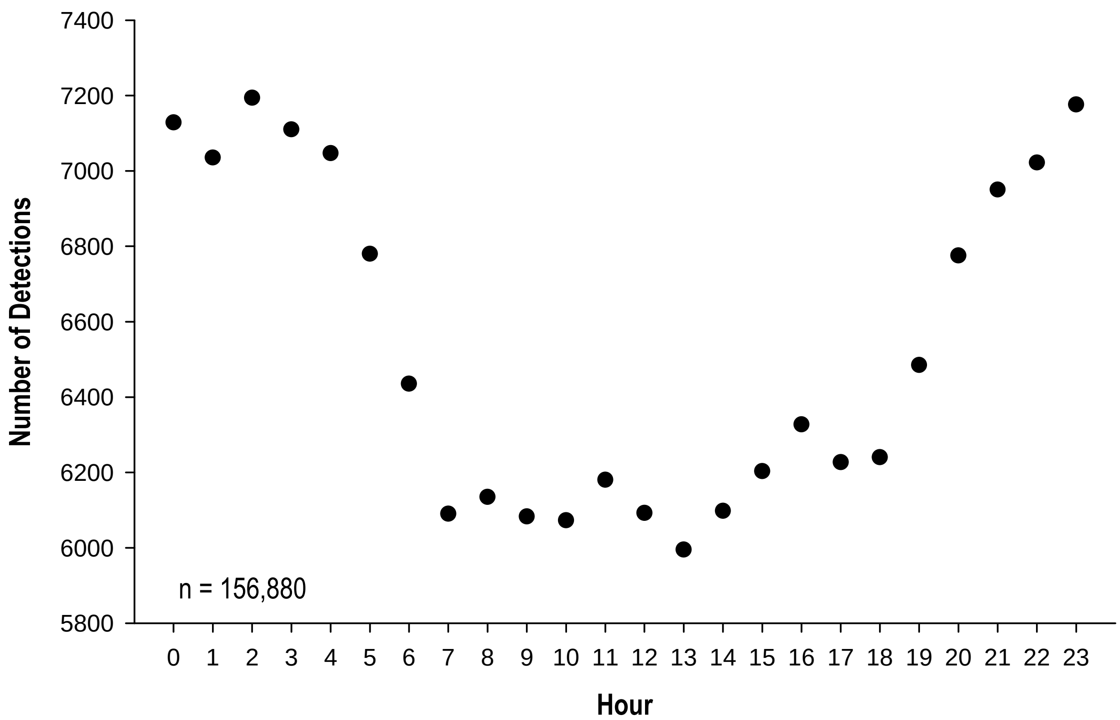

Figure 7. Detections of acoustic tags by hour of day for all locations for the duration of the study in 2012.

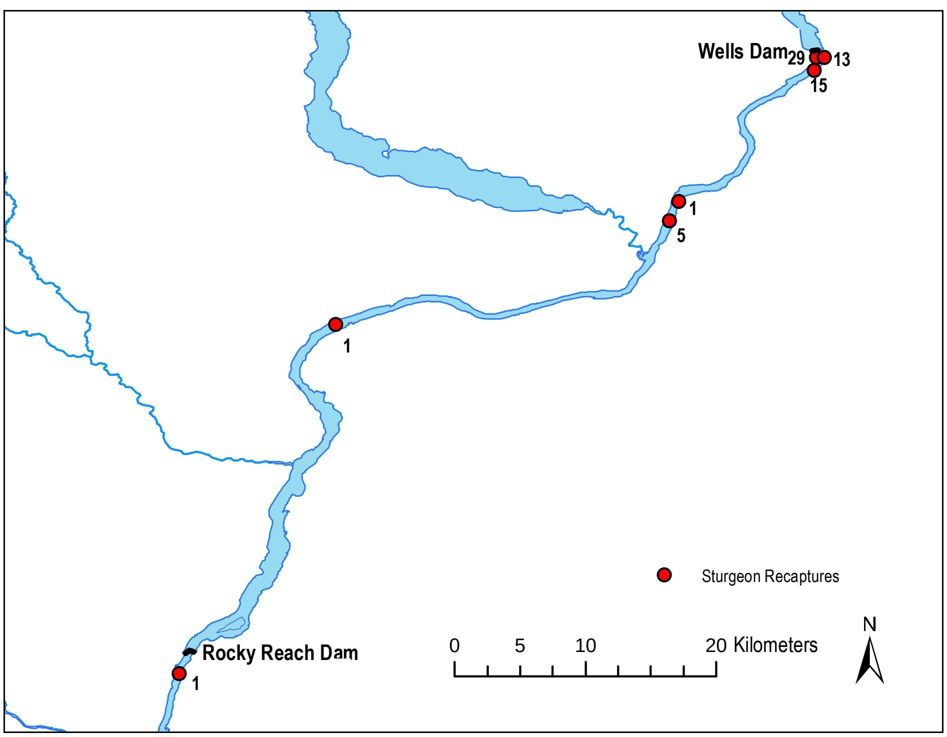

Figure 8. Approximate locations and numbers of juvenile white sturgeon recaptured incidentally during northern pikeminnow removal effort (n=65) in Rocky Reach Reservoir in 2011. Northern pikeminnow removal effort was spread throughout the Reservoir from April to November 2011.

PIT-Tagged Fish Recaptured in 2012

In 2012, there were a total of 98 capture events (Figure 9) that included 91 unique fish. 89 of the capture events involved fish that were PIT-tagged by Chelan PUD in March of 2011, of which 83 were unique fish. All 83 of these fish were included in analyses of growth, condition and survival. The remaining nine capture events involved eight unique fish, none of which were included in analyses of growth and condition or survival. Six of the eight fish were PIT-tagged by Chelan PUD in March 2012. The last two fish did not have a PIT tag, so we injected a tag subcutaneously and released the fish (one of the two was recaptured a few weeks later).

