Recruitment Biochronology of Nechako White Sturgeon

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1 INTRODUCTION

The population of white sturgeon (*Acipenser transmontanus*) in the Nechako River has been in decline over much of the last century. The decline has been primarily associated with the damming of the river in the early 1950s. Prior to 1950, the population of sturgeon in the Nechako River was estimated to be over 5000 fish (Korman and Walters 2001), as of 2006 the estimated population of mature individuals had decreased to 305 (Wood et al 2007). The white sturgeon population in the Nechako River has been designated as "Endangered" under the Federal *Species at Risk Act*, and provincially is considered "Critically Imperiled" (BC Conservation Data Centre 2013). The BC Government (Ministry of Forest, Lands and Natural Resource Operations (FLNRO) and Ministry of Environment (MoE)) is the lead agency for the recovery process of the Nechako White Sturgeon.

Flows in the Nechako River have been regulated since the completion of the Kenny Dam in 1952. The population of white sturgeon in the Nechako River has been experiencing decades of recruitment failure. Past studies link recruitment failure to the increased sediment inputs from the 1961 Cheslatta River avulsion, with notable and rapid decrease in recruitment occurring during the mid-1960s (Korman and Walters 2001, Northwest Hydraulics 2003). Chronic recruitment failure of Nechako white sturgeon has been ongoing since 1967 (McAdam et al. 2005). Although recruitment since approximately 1967 has remained very low, some limited recruitment continues to occur with the number of individuals varying from year to year.

In the Terms of Reference for this project, FLNRO indicated that the study was to focus on sturgeon recruitment after 1967. As the cause of the recruitment failure is likely attributed to the effects of the Cheslatta River avulsion and changes to river hydrology, this study is intended to investigate environmental factors that have contributed to the survival and low level variation in recruitment of white sturgeon under altered habitat conditions since 1967.

FLNRO has previously collected aging samples (fin rays) from Nechako white sturgeon of all age cohorts recruited since 1967. These aging structures represent an important opportunity to potentially identify environmental factors that influence the growth and recruitment of white sturgeon in the Nechako River. FLNRO has retained EDI Environmental Dynamics Inc. (EDI) to age a number of archived fin rays, confirm hatch year, and assess factors that may have enhanced the recruitment of white sturgeon over the past 45 years.

2 OBJECTIVES

Two of the main objectives associated with this project were:

- Determine the age and hatch year for previously un-aged fin ray structures, and confirm age and hatch year for a subset of previously aged structures.
- Determine trends in recruitment and assess biotic and abiotic factors that may have influenced recent recruitment.

3 METHODS

3.1 AGEING

The first phase of this project involved assigning ages to previously un-aged structures, as well as confirming ages of a subset of previously aged fin ray samples. All ageing structures used in this study were archived samples of white sturgeon pectoral fin rays collected from the Nechako River. The collection belongs to FLNRO and the Nechako White Sturgeon Recovery Initiative (NWSRI).

A total of 65 un-aged pectoral fin ray structures were provided to EDI for ageing. These fin rays were transversely sliced into thin sections using a jeweler's saw, mounted on glass microscope slides with a quick-drying epoxy or contact cement, and polished with 1500 grit sandpaper. Fin ray sections were viewed through a stereo-zoom microscope with transmitted light. The microscope was fitted with a digital camera, and a photo was taken of each fin ray structure. The photos provide a visual record of the structure. These images were archived and included with the final project deliverables.

According to the NWSRI Access database (Version: January 21, 2013) maintained by FLNRO, 328 fin ray structures of sturgeon from the Nechako River have been previously aged. To select a subset of these structures for age confirmation, a database query was performed to identify fish that were less than 1.5 m in length when last captured and assigned hatch year was 1967 or later. The structures of a 101 fish were listed. The age structures of 28 fish could not be located within the sample set provided. A total of 73 structures were reassessed to confirm the precision of age assignments. A number of these structures, approximately 15, required re-polishing and/or re-mounting prior to re-aging.

Age from fin rays was determined by counting the number of consecutive pairs of opaque and translucent zones in the structure's cross section. It is important to note the first translucent zone from the core of the structure was counted as 0.5 of a year. This zone represents growth during the first summer of life, and not a complete year of growth. The method of ageing was corroborated with the structures from hatchery raised fish of a known age.

Two readers independently aged each of the previously un-aged sectioned fin rays. The structure was aged by the first reader, followed by a blind read by the second reader. If age estimates from the two readers agree for a particular fish, then that age would assigned to the fish. If age estimates from the readers differ, then the readers will collectively examine the sectioned fin-ray and reach a consensus regarding age. Fin ray structures that could not be accurately aged due to unresolvable sections of annuli growth were not included in the analysis. Precision among readers was assessed by calculating percent agreement (PA), average percent error (APE) and coefficients of variation (CV) in age estimates. The formula presented by Beamish and Fournier (1981) was used to calculate APE:

$$\mathrm{APE} = \frac{1}{N}\sum_{j=1}^{N}\left(\frac{1}{R}\sum_{i=1}^{R}\frac{|x_{ij} - x_j|}{x_i}\right) \times 100,$$

Where *N* is the number of fish aged, *Xij* is the *i*th reading of the *j*th fish, *Xj* is the average inferred age of the *j*th fish, and *R* in the number of readings of a sample.

It is recognized that ageing of white sturgeon using the fin ray method is widely accepted; however it is known that difficulties in the interpretation and expression of annuli contribute to uncertainty of age estimates. Rien and Beamesderfer (1994) found low precision in age estimates for white sturgeon relative to reported values for other species. The use of Oxytetracycline (OTC) to validate ages of white sturgeon in the Columbia River found counts of fin ray annuli tend to underestimate age (Rien and Beamesderfer 1994). The accuracy of age interpretation is related to growth rate and age, with sturgeon exhibiting slow growth and/or older being more difficult to accurately age. Readers were aware of these and other factors, and this information was considered during interpretation of age. The opportunity to utilize fin rays from fish with known hatch years or from fish where age structures were collected over multiple years provided an opportunity to monitor and confirm age assignment accuracy.

3.2 RECRUITMENT TRENDS

The precise cause of recruitment failure in the Nechako white sturgeon population since 1967 is not known, but is thought to be attributed to changes in river morphology and substrate composition associated with the Cheslatta River avulsion (NHC 2003, McAdam et al 2005). The primary intent of this project is to examine biotic and abiotic factors such as temperature, flow, and salmon escapement and their potential influence on continued low level recruitment variation in white sturgeon.

From the age composition data, relative recruitment trends were estimated. Relative recruitment estimates, or recruitment index, is basically an expansion of the age composition data to account for fish lost from the years of recruitment due to mortality. Relative recruitment for each individual (R) was calculated using

$$R = a\, e^{aM}$$

where *a* is the age of the individual and M is the natural mortality rate. A natural mortality rate of M = 0.04 was used for this study, and is based on the work of Korman and Walters (2001) and McAdam et al. (2005). The relative recruitment for each individual was summed for each hatch year in the study to develop a recruitment index.

Relative recruitment values for fish born since 1967 were placed on a timeline to visually determine particular periods where recruitment appeared to have been promoted or inhibited. Correlative statistical analysis was used to determine the level of relationship between specific environmental factors and recruitment. Environmental factors examined included:

- Hydrometric data and seasonal flow conditions within the Nechako River. This includes river discharge and water temperature.
- Climate data including mean annual summer and winter air temperatures. Air temperature influences water temperature. LeBreton and Beamish (2000) demonstrated a significant correlation between white sturgeon growth and mean annual air temperature.

- Sockeye (*Oncorhynchus nerka*) and Chinook salmon (*Oncorhynchus tshawytscha*) escapement numbers in the Nechako River watershed, including runs in the Stuart River system.

3.2.1 Environmental Data

At the time of the study structures were available from fish captured as recently as 2012, however once aged, hatch years were always from 2009 or older. Recruitment numbers from 1967 to 2009 were compared to hydrometric, climate and salmon escapement values. Analysis included:

Discharge:

Source: Environment Canada (Water Survey of Canada)
Mean Discharges: Annual, Winter (December/January/February), Early Spring (March/April), Late Spring (May/June), Summer (July/August), Fall (September/October/November).

- Nechako River, Vanderhoof (Station 08JC001): 1967-2009
- Nechako River, Isle Pierre (Station 08JC002): 1967-2009
- Skins Lake Spillway, Nechako Reservoir (Station 08JA013): 1967-2009
- Stuart River Near Ft. St. James (08JE001): 1967-2009

Water Temperature:

Sources: Nechako Fisheries Conservation Program, Rio Tinto Alcan, and Environment Canada (Water Survey of Canada)
Mean July 10 to August 20 Nechako water temperatures, Finmoore Station.

Air Temperature:

Source: Environment Canada (National Climate Data and Information Archive)
Mean Air Temperature: Annual, Spring (May/June), Summer (July/August).

Salmon Escapement:

Source: Fisheries and Oceans Canada (DFO)

- Nechako River Sockeye Escapement: 1967-2009
- Stellako River Sockeye Escapement: 1967-2009
- Early Stuart River Sockeye Escapement: 1967-2009
- Late Stuart River Sockeye Escapement: 1967-2009
- Nechako Watershed Sockeye Escapement (excluding Stuart system): 1967-2009
- Total Nechako Watershed Sockeye Escapement (including Stuart system): 1967-2009
- Nechako River Chinook Escapement: 1967-2009
- Stuart River Chinook Escapement: 1967-2009

Escapement data were not only examined in relation to the recruitment in a given year, but also conditions in the preceding year.

3.2.2 Analysis

Correlative statistical analyses were conducted to determine the level of relationship between specific environmental factors and recruitment. All data analyses were performed using the Data Analysis Tool Pack for Microsoft Excel 2010. An Analysis of Variance (ANOVA) was used to investigate differences in means for the number of individuals, discharge, water temperature and air temperature between decades. In situations where a significant difference was detected, direct pair-wise comparison using t-tests were conducted. For all statistical analyses, a p-value of 0.05 was used to determine significance. The relative strength of correlation coefficients were determined using the following guidelines:

- 0.0 to 0.2 - Very weak to negligible correlation
- 0.2 to 0.4 - Weak, low correlation
- 0.4 to 0.7 - Moderate correlation
- 0.7 to 0.9 - Strong, high correlation
- 0.9 to 1.0 - Very strong correlation

4 RESULTS

4.1 AGEING

EDI cut, mounted and examined a total of 65 previously un-aged pectoral fin ray structures. Appendix A provides a table of age assignments and comments for each structure. Of the fin-rays examined, two were found to belong to fish treated with OTC. Of the structures, ages could not be confidently assigned to 31 fin rays due to core damage or extremely compressed annuli. Of the structures that were assigned ages (n=47), there was 47% percent agreement between the first and second reader where the two ages were the same, and 66% agreement where age comparisons were within 1 year. In cases where there was disagreement between readers, the readers collectively examined the sectioned fin-ray to reach a potential consensus. For calculations of precision between readers, APE was 5.44 and CV was 10.48%. These results were comparable with other white sturgeon age estimate studies (Rien and Beamesderfer 1994). Ageing methods were corroborated with the structures from hatchery raised fish of a known age. The image presented in Figure 1, shows annuli increments of a hatchery fish hatched in 2006 and captured in 2012. Although it is possible for hatchery grown fish to exhibit different growth patterns than wild fish, there were no notable differences observed in the presence or characteristics of annuli that would affect age readings between hatchery and wild sturgeon.

