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NECHAKO WHITE STURGEON MONITORING

2009

Prepared for:

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Executive Summary

The goal of the 2009 Nechako River white sturgeon monitoring program was to use egg mat, drift nets, telemetry and observational techniques (e.g. underwater camera, DIDSON sonar) to precisely identify spawning locations within the more broadly defined spawning area located in Vanderhoof, BC. The brood stock program captured and assessed a total of 71 fish, 20 of which were considered ready to spawn. The tracking of fish movements in the spring through aerial and base station telemetry, along with monitoring of water temperatures were used to identify the approximate spawning window. Artificial substrate mats were deployed throughout the spawning area on May 29th with eggs collected on June 2nd, 3rd, 5th, 7th, 9th and 11th. The subsequent timing of the captured eggs hatching suggests spawning occurred in 4 events: May 31st - June 3rd; June 3rd – 5th; June 5th-7th; and June 7th - 9th. This is later then in 2004 and 2006 (May 18th and 19th, respectively) but similar timing to 2007 and 2008 (June 4th, and June 2nd - 9th, respectively). The location of spawning varied between the events. The initial two spawning events occurred primarily in the vicinity of the Stoney Creek confluence with eggs also being collected around the top island. Alternatively the 3rd and 4th events occurred both at the upstream end (i.e. above the top island) and downstream end (i.e. upstream of the Burrard Ave. Bridge) of the spawning area.

The initial spawning event (May 31st – June 3rd) occurred at a mean daily temperature of 11°C, which is 2°C cooler then the temperature at which spawning occurred in 2004, 2006, 2007 and 2008. While micro-habitat conditions downstream of Stoney Creek could have resulted in slightly warmer conditions at the spawning site, the fact that eggs were also collected upstream suggests an environmental variable in addition to water temperature is likely involved in spawn timing. This variable, likely photoperiod, would ensure that spawning still occurs if threshold temperatures are not achieved by a particular date.

Habitat surveys completed throughout the spawning area identified that while depths and velocities are considered suitable at the sites, the presence of fine sediments and infilling

of interstitial spaces is likely detrimental to egg and larval survival. The percent composition of fine sediment was lowest at the upstream end of the site, which corresponded to the area of highest velocity, and increased at the downstream end. Specific spawning locations in 2009 did not necessarily correspond to the areas with favourable substrates. This suggests that while substrate composition may play a role in defining the general spawning area, specific sites are likely selected based on other parameters such as depth and velocity. Lastly, since spawning continues to occur in the area it suggests habitat restoration may be required to restore habitat and ensure better survival of eggs and larvae.

Acknowledgements

Triton Environmental Consultants Ltd. would like to thank the following for their contribution to the 2009 Nechako River Adult White Sturgeon Monitoring Program:

- The Ministry of Environment (MOE) and their representatives Cory Williamson and Steve McAdam for providing assistance, data, and direction throughout the project. MOE also provided a telemetry receiver and access to their base station data for use on the project. Lastly, they made many helpful comments and suggestions they greatly improved this report.

- The Carrier Sekani Tribal Council for providing a boat and a crew to assist with the deployment of egg mats and physical data collection. Thanks in particular to James (Jako) Prince for assistance with the field work.

- Guardian Aerospace for providing a pilot, plane and telemetry equipment for the aerial telemetry flights.

- Freshwater Fisheries Society of BC staff for handling and independent identification of the collected eggs.

- The Water Survey of Canada for providing access to real-time hydrometric data from their station located at the Burrard Ave. Bridge in Vanderhoof.

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1 Introduction

The Nechako River population of white sturgeon (*Acipenser transmontanus*) is listed as a critically imperilled species in British Columbia (BC Conservation Data Centre 2009), as well as endangered on Schedule 1 under the Species at Risk Act (SARA). Genetic analysis indicates that the Nechako River population is distinct from that of the Fraser River, suggesting that there is no or limited inter-breeding between the populations (Smith *et al*. 2002). Research also suggests that the Nechako population is experiencing recruitment failure, with the population dominated by larger and older fish with few juveniles (Nechako White Sturgeon Recovery Initiative (NWSRI) 2008). At present the reasons for the recruitment failure are unknown, however, a recent report has suggested that alteration of critical spawning habitats may play a role (McAdam *et al.* 2005).

Extensive radio tagging programs in recent years have allowed for the tracking of adult white sturgeon movements in the Nechako River. As of the spring of 2008, there were approximately 75 radio tagged adults in the system the majority of which were implanted in the spring of 2006 through 2009 by the BC Ministry of Environment (MoE) in conjunction with the Carrier Sekani Tribal Council (CSTC). The MoE/CSTC tagging was initiated by the Nechako White Sturgeon Recovery Initiative Technical Working Group, in conjunction with the capture of brood stock and subsequent incubation, hatching and release of juvenile in order to meet the goals of the breeding plan (NWSRI 2005). These programs also provided an assessment of fish reproductive state, which helped focus telemetry effort and the interpretation of telemetry data for the study reported here.

Radio tagging efforts, and work completed by Triton Environmental Consultants Ltd. (Triton) in 2004 through 2008 formed the basis for the monitoring and sampling plan for 2009. In particular, a previously identified spawning area in the vicinity of Vanderhoof (Triton 2004) was the focus for the work in 2009. In addition, the physical conditions in the river around the time of the congregation in 2004 to 2008 (*i.e.* water temperature and discharge) were examined to identify the critical monitoring period for 2009. In particular, the information on timing and location of the 2004, 2006 and 2008 congregations was used since those years had similar temperature and flow regimes as were expected to occur in 2009.

The goal of the 2009 white sturgeon monitoring program was to use egg mat, drift nets, telemetry and observational techniques (e.g. underwater camera, DIDSON sonar) to precisely identify spawning locations within the more broadly defined spawning area previously identified (see Triton 2004 – 2008). Once identified, fine scale habitat data collected from those locations will be used to better understand the environmental cues associated with spawning. The identification of specific spawning locations and associated biophysical characteristics will also be used to help direct future habitat restoration projects. This report outlines the methods used to monitor the timing and location of white sturgeon spawning in the Nechako River in 2009, presents the results of field activities undertaken in May and June, and provides details on the spawning locations identified.

2 Methods

2.1 BROOD STOCK COLLECTION AND RADIO TAGGING

Brood stock collection was completed between April 30th and May 23rd, 2009. A total of 133 set lines with between 5 and 29 baited hooks each (1,949 hooks total) were fished for 12-24 hours at a time. In addition, angling from a boat with baited hooks was completed on three occasions for a total of 25 minutes.

Captured fish were scanned using a Passive Integrated Transponder (PIT) tag reader in order to determine if the individual was a new fish or a recapture. New fish were implanted with a PIT tag and those thought likely to spawn in 2009 were also implanted with a radio tag. For all fish, data was collected on body length (fork length, total length, post-opercula length, and post-orbital snout length), girth, and weight. Ageing structures and DNA samples were collected from select fish and external marks were recorded. Internal assessments for sexual maturity were completed using an otoscope (see Appendix 6 for list of maturity stages). Ripe females (code 15) and flowing males (code 5) were either collected for brood stock or, if sufficient numbers had been collected, were radio tagged and released. Brood fish were transported to the Freshwater Fisheries Society of BC (FFSBC) hatchery in Prince George in a trailer mounted tank where they were held for several days. Manipulation of water temperature and injection of hormones was used to induce spawning and fertilized eggs were transported to the temporary hatchery facility in Vanderhoof for development. Spawned brood fish were radio tagged and then released back into the river.

2.1.1 EMG TAGS

As part of the 2009 radio tagging program, electromyogram (EMG) tags were available to be implanted in any mature (i.e. ready to spawn) fish captured. EMG tags connect directly to the muscle tissue of the fish and the contractions of those muscles can be used to identify specific activities such as swimming and spawning. The collection of data during known activities such as swimming is then used to calibrate the units such that unique activities such as spawning can be identified. The goal of the program was to implant several fish with EMG tags and continuously track their activity with an SRX_600 receiver. In this way the precise timing and location of spawning events could be determined.

2.2 TEMPERATURE AND FLOW MONITORING

Monitoring of the Water Survey of Canada (WSC) station at the Burrard Ave. Bridge (station 08JC001) was initiated upon award of the contract and continued until completion of the field program. The station provides real-time data on water temperature, primary water level and discharge. To confirm that the WSC station temperature readings were correct spot temperatures were collected during the field surveys and compared with the WSC record. The comparison showed that on May 29th, June 4th, 10th, 12th and 15th the spot temperatures recorded at the Burrard Ave. Bridge was within 1°C of that recorded by the WSC station. In addition, a review of the data recorded from the station between May 5th and July 7th, 2009 did not identify any potentially anomalous datapoints. As a result, it is assumed that the WSC station was operating correctly during spawning time period.

2.3 RADIO TELEMETRY

Two Lotek receivers, one SRX_400-W7 and one SRX_600 were used for the project. The SRX_600 was borrowed from the Ministry of Environment in Prince George while the SRX_400 used was owned by Triton. Both receivers were used during aerial and boat surveys. Lastly, a third MOE receiver (SRX_400) in the base station located downstream of the Burrard Ave. Bridge was downloaded by the Triton crew during the project.

2.3.1 AERIAL TELEMETRY

Telemetry overflights of the Nechako River between the Stuart River and the Braeside boat launch (rkm 164) were conducted on May 21 and May 28 in order to determine the presence or absence and movement patterns of tagged fish in the study area (Figure 1). Telemetry flights originated from the Prince George airport and were flown over the Nechako River from the Stuart River (rkm 92) upstream to the Braeside boat launch (rkm 164), at which point the plane would turn around and follow the river downstream past Vanderhoof (rkm 136) back to the Stuart River where the flight would continue on a direct course back to the Prince George airport. This flight pattern resulted in two complete passes of the study area on each flight; a total distance of approximately 150 rkm. Both passes of the telemetry flights were flown at a height of 200 – 250 m above the river.

A fixed-wing plane (Cessna 172) wired for telemetry work was used to complete the aerial surveys. "H" antennae were mounted with the vertical orientation set at an angle slightly forward of 45° down, on both wings of the aircraft. One Lotek receiver (SRX_400-W7) was used during the overflight on May 21 and two Lotek receivers (SRX_400-W7 and SRX_600), one per antenna, were used during the overflight on May 28. To reduce the chance of missing a tag during scan time and to prioritize those tags which may be potential spawners, 4 active frequencies (149.800, 149.700, 158.280 and 148.320) were used during the May 21 flight while the 7 active frequencies (149.800, 149.700, 158.280, 148.420, 148.400, 148.320, and 148.380) were split between the two receivers for the May 28 flight.

As each signal was received, the frequency, code, and river kilometre were recorded on data collection sheets. If at anytime the river kilometre location was unknown a UTM (Universal Transverse Mercator) coordinate of where the signal was received was taken using a Garmin 12XL handheld GPS unit. Effort was not spent circling the plane to try and identify the exact location of each fish, as the goal of the telemetry data was to document general movement trends and timing. However, in the event that a tag was located but a code was not initially resolved, the aircraft circled the area until it was thought that all codes had been received.

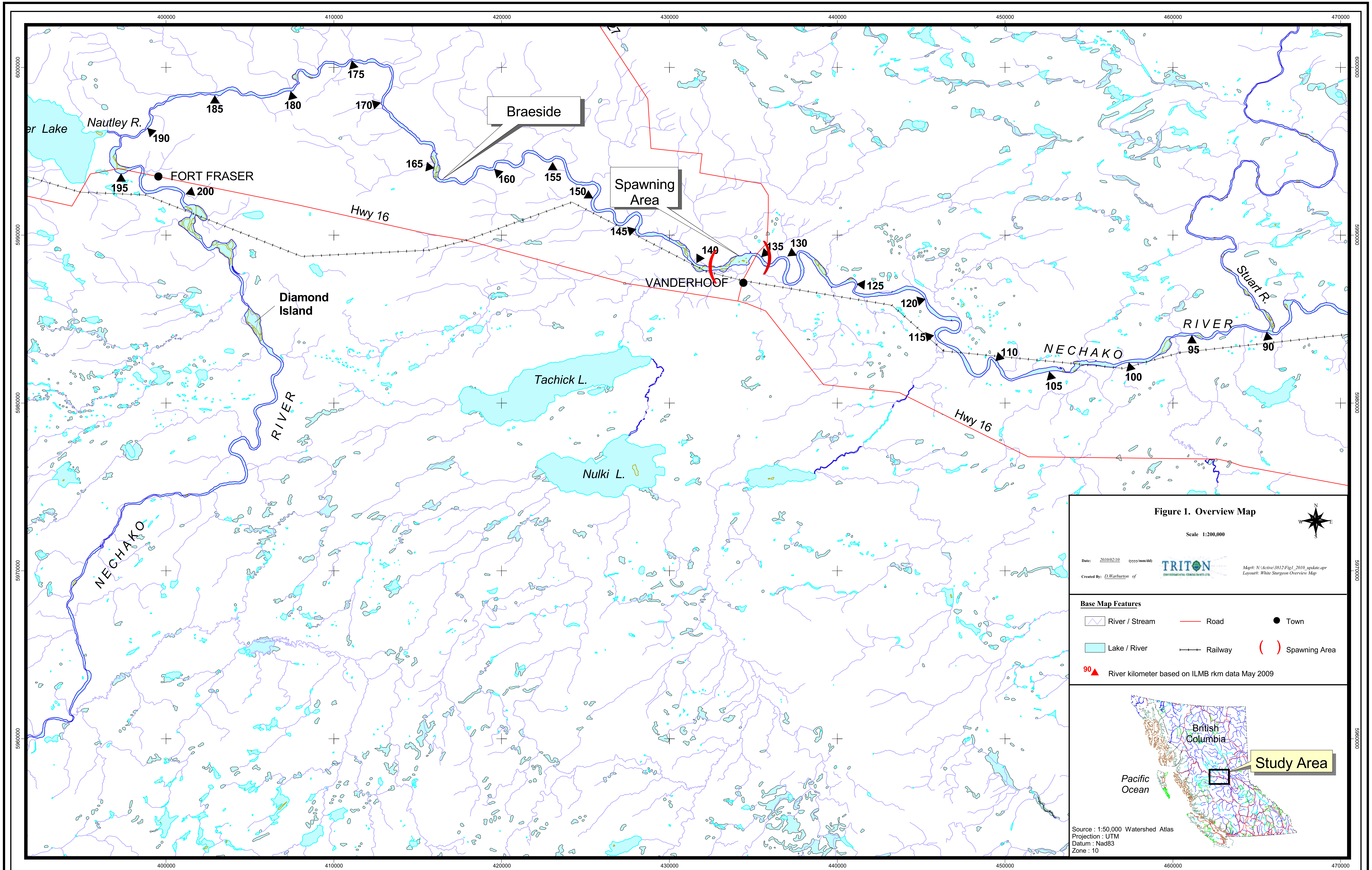
Figure 1. Overview Map
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Layout#: White Sturgeon Overview Map
Base Map Features
River / Stream
Road
Town
Lake / River
Railway
Spawning Area
90
River kilometer based on ILMB rkm data May 2009
British Columbia
Pacific Ocean
Study Area
Source : 1:50,000 Watershed Atlas
Projection : UTM
Datum : Nad83
Zone : 10
Braeside
Spawning Area
Nautley R.
FORT FRASER
VANDERHOOF
Diamond Island
Hwy 16
Hwy 16
Tachick L.
Nulki L.
Stuart R.
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RIVER
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2.3.2 TELEMETRY BASE STATIONS

The telemetry base station located downstream of the Burrard Ave. Bridge at the property of Wayne Salewski has run continuously from the fall of 2006. The station includes antennae oriented vertically with one angled upstream and the other angled downstream. The receiver scans both antennae until a tag is detected at which time it scans each antenna in sequence. Comparison of the signal strength from each antenna can then be used to determine whether the fish is upstream or downstream of the station and direction of travel. In 2009 the frequencies monitored included 148.320, 148.380, 148.400, 148.420, 149.440, 149.700, and 149.800. Data from this station was downloaded on June 9th, 2009 and is summarized in Appendix 2.

2.3.3 BOAT TELEMETRY

Boat based telemetry surveys of the spawning area (i.e. river km 134 to 137) were completed daily from June 2nd to 12th as well as on June 16th and 19th. The crew worked in a downstream direction using a handheld antenna for the telemetry receiver. Whenever possible the boat motor was turned off and the boat allowed to drift to limit interference from the engine. When a tag was identified the boat was manoeuvred as close as possible based on the power reading on the telemetry receiver. A power level of 200 mHz or higher was used as an indicator that the fish was close enough to log a UTM coordinate.

2.4 SAMPLING FOR EGGS

Egg collection mats were used from May 29th to June 11th, 2009 to document egg deposition and to assess the time and location of sturgeon spawning. The egg mats provide an artificial surface to which the adhesive sturgeon eggs can attach, and have been used successfully in numerous sturgeon studies (*e.g.* Parsley and Beckman 1994; Paragamian *et al*. 2001; Brown, 2007; Triton 2004, 2006, 2007, 2008). Egg mats were constructed from polyurethane industrial filter fabric sandwiched between an angle iron frame with cross supports following the procedure outlined in McCabe and Beckman (1990). Mats were deployed in pairs with one buoy line attached to the upstream mat which allowed for retrieval of the gear. As there was substantial boat traffic in the area, fluorescent buoys were used as they were clearly visible even in low light conditions. Separate anchors were not required as the two angle iron frames had a low profile and were heavy enough to remain stationary under typical flows. Mats were checked and cleaned at 2 – 4 day intervals. Eggs collected from the mats were stored in vials of river water at ambient temperature and transferred to the hatchery staff for incubation. Monitoring of egg hatch was then used to estimate spawning dates. Section 3.9.2 provides additional information on egg handling and ID.