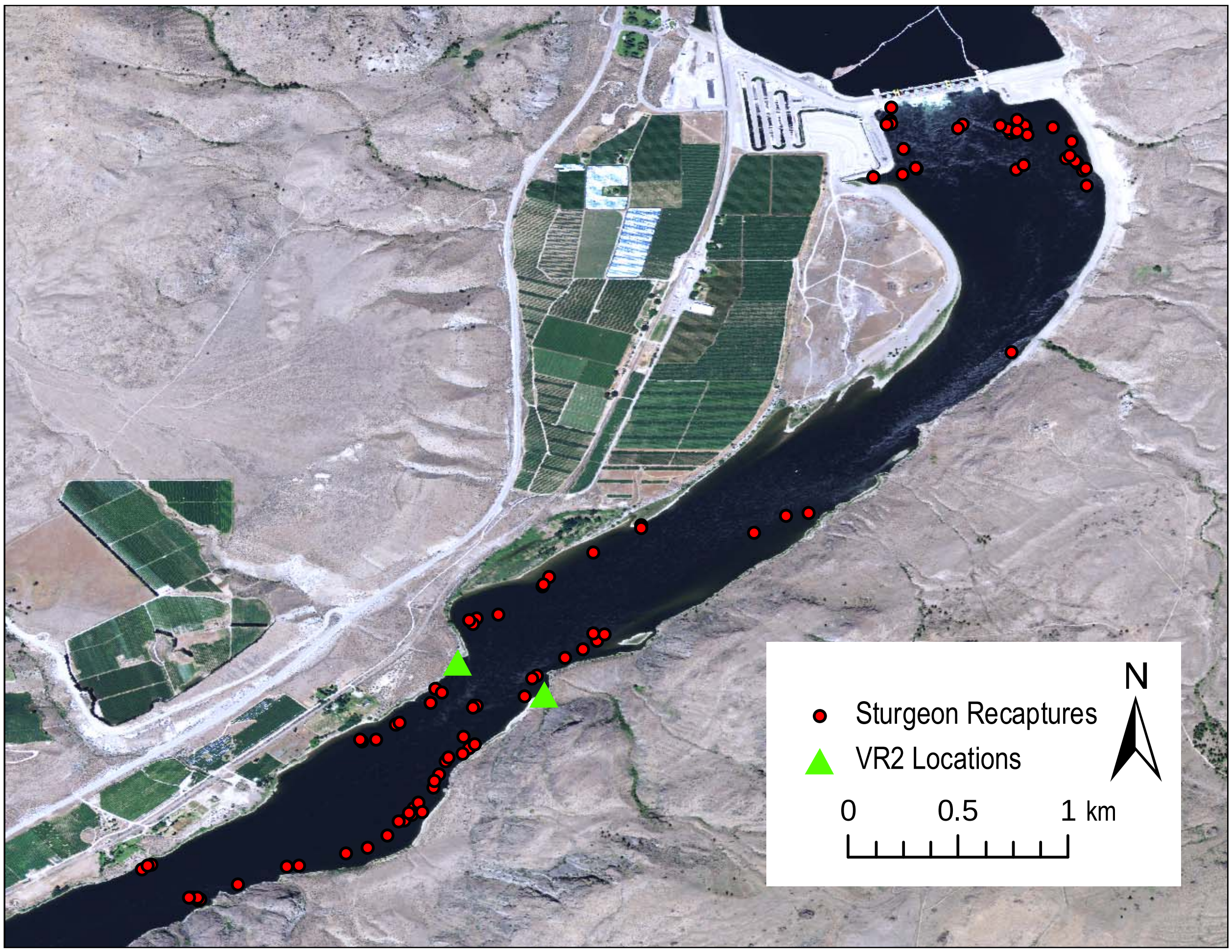

Figure 9. Locations of juvenile white sturgeon recaptured incidentally during northern pikeminnow removal effort (n=72) and during focused sturgeon fishing for tagging efforts (n=26) in Rocky Reach Reservoir in 2012. Northern pikeminnow removal effort was spread throughout the Reservoir from June to October 2012. Each red dot is a unique recapture.

Length, Weight, and Condition

Analysis of fish length, weight and condition was restricted to fish released as part of the 2011 release group that were at large for at least 60 days before recapture. This included 55 fish captured during northern pikeminnow fishing in 2011, and 83 fish captured during northern pikeminnow fishing or acoustic tagging in 2012. The individual weight was not recorded for every fish at the time of tagging and was also not recorded for any recaptured fish in 2011. Though weight was measured for all fish recaptured in 2012, changes in weight could only be assessed for 24 of the fish.

On average, fish caught during the 2011 surveys (i.e., after their first 4.2-6.6 months post-tagging) increased in length by 58.8 mm (n = 54, se = 3.1), with length increases ranging from 12 to 124 mm (Figure 10). Fish caught during the 2012 surveys (i.e., after their first 16.5-19.7 months post-tagging) increased in length by 85.5 mm (n = 83, se = 4.0), with increases ranging from 26 to 216 mm (Figure 10). The average growth values suggests that growth between 2011 and 2012 was 26.7 mm, although the five fish that were recaptured during both survey years grew at varied rates, increasing by 4, 8, 14, 18 and 37 mm (mean = 16.2 mm).

The recorded changes in weight from release until recapture in 2012 ranged from a decrease of 13 g to an increase of 533 g (mean = 135.3 g, n = 24, se = 26.3; Figure 11). The increases in weight appeared to be commensurate with recorded increases in length (Figure 12). On average, condition factor declined between tagging and 2012 recapture by 0.07 (n = 24, se = 0.01, range -0.17 to 0.06; Figure 13,), indicating that weight increased at a rate that was less than a cubic function of length. Further information is required to assess potential implications of this rate.

Survival Estimation

Analysis of survival was restricted to fish that were PIT-tagged as part of the 2011 Chelan PUD hatchery supplementation releases. Recapture events were grouped into two protracted ‘surveys’. Included in the first survey were 55 fish that were recaptured in northern pikeminnow gear between 15 July and 30 September 2011 (i.e., they were in the Reservoir between 2.8 and 5.4 months after they were originally released). Included in the second survey were 83 fish that were recaptured between 29 July and 27 October 2012 (i.e., they were in the Reservoir between 15.3 and 18.3 months after release). The 83 fish included 64 that were recaptured in northern pikeminnow gear between 29 July and 9 October 2012, and 19 additional fish captured only during acoustic tagging efforts between 10 September and 27 October 2012. Since CJS models require two surveys ‘post release’ to be able to distinguish the effects of survival from detection probability, the data available allowed us to estimate the survival of fish released in 2011 for the first 2.8-5.4 months after release.

