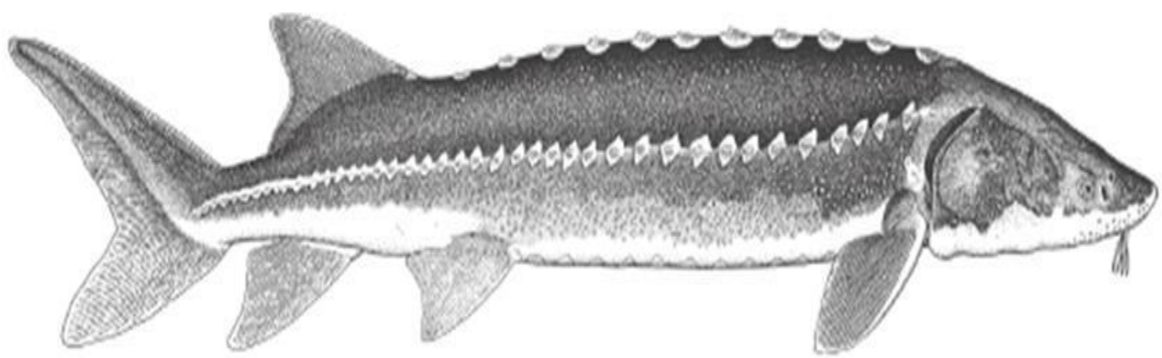
Nechako Environmental Enhancement Fund (NEEF)
Project Summary

Quantitative Risk Analysis of the Upper Fraser River White Sturgeon (*Acipenser transmontanus)* using a Probability Viability Analysis (PVA)



Yue, M., & Barr, C.

UNBC BIOL: 411 – Conservation Biology

Project: White Sturgeon *(Acipenser transmontanus)* Quantitative Risk Analysis Funding: $4,000,000.00 CAN

April 12, 2017

STATUS: THREATENED
CATEGORY: ENDANGERED

Partnerships:

NEEF PROPOSAL

Project Title: BC Proposal for Comprehensive Stochastic Simulation Model of White Sturgeon (*Acipenser transmontanus)* from the Upper Fraser River using Probability Viability Analysis (PVA)

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Date Received

Complete: Y / N **Approved: Y / N**

BC Proposal for Comprehensive Stochastic simulation model of white sturgeon (*Acipenser transmontanus*) from the Upper Fraser River using Probability Viability Analysis (PVA)

PROJECT SUMMARY

Subpopulation of White Sturgeon (*Acipenser transmontanus*) from the Upper Fraser system are crucially endangered Designatable Unit (DU) in BC which are facing ubiquitous environmental threats towards their unique long-life history and population dynamics (COSEWIC, 2003). The objective of this proposal is to construct a reflective Probability Viability Analysis (PVA) on this DU by using existing life history parameters derived from peer-reviewed scientific literature. Funding from Nechako Environmental Fund (NEEF) will grant for an in-depth qualitative and quantitative population projection for this DU's probability of extinction (PE) in the future decades. Results derived from this PVA may allow for more empirically reflective and cost-efficient management and conservation efforts and protocols towards Upper Fraser White Sturgeon.

PROJECT GOALS

(1) To construct a reflective PVA for White Sturgeon population dynamics in the Upper Fraser system

(2) Gain insight towards the PE over a projected 1000-year time interval period based on a decade generation persistency estimate

(3) Allow for future inferences and protocols towards White Sturgeon recovery and management plans

(4) To determine the DU's relative sensitivity or resilience towards environmental stochasticity

(5) To provide a reflective population model for Upper Fraser White Sturgeon in the scientific literature

POPULATION VIABILITY ANALYSIS (PVA)

PVA is a species-specific simulation model which projects future population dynamics over a predicted period of time (Ruggiero et al., 1994). This analysis is particularly useful towards the risk assessment and management of sensitive species for conservation biology efforts. By integrating the presence of stochasticity within life history parameters, a more robust and reflective population prediction can be made compared to simplified deterministic models (Ruggiero et al., 1994). In addition to quantitative determination of the PE of a particular species, it also qualitatively displays the relationship of the PE trend (Johnson Pers Com., 2017) By examining the population dynamic trends, multiple sensitivity analyses can allow for adequate and effective science-based prioritization protocols towards conservation, management, and recovery effects (Ruggiero et al., 1994). This statistical model is ubiquitously used throughout the scientific literature of conservation biology and management, becoming a common standardized risk determination for conservational assessments such as IUCN Red List, COSEWIC, and SARA (Waples et al., 2013). With considerations of spatiality, habitat availability, carrying capacity (K), predator-prey dynamics, metapopulations, and stochastic vital rates, PVA would be an appropriate ecological model for White Sturgeon assessment. PVA is commonly conducted on a software program called Vortex. By having Vortex permitting open public access to this refined resource, statistical computational cost will be conserved for this project. By utilizing an advanced scientific non-profit program model, monopolization to skew results will be negligible.

PROPOSED STOCASTIC SIMULATIONS IN VORTEX

Due to high species sensitivity towards stochastic abiotic factors of White Sturgeon, the three most predominant deleterious threats to the population dynamics will be simulated in Vortex.