Not all of the previously un-aged structures were used in recruitment analyses. Some structures simply could not be aged due to growth anomalies. Some structures were assigned an age, but confidence in the accuracy of exact age assignment was not certain. These structures were not included in the analysis. Ages of structures that were from hatchery produced fish, or from fish that had a hatch year prior to 1967, were also removed from the analysis. Of the total number of previously un-aged structures, 22 were assigned ages with suitable confidence to be used in recruitment analysis.

A query of the FLNRO Access database (Version: January 21, 2013) for fish under 1.5 m in length and born in 1967 or later resulted in 101 previously aged fish. Of this number, 73 structures were re-examined for age confirmation. The remaining structures could not be located and were not a part of the collection provided to EDI. From the 73 structures assessed, 14 could not be aged with confidence due to core damage or annuli compression. A total of 59 structures were examined. There was a 49.2% percent agreement between the new readings and previous age assignments. In many cases, particularly in comparison to structures aged by R,L&L, ages assigned by EDI were typically within a difference of 1 year. There was a 74.6% agreement where age comparisons were within 1 year. With the exception of one structure, all reading comparisons were within 3 years. The only structure with a discrepancy greater than 3 years belonged to a fish captured in 2001, after repolishing the structure the age was determined to be 13 years older than the original assignment. In many cases it is suspected that the discrepancy between readings is attributed to the counting of the first annuli as 1 year of growth, instead of 0.5 year of growth in the first summer of life. Appendix B provides a table of queried fish and age comparisons.

In general for both the previously un-aged and the reassessed structures, age agreement was most common in younger fish (i.e. less than 25 years old); however examples of perfect agreement included fish up to 49 years of age. Bruch et al. (2009), report that error in aging pectoral fin rays in lake sturgeon (*Acipenser fulvescens*) increased with age and that age of fish older than 14 years was typically an underestimate of the true age. It is recognized that accurately ageing sturgeon with fin rays can be difficult, particularly in older fish (Rien and Beamesderfer 1994, Bruch et al. 2009). Attempts were made to accurately age the fin ray structures in this study and when necessary structures were removed from the analyses; however based on the literature, some level of undetermined error may be present and inherently unavoidable. Precision and accuracy in determining the "actual" hatch year on an individual is expected decrease with the age.

Bruch et al. (2009) indicates that otoliths provide a more accurate age estimate and that they be used for age determination where possible. However, lethal sampling of an Endangered species to obtain otoliths would not be a prudent option. McAdam (2012) suggests that the degree of ageing error effects in the Nechako population may be limited for fish under the age of 25 years. For the purpose of this study, given that the majority of fish were relatively young (less than 25 years) it was assumed that the age estimations used in the analyses were accurate. Consideration was given to removing fish greater than 25 years of age from the analysis; however the decision was made that if the readers were confident in the assigned age the structure would be included in the analysis to help maintain a suitable sample size. It is expected that any imprecision in age estimates would affect the degree of variation but would not mask overall trends.

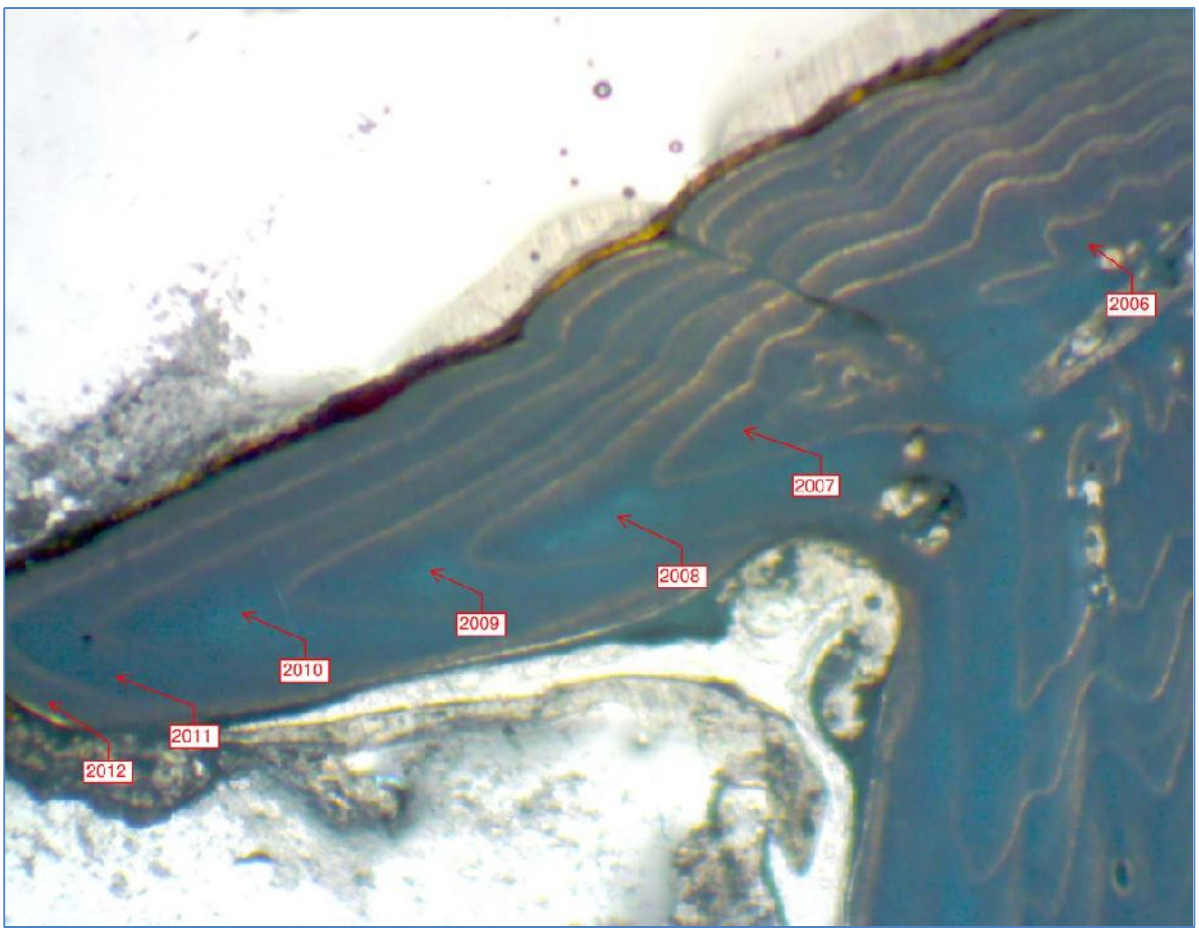

Figure 1. Image of annuli increments of a hatchery fish born in 2006 and captured in 2012.

4.2 RECRUITMENT ANALYSIS

Hatch years for recruitment analysis ranged from 1967 to 2009. For this study, the ages of 189 fish were used. Hatch years were a combination of those calculated from structures aged during this project, and hatch years determined from the NWSRI Access database. Ages were used to calculate the relative recruitment for each year. The histogram in Figure 2 displays Nechako white sturgeon recruitment between 1967 and 2009. The figure shows the actual number of individuals associated with each year as well as the calculated recruitment index. In general terms, recruitment appeared to decline through the 1970s, remained low throughout the 1980s, with a slight improvement in select years in the 1990s and 2000s. Recruitment was absent in 1980, 1982, 1991, and 2002. There were notable spikes in recruitment occurring in 1994 and 1995, and a very large spike in recruitment in 2007.

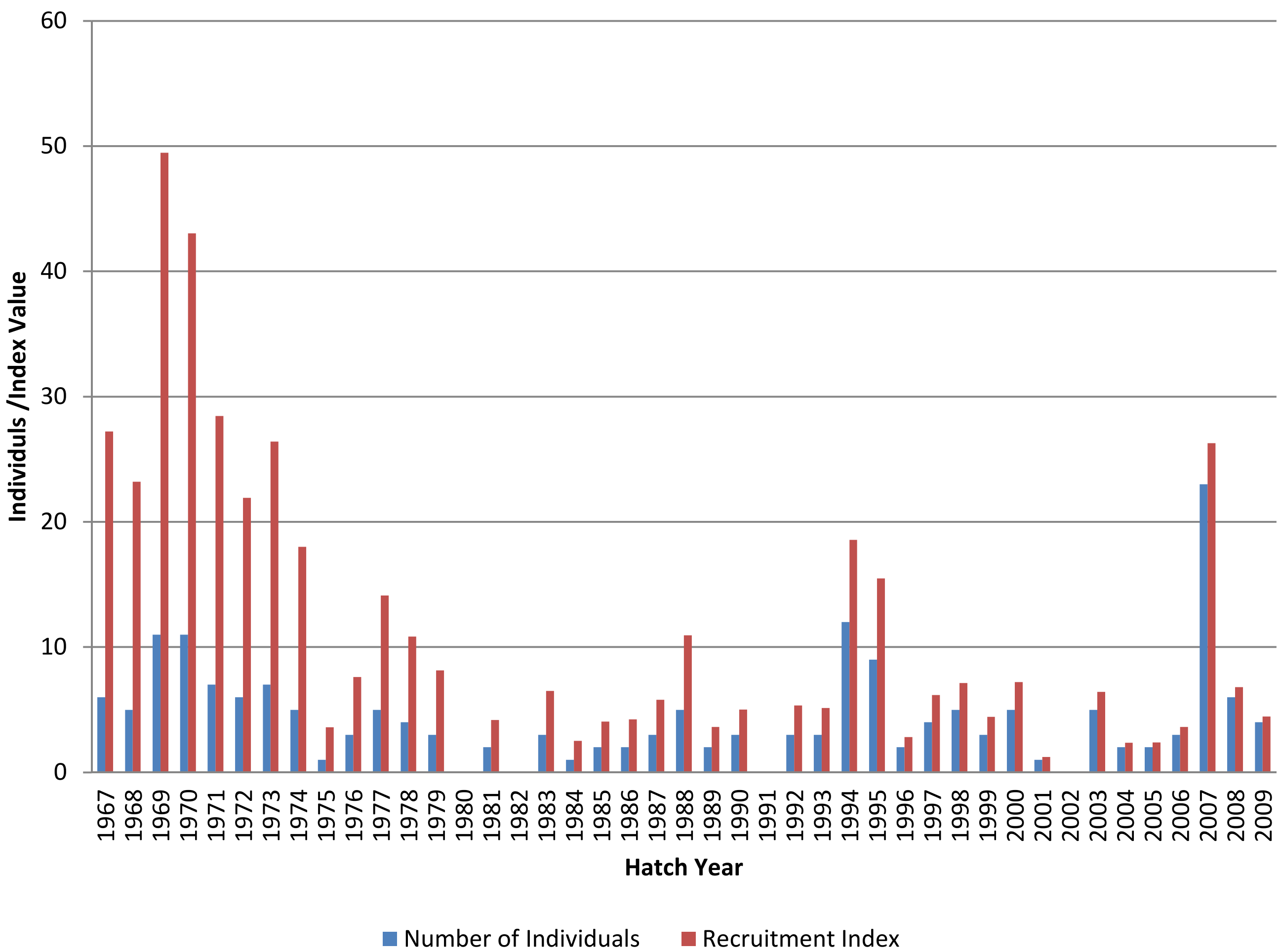

Figure 2. Display of the number of individuals for each hatch year, and corresponding recruitment index values.