Having at least one fish recaptured in both 2011 and 2012 was a minimum criterion for survival calculation. In all, five fish were recaptured in both 2011 and 2012, all of which were from the Chelan Hatchery and progeny of wild-origin broodstock (Table 4). It was therefore not possible to independently estimate survival for Marion Drain fish or for those from captive broodstock, or any combination thereof (Table 5). As such, we could not resolve differences between rearing locations (Marion Drain vs. Chelan) or between parental origins (wild-origin vs. captive broodstock).

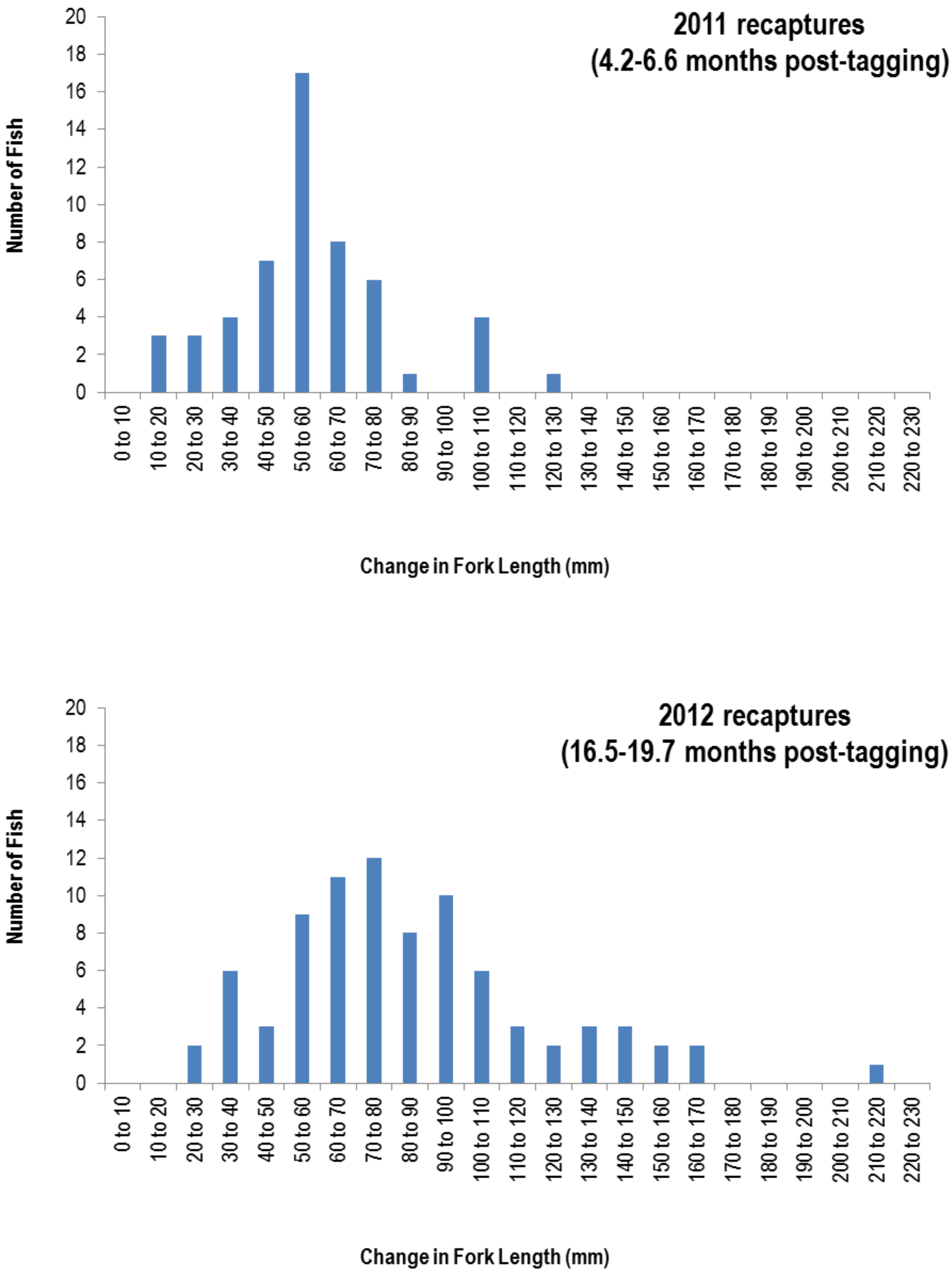

Figure 10. **Change in length between tagging and recapture for white sturgeon that were PIT-tagged by Chelan PUD in March 2011. Lengths at recapture are presented separately for each survey year.**