2.5 DEPTH AND VELOCITY

Water depth and water velocity was collected in conjunction with the deployment of egg mats. Water velocity was measured using a velocity sensor (Swoffer Instruments, Seattle, Washington) and depths were collected using a graduated rod. Water velocities were collected as close to the channel bottom as possible (near-bed), without having the substrates interfere with the measurement (typically 10 cm above bed height). Near-bed velocities are measured as they are reflective of conditions experienced by the demersal sturgeon eggs and incubation conditions that may be targeted by spawning adults.

2.6 UNDERWATER VIDEO

Substrates on the surface of the river bed at the spawning locations were examined and photographed under ambient light conditions with a high resolution underwater video camera (Aqua-Vu Explorer 7) attached to an adjustable aluminum camera pole. The boat’s UTM coordinates were recorded using a global positioning system unit (Garmin Model 12 XL), following Chiotti *et al*. (2008). Video was collected at a total of six sites with three parallel transects completed at each site. The location of each site was determined based on the location of egg mat clusters and the abundance of eggs captured on mats. Transects consisted of three observation points, at which substrate footage was recorded for a minimum of 30 seconds. Transects ran perpendicular to shore line, with an average of 20 m between each observation point. The camera, attached by coaxial cable to a 30 · 30-cm television monitor onboard, was deployed from the boat while maintaining fixed position in the water. Camera position was maintained less than 0.25 m from the river bottom and angled down at approximately 45°. The camera was then rotated, so as to view as wide a distance as possible. Substrates observed and recorded were then described based on visual observations according to categories defined as either fines (< 2 mm), gravels (2-64 mm), cobbles (64-256 mm), boulders (256 – 4000 mm), or bedrock (> 4000 mm). Prior to collecting the data, a standardization exercise was completed where the crew observed substrates in shallow water that could then be measured. This help to correct for any magnification associated with the camera and ensure correct categories were assigned.

2.7 DIDSON SONAR

In order to investigate the feasibility of using high-resolution sonar (DIDSON) to collect data on white sturgeon spawning behavior, CSTC crews and Pete Nicklin (Indisea Enterprises) completed surveys within the spawning area between May 26th and 29th, 2009. The DIDSON unit produces near video quality imaging underwater and has been used to make observations of fish behavior in a wide range of conditions. For the purposes of this study the DIDSON unit was mounted to the side of a riverboat and a radio telemetry receiver was used to locate tagged fish. Once located, the boat was anchored and scans were initiated using a 180 degree port-side sweep of the area. A low frequency setting allowing for a viewing distance of approximately 40 m was used to increase ease of target acquisition (Nicklin, 2009). When a fish was identified with the DIDSON, the frequency was adjusted to allow for better resolution and the data file was recorded. Additional information on the setup and methodology is provided in Nicklin (2009).

2.8 DRIFT NET SAMPLING

A drift net sampling program was initiated in 2009 by the Ministry of Environment (MoE) to sample for wild spawned eggs and larvae. Sampling locations were distributed throughout the known spawning area upstream of the Burrard Ave. Bridge. The goal of the program was to assess the drift patterns of eggs and larvae within the spawning area and attempt to identify preferred rearing habitats.

Day sampling was completed on June 5, 8, 9, 11, 13, 15, 17 and 19 at a total of 4 sites (Figure 4). Nets were typically allowed to soak for 1 – 1.5 hours before being checked and were then redeployed (see Appendix 4 Table 10 for set times). Night sampling was conducted on June 19, 20, 23, 24, 27, 28, July 2, 3, and 4. A total of six drift nets (2 D-ring, 2 rectangular, 2 triangular) were used with soak times ranging from 6 – 11 hours. Nets were installed after dark (approximately 23:00) and removed the following morning (see Appendix 4 Table 11 for set times). Following collection all samples were sorted and any sturgeon eggs or larvae were recorded and preserved in 50% ethyl alcohol.

3 Results and Discussion

3.1 BROOD STOCK COLLECTION AND RADIO TAGGING

A total of 71 fish were captured in 2009. This included 40 recaptures and 31 new individuals. Males were more frequently captured accounting for 59% (42/71) of the total. A total of 18 of the 42 males were assessed as being ready to spawn (7 code 4 and 11 code 5) and 3 were taken as brood stock (Table 1). Females accounted for 27% of the total number of fish captured (19/71) with 2 being assessed as ready to spawn (code 15). Both fish were taken for brood stock. The remaining 10 individuals were either assessed as juveniles (code 97 – 3 fish), adults of unknown sex (code 98 – 6 fish) or the maturity was not recorded (1 fish).

Table 1. White sturgeon taken as brood stock for the 2009 hatchery program.

Brood ID	Maturity	Total Length (cm)	Weight (kg)	PIT tag	Radio Tag Frequency	Radio Tag Code	Crosses
Male #1	5	214.0	51.5	4A0C6E3448	149.800	66	Female 1 and 2
Male #2	5	236.5	80.5	4A0D3A7D31	149.800	69	Female 1 and 2
Male #3	5	204.0	48.6	7F7D7D2D24	N/A	N/A	Female 1 and 2
Female #1	15	210.5	57.3	41250F5929	149.800	65	Male 1, 2 and 3
Female #2	15	261.0	100.0	452A4D4A58	149.800	63	Male 1, 2 and 3

Based on the assessments completed during the brood collection program, several male fish in addition to those taken as brood stock were identified as being likely to spawn in 2009 (i.e. assessed as Code 5). These fish were all radio tagged and their movements were tracked to better identify spawning location and timing. Since only two mature females were captured, both of which were used as brood stock, no females confirmed to be ripe were available to be tracked. Several other fish were also identified as being likely to spawn based on assessments completed in previous years and their presence within the vicinity of the spawning area during the period when spawning was expected to occur. Table 2 provides a list of the fish that potentially spawned in 2009.

Table 2. White sturgeon identified as potential spawners in 2009 based on assessed maturity and location during spawning period.

Frequency	Code	Sex	Maturity	Year Assessed	Notes	Reporting ID Label[1]
148.320	25	male	5	2009		148.320-25-5-2009
148.420	13	male	3	2006	Potentially mature 2009	148.420-13-3-2006
149.700	25	male	5	2009	Likely spawned in 2006	149.700-25-5-2009
149.700	27	male	3	2005	Potentially mature 2009	149.700-27-3-2005
149.700	29	male	4	2005	Potentially mature 2009	149.700-29-4-2005
149.700	30	male	4	2005	Potentially mature 2009	149.700-30-4-2005
149.700	32	male	3	2008	Potentially mature 2009	149.700-32-3-2008
149.800	51	male	5	2006	Likely spawned in 2006	149.800-51-5-2006
149.800	55	male	3	2008	Assessed as code 5 in 2007	149.800-55-3-2008
149.800	59	male	5	2006	Likely spawned in 2006	149.800-59-5-2006
149.800	60	male	5	2009		149.800-60-5-2009
149.800	61	male	5	2009		149.800-61-5-2009
149.800	64	male	5	2009		149.800-64-5-2009
149.800	67	male	5	2009		149.800-67-5-2009
149.800	68	Male	5	2009		149.800-68-5-2009
150.280	11	male	5	2009	EMG tag	150.280-11-5-2009

[1] The reporting label consists of the radio tag frequency – tag code – most recent maturity assessment – year of assessment.

3.1.1 EMG Tagging

Only one fish was implanted with an EMG tag in 2009. Fish 150.280-11-5-2009 was a mature male captured May 7th, 2009 and assessed as being ready to spawn. Its location was tracked during all subsequent boat and aerial telemetry surveys however only two records were identified: June 4th and 8th, both within the spawning area. No EMG data was collected, however, due to the limited number of EMG tagged fish, and limited encounters with that individual it is unlikely that sufficient and representative data could have been collected.

3.2 TEMPERATURE AND FLOW MONITORING

Figure 2 shows that daily mean discharge for 2009 peaked on May 14th at 267 m^3/s, which was an increase over that of the same date in 3 of the previous 4 years where spawning was observed (2004 - 133 m^3/s; 2006 - 97 m^3/s; 2008 - 220 m^3/s). 2007 was the only year where discharge was higher at the time of spawning (449 m^3/s), however, that year is considered anomalous due to emergency spilling from the Nechako Reservoir. Following the peak in discharge on May 14th, flows began to drop and by mid June they were comparable to that of previous years (with the exception of 2007). During the period where spawning was assumed to have occurred in 2009, the hydrograph was descending from 227 m^3/s on May 29th to 173 m^3/s on June 9th. This is similar to the range recorded during the spawning period in 2008 (229 m^3/s – 177 m^3/s) but higher than the discharge at which spawning occurred in either 2004 (131 m^3/s) or 2006 (98 m^3/s).

Mean daily water temperature at the Burrard Ave. Bridge during the monitoring period ranged from 6.6°C on May 4th and 6th to a high of 17.5°C on June 17th and 18th and July 4th. The maximum daily water temperature ranged from 7.4°C on May 5th to a high of 19.1°C on July 4th. In general, water temperatures in 2009 were cooler than previous years with the exception of 2007, which had abnormally high flows and low temperatures due to forced spills from the Nechako Reservoir.

Comparison of the mean daily water temperature from dates when spawning is assumed to have occurred for 2004 and 2006-2009 (Table 3), showed that in 2009 spawning occurred when water temperature were approximately 3°C cooler than in previous years. In 2009 daily means of 13°C or greater, which is the threshold where spawning has occurred in the past, were not recorded until June 3rd however, eggs were collected one day prior on June 2nd. In previous years, daily means of 13°C were achieved and spawning was observed 1 to 3 days later.

Table 3. Summary of daily mean temperature (°C) on the assumed date of spawning for 2004, 2006-2009.

Year	Spawning Date(s)	Daily Mean Temperature (°C)
2004	May 18th	13.9
2006	May 19th	13.5
2007	June 3rd	13.3
2008	June 2nd – 9th	12.8 – 14.2
2009	May 29th – June 9th	10.5 – 15.5

Detailed flow and temperature data can be found in Appendix 1 along with the historical temperature and flow data from 2004 – 2008 (Figure 13).

Water turbidity was not assessed in 2009 as visibility was regularly being assessed with the underwater camera footage of the spawning area. Throughout the study period, visibility was estimated to be 1 to 1.5 m. This was sufficient to be able to clearly see substrates and egg mats beginning the first week of June.

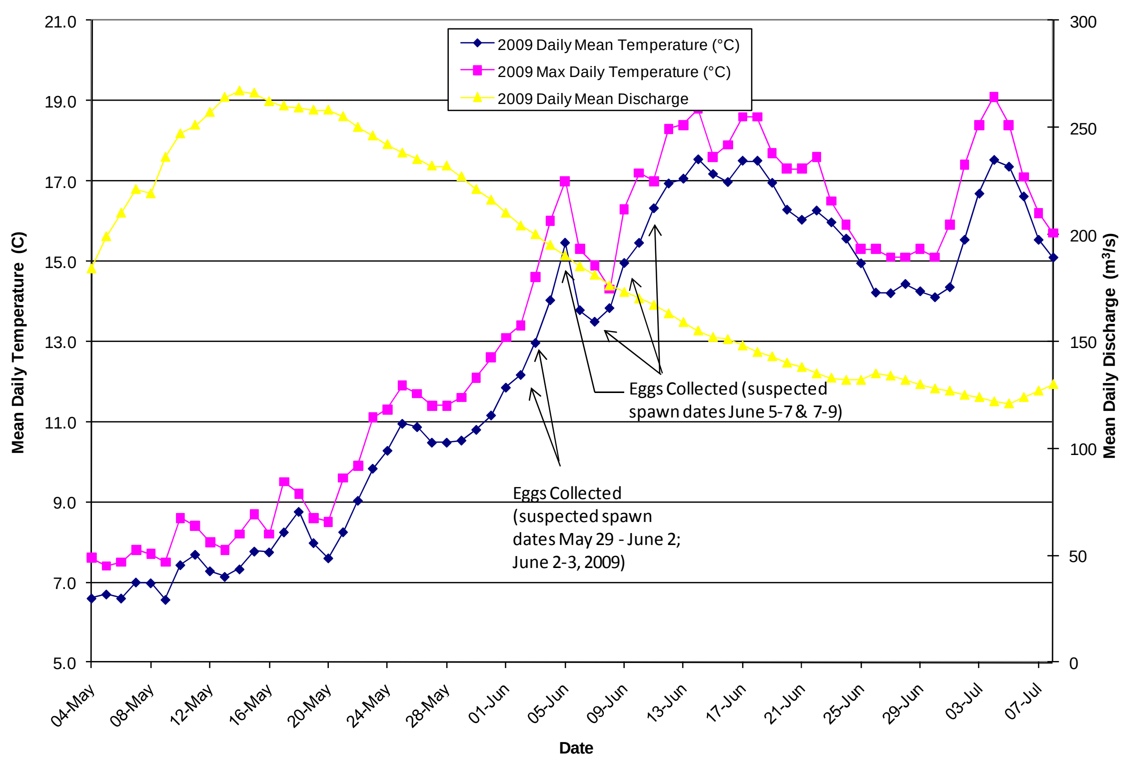


Figure 2. Daily mean and maximum temperature and daily mean discharge at the Burrard Ave. Bridge (WSC Station 08JC001) for April 1st to July 5th, 2009.

3.3 AERIAL TELEMETRY

Aerial telemetry flights were conducted on May 21st and 28th, 2009. Both flights originated from the Prince George airport and were flown over the Nechako River from the Stuart River (rkm 92) upstream to the Braeside boat launch (rkm 164), at which point the plane would turn around and follow the river downstream past Vanderhoof (rkm 136) back to the Stuart River. A total of 25 and 22 active tags were recorded during each flight, respectively, with the majority of fish detected found between km 90 (Stuart River confluence) and km 136 (the Burrard Ave. Bridge; see Appendix 2 for details).

The focus of the aerial telemetry flights in 2009 was to detect the onset of spawning characterized by the movement of fish upstream from overwintering habitats to the spawning area located at Vanderhoof. The results show that by the first flight on May 21st, most fish had left the overwintering habitats and were distributed throughout the river downstream of the spawning area. This pattern is similar to what had been observed in previous years and is typical of pre-spawn staging behavior. On May 28th a total of 8 tags were detected within the spawning area, 5 of which were potential male spawners based on maturity (148.320-25-5-2009, 149.700-30-4-2005, 149.800-51-5-2006, 149.800-64-5-2009 and 149.800-67-5-2009), 1 code 2 fish (148.320-12-2-2007), 1 code 3 fish (149.700-47-3-2009) and 1 code 4 fish (149.800-62-4-2009). Based on these results the egg mats were deployed throughout the spawning area the following day.

3.4 BOAT TELEMETRY

Boat telemetry surveys of the spawning area identified a total of 68 tags over the 12 days of the survey. June 5th and 9th were the most active days with a total of 10 and 11 tags detected, respectively (see Appendix 2 for details). Individuals that were likely to have spawned based on assessed maturity (Table 2) were identified on each day of the survey and their locations have been mapped on Figure 3.

3.5 TELEMETRY BASE STATION

The Vanderhoof base station was downloaded on June 9th, 2009. Data from May 13th to June 9th is summarized in Appendix 2. The results show that activity at the base station began to increase on May 25th and peaked on May 29th with 23 individuals detected, 11 of which were potential spawners based on assessed maturity (see Table 2). Activity at the base station remained high through June 5th with an average of 16 tags per day recorded. On June 6th, the number of recorded tags decreased to 7 and remained below 10 until June 9th when 11 fish were identified, 8 of which were potential spawners and 1 was a brood fish. Many fish were detected on subsequent days suggesting regular movements past the station, between downstream staging areas and the spawning area.