4.2.1 Discharge

The upper portion of Nechako River was impounded in 1952 and downstream flows have since been regulated. Over the decades there have been numerous studies examining changes in annual flows and peak annual flows associated with flow regulation. During the 1960s and 1970s average annual flows released to the Nechako River via the Skins Lake Spillway steadily declined (NHC 2003). Spring freshet flows were reduced by approximately half compared to pre-regulation conditions. In 1980 a new flow management regime intended to benefit salmon resulted in further reduction in spring flows and the elimination of a regular spring freshet (NHC 2003). Autumn and winter flows were also substantially reduced. To meet summer temperature objectives for salmon, the peak flow period shifted to July and August, however summer flows were still lower than those prior to regulation. Mean annual discharge of the Nechako River at Vanderhoof decreased from 242 m^3/s pre impoundment (1930-1951), to 85 m^3/s (1980-1989); representing a 65% reduction in mean annual discharge.

In 1987, a Settlement Agreement was signed between Alcan and the Provincial and Federal governments. The agreement specified an annual water allocation to be released from Nechako Reservoir with the intent of achieving an approximate mean annual flow of 41.7 m^3/s in the Nechako River below Cheslatta Falls (Triton 2006). Although flow conditions in the 1990s and 2000s remained low, there was a slight increase in mean annual discharge during this period compared to the 1980s. Figure 3 illustrates the changes in the annual Nechako River hydrograph for each decade, with information obtained from the Environment Canada Water Survey Station located in the community of Vanderhoof.

Table 1 presents the mean annual discharge for the Skins Lake Spillway, three stations on the Nechako River, and one station on the Stuart River. Although the mean discharge was consistently the lowest for the period during the 1980s, the difference in means was only significant at the Isle Pierre station (p=0.05). Note that even though flows on the Stuart River were not regulated, the mean annual discharge was also lowest in the 1980s.

Table 1. Mean annual discharge at five Water Survey Canada stations for the decades spanning 1970 -2009.

Period of Discharge	Skins Lake Spillway Mean Annual Discharge (m^3/s)	Nechako River at Chestlatta Falls Mean Annual Discharge (m^3/s)*	Nechako River at Vanderhoof Mean Annual Discharge (m^3/s)	Nechako River at Isle Pierre Mean Annual Discharge (m^3/s)	Stuart River Mean Annual Discharge (m^3/s)
1970-1979	103	-	152	302	141
1980-1989	54	61	85	202	112
1990-1999	70	72	115	257	134
2000-2009	72	76	119	261	138

* Record from 1981 to 2009

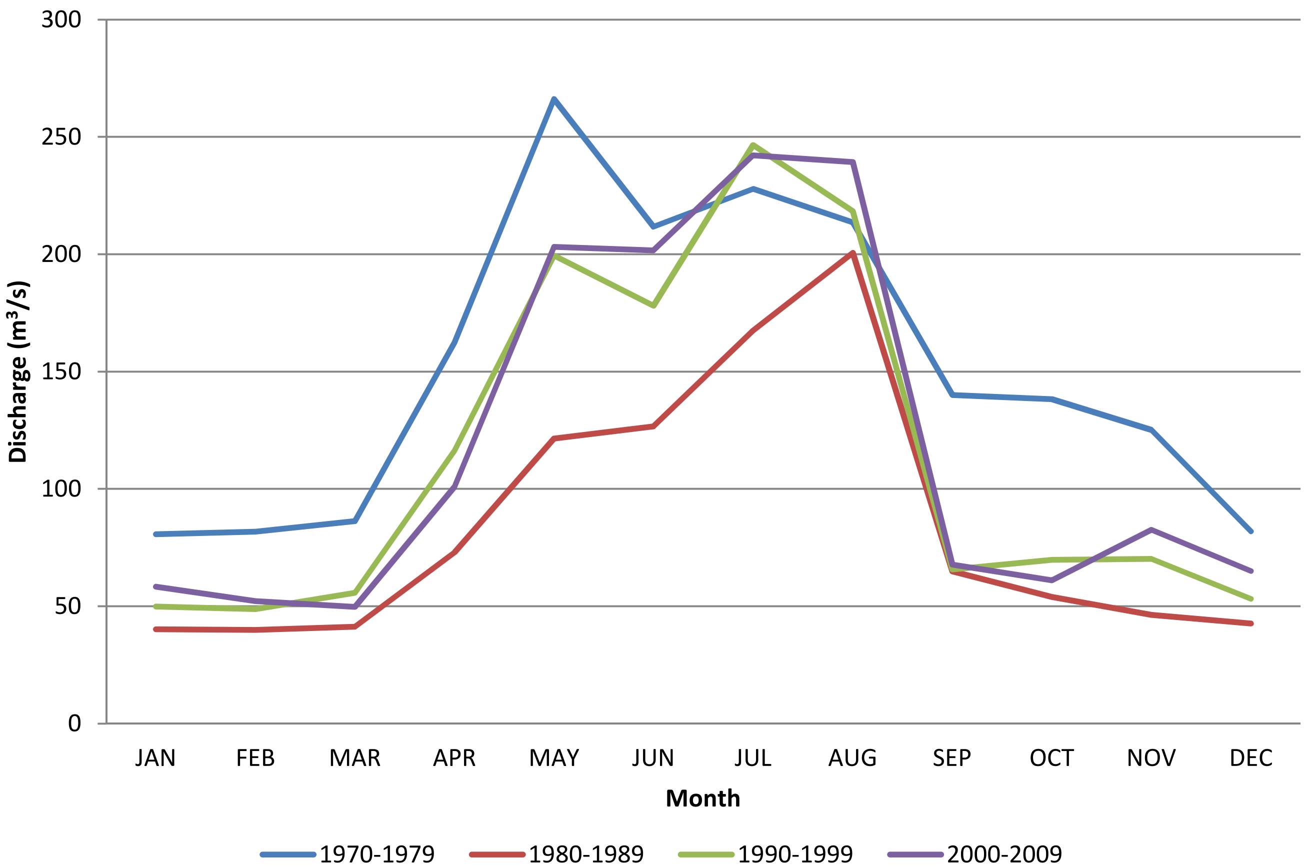

Figure 3. **Changes in the Nechako River hydrograph at the Vanderhoof Water Survey Station over the past four decades.**

Correlation and regression analyses of relative recruitment were conducted for specific periods of discharge at four Water Survey Stations in the Nechako River Watershed. Annual discharge was separated into the seasonal periods of Winter, Early Spring, Late Spring, Summer and Fall (Table 2). In the case of the Vanderhoof station monthly discharge was also investigated. The extra emphasis at this station was done in part due to its proximity to known white sturgeon spawning habitat at Vanderhoof. At the Vanderhoof station, analysis resulted in weak to moderate positive correlations between discharge variables and recruitment (Table 2). From a seasonal perspective the strongest correlation between discharge and recruitment occurred in the fall (r = 0.46) and winter (r = 0.44), weakening through the seasons, with the weakest correlation occurring in summer (r = 0.10) (Table 2). When discharges for individual months were analyzed separately, March exhibited the greatest correlation (r = 0.50). Based on the analysis, it appears that factors associated with increased flows in late winter (January to March) and again in autumn (September and October) positively influence recruitment. There was very little relationship between summer flows and recruitment.

Table 2. Correlation coefficients associated with recruitment and seasonal/monthly discharge of the Nechako River at the Vanderhoof Station.

Period of Discharge	Correlation Coefficient
Winter Discharge (Dec, Jan, Feb)	0.44
Early Spring Discharge (March, April)	0.42
Late Spring Discharge (May, June)	0.31
Summer Discharge (July, Aug)	0.10
Fall Discharge (Sept, Oct, Nov)	0.46
Annual Discharge	0.36
January Discharge	0.41
February Discharge	0.42
March Discharge	0.50
April Discharge	0.34
May Discharge	0.30
June Discharge	0.30
July Discharge	0.17
August Discharge	<0.01
September Discharge	0.48
October Discharge	0.47
November Discharge	0.35
December Discharge	0.35

Select periods of discharge at the Vanderhoof Station were graphed in relation to sturgeon recruitment (Figure 4). The graph illustrates low flow conditions in the fall and in March when the correlation between discharge and recruitment was the greatest. Figure 4 also displays summer discharge; this period had the poorest correlation between variables. One of the most obvious initial observations is the large summer spike in 2007 discharge and the corresponding spike in sturgeon recruitment. This may be simply coincidental, as increased recruitment does not mimic this trend during other periods of elevated discharge, for example in 1976 and 1997 (Figure 4). Likewise during periods of stronger recruitment (e.g. 1970 and 1994) summer and annual flows were relatively low.