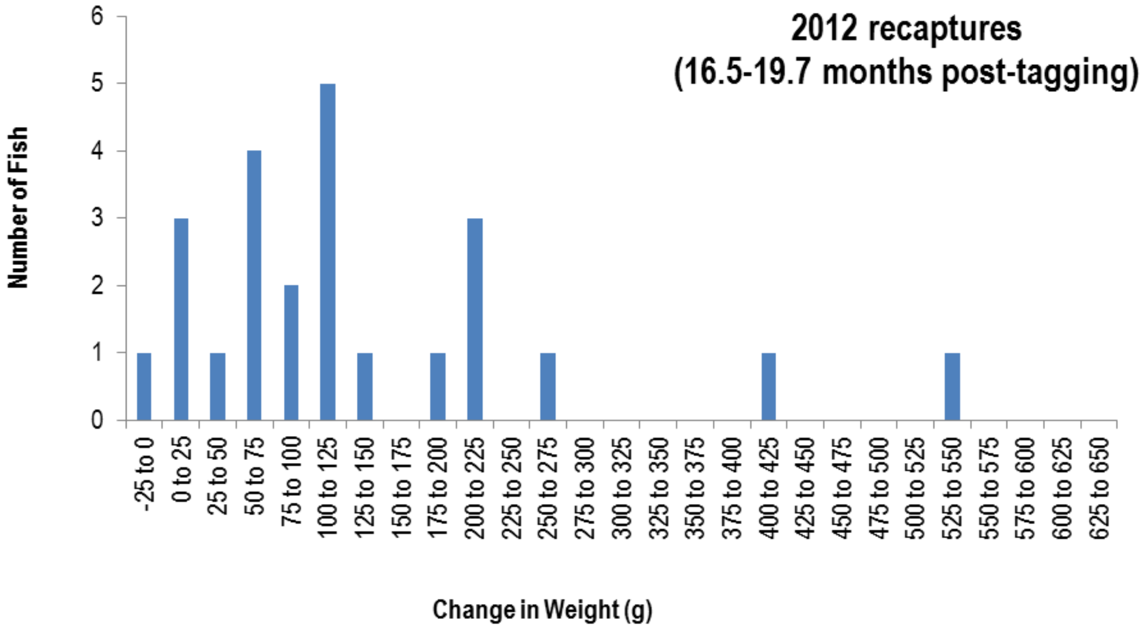

Figure 11. Change in weight between tagging and recapture for white sturgeon that were PIT-tagged by Chelan PUD in March 2011. Weight was not measured at recapture in 2011. Weight at the time of hatchery-release was not recorded for every individual fish.

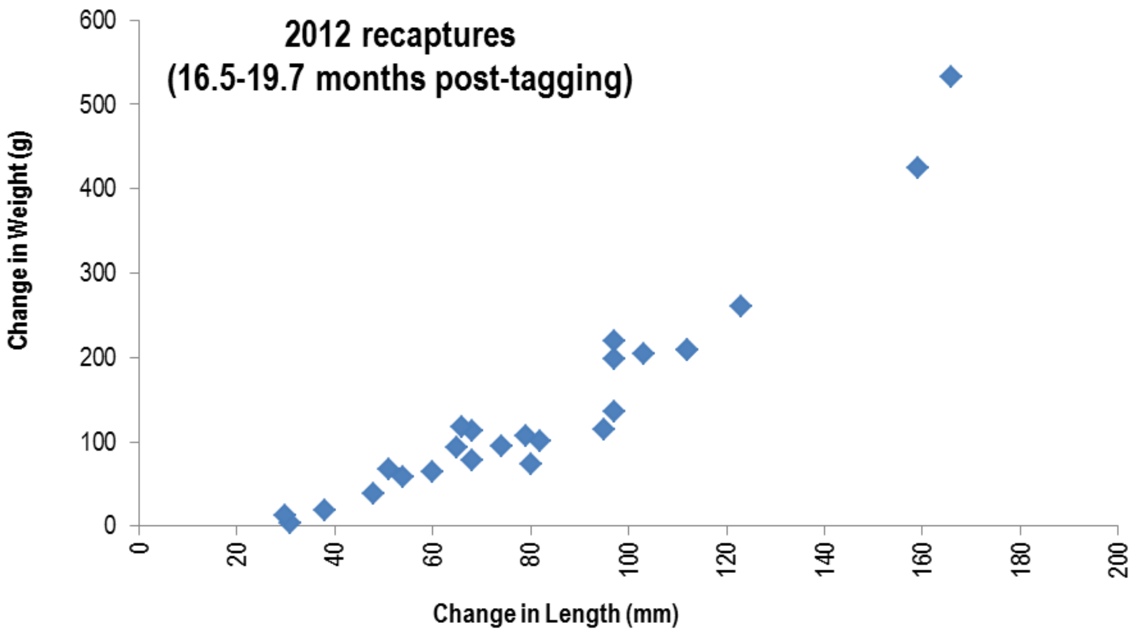

Figure 12. Relationship between the change in weight and the change in length for white sturgeon that were PIT-tagged by Chelan PUD in March 2011, and recaptured during the 2012 surveys. Weight at the time of hatchery-release was not recorded for every individual fish.

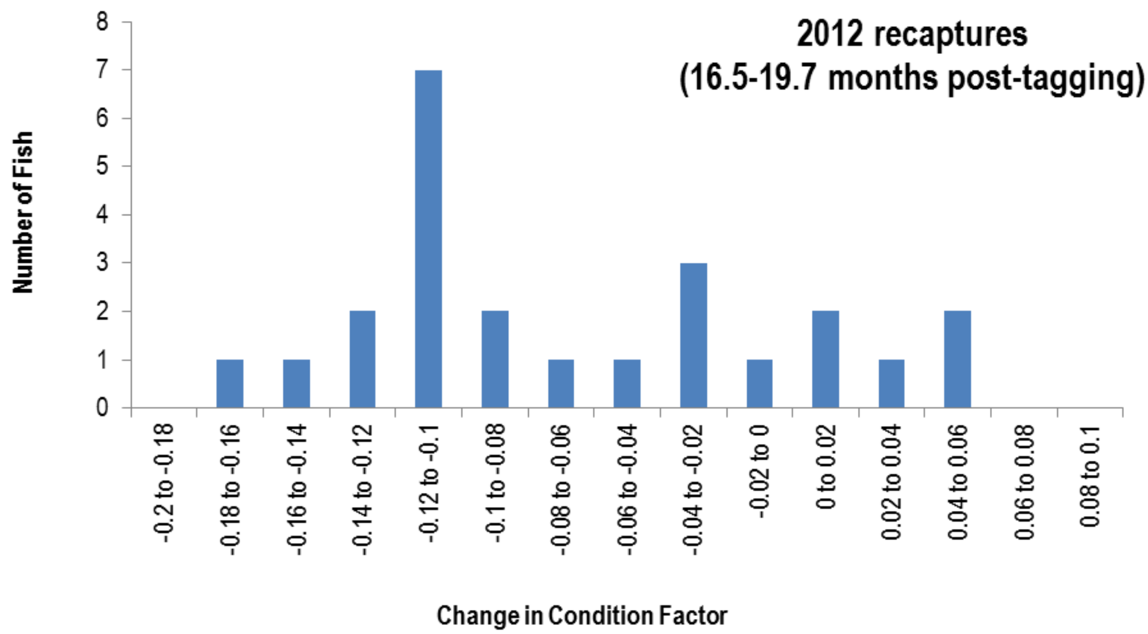

Figure 13. Change in condition factor between tagging and recapture for white sturgeon that were PIT-tagged by Chelan PUD in March 2011. Weight was not measured at recapture in 2011. Weight at the time of hatchery-release was not recorded for every individual fish.