3.6 VISUAL OBSERVATIONS

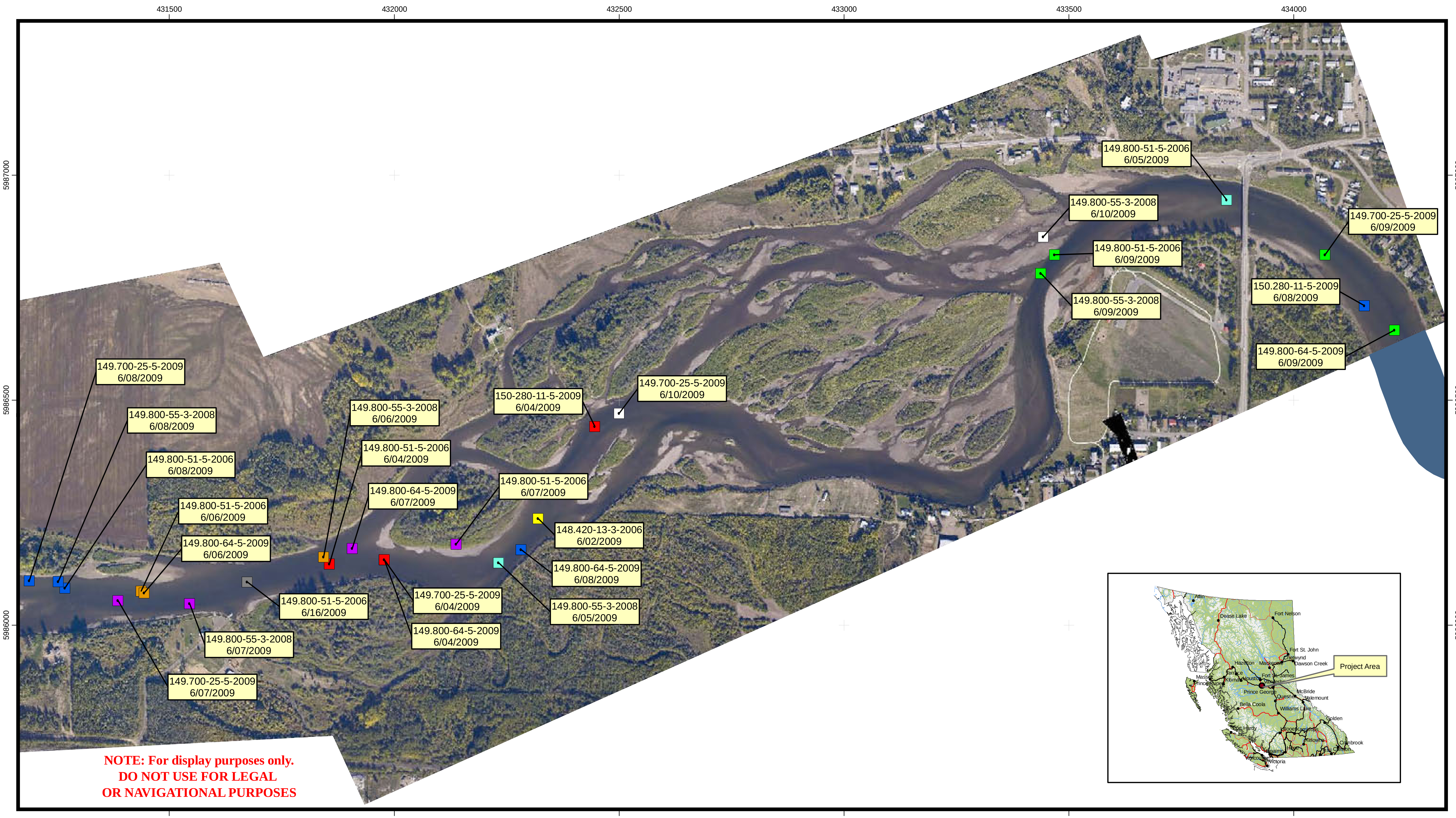
No visual observation flights of the spawning area were completed in 2009. Instead, boat based telemetry and egg mat sampling were used to identify general spawning locations. No observations of sturgeon spawning activity (e.g. breaching, congregating) were documented by Triton personnel.

3.7 DIDSON SONAR

The results of the DIDSON investigation suggest that the technology could be used to observe white sturgeon spawning behavior (Nicklin, 2009). A total of five individuals were identified by the DIDSON during the monitoring period in 2009. All fish were located near the confluence of Stoney Creek however no specific spawning behaviors were observed.

3.8 DRIFT NET SAMPLING

Day sampling was completed on 8 days over a two week period for a total effort of 82 hrs and 30 min (Appendix 4 Table 10). Sampling resulted in the collection of one yolk sac larva (like 1 day post hatch) on June 8th from site #2. No eggs were collected. Night sampling was completed on 9 nights over two weeks for a total effort of 527 hrs and 42 min (Appendix 4 Table 11). A total of 4 larvae were collected: 3 on June 19th from net 1 and 1 on July 3rd from net 5. The larvae collected on the 19th were yolksac larvae (1 – 2 days post hatch approximately) but no description of the July 3rd larvae was recorded. Based on the date it is assumed to be a feeding larvae (i.e. more than 10 days post hatch). There is also a note of a potential sturgeon egg being collected on June 20th in net 6.



Sturgeon locations by date

- 6/16/2009
- 6/10/2009
- 6/09/2009
- 6/08/2009
- 6/07/2009
- 6/06/2009
- 6/05/2009
- 6/04/2009
- 6/02/2009

NO.	DATE (yyyy/mm/dd)	REVISION	BY
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NECHAKO RIVER STURGEON PROJECT 2009

Figure 3. Sturgeon Locations

0 100 200 400 600 Meters

Scale: 1:8,000

Basemap Source: September 2009 Orthophoto - Rio Tinto Alcan

Map Datum: UTM NAD 83 Zone 10

Project No: 4170

File No: Map#: 4170_Nechako_Sturgeon_2009\MXD\Sturgeon_Locations_11x17.mxd

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3.9 SAMPLING FOR EGGS

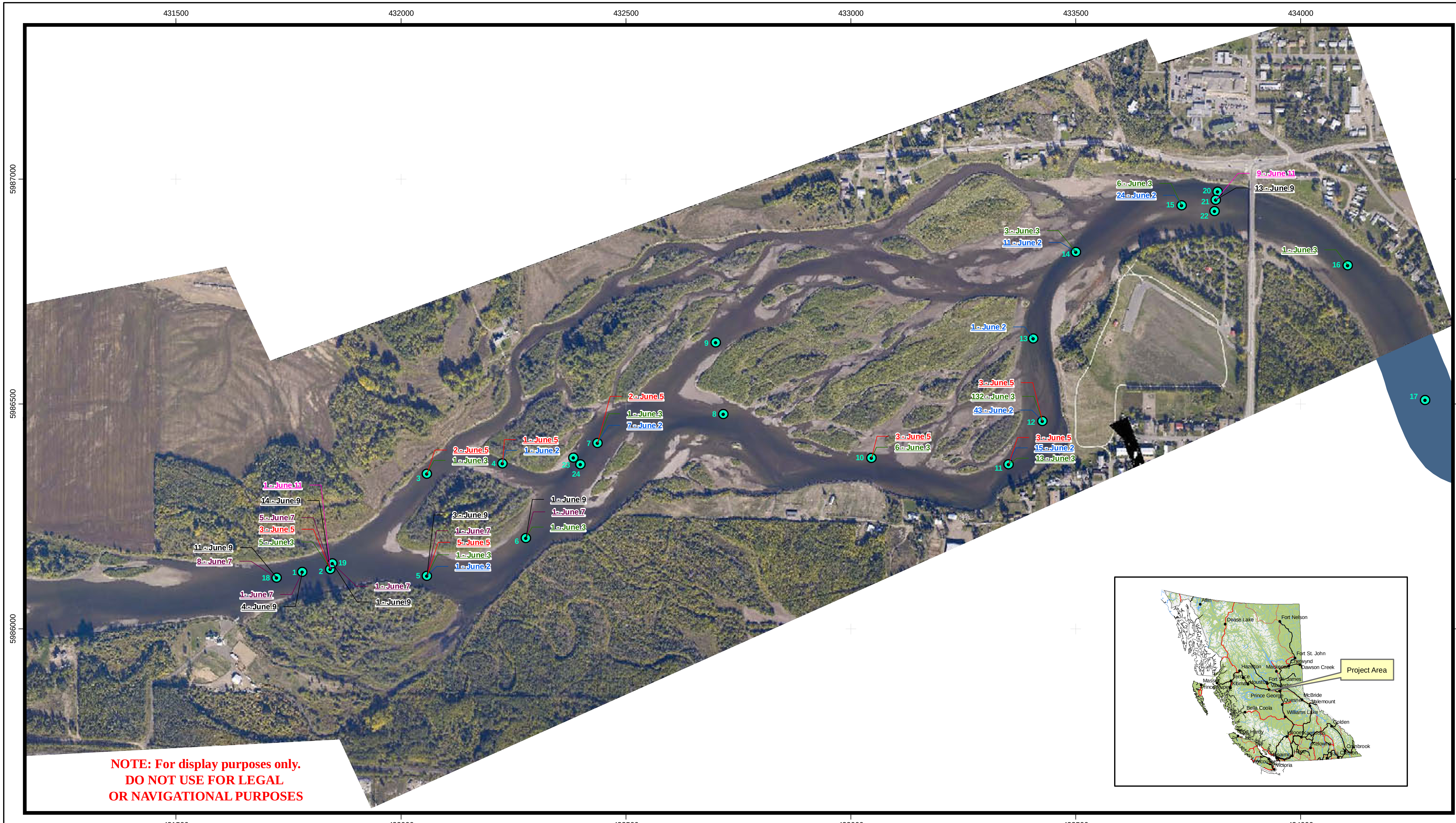
3.9.1 EGG MATS

A total of 48 egg mats were deployed in groups of 2 between river kilometer 135 and 140 on May 29th (Figure 4). Depths ranged from 0.6 to 3.8 m, and near-bed velocities ranged from 0.14 to 1.15 m/s. The mats were checked and cleaned on June 2nd, 3rd, 5th, 7th, 9th, 11th, and 15th and retrieved on June 22nd. Mats were set for a combined total of 26, 042 hours. A total of 369 sturgeon eggs were captured, with the majority of eggs captured in the vicinity of Stoney Creek. Eggs were collected on 6 separate days: June 2nd (103 eggs), June 3rd (170 eggs), June 5th (22 eggs), June 7th (17 eggs), June 9th (47 eggs) and June 11th (10 eggs). The catch per unit effort (CPUE) for the egg mats ranged from 0.000 – 1.933 eggs/hour/m^2, which was an increase from 2008 when CPUE ranged from 0.000 - 0.003 eggs/hour/m^2. Egg mats were generally stable, with minimal downstream movement. All sets were well marked with orange buoys for the duration of the sampling period and no gear was lost or damaged.

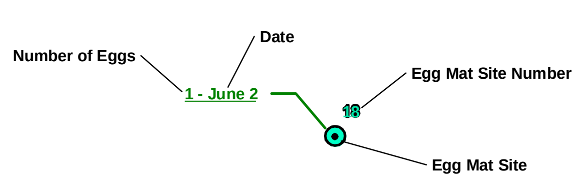
3.9.2 EGG IDENTIFICATION AND VIABILITY

Eggs collected from egg mats during the study were stored in vials of river water and held in a cooler to ensure a stable temperature. The eggs were then transferred to the Freshwater Fisheries Society hatchery in Vanderhoof and incubated in separate containers to prevent mixing with the hatchery stock. Once transferred to the hatchery, MoE staff monitored the status of the wild eggs. It was noted that the eggs collected on June 3rd were either pre- or post-neurulation suggesting at least two deposition periods. Subsequent assessment of the same eggs on June 5th identified approximately 30 live eggs not including those from mat #12, which were too numerous to easily count (total of 175 eggs collected on June 2nd and 3rd). Additional assessments of the eggs were completed and found that by June 9th, several of the eggs collected on June 3rd had hatched. One egg collected on June 5th hatched by the 11th, and multiple eggs collected on the 7th had hatched by the 13th. Lastly, eggs collected on the 9th were assessed as being at neurulation on the 11th. This data confirms that a wild spawning event occurred in 2009 that produced viable eggs.

Assuming an incubation temperature of approximately 13-15°C neuralation occurs 3 days after fertilization while hatch typically occurs between 7 and 9 days after fertilization (Wang 1984 in Conte et al. 1988). This timing suggests that the eggs collected on June 3rd (hatched on the 9th) were spawned between May 30th and June 2nd; eggs collected on June 5th (hatched on the 11th) were spawned between the 2nd and 5th; eggs collected on June 7th (hatched on the 13th) were spawned between the 5th and 7th; and eggs collected on June 9th (neuralation June 11th) were spawned on June 8th or 9th.



Legend



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NECHAKO RIVER STURGEON PROJECT 2009

Figure 4. Egg Mat Locations

0 100 200 400 600 Meters

Scale: 1:8,000

Basemap Source: September 2009 Orthophoto - Rio Tinto Alcan

Map Datum: UTM NAD 83 Zone 10

Project No: 4170

File No: Map#: 4170_Nechako_Sturgeon_2009\MXD\Fig1_11x17.mxd

Date: Feb 10, 2010

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3.10 SPAWNING ASSESSMENT

Based on the egg sampling and telemetry results, a series of wild spawning event occurred between May 29th and June 9th. A summary of the eggs collected by egg mat and date is provided in Table 4. Figure 4 shows the location of each mat.

Table 4. Egg mat sampling summary for 2009. Shaded cells identify days traps were not fished.

Site	UTM	Eggs Collected								Total
		02-Jun	03-Jun	05-Jun	07-Jun	09-Jun	11-Jun	15-Jun	22-Jun	
1	10.431781.5986127				1	4				**5**
2	10.431843.5986133		5	3	5	14	1			**28**
3	10.432058.5986345		1	2						**3**
4	10.432226.5986368	1		1						**2**
5	10.432058.5986118	1	1	5	1	3				**11**
6	10.432278.5986202		1		1	1				**3**
7	10.432437.5986413	7	1	2						**10**
8	10.432717.5986478									**0**
9	10.432700.5986637									**0**
10	10.433046.5986380		6	3						**9**
11	10.433351.5986366	15	13	3						**31**
12	10.433426.5986462	43	132	3						**178**
13	10.433406.5986646	1								**1**
14	10.433501.5986838	11	3							**14**
15	10.433736.5986942	24	6							**30**
16	10.434105.5986808		1							**1**
17	10.434277.5986509									**0**
18	10.431724.5986114				8	11				**19**
19	10.431848.5986146				1	1				**2**
20	10.433816.5986972									**0**
21	10.433812.5986954					13	9			**22**
22	10.433809.5986929									**0**
23	10.432384.5986381									**0**
24	10.432399.5986366									**0**
Total Eggs Collected		**103**	**170**	**22**	**17**	**47**	**10**	**0**	**0**	**369**

Interpretation of the egg mat results and subsequent analysis of the development stage of the collected eggs (see section 3.9.2) suggests there were 4 distinct spawning events in 2009 in 3 primary locations (Stoney Creek, upstream end of spawning area, downstream end of spawning area). The first event occurred between May 29th and June 2nd and corresponded to the period of greatest activity at the telemetry base station located downstream of the Burrard Ave. Bridge (see Appendix 2). Temperatures during this period ranged from a daily mean of 10.5-12.2°C and daily maximum of 11.6-13.4°C. These temperatures are cooler than that of past spawning events which generally occurred at a daily mean temperature of 13.5°C. Telemetry base station data (Appendix 2) identified 10 individuals assumed to be spawners each day between May 29th and June 2nd suggesting fish were present within the spawning area throughout that period. No boat telemetry was completed prior to June 2nd. The majority of eggs collected on June 2nd were located in the vicinity of Stoney Creek suggesting spawning was localized in that area. Additional eggs were captured at mats 4, 5 and 7 on both sides and downstream of the top island (see Figure 4). No eggs were collected upstream of the top island or downstream of the Burrard Ave. Bridge during the initial event. The data could suggest two separate spawning events (i.e. 1 group of spawners in each location) or 1 spawning event with the same individuals moving between the two locations.

The second spawning event is thought to have occurred between June 3rd and 5th based primarily on a significant increase in the number of eggs collected on egg mat #12 and the presence of eggs on mats 2 and 3, which previously had none. The location of that mat suggests spawning was again located primarily in the vicinity of Stoney Creek however eggs on mats 2 and 3 suggest activity at the upstream end of the spawning site as well. Temperatures on the 3rd reached a daily mean of 13°C with a daily max of 14.6°C which is similar to the range at which spawning occurred in previous years.

The third event is thought to have occurred between June 5th and 7th of June. While a significant increase in eggs was not observed, the presence of eggs on mats that had not previously had any (e.g. mats 1, 18 and 19) suggest another event. It should be noted that no eggs were collected from this event at the Stoney Creek mats. This suggests that the spawning location had shifted towards the upstream and downstream ends of the spawning area. Temperatures between the 5th and 7th ranged from a mean of 15.5°C to 13.5°C, respectively.

The fourth event occurred between the 7th and the 9th of June and was identified primarily from the increase in eggs collected at mat #2. Similar to the third event it was primarily located at the upstream end of the spawning area however eggs were also collected on mat 21 located immediately upstream of the Burrard Ave. Bridge. While it is possible that the eggs collected at the downstream end had drifted onto the mats, accumulations of fine sediments which would be expected from drifting eggs was not observed. Additional eggs were collected on June 11th, however all were from mats that had eggs on June 9th and therefore it is possible they were left over from the earlier event as opposed to being from a new event. Subsequent egg mat checks on June 15th and 22nd failed to collect any eggs suggesting that the spawning period had ended following the activity on the 9th.

3.11 HABITAT DOCUMENTATION

Spawning in 2009 occurred in the same general area as in 2004, 2006, and 2008. Sites for habitat assessments were chosen based on spawning results in 2009 (primarily) as well as in previous years. A total of 18 videography transects (Figure 6) were visited over six sites in order to gather habitat data for the spawning area. Transects were located in the main channels and side channels where sturgeon were observed to be congregating, as well as in channels upstream and downstream of that area.