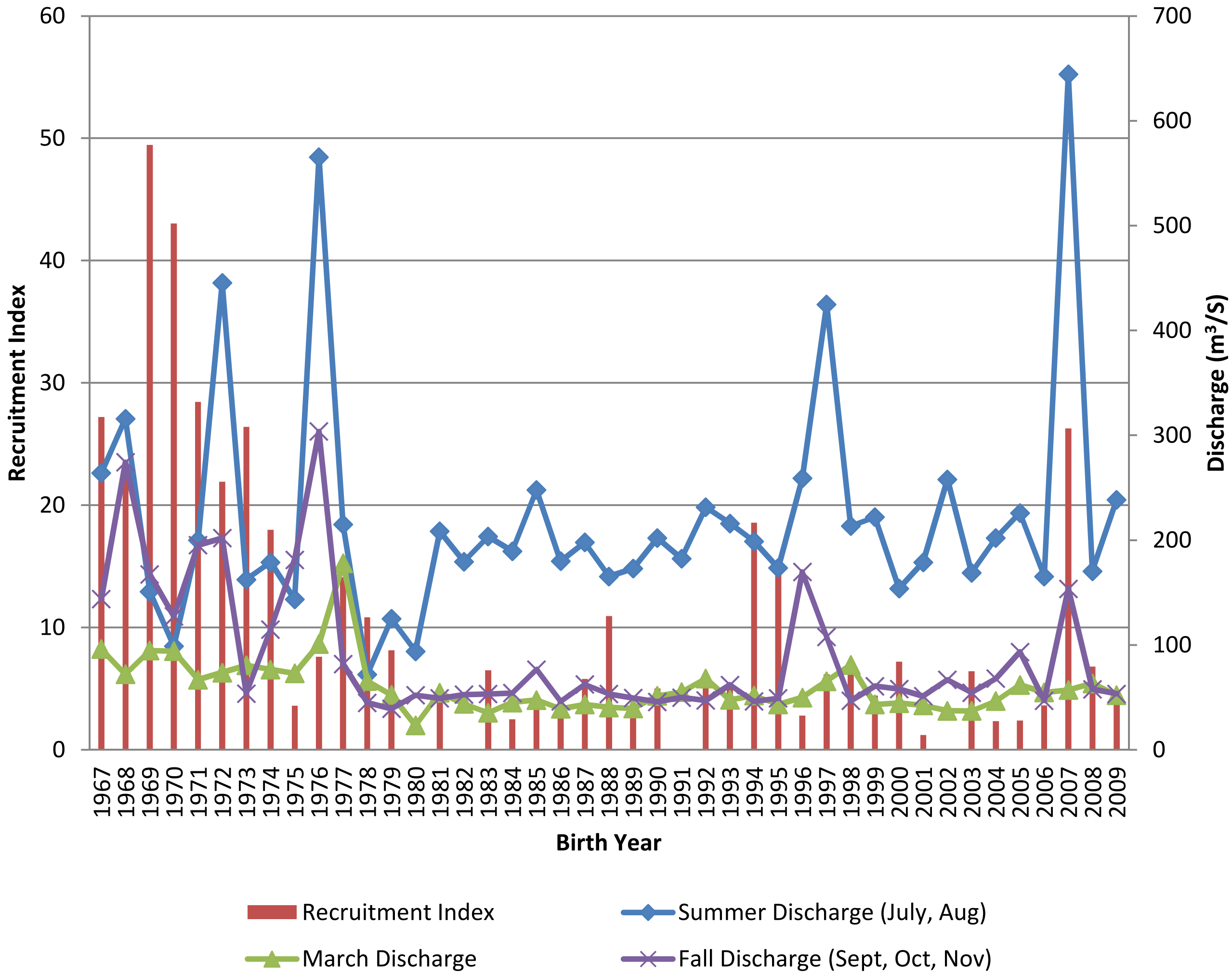

Figure 4. **Nechako River Early spring, summer and fall discharge conditions at the Vanderhoof Station in relation to yearly recruitment index.**

Relationships between seasonal discharge and recruitment were also explored at the Isle Pierre Station on the Nechako River and the Skins Lake Spillway Station on the Nechako Reservoir. At both stations, the lowest correlation values were always associated with summer flows. Fall and winter correlation values were comparable to those for the Vanderhoof Station, and indicated a stronger relationship during these low flow periods than during higher flow conditions in the spring and summer (Table 3). Similar to results on the Nechako River, winter flows at the Stuart River Station also exhibited the greatest correlation coefficient ($r = 0.42$) when compared to other seasons (Table 3). McAdam and Lu (2002) observed a significant positive relationship between modeled recruitment index of Nechako white sturgeon and winter flows.

Table 3. Correlation coefficients associated with recruitment and seasonal discharge at the Skins Lake Spillway, Isle Pierre, and Stuart River Stations.

Period of Discharge	Skins Lake Spillway Correlation Coefficient	Nechako River at Isle Pierre Correlation Coefficient	Stuart River Correlation Coefficient
Winter Discharge (Dec, Jan, Feb)	0.47	0.49	0.42
Early Spring Discharge (March, April)	0.39	0.42	0.15
Late Spring Discharge (May, June)	0.33	0.24	0.10
Summer Discharge (July, Aug)	0.08	0.12	0.17
Fall Discharge (Sept, Oct, Nov)	0.44	0.43	0.35
Annual Discharge	0.38	0.35	0.28

4.2.2 Water Temperature

Due to concerns expressed by DFO regarding the volume of water released from the Nechako Reservoir, in 1980 Alcan began releasing flows designed to protect salmon values in the Nechako River. These flows consisted of year-round minimum flow requirements for the benefit of Chinook salmon and summer "cooling flows" for the benefit of Sockeye salmon (Macdonald et al 2007). The release of summer cooling flows is referred to as the Summer Temperature Management Program (STMP). The STMP is intended to moderate potential high water temperatures in the Nechako River, with the specific goal of reducing the frequency of observed mean daily water temperatures >20 °C at Finmoore, located just upstream of the confluence with the Stuart River, between July 20th and August 20th (NFCP 2005). This is achieved by releasing reservoir surface water through the Skins Lake Spillway based on computer generated water temperature responses to anticipated meteorological conditions in the watershed (Triton 2004, NFCP 2005).

The interest in water temperatures in the Nechako River has primarily focused on summer values and temperature requirements for Sockeye. With the exception of July and August, long term datasets for annual/monthly water temperatures were unavailable. July and August Nechako River water temperatures have been recorded at a number of locations along the river; however only temperature records from Finmoore were available for the entire study period (1967-2009). July/August water temperatures have been recorded at Finmoore since 1950. As a component of the STMP, water temperatures in the Nechako River at Finmoore have been recorded from July 10th to August 20th. For this study, sturgeon recruitment was compared to July 10th to August 20th water temperatures at Finmoore.

In this study a weak negative correlation between water temperature and relative recruitment was observed; however not enough to suggest that water temperature would be reliable a predictor of recruitment. Table 4 provides the correlation coefficients associated with July and August water temperatures and recruitment. Figure 5 depicts July 10th- August 20th water temperatures in relation to yearly sturgeon recruitment. No discernible pattern was detected between water temperature and recruitment. For example, water temperatures in 1976 were near 15 °C and there was relatively poor recruitment, compared to similar temperature conditions in 2007 where recruitment considerably greater (Figure 5). Similar conflicting observations were noted during periods of warmer water temperatures.

Table 4. Correlation coefficients associated with recruitment and July and August Nechako River water temperatures.

Period	Correlation Coefficient
July 10th –July 31st Water Temperature	-0.28
August 1st – August 20th Water Temperature	-0.30
July 10th -August 20th Water Temperature	-0.31

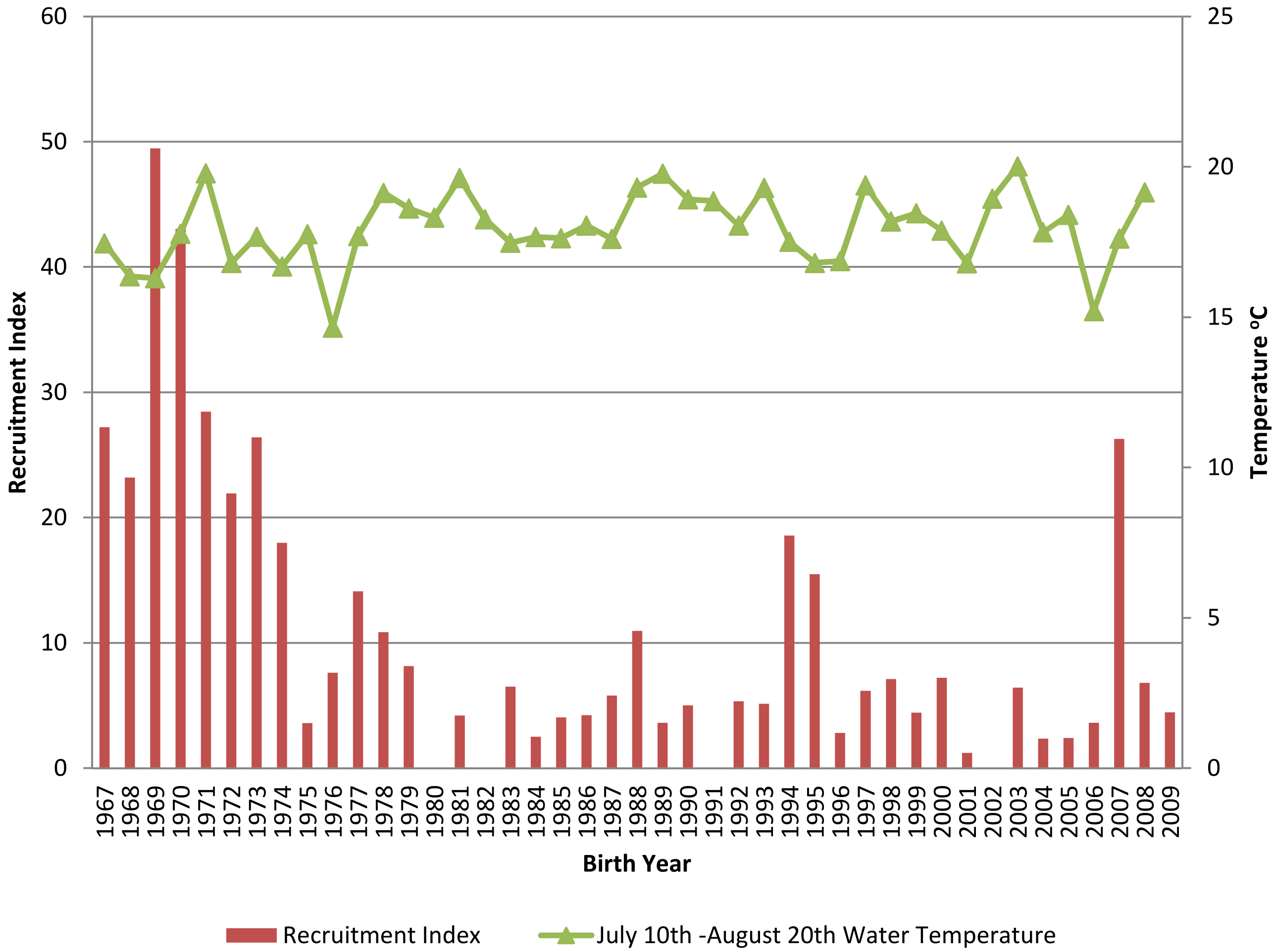

Figure 5. July 10th - August 20th Nechako River water temperatures in relation to yearly sturgeon recruitment.

4.2.3 Air Temperature

Since water temperatures in the Nechako River were only available for the months of July and August, ambient air temperature was investigated as a possible surrogate for water temperature. Past research has shown that air temperature could be correlated with lake sturgeon growth (LeBreton et al 1999). In this study correlative analysis was used to determine the possible influence of air temperature on sturgeon relative recruitment.