Table 4. The number of fish in each population by detection history.

	Years Fish were Recaptured			
Population	**2011 and 2012**	**2012 only**	**2011 only**	**none**
All 2011 Releases	5	78	50	6,243
Rearing Location				
Marion Drain Hatchery	0	29	10	3,502
Chelan Hatchery	5	49	39	2,742
Parental Origin				
Wild-origin Broodstock	5	77	49	3,715
Captive Broodstock	0	1	0	2,529
Location × Origin				
Marion Drain× Wild-origin Broodstock	0	28	10	1,929
Marion Drain × Captive Broodstock	0	1	0	1,573
Chelan × Wild-origin Broodstock	5	49	39	1,786
Chelan × Captive Broodstock	0	0	0	956

Table 5. Apparent survival estimates and detection probabilities of hatchery-reared juvenile white sturgeon, from CJS model outputs. Survival is for the first 2.8 to 5.4 months post-release. 'Probability of Detection' refers to the chance of being captured in setlines deployed to capture northern pikeminnow, 15 July - 30 September 2011. Standard errors of the estimates are also shown.

	Probability of Survival, φ		Probability of Detection, p		
Test	**Estimate**	**SE**	**Estimate**	**SE**	**Note**
All 2011 Releases	0.143	0.059	0.060	0.026	Test was run
Rearing Location					
Marion Drain Hatchery	.	.	.	.	Computation not possible
Chelan Hatchery	0.168	0.068	0.093	0.039	Test was run
Parental Origin					
Wild-origin Broodstock	0.230	0.095	0.061	0.026	Test was run
Captive Broodstock	.	.	.	.	Computation not possible
Location × Origin					
Marion Drain × Wild-origin Broodstock	.	.	.	.	Computation not possible
Marion Drain × Captive Broodstock	.	.	.	.	Computation not possible
Chelan × Wild-origin Broodstock	0.253	0.102	0.093	0.039	Test was run
Chelan × Captive Broodstock	.	.	.	.	Computation not possible

Apparent survival (ϕ) of the 2011 releases, during the first 2.8-5.4 months post-release was estimated to be 14.3% (SE = 5.9%; Table 5). Chelan Hatchery fish were estimated to have a survival of 16.8% (SE = 6.8%). Survival of fish from wild-origin broodstock was estimated at 23.0% (SE = 9.5%). Lastly, fish from wild-origin broodstock that were reared at the Chelan Hatchery were estimated to have a 25.3% survival (SE = 10.2%).

The probability of detection in the 2011 survey was estimated to be 6.0 % (SE = 2.6%). Estimates of p varied depending on the population in question (Table 5).

Simulation exercises showed that the effects of emigration on perceived survival were non-linear. Specifically, relatively low emigration rates had relatively little impact on survival (i.e., that the perceived and true survival rates were similar; Figure 14). Survival differences increased more quickly as emigration increased. In future years, results from our acoustic tracking efforts will include a more robust estimate of emigration rate.

To date, two mortality events have been confirmed for the white sturgeon that were released in 2011 (Table 6). The PIT tags for both of these fish were recovered on Badger Island, a known American white pelican (*Pelecanus erythrorhynchos*) colony in the McNary National Wildlife Refuge (RM 318). One tag was recovered on 28 September 2011 and the other 24 September 2012. These fish have no other detection information, thus the locations and timing of the predation events are unknown.

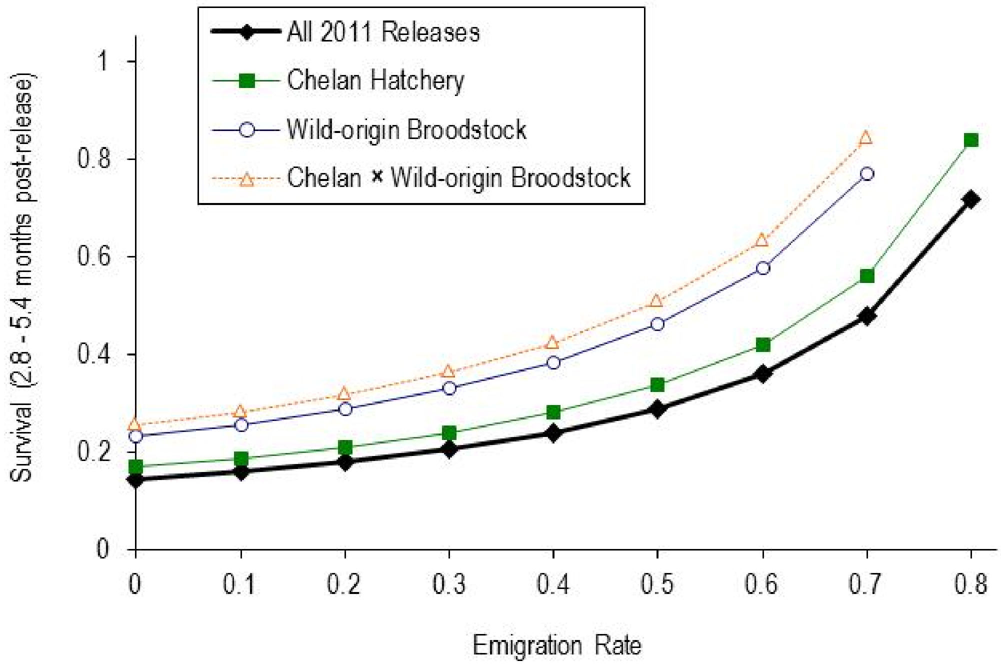

Figure 14. **Effect of emigration on survival estimates. Survival is for the first 2.8 to 5.4 months post-release. Survival at 0% emigration was equal to that outputted from the CJS models. Survival at higher emigrations rates are modeled using the recapture data in hand, but by varying the total number of fish 'available' for detection.**