1. Climate Change

In the aquatic ecosystem, temperature is known to be the most important biotic factor affecting distribution, life history, stress, and success of fish fauna (Brett, 1969). Due the extremely narrow temperature optimums, the accumulated thermal units (ATUs) significantly affects the physiology, functionality, and viability of developing fish based on proportionally thermal size sensitivity (Brett, 1969; Hung et al., 1993; Kynard & Parker, 2005). Based on the relationship between ATUs and thermal size sensitivity, highest stochasticity is expected to be extrapolated from age-dependent cohort populations of earlier developmental life stages (Glova et al.,2009; Kynard & Parker, 2005)

2. Water & Substrate Quality

As a result of White Sturgeon's life history as broadcast spawners, developing embryos on the river gravel bed may be highly susceptible to fluctuations in stream water quality. Deviation in concentration or magnitude of bacterial and viral presence, pH, siltation, pollution, turbidity, aeration, pathogens, and substrate gravel quality are documented to have catastrophically negative effects towards to viable Acipenseriformes offspring (Malmqvist & Rundle, 2002).

3. Habitat Availability

White Sturgeon population dynamics are known to be greatly influenced by ecological density dependent factors such as spatiality (Kock et al., 2006). Within the natural aquatic environment, successful spawning is highly dependent on habitat availability. A reduction in mean habitat increases confinement for environmental stress which limits spawning availability and redd establishment within the river system (Jager et al., 2000; Stanford et al., 1996)

POTENTIAL RECOVERY ACTIONS

Table 1. Summary protocols for conservation, management, and recovery suggestions to major environmental threats to Upper Fraser White Sturgeon (*Acipenser transmontanus*). List of parameters and recommendations are not exhaustive.

Parameter	Mitigation Recommendations	References
Climate Change	(1) Establish controlled thermal buffers and/or thermal habitat refugia towards aquatic environment (2) Reduce climate change rate of acceleration by controlling emission of greenhouse gases (3) Restore riparian vegetation to attenuate heat transfer from the sun to sensitive water systems	(1) Davis et al., 2013 (2) Malmqvist & Rundle, 2002 (3) Fields et al., 1993; Jager et al., 2000
Water Quality	(1) Decrease and remove deleterious abiotic and biotic substances in the water column (2) Restore exposed cut banks with vegetation to decrease erosional siltation (3) Clean gravel supplementation	(1) Fields et al., 1993 (2) Johnson, 2002 (3) Baker et al., 2014; McAdam, 2011
Habitat Availability	(1) Construct artificial spawning channels may supplementation for early life stages (2) Coarse filter approach to restore lost stream habitat connectivity (3) In situ habitat alterations to increase river system carrying capacity	(1) Rochard et al., 1990 (2) Stanford et al., 1996 (3) Coutant, 2004; McAdam, 2011

EXTERNAL BUDGET

Table 2. Estimated expenditures for proposed Probability Viability Analysis (PVA) Module for Upper Fraser White Sturgeon (*Acipenser transmontanus)*

Itemization	Description	Cost ($)	Quantity (n)	Total ($)
Personnel				
Wage - MY	Daily	750	14	10500
Wage - CB	Daily	750	14	10500
Materials				
Computer	Once	1900	2	3800
Office Supplies	Miscellaneous	500		500
Advocate	Weekly	138	8	1104
Unexpected Costs	+10%	Variable	Variable	2640
Mitigation Practices	+	~ 590,000	Variable	590,000
Total costs				619,044
Funding Organization	**Confirmed**	**Pending**		
NEEF Allocation Fund	0	619,044		
(Available: $4,000,000)				

Budget Proposal

Date Received:

Complete: Y / N **Approved Funding: Y / N**

PROPOSAL CHECKLIST

Table 3. Summary checklist for proposed Probability Viability Analysis (PVA) for Upper Fraser White Sturgeon from Yue & Barr (2017).

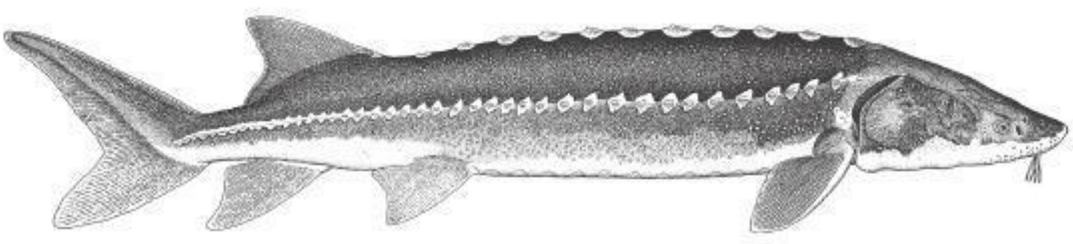
Have you clearly provided / identified:	Yes	No
1. Information on your organization, including contact information?		
2. The goals of your project?		
3. Relevance to NEEF mandate, priorities, decisions, and criteria?		
4. Who will use / benefit from your project, and their needs?		
5. The potential long and short-term benefits of your project?		
6. How the benefits will be sustained?		
7. A realistic work plan with timeframes and management plan?		
8. The anticipated outcomes, deliverables, results?		
9. An evaluation plan, showing how you will measure your results?		
10. Who your partners are and what they will provide?		
11. Have you listed all funding options explored and the results?		
12. Have you considered and addressed all stakeholder concerns?		
13. Who is paying for what parts of the project in your budget?		
14. Quotes and estimates from suppliers supporting the budget?		
15. Evidence of community support, including letters from municipal and First Nations governments and/or businesses?		
16. How the NEEF, the funding partners (Province of BC and Rio Tinto Alcan) contribution will be publicly recognized?		