Mean monthly air temperatures for May through August, as well as mean annual air temperature was compiled from the Vanderhoof Environment Canada Weather Station. Air temperature during winter and early spring months where there was the potential for ice coverage was considered to be a poor representative for water temperature. Table 5 provides the mean annual and monthly summer air temperatures in Vanderhoof for decades encompassed in this study. The most notable observation in the air temperature data was the warming trend between the 1970s and the following decades. Consistently, the mean air temperatures during the 1970s were significantly ($p<0.01$) lower than the mean temperatures for those of following decades.

Table 5. Mean annual and monthly summer air temperatures in Vanderhoof for the time period encompassed in this study.

Period	Mean May Air Temperature (°C)	Mean June Air Temperature (°C)	Mean July Air Temperature (°C)	Mean Aug Air Temperature (°C)	Mean Annual Air Temperature (°C)
1970-1979	8.1	11.7	13.9	13.4	1.6
1980-1989	10.3	13.7	15.9	15.5	4.2
1990-1999	11.2	14.5	16.4	16.0	4.1
2000-2009	10.4	14.9	16.8	15.7	4.4
1967-2009	9.9	13.7	15.6	15.0	3.5

Correlative analysis indicated that there was a weak to moderate negative relationship between mean annual and summer monthly air temperatures and relative sturgeon recruitment. Table 6 provides the correlation coefficients values associated with Vanderhoof air temperatures and relative recruitment. Of the variables examined, mean August air temperature exhibited the strongest negative correlation (r = -0.59). However the results may be somewhat misleading, as air temperatures in the 1970s were on average lower than in preceding decades while recruitment during the early portion of this period was relatively high. Mean annual and August air temperatures were plotted against relative sturgeon recruitment in Figure 6. There was no discernible pattern observed between air temperatures and the relative recruitment in a particular year. For example, years with higher air temperatures did not correlate to years with greater or lesser recruitment.

Table 6. Correlation coefficients associated with relative recruitment and Vanderhoof air temperatures.

Period	Correlation Coefficient
May Air Temperature	-0.27
June Air Temperature	-0.18
July Air Temperature	-0.45
August Air Temperature	-0.59
Annual Air Temperature	-0.41

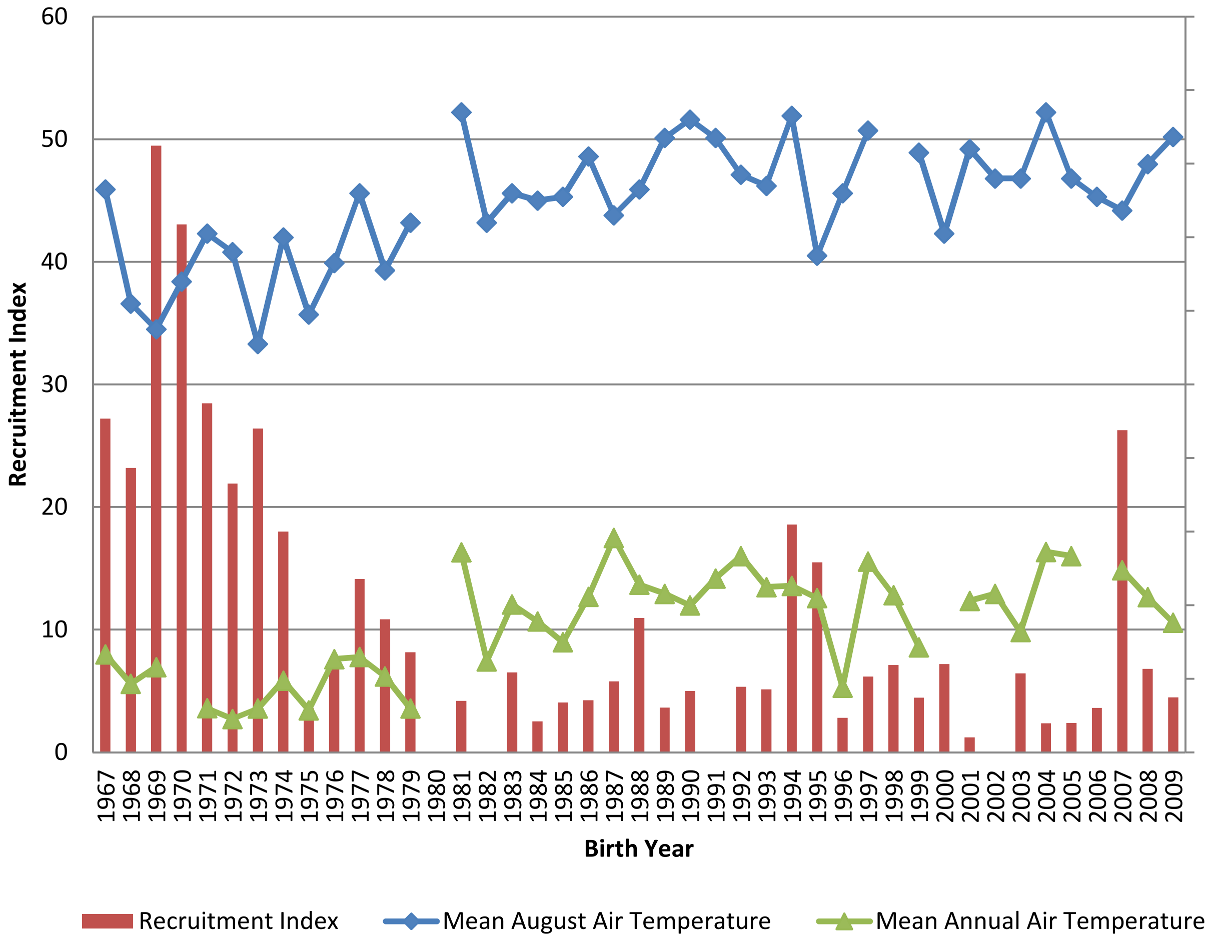

Figure 6. Mean annual and August air temperatures in relation to yearly sturgeon recruitment.

4.2.4 Salmon Escapement

Annual Sockeye and Chinook salmon returns in the Nechako and Stuart River systems are thought to represent an important source of food for white sturgeon. DFO salmon escapement numbers were compared to sturgeon recruitment numbers. The study included annual Sockeye escapement numbers for the Stellako River, the Nechako River and tributaries excluding the Stuart River, early and late Stuart runs, combined Stuart runs, and total escapement for the entire Nechako River watershed inclusive of Stuart runs. Annual Chinook escapement numbers for the Nechako River and tributaries excluding the Stuart River, Stuart River system, and combined total Nechako River watershed were also investigated.

Correlative analysis indicated that there were weak to very weak negative relationships between various Sockeye escapements and relative sturgeon recruitment (Table 7). There was less of a relationship between Sockeye runs in the Stuart system than in the Nechako River. Sockeye escapement in the Stellako River appeared to have the greatest negative correlation with sturgeon recruitment (r = -0.32); however this was still considered a weak relationship. To determine whether Sockeye escapement in one year may relate to fecundity and recruitment the following year, analysis included investigation of relative sturgeon recruitment when offset by one year. Results indicated that there was even less of a relationship between Sockeye escapement and sturgeon recruitment in the following year (Table 7).

Chinook escapement seemed to be more of an important factor to sturgeon recruitment than Sockeye. In the Nechako River there was a moderate negative correlation (r = -0.49) between Chinook escapement and sturgeon recruitment (Table 7). In comparison, Chinook escapement solely in the Stuart system exhibited a weaker relationship (r = -0.28). Correlation coefficient values for Chinook escapement were lower when recruitment numbers were offset by one year, but still indicated more influence than corresponding Sockeye values.

Visually, there was little observable pattern between salmon escapement and sturgeon recruitment. However in general terms, it would appear that sturgeon recruitment was greater in years when Sockeye and Chinook were relatively low, and vice-versa. Predation is likely the primary mechanism for mortality of juvenile sturgeon (McAdam 2012). Chinook fry are known to prey on free-swimming sturgeon larvae. For particular years there may be a possible linkage between high salmon recruitment and low sturgeon recruitment in the absence of good hiding habitat for sturgeon eggs and yolk-sac larvae. Figure 7 displays annual Sockeye escapement values for the Stuart and Nechako Rivers, as well as for the total combined watershed. The cyclical nature of Sockeye runs are observed approximately every four years; although not always consistent recruitment numbers tended to be greater during years of low Sockeye escapement. Figure 8 is similar, except for Chinook escapement. A similar weak pattern was observed, where sturgeon recruitment was generally greatest in years when Chinook escapement was relatively low; particularly for total watershed Chinook escapement (Figure 8). Both overlapping Sockeye and Chinook escapement in 2007 were quite low, and yet white sturgeon exhibited the greatest year of recruitment in at least three decades.

When considering the possible influence of salmon escapement on recruitment in the subsequent year there did not appear to be any consistency between years of strong salmon returns and sturgeon recruitment in the immediate year or following years. It is interesting to note that after a decade of low recruitment through the 1980s, there was a spike in sturgeon recruitment numbers in 1994 and 1995, following very large runs of Chinook in 1992 and Sockeye in 1993 (Figures 7 and 8). However this may be merely coincidental, as similar recruitment numbers in 1969 and 1970 did not correspond to high escapement values.

The extent of the possible negative influence of high salmon escapement on sturgeon recruitment may be exaggerated in the results. In both cases, Sockeye and Chinook escapement was relatively low during the late 1960s and 1970s, while sturgeon recruitment was relatively high during this period. McAdam and Lu (2002) mention a shift in oceanic conditions occurring in the late 1970s resulting in increased numbers of Sockeye and Chinook in the Nechako system. While salmon numbers generally increased in the following decades, sturgeon recruitment continued to decline from previous levels (Figures 7 and 8). It is possible that these two trends were coincidental and unrelated. Henderson and Graham (1998) reported that a salmon treaty between Canada and the United Stated in 1985 resulted in overall reductions in exploitation and increased escapement for Chinook beginning at this time. Based on this observation and other factors that may influence salmon escapement trends beyond the scope of this project, it would appear that there are a number of confounding factors occurring that may have influenced and exaggerated the relationship between salmon escapement and sturgeon recruitment.

Table 7. Correlation coefficients associated with Sockeye and Chinook escapement in the greater Nechako River watershed and white sturgeon recruitment.