Table 6. **Details on confirmed mortality events of PIT tags recovered on Badger Island American White Pelican breeding colony.**

PIT ID	Release Date	Recovery Site	Recovery Date	Rearing Location	Parental Origin
3D9.1C2D89AF3E	4/20/2011	Badger Island	9/28/2011	Marion Drain	Wild-Origin
3D9.1C2D8E9506	4/20/2011	Badger Island	9/24/2012	Marion Drain	Captive

Discussion

Acoustic Telemetry

Behavioral movements of white sturgeon will vary among population locations; these behavioral differences have been attributed to variations in hydraulic conditions, prey availably, population density, and habitat types. For instance, downstream of Bonneville Dam long-distance seasonal migrations of white sturgeon have been well documented and are believed to be based on prey availability, as sturgeon move upstream in the fall and downstream in the summer (Bajkov 1951, DeVore et al. 1995, Parsley et. al. 2008). However, in smaller river systems and reservoirs of the Upper Columbia, some studies have shown limited to no seasonal patterns (Hildebrand et al. 1999). Conversely, studies on Snake River sturgeon populations have suggested that impounded populations may move extensively within reservoirs, especially over free-flowing sections of the river where it is speculated that feeding behaviors are different as sturgeon must forage more for food sources (Lepla et al. 2003). It should not be overlooked that differences in behavioral movements of sturgeon are also likely related to size and life stage. Haynes et al. (1978) found that smaller sturgeon in the Hanford Reach moved downstream in the summer months while larger sturgeon were recorded moving upstream in summer and fall months; intermediate sized sturgeon were not observed moving throughout the Hanford Reach.

In this study, all acoustic tagged fish were either initially released from the hatchery or recaptured in the upper 12 km of the Reservoir. The majority of these sturgeon remained concentrated in the upper Reservoir over the study period (April-December 2012). Half (7 of 14) of the sturgeon that were recaptured, acoustically tagged and released in the lower parts of the Reservoir returned to the upper 18 km of the Reservoir. Additionally, all of the fish that returned to the upper Reservoir did so quickly following release, and 5 of the 7 traveled all the way to the Wells tailrace receivers (within 2-3 km of Wells Dam). This concentration in the upper Reservoir is likely related to initial release location; however it is also noteworthy that these fish remained in the upper Reservoir despite very high spring flows in both 2011 and 2012. Additionally Chelan PUD released 36 HTI (Model 795 LG, 4.5 g in air, 7.5 sec mean delay, 3.5-4 month tag life) acoustic tags with the 2011 release, utilizing salmonid survival study receivers, and only 2 of the 36 (5%) were detected below the release location at Beebe Bridge over the life of the tags (Josh Murauskas, personal communication). Limited large-scale movements of juvenile sturgeon from release location has also been shown in other studies of acoustically tagged juvenile sturgeon in the upper Columbia (e.g., Golder Associates 2010) and could indicate that favorable habitat, trophic, or hydraulic conditions are present in the upper reservoir. The propensity to return upstream following transplant to the lower parts of the Reservoir might suggest site fidelity similar to the seasonal site fidelity shown in Parsley et al. (2008); or, the conditions in the upper Reservoir may be more favorable.

Within the upper Reservoir there seems to be distinct locations where conditions are desirable for longer term residence. Specifically, the Airport 2 and Wells Tailrace receivers had multiple individuals reside within detections range for months at a time, while the other upper reservoir receiver, Airport 1, only detected sturgeon as they moved past either in the upstream or downstream direction. Limited movement from desired habitats has also been seen in the other juvenile sturgeon studies (Howell and McLellan

2007). Due to the high concentration of sturgeon in the upper Reservoir a mobile tracking survey and/or redistribution of VR2W receivers through this area may be warranted to further identify finer-scale habitat use. It's interesting to note that all downstream movements happened in the fall however the dataset is in its infancy. Though the tags from the 10 fish released with the 2012 supplementation hatchery release have lived out their 6-7 month battery life, the additional 25 sturgeon have tags that are expected to last 1.6 to 2.3 years (depending on the model), and have only been at large for 3 months. Subsequent study years with more tags in the Reservoir over longer periods will provide much greater detail on potential seasonal movements and preferred habitat types as well as more robust estimates of emigration.

Some diel patterns similar to Parsely et al. (2008) were observed though not as apparent and more variable over the entire detection period, likely the result of local bathometric characteristics and potentially related to the smaller size of our study fish. However, an increase in detections during nighttime periods, as seen, supports the understanding of phototactic behavior in sturgeon which will be considered in future indexing efforts. Future analysis will include more extensive association of detection locations, depths and movements with habitat classifications and bathometry information to develop understanding of preferred habitat types.

Emigration

Emigration of acoustically-tagged sturgeon was quite low with only one individual detected leaving the Reservoir in 2012. On 23 November 2012, one sturgeon, ID 29544, performed a quick volitional exit of the Reservoir after residing there for over a year and a half after initial release. It is generally understood, at least for larger white sturgeon, that fish may overwinter in specific, usually deeper, locations and don't exhibit large scale moments during winter months (Haynes et al. 1978, Howell and McLellan 2007). This late fall emigration may have been movement seeking suitable overwintering habitat or a response to a change in trophic conditions resulting in alimental migration.

The preliminary estimate of emigration rate (< 0.5%), based on PIT-tag detections at downstream hydropower dams, was likely an underestimate. It is known that PIT-receivers detect a fraction of the passing fish (Hockersmith et al. 2003). Nevertheless, our sturgeon could have left the reservoir without moving the entire distance to the next downstream PIT receiver, hence never coming within detection range of the receivers.