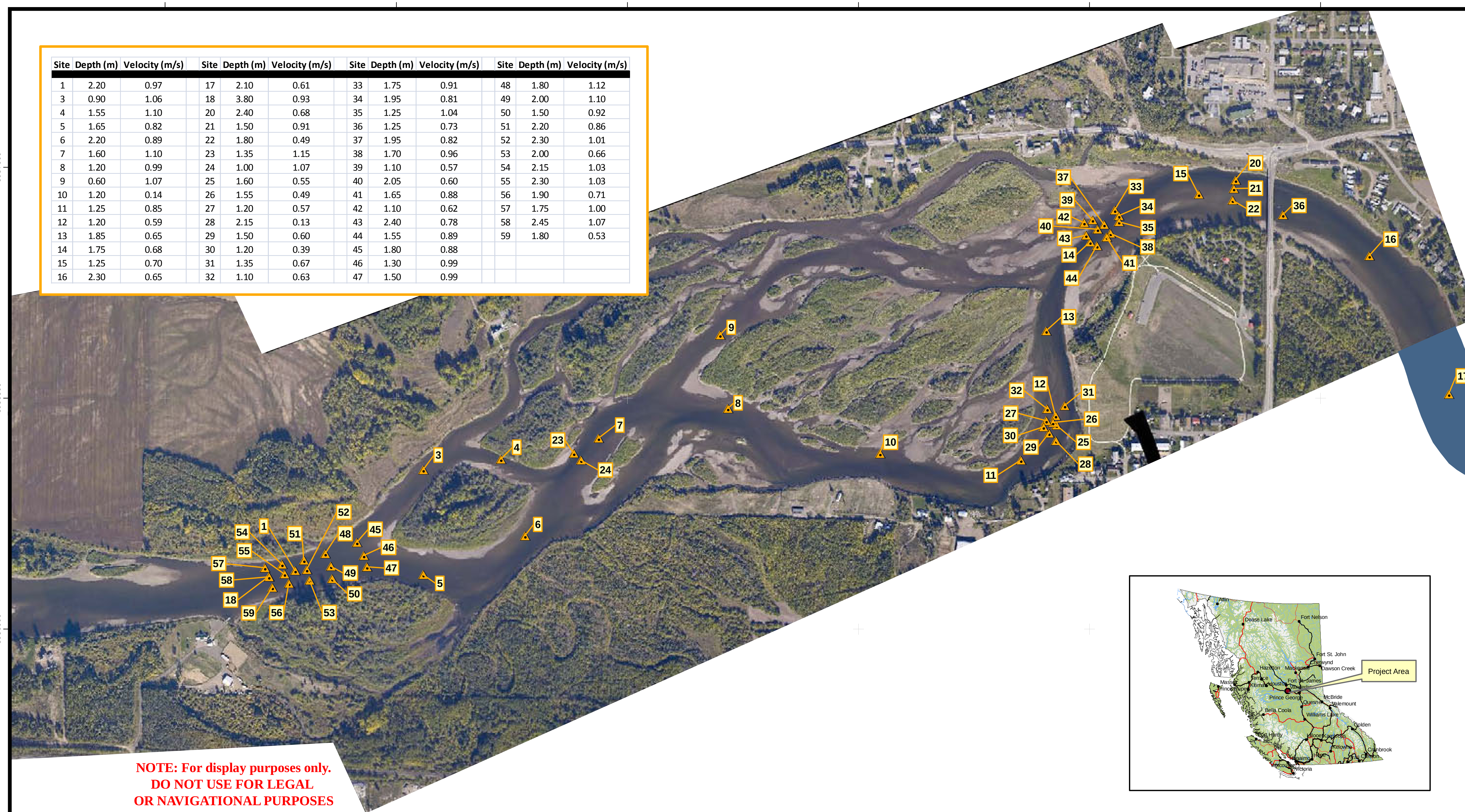
Water Velocity

Water velocities in 2009 were collected from each of the 24 egg mat sites as well as 12 additional transect sites throughout the spawning area (Figure 5). Velocities were collected between May 29th and June 10th and are therefore considered representative of conditions during the spawning events. One quarter of the water velocities (25%) collected were equal to or above 1.0 m/s. The highest water velocity recorded was 1.15 m/s at an egg mat site located at the upstream end of the braided section in a flow directly connected to the main channel (set #23). The average near bed velocities measured in 2009 were 0.80 m/s which were lower than that of 2008 (0.99 m/s) and 2007 (1.03 m/s). A complete list of the water depth and velocities is found in Appendix 5.

Substrate

Composition of substrates and availability of spawning habitat was assessed at six study sites using mainly videography as well as from observations made during the collection of velocity and depth data as well as the retrieval of egg mats. The videography shows that the bed surface of the study area over all six sites is primarily dominated by gravel and fine substrates. Gravel was the dominant substrate at transects located in the middle section of the study area with cobble substrates located in the upstream section of braided channel. Fine substrates were abundant at sites located close to and downstream of the Burrard Ave. Bridge but were also prevalent within back channel habitats throughout the study area. Throughout the spawning area, coarse substrates (gravel and cobble) tend to be embedded with fine substrates. It should be noted that neither the degree of embeddness nor the composition of the subsurface layers could readily be estimated. Detailed description of the substrates at each of the six sites is provided below.

Site	Depth (m)	Velocity (m/s)	Site	Depth (m)	Velocity (m/s)	Site	Depth (m)	Velocity (m/s)	Site	Depth (m)	Velocity (m/s)
1	2.20	0.97	17	2.10	0.61	33	1.75	0.91	48	1.80	1.12
3	0.90	1.06	18	3.80	0.93	34	1.95	0.81	49	2.00	1.10
4	1.55	1.10	20	2.40	0.68	35	1.25	1.04	50	1.50	0.92
5	1.65	0.82	21	1.50	0.91	36	1.25	0.73	51	2.20	0.86
6	2.20	0.89	22	1.80	0.49	37	1.95	0.82	52	2.30	1.01
7	1.60	1.10	23	1.35	1.15	38	1.70	0.96	53	2.00	0.66
8	1.20	0.99	24	1.00	1.07	39	1.10	0.57	54	2.15	1.03
9	0.60	1.07	25	1.60	0.55	40	2.05	0.60	55	2.30	1.03
10	1.20	0.14	26	1.55	0.49	41	1.65	0.88	56	1.90	0.71
11	1.25	0.85	27	1.20	0.57	42	1.10	0.62	57	1.75	1.00
12	1.20	0.59	28	2.15	0.13	43	2.40	0.78	58	2.45	1.07
13	1.85	0.65	29	1.50	0.60	44	1.55	0.89	59	1.80	0.53
14	1.75	0.68	30	1.20	0.39	45	1.80	0.88			
15	1.25	0.70	31	1.35	0.67	46	1.30	0.99			
16	2.30	0.65	32	1.10	0.63	47	1.50	0.99			



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Depth & Velocity Sites

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Figure 5. Depth & Velocity Sites

0 100 200 400 600 Meters

Scale: 1:8,000

Basemap Source: September 2009 Orthophoto - Rio Tinto Alcan

Map Datum: UTM NAD 83 Zone 10

Project No: 4170

File No: Map#: 4170_Nechako_Sturgeon_2009\MXD\Depth_Velocity_11x17.mxd

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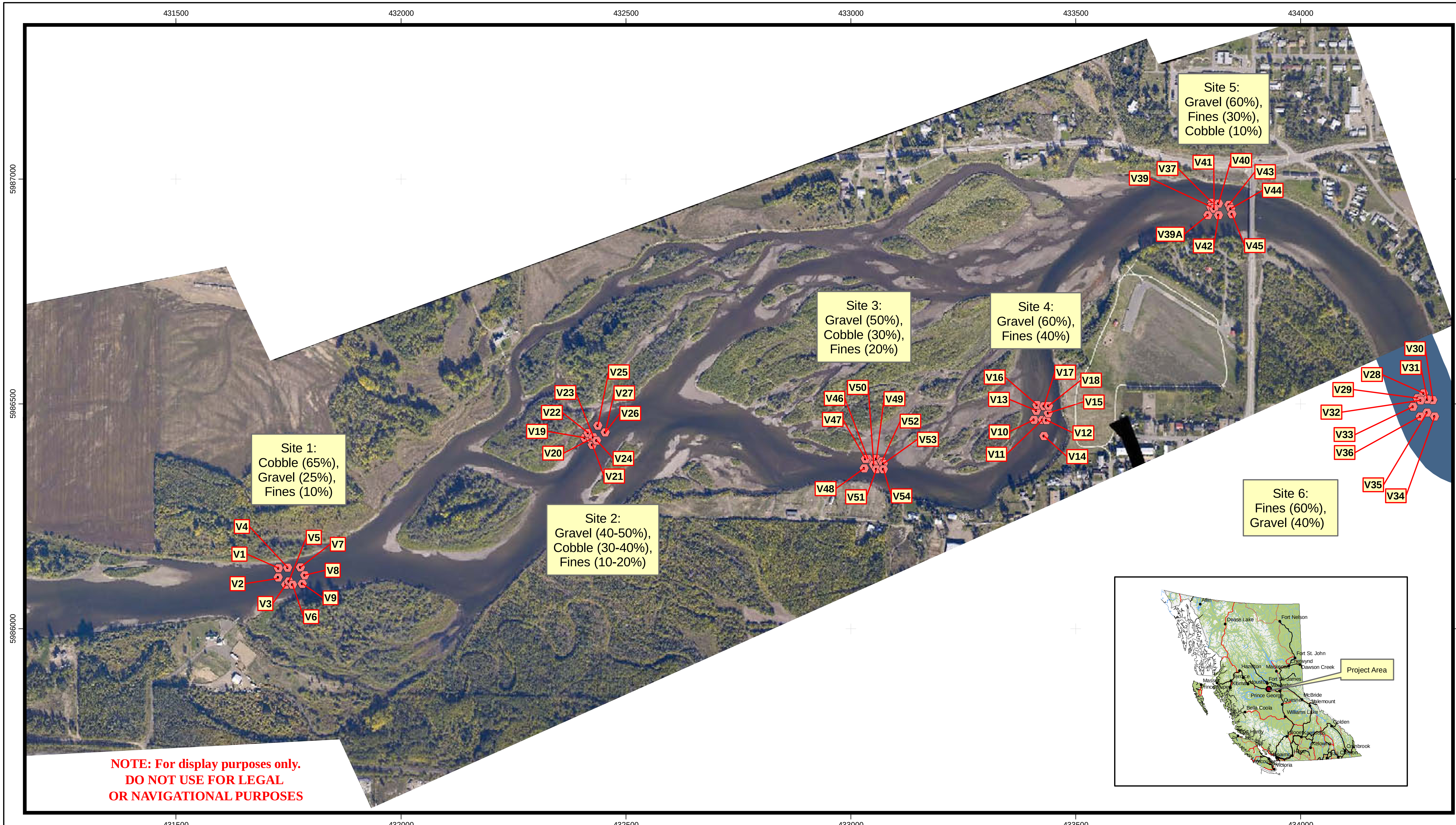

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Video Sites 2009

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Figure 6. Videography Locations

0 100 200 400 600 Meters

Scale: 1:8,000

Basemap Source: September 2009 Orthophoto - Rio Tinto Alcan

Map Datum: UTM NAD 83 Zone 10

Project No: 4170

File No: Map#: 4170_Nechako_Sturgeon_2009\MXD\Video_11x17.mxd

Date: Feb 10, 2010

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<u>Site 1</u>

Site 1 was located upstream of the braided section in the main channel thalweg encompassing the most upstream egg mats (mat 1, 2, 18, and 19; Figure 6). A total of 54 eggs were retrieved from the egg mats at this site over the course of the study, which is 15% of eggs from all sites. As can be seen in the representative photo in Figure 7, the dominant surface substrate was cobble (estimated to be 10 – 30 cm in diameter) with lower proportions of gravels (2 - 6 cm diameter) interspersed throughout. Trace amounts of fines were also observed primarily in depositional areas such as behind larger substrate pieces and in interstitial spaces. While the infilling of these spaces could be having a detrimental effect on egg and larval survival, it is not as extensive as in areas downstream. Depth at these sites averaged 2.04 m with an average near-bottom flow velocity of 0.93 m/s. Analyses of the video shows the velocity in this area was high enough to mobilize the fine substrates as well as some of the gravels. A small amount of macrophytic plants and decaying organic matter can also be seen on the substrates at this site which may work to further reduce the amount of interstitial space.

Figure 7. Representative underwater photo of cobble dominant substrate of Site 1.

Habitat transects were also completed in this location as part of the 2004 sturgeon monitoring program (Triton, 2004). At that time, mean depths of 1.28 to 2.05 m and mean velocities of 0.95 – 1.03 m/s were observed. Substrate composition was estimated to be 60% cobble, 25% gravel and 15% fines at that time. Review of camera footage in 2009 suggest a slightly lower composition of fines (estimated to be 5 – 10%) which could be as a result of the high discharge in the system in 2007 mobilizing those particles downstream. In 2007, northwest hydraulic consultants (nhc) completed transects in this area using an Acoustic Doppler Channel Profiler (ADCP). They found velocities as high as 2.0 m/s at transect "AA" just upstream of the site 1 location (nhc, 2008). However, their data included the entire water column as opposed to just the near-bed velocity that Triton has focused on, which explains the higher velocities. Model analysis of the data shows this area to experience the highest velocity discharge in the area which would account for generally cleaner substrates as compared to downstream sites.

Observations of fish and/or the collection of eggs have occurred in this area in 5 of the 6 years monitored (2004, 2006, 2007, 2008 and 2009). The only year spawning was not confirmed to have occurred in this area was 2005 and no eggs or observations were made that year anywhere in the spawning area (Triton, 2005). The frequency of spawning in this area suggests that habitat conditions are favourable for spawning to occur. In particular flow velocity, which is high relative to other locations in the spawning area, is thought to be a key variable for spawning habitat selection. Other variables such as depth may also be a factor in habitat selection. It is unknown what role substrate composition plays in spawning habitat selection for adults. This variable is considered very important for egg and juvenile survival but whether adults seek out specific substrates for spawning is unclear. Being broadcast spawners white sturgeon have less direct interaction with the substrate then fish such as salmon, which are known to target specific substrate types. However, the fact that other white sturgeon spawning sites in the river have not been identified suggests there are specific habitat characteristics or combination of characteristics that are being selected. For example, substrate suitability could broadly define a spawning area whereas factors such as velocity and temperature determine specific spawning sites.

Site 2

Site 2 was located in the main channel thalweg, upstream area of the braided section encompassing egg mats 7, 20, and 21 (Figure 6). A total of 10 eggs were retrieved from the egg mats at this site over the course of the study, which is 3% of eggs from all sites. As can be seen from the representative photo in Figure 8, the dominate substrate was gravel and cobble with fines interspersed throughout. Compared to site 1, a higher percent composition of gravel (estimated to be 40-50%) and lower percent composition of cobble (estimated to be 40%) was observed. Fines were estimated to comprise 10-20% which was slightly higher than that of site 1. Data collected in 2004 identified a higher component of gravel (80%) and lower cobble component (5%; Triton 2004) at this location. Depth at this site averaged 1.32 m with a flow velocity of 1.11 m/s, which was slightly higher than that of site 1 but consistent with data collected in 2004 (mean depth 1.30 – 1.37 m and mean velocity of 0.97 – 1.02 m/s; Triton 2004). These velocities are likely high enough to mobilize the fine substrates as well as more inconsistently mobilize gravels. The shift towards coarser substrates, based on the comparison between 2004 and 2009 data, is likely due to the high flow event experienced in 2007. Macrophytic plants and decaying organic matter were not observed on the substrates at this site which differs from site 1. Observations of spawning fish in this area occurred in 2004 and eggs were collected here in 2008 and 2009 suggesting favourable habitat conditions for spawning. However the composition of fines and embedded substrates suggests the area is less favourable for the subsequent survival of eggs and larvae.

Figure 8 Representative underwater photo of gravel and cobble dominant substrate of site 2.

Site 3

Site 3 was located upstream of the Stoney Creek confluence in the main stem of the braided section at egg mat 10 (Figure 6). A total of 9 eggs were retrieved from the egg mats at this site over the course of the study, which is 2% of eggs from all sites. The representative photo (Figure 9), shows the dominate substrate was gravel (50%) with cobble (30%) and fines (20%) interspersed throughout. As compared to the upstream sites, there was a greater component of gravel (compared to site 1) and the gravel that was present tended to be coarser (compared to site 2). Depth at this site averaged 1.00 m with a flow velocity of 0.73 m/s. Data from nhc (2008) showed velocities in the mid channel in this area to be approximately 0.8 m/s. A small amount of macrophytic plants and decaying organic matter can also be seen on the substrates at this site likely due to the lower velocity then was observed upstream at site 2. This area was not extensively sampled in past years and as a result, information on the degree of past use is limited to observations of individual fish (i.e. not pairs or congregations) from 2004. However, based on the collection of eggs in this location in 2009, it can be assumed that at present habitat conditions are appropriate for spawning.

Figure 9 Representative underwater photo of gravel and cobble dominant substrate of site 3.

Site 4

Site 4 was located downstream of the Stoney Creek confluence in the main stem of the braided section at egg mats 11 and 12 (Figure 6). A total of 206 eggs were retrieved from the egg mats at this site over the course of the study, which is 56% of eggs from all sites. The representative photo (Figure 10) shows gravel dominated substrates (60%) and a high component of fines (40%). This is similar to the results of the habitat surveys completed in 2006 which estimated gravel and fines to be nearly equal (43% and 48%, respectively). Cobble substrates were not observed at the site during either assessment. It is thought that the high percent of fine substrates would limit the availability of interstitial spaces and adversely affect egg incubation and survival. Depth in 2009 at this site averaged 1.48 m with a flow velocity of 0.57 m/s. Macrophytic plants and decaying organic matter can also be seen on the substrates at this site which would be expected at lower velocity sites. Eggs were collected in this area in 2006, 2008 and 2009. The number of eggs collected in 2009 suggests localized spawning in the immediate vicinity of this location. Therefore, habitat conditions can be assumed to be favourable for spawning to occur, but are likely less favourable for subsequent survival of eggs and larvae.

Figure 10 Representative underwater photo of gravel and fine dominant substrate of site 4.

Site 5

Site 5 was located upstream of the Burrard Avenue Bridge encompassing egg mats 15, 22, 23, and 24 (Figure 6). A total of 43 eggs were retrieved from the egg mats at this site over the course of the study, which is 12% of eggs from all sites. The representative photo (Figure 11), shows the dominate substrate to be gravel (60%) with cobble (10%) and fines (30%). The site differs from site 4, located upstream, due to the presence of cobble and lower percent composition of fines. The results are consistent with the habitat data collected in 2006 which estimated 60% gravel and 40% fines, but no cobbles were identified during that survey. It is thought that the high percent of fine substrates would limit the availability of interstitial spaces and adversely affect egg incubation and larval survival. Depth at this site averaged 1.89 m with a mean near bed velocity of 0.67 m/s. This site is downstream of the braided section and the increased confinement could explain the decrease in fine substrates and increase in coarse substrates as compared to site 4. A small amount of macrophytic plants and decaying organic matter can also be seen on the substrates at this site. Eggs have consistently been collected at this location (2006, 2007, 2008 and 2009), and observations of breaching and potential congregations have also been made. This suggests spawning does occur in this area and that the habitat is therefore favourable.