Escapement Run	Year of Run Correlation Coefficient	1-Year Offset Correlation Coefficient
Stellako River Sockeye Escapement	-0.32	-0.22
Early Stuart Sockeye Escapement	-0.09	-0.13
Late Stuart Sockeye Escapement	-0.14	-0.18
Total Stuart Sockeye Escapement	-0.13	-0.17
Total Nechako Sockeye Escapement	-0.29	-0.20
Total Watershed Sockeye Escapement	-0.20	-0.22
Total Stuart Chinook Escapement	-0.28	-0.27
Total Nechako Chinook Escapement	-0.49	-0.36
Total Watershed Chinook Escapement	-0.49	-0.42

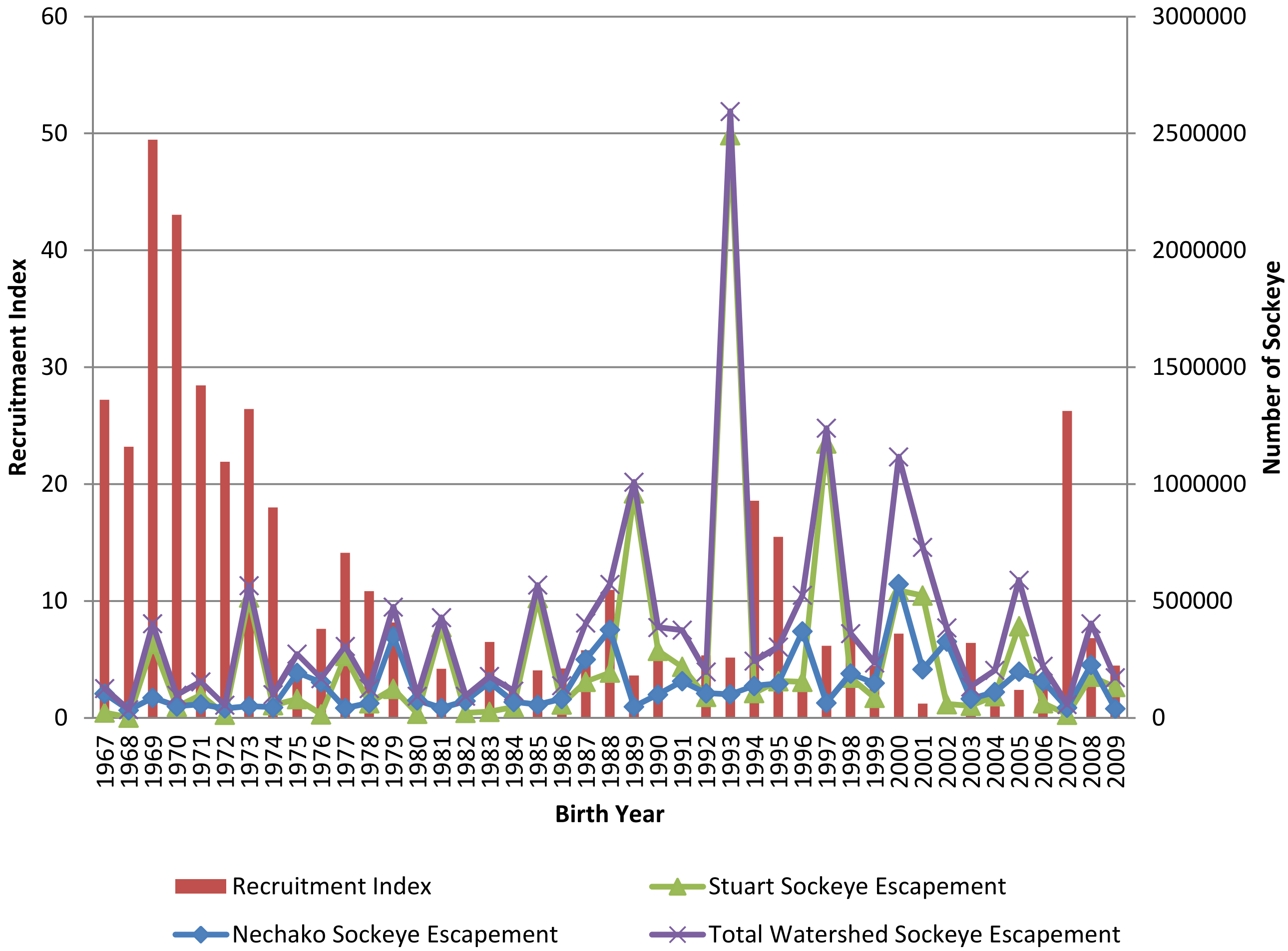

Figure 7. **Sturgeon recruitment compared to annual Sockeye escapement in the Stuart and Nechako River systems, as well as the total greater Nechako watershed.**

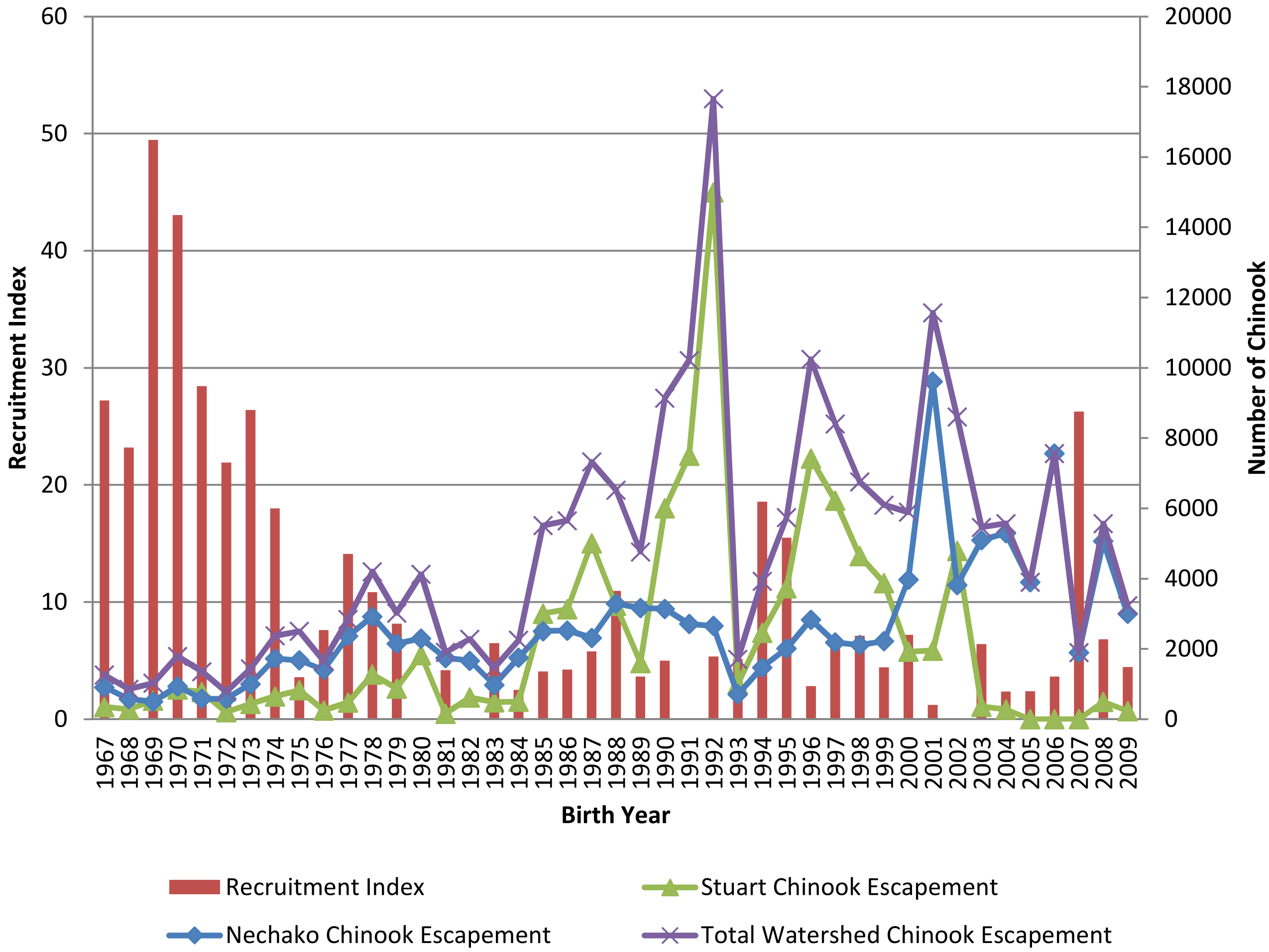

Figure 8. **Sturgeon recruitment compared to annual Chinook escapement in the Stuart and Nechako River systems, as well as the total greater Nechako watershed.**

5 DISCUSSION

Accurate age estimations were critical for analyzing environmental factors and associated relationships with sturgeon recruitment. Ageing methods used in this study were corroborated with the structures from hatchery raised fish of a known age. The age dataset used for this study included previously un-aged pectoral fin ray structures as well as ages obtained from the NWSRI Access database. A number of aged fin ray structures from the database were re-examined for age confirmation. The ageing of white sturgeon using the fin ray method is widely accepted, but is known that difficulties in the interpretation and expression of annuli contribute to uncertainty of age estimates (Rien and Beamesderfer 1994). To limit potential errors, structures with uncertainty associated with the given age determination were omitted from the dataset used for analysis however, errors associated with ageing bias cannot be entirely ruled out in this study or others using similar methods. For the purpose of this study, given that the majority of fish were relatively young (less than 25 years) it was assumed that the age estimations used in the analyses were accurate. It is expected that any imprecision in age estimates would affect the degree of variation but would not interfere with the interpretation of overall trends.

A number of abiotic and biotic factors were examined in relation to white sturgeon recruitment from 1967 to 2009. Flows of the Nechako River were regulated during this period, and environmental factors were not compared to pre-impoundment conditions. Environmental factors examined included discharge, water temperature, air temperature, and salmon escapement. Of the factors investigated, fall and winter flows appeared to have the greatest positive relationship to sturgeon recruitment. However there was no single contributing factor examined in this study that could be attributed to recruitment success in the Nechako sturgeon population, suggesting that other environmental factors may be at play.

There was a moderate negative correlation between Chinook escapement, and a weak negative correlation between Sockeye escapement and sturgeon recruitment. Results suggest that in years of greater escapement there is poorer sturgeon recruitment. The relationship between salmon escapement and sturgeon recruitment in the following year was poorer than the year of the run. It is unclear why years with strong salmon runs, an important food source for sturgeon, would negatively affect recruitment in the same year. Predation is a primary mechanism for mortality of juvenile sturgeon. Chinook fry are capable of preying upon on free-swimming larvae, so it is possible that high Chinook recruitment may directly impact sturgeon. However if this was the case, a greater response would be expected in the year following a large escapement year as a greater number of Chinook fry would be anticipated in the system.

As stated previously, increases in salmon escapement and poor sturgeon recruitment trends such as those observed through the mid 1980's may function independently of one another. The increase in salmon numbers starting in the mid 1980's also did not appear to provide benefit to recruitment trends either. Perhaps there are unforeseen predator-prey interactions at play, possibly associated greater biomass inputs into the system. It may also be possible that relatively high but declining recruitment during the late 1960s and 1970s was coincidentally followed by increases in salmon numbers following the 1970s with changes in the overall management of salmon stocks and reduced exploitation rates. This trend would be reflected in the results as an exaggeration of the actual relationship between salmon escapement and sturgeon recruitment.