Survival Estimation

In this report we estimated the post-release survival of juvenile hatchery sturgeon released in April 2011. From the time of release to the time of the recaptures in 2011, 2.8 to 5.4 months had elapsed. Survival during this period was estimated to be 14.3% overall, whereas that for fish reared at the Chelan Hatchery from wild-origin broodstock was 25.3%. In comparable juvenile sturgeon survival studies, conducted from 2002 to 2006 in the Upper Columbia River, survival in the first half-year post-release was between 27% and 29% (Golder Associates 2009). Continued monitoring will better inform the effects of rearing location and parental origin, but results to date indicate that progeny of wild-origin broodstock reared at Chelan Hatchery have outperformed other juveniles.

Our survival estimates may have been biased (too low) as a result of being based only on incidental sturgeon recapture data collected during northern pikeminnow removal efforts. If the hatchery sturgeon moved little during the fishing period, or if some fish were resident in areas where little northern pikeminnow fishing occurred, they would have 'appeared dead' to the survival model, thus resulting in an underestimated survival value. The formal annual indexing surveys scheduled for 2013-2015 will not simply target areas of known catch rate, but they will include time for 'exploratory' fishing and will ensure that a variety of habitats are sampled throughout the Reservoir.

One indication that the '2.8 to 5.4 month' survival estimates may have been biased low, is the fact that 90% of the acoustically-tagged sturgeon released in 2012 were still actively moving (and presumed alive) a few months after release. Granted, the acoustic-tagged fish were sized on the larger half of the BB03 release group, which may have biased survival high. Nevertheless , actual survival may lie somewhere between the two estimates.

Justice et al. (2009) found evidence of density- and size-dependent mortality of age 1 hatchery-reared juvenile sturgeon. In the Reservoir, density-dependent mortality is not likely a critical factor as the supplementation program is in its infancy, and the overall abundance of sturgeon is not yet expected to be approaching the carrying capacity. However, size-dependent effects may have impacted survival for Chelan PUD releases. The survival-at-length curves presented in Justice et al. (2009) show a general increase in survival with size-at-release. Moreover, the average size of Chelan PUD's 2011 supplementation fish (243 mm) fell onto curves that predicted lower-than-average survival rates. It is possible that Reservoir survival of age 1 fish could be improved by releasing sturgeon of a larger size, though increased time in the hatchery environment may have negative consequences.

In the Golder Associates (2009) study, hatchery sturgeon had highest mortality rates soon after release, after which survival probability increased substantially. After the first half-year at large, sturgeon survival in the Upper Columbia River basin was consistently between 84% and 90% per year (Golder Associates 2009). It remains to be seen if the survival of Chelan PUD hatchery sturgeon will follow the same pattern. Our planned indexing surveys will provide late-summer recapture opportunities in 2013, 2014, and 2015. With these surveys and the data in hand, we should be able to generate 4 separate survival estimates for the 2011 cohort: 1) survival during the first ~ half year (2.8 to 5.4 months); 2) survival from 0.5 to 1.5 years at large; 3) survival from 1.5 to 2.5 years at large; and 4) survival from 2.5 to 3.5 years at large. Based on the Golder Associates (2009) results, it is our expectation that the three last survival rates will be considerably higher than those reported in Table 5.

The survival estimates listed in Table 5 do not include any adjustment for emigration. Since animals that emigrate from the study area are not available for recapture, they will appear to have died. As such, the estimates reported (ϕ) are equal to $S \cdot (1-E)$, where S is the 'true' survival and E is the probability of emigrating from the study area. In future years, results from acoustic tracking efforts will include a robust estimate of E, thus allowing us to calculate S from ϕ. In this report, we showed that true survival (S) would be less than 30% for all likely emigration rates (e.g., less than 50%). Emigration is not mentioned in Golder Associates (2009), so their reported rate of 27-29% is presumably ϕ and not S.

The survival estimates provided in this report were based only on incidental sturgeon recapture data, which were collected during northern pikeminnow removal efforts. As such, fishing effort was not randomly distributed throughout the watershed (efforts was targeted in areas in which northern pikeminnow catch rates would be maximized), and catch rates were relatively low (no targeted sturgeon fishing occurred). Because the fishing effort had no randomized component, it was not possible to use the recapture data to make any inference about sturgeon distribution in the reservoir. Although we have data on sturgeon presence or absence in certain parts of the Reservoir, there are currently no data for the majority of the study area. This difficulty will be alleviated once the formal annual indexing surveys begin and additional acoustic telemetry data are collected. There were several consequences of having relatively low catch rates. First, the confidence bounds around the survival estimates were relatively wide (Table 5). Second, the probability of meeting minimum data requirements for survival estimation was reduced. The CJS survival models depend on having at least one fish that was recaptured in both 2011 and 2012. In this report, we did not meet this requirement for Marion Drain fish, or progeny of captive broodstock (Table 4). As such, we could not resolve differences between rearing locations or between parental origins (Table 5). Catch rates will be higher in future years (2013-2015), as the incidental catches from the northern pikeminnow gear will be supplemented by 35 to 50 days of directed sturgeon fishing effort as part of formal annual indexing surveys. With the higher catch numbers in future years, survival estimates should have tighter confidence limits, and we should have a higher probability of being able to resolve differences between the various rearing locations and/or parental origins.

Growth

Growth rates of juvenile white sturgeon in the Reservoir, when extrapolated to 365 days, averaged 175 mm/year for recaptures in 2011. This rate is within the range reported for age 1 sturgeon in the Keenleyside and Roosevelt reaches (280 mm/year; n=326; Golder Associates 2009), in the middle Columbia River (143 mm/year; n =3; Golder Associates 2010) or in the Kootenay River (120 mm/year; n = 52; Neufeld and Spence 2002). Over the next year, growth rates slowed such that extrapolated growth rates of sturgeon caught in 2012, integrated over their entire time at large, averaged 61 mm/year. Again, this value was within the range of growth rates reported for age 2 sturgeon in the Keenleyside and Roosevelt reaches (160 mm/year; n=422; Golder Associates 2009) and in the middle Columbia River (54 mm/year; n =2; Golder Associates 2010). White sturgeon caught in the Reservoir in 2012 gained 95 g/year (extrapolated). Literature values ranged wildly from 37 g/year in the middle Columbia River (Golder Associates 2010) to 389 g/year in the Keenleyside and Roosevelt reaches (Golder Associates 2009).