Figure 11 Representative underwater photo of gravel and fine dominant substrate of site 5.

Site 6

Site 6 was located downstream of the Burrard Avenue Bridge at egg mat 17 (Figure 6). Only 1 egg was retrieved from the egg mats at this site over the course of the study. The representative photo (Figure 12) shows the substrate to be dominated by fines (60%) and gravel (40%). It is thought that the high percent of fine substrates would limit the availability of interstitial spaces and adversely affect egg incubation and survival. Depth at this site averaged 2.20 m with a flow velocity of 0.63 m/s. These results were consistent with the assessment completed in 2006. Macrophytic plants and decaying organic matter can also be seen on the substrates at this site which is consistent with other lower velocity sites surveyed.

Eggs have been regularly collected in the vicinity of this site (2006, 2007, 2008, and 2009), however it has been speculated that it is the result of drift as opposed to spawning in this area. Observations of fine substrates adhering to some of the eggs collected support this assumption. However, fish have also been visually observed breeching in this area and spawning behavior was observed here in 2003 (Pers. Comm. Cory Williamson, MoE).

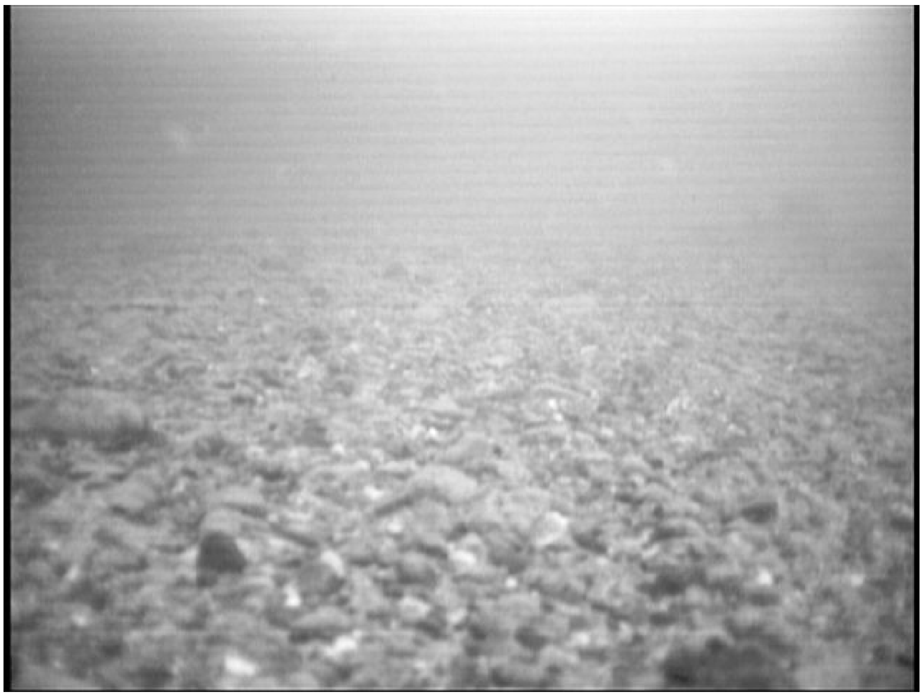


Figure 12 Representative underwater photo of fine and gravel dominant substrate of site 6.

4 SUMMARY DISCUSSION

During the 2009 adult white sturgeon monitoring program, river discharge was higher than in 2004 and 2006, but was comparable to that of 2008. Mean daily water temperatures during the period when spawning was assumed to have initially occurred (May 29^{th} to June 2^{nd}) were lower than in previous years (10.5°C vs. approximately 13.5°C in 2004, 2006 and 2008) however warmed up to comparable levels by the end of the spawning period. Although no visual observations of spawning were made, the collection of fertilized sturgeon eggs on multiple days (June 2^{nd}, 3^{rd}, 5^{th}, 7^{th}, 9^{th}, and 11^{th}) and from 17 different egg mat sample sites confirms that spawning did occur. The following sections summarize the findings of the 2009 program and provide recommendations for future work.

4.1 SPAWNING CONGREGATION

White sturgeon spawning in 2009 occurred over a span of approximately 12 days (May 29th to June 9th, inclusive). Based on egg mat sampling results, four distinct events can be identified where new deposits of eggs were identified. The initial event was estimated to have occurred between May 29th and June 2nd, which was approximately 2 weeks later than the spawning events of 2004 and 2006 (May 18th/19th), but approximately the same dates as 2007 (June 2nd) and 2008 (May 26th to June 2nd). However, despite occurring on the same approximate dates, spawning in 2009 occurred at a mean daily water temperature that was 3°C cooler than previous years. In 2004, 2006, 2007, and 2008 the variability in spawning date could be attributed to differences in water temperature since in all 4 years spawning occurred when water temperatures reached approximately 13°C (Triton 2004, 2006, 2007, 2008). However, 2009 deviated from this pattern with spawning initially occurring at mean daily water temperatures of 10.5°C. These results could suggest that while temperature is likely still the driving factor for spawn timing, if it gets late enough in the year and optimal temperatures have not been achieved, spawning will occur at cooler, potentially less optimal temperatures. One potential explanation for the pattern observed in 2009 is that there is another environmental cue that helps define the spawning window. That cue, which is likely photoperiod, initiates the spawning process while temperature controls the precise timing once underway. The 2009 data shows that in the event that suitable temperatures are not achieved within a particular time period, spawning will still occur at a less optimal temperature. Reliance on a combination of environmental cues, and in particular photoperiod and temperature, has been linked to other fish behaviours such as the timing of salmon smolt migrations (Sykes et al. 2009).

By June 3rd, daily mean water temperatures had warmed up to 13°C and remained above that level for the remainder of the spawning event. Because additional eggs were collected up to the 9th and at least three additional spawning events occurred during that period, it seems that the cue to spawn early was not universal but rather only applied to one group of fish while the remainder waited for conditions similar to those in previous years. Alternatively, it is possible that different spawning populations may exist that have different threshold cues for spawning. Additional tracking and tagging of fish from other locations in the river may help to identify if different population groups exist in the system. The relationship between the timing of sturgeon spawning and water temperatures was investigated through a modeling analyses completed in 2008 based on data collected from 2005-2007 (see Triton 2008). Each of the selected models to explain observed sturgeon migration patterns in that analysis included a temperature component (mean daily temperature) highlighting the importance of that parameter to migration. Based on those results it was speculated that manipulations of the flow regime that result in temperature changes could result in spawning that occurs too early or too late potentially impacting the survival of eggs, larvae and juveniles due to lack of available food (in the case of spawning occurring early) or insufficient time for rearing and growth before winter (in the case of spawning occurring late). While the 2009 results do not necessarily dispute those conclusions, they could suggest the fish have greater plasticity in terms of temperature than originally thought when it comes to spawning. Despite that, potential implications to white sturgeon spawn timing should be considered when making management decisions for the system and severe deviations from normal flow and temperature regimes should still be avoided whenever possible.

Another potential explanation for spawning in 2009 occurring at a cooler temperature than previously observed is that micro-habitat conditions could be a factor. Based on egg mat results, initial spawning events in 2009 (i.e. those that occurred before a daily mean temperature of 13°C was achieved), were localized around the confluence of Stoney Creek. It is possible that the temperature at that location was slightly higher than that of the Burrard Bridge WSC location approximately 900 m downstream. Stoney Creek is a low gradient, unconfined stream with minimal riparian shading in at least the lower few kilometers. Therefore it is reasonable to expect that its temperature could be slightly elevated over that of the main Nechako River and that it could increase temperatures in the river for a short distance downstream of the confluence. In addition groundwater influences near the stream outlet may also have played a roll. Fish in that area may have responded to that deviation resulting in a localized spawning event suggesting they may be sensitive to smaller-scale changes in key variables than originally thought.

Unfortunately, no temperature data was collected for that location and therefore the theory cannot be tested.

The variation in spawn location between the beginning (May 29th to June 3rd; Stoney Creek) and end of the spawning period (June 3rd to 9th; upper and lower ends) does suggest that habitat preference or micro-habitat conditions or a combination may be a controlling factor when determining spawn location. When compared to sites where eggs have regularly been collected, habitat conditions at the Stoney Creek area where spawning initially occurred in 2009 differed primarily in substrate composition with a greater proportion of small gravel and fines being present. However, other parameters such as depth and velocity were similar to that of other sites. These types of substrates have not generally been considered favourable for sturgeon spawning due primarily to the lack of interstial spaces due to the high percent composition of fines. If this is the case then the results would support the speculation that it is variables such as temperature and flow velocity that drive spawning location and not factors such as substrate. This seems reasonable given sturgeon are broadcast spawners and do not directly deposit eggs within the substrate as do other fish such as salmonids. Despite this the lack of other identified spawning areas within the river suggests they are more selective than other broadcast spawners such as suckers. Therefore, while conditions in the past throughout the spawning area may have been favourable for egg and larval survival so the exact location of spawning was less critical, changes that have occurred in the river in the last half century, have made this no longer the case.

The duration of the spawning event in 2009 is estimated to have been 12 days. Egg mats were deployed on May 29th and eggs were first collected on June 2nd through June 9th. Telemetry data showed increased activity in the vicinity of the spawning area beginning on May 28th. This is comparable to the duration of spawning in 2008 which occurred over a similar period (May 28th to June 9th) and was separated into two distinct events (May 28th to June 2nd and June 4th to 9th). In contrast, the duration of the 2004, 2006 and 2007 spawning events was estimated to be much shorter ranging from 36 hours (2004) to 3 days (2006 and 2007) (Triton 2004, 2006 and 2007). General spawning periods reported in the literature vary from several weeks in the unregulated Fraser River (Perrin *et al.* 2003) to several months in the regulated Columbia River (Parsley *et al.* 1993). Data from individual spawning sites in the Fraser River provide estimates of spawning periods varying from 1 to 9 days (Perrin *et al.* 2003). Kootenai River female sturgeon demonstrated a residency of between 1-28 days (average 10.5) in the documented spawning reach (Paragamian and Kruse 2001). However spawning periods in larger systems may reflect spatial/temporal differences in spawning cues and/or multiple spawning populations. 2008 and 2009 were the only years where prolonged or multiple spawning events are thought to have occurred based on egg mat and telemetry data. This could be due to more individuals spawning in those years or prolonged favourable conditions or both.

4.2 HABITAT

The distinction between spawning site suitability and incubation site suitability is important to the recovery effort. Typically these should overlap such that fish spawn in areas where survival and incubation of eggs and larvae is high. However, for white sturgeon in the Nechako it appears that these no longer overlap. Further, because it is known that the fish are spawning and capable of producing viable eggs and larvae it appears that conditions are still suitable for spawning. However, the lack of larvae and juveniles suggests incubation suitability has decreased in the system likely as a result of sediment deposition. However the fish continue to spawn in the same general location suggesting they are predisposed to do so. A similar pattern has been observed in the Kootenai River system where white sturgeon spawning is thought to be occurring in the historical location however changes in discharge post-Libby Dam have resulted in sedimentation and impairment of spawning substrates (Paragamian et al. 2009).

Based on the results of the egg sampling, spawning in 2009 occurred in the same general area as in 2004, 2006, 2007 and 2009. Eggs were collected from both the upstream portion (upstream and downstream of top island) and lower portion (Stoney Creek to Burrard Ave. Bridge) of the spawning area (Figure 4). However, the lower portion, particularly in the vicinity of Stoney Creek appears to have been utilized more in 2009 than in previous years. In the past only a few eggs have been collected in this location and most were assumed to have drifted there due to the presence of fine substrate adhering to the eggs. In 2009 a total of 206 eggs were collected from mats 12 and 13 located immediately downstream of Stoney Creek. Many of these eggs were fertilized and the majority were free of substantial sediment accumulation suggesting they did not drift there but rather that spawning occurred in the immediate vicinity. Substrates in this area were found to be dominated by gravel (60%) with a relatively high component of fines (40%) and there was a general lack of larger, cobble substrates. A high component of fines is generally thought to be detrimental to subsequent egg survival and therefore fish are likely not spawning there as a result of the substrates. However, conditions in the area are clearly appropriate for spawning to occur and the concentration of eggs that were collected in this area suggests it may be an area to consider for habitat enhancement to increase the potential survival of eggs and juveniles in the future.

As in previous years eggs were also consistently collected in the upper half of the spawning area. Habitat analysis of this area showed substrates to be dominated by cobble and gravel with generally lower proportions of fines due to the greater velocities this area can experience. Eggs were collected in this area in 2006, 2007 and 2008. In 2004, sampling was limited but eggs were collected in the main channel to the right of the island immediately downstream of that location. In 2004 and 2008, numerous fish were visual observed in that area and 1 of only 2 larvae that has been collected prior to the 2009 drift net sampling was from the left-hand side channel of the top island (Triton 2004). Based on these results it is thought that this area represents the highest value spawning habitat based on utilization and therefore would be most suitable as a guide upon which to define preferred spawning conditions. In general, substrates upstream of the island are thought to be more favourable to egg and larvae survival and therefore it is considered less of a priority for habitat restoration.

In 2008 Northwest Hydraulics Consultants (NHC) completed a hydrodynamic model (NHC, 2008) to predict depths and flow velocities within the spawning area at a range of discharge levels. The model predicted that the highest velocity flows within the braided reach at moderate to high discharge levels would correspond to the two key egg sampling locations (upstream of the top island and between Stoney Creek and the Burrard Ave. Bridge; NHC 2008). This suggests the flow velocity is a factor for sturgeon to select spawning habitat and that higher velocities are preferred. Therefore the effects of habitat manipulations on flow velocities should also be considered.

4.3 OBSERVATION AND SAMPLING TECHNIQUES

Similar to previous years the egg mats proved effective at capturing eggs in 2009 and confirming that spawning had occurred. Without the positive egg sampling results, it would not be possible to say with certainty that spawning had occurred (for example based on visual observation or telemetry alone). The location of the eggs collected also provides valuable information on where spawning is likely to have occurred. In particular, the 2009 egg mat data suggest the location of the initial spawning which occurred in the vicinity of Stoney Creek differed from that of the subsequent spawning events which were located at the upper and lower ends of the spawning area. Results also suggest that lower velocity habitats were avoided (i.e. those with velocities less than 0.5 m/s) in favour of the main thalweg, which provided the best opportunity for collecting dispersing eggs. Unlike in previous years where egg mats were deployed in groups of four, in 2009 they were deployed in pairs. This allowed for greater coverage of the spawning area and helped to better identify spawning locations. The total number of eggs collected in 2009 exceeded that of previous years (369 in 2009 vs. 56 in 2008) and therefore the change in technique did not reduce sampling success and is likely a better strategy.

5 Recommendations for Future Work

As outlined in the *Nechako White Sturgeon Habitat Management Plan* (NWSRI, 2008), the overall goal of the recovery program is to restore natural recruitment for the population. To that end there were 3 objectives identified: 1) identify habitat management options supported by available data; 2) address data gaps; and 3) implement habitat management activities. Data collected during the 6 years of the Nechako white sturgeon monitoring program (2004 – 2009) have contributed a substantial amount of information towards addressing the first and second goals. The capabilities of the population to spawn and produce viable eggs and larvae have been confirmed and a key spawning area has been identified. The timing of spawning in relation to environmental cues has been investigated and are generally understood. Observations of migration patterns and spawning have increased our general understanding of adult behavior patterns. Egg mat data have identified spawning locations and egg drift patterns and have provided the focus for more detailed habitat descriptions of high value spawning areas. Although there would certainly be value in continuing on with the white sturgeon monitoring program in its current form, given the amount of data that has been collected on the Vanderhoof spawning area in particular, it is recommended that consideration be given to changing the focus of the program. For example, given what is known of spawning timing and behavior a tagging and telemetry program that focuses on other areas of the river and that would potentially identify other spawning locations or critical habitats could provide important information that would further our understanding of the population in general.

It is also recognized, however, that the critically imperiled nature of the population suggests that it would be prudent to move on to the third goal of the Management Plan: implementation of habitat management strategies. Further, since funding limitations may not allow both programs (along with any hatchery programs) to occur simultaneously, it is recommended that priority be given to implementing strategies that could have potential benefits to the population in the short term. Once in place, efforts could then turn to identifying other critical habitat areas elsewhere in the system. To that end the following areas are recommended as potential areas for habitat enhancement and are listed in order of priority:

1. **Stoney Creek confluence**
   - Spawning is known to occur in this area and 2009 results suggest it could be more important than previously thought;
   - Current substrate conditions not favourable to egg/larvae survival due to infilling of fines and lack of interstitial spaces;

Pros:

- Due to degree to which current substrates are considered impaired the degree to which it can be improved is considerable;
- Area is easily accessible with road access and areas to stockpile materials close by to facilitate the works;
- Established drift net sampling sites in the vicinity that could potentially be used as baseline data;

Cons:

- Without changes to flow patterns area would be subject to repeated infilling therefore habitat gains may only be temporary.

2. <u>Burrard Ave. Bridge</u>

- Spawning known to regularly occur in this area;
- Current substrate conditions not favourable to egg/larvae survival due to infilling of fines and lack of interstitial spaces;

Pros:

- Area is easily accessible with road access and areas to stockpile materials close by to facilitate the works;
- Higher velocity flows may prevent or delay future infilling of manipulated sites;

Cons:

- Area may be difficult to work in given higher velocity flows;
- Area not considered as impaired as that of Stoney Creek

3. <u>Downstream of top island</u>

- Spawning known to occur in this area with eggs and larvae collected.
- Increased accumulations of fine substrates (compared to upstream of island) observed.