Proposal Checklist

Date Received:

Complete: Y / N **Proposal Acceptation: Y / N**

Quantitative Risk Analysis of the Upper Fraser River White Sturgeon (*Acipenser transmontanus)* using Probability Viability Analysis (PVA)



META-ANALYSIS REPORT

EXECUTIVE SUMMARY

The Upper Fraser River White Sturgeon (*Acipenser transmontanus)* population is a vulnerable designated unit (DU) to external environmental abnormalities and socioecological transformations, including stream manipulation and human-induced bioaccumulation, respectively within local fresh water streams. These changes have resulted in increased age-dependent mortality (q_{x+n} > 0.99) and caused extreme probability of recruitment failure (l_{x+n} < 0.01). A population viability assessment was performed utilizing Vortex 10 software, which logistically analysed and determined associative probability the long-term persistence values of the White Sturgeon population which achieved sexual maturation (M = 11; F = 26). Our best model of current conditions shows that the DU White Sturgeon population continually declined, despite environmental conditions which remained constant. We found that when habitat loss, environmental conditions, or other factors worsen, the population could face extirpation in the near future.

Several recovery strategies were considered with the most successful being a modest supplementation program followed by a habitat restoration program. It is our recommendation that the population be maintained with a supplementation program while a habitat restoration program is enacted to ensure the survival of the population in the absence of human support.

INTRODUCTION

White Sturgeon are an exceptionally large and long-lived species that is particularly vulnerable due to this exceptional life strategy (Baker et al., 2014; Schreir, et al.,2012). White Sturgeon are present in the ocean along on the west coast of North America and in the Fraser and Columbia River systems. Based on meta-analysis of DU of the Upper Fraser River White Sturgeon, extrapolation of geographic confinement of genetic transfer is often considered to be anterior of the basal flow of latitude and longitude associated with Hell's Gate (Coordinates: 49.78, -121.45) (Dixon, 1986; McAdam, et al., 2005). Adult sturgeon utilizes deep, broad areas of the river which are fairly abundant, however there are only 12 suspected spawning sites in this DU (Schreir, et al.,2013). Currently, all of the populations in British Columbia have been assessed by Committee on the status of endangered wildlife in Canada (COSEWIC) and are listed as either threatened or endangered (COSEWIC 2012).

Sturgeon develop slowly, generally not reaching sexual maturity for more than one to two decades depending on environmental conditions (Hildebrand et al., 2016). Recruitment failure coupled with localized habitat degradation are key impacts resulting from the influences of changing environmental conditions that have negatively influenced White Sturgeon population dynamics. (Nelson et al., 2013a). More specifically, White Sturgeon are known to be sensitive to flow rate changes, pollution, increases in turbidity, indirect effects of commercial and non-commercial fishing, changes to thermal regimes within river channels, and impacts from aquaculture such as disease and increased parasite load (COSEWIC, 2012; DFO 2014; Kappenman & Parker, 2007; Kock et al., 2006; LaPatra et al., 1999; McAdam et al., 2005). In a 2012 population dynamic assessment of Upper Fraser DU White Sturgeon, COSEWIC listed the population as endangered in the region.

Vortex (V. 10) was used to generate a baseline population estimate for the probability persistence (PE) of White Sturgeon over a 1000 year period, with the presence of risk scenarios and recovery actions applied in the determination of potential outcomes for the Upper Fraser population. We compared the viability of several recovery options that can be implemented to reduce the probability of the Upper Fraser population becoming extirpated or extinct. To mitigate the effects of recruitment failure, habitat restoration and juvenile supplementation was prioritized in the modelling. A variability analysis was completed for parameters that may have significantly influenced the baseline model towards sturgeon population dynamics (Table 1).

Our model predicts that the population will continue to steadily decline until extirpated unless recovery actions are successfully implemented, mitigating or preventing an extinction Vortex from occurring (Figure 1). The objective of this report is to examine potential recovery strategies based on science-derived projection data, using sensitivity simulations models of White Sturgeon from PVA.