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Literature Cited

Anderson, R.O. and R.M. Neumann. 1996. Length, weight, and associated structural indices. pp. 447-481. In: B.R. Murphy & D.W. Willis (ed.) Fisheries Techniques, 2nd edition, American Fisheries Society, Bethesda.

Bajkov, A. D. 1951. Migration of White Sturgeon (Acipenser transmontanus) in the Columbia River. Fisheries Commission of Oregon, Portland, OR. Research Briefs 2(2): 3-10.

Beamesderfer, R.C.P., T.A. Rien, and A.A. Nigro, 1995. Differences in the dynamics and potential production of impounded and unimpounded white sturgeon populations in the lower Columbia River. Transactions of the American Fisheries Society, 124: 857-872.

Bolger, T. and P.L. Connolly. 1989. The selection of suitable indices for the measurement and analysis of fish condition. Journal of Fish Biology, 34: 171-182.

DeVore, J.D., B.W James, C.A. Tracy, and D. A. Hale, 1995. Dynamics and potential production of white sturgeon in the unimpounded lower Columbia River. Transactions of the American Fisheries Society, 124: 845-856.

DeVries, D.R. and R.V. Frie. 1996. Determination of age and growth. pp. 483–512. In: B.R. Murphy & D.W. Willis (ed.) Fisheries Techniques, 2nd edition, American Fisheries Society, Bethesda.

Golder Associates. 2003. Rocky Reach white sturgeon investigations. 2002 study results. Report prepared for the Public Utility District No. 1 of Chelan County.

Golder Associates. 2009. Upper Columbia River juvenile white sturgeon monitoring: Phase 5 investigations, November 2006. Report prepared for BC Hydro, Revelstoke, B.C.

Golder Associates. 2010. Middle Columbia River juvenile white sturgeon monitoring: 2009 investigations. Report prepared for BC Hydro, Castlegar, B.C.

Haynes, J.M., R.H. Gray, and J.C. Montgomery. 1978. Seasonal movements of white sturgeon (*Acipenser transmontanus*) in the mid-Columbia River. Transactions of the American Fisheries Society, 107: 275-280.

Hildebrand, L., C. McLeod, and S. McKenzie. 1999. Status and management of white sturgeon in the Columbia River in British Columbia, Canada: an overview. Journal of Applied Ichthyology, 15: 164:172.

Hockersmith, E.E. , W.D. Muir , S.G. Smith , B.P. Sandford , R.W. Perry , N.S. Adams, and D.W. Rondorf. 2003. Comparison of migration rate and survival between radio-tagged and PIT-tagged migrant yearling Chinook salmon in the Snake and Columbia Rivers. North American Journal of Fisheries Management, 23: 404-413.

Howell, M.D. and J.G. McLellan. 2007. Lake Roosevelt white sturgeon recovery project. Annual Progress Report, April 2005 - March 2006. Prepared for the U.S. Department of Energy, Bonneville Power Administration, Environment, Fish and Wildlife. Project Number: 1995-027-00.

Jerald, T. 2012. 2012 Public Utility District No. 1 of Douglas County northern pikeminnow removal and research program. Report prepared by Columbia Research Specialists for the Public Utility District No. 1 of Douglas County.

Justice, C., B.J. Pyper, R.C.P. Beamesderfer, V.L. Paragamian, P.J. Rust, M.D. Neufeld, and S.C. Ireland. 2009. Evidence of density- and size-dependent mortality in hatchery-reared juvenile white sturgeon (*Acipenser transmontanus*) in the Kootenai River. Canadian Journal of Fisheries and Aquatic Sciences, 66: 802-815.

Lebreton, J.D., K.P. Burnham, J. Clobert, and D.R. Anderson. 1992. Modeling survival and testing biological hypotheses using marked animals - a unified approach with case studies. Ecological Monographs, 62: 67-118.

Lepla, K.B., J.A. Chandler, and P.B. Bates. 2003. Status of Snake River white sturgeon associated with the Hells Canyon Complex. In: Lepla, K.B, editor. Chapter 1. Status and habitat use of Snake River white sturgeon associated with the Hells Canyon Complex. Technical appendices for Hells Canyon Hydroelectric Project. Idaho Power, Boise. Technical Report E.3.1-6.

Liedtke, T.L., J.W. Beeman, and L.P. Gee. 2012. A standard operating procedure for the surgical implantation of transmitters in juvenile salmonids: U.S. Geological Survey Open-File Report 2012-1267.

Neufeld, M.D., and C.R. Spence. 2002. Kootenay River white sturgeon - Studies in British Columbia, 2001. Report prepared for the Ministry of Water, Land and Air Protection, Nelson, BC.

North, J.A., R.C. Beamesderfer, and T. A. Rien. 1993. Distribution and Movements of White Sturgeon in Three Lower Columbia River Reservoirs. Northwest Science, 67: 105-111.

Parsley, M. J., and L. G. Beckman. 1994. White sturgeon spawning and rearing habitat in the lower Columbia River. North American Journal of Fisheries Management 14:812–827.

Parsley, M.J., N.D. Popoff, B.K. van der Leeuw, and C.D. Wright. 2008. Seasonal and diel movements of white sturgeon in the lower Columbia River. Transactions of the American Fisheries Society, 137: 1007-1017.

Rien, T.A. and R.C. Beamesderfer 1994. Accuracy and precision of white sturgeon age estimates from pectoral fin rays. Transactions of the American Fisheries Society, 123: 255-265.

White, G.C., and K.P. Burnham. 1999. Program MARK: Survival estimation from populations of marked animals. Bird Study, 46 Supplement: 120-138.

Wydoski, R.S. and R.R. Whitney. 2003. Inland fishes of Washington. University of Washington Press, Seattle.