There was a negative correlation between increased summer air temperatures and recruitment. Of all the variables investigated in this study, August air temperature exhibited the strongest negative relationship to sturgeon recruitment. Although not as pronounced, there was also a weak negative correlation between July and August water temperatures in the Nechako River and recruitment. Graphically, years of low summer water temperature corresponded to years of increased summer flow. It is reasonable to expect a linkage between summer air temperature, water temperature and summer flows; however analysis of multiple factors was not explored in this study. Typically warmer summer air temperatures translate into drier conditions, lower flows and increased water temperatures; all of which may negatively impact juvenile success.

The year 2007 represented the largest recruitment event in at least three decades. Although speculation, the extreme discharge event of 2007 in combination with the notable recruitment event may suggest the possibility of threshold requirements. Perhaps habitat conditions during, what under the current hydrograph would constitute as an extreme event, provide greater opportunities for recruitment success (i.e. greater access to off channel habitat, and increased turbidity for cover). Given the magnitude and duration of the 2007 flood event, more sediment was likely moved than in previous discharge events. Increased flows may have resulted in improved substrate conditions, allowing for greater interstitial hiding habitat and predator avoidance. Both Sockeye and Chinook escapement numbers were also very low in 2007, which may have also had some contributing, but unexplained influence.

The primary intent of this project is to examine select environmental factors and their potential influence on continued low level recruitment variation in white sturgeon. No single contributing factor examined in this study could be attributed to recruitment variation in the Nechako sturgeon population. This suggests that other environmental factors, or the interaction of multiple factors, may be at play. There are spawning female sturgeon in the Nechako River each year therefore reproduction may not be the issue, but rather egg/larval/juvenile survival. Alterations to river morphology and substrate associated with the Cheslatta River avulsion are thought to have contributed to recruitment failure (NHC 2003, McAdam et al 2005). The downstream transport of sediment from the avulsion has resulted in loss of side channel and floodplain habitat; however alterations to bed substrate in main channel habitats are more likely responsible for recruitment failure (McAdam et al 2005). McAdam (2012) indicated that increased fine substrates at sturgeon spawning sites were the most likely mechanism of recruitment failure. Increased fine substrate affects early life stages by increasing embryo mortality due to smothering, as well infilling of interstitial habitats resulting in a loss of cover, increased larval drift and susceptibility to predation.

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APPENDIX A TABLE PREVIOUSLY UNAGED STRUCTURES

Table A1. Age assignment and hatch year for previously un-aged white sturgeon fin ray structures.

Structure No.	Pit Tag No.	Structure Photo No. (Same as Pit)	Age First Read	Age Second Read	Assigned Age*	For use in Recruitment Year Analysis**	Date of Capture (MM/DD/YY)	Hatch Year	Hatchery/ Wild (H/W)	Comments
1	4A0D3C3446	4A0D3C3446	4+	4+	4+	Y	09/25/12	2008	H	OTC in 2009
2	4A0C694256	4A0C694256	4+	4+	4+	Y	09/25/12	2008	H	Released in 2009 OTC
3	4868455250	4868455250	6+	6+	6+	Y	09/26/12	2006	H	Known hatch year of 2006
4	48664C3A0E	48664C3A0E	5+	5+	5+	Y	09/23/12	2007	H	
5	4B002E1006	4B002E1006	16+	16+	16	Y	05/20/11	1995	W	
6	6C00073054	6C00073054	3+	3+	3+	Y	09/21/12	2009	W	
7	6C00073118	6C00073118	5+	4+	5+	Y	09/25/12	2007	W	
8	4849247305	4849247305	5+	5+	5+	Y	09/25/12	2007	W	Damaged core-Fish was aged in 2009 @ 4yrs old but after review it was 1.5 yrs old
9	6C00073055	6C00073055	4+	5+	5+	Y	09/25/12	2007	W	
10	4867530C7D	4867530C7D	6+	6+	6+	Y	09/23/12	2006	H	Both saw 5+ at first but then found known age to be 6+ was determined
11	4A75644774	4A75644774	4+	4+	4+	Y	09/20/12	2008	H	
12	6C00073001	6C00073001	3+	3+	3+	Y	09/25/12	2009	W	
13	48674C7558	48674C7558	6+	6+	6+	Y	09/27/12	2006	W	
14	6C00073018	6C0073018	4+	4+	4+	Y	09/23/12	2008	W	
15	424D4B206C	424D4B206C	16+	16+	16+	N	09/19/07	1991	W	Repolished on second read- not confident in age
16	6C00073009	6C00073009	3+	3+	3+	Y	09/20/12	2009	W	
17	6C00073014	6C00073014	4+	5+	5+	Y	09/25/12	2007	W	

Structure No.	Pit Tag No.	Structure Photo No. (Same as Pit)	Age First Read	Age Second Read	Assigned Age*	For use in Recruitment Year Analysis**	Date of Capture (MM/DD/YY)	Hatch Year	Hatchery/ Wild (H/W)	Comments
18	4B18396613	4B18396613	24+	38+	39	N	05/18/11	1972	W	Hard to read, No confidence, repolished still very compressed
19	6C00073078	6C00073078	7+	7+	7+	N	09/25/12	2005	W	Core damage
20	401D4F2016	401D4F2016	39+	49+	50	N	05/26/12	1962	W	Very compressed hard to read with confidence
21	4A0D1E121B	4A0D1E121B	52+	53+	53+	NA	2012	1959	W	
22	6C00073027	6C00073027	16+	17+	17+	Y	09/20/12	1995	W	Repolished good read
23	6C00073071	6C00073071	13+	13+	13+	Y	09/24/12	1999	W	Repolished on 2nd read good read
24	4B0A17720D	4B0A17720D	46+	59+	59	NA	05/03/11	1952	W	Outer rings very close together - repolished on 2nd read
25	6C00073021	6C00073021	8+	8+	8+	N	09/30/11	2003	W	Very close rings, core damage.
26	6C00073013	6C00073013	7+	13+	-	N	09/30/11	-	W	Structure core very damaged not confident in age
27	401D612E55	401D612E55	24+	>27	-	N	04/28/11	-	W	Damaged core- Not usable
28	424E2E0977	424E2E0977	27+	28+	28+	Y	09/17/07	1979	W	Resectioned on 2nd read
29	424F17527D	424F17527D	33+	34+	34+	Y	09/17/07	1973	W	Re-read 33+ is correct
30	401D49007E	401D49007E	21+	43+	-	N	05/02/11	-	W	Damaged core- Not usable
31	6C00073119	6C00073119	5+	5+	5+	Y	09/23/12	2007	W	Repolished on 2nd read

Structure No.	Pit Tag No.	Structure Photo No. (Same as Pit)	Age First Read	Age Second Read	Assigned Age*	For use in Recruitment Year Analysis**	Date of Capture (MM/DD/YY)	Hatch Year	Hatchery/ Wild (H/W)	Comments
32	41247A5430	41247A5430	30+	37+	37+	N	09/21/12	1975	W	Repolished on 2nd read but not entirely confident in age
33	401D6C112C	401D6C112C	50	50	50	NA	04/28/10	1960	W	Resectioned on 2nd read. Better read but annuli were very compressed
34	401D525326	401D525326	41+	~57	-	NA	05/01/10	-	W	Resectioned. Do Not Use. Very compressed annuli and damage to core
35	401D615E51	401D615E51	31+	~54	-	NA	04/27/10	-	W	Resectioned- core damage
36	422E2F733F	422E2F733F	26+	25+	25+	N	09/17/07	1982	W	Resection +polished on 2nd read--difficult to read outer margins
37	401D666953	401D666953	24+	-	-	N	04/30/10	-	W	Cannot read
38	401D5A2B33	401D5A2B33	23+	-	-	N	-	-	W	Cannot read
39	6C00073064	6C00073064	19+	19+	19+	N	10/10/12	1993	W	Core Damage. Not confident
40	401D5B312B	401D5B312B	30+	40	40	Y	04/30/11	1971	W	Core Damage. But likely ok read on 2nd read
41	401D510166	401D510166	27+	>45	-	N	05/02/11	-	W	Cannot read. Core damage.
42	401D655D4A	401D655D4A	22+	43	43	N	05/01/11	1968	W	Outer rings very faded difficult to read. 2nd read agrees
43	401D677C0D	401D677C0D	40	40	40	Y	04/30/10	1970	W	Good read.
44	423827612F	423827612F	24+	24+	24	Y	04/08/12	1988	W	Good read.

Structure No.	Pit Tag No.	Structure Photo No. (Same as Pit)	Age First Read	Age Second Read	Assigned Age*	For use in Recruitment Year Analysis**	Date of Capture (MM/DD/YY)	Hatch Year	Hatchery/ Wild (H/W)	Comments
45	401D6F1545	401D6F1545	44+	50+	50	N	04/29/10	1960	W	Annuli to compressed to be confident.
46	42382121D	42382121D	34+	39+	-	N	04/30/10	-	W	Core damage no confidence in ages.
47	4012666F70	4012666F70	41+	44+	44	N	04/27/10	1966	W	Very compressed annuli not a great read.
48	6C00073017	6C00073017	24+	37+	37+	N	10/10/12	1975	W	Outer rings very faded difficult to read. 2nd read repolished and was not confident.
49	4B17243A2E	4B17243A2E	25+	>43	-	N	05/04/11	-	W	Very compressed annuli. Not confident.
50	401D502171	401D502171	31+	>54	-	N	04/24/00	-	W	Very compressed annuli. Not confident.
51	401D52192D	401D52192D	34+	>38	-	N	04/27/10	-	W	Center of structure very damaged cannot use.
52	757D7D2D24	757D7D2D24	42+	44+	44+	N	10/10/12	1968	W	Outer annuli very compressed.
53	401D5A064F	401D5A064F	23+	>37	-	N	04/30/10	-	W	Repolished, inclusion yr 4-8---dense annuli ~Yr31
54	6C00073040	6C00073040	33+	-	-	N	09/21/12	-	W	Structure is very damaged could not get 2nd read with confidence.
55	401D4D696D	401D4D696D	47+	>62	-	N	04/30/11	-	W	Very old fish- under aged suspected.
56	6C00073061	6C00073061	35+	43+	43+	Y	10/09/12	1969	W	Some core damage but readable
57	424D3D5403	424D3D5403	33+	35+	35+	Y	10/06/12	1977	W	Repolish good read

Structure No.	Pit Tag No.	Structure Photo No. (Same as Pit)	Age First Read	Age Second Read	Assigned Age*	For use in Recruitment Year Analysis**	Date of Capture (MM/DD/YY)	Hatch Year	Hatchery/ Wild (H/W)	Comments
58	412500497F	412500497F	39+	>38	-	N	10/09/12	-	W	Old fish-not confident
59	401D4D423F	401D4D423F	19+	>42	-	N	05/20/11	-	W	Very compressed annuli-- Not good read
60	6C00073033	6C00073033	35+	>48	-	N	09/21/12	-	W	Compressed annuli- -Not good read
61	4B094D2224	4B094D2224	23+	29+	29	N	05/20/12	1983	W	Difficult read-- outer annuli compressed
62	4B1810071E	4B1810071E	36	38	38	Y	05/05/12	1974	W	Resection,
63	401D6D5375	401D6D5375	30+	42+	42	N	05/02/11	1969	W	Yr10--may be 2yrs between 14-15--may be more
64	401D6C4626	401D6C4626	43+	58+	58	N	04/28/11	1953	W	Repolished- very old
65	6C00073003	6C00073003	7+	6+	6+	Y	09/21/12	2006	W	Repolished

* Ages for fish captured in April or May are not denoted with a "+" as this is at the end of the growing year.