Table 1. Changes in Vortex from baseline variables for the creation of risk, recovery, and variation scenarios for the Upper Fraser River White Sturgeon population model

Situation	Change(s) in Vortex
Mortality Variation	±15% mortality in all 3 juvenile age classes with mortality
Spawning Variation	Change from 16 max to 5 for lower, and 18 for Upper bounds.
Sex Ratios	Change from 1:1 to 1.5:1 for males and females
Supplementation	Add 10 females (2-3 years) every 7 years
Improved Juvenile habitat	Reduced juvenile mortality in 1-2 year age class by 30%
Increased exchange with other populations	Lethal equivalents reduced to 1.29
Habitat Degradation	Reduce max progeny from 16 to 8
Disease	Catastrophe: 1 percent probability, 75% survival
Climate Change	Increase juvenile (1-2 years) mortality from 9% to 11%

METHODS – MODEL PARAMETERIZATION

Formulation of Baseline Population Scenario

While the Vortex 10 program is a powerful tool for modeling the futures of endangered species, it is tailored for very small populations of animals that produce few offspring. As the Upper Fraser White Sturgeon population is larger than most endangered populations and spawns large numbers of eggs when they reproduce, we were forced to simplify some parameters to optimize the model. Most importantly we pre-calculated the survival of eggs (~.0003%) to one year of age and programed the model to skip first year mortality. This vastly reduces the number of individuals Vortex needs to track. The reproductive age was capped at 100 years based on maximum lifespan of White Sturgeon, however, it may fluctuate significantly. One hundred iterations were computed for each scenario to increase model precision, over a timespan of 1000 years due to the long generation time of White Sturgeon. Base case parameters are defined in Table 2.

Table 2 Base case scenario for Vortex PVA for the Upper Fraser White Sturgeon (*Acipenser transmontanus*). CS = Case Study. N/A = Not Available.

Parameter	Value	Reference(s)
Breeding System	Polygynous	Jay et al. 2014
Size of initial population (N_i)	815	Yarmish & Toth, 2002
Reproductive adult males (%)	100	Jay et al., 2014
Reproductive adult females (%)	100	Jay et al., 2014
Juvenile mortality rate (age dependent)	99.999604%	DFO, 2014
Male age at maturity (years)	11	Yarmish & Toth, 2002
Female age at maturity (years)	26	Gross et al., 2002
Maximum reproductive age (years)	100	Gross et al., 2002
Maximum viable hatching offspring per 4 yrs	3	COSEWIC, 2012
Maximum viable hatching offspring per 11 yrs	16	COSEWIC, 2012
Annual adult male mortality (% ∓ SD)	6 ∓ 3	DFO, 2014
Annual adult female mortality (% ∓ SD)	3 ∓ 3	DFO, 2014
Sex ratio (male:female)	50:50	Jager et al., 2001
PVA iterations	100	CS
PVA projection (years)	1000	CS

Uncertainty Scenario Development

Mortality

In long lived species, small variations in the annual mortality rate can have significant consequences on modelled survivability and probability of extinction. As it is difficult to measure the exact mortality rates of wild populations (Boyce, 1992), we modeled variation in mortality with a ±15% adjustment in the mortality of two of the three juvenile age groups. To simplify our Vortex model, we assumed that age dependent mortality was linear.

Sex ratio

To understand the importance of sex ratio on species persistence, the ratio was skewed either to increase the proportion of breeding males or increase the proportion of breeding females away from the equivalent sex demographic ratio (1:1) (Jager et al. , 2001) used in the base case. The two scenarios were defined by a decrease of 100 individuals from one sex, and a corresponding increase of 100 individuals of the other sex. The changes in sex ratios were applied towards the entire age distribution, however the effects were proportional to the number of individuals within each age class.

Number of Progeny per Brood

Since White Sturgeon lay up to 4 million eggs, this creates a computational restriction in Vortex due to the difficulty in modelling a high number of individuals; the egg life history was omitted. This simplification resulted in a PVA assessment from 1 to 100 years. Varying the maximum number of progeny per brood should provide a reflective indication of population sensitivity. To account for the variation, the maximum number of offspring were increased to 18; the minimum was decreased to 5 individuals.

Risk Scenario Development

The risk scenarios we modeled include disease, habitat degradation, and climate change, as these are known to negatively influence White Sturgeon population dynamics (Nelson et al. 2013a).

Disease

Disease such as the iridovirus and selenium toxicity (Zee et al., 2016) in White Sturgeon can greatly affect natural mortality, especially due to the small population size (LaPatra et al. 1999). With increased human induced pollution in the Fraser River, disease has increased over the last decade (LaPatra et al., 1999). Health complications, such as polycystic lesions of the liver (Taylor et al., 2009), caused by pollution, have become increasingly prevalent in White Sturgeon. Our disease risk scenario was modeled using the catastrophe function in Vortex. Frequency of event occurrence was 1%, decreasing the proportion of survivability from 1 to 0.75.

Habitat Degradation

Habitat alteration and degradation are important factors negatively affecting the Upper Fraser population (COSEWIC, 2013; Perrin et al., 2003). Degradation includes changes to water clarity, temperature, pH, and water contamination (Wishingrad et al., 2015). Early life history stages, primarily eggs and newly hatched juveniles, are the most susceptible to environmental stochasticity. We modeled habitat degradation by decreasing the maximum number of progeny from a single female from 16 to 8 individuals.