Pros:

- Due to frequency of use and the fact that larvae in particular have been captured here in the past suggests there could be immediate benefits

Cons:

- Area difficult to access as compared to lower sites;
- Area not considered as impaired as that of lower sites but level of embeddedness of substrates and composition of subsurface layers not yet investigated.

4. <u>Upstream of top island</u>

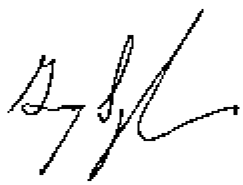
- Spawning known to occur in this area with eggs collected.
- Increased accumulations of fine substrates (compared to upstream of island) observed.

Pros:

- Due to frequency of use and presence of courser substrates there could be immediate benefits;

Cons:
- Area difficult to access as compared to lower sites;
- Area not considered as impaired as that of lower sites but level of embeddedness of substrates and composition of subsurface layers not yet investigated.

Lead Author:



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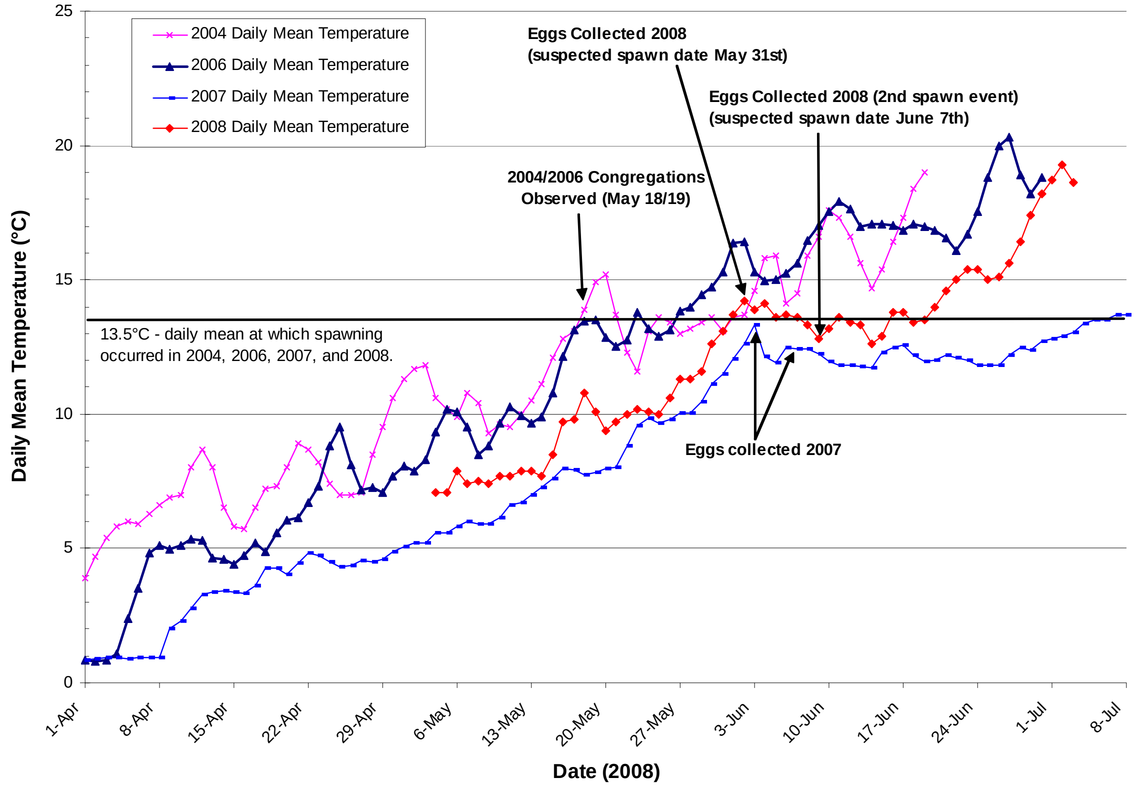
Appendix 1

Water Temperature and Discharge Data

Table 5. Daily mean discharge, and daily mean temperature at the Burrard Ave. Bridge (Water Survey of Canada station 08JC001) from May 4th to July 8th, 2009. Red highlighting identifies dates when eggs were collected.

Date	Daily Mean Temperature (°C)	Daily Maximum Temperature (°C)	Daily Mean Discharge (m^3/sec)
5/4	6.6	7.6	184
5/5	6.7	7.4	199
5/6	6.6	7.5	210
5/7	7.0	7.8	221
5/8	7.0	7.7	219
5/9	6.6	7.5	236
5/10	7.4	8.6	247
5/11	7.7	8.4	251
5/12	7.3	8.0	257
5/13	7.1	7.8	264
5/14	7.3	8.2	267
5/15	7.8	8.7	266
5/16	7.8	8.2	262
5/17	8.2	9.5	260
5/18	8.8	9.2	259
5/19	8.0	8.6	258
5/20	7.6	8.5	258
5/21	8.3	9.6	255
5/22	9.0	9.9	250
5/23	9.8	11.1	246
5/24	10.3	11.3	242
5/25	11.0	11.9	238
5/26	10.9	11.7	235
5/27	10.5	11.4	232
5/28	10.5	11.4	232
5/29	10.5	11.6	227
5/30	10.8	12.1	221
5/31	11.2	12.6	216
6/1	11.9	13.1	210
6/2	12.2	13.4	204
6/3	13.0	14.6	200
6/4	14.0	16.0	195
6/5	15.5	17.0	190
6/6	13.8	15.3	185
6/7	13.5	14.9	181
6/8	13.8	14.3	176
6/9	15.0	16.3	173
6/10	15.5	17.2	170
6/11	16.3	17.0	167
6/12	16.9	18.3	163
6/13	17.1	18.4	159
6/14	17.5	18.8	155
6/15	17.2	17.6	152

Date	Daily Mean Temperature (°C)	Daily Maximum Temperature (°C)	Daily Mean Discharge (m^3/sec)
6/16	17.0	17.9	151
6/17	17.5	18.6	148
6/18	17.5	18.6	145
6/19	17.0	17.7	143
6/20	16.3	17.3	140
6/21	16.0	17.3	138
6/22	16.3	17.6	135
6/23	16.0	16.5	133
6/24	15.6	15.9	132
6/25	14.9	15.3	132
6/26	14.2	15.3	135
6/27	14.2	15.1	134
6/28	14.4	15.1	132
6/29	14.3	15.3	130
6/30	14.1	15.1	128
7/1	14.4	15.9	127
7/2	15.5	17.4	125
7/3	16.7	18.4	124
7/4	17.4	19.1	122
7/5	16.6	18.4	121
7/6	15.5	17.1	124
7/7	15.1	16.2	127
7/8	17.4	15.7	130



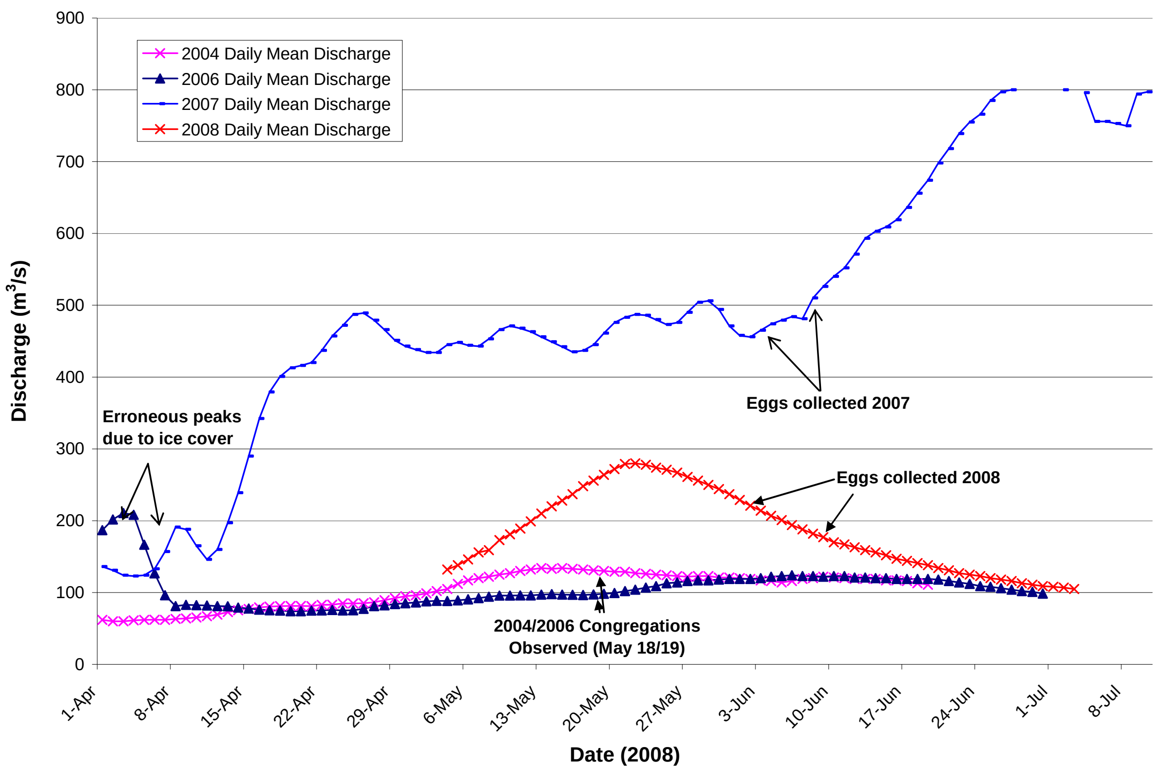


Figure 13. Daily mean temperature (top) and daily mean discharge (bottom) at the Burrard Ave. Bridge (WSC Station 08JC001) for April 1 to July 5, 2004, 2006, 2007 and 2008.

Appendix 2

Telemetry Data

Table 6. Detailed telemetry data from the Burrard Ave. Bridge base station – May 13 – June 9, 2009. Highlighted fish are either potential spawners based on maturity (yellow) or 2009 brood fish (blue).

Date (2009)	Frequency (MHz)	Code(s) detected
13-May	149.800	63
14-May	149.800	63
15-May	148.380	1
16-May	149.700	26
17-May	All frequencies	NSD
18-May	148.420	51
	149.800	49
19-May	149.700	25, 27
	149.800	49
20-May	149.800	49
21-May	All frequencies	NSD
22-May	149.700	25, 30
	149.800	49
23-May	148.380	4
	149.700	26
	149.800	49, 51
24-May	149.700	26, 47
25-May	148.320	12
	148.380	4
	148.420	2
	149.700	26, 29, 30,
	149.800	51, 64, 68
26-May	148.320	12, 25
	148.380	4
	149.700	47
	149.800	46, 51, 55, 59, 60, 61, 64, 68
27-May	148.320	12, 25
	148.420	13
	149.700	25, 30, 32, 47, 56
	149.800	46, 49, 51, 55, 57, 59, 60, 61, 62, 67, 68
28-May	148.320	12, 25
	148.400	9
	148.420	13
	149.700	25, 30, 32, 44
	149.800	49, 51, 55, 57, 59, 60, 61, 62, 64, 67, 68
29-May	148.320	12, 20, 21, 25
	148.380	27
	148.400	51
	148.420	2
	149.700	20, 25, 29, 30, 47
	149.800	49, 51, 55, 57, 59, 60, 61, 62, 66, 67, 68
30-May	148.320	25
	148.380	51
	149.700	25, 29, 32
	149.800	46, 47, 49, 51, 57, 59, 60, 61, 62, 63, 67
31-May	148.320	12, 25
	148.380	4
	149.700	25, 30, 32
	149.800	46, 51, 57, 59, 60, 61, 62, 65, 67, 68
1-June	148.320	12, 25
	148.380	4
	149.700	25, 30, 32, 47
	149.800	46, 49, 51, 59, 60, 61, 62, 64, 65, 67, 68
2-June	148.320	12, 25
	148.380	4
	149.700	25, 29, 32, 47
	149.800	39, 40, 49, 53, 55, 59, 61, 64, 65, 67, 68
3-June	148.320	12, 25
	148.380	4
	149.700	32, 47
	149.800	46, 49, 51, 55, 59, 60, 61, 64, 67, 68
4-June	148.320	12
	148.380	4
	149.700	32, 47
	149.800	46, 50, 60, 67, 68
5-June	148.320	12, 25
	148.380	4
	149.700	12, 25, 27
	149.800	46, 49, 51, 59, 60, 61, 68

Notes:
"All frequencies (MHz)": 148.320, 148.380, 148.400, 148.420, 149.440, 149.700, 149.800.

"NSD" stands for No Sturgeon Detected.

Brood Fish 2009
Potential spawners (based on maturity)

Date (2009)	Frequency (MHz)	Code(s) detected
6-June	148.320	12
	148.380	4
	149.700	25, 47
	149.800	59, 60, 61
7-June	148.320	12
	148.380	4
	149.700	47
	149.800	46, 55
8-June	148.320	25
	148.380	4
	149.700	26, 27, 47
	149.800	46, 62, 64
9-June	148.320	25
	149.700	27, 47
	149.800	46, 51, 55, 59, 60, 61, 64, 66

Notes:
"All frequencies (MHz)": 148.320, 148.380, 148.400, 148.420, 149.440, 149.700, 149.800.

"NSD" stands for No Sturgeon Detected.

Brood Fish 2009
Potential spawners (based on maturity)

Table 7. Detailed telemetry data from the telemetry flights in 2009. Highlighted fish are potential spawners based on maturity.

Frequency	Code	Sex	Maturity	Year Assessed	21-May-09	28-May-09
148.320	**12**	U	2	2007	128	136
148.320	**17**	F	15	2007	108	108
148.320	**21**	M	3	2008		127
148.320	**24**	F	15	2008	130	127
148.320	**25**	M	5	2009	126	136
149.700	**20**	M	98	2008	102	104
149.700	**21**	M	97	2008	127	125
149.700	**23**	F	2	2008		130
149.700	**24**	M	3	2009	119	
149.700	**25**	M	5	2009	108	
149.700	**26**	F	11	2005	150	155
149.700	**30**	M	4	2005	127	135
149.700	**31**	F	12	2005	102	98
149.700	**32**	M	3	2008	128	
149.700	**33**	M	2	2008		102
149.700	**36**	M	2	2005	125	102
149.700	**37**	F	12	2005		90
149.700	**40**	M	3	2009	130	
149.700	**47**	M	3	2009		135
149.800	**46**	98	4	2009	107	
149.800	**47**	M	3	2006	125	125
149.800	**50**	M	4	2009	126	
149.800	**51**	M	5	2006	126	136
149.800	**53**	F	13	2006	100	100
149.800	**55**	M	3	2008	129	
149.800	**57**	F	15	2007		125
149.800	**60**	M	5	2009	128	
149.800	**61**	M	5	2009	128	
149.800	**62**	M	4	2009	110	136
149.800	**64**	M	5	2009	130	136
149.800	**67**	M	5	2009	120	136

Table 8. Detailed telemetry from boat surveys completed in 2009 (rkm 134 to 137).

Date	UTM	Frequency	Code	Sex	Maturity	Year Assessed	Notes
02-Jun-09	10.434377.5986639	148.320	12	male	2	2007	
02-Jun-09	10.435463.5986735	148.400	9	unknown	97	2004	
02-Jun-09	10.432320.5986237	148.420	13	male	3	2006	
02-Jun-09	10.434598.5986213	149.800	61	male	5	2009	
02-Jun-09	10.434441.5986289	149.800	68	male	5	2009	
03-Jun-09	10.434489.5986335	148.420	13	male	3	2006	
04-Jun-09	10.431978.5986146	149.700	25	male	5	2009	
04-Jun-09	10.433568.5986905	149.700	32	male	3	2008	
04-Jun-09	10.432239.5986169	149.700	47	male	3	2009	
04-Jun-09	10.431856.5986136	149.800	51	male	5	2006	
04-Jun-09	10.431978.5986146	149.800	64	male	5	2009	
04-Jun-09	10.434866.5986250	149.800	68	male	5	2009	
04-Jun-09	10.432446.5986442	150.280	11	male	5	2009	EMG tag.
05-Jun-09	10.432435.5986448	148.320	12	male	2	2007	
05-Jun-09	10.433684.5986955	149.700	27	male	3	2005	
05-Jun-09	10.433808.5986955	149.700	30	male	4	2005	
05-Jun-09	10.431684.5986127	149.700	32	male	3	2008	
05-Jun-09	10.433684.5986955	149.700	47	male	3	2009	
05-Jun-09	10.433851.5986945	149.800	46	male	4	2009	Assessed as code 5 in 2006.
05-Jun-09	10.433808.5986955	149.800	49	male	2	2006	
05-Jun-09	10.433851.5986945	149.800	51	male	5	2006	
05-Jun-09	10.432232.5986139	149.800	55	male	3	2008	Assessed as code 5 in 2007.
05-Jun-09	10.433684.5986955	149.800	68	male	5	2009	
06-Jun-09	10.431603.5986115	149.700	32	male	3	2008	
06-Jun-09	10.431437.5986076	149.800	51	male	5	2006	
06-Jun-09	10.431843.5986152	149.800	55	male	3	2008	Assessed as code 5 in 2007.
06-Jun-09	10.431444.5986072	149.800	64	male	5	2009	
07-Jun-09	10.431386.5986055	149.700	25	male	5	2009	
07-Jun-09	10.431344.5986072	149.700	32	male	3	2008	
07-Jun-09	10.432138.5986180	149.800	51	male	5	2006	
07-Jun-09	10.431545.5986048	149.800	55	male	3	2008	Assessed as code 5 in 2007.
07-Jun-09	10.431907.5986171	149.800	64	male	5	2009	
08-Jun-09	10.431801.5986144	148.320	12	male	2	2007	
08-Jun-09	10.431189.5986099	149.700	25	male	5	2009	
08-Jun-09	10.433552.5986921	149.700	27	male	3	2005	
08-Jun-09	10.431737.5986125	149.700	32	male	3	2008	
08-Jun-09	10.433458.5986821	149.800	46	male	4	2009	Assessed as code 5 in 2006.
08-Jun-09	10.431268.5986083	149.800	51	male	5	2006	
08-Jun-09	10.431253.5986097	149.800	55	male	3	2008	Assessed as code 5 in 2007.
08-Jun-09	10.432282.5986168	149.800	64	male	5	2009	
08-Jun-09	10.434157.5986710	150.280	11	male	5	2009	EMG tag.
09-Jun-09	10.434704.5986201	148.320	12	male	2	2007	
09-Jun-09	10.434070.5986823	149.700	25	male	5	2009	
09-Jun-09	10.434291.5986495	149.700	27	male	3	2005	
09-Jun-09	10.434019.5986903	149.700	47	male	3	2009	
09-Jun-09	10.434224.5986656	149.800	46	male	4	2009	Assessed as code 5 in 2006.