** Confidence in final age sufficient for recruitment data analysis (yes or no)

NA: Not applicable, hatch year older than 1967

APPENDIX B DATABASE AGE COMPARISON TABLE

Table B1. Age confirmation for previously aged fin ray structures from fish less than 150 cm and born since 1967.

Structure No.	PIT Tag No.	Fork Length (cm)	Release Date	Original Age	Previously Assigned Hatch Year	Re-assessed Age	New Hatch Year	Comments
1	7F7B0B1B5C	114.5	10/06/1995	18	1977	-	-	Do not have samples for fish captured in 1995 (Assumed RL&L -1yr)
2	7F7D7D4335	96.5	11/06/1995	16	1979	-	-	Do not have samples for fish captured in 1995 (Assumed RL&L -1yr)
3	22234A7C59	109	18/08/1995	23	1972	-	-	Do not have samples for fish captured in 1995 (Assumed RL&L -1yr)
4	7F7D7D373D	138.5	15/09/1995	19	1976	-	-	Do not have samples for fish captured in 1995 (Assumed RL&L -1yr)
5	7F7D77302F	119	13/06/1996	18	1978	-	-	Do not have samples for fish captured in 1996 (Assumed RL&L -1yr)
6	7F7B0B1458	120.5	23/06/1996	25	1971	-	-	Do not have samples for fish captured in 1996 (Assumed RL&L -1yr)
7	7F7D773228	120.5	24/06/1996	26	1970	-	-	Do not have samples for fish captured in 1996 (Assumed RL&L -1yr)
8	7F7B031D1B	69	06/09/1996	11	1985	-	-	Do not have samples for fish captured in 1996 (Assumed RL&L -1yr)
9	7F7D767116	121	07/09/1996	26	1970	-	-	Do not have samples for fish captured in 1996 (Assumed RL&L -1yr)
10	7F7B03670D	127	07/09/1996	29	1967	-	-	Do not have samples for fish captured in 1996 (Assumed RL&L -1yr)
11	7F7B03057D	90	12/09/1996	13	1983	-	-	Do not have samples for fish captured in 1996 (Assumed RL&L -1yr)
12	7F7D7D2A42	139.5	07/09/1998	24	1974	-	-	Cannot locate structures
13	7F7D572F22	132	07/09/1998	26	1972	-	-	Cannot locate structures
14	7F7B03326A	129	07/09/1998	22	1976	-	-	Cannot locate structures
15		57	01/07/1999	6	1993	-	-	Cannot locate structures
16	41392C0A2D	77	05/07/1999	10	1989	10	1989	
17	41247D310C	133	05/08/1999	22	1977	22	1977	
18		46	20/08/1999	5	1994	-	-	Cannot locate structures
19		52	20/08/1999	5	1994	-	-	Cannot locate structures
20		46	25/08/1999	5	1994	-	-	Cannot locate structures
21	41493F7C14	84	09/09/1999	9	1990	-	-	Cannot locate structure

Structure No.	PIT Tag No.	Fork Length (cm)	Release Date	Original Age	Previously Assigned Hatch Year	Re-assessed Age	New Hatch Year	Comments
22	41247350	137	09/09/1999	29	1970	-	-	PIT tag number error
23	413931641C	98.5	10/09/1999	18	1981	18	1981	
24	4124747221	141.5	10/09/1999	22	1977	22	1977	
25	4124751461	138.5	11/09/1999	30	1969	-	-	Core damage - no age
26	4124671F3B	143.5	12/09/1999	30	1969	-	-	Core damage - no age
27	4139256371	122.5	12/09/1999	29	1970	-	-	29 but suspect older, very compressed annuli
28	50283B403A	140	15/07/2000	19	1981	-	-	Cannot locate structure
29	5027512B12	93	15/07/2000	15	1985	13	1987	Definitely 13, not 15
30	501F703F2A	122.5	15/07/2000	22	1978	22	1978	
31	424D772278	87	21/07/2001	15	1986	-	-	Cannot locate structure
32	424E6E1700	74	27/07/2004	5	1999	4	2000	
33	424E087403	66	27/07/2004	9	1995	8	1996	
34	422F415376	51.5	29/08/2004	8	1996	7	1997	
35	5020243915	85	29/08/2004	10	1994	9	1995	
36	5020145C2D	83	23/09/2004	14	1990	-	-	Cannot locate structure
37	424D3B7366	82	23/09/2004	13	1991	12	1992	
38	423C0F640A	88	23/09/2004	8	1996	6	1998	
39	424E707876	65.5	31/08/2006	5	2001	-	-	Cannot locate structure
40	422E616706	79	31/08/2006	12	1994	-	-	Cannot locate structure
41	422E2A6E26	104.5	31/08/2006	14	1992	-	-	Cannot locate structure
42	4528404012	35.5	31/08/2006	2	2004	-	-	Cannot locate structure
43	5020135414	33	01/09/2006	3	2003	-	-	Cannot locate structure
44	423C1B2E61	71.5	18/10/2006	7	1999	-	-	Cannot locate structure
45	452B05415B	78	12/05/2007	9	1998	9	1998	
46	4527132936	93	13/05/2007	11	1996	9	1998	
47	4528493E3D	146	15/05/2007	34	1973	-	-	39 but likely older

Structure No.	PIT Tag No.	Fork Length (cm)	Release Date	Original Age	Previously Assigned Hatch Year	Re-assessed Age	New Hatch Year	Comments
48	45275F7763	145	15/05/2007	29	1978	-	-	Core damage - no age
49	45227F1A49	87.5	15/05/2007	14	1993	12	1995	
50	452A03165E	148	31/05/2007	37	1970	-	-	Annuli too compressed, would not use with confidence
51	4A0D341A7A	147.5	01/05/2008	34	1974	-	-	43+ Not a confident read
52	4A0C326F48	115	01/05/2008	17	1991	14	1994	
53	4A0C03771F	99	01/05/2008	13	1995	10	1998	
54	4A0D312A1F	84.5	04/05/2008	16	1992	14	1994	
55	4A0C001A69	148	04/05/2008	35	1973	-	-	Annuli too compressed, would not use with confidence
56	4A0D3E5C1D	69.5	05/05/2008	13	1995	14	1994	
57	4A0D320B4C	100.5	06/05/2008	13	1995	10	1998	
58	422E256066	129	07/05/2008	18	1990	19	1989	
59	4A0C2E2279	147	10/05/2008	37	1971	-	-	Annuli too compressed, would not use with confidence
60	4868214C3C	103.5	30/05/2008	12	1996	9	1999	
61	4847393069	135	31/05/2008	23	1985	-	-	Annuli too compressed, would not use with confidence
62	4A0C304B36	105	01/05/2009	17	1992	-	-	Cannot locate structure
63	4B08443453	95.5	22/05/2009	15	1994	14	1995	
64	484942465C	37.7	28/08/2009	5	2004	2	2007	Very young fish!
65	4849247305	45	04/09/2009	4	2005	2	2007	Very young fish!
66	48681D0F72	56.4	15/09/2009	6	2003	5	2004	
67	4868372B4C	96.5	17/09/2009	14	1995	14	1995	
68	484916465D	95.5	17/09/2009	15	1994	14	1995	
69	4848735629	99.3	18/09/2009	12	1997	12	1997	
70	48653B5A02	76.1	05/10/2009	15	1994	16	1993	
71	487058171F	43	06/10/2009	5	2004	2	2007	Very young fish!

Structure No.	PIT Tag No.	Fork Length (cm)	Release Date	Original Age	Previously Assigned Hatch Year	Re-assessed Age	New Hatch Year	Comments
72	486841171C	68.8	31/08/2010	5	2005	7	2003	
73	48643A136E	50.5	31/08/2010	3	2007	3	2007	
74	48682838	55.6	31/08/2010	3	2007	3	2007	PIT Tag number is supposed to be 4868280E32
75	48702C141E	51.5	01/09/2010	3	2007	3	2007	
76	486809651A	51	01/09/2010	3	2007	3	2007	
77	48673F6242	55	01/09/2010	3	2007	3	2007	
78	4864502D3D	52	01/09/2010	3	2007	3	2007	
79	48641C462C	97.5	01/09/2010	15	1995	15	1995	
80	48640F101A	49	01/09/2010	3	2007	3	2007	
81	48476A3972	53.5	01/09/2010	3	2007	3	2007	
82	4870395627	57	01/09/2010	10	2000	-	-	Could be 11 or 12 - not confident read
83	48703C5A63	80	02/09/2010	5	2005	6	2004	
84	486A0F0B14	52	02/09/2010	3	2007	3	2007	
85	4868437622	50.5	02/09/2010	3	2007	3	2007	
86	4848731773	53.5	02/09/2010	3	2007	3	2007	
87	4847547510	57	02/09/2010	3	2007	3	2007	
88	4869225C55	46.5	03/09/2010	3	2007	3	2007	
89	4866132F6C	73	06/09/2010	9	2001	22	1988	Repolished, much older
90	48645C513E	71.5	06/09/2010	15	1995	17	1993	
91	4849143A62	55	07/09/2010	3	2007	3	2007	
92	4868273849	98.5	30/09/2010	13	1997	-	-	15 or bit older, cannot age with certainty
93	6C00073103	66	03/10/2010	6	2004	7	2003	
94	6C00073062	53.5	03/10/2010	3	2007	3	2007	
95	6600073113	48.3	03/09/2011	3	2008	3	2008	
96	6C00073011	74.4	04/09/2011	8	2003	-	-	Older than 8yrs , outer annuli compression
97	6C00073073	53.8	06/09/2011	3	2008	3	2008	

Structure No.	PIT Tag No.	Fork Length (cm)	Release Date	Original Age	Previously Assigned Hatch Year	Re-assessed Age	New Hatch Year	Comments
98	6C00073074	55.7	16/09/2011	3	2008	3	2008	
99	6C00073037	59.4	16/09/2011	2	2009	2	2009	
100	6C00073012	60	16/09/2011	3	2008	3	2008	
101	6C00073106	65.5	18/09/2011	6	2005	7	2004	