Climate change

Juveniles require an optimum specific temperature to facilitate proper growth. The changes in water temperature, resulting from climate change have decreased juvenile survival and recruitment leading to an increase in juvenile mortality. To simulate the climate change risk scenario, the baseline juvenile mortality was increased from 9% to 11% in the age class 2-3 years.

Recovery Scenario Development

Our Recovery scenarios include supplementation using hatchery reared sturgeon, habitat restoration with an emphasis on optimal breeding conditions, and the introduction of male sturgeon from the meta-population.

Habitat Restoration

As critical spawning habitat is sensitive and represents a small percentage of the total useable habitat, restoration to ecosystem services has been prioritized. We represented the restoration program by reducing the mortality of juveniles in one and two year age classes for both male and females by 30%.

Supplementation

Supplementation programs are a common and effective method for bolstering the population size. The Danube (Sandu et al., 2013) and Lake Sturgeon in Manitoba (Schueller & Hayes, 2011) have benefited from supplementation. In British Columbia, existing supplementation has also been reasonably effective in increasing the White Sturgeon population size of the Nechako River (Yarmish, 2002). Supplementation was modeled by adding 10 hatchery reared females once every 7 years. The supplemented females were 2 to 3 years old. After 600 years, supplementation stopped to represent the likelihood of the program becoming defunded.

Introduction of Males from Meta-population

To reduce inbreeding depression, males were introduced from the greater meta-population. Introduction occurred prior to spawning season to decrease the prevalence of deleterious alleles within the Upper Fraser population. This was modeled by decreasing the effect of inbreeding depression from 6.29 lethal equivalents to 1.29.

RESULTS & DISCUSSION

Our baseline scenario shows a steady decline of individuals with the Upper Fraser population becoming extinct in every iteration (PE = 1) after 1000 years. Supplementation was our most successful recovery action; however when supplementation recovery was prematurely stopped or impeded, the White Sturgeon population declined with the same pattern as the baseline. Habitat restoration with supplementation of sturgeon from other populations during spawning merely reduced the slope of the decline, ultimately prolonging extirpation of the population. The catastrophe and competition scenarios show a steeper slope than the base case. Our models predict the extirpation of the Upper Fraser River White Sturgeon population unless recovery methods are effectively implemented.

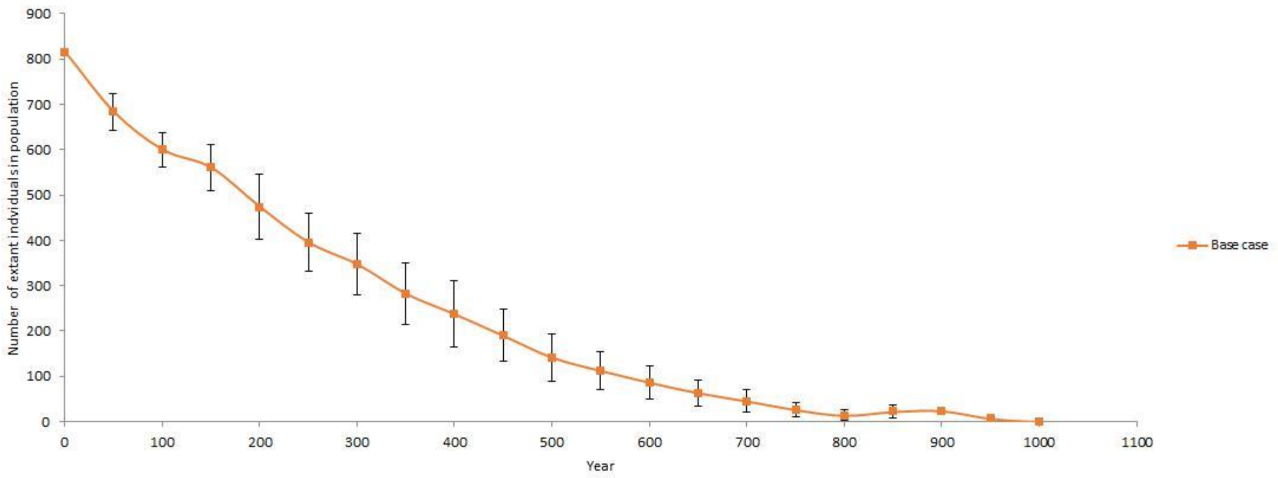


Figure 1 Base case scenario of the Upper Fraser River *Acipenser transmontanus* population over a 1000 year interval modeled using Vortex 10 software

Our base case (Figure 1) shows a steady decline once supplementation (Figure 2) stopped, suggesting that mortality is a sensitive parameter in Vortex and that a small change can have a large effect on the long term viability of the population. Our population outcome was supported by scientific publications where supplementation can be used to offset recruitment failure (McAdam, 2011; Nelson et al., 2013a; Nelson et al., 2013b). Habitat restoration and introduction of male sturgeon from the meta-population (Figure 2) were considerably less successful than supplementation.