Date	UTM	Frequency	Code	Sex	Maturity	Year Assessed	Notes
09-Jun-09	10.433468.5986823	149.800	51	male	5	2006	
09-Jun-09	10.433438.5986782	149.800	55	male	3	2008	Assessed as code 5 in 2007.
09-Jun-09	10.434458.5986287	149.800	55	male	3	2008	Assessed as code 5 in 2007.
09-Jun-09	10.434483.5986295	149.800	60	male	5	2009	
09-Jun-09	10.434369.5986365	149.800	62	male	4	2009	
09-Jun-09	10.434224.5986656	149.800	64	male	5	2009	
10-Jun-09	10.435612.5986729	148.400	9	unknown	97	2004	
10-Jun-09	10.432500.5986471	149.700	25	male	5	2009	
10-Jun-09	10.433443.5986863	149.800	55	male	3	2008	Assessed as code 5 in 2007.
10-Jun-09	10.435416.5986726	149.800	60	male	5	2009	
11-Jun-09	10.435703.5986608	149.800	55	male	3	2008	Assessed as code 5 in 2007.
11-Jun-09	10.431736.5986079	149.800	57	female	15	2007	Not likely to have spawned in 2009.
12-Jun-09	10.435517.5984394	148.400	9	unknown	97	2004	
12-Jun-09	10.436651.5985901	149.700	25	male	5	2009	
16-Jun-09	10.435477.5986692	148.320	24	female	15	2008	Unused brood fish in 2008.
16-Jun-09	10.435567.5986669	148.400	9	unknown	97	2004	
16-Jun-09	10.435230.5986650	149.700	25	male	5	2009	
16-Jun-09	10.435230.5986650	149.700	27	male	3	2005	
16-Jun-09	10.434641.5986218	149.700	47	male	3	2009	
16-Jun-09	10.435477.5986692	149.800	48	male	2	2006	
16-Jun-09	10.433360.5986722	149.800	49	male	2	2006	
16-Jun-09	10.431673.5986096	149.800	51	male	5	2006	

Appendix 3

Egg Mat Field Survey Data

Table 9. Egg mat sampling results

Deployment						Retrieval			
Set #	**Date**	**Time**	**UTM**	**Depth**	**Velocity**	**Date**	**Time**	**Eggs**	**Comment**
1	29-May-09	9:00	10.431781.5986127	2.2	0.97				buoy sank
2	29-May-09	9:05	10.431843.5986133			02-Jun-09	10:19	0	
3	29-May-09	9:10	10.432058.5986345	0.9	1.06	02-Jun-09	10:29	0	
4	29-May-09	9:15	10.432226.5986368	1.55	1.1	02-Jun-09	10:34	1	ruptured
5	29-May-09	9:20	10.432058.5986118	1.65	0.82	02-Jun-09	10:39	1	
6	29-May-09	9:25	10.432278.5986202	2.2	0.89	02-Jun-09	10:48	0	
7	29-May-09	9:30	10.432437.5986413	1.6	1.1	02-Jun-09	10:54	7	
8	29-May-09	9:35	10.432717.5986478	1.2	0.99	02-Jun-09	11:06	0	
9	29-May-09	9:40	10.432700.5986637	0.6	1.07	02-Jun-09	11:15	0	
10	29-May-09	9:45	10.433046.5986380	1.2	0.14	02-Jun-09	11:27	0	
11	29-May-09	9:50	10.433351.5986366	1.25	0.85	02-Jun-09	11:38	15	
12	29-May-09	9:55	10.433426.5986462	1.2	0.59	02-Jun-09	11:48	43	
13	29-May-09	10:00	10.433406.5986646	1.85	0.65	02-Jun-09	11:54	1	
14	29-May-09	10:05	10.433501.5986838	1.75	0.68	02-Jun-09	12:07	11	
15	29-May-09	10:10	10.433736.5986942	1.25	0.7	02-Jun-09	12:15	24	
16	29-May-09	10:15	10.434105.5986808	2.3	0.65	02-Jun-09	12:22	0	
17	29-May-09	10:20	10.434277.5986509	2.1	0.61	02-Jun-09	12:25	0	
1			10.431781.5986127	2.2	0.97				not recovered
2	02-Jun-09	10:19	10.431843.5986133			03-Jun-09	11:14	5	
3	02-Jun-09	10:29	10.432058.5986345	0.9	1.06	03-Jun-09	11:19	1	
4	02-Jun-09	10:34	10.432226.5986368	1.55	1.1	03-Jun-09	11:23	0	
5	02-Jun-09	10:39	10.432058.5986118	1.65	0.82	03-Jun-09	11:28	1	
6	02-Jun-09	10:48	10.432278.5986202	2.2	0.89	03-Jun-09	11:33	1	
7	02-Jun-09	10:54	10.432437.5986413	1.6	1.1	03-Jun-09	11:37	1	
8	02-Jun-09	11:06	10.432717.5986478	1.2	0.99	03-Jun-09	11:42	0	
9	02-Jun-09	11:15	10.432700.5986637	0.6	1.07	03-Jun-09	11:48	0	
10	02-Jun-09	11:27	10.433046.5986380	1.2	0.14	03-Jun-09	11:57	6	
11	02-Jun-09	11:38	10.433351.5986366	1.25	0.85	03-Jun-09	11:59	13	5 crushed
12	02-Jun-09	11:48	10.433426.5986462	1.2	0.59	03-Jun-09	12:11	132	2 crushed
13	02-Jun-09	11:54	10.433406.5986646	1.85	0.65	03-Jun-09	12:28	0	
14	02-Jun-09	12:07	10.433501.5986838	1.75	0.68	03-Jun-09	12:32	3	
15	02-Jun-09	12:15	10.433736.5986942	1.25	0.7	03-Jun-09	12:40	6	
16	02-Jun-09	12:22	10.434105.5986808	2.3	0.65	03-Jun-09	12:45	1	
17	02-Jun-09	12:25	10.434277.5986509	2.1	0.61	03-Jun-09	12:50	0	
1	29-May-09	9:00	10.431781.5986127	2.2	0.97	05-Jun-09	13:40	0	
2	03-Jun-09	11:14	10.431843.5986133			05-Jun-09	12:50	3	
3	03-Jun-09	11:19	10.432058.5986345	0.9	1.06	05-Jun-09	13:49	2	
4	03-Jun-09	11:23	10.432226.5986368	1.55	1.1	05-Jun-09	13:57	1	crushed
5	03-Jun-09	11:28	10.432058.5986118	1.65	0.82	05-Jun-09	14:05	5	
6	03-Jun-09	11:33	10.432278.5986202	2.2	0.89	05-Jun-09	14:02	0	
7	03-Jun-09	11:37	10.432437.5986413	1.6	1.1	05-Jun-09	14:14	2	
8	03-Jun-09	11:42	10.432717.5986478	1.2	0.99	05-Jun-09	14:20	0	
9	03-Jun-09	11:48	10.432700.5986637	0.6	1.07	05-Jun-09	14:23	0	
10	03-Jun-09	11:57	10.433046.5986380	1.2	0.14	05-Jun-09	14:28	3	
11	03-Jun-09	11:59	10.433351.5986366	1.25	0.85	05-Jun-09	14:33	3	
12	03-Jun-09	12:11	10.433426.5986462	1.2	0.59	05-Jun-09	14:39	3	
13	03-Jun-09	12:28	10.433406.5986646	1.85	0.65	05-Jun-09	14:45	0	
14	03-Jun-09	12:32	10.433501.5986838	1.75	0.68	05-Jun-09	15:26	0	
15	03-Jun-09	12:40	10.433736.5986942	1.25	0.7	05-Jun-09	15:31	0	
16	03-Jun-09	12:45	10.434105.5986808	2.3	0.65	05-Jun-09	15:35	0	
17	03-Jun-09	12:50	10.434277.5986509	2.1	0.61	05-Jun-09	15:40	0	

Deployment						Retrieval			
Set #	**Date**	**Time**	**UTM**	**Depth**	**Velocity**	**Date**	**Time**	**Eggs**	**Comment**
1	05-Jun-09	13:40	10.431781.5986127	2.2	0.97	07-Jun-09	10:36	1	
2	05-Jun-09	12:50	10.431843.5986133			07-Jun-09	10:54	5	
3	05-Jun-09	13:49	10.432058.5986345	0.9	1.06	07-Jun-09	11:00	0	
4	05-Jun-09	13:57	10.432226.5986368	1.55	1.1	07-Jun-09	11:05	0	
5	05-Jun-09	14:05	10.432058.5986118	1.65	0.82	07-Jun-09	11:11	1	
6	05-Jun-09	14:02	10.432278.5986202	2.2	0.89	07-Jun-09	11:17	1	
7	05-Jun-09	14:14	10.432437.5986413	1.6	1.1	07-Jun-09	11:24	0	
8	05-Jun-09	14:20	10.432717.5986478	1.2	0.99	07-Jun-09	11:38	0	
9	05-Jun-09	14:23	10.432700.5986637	0.6	1.07	07-Jun-09	11:43	0	
10	05-Jun-09	14:28	10.433046.5986380	1.2	0.14	07-Jun-09	11:48	0	
11	05-Jun-09	14:33	10.433351.5986366	1.25	0.85	07-Jun-09	11:54	0	
12	05-Jun-09	14:39	10.433426.5986462	1.2	0.59	07-Jun-09	11:58	0	
13	05-Jun-09	14:45	10.433406.5986646	1.85	0.65	07-Jun-09	12:02	0	
14	05-Jun-09	15:26	10.433501.5986838	1.75	0.68	07-Jun-09	12:07	0	
15	05-Jun-09	15:31	10.433736.5986942	1.25	0.7	07-Jun-09	12:11	0	
16	05-Jun-09	15:35	10.434105.5986808	2.3	0.65	07-Jun-09	12:26	0	
17	05-Jun-09	15:40	10.434277.5986509	2.1	0.61	07-Jun-09	12:30	0	
18	05-Jun-09	12:42	10.431724.5986114	3.8	0.93	07-Jun-09	10:30	8	
19	05-Jun-09	12:48	10.431848.5986146			07-Jun-09	10:43	1	
20	05-Jun-09	13:21	10.433816.5986972	2.4	0.68	07-Jun-09	12:15	0	
21	05-Jun-09	13:25	10.433812.5986954	1.5	0.91	07-Jun-09	12:18	0	
22	05-Jun-09	13:27	10.433809.5986929	1.8	0.49	07-Jun-09	12:21	0	
23	05-Jun-09	15:14	10.432384.5986381	1.35	1.15	07-Jun-09	11:27	0	
24	05-Jun-09	15:16	10.432399.5986366	1	1.07	07-Jun-09	11:32	0	
1	07-Jun-09	10:36	10.431781.5986127	2.2	0.97	09-Jun-09	11:52	4	2 crushed
2	07-Jun-09	10:54	10.431843.5986133			09-Jun-09	12:01	14	3 crushed
3	07-Jun-09	11:00	10.432058.5986345	0.9	1.06	09-Jun-09	12:24	0	
4	07-Jun-09	11:05	10.432226.5986368	1.55	1.1	09-Jun-09	12:30	0	
5	07-Jun-09	11:11	10.432058.5986118	1.65	0.82	09-Jun-09	12:19	3	1 crushed
6	07-Jun-09	11:17	10.432278.5986202	2.2	0.89	09-Jun-09	12:35	1	crushed
7	07-Jun-09	11:24	10.432437.5986413	1.6	1.1	09-Jun-09	12:45	0	
8	07-Jun-09	11:38	10.432717.5986478	1.2	0.99	09-Jun-09	13:07	0	
9	07-Jun-09	11:43	10.432700.5986637	0.6	1.07	09-Jun-09	13:02	0	
10	07-Jun-09	11:48	10.433046.5986380	1.2	0.14	09-Jun-09	13:22	0	
11	07-Jun-09	11:54	10.433351.5986366	1.25	0.85	09-Jun-09	13:26	0	
12	07-Jun-09	11:58	10.433426.5986462	1.2	0.59	09-Jun-09	13:29	0	
13	07-Jun-09	12:02	10.433406.5986646	1.85	0.65	09-Jun-09	13:33	0	
14	07-Jun-09	12:07	10.433501.5986838	1.75	0.68	09-Jun-09	13:41	0	
15	07-Jun-09	12:11	10.433736.5986942	1.25	0.7	09-Jun-09	11:10	0	
16	07-Jun-09	12:26	10.434105.5986808	2.3	0.65	09-Jun-09	11:30	0	
17	07-Jun-09	12:30	10.434277.5986509	2.1	0.61	09-Jun-09	11:34	0	
18	07-Jun-09	10:30	10.431724.5986114	3.8	0.93	09-Jun-09	11:45	11	1 crushed
19	07-Jun-09	10:43	10.431848.5986146			09-Jun-09	11:56	1	
20	07-Jun-09	12:15	10.433816.5986972	2.4	0.68	09-Jun-09	11:15	0	
21	07-Jun-09	12:18	10.433812.5986954	1.5	0.91	09-Jun-09	11:23	13	
22	07-Jun-09	12:21	10.433809.5986929	1.8	0.49	09-Jun-09	11:25	0	
23	07-Jun-09	11:27	10.432384.5986381	1.35	1.15	09-Jun-09	12:49	0	
24	07-Jun-09	11:32	10.432399.5986366	1	1.07	09-Jun-09	12:53	0	
1	09-Jun-09	11:52	10.431781.5986127	2.2	0.97	11-Jun-09	10:04	0	
2	09-Jun-09	12:01	10.431843.5986133			11-Jun-09	10:13	1	
3	09-Jun-09	12:24	10.432058.5986345	0.9	1.06	11-Jun-09	10:18	0	
4	09-Jun-09	12:30	10.432226.5986368	1.55	1.1	11-Jun-09	10:22	0	
5	09-Jun-09	12:19	10.432058.5986118	1.65	0.82	11-Jun-09	10:26	0	
6	09-Jun-09	12:35	10.432278.5986202	2.2	0.89	11-Jun-09	10:31	0	
7	09-Jun-09	12:45	10.432437.5986413	1.6	1.1	11-Jun-09	10:45	0	
8	09-Jun-09	13:07	10.432717.5986478	1.2	0.99	11-Jun-09	11:17	0	
9	09-Jun-09	13:02	10.432700.5986637	0.6	1.07	11-Jun-09	10:54	0	
10	09-Jun-09	13:22	10.433046.5986380	1.2	0.14	11-Jun-09	11:14	0	
11	09-Jun-09	13:26	10.433351.5986366	1.25	0.85	11-Jun-09	11:28	0	
12	09-Jun-09	13:29	10.433426.5986462	1.2	0.59	11-Jun-09	11:34	0	
13	09-Jun-09	13:33	10.433406.5986646	1.85	0.65	11-Jun-09	11:37	0	
14	09-Jun-09	13:41	10.433501.5986838	1.75	0.68	11-Jun-09	11:41	0	
15	09-Jun-09	11:10	10.433736.5986942	1.25	0.7	11-Jun-09	11:45	0	
16	09-Jun-09	11:30	10.434105.5986808	2.3	0.65	11-Jun-09	12:17	0	
17	09-Jun-09	11:34	10.434277.5986509	2.1	0.61	11-Jun-09	12:22	0	
18	09-Jun-09	11:45	10.431724.5986114	3.8	0.93	11-Jun-09	10:02	0	
19	09-Jun-09	11:56	10.431848.5986146			11-Jun-09	10:10	0	
20	09-Jun-09	11:15	10.433816.5986972	2.4	0.68	11-Jun-09	12:08	0	
21	09-Jun-09	11:23	10.433812.5986954	1.5	0.91	11-Jun-09	12:05	9	
22	09-Jun-09	11:25	10.433809.5986929	1.8	0.49	11-Jun-09	11:59	0	
23	09-Jun-09	12:49	10.432384.5986381	1.35	1.15	11-Jun-09	10:36	0	
24	09-Jun-09	12:53	10.432399.5986366	1	1.07	11-Jun-09	10:41	0	