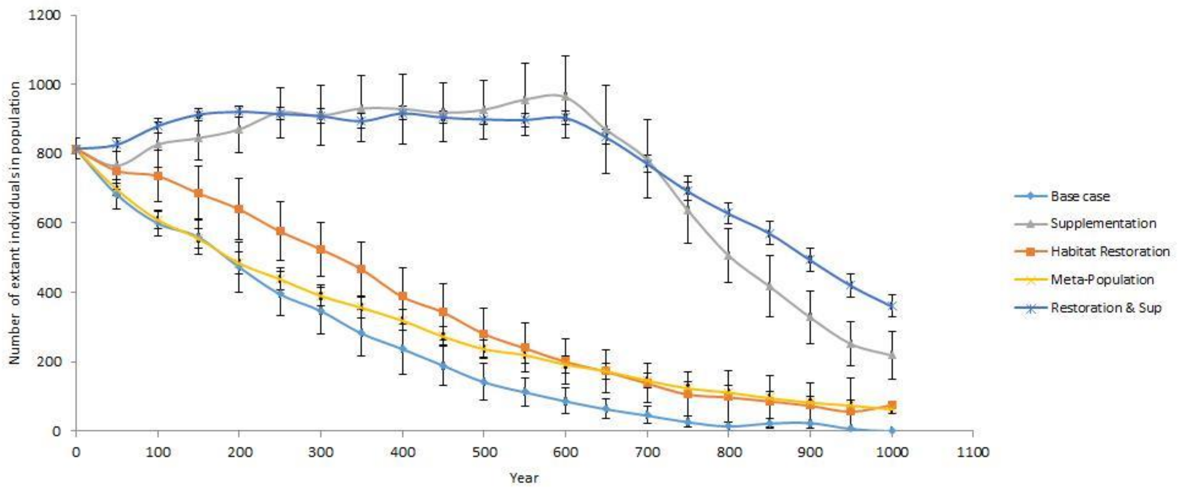


Figure 2 Recovery scenarios compared to base case of the Upper Fraser River *Acipenser transmontanus* population over a 1000 year interval modeled using Vortex 10 software

Population decline was not as severe in the restoration and introduction scenarios. Despite ultimately illustrating the same result, the population could not be stabilized or sustained with any of our recovery efforts. Habitat loss was shown in our modelling scenarios to be the greatest threat facing the Upper Fraser population (Figure 3). The number of extant individuals decreased significantly more than in the disease and climate change risk scenarios compared to the base case (Figure 3).

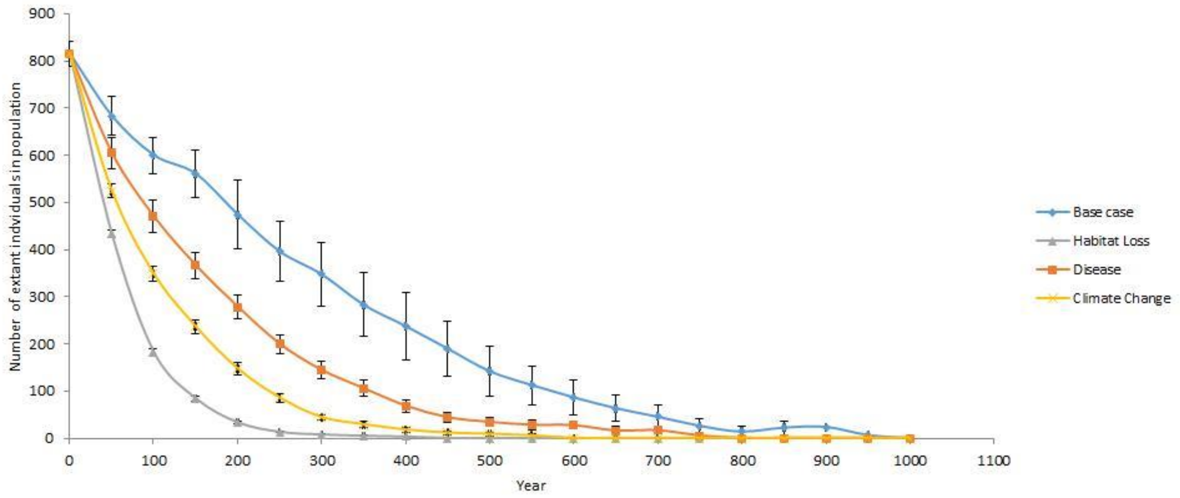


Figure 3 Risk scenarios compared to base case of the Upper Fraser River *Acipenser transmontanus* population over a 1000 year interval using Vortex 10 software

For the uncertainty associated with the mortality rate, there was the greatest variation from the base case in early generations which became less pronounced over time and indistinguishable at a thousand years (Figure 4). Further experimentation will be required to understand the appropriate stable population mortality rate. As a result of the simplification made in our model, linear age-dependent mortality rate may not adequately reflect the population dynamics of the Upper Fraser White Sturgeon. By manipulating the equal sex ratio to a 1.5:1 distribution for male and females respectively, after 4 generations population size substantially decreased; when sex ratio was reciprocated to 1:1.5, population size significantly increased (Figure 5).

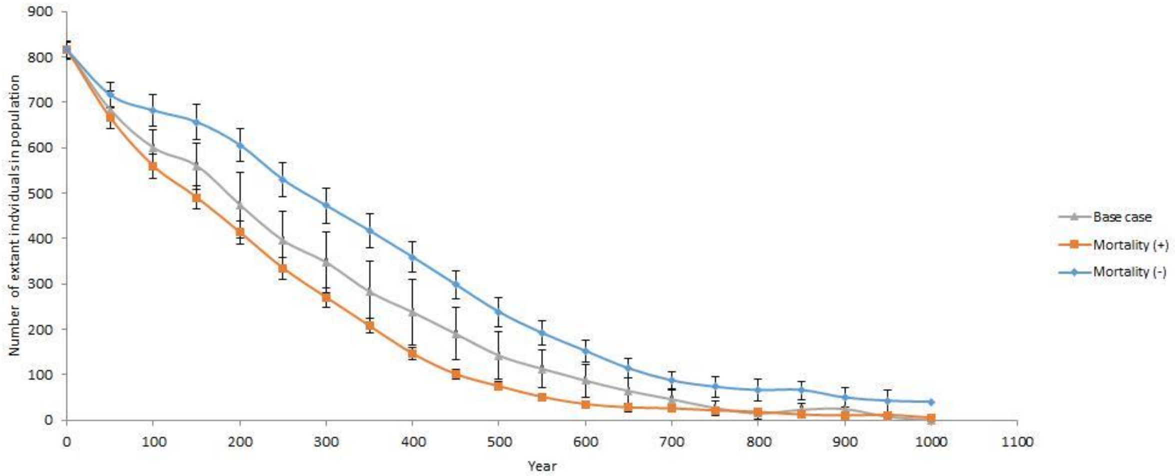


Figure 4 Estimate of uncertainty of the mortality rates among age classes compared to the base of the Upper Fraser River *Acipenser transmontanus* population over a 1000 year interval modeled using Vortex 10 software

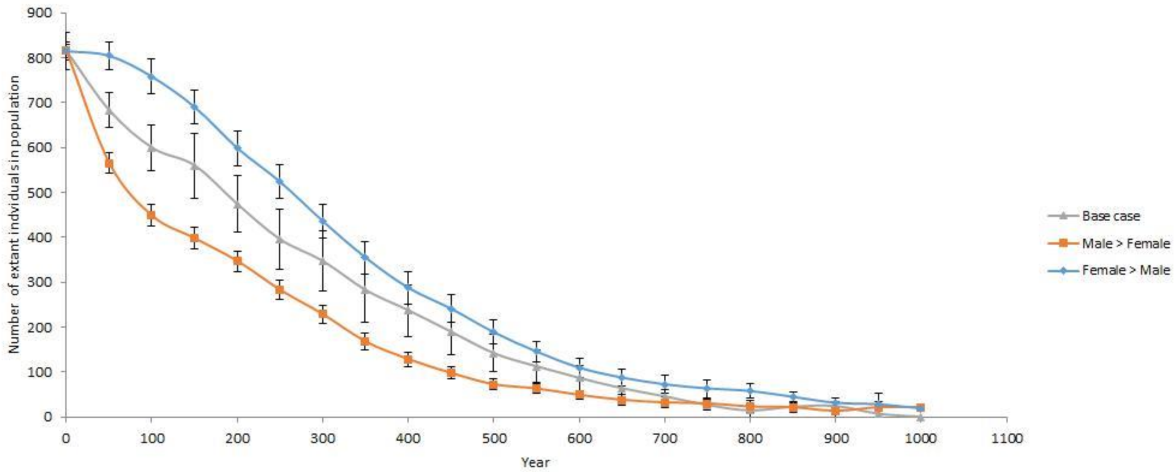


Figure 5 Estimate of uncertainty of the sex ratio compared to the base case of the Upper Fraser River *Acipenser transmontanus* population over a 1000 year interval modeled using Vortex 10 software

By analysing the sex ratio variation, we can understand the complex population dynamics which may allow for effective conservation and management recovery actions. Current White Sturgeon hatchery programs focus on the addition of females towards the wild stock which progressively alters the sex ratio. This leads to the increase in net brood amount during spawning season (Conte 1988). Alteration of maximum number of progeny per brood did not not significantly impact the population model. This is highlighted by the overlapping confidence intervals (Figure 6).