Deployment						Retrieval			
Set #	Date	Time	UTM	Depth	Velocity	Date	Time	Eggs	Comment
1	11-Jun-09	10:04	10.431781.5986127	2.2	0.97	15-Jun-09	10:19	0	
2	11-Jun-09	10:13	10.431843.5986133			15-Jun-09	10:25	0	
3	11-Jun-09	10:18	10.432058.5986345	0.9	1.06	15-Jun-09	10:28	0	
4	11-Jun-09	10:22	10.432226.5986368	1.55	1.1	15-Jun-09	10:33	0	
5	11-Jun-09	10:26	10.432058.5986118	1.65	0.82	15-Jun-09	10:37	0	
6	11-Jun-09	10:31	10.432278.5986202	2.2	0.89	15-Jun-09	10:41	0	
7	11-Jun-09	10:45	10.432437.5986413	1.6	1.1	15-Jun-09	10:51	0	
8	11-Jun-09	11:17	10.432717.5986478	1.2	0.99	15-Jun-09	10:55	0	
9	11-Jun-09	10:54	10.432700.5986637	0.6	1.07	15-Jun-09	10:59	0	
10	11-Jun-09	11:14	10.433046.5986380	1.2	0.14	15-Jun-09	11:02	0	
11	11-Jun-09	11:28	10.433351.5986366	1.25	0.85	15-Jun-09	11:07	0	
12	11-Jun-09	11:34	10.433426.5986462	1.2	0.59	15-Jun-09	11:10	0	
13	11-Jun-09	11:37	10.433406.5986646	1.85	0.65	15-Jun-09	11:13	0	
14	11-Jun-09	11:41	10.433501.5986838	1.75	0.68	15-Jun-09	11:18	0	
15	11-Jun-09	11:45	10.433736.5986942	1.25	0.7	15-Jun-09	11:23	0	
16	11-Jun-09	12:17	10.434105.5986808	2.3	0.65	15-Jun-09	11:38	0	
17	11-Jun-09	12:22	10.434277.5986509	2.1	0.61	15-Jun-09	11:42	0	
18	11-Jun-09	10:02	10.431724.5986114	3.8	0.93	15-Jun-09	10:17	0	
19	11-Jun-09	10:10	10.431848.5986146			15-Jun-09	10:22	0	
20	11-Jun-09	12:08	10.433816.5986972	2.4	0.68	15-Jun-09	11:32	0	
21	11-Jun-09	12:05	10.433812.5986954	1.5	0.91	15-Jun-09	11:35	0	
22	11-Jun-09	11:59	10.433809.5986929	1.8	0.49	15-Jun-09	11:29	0	
23	11-Jun-09	10:36	10.432384.5986381	1.35	1.15	15-Jun-09	10:47	0	
24	11-Jun-09	10:41	10.432399.5986366	1	1.07	15-Jun-09	10:44	0	
1	15-Jun-09	10:19	10.431781.5986127	2.2	0.97	22-Jun-09	12:05	0	eggs mats removed
2	15-Jun-09	10:25	10.431843.5986133			22-Jun-09	12:13	0	eggs mats removed
3	15-Jun-09	10:28	10.432058.5986345	0.9	1.06	22-Jun-09	12:18	0	eggs mats removed
4	15-Jun-09	10:33	10.432226.5986368	1.55	1.1	22-Jun-09	12:20	0	eggs mats removed
5	15-Jun-09	10:37	10.432058.5986118	1.65	0.82	22-Jun-09	12:26	0	eggs mats removed
6	15-Jun-09	10:41	10.432278.5986202	2.2	0.89	22-Jun-09	12:42	0	eggs mats removed
7	15-Jun-09	10:51	10.432437.5986413	1.6	1.1	22-Jun-09	12:50	0	eggs mats removed
8	15-Jun-09	10:55	10.432717.5986478	1.2	0.99	22-Jun-09	13:00	0	eggs mats removed
9	15-Jun-09	10:59	10.432700.5986637	0.6	1.07	22-Jun-09	12:44	0	eggs mats removed
10	15-Jun-09	11:02	10.433046.5986380	1.2	0.14	22-Jun-09	13:31	0	eggs mats removed
11	15-Jun-09	11:07	10.433351.5986366	1.25	0.85	22-Jun-09	13:07	0	eggs mats removed
12	15-Jun-09	11:10	10.433426.5986462	1.2	0.59	22-Jun-09	13:10	0	eggs mats removed
13	15-Jun-09	11:13	10.433406.5986646	1.85	0.65	22-Jun-09	13:30	0	eggs mats removed
14	15-Jun-09	11:18	10.433501.5986838	1.75	0.68	22-Jun-09	13:34	0	eggs mats removed
15	15-Jun-09	11:23	10.433736.5986942	1.25	0.7	22-Jun-09	13:40	0	eggs mats removed
16	15-Jun-09	11:38	10.434105.5986808	2.3	0.65	22-Jun-09	14:17	0	eggs mats removed
17	15-Jun-09	11:42	10.434277.5986509	2.1	0.61	22-Jun-09	14:20	0	eggs mats removed
18	15-Jun-09	10:17	10.431724.5986114	3.8	0.93	22-Jun-09	12:02	0	eggs mats removed
19	15-Jun-09	10:22	10.431848.5986146			22-Jun-09	12:09	0	eggs mats removed
20	15-Jun-09	11:32	10.433816.5986972	2.4	0.68	22-Jun-09	13:42	0	eggs mats removed
21	15-Jun-09	11:35	10.433812.5986954	1.5	0.91	22-Jun-09	13:45	0	eggs mats removed
22	15-Jun-09	11:29	10.433809.5986929	1.8	0.49	22-Jun-09	13:52	0	eggs mats removed
23	15-Jun-09	10:47	10.432384.5986381	1.35	1.15	22-Jun-09	12:50	0	eggs mats removed
24	15-Jun-09	10:44	10.432399.5986366	1	1.07	22-Jun-09	12:52	0	eggs mats removed

Appendix 4

Drift Sampling Data

Table 10. Drift net sampling summary – day sampling.

Date	Site	Time In	Time Out	Effort		Result	Comment
				Hours	Minutes		
05-Jun	1			1	0		Time in/out not reported
	2			1	0		Time in/out not reported
08-Jun	1	10:40	14:00	3	20		
	2	10:40	14:10	3	30	1 larvae	
09-Jun	1	11:47	13:03	1	16		
	1	13:00	14:55	1	55		
	2	11:37	12:55	1	18		
	2	13:00	14:55	1	55		
11-Jun	1	12:20	1:47	1	27		
	1	1:50	3:20	1	30		
	2	12:25	1:53	1	28		
	2	1:55	3:25	1	30		
13-Jun	1	10:55	12:22	1	27		
	1	12:25	1:45	1	20		
	2	10:57	12:30	1	33		
	2	12:35	1:55	1	20		
	3	11:55	1:27	1	33		
	4	12:15	1:35	1	20		
15-Jun	1	12:10	12:42	0	32		
	1	12:45	14:51	2	6		
	1	14:54	16:35	1	41		
	2	12:15	14:15	2	0		
	2	14:17	16:28	2	11		
	3	12:20	14:25	2	5		
	3	14:29	16:20	1	51		
	4	12:24	14:35	2	11		
	4	14:41	16:10	1	29		
17-Jun	1	10:40	12:47	2	7		
	1	12:50	2:25	1	35		
	1	2:29	4:05	1	36		
	2	10:45	12:40	1	55		
	2	12:43	2:33	1	50		
	2	3:15	4:29	1	14		
	3	10:52	12:33	1	41		
	3	12:35	2:43	2	8		
	3	2:45	4:15	1	30		
	4	12:06	1:07	1	1		
	4	1:09	2:50	1	41		
	4	3:24	4:23	0	59		
19-Jun	1	9:02	10:36	1	34		
	1	10:38	11:58	1	20		
	1	12:00	13:26	1	26		
	2	9:07	10:43	1	36		
	2	10:46	12:05	1	19		
	2	12:08	13:32	1	24		
	3	9:20	10:53	1	33		
	3	10:55	12:13	1	18		
	3	12:15	13:48	1	33		
	4	9:25	11:00	1	35		
	4	11:03	12:19	1	16		
	4	12:22	13:57	1	33		
Total				82	30	1 larvae	

Table 11. Drift net sampling results – night sampling

					Effort			
Date Set	**Net #**	**Net Type**	**Time In**	**Time Out**	**Hours**	**Minutes**	**Results**	**Comments**
19-Jun-09	1	Dee	23:00	10:08	11	8	3	very full, possibly one other misidentified, not collected sturgeon
	2	Rec	23:10	10:15	11	5	0	full
	3	Tri	23:15	10:22	11	7	0	clean
	4	Rec	23:25	9:30	10	5	0	very clean
	5	Dee	23:35	9:35	10	0	0	full of gravel
	6	Tri	23:45	9:45	10	0	0	very clean
20-Jun-09	1	Dee	22:27	8:35	10	8	0	
	2	Rec	22:22	8:24	10	2	0	
	3	Tri	22:18	8:20	10	2	0	
	4	Rec	22:12	8:00	9	48	0	
	5	Dee	22:07	7:52	9	45	0	
	6	Tri	22:02	7:40	9	38	0	Possible sturgeon egg found.
23-Jun-09	1	Dee	22:10	4:40	6	30	0	
	2	Rec	20:40	4:31	5	51	0	
	3	Tri	20:36	4:27	5	51	0	
	4	Rec	21:08	4:20	6	12	0	net ripped at cod endand not fishing square
	5	Dee	21:04	4:12	6	8	0	
	6	Tri	21:14	4:05	6	51	0	
24-Jun-09	1	Dee	21:50	7:10	9	20	0	
	2	Rec	21:53	7:18	9	25	0	
	3	Tri	21:55	7:22	9	27	0	lots of sand
	4	Rec	22:00	7:32	9	32	0	weights fell off but fishing ok
	5	Dee	22:02	7:42	9	40	0	
	6	Tri	22:10	7:54	9	46	0	
27-Jun-09	1	Dee	21:15	8:11	10	56	0	
	2	Rec	21:26	8:07	10	41	0	
	3	Tri	21:20	8:00	10	40	0	
	4	Rec	21:37	7:49	10	12	0	
	5	Dee	21:40	7:46	10	6	0	
	6	Tri	21:47	7:39	9	52	0	Rope Tangled! Not set and/or fishing properly
28-Jun-09	1	Dee	22:30	8:15	9	45	0	
	2	Rec	22:27	8:05	9	38	0	
	3	Tri	22:23	7:58	9	35	0	
	4	Rec	22:15	7:48	9	33	0	
	5	Dee	22:18	7:46	9	28	0	
	6	Tri	22:05	7:40	9	35	0	
02-Jul-09	1	Dee	21:13	8:43	11	30	0	Vel (m/s): 0.6-1.05 (am); 0.5-0.7 (pm)
	2	Rec	21:25	8:34	11	9	0	Vel (m/s): 0.18-0.22 (am); 0.35-0.48 (pm)
	3	Tri	21:35	8:26	10	51	0	Vel (m/s): 0.65-0.75 (am); 0.15-0.2 (pm)
	4	Rec	21:50	7:55	10	5	0	Vel (m/s): 0.5-0.8 (am); 0.15-0.4 (pm)
	5	Dee	22:00	8:01	10	1	0	Vel (m/s): 0.85-1.05 (am); 0.42-0.51 (pm)
	6	Tri	22:10	7:45	9	35	0	Vel (m/s): 0.7-0.8 (am); 0.1-0.5 (pm)
03-Jul-09	1	Dee	21:37	8:20	10	43	0	
	2	Rec	21:33	8:12	10	39	0	
	3	Tri	21:30	8:05	10	35	0	
	4	Rec	21:23	7:50	10	27	0	
	5	Dee	21:19	7:55	10	36	1	
	6	Tri	21:13	7:45	10	32	0	
04-Jul-09	1	Dee	21:30	8:10	10	40	0	
	2	Rec	21:26	7:57	10	31	0	
	3	Tri	21:23	8:06	10	43	0	
	4	Rec	21:10	7:45	10	35	0	
	5	Dee	21:14	7:53	10	39	0	
	6	Tri	21:02	7:35	10	33	0	
Total					527	42	4	

Appendix 5

Water Depth and Velocity Data

Table 12. Depth (m) and velocity (m/s) data for sites surveyed in 2009 (see Figure 5 for site locations)

Site	Date	UTM	Depth (m)	Velocity (m/s)
1	29-May-09	10.431781.5986127	2.2	0.97
2	29-May-09	10.431843.5986133	NR	NR
3	29-May-09	10.432058.5986345	0.9	1.06
4	29-May-09	10.432226.5986368	1.55	1.1
5	29-May-09	10.432058.5986118	1.65	0.82
6	29-May-09	10.432278.5986202	2.2	0.89
7	29-May-09	10.432437.5986413	1.6	1.1
8	29-May-09	10.432717.5986478	1.2	0.99
9	29-May-09	10.432700.5986637	0.6	1.07
10	29-May-09	10.433046.5986380	1.2	0.14
11	29-May-09	10.433351.5986366	1.25	0.85
12	29-May-09	10.433426.5986462	1.2	0.59
13	29-May-09	10.433406.5986646	1.85	0.65
14	29-May-09	10.433501.5986838	1.75	0.68
15	29-May-09	10.433736.5986942	1.25	0.7
16	29-May-09	10.434105.5986808	2.3	0.65
17	29-May-09	10.434277.5986509	2.1	0.61
18	29-May-09	10.431724.5986114	3.8	0.93
19	29-May-09	10.431848.5986146	NR	NR
20	29-May-09	10.433816.5986972	2.4	0.68
21	29-May-09	10.433812.5986954	1.5	0.91
22	29-May-09	10.433809.5986929	1.8	0.49
23	29-May-09	10.432384.5986381	1.35	1.15
24	29-May-09	10.432399.5986366	1	1.07
25	08-Jun-09	10.433428.5986442	1.6	0.55
26	08-Jun-09	10.433420.5986447	1.55	0.49
27	08-Jun-09	10.433406.5986451	1.2	0.57
28	08-Jun-09	10.433427.5986408	2.15	0.13
29	08-Jun-09	10.433412.5986424	1.5	0.6
30	08-Jun-09	10.433400.5986438	1.2	0.39
31	08-Jun-09	10.433446.5986484	1.35	0.67
32	08-Jun-09	10.433408.5986477	1.1	0.63
33	10-Jun-09	10.433554.5986907	1.75	0.91
34	10-Jun-09	10.433563.5986895	1.95	0.81
35	10-Jun-09	10.433563.5986882	1.25	1.04
36	10-Jun-09	10.433918.5986897	1.25	0.73
37	10-Jun-09	10.433531.5986876	1.95	0.82
38	10-Jun-09	10.433545.5986857	1.7	0.96
39	10-Jun-09	10.433506.5986886	1.1	0.57
40	10-Jun-09	10.433517.5986866	2.05	0.6
41	10-Jun-09	10.433537.5986849	1.65	0.88
42	10-Jun-09	10.433488.5986880	1.1	0.62
43	10-Jun-09	10.433492.5986853	2.4	0.78
44	10-Jun-09	10.433516.5986830	1.55	0.89
45	10-Jun-09	10.431914.5986188	1.8	0.88
46	10-Jun-09	10.431929.5986159	1.3	0.99
47	10-Jun-09	10.431936.5986135	1.5	0.99
48	10-Jun-09	10.431846.5986163	1.8	1.12
49	10-Jun-09	10.431858.5986136	2	1.1
50	10-Jun-09	10.431861.5986109	1.5	0.92
51	10-Jun-09	10.431800.5986149	2.2	0.86
52	10-Jun-09	10.431806.5986129	2.3	1.01
53	10-Jun-09	10.431812.5986106	2	0.66
54	10-Jun-09	10.431752.5986140	2.15	1.03
55	10-Jun-09	10.431758.5986119	2.3	1.03
56	10-Jun-09	10.431767.5986099	1.9	0.71
57	10-Jun-09	10.431715.5986133	1.75	1
58	10-Jun-09	10.431724.5986113	2.45	1.07
59	10-Jun-09	10.431731.5986090	1.8	0.53

Appendix 6

White Sturgeon Developmental Stage Description

Maturity Code	Sex	Description
1	Male	Non-reproductive, testes appear as thin strips with no pigmentation.
2	Male	Maturing; small testes, some folding may be apparent; translucent, smoky pigmentation.
3	Male	Early reproductive; large testes, folds beginning to form lobes; some pigmentation still present. Testes more white than cream coloured.
4	Male	Late reproductive; testes large, often filling posterior of body cavity; white with little or no pigmentation.
5	Male	Ripe; milt flowing; large white lobular testes; no pigmentation.
6	Male	Spent; testes pinkish-white, flaccid, and strongly lobed.
10	Male	General unknown maturity.
11	Female	Non-reproductive; ovaries small, folded with no visible oocytes; tissue color white to yellowish.
12	Female	Pre-vitellogenic, moderate size ovary with small eggs present (0.2 to 0.5 mm diameter) may have “salt and pepper” appearance.
13	Female	Early vitellogenic; large ovary varying in color from white to yellowish-cream to light grey; eggs 0.6 to 2.11 mm diameter.
14	Female	Late vitellogenic; ovaries large with pigmented oocytes still attached to ovarian tissue; eggs 2.2 to 2.9 mm in diameter; sometimes with “salt and pepper” appearance.
15	Female	Ripe; eggs fully pigmented and easily detached from ovarian tissue; eggs 3.0 to 3.4 m in diameter.
16	Female	Spent; ovaries are flaccid with some residual eggs.
17	Female	Pre-vitellogenic with attritic oocytes; small eggs (< 0.5 mm diameter) present; dark pigmented tissue present that may be reabsorbed eggs.
20	Female	General unknown maturity.
97	Unknown	Gonad not visible; juvenile based on size.
98	Unknown	Gonad not visible; adult based on size.

* Description of maturity state classifications adapted from Conte et al. (1988).