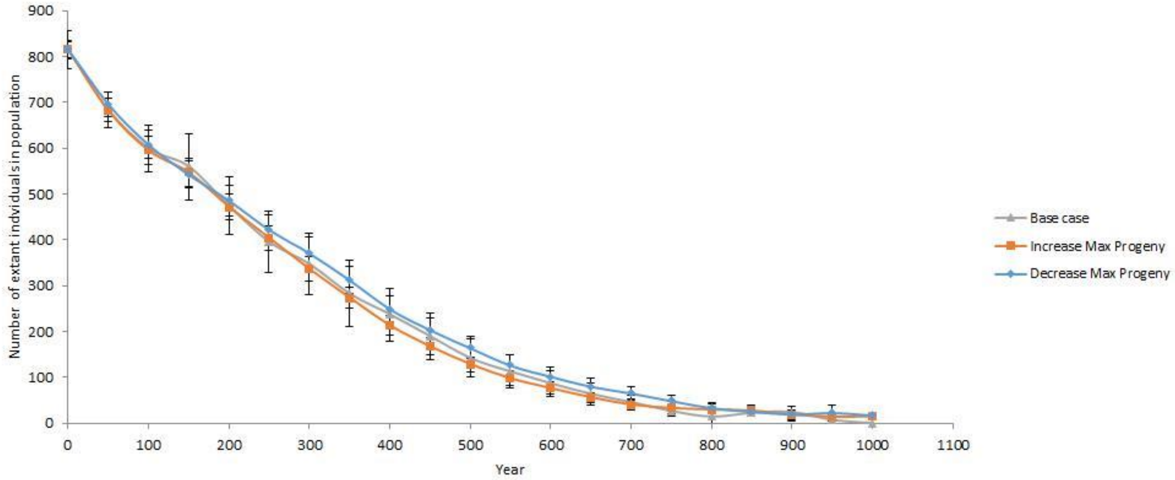


Figure 6 Estimate of uncertainty of the maximum progeny compared to the base case of the Upper Fraser River *Acipenser transmontanus* population over a 1000 year interval modeled using Vortex 10 software.

The uncertainty analysis resulted in the discovery that the two tested parameters, sex ratio and mortality exhibited the greatest sensitivity to stochasticity, while brood capacity remained more resilient. Despite uncertainty analysis suggesting sensitivity towards some unaccounted variables, this Vortex model represents a reflective population projection for the Upper Fraser White Sturgeon because it is based on existing scientific and peer-reviewed data. Age class distribution was simplified in our model due data deficiencies, thus may not be reflective of the biological population. Simulated supplementation was effective at maintaining the population size, which suggests that a combinatory approach such as the inclusion of habitat restoration may be viable (Figure 2). This combination approach may represent a synergistic conservation and management strategy. Although supplementation was an effective strategy, it did not provide population stability once stopped (Figure 2). Therefore, biological and environmental factors must be assessed to further understand the declining population dynamics. Our 2017 status assessment resulted in a listing of Upper Fraser White Sturgeon as Threatened. This is despite the 2012 COSEWIC Status Assessment listing this designatable unit as Endangered (COSEWIC, 2012), changes in parameters over time may account for classification downlisting. Listing discrepancies may be a result of failure to meet inflexible thresholds dictated by COSEWIC's status assessment criteria (Table 3). Even though Endangered status was not achieved, the PVA projections were less than 2% above the criteria threshold (Criterion A and C). This may be accounted for by stochasticity associated with the standard error of mean parameters.

STATUS ASSESSMENT

Table 3 COSEWIC status assessment criteria for the Upper Fraser White Sturgeon (*Acipenser transmontanus*)

Current Status

COSEWIC: Endangered (2012)

Status and Reason for Designation

Status: Threatened	Alpha-numeric code: C1; D1
Reasons for designation: White Sturgeons' long life span makes it a susceptible species to environmental stochasticity given the high juvenile mortality. As such, the Upper Fraser River population is at risk of extirpation.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Almost meets Threatened A3 as decline rate is ~28.38% over next three generations based on average generation time of 40.
Criterion B (Small Distribution Range and Decline or Fluctuation)**:** Not applicable, although does meet B2b criteria, but population is not fragmented due to river structure.
Criterion C (Small and Declining Number of Mature Individuals): C1, does not meet endangered criteria based on 19% decrease over 2 generations, does meet threatened criteria.
Criterion D (Very Small or Restricted Total Population): D1 meets threatened criteria (815 individuals starting population), population below endangered status
Criterion E (Quantitative Analysis): Not applicable; probability of extinction within 20 years or 5 generations is 0 due to low mortality in mature individuals.

PVA Limitations and Assumptions

Assumptions:

(1) Meta-anaylsis of PVA: collected parameters relatively reflected natural rate parameters, supported by scientific literature

(2) Density dependence of carry capacity (K) was assumed to be negligible due substantial magnitude of K beyond current White Sturgeon population (K >> Ne)

(3) Mortality was assumed to be linear and proportional to age-dependence, corrected by integrating stochasticity around the mean with integration of SE

Limitations:

(1) Low validity of robustness protocols and criteria of PVA credibility

(2) Quantitative analysis of Upper Fraser White Sturgeon based on a single species model which simplifies complex community interactions and dynamics

(3) Linear growth/decline of PVA model may distort density dependent relationships

Population Prospects

To effectively maintain the population of Upper Fraser White Sturgeon over the next millennia, supplementation protocols must be implemented to prevent extirpation. Alternative conservation protocols such as habitat restoration and integration of White Sturgeon subpopulations were not nearly as effective at maintaining the population. By using a minimalistic supplementation protocol of 10 mature female White Sturgeons every 7 years, sustainability of population can be achieved on a reasonable budget as long recovery actions persist